IDM DOCUMENT UID
2MRU8E

DOCUMENT VERSION / STATUS
4.2 / Approved

CHANGE NOTICE LAST INDEX
A

System Requirement (SRD) Document

SRD-53-04 (DNB) from DOORS

Warning: Change Notices apply to this document's version.
Please refer to the Change Notice summary page (next page).

Change Notice summary page

#	Approval date	Justified by	Justification
A	18/02/2021 09:37:00	TL5BR3	Establishment of the 2016 ITER Baseline

The following changes apply to the following document 2MRU8E_v4_2

Change Notice A.38S7P4. Approved on 18/02/2021 09:37:00
Change 1. Chapter / Section / Paragraph to be changed : Purpose
From (old): Change log table (and description for IDM version change) --- **To (new):** Reconciliation of the SRD-53-04 with the baselined PRv6.3, as agreed in Change Notice ITER_D_38S7P4
Change 2. Chapter / Section / Paragraph to be changed : 3.1 Safety design criteria
From (old): [5304s865-R;Defined Requirement] VV blank flanges shall be installed for temporary closure where the systems are not installed as functional. Temporary blanking shall be listed, planned, supplied and commissioned on all open penetrations to the vacuum boundaries (PBS16). The appropriateness of any temporary provisions shall be demonstrated by systematic safety analysis based on the quantities, location, and operation ~~related to hazardous inventories~~. For the confinement of radioactive materials, definitive provisions shall be available for the start of Assembly and Integrated Commissioning phase IV (prior to FPO). Prior to the definitive provisions being available, the safety functions to be achieved by the intermediate ITER configurations shall be guaranteed using temporary provisions with requirements similar to the definitive provisions (e.g. redundancy, back-up power supply) or with reduced requirements scope (case by case: no redundancy, limited use of back-up power supply, limited resistance to external events...). --- **To (new):** [5304s865-R;Defined Requirement] VV blank flanges shall be installed for temporary closure where the systems are not installed as functional. Temporary blanking shall be listed, planned, supplied and commissioned on all open penetrations to the vacuum boundaries (PBS16). The appropriateness of any temporary provisions shall be demonstrated by systematic safety analysis based on the quantities, location, and operation related to radioactive and toxic inventories. For the confinement of radioactive and toxic material, definitive provisions shall be available for the start of Assembly and Integrated Commissioning phase IV (prior to FPO). Prior to the definitive provisions being available, the safety functions to be achieved by the intermediate ITER configurations shall be guaranteed using temporary provisions with requirements similar to the definitive provisions (e.g. redundancy, back-up power supply) or with reduced requirements scope (case by case: no redundancy, limited use of back-up power supply, limited resistance to external events...).
Change 3. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact

requirements
From (old): [5304s891-R;Defined Requirement] Note 1: Total dose rate shall be the sum of external dose rate and internal dose rate. Internal dose rate can be calculated, using airborne concentration, as a ratio of "Derived Air Concentration" (DAC) (see definition of DAC in PR1242). At levels higher than 1 DAC, specific authorization shall be required to enable access of personnel equipped with appropriate individual protections. --- **To (new):** [5304s891-R;Defined Requirement] Where personnel access is authorized in rooms with airborne contamination, the airborne contamination level shall be monitored with alarms to: • Alert the personnel when the room contamination level has reached a specified fraction of the defined DAC limit for that room (usually 10%); • Evacuate personnel when the room DAC limit is reached.
Change 4. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirements
From (old): ~~[5304s887-R;Defined Requirement] The radiological zoning shall be based on total dose, as listed in Table 7-6, or on equivalent doses to hands and feet, as also listed in Table 7-6, when the external exposure to hands and feet exceeds the total exposure.~~ --- **To (new):** *Deleted*
Change 5. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirements
From (old): ~~[5304s888-R;Defined Requirement] The radiological zoning shall be defined for each plant operation state, following the criteria of Table 7-6, see also [35], [36], [53], [52].~~ --- **To (new):** *Deleted*
Change 6. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirements
From (old): ~~[5304s889-R;Defined Requirement] The marking (signing) of the radiation zones from greyish blue to red shall follow the norm (ref. MF M 60-101) and shall be clearly posted on all access routes to the zones. The marking of the radiation zones shall be modified according to every change to the zoning.~~ --- **To (new):** *Deleted*
Change 7. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirements
From (old): ~~[5304s892-R;Defined Requirement] Note 2: In case of exposure of the eye lens (crystalline), these values shall be multiplied by 0.3 (150/500).~~

To (new): *Deleted*
Change 8. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirements
From (old): [5304s876-R;Defined Requirement] ~~Magnetic field zones and access and control conditions shall be established as per Table 7-11.~~ --- **To (new):** [5304s876-R;Defined Requirement] DNB compnents shall comply with the requirements of the zoning classification where they are located (Ventilation, Radiological, Anti-deflagration, Beryllium, Magnetic, Radiofrequency, Fire, Waste) as identified in the Safety Roombook.
Change 9. Chapter / Section / Paragraph to be changed : 3.11 Other requirements
From (old): ~~[5304s936-R;Defined Requirement] The ITER installations shall be designed to withstand extreme heat conditions; that is, air temperatures up to +45ºC and temperatures of +40ºC for buildings [39].~~ --- **To (new):** *Deleted*
Change 10. Chapter / Section / Paragraph to be changed : 4.1.2 Operational conditions
From (old): ~~[5304s905-R;Defined Requirement] Electromagnetic loads shall be kept within acceptable limits even in the event of potential failures in control.~~ --- **To (new):** [5304s905-R;Defined Requirement] Electromagnetic loads shall be kept within acceptable limits even in the event of potential failures in control. [12]
Change 11. Chapter / Section / Paragraph to be changed : 4.1.2 Operational conditions
From (old): [5304s903-R;Defined Requirement] ~~The DNB shall be designed to operate with a duty factor of at least 25% for burn duration greater than 450 s.~~ --- **To (new):** [5304s903-R;Defined Requirement] DNB shall be capable of executing the next pulse after a duration not exceeding three times the duration of the previous pulse or 1800 s whichever is longer.
Change 12. Chapter / Section / Paragraph to be changed : 6 APPLICABLE CODES AND STANDARDS
From (old): *None* --- **To (new):** Addition of table 7-2 after 5304s368-R DRQ
Change 13. Chapter / Section / Paragraph to be changed : 3.1 Safety design criteria
From (old): *None* --- **To (new):**

Addition of table 7-4 after 5304s861 -R DRQ

Change 14. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirements

From (old):
None

To (new):
Addition of table 7-5 after 5304s884-R DRQ

Change 15. Chapter / Section / Paragraph to be changed : 3.9 Environmental impact requirement

From (old):
None

To (new):
Addition of table 7-8 after 5304s872-R DRQ, 5304s873-R DRQ, 5304s874-R DRQ

Change 16. Chapter / Section / Paragraph to be changed : 7.1 First Plasma

From (old):
None

To (new):
[5304s959-R] DNB captive componenets shall be installed before FP phase.

Change 17. Chapter / Section / Paragraph to be changed : 7.2 Pre-Fusion Power Operation 1 phase

From (old):
None

To (new):
[5304s960-R] DNB shall be fully operational in its final configuration for PFPO-2 .

Change 18. Chapter / Section / Paragraph to be changed : 7.2 Pre-Fusion Power Operation 1 phase

From (old):
~~[5304s922-R;Defined Requirement] Before the first deuterium-tritium starts, the ITER device and facility shall be capable of being upgraded to provide personnel access to the interior of the ITER vacuum vessel in the presence of Be dust for hands-on maintenance.~~

To (new):
Deleted

Change 19. Chapter / Section / Paragraph to be changed : 7.2 Pre-Fusion Power Operation 1 phase

From (old):
~~[5304s923-R;Defined Requirement] The FPO Deuterium Operation shall aim at achieving 15 MA plasmas in Deuterium with a robust plasma control, and commissioning ITER systems prior to operations with Tritium.~~

To (new):
Deleted

Change 20. Chapter / Section / Paragraph to be changed : 7.4 DD-DT phase

From (old):
~~[5304s920-R;Defined Requirement] The NB H&CD system shall be installed in stages as stated in the staged approach configuration [28]~~

To (new):
Deleted

Change 21. Chapter / Section / Paragraph to be changed : 7.4 DD-DT phase

From (old):
~~[5304s924-R;Defined Requirement] ITER shall be designed to provide an average neutron fluence of 0.30 MW.y.m-2 in the active phase in order to satisfy the overall requirement specified in the Project Specification document [44].~~

To (new):
Deleted

Change 22. Chapter / Section / Paragraph to be changed : 7.4 DD-DT phase

From (old):
~~[5304s930-R;Defined Requirement] "For the following safety functions, these definitive provisions shall be implemented before the start of PFPO-1 (at the end of Assembly and Integrated Commissioning phase II): · the confinement of toxic materials; · support systems required to enable the confinement of both radioactive and toxic materials; · prevention of hazards challenging safety functions; · environmental surveillance; · crisis management.~~

To (new):
Deleted

Change 23. Chapter / Section / Paragraph to be changed : 7.4 DD-DT phase

From (old):
~~[5304s927-I;Defined Requirement] The Overall Strategy to construct and to operate ITER is presented in ITER Research Plan [40]. This strategy has been revised to integrate a staged approach where the following four plasma operation phases will be performed: First Plasma (FP), Pre-Fusion Power Operation 1 (PFPO-1), Pre-Fusion Power Operation 2 (PFPO-2) and Fusion Power Operation (FPO). Each of these plasma operation phases is preceded by an assembly and an integrated commissioning campaign. They correspond to four configurations of the ITER Plant, the FPO configuration being the final one, corresponding to the ITER Baseline, to undertake the full D-T plasma operation~~

To (new):
Deleted

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EXTERNAL REFERENCE / VERSION

System Requirement (SRD) Document

SRD-53-04 (DNB) from DOORS

This SRD contains all of the functional, design, safety, operational and quality requirements for the DNB.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Schunke B.**	**13 Dec 2019:signed**	**IO/DG/COO/TED/HCD/NB**
Co-Authors	**Luciathe C. E.**	**13 Dec 2019:signed**	**IO/DG/COO/CIO/CMD/DCC**
Reviewers	**Grosset K.**	**13 Dec 2019:recommended (Fast Track)**	**IO/DG/COO/CIO/CMD/DCC**
Previous Versions Reviews	**Bansal L. K. Rotti C. Belot arnaud F. Josseaume F. * Seropian C. Vertongen P.**	**12 Dec 2019:recommended (Fast Track) v4.1 03 Dec 2019:recommended v4.1 25 Sep 2019:reviewed v4.0 02 Oct 2019:recommended v4.0 10 Oct 2019:reviewed v4.0 23 Sep 2019:recommended v4.0**	**IO/DG/COO/CIO/DCIN/SIS IO/DG/COO/TED/HCD/NB IO/DG/RCO/SD/SHS/OHS IO/DG/COO/CIO/DCIN/DINS IO/DG/RCO/SD/EPNS/SAA IO/DG/QMD**
Approver	**Boilson D.**	**13 Dec 2019:approved**	**IO/DG/COO/TED/HCD**
Document Security: Internal Use RO: Croset Jean-Philippe			
Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: F4E_NB_PS, AD: OBS - Neutral Beam Section (NB) - EXT, AD: OBS - Neutral Beam Section (NB), LG: ...**		

Change Log			
SRD-53-04 (DNB) from DOORS (2MRU8E)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	12 Jan 2009	
v1.0	Signed	04 Mar 2009	
v1.1	Approved	10 Apr 2009	
v2.0	Approved	29 Oct 2009	List of modifications to the SRD after checking consistency with the Project Requirements (PR) (27ZRW8) version 4.1: Sections 1, 1.5, 2.1, 2.13, 3.2, 5.1
v2.1	Approved	30 Nov 2009	In the report from the IC/STAC – 7 meeting there were inconsistencies detected between the PR and the NB SRD documents. The SRD has now been corrected, taking these comments on-board. The gas requirements have also been updated.
v3.0	Approved	13 Jun 2012	Changes as a result of PCR 068, and also editorial changes as part of the SRD Harmonisation process
v3.1	Revision Required	26 Nov 2013	Changes as a result of PCR-409: Sections 1.2 (revised figure), 1.5 (interfaces to PBS 47 and 64, and title changes on BSI ICDs), 2.2.2 (gas quality requirement), 2.13 (thermal management), 3.7 (safety related operations), and 6 (design code)
v3.2	Signed	11 Jun 2014	Changes (since v3.0) due to PCR-409, and PCR-300 via CN-000271
v3.3	Signed	16 Sep 2014	Fully implemented PCR 409
v3.4	Approved	20 Feb 2015	Section 1.3 (up-date of classifications as a result of review of v3.3) and also due to the review of the classification table in SRD-53-01,-02,-03 (version 3.4) due to that the components of the DNB and the HNB should be the same: • Cooling water lines for beamline components outside the beamline vessel mentioned explicitly; • Neutralizer gas line outside the beamline vessel mentioned explicitly; • Vessel PMS bottom part seismic class from 1 to 1 (s)
v4.0	Signed	12 Sep 2019	This SRD-53-04 has been updated in the framework of the RPM exercise, to include the staged approach as well as the approved "ITER_D_LAMFG2 - Defined requirements for PBS53" requirements.
v4.1	Signed	25 Nov 2019	Please refer to the attached document which lists all the small editing changes made as requested by the reviewers. The checks requested by L. Kant are also listed. This SRD update takes into account PR v6.1. PR v6.2 will be implemented in the next update, which will also include the planned update of the DRD for PBS53.
v4.2	Approved	13 Dec 2019	Format correction in this version of SRD.

Table of Contents

List of Captions

PURPOSE

[5304s633-I] This System Requirements Document (SRD) lists the technical requirements and constraints on this system, and shows (via the use of links) how they arise from the overall project requirements that are listed in *Project Requirements (PR)* [7]. This leads to the identification of interfaces with the other systems of the ITER plant. This SRD also acts as the parent document for the technical requirements that need to be addressed in lower level design description documents.

[5304s634] **Table 0.1: Record of changes induced on this document by PCRs**

[5304s635]

SRD version	Section / Paragraph identifier	PCR reference
v1.0 to v2.1	Whole document	PCR-200
v3.0	Section 1.3 and then the whole document (due to the editorial changes of the SRD Harmonisation process)	PCR-068
v3.1 to v3.4	Sections 0.4 (references), 1.2 (revised figure), 1.3 (up-date of classifications), 1.4 (Added new hypothetical accident, and updated the pressure in NB cell limited by the VVPSS system), 1.5 (interfaces to PBS 47 and 64, and title changes on BSI ICDs), 2.1 (new requirement), 2.2.2 (gas quality requirement), 2.9.1 (new requirements), 2.12.1 (allowable leak rates) 2.13 (thermal management), 2.19 (New requirement), 3.1 (new requirements), 3.2 (correction of inventory limits of hydrogen), 3.3 (New requirement), 3.7 (safety related operations), 3.9 (New requirements), 6 (correction of applicable standards)	PCR-409 PCR-558 PCR-300 via CN-000271 PCR780 (no SRD update required as PCR had only financial impact)
V4.0	Whole document	PCR 738 PCR-m386
V4.1	Updated as per reviewer comments on SRD-53-04 v4.0	

SCOPE

[5304s637-I] This SRD contains all of the top level functional, design, safety, operational, maintenance and quality requirements for the Diagnostic Neutral Beam (DNB) system (PBS 53-04). In addition to the requirements specified in this SRD, this system has to comply completely with the requirements given in the Project Requirements (PR) document [7], in the PR annex documents, and in the Preliminary Safety Report (RPrS [14]]) .

[5304s777-I] Sections 1 to 6 of the SRD describe the system in its final configuration and the associated requirements that this system has to satisfy to undertake the Deuterium-Tritium operation campaigns (i.e. required capabilities to start the Fusion Power Operation (FPO) phase). The new section 7 presents specific requirements (if any) that the system has to satisfy for the planned construction and operation campaigns prior to FPO (i.e. during each of the 3 phases: First Plasma (FP), Pre-Fusion Power Operation 1 (PFPO-1), and Pre-Fusion Power Operation 2 (PFPO-2)).

DEFINITIONS

[5304s639] **Table 0.3: NB-specific abbreviations**

AC	Alternating Current
ACCC	Active Correction and Compensation Coils
ACP	Activated Corrosion Products
AGPS	Acceleration Grid Power Supply
ALARA	As Low as Reasonably Achievable
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
Be	Beryllium
C	Carbon
CCPS	Correction Coil Power Supply
CCS	Civil Construction and Site support
CD	Current Drive
CIS	Central Interlock System
CODAC	Control Data Access and Communications
Cs	Caesium
CSS	Central Safety System
CXRS	Charge Exchange Recombination Spectroscopy
D	Deuterium
DCR	Design Change Request
DD	Drift Duct
DIN	Deutsches Institut für Normung
DNB	Diagnostic Neutral Beam
DP1	Delivery Point 1
DP2	Delivery Point 2
DS	De-tritiation System
EDH	Electrical Design Handbook
EM	Electro Magnetic
ESPN	Equipements sous pression nucléaires
GRPS	Ground Related Power Supplies
H	Hydrogen
H-mode	High Confinement mode
He	Helium
HRS	Heat Rejection System
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
HVD1	High Voltage Deck 1
HVD2	High Voltage Deck 2

[5304s640]

ICE	Ingress of Coolant Event
IEC	International Electrotechnical Commission
IPP	Max-Planck-Institut für Plasmaphysik
ISEPS	Ion Source and Extraction Power Supplies
ISO	International organization for standardization
ISTF	Ion Source Test Facility
JIS	Japanese Industrial Standards
L-mode	Low confinement mode
LCC	Local control cubicle
MSE	Motional Stark Effect
NB	Neutral Beam
NBH	Neutral Beam Heating
NB H&CD	Neutral Beam Heating and Current Drive
NBI	Neutral Beam Injection
NDE	Non-Destructive Examination
Ne	Neon
O	Oxygen
PBS	Plant Breakdown Structure
PCDH	Plant Control Design Handbook
PHTS	Primary Heat Transfer System
PLC	Programmable Logic Controller
PMS	Passive Magnetic Shield
PR	Project Requirements
PRS	Pump regeneration Sequence
PS	Power Supply
Q	Fusion energy gain factor
q	Safety factor
QC	Quality Class
RIC	Radiation Induced Conductivity
RID	Residual Ion Dump
RIED	Radiation Induced Electric Degradation
RF	Radio Frequency
RH	Remote Handling
RPrS	Rapport Préliminaire de Sûreté
RoHS	Restriction of Hazardous Substances

[5304s641]

SF6	Sulfur hexafluoride
SIC	safety importance component
SL-1	Seismic Level-1
SL-2	Seismic Level-2
SRD	Systems Requirement Document
SVS	Service Vacuum System
TL	Transmission Line
VHB	Vacuum Hand Book
VQC	Vacuum Quality Class
VV	ITER Vacuum Vessel
VVPSS	Vacuum Vessel Pressure Suppression System

[5304s642]

[5304s643-I] For a complete list of ITER abbreviations see *ITER Abbreviations* [8].

References

[5304s744-I] This SRD makes reference to the following documents, and to the Interface Control Documents (ICDs) that are listed in Section 1.5.

[5304s943-R] The system shall be compliant with the applicable versions for each Complementary and Input Applicable Documents that are given in the IDM document XEZ3WW.

Complementary Applicable Documents

[5304s944-I] The following documents, which contain mandatory technical requirements to be satisfied by the system, are complementary to this SRD. ADc include the Interface Control Documents (ICDs) that are listed in section 1.5. Propagation and compliance of the system with the requirements recorded in these documents must be demonstrated in the same manner than this SRD.

[5304s745-ADc] [1] Codes and Standards for ITER Mechanical Components ITER_D_25EW4K

[5304s746-ADc] [2] ITER Vacuum Handbook ITER_D_2EZ9UM

[5304s747-ADc] [3] Electrical Design Handbook (EDH) - EDH Part 1: Introduction ITER_D_2F7HD2

[5304s748-ADc] [4] Plant Control Design Handbook ITER_D_27LH2V

[5304s749-ADc] [5] MPH Handbook Organization (G 74 MA 4 98-06-28 R0.1) ITER_D_222RDA

[5304s750-ADi] [6] Operations Handbook: 2 Operational States ITER_D_2LGF8N

[5304s753-ADc] [9] Liste détaillée des SIC_NoTritium Plant ITER_D_2LWAMF

[5304s754-ADc] [10] ITER Quality Assurance Program (QAP) ITER_D_22K4QX

[5304s760-ADc] [15] ITER Human Factor Integration Plan ITER_D_2WBVKU

[5304s763-ADc] [18] Safety requirement Roombook ITER_D_KF63PB

[5304s764-ADc] [19] Safety Functions, Systems, Signals Definition for I&C CSS Design ITER_D_3R7ECW

[5304s766-ADc] [21] ITER Fire Safety Approach ITER_D_25SDBD

[5304s767-ADc] [22] Penetrations through safety barriers ITER_D_JLDU7W

[5304s774-ADc] [23] In-vessel Components, SDC-IC ITER_D_222RHC

[5304s775-ADc] [24] ITER Materials Properties Handbook, Introduction, baseline 2009 (ITER_D_2NRCSB)

[5304s776-ADc] [25] List of Codes and Standards for ITER Systems, Structures and Components (MPH) (ITER_D_FPSNMT)

[5304s781-ADc] [27] ITER Remote Maintenance Management System (ITER_D_2FMAJY)

[5304s786-ADc] [32] Load Specification Annex - Internal Explosions: Hydrogen Deflagration in Tokamak Complex (ITER_D_BMQ9XM)

[5304s789-ADc] [35] ITER Radiation Maps: During DT plasma operations (Mode 0) : Radiation Maps During Plasma Operations (Mode-0) (ITER_D_RJLLFY)

[5304s954-ADc] [36] During cask movements (Mode 2) : ITER Radiation Maps: Subtask 3 report (ITER_D_F8UEXR)

[5304s955-ADc] [53] ITER Radiation Maps: Subtask 4 report (ITER_D_67CN24)

[5304s956-ADc] [52] ITER Radiation Maps: Subtask 5 report (ITER_D_HPX254)

[5304s796-ADc] [42] ITER Site Signage & Graphics Standards (ITER_D_4ALJEU)

[5304s799-ADc] [45] Electrical Design Handbook (EDH) - EDH Part 3: Codes & Standards (ITER_D_2E8DLM)

[5304s800-ADc] [46] Electrical Design Handbook (EDH) - EDH Part 4: Electromagnetic Compatibility (EMC) (ITER_D_4B523E)

[5304s801-ADc] [47] Electrical Design Handbook (EDH) - EDH Part 5: Earthing and Lightning Protection (ITER_D_4B7ZDG)

[5304s802-ADc] [48] Chemical composition and impurity requirements for materials ITER_D_REYV5V

[5304s784-ADi] [30] ATEX - requirements for risk assessment and mitigation (ITER_D_SGMUYM)

[5304s785-ADi] [31] ITER Remote Handling Code of Practice (ITER_D_2E7BC5|)

[5304s755-ADi] [11] Heat and Nuclear Load Specifications ITER_D_2LULDH

[5304s756-ADi] [12] Load Specifications (LS) ITER_D_222QGL

[5304s765-ADi] [20] ITER Seismic Nuclear Safety Approach ITER_D_2DRVPE

[5304s782-ADi] [28] Staged approach Configuration – PBS Level 3 (ITER_D_SNE6G8)

Input Applicable Documents

[5304s945-I] The following documents have been used as input to produce this SRD. It means that all the technical requirements they contain that are applicable to the system have been fully propagated to this system and that the resulting system requirements have been recorded in this SRD and/or one of its complementary applicable documents. Compliance with an Input Applicable Document (ADi) to this SRD will be demonstrated via the achieved compliance of this SRD and its ADc. An ADi only partially propagated to the system is identified as ADc until its propagation is complete.

[5304s751-ADi] [7] Project Requirements (ITER_D_27ZRW8)

[5304s779-ADi] [17] Defined requirements for PBS53 (ITER_D_LAMFG2)

[5304s803-ADi] [49] RPM from PR to SRD-53-04 (ITER_D_VH8YZP)

[5304s958-ADi] [51] RTM from DRD-53 to SRD 53-04 (ITER_D_25WKSU)

Reference Documents

[5304s946-I] A reference document is a document only "For information". It provides background information to improve the understanding of the project, system and its requirements. There is no need for the supplier to demonstrate compliance with an information (except for some information classified as Defined Requirement by SD that must be transmitted down the supply chain for awareness).

[5304s752-I;Defined Requirement] [8] ITER Abbreviations ITER_D_2MU6W5

[5304s758-I;Defined Requirement] [13] Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN ITER_D_7M2YKF

[5304s759-I;Defined Requirement] [14] Preliminary Safety Report (RPrS) ITER_D_3ZR2NC

[5304s783-I;Defined Requirement] [29] ITER Coordinate Systems, ITER_D_2A9PXZ

[5304s791-I;Defined Requirement] [37] Agreement on the Establishment of the ITER Organization (also called ITER Agreement) ITER_D_2EW6RK

[5304s793-I;Defined Requirement] [39] Etude d'impact - Partie 1: Analyse de l'état initial du site et de son environnement (ITER_D_7A7RDB)

[5304s794-I;Defined Requirement] [40] ITER Research Plan ITER_D_2FB8AC

[5304s795-I;Defined Requirement] [41] Electrical Design Handbook (EDH) - EDH Part 2: Terminology & Acronyms ITER_D_2E8QVA

[5304s798-I;Defined Requirement] [44] ITER Project Specification (ITER_D_2DY7NG) under configuration control

[5304s797-I;Defined Requirement] [43] Agreement between the Government of the French Republic and the ITER International Fusion Energy Organization ITER_D_29P59M

1 FUNCTIONS, BASIC CONFIGURATION, CLASSIFICATION AND SYSTEM BOUNDARIES

1.1 System Functions

[5304s15-R;Defined Requirement] The diagnostic neutral beam (DNB) injector shall provide a probe beam of 100 keV H0 to be used by the CXRS diagnostic system (PBS 55 E). The main purpose is to allow a measurement of the local density of thermal alpha particles (helium ash) [44].

[5304s16-R;Defined Requirement] The diagnostic neutral beam (DNB) injector shall also be used for other diagnostic measurements such as:

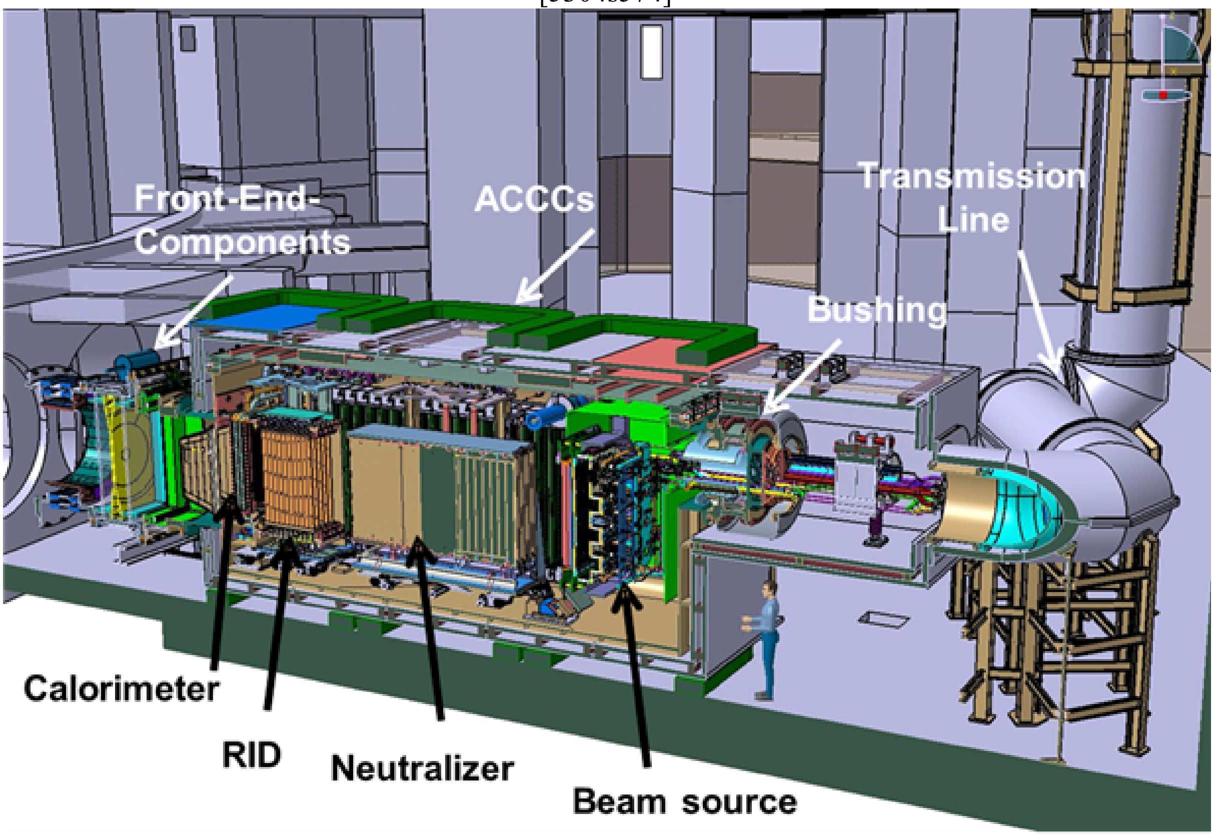
- The local density of light impurities (Be, C, O, Ne)
- The plasma rotation velocity
- The ion temperature
- For MSE measurements.

1.2 System Basic Configuration

[5304s21-I] The diagnostic beam-line is referred to as the DNB. The DNB has a configuration very similar to the NB H&CD injector.

[5304s546] **Figure 1.2-1: The DNB injector**

[5304s574]



[5304s23-I] The main components of the DNB systems are introduced here.

[5304s24-R;Defined Requirement] The DNB injector shall consist of the following sub-components:

- The beam source, where H^- ions are produced and accelerated. The beam source includes:

- The RF based plasmasource
- The 100 keV ion accelerator
- The electron dumps
- The beam-line components
- The primary vacuum confinement components
- The Passive Magnetic Shield (PMS), which shields the injector volume from the tokamak magnetic field, and which also, acts as a radiation shield for the NB cell
- The Active Correction and Compensation Coils (ACCC) that, together with the passive magnetic shield, limit the magnetic field in the injector volume.

ITER Systems, Structures, and Components (SSC) shall be classified for safety class, quality class, seismic class, vacuum class, and remote handling class. The DNB components shall comply with the classification listed in Table 1.3 [8], [9].

[5304s32-R;Defined Requirement] The beam-line components shall include:

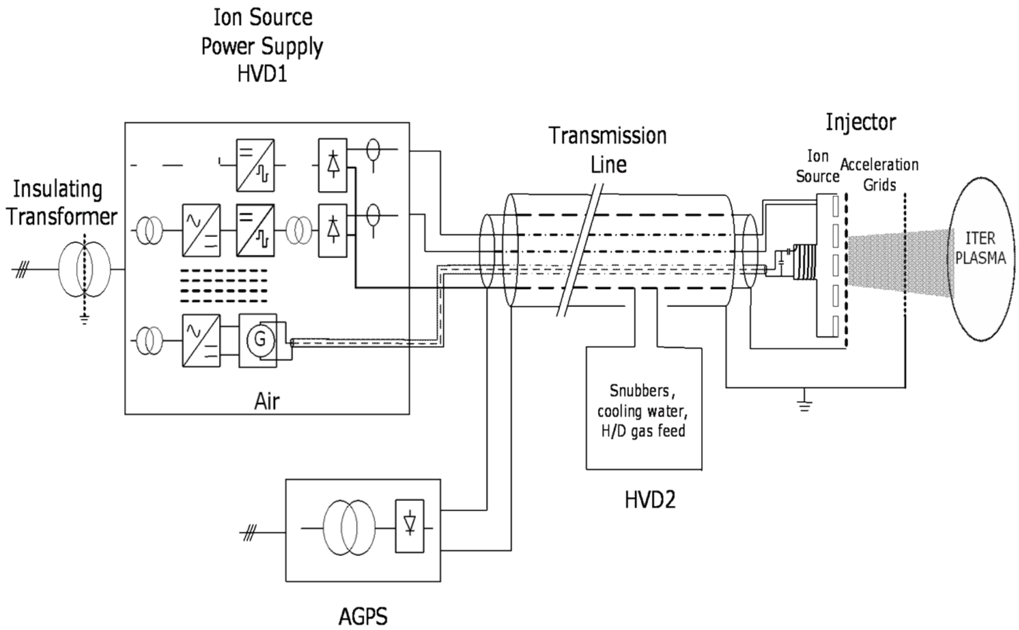
- The neutraliser, where a large fraction of the H^- ions that are produced by the beam source are converted to neutrals by collisions with H_2 or D_2 gas
- The residual ion dump (RID), where the ions that emerge from the neutraliser are deflected on to a set of water-cooled plates
- The calorimeter, which is a moveable beam dump that can be introduced into the beam path downstream of the RID, and which allows the DNB injector to be commissioned and tested independently of plasma operation
- The exit scraper, which intercepts the edges of the beam before it is transmitted to the Tokamak
- The cryopumps (provided by PBS 31), which are needed to maintain the appropriate vacuum level inside the DNB vacuum vessel.

[5304s37-R;Defined Requirement] The DNB vacuum boundary shall consist of:

- The High Voltage (HV) bushing, which allows the passage of all the coolant, gas and electrical lines from the air-insulated transmission line to the beam source, that is immersed in the vacuum
- The DNB vessel, which contains the beam source and the beam-line components
- The fast shutter, which can close the DNB vessel, avoiding the back-streaming of tritium from the ITER Vacuum Vessel (VV) to the injector's cryopumps (during tokamak operation without beams), reducing the dust ingress to the injector and allowing the regeneration of the injector cryopumps with the minimum release of gas to the VV. Methods to perform local monitoring and sampling to assess local dust erosion and deposition in the ITER vacuum vessel should also be provided; so that the flow into the NB injectors can be estimated. It is noted that the ITER VV provides the possibility of dust removal via vacuum cleaning of the plasma-facing component surfaces using the in-vessel remote handling systems.
- The absolute valve, which can isolate the DNB vessel from the vacuum of the VV
- The drift duct (DD), which consists of a set of bellows (de-coupling the beam-line vessel from the displacements of the vacuum vessel) and an internal liner that intercepts the fractionally ionised parts of the beam, deflected by the magnetic field
- The vacuum pipe that connects the DNB vessel to the roughing system. One isolation valve shall be installed to separate the vacuum systems. The valve shall be controlled by PBS 31.

[5304s461-R;Defined Requirement] The DNB Power Supply (PS) System shall provide the electrical power at High Voltage (HV) to the accelerator grids and supplies the ion source and the auxiliary components. A simplified block scheme of the DNB PS system is shown in Figure 1.2.

[5304s553] **Figure 1.2: Block schematic of the DNB system**



[5304s580]

[5304s462-I] The section that supplies the acceleration grids is called the Acceleration Grid Power Supply (AGPS). All the electronics that provides the voltage regulation and the switching off in case of grid breakdown, will be installed at ground potential in the AGPS.

[5304s463-I] The air-insulated HV deck is called High Voltage Deck 1 (HVD1). It will contain the equipment that makes up the Ion Source and Extraction Power Supply (ISEPS). All the power supply equipment that is installed in HVD1 will be at -100 kV potential for the DNB. HVD1 will be fed by one 50-Hz insulating transformer.

[5304s464-I] The Ground Related Power Supplies (GRPS) will be referenced to ground and will include the power supply systems to feed the Residual Ion Dump (RID) and the power supply of the ITER magnetic field compensation coils named Correction Coils Power Supply (CCPS). They are not shown in Figure 1.2.

[5304s465-I] The power will be transmitted to the ion source and the acceleration grid via a high voltage (HV) transmission line (TL), which will contain air at atmospheric pressure. The latter will provide the electrical insulation between the various electric potentials within the HV transmission, which will vary between -100 kV and ground.

[5304s466-I] The High Voltage Deck 2 (HVD2) will contain the interfaces for the cooling water and the gas feeding pipes for the beam source.

[5304s304-I] The Neutral Bam interlock system will detect off-normal conditions, and stop the beam within a time that is suitable for limiting the possible damage to the high heat flux components, and possibly a breech in primary confinement.

[5304s305-I] The beam interlock system has to ensure normal operation (such as the extraction grid current must be below a pre-set threshold). It has to also prevent damage to the accelerator or the high heat flux elements.

1.3 Classification of Systems, Structures and Components (SSCs)

[5304s805-R;Defined Requirement] The DNB components shall comply with the classification in the table 1.3 [16].

[5304s649] **Table 1.3: Classification of Systems, Structures and Components (SSCs)**

[5304s650]

DNB		Classifications						
		Safety Class[3]	Remote Handling Class	Vacuum Class	Seismic Class[3]	Seismic level	Quality Class	Tritium Class
Vessel	DNB vacuum vessel	SIC 1	Un-classified	1A	1 (S)	SL-2 & SL-1	1	1A
	Top lid [1]	SIC 1	2	1A	1 (S)	SL-2 & SL-1	1	1A
	Top Intermediate flange	SIC 1	2	1A	1 (S)	SL-2 & SL-1	1	1A
	Feedthrough box	SIC 1	3	1A	1 (S)	SL-2 & SL-1	1	1A
	BLC Adjustable bed	Non-SIC	3	1B	1 (S)	SL-2 & SL-1	2	-
	Exit scraper	Non-SIC	2	1A	2	SL-2 & SL-1[7]	2	1A
Beam Source	RF Ion Source	Non-SIC[5]	2	1A	2	SL-2 & SL-1 [7]	2	1A
	Accelerator + support and electron dump							
	Cesium oven	SIC 1	1	1A	2	SL-2 & SL-1 [7]	1	1A
Beam Line[2] Components	Neutraliser	Non-SIC[11]	2	1A	2	SL-2 & SL-1 [7]	2	1A
	Residual Ion Dump (RID or ERID)	Non-SIC[11]	2	1A	2	SL-2 & SL-1 [7]	2	1A
	Calorimeter	Non-SIC[11]	2	1A	2	SL-2 & SL-1 [7]	2	1A
HV Bushing		SIC 1[4]	3	1A	1 (S)	SL-2 & SL-1	1	1A (1B for inter-space)
Cooling water lines for beamline components outside the beamline vessel		SIC 1[11]	Un-classified	-	1 (S)	SL-2 and SL-1	1	1B
Neutraliser gas line outside the beamline vessel		SIC 1	Un-classified	1A	1 (S)	SL-2 and SL-1 [8]	1	1A
Cryo pump [13]	Cryosorption panel	SIC 1	3	1A	1 (S)	SL-2 & SL-1 [7]	1	1A
	Thermal shield							
	Flange							

[5304s651]

DNB		Classifications						
		Safety Class[3]	Remote Handling Class	Vacuum Class	Seismic Class[3]	Seismic level	Quality Class	Tritium Class
Front components	Fast shutter casing	SIC 1[6]	3	1A	1 (S)	SL-2 & SL-1	1	1A
	Fast Shutter Mechanism		2		1 (SF)			
	Abs valve casing	SIC 1[6]	3	1A	1 (S)	SL-2 & SL-1	1	1A
	Abs valve Mechanism				1 (SF)			
	Drift duct bellow	SIC 1	3	1A	1 (SF)	SL-2 & SL-1	1	1A
	Drift duct liner	Non-SIC		1A	2	SL-2 & SL-1 [7]	2	
HV Transmission Line	TL 3	Non SIC[12]	Un-classified	-	2[12]	SL-2 & SL-1	2[9]	-
	Core Snubber							
	HVD2							
	Disk bushing and supporting flange in TL3	SIC 1	Un-classified	-	2[12]	SL-2 & SL-1	1	4B
	Water cooling lines	SIC-1[5]	Un-classified	-	1 (S)	SL-2 & SL-1	2	1B
	H2/D2 lines and valves	SIC 1	Un-classified	1A	1 (S)	SL-2 & SL-1	1	1A
	Interspace circulation line	SIC 1	Un-classified	1A	1 (S)	SL-2 & SL-1	1	1B
Vessel PMS	Bottom part	SIC2	Un-classified	-	1 (S)	SL-2 & SL-1 [7]	1	-
	Top plates	Non-SIC	2		2		3	
	Rest of PMS	Non-SIC	Un-classified		2		3	
Residual Magnectic	Bottom coils (coil #1-2-3)[8]	Non-SIC	3	-	2	SL-2 & SL-1 [7]	3	2A[10]
	Top coils (coil #4-5 &6) [8]	Non-SIC	2	-	2	SL-2 & SL-1 [7]	3	2A[10]

[5304s653-I] Note 1: With intermediate flange.

[5304s654-I] Note 2: With their support.

[5304s659-I] Note 3: Going in the detail of the component the classification may change for specific part. For more details see *Liste détaillée des SIC_NoTritium Plant* [9].

[5304s660-I] Note 4: All HV bushing and air circulation line with corresponding pump and valves are classified SIC-1.

[5304s661-I] Note 5: Cooling pipes of the Beam Source are SIC-1 between the HV Bushing and the SIC-1 classified isolation valves outside HVD2. They are thereafter SIC-2 for confinement of ACP and tritium in the coolant.

[5304s662-I] Note 6: The mechanism is non-SIC, but the part of the casing which comes with the mechanism is SIC1.

[5304s663-I] Note 7: For SL-2 no collapse allowed impacting to SIC-1 and 2 components with SL-2 in case of SC2. SL-1 is for investment protection in case of SC2.

[5304s664-I] Note 8: Information does not include supports (design on-going).

[5304s666-I] Note 9: The support of transmission line is class 3.

[5304s667-I] Note 10: Tritium class for ACCCs concern the confinement of ACP.

[5304s768-I] Note 11: Cooling pipes of the Beam Line Components are SIC-1 between the Beam Line Vessel and the SIC-1 classified isolation valves. They are thereafter SIC-2 for confinement of ACP and tritium in the coolant.

[5304s769-I] Note 12: The support function of the SIC classified pipes inside the transmission line is SIC classified. The seismic class for the support function is SC1.

[5304s770-I] Note 13: the cryo pump belongs to PBS 31 but is mentioned here for completeness.

[5304s496-I] The NB cell and the level 3 area above the NB cell will be classified as clean rooms during the assembly of internal components and the transmission line. The classification of the air cleanliness is defined in the *ITER Vacuum Handbook* [2].

[5304s668-R] The NB cell shall be classified as a yellow radiological zone [18] [35], [36], [53], [52].

[5304s669-R] The level 3 area above the NB cell shall be classified as a yellow radiological zone [18] [35], [36], [53], [52].

[5304s724-R;Defined Requirement] The DNB system components shall be designed and tested according to the Pressure Equipment Directive (PED) and the Nuclear Pressure Equipment Directive (ESPN).

[5304s807-I;Defined Requirement] The ASN Decision 2013-DC-0379, dated 12 November 2013 [34], establishes the prescription for the design and the construction of the licensed nuclear facility INB No. 174 called ITER.

[5304s808-R;Defined Requirement] Vacuum classification shall be determined in accordance with the ITER Vacuum Handbook [2].

[5304s809-R;Defined Requirement] Remote handling classification shall be determined in accordance with the ITER Remote Maintenance Management System [27].

1.4 Design Basis Conditions and Events

[5304s670] **Table 1.4: Design Basis Conditions and Events**

[5304s671]

Category	Description of event	Annual Frequency	Safety relevance	Requirements on System
Normal situations	Fault of equipment linked to the DNB PS that can be easily replaced		NSR	Average interruption time of the DNB system of less than 4 hours
Incidental situations	SL-0 earthquake		NSR	Interruption time will be 1day to check entire system.
	Loss of site-power (1hour)		NSR	Interruption of operation during the power outage.
	BLV over pressure during beam operation		SR	Beam inhibited. Close Fast shutter and absolute valve.
	SF6 detected in NB cell		SR	Close isolation valve to de-tritiation system.
Accidental situations	SL-1 earthquake	10^{-2}	NSR	Interruption time will be >1week to check entire system.
	Water leak in DNB vessel		SR	Beam operation stopped. Isolate injector.
	Air leak into DNB vessel		SR	Beam operation stopped. Isolate injector.
	Fire in an I&C cubicle		NSR	Interruption time will be >1week to check entire system.
Hypothetical accidents	SL-2 earthquake	10^{-4}	SR	DNB system stopped but without significant leakage of activity.
	Fire in NB cell	10^{-4}	SR	DNB system stopped but without significant leakage of activity.
	Fire in NB cell and SL2 earthquake	10^{-4}	SR	DNB system stopped but without significant leakage of activity.

[5304s45-R;Defined Requirement] All DNB components that are classified as SIC in Section 1.3 shall withstand the maximum foreseen over pressure in any incident.

[5304s426-I] Over pressurization can be caused by:

• A pressure rise due to loss of coolant in the ITER VV, which will be limited to 0.2 MPa by the Vacuum Vessel Pressure Suppression System (VVPSS)

• Loss of coolant in the DNB vessel

• Leak of Helium from the DNB cryo pumps

• A H_2 leak from the gas introduction system

• A dry air leak from the DNB HV bushing.

1.5 System Boundaries and Interfaces

[5304s810-R;Defined Requirement] The port numbering scheme shall comply with the ITER Coordinate Systems [29] document.

[5304s47-I] The main boundary of the DNB System, on the ITER VV side, shall lie at the flange connecting the duct liner of the injector and the port extensions on port # 4. On the power supplies side, it will lie at the flanges that connect the HV bushing and the transmission line.

[5304s48-R;Defined Requirement] PBS 15 (Vacuum Vessel, ELM and Manifolds):

- Physical and functional interface
- ICD 15 - 53 ITER_D_2WJF4K shall describe the interface.
- The DNB duct is installed on port # 4.

[5304s672-R;Defined Requirement] PBS 16 (Blanket System):

- Physical and functional interface
- ICD-16-53-Blanket-NB ITER_D_2MCUSN
- Wall armour, provided by PBS 16, shall be installed to protect against beam shine through.

[5304s434-R;Defined Requirement] PBS 18 (Fuelling and Wall Conditioning System):

- Physical and functional interface
- ICD-18-IC-53_Gas Injection - NBI ITER_D_2L8ZUH
- The fuelling and wall conditioning system shall supply H2 and D2 gases for the DNB System.

[5304s435-R;Defined Requirement] PBS 22 (Machine assembly and tooling):

- Physical and functional interface
- ICD-22-53 Machine Assembly - NB ITER_D_2ML4V2 shall describe the interface.
- To support the assembly of the In-port components from the DNB System.

[5304s436-R;Defined Requirement] PBS 23 (Remote Handling System):

- Physical and functional interface
- ICD-23-05-53-04 RH - DNB ITER_D_2NJKRW shall describe the interface.
- The same RH system should be applied to the DNB System and the NB Heating and CD System. The RH system should be compatible with the NB cell logistics. The Cs oven is a RH class 1 component. The DNB ion source, neutraliser, RID, calorimeter and fast shutter are RH class 2. The absolute (isolation) valve is RH class 3. See detailed description in Section 4.2.

[5304s437-R;Defined Requirement] PBS 24 (Cryostat and VVPSS):

- Physical and functional interface
- Interface Control Document (ICD) between Cryostat VVPSS (PBS 24) - NB HCD (PBS 53) ITER_D_3V8PBR
- The DNB duct shall penetrate the cryostat, and shall be connected to the cryostat and to the bioshield, through bellows. These bellows, and associated structure, shall be considered part of the cryostat.

Passive devices (such as rupture disks) shall be used in the flow path between the ITER vacuum vessel and the Vacuum Vessel Pressure Suppression system (VVPSS) tank. The system that supplies liquid helium to ITER systems shall limit the potential release of helium within the vacuum vessel to 50 kg (protection measure to guarantee the confinement function of the VVPSS).

[5304s438-R;Defined Requirement] PBS 26 (Cooling Water System):

- Physical and functional interface
- ICD-26-53 CWS NBI ITER_D_2NST3N shall describe the interface.
- The function of the NBI PHTS is to provide cooling water to the NB components. The CCWS-2A is used for cooling of the ACCC’s.

The appropriate water chemistry shall be established and controlled by PBS26 within specified limits for all modes of operation including commissioning, plasma operation, baking, and hot and cold standby states to prevent corrosion damage of materials in cooling circuits.

Materials and their joints which are in contact with fluid shall be selected taking into account their corrosion resistance during ITER lifetime.

[5304s439-R;Defined Requirement] PBS 31 (Vacuum System):

- Physical and functional interface
- ICD-31-53 Vacuum Neutral Beams ITER_D_2LJ9V5 shall disribe the interface.
- The DNB injector interfaces to the roughing system.

[5304s440-R;Defined Requirement] PBS 32 (Tritium Plant):

- Physical and functional interface
- ICD-32-53 ITER_D_2MQWZ7 shall describe the interface.
- The NB cell ventilation shall be permanently connected to the de-tritiation system.

Air flow within the buildings shall be directed from lower to higher zones of contamination.

Ventilation exhaust shall go through controlled and monitored release points.

[5304s443-R;Defined Requirement] PBS 43 (Steady state electrical power network):

- Physical and functional interface
- ICD-43-53 SSEN - NB ITER_D_2L98AE
- The Steady-State Electric Power Supply Networks (SSEPN) shall supply AC power to the DNB System.

[5304s673-R;Defined Requirement] PBS 44 (Cable Trays System):

- Physical and functional interface
- ICD-44-53 cable trays system - NB ITER_D_3C4R9M
- The Cable trays System shall supply cable trays for the DNB System.

All cables shall be installed in steel cable trays and conduits, which shall provide adequate physical protection and ensure reliable support to the cables during and after installation. In addition, in all nuclear buildings, all cable trays shall have a metallic cover to minimize the risk of fire propagation.

[5304s421-R;Defined Requirement] PBS 45 (CODAC):

- Physical and functional interface
- ICD-45-53 CODAC NB ITER_D_2NKSRL
- All control, data access and communication shall be provided by CODAC. A real time power control system of the DNB System shall be provided by CODAC.
- **[5304s444-R;Defined Requirement]** The DNB System shall provide events to PBS 46 (Central Interlock System). Central Interlock system shall provide actions to PBS 53 (DNB System) [19].

[5304s728-R;Defined Requirement] PBS 47 (Plasma Control System):

- Functional interface
- Interface_Control_Document_(ICD)_Plasma ITER_D_46FMWF shall describe the interface.
- Data to be transferred to and from PBS 47 from PBS 53 for plasma control.

[5304s445-R;Defined Requirement] PBS 48 (Central Safety System):

- Physical and functional interface
- Interface Control Document (ICD) Central Safety System (PBS 48) - NBH & CD (PBS 53) ITER_D_2M3F8D
- PBS 53 (DNB System) shall provide events to PBS 48 (Central Safety System).

[5304s446-R;Defined Requirement] PBS 55 (Diagnostics):

- Physical and functional interface
- 53.7-55 IC Diagnostic Neutral Beam - Diagnostics ITER_D_27VQD7 shall describe the interface.
- Provision of a timing signal and beam data from the DNB for the diagnostics.

[5304s583-R;Defined Requirement] PBS 62-11 (Tokamak Building):

- Physical and functional interface
- Interface Control Document (ICD) between Tokamak Building (PBS 62-11) - Neutral Beam H&CD System (PBS 53) ITER_D_27SB82 shall disribe the interface.

[5304s953-R;Defined Requirement] PBS 62.21 (Hot Cell Facility Bldg) : Physical and functional interfaces shall be as described in the ICD and associated interface sheets.

- Physical and functional interface
- ICD-53-62.21 (ITER_D_TRBNWS)
- Maintenance and replacement of neutral beam cell equipment during the transfer of that equipment through the HCC where there is no interface with RH systems.

[5304s729-R;Defined Requirement] PBS 64 (Radiological and Environmental Monitoring):

- Physical and functional interface
- ICD-53-64A (ITER_D_2MP3GY)
- Radiological and Environmental Monitoring system shall have equipment in the NB cell and in HV deck room on Level 3.

The Radiological and Environmental Monitoring system shall provide monitoring and warnings for chemical and radiological hazards, and for ionizing radiation fields.

Monitoring shall be provided in rooms/areas that are under access control, and shall confirm or override the logic of the Access Control and Security System to allow or deny access, based on actual measured conditions.

Personnel exposure to ionizing radiation shall be monitored via a network of detectors that are located in rooms together with, as appropriate, active and passive dosimeters that are worn by the personnel and individual medical surveillance. This includes but is not limited to monitoring of tritium, neutron, gamma, radon gas, particles, and 14C.

[5304s447-R;Defined Requirement] PBS 65-00-CA (Compressed Air System):

- Physical and functional interface
- Interface Control Document (ICD) between Compressed Air (PBS 65-00-CA) - Neutral Beam H&CD System (PBS 53) ITER_D_2EPZ8L
- The liquid and gas networks shall provide compressed air to PBS 53 (DNB).

[5304s448-R;Defined Requirement] PBS 66 (Radwaste Treatment and Storage):

- Physical and functional interface
- ICD-53-66-NB-Radwaste Treatment and Storage ITER_D_2MEYXZ
- The caesium ovens shall be replaced regularly and the used ovens will become radwaste.

2 DESIGN REQUIREMENTS

[5304s50-I] The system internal requirements are, in general, the same for the DNB as for the HNB's.

2.1 General requirements

[5304s675-R;Defined Requirement] The DNB System shall be designed for an active (D-T) phase that lasts at least 14 years.

[5304s54-R] The main parameters of the DNB System for the two phases of operation shall be summarized in the following table 2.1.

[5304s548] **Table 2.1: Main parameters of the DNB System for the two phases of operation**

[5304s578]

	Unit	
DNB species		H
DNB injection current	A	17
DNB beam energy	keV	100
DNB injection power (unmodulated)	MW	1.4
DNB beam on time (modulated)	s	3600
DNB# of allocated equatorial ports		1
DNB injection angle in horizontal (radial) direction	deg	~6
DNB injection angle in vertical direction	deg	0.89
DNB injection height above machine axis centre line	mm	461

[5304s730-R;Defined Requirement] The Safety-Important Classified (SIC) Components of the Diagnostic Neutral Beam System [17] shall be subject to monitoring as needed to ensure that they will perform their accredited safety functions.

[5304s432-R;Defined Requirement] The DNB system shall be equipped with an interlock to stop the beam if the plasma density is too low to avoid shine-through.

[5304s811-R;Defined Requirement] The NB H&CD system shall be designed, constructed, and operated in accordance with the requirements in the ITER Tritium Handbook 181.

2.2 System specific requirements

2.2.1 Layout requirements

[5304s67-R;Defined Requirement] The DNB injector shall share the use of port # 4 with one of the injectors of the NB Heating and CD System and shall be connected by a duct to the vacuum vessel.

[5304s68-R;Defined Requirement] The DNB System shall inject near radially into the plasma in compliance with the viewing geometry of the charge exchange spectroscopy.

[5304s71-R;Defined Requirement] The NB Heating and CD System and the DNB, outside the bioshield surrounding the cryostat, shall be fully contained inside one single volume (referred to as the NB cell).

The DNB shall conform to the space envelope constraints and interface characteristics specified in the CAD assemblies, parts, and drawings in the CMM.

[5304s72-R;Defined Requirement] The layout of the NB Heating and CD System and the DNB shall be compatible with the use of the upper ports # 4, 5, 6 and 7, which must be accessible for maintenance through the NB cell.

[5304s450-I] A dedicated safe opening in the NB cell will connect to the NB corridor close to the Hot cell Facility. This access will allow transferring NB components from the NB cell to the Hot Cell.

2.2.2 Gas quality and quantity requirements

[5304s622-R] The requirement for the ion source gas and the neutraliser gas for the DNB System injector shall be defined in the Table 2.2.

[5304s623] **Table 2.2: Gas requirements for the DNB injector for the two phases of operation**

[5304s628]

	Parameter	Unit	H/He Phase	DD/DT Phase	
Ion Source	Gas type		H_2	H_2	
	Gas flow	Pam³/s	7.6	7.6	
	Gas purity	Atom %	>99.999% of H_2 <1PPB of ^3H <1 PPM of O_2 <10 PPM of N_2 <1 PPM of H_2O <0.001% of other gases	>99.999% of H_2 <200PPM of ^3H <1 PPM of O_2 <10PPM of N_2 <1PPM of H_2O <0.001% of other gases	
	Supply pressure (absolute)	MPa	0.5	0.5	
Neutralizer	Gas type		H_2	H_2	D_2
	Gas flow	Pam³/s	8	8	5
	Gas purity	Atom %	>99.9% of H_2 <1PPB of ^3H <5 PPM of O_2 <10 PPM of N_2 <5 PPM of H_2O <0.1% of other gases	>99% of H_2 <1% of ^3H <5 PPM of O_2 <10 PPM of N_2 <5PPM of H_2O <0.1% of other gases	>99% of D_2 <1% of ^3H <5 PPM of O_2 <10 PPM of N_2 <5PPM of H_2O <0.1% of other gases
	Supply pressure (absolute)	MPa	0.09 – 0.5	0.09 – 0.5	0.09 – 0.5

2.3 Structural requirements

2.3.1 Normal operation requirements

[5304s76-R;Defined Requirement] All of the components that form the primary vacuum confinement shall be designed for the combination of:

- The external pressure of 0.1 MPa (absolute)
- The weight of the components that are supported by the primary vacuum boundary
- The operation displacements (for the bellows that connect the DNB injector to the NB duct and for the thermal expansion of the vessel).

[5304s80-R;Defined Requirement] The design shall include the fatigue verification for a maximum of 500 evacuation/pressurisation cycles, consistent with tokamak operation and the maintenance schedule; and the operation displacements at the NB duct / drift duct interface flange (such as VV displacements due to thermal expansion due to baking, VV supports displacement and electromagnetic forces).

[5304s812-R;Defined Requirement] The scope of design verification shall be applied to all safety-related systems, structures, and components. However, certain important non-safety-related systems and structures are included in the design verification at the discretion of ITER Organization management.

[5304s83-R;Defined Requirement] The alignment of the beam source and of the beam-line components shall be done at atmospheric pressure and at room temperature.

[5304s84-R;Defined Requirement] For normal operation loads, the deformation of the primary vacuum confinement, with respect to alignment conditions, shall be calculated and verified to remain within the prescribed limits.

[5304s85-R;Defined Requirement] The neutraliser, the RID and the calorimeter (high heat flux components) shall be designed for normal operation coolant parameters, and maximum power and power density.

[5304s86-R;Defined Requirement] The design shall provide a thermal fatigue life that is consistent with the total number of pulses/pulse duration that is foreseen by ITER operation (30000) and by the commissioning and testing of the system.

[5304s87-R;Defined Requirement] The thermal fatigue life cycles shall include the effect of power supply switch-off/switch-on at the occurrence of an electrical breakdown.

[5304s88-R;Defined Requirement] For the DNB, the additional thermal fatigue due to the pulse operation mode shall be taken into account.

[5304s89-R;Defined Requirement] The supports of the passive magnetic shielding and of the active compensation coils shall be designed for the forces that derive from magnetic field variations during normal operation and disruptions.

[5304s451-R;Defined Requirement] The maximum quantity of H_2 isotopes in one beam-line shall be below the deflagration limit.

2.3.2 Over-pressure protection requirements

[5304s91-R;Defined Requirement] All of the components that form part of the primary confinement barrier, with respect to radioactive material that comes from the torus, shall be designed for an over-pressurisation accident that is due to a large coolant leak in the vacuum vessel, (ICE category IV) with a maximum absolute pressure of 0.2 MPa. The pressure rise shall be limited to 0.2 MPa by the Vacuum Vessel Pressure Suppression System (VVPSS).

2.3.3 Investment protection requirements

[5304s453-R;Defined Requirement] The integrity of the DNB System shall be retained under off-normal events.

[5304s676-R;Defined Requirement] The beam source and the beam-line components are not classified as SIC components, so they shall be designed to withstand, without damage, a SL-1 seismic load case [20]. The seismic classification shall be determined in accordance with the ITER Seismic Nuclear Safety Approach [20].

[5304s677-R;Defined Requirement] The water pipes outside the beam-line vessel are classified as SIC components, so they shall be designed to withstand, without damage, a SL-2 seismic load case.

[5304s678-R;Defined Requirement] The high heat flux components of the beam-line shall be designed to withstand, without damage, the increased power that is due to the loss of neutralisation or loss of deflection voltage, for the time that is required for fault detection and beam switch-off.

[5304s813-R;Defined Requirement] The NB H&CD system design shall take into account possible impact on other SSC, for example due to collapse, debris, leaks and deflagration.

2.4 Mechanical requirements (including load conditions)

[5304s98-R;Defined Requirement] The design of the ITER systems shall withstand loading conditions (including seismic) and combinations as specified and classified in four different likelihood categories in the *Load Specifications (LS)* [12]. The combination of loads from earthquakes with other loading events shall be considered. Structural integrity of buildings shall be ensured in case of underpressure, for example due to failure of vacuum boundaries (even in worst-case scenarios).

All ITER systems, structures and components - including the DNB- shall provide means to accommodate the pressure loads that are due to unplanned release of coolants, in particular those that are used for in-vessel components, vacuum vessel and superconducting magnets.

The design of all ITER systems shall include provisions to minimize the potential for other hazards that could challenge confinement systems. These include internal aggressions, such as fire or flooding, and external aggressions, such as earthquakes or extreme weather conditions.

[5304s427-I] The NB cell will be designed to take the weight of the DNB and the NB Heating and CD System, and the NB cell logistics should support the integration of NB Heating and CD Systems and future maintenance.

[5304s455-I] The beam-line components should be mounted via devices that allow any misalignment due to assembly tolerances and support deformations to be recovered.

[5304s456-R;Defined Requirement] The system shall be subdivided in components to be assembled on-site, whose maximum dimensions and weights are consistent with the available access route.

[5304s457-R;Defined Requirement] Dedicated lifting equipment shall be used for the assembly of the DNB. The remote handling crane will be used for the assembly of all components.

[5304s458-R;Defined Requirement] The design of the DNB shall use, to the maximum possible extent, the same components and the same maintenance approach that is used for the HNBs.

2.5 Seismic requirements

[5304s428-R;Defined Requirement] The DNB System shall be designed to withstand a SL-2 earthquake [20].

[5304s429-R;Defined Requirement] There shall be no significant leakage of activity from the system into rooms during or following a SL-2 earthquake.

[5304s134-R;Defined Requirement] Beyond the safety requirements, all of the components shall be designed to maintain their functional requirements under a SL-1 seismic event [20].

[5304s417-R;Defined Requirement] The combination of loads from earthquakes with other loading events shall lead to no significant leakage of activity from the system into rooms.

[5304s814-R;Defined Requirement] The ITER installation shall be equipped with a seismic detection system to provide a warning notification of a seismic event.

2.6 Fire protection requirements

[5304s248-R;Defined Requirement] The provisions that concern fire safety shall comply with the latest versions of the relevant codes and standards and the ITER Fire safety Approach [21]. In particular, the Assemblée Plénière des Sociétés d'Assurances Dommages (APSAD) rules R7 (fire detection) and R13 (fire-extinguishing), the NF C 13-000 and NF C 17-300, the IEC standards as well as the Electrical Design Handbook (EDH) [3], [41], [46], [45], [47] shall be taken into account.

2.7 Electrical requirements

[5304s460-R;Defined Requirement] The electrical system shall conform to the Electrical Design Handbook (EDH) [3], [41], [46], [45], [47].

[5304s93-I] A set of reference design criteria for the electrostatic design of the beam source and the HV bushing are to be developed, based on the review of experimental data on vacuum and pressurised gas insulation. This should be completed prior to the FDR.

[5304s94-R;Defined Requirement] Reduction of the insulating properties of material and insulation media (air) as a result of irradiation shall be taken into account, using appropriate safety factors.

[5304s95-R;Defined Requirement] The selection of the insulating materials and pressurised insulating gases shall take into account their levels of RIC (radiation induced conductivity) and RIED (radiation induced electric degradation) under the relevant neutron and ionising radiation fluxes.

[5304s96-R;Defined Requirement] Provisions shall be included, as necessary, for the removal of the power that is lost in the insulating gas, as a consequence of the RIC and associated leakage currents.

[5304s679-R;Defined Requirement] Electrical systems that are installed within the Tokamak Building for the NB Heating and CD System shall be either designed to withstand all electrical or magnetic fields that are present during ITER operation, or if sensitive to such perturbations, they shall be subject to specific protection and/or alternative measures.

[5304s680-R;Defined Requirement] The DNB System shall include appropriate systems to enable the evacuation of accumulated heat from electrical equipment under any design basis situations in order to protect the personnel and SIC elements.

2.7.1 Power supply requirements

[5304s467-R;Defined Requirement] The NB control system shall be supplied with power from an UPS from the power supply network.

[5304s584-R;Defined Requirement] The power that is demanded from the 0.4kV class II, IP power supply network shall be not greater than 20 kW for the control cubicles of the DNB System.

[5304s585-I] The power that is demanded from the 0.4kV class IV, IP power supply network will be not greater than 10 kW for general usage.

[5304s815-R;Defined Requirement] The maximum power interruption times shall be:

- Class I: no time delay
- Class II: full load transfer within one-half cycle of the degraded power-sensing signal
- Class III: full load transfer within a specified time of the degraded power-sensing signal (30 s or more, depending on the startup sequence of the electrical consumers that are supplied by the emergency diesel generators).

[5304s816-R;Defined Requirement] The electrical power for all safety control systems shall be non-interruptible.

[5304s817-R;Defined Requirement] Steady-state power supplies shall provide remote-controlled breakers and switchgear, such that all major non-safety loads may be disconnected by the plant electrical control centre.

[5304s818-R;Defined Requirement] The Class I and II safety-relevant power supply systems shall provide power for at least one hour to safety loads.

[5304s819-R;Defined Requirement] The Class I and II safety-relevant power supply systems shall have a reliability that exceeds 0.999 per hour.

[5304s820-R;Defined Requirement] The Class III safety-relevant power supply systems shall have a reliability that exceeds 0.99 per loss of power event.

[5304s821-R;Defined Requirement] The Class III safety-relevant power supply systems shall have sufficient on-site fuel to maintain full safety loads for 3 days.

[5304s822-R;Defined Requirement] ITER shall include appropriate systems to enable the removal of accumulated heat (from electrical equipment) under any design basis situations, in order to protect the personnel and SIC components.

2.8 Grounding and Insulation requirements

[5304s250-R;Defined Requirement] The DNB System shall be connected directly to the tokamak via the metallic NB duct. (There shall be no insulating break.)

[5304s251-R;Defined Requirement] The earth point for the NB power supplies shall be the injector vacuum vessel.

[5304s469-R;Defined Requirement] Ground loops shall be avoided by installation of isolation breaks where needed (such as water feed lines, cryogenic lines, and gas lines).

[5304s823-R;Defined Requirement] For EMC considerations, the Tokamak complex earthing shall be realised as described in the chapter 8 of the EDH-Part 4 [46].

2.9 Instrumentation and control requirements

2.9.1 Instrumentation to ensure safe operation

[5304s824-R;Defined Requirement] The DNB I&C shall comply with the Safety Functions, Systems, Signals Definition for I&C CSS Design [19].

[5304s732-R;Defined Requirement] The components of the Diagnostic Neutral Beam System containing water or liquid effluents shall be designed to limit, to the maximum extent possible, leakage, and in the event of a leakage, it shall be possible to isolate the leaking system, purge it and/or to collect the leakage.

[5304s733-R;Defined Requirement] The components of the Diagnostic Neutral Beam System containing water or liquid effluents shall be suitably monitored (including periodic inspection) to detect as soon as possible a leakage and be equipped of appropriate alarm system.

[5304s101-R;Defined Requirement] The instrumentation to ensure safe operation of the DNB System shall include the measurements of:

- Beam source cooling water temperatures (PBS26)
- Caesium oven temperatures (PBS53)
- Coolant temperature and flow rate for all beam-line components and the ACCCs (PBS26)
- Exit scraper water temperatures (PBS26)
- Duct liner temperatures (PBS53)
- Cryo pump temperatures (PBS31)
- Measurement of the quantity of gas that is trapped on the cryo pump (PBS31)
- Vacuum measurements in the DNB vessel and duct (PBS31)
- Magnetic field, at relevant locations inside the injector's volume (PBS53)
- Gas flow, for the neutraliser and ion source (PBS18)
- Cooling water conductivity for the beam source and RID (PBS26)
- Insulation gas pressure and temperature, in the transmission line (PBS53)
- Calorimeter position (open/closed) (PBS53)
- Fast shutter position (open/closed) (PBS53)
- Fast shutter temperature (PBS53)
- Absolute valve position (open / closed) (PBS53)
- Absolute valve position (locked / unlocked) (PBS53)
- Absolute valve temperatures (PBS53)
- Absolute valve protection shield temperatures (PBS53)

• The total power that is injected to the tokamak will be indirectly measured (PBS53). The power will be calculated from the electrical measurements at the power supplies, the measured power that is intercepted on the beam-line components and the measured power that is intercepted on the duct liner. Reference pulses into the calorimeter will be performed as required.

[5304s112-R;Defined Requirement] All measurements of voltage and current (beam source, RID and active compensation coils) shall be derived from the instrumentation that is foreseen as part of the DNB power supplies.

[5304s470-R;Defined Requirement] Instrumentation and Control elements shall be compatible with the electromagnetic and ionizing radiation fields in which they operate.

[5304s471-R;Defined Requirement] Sufficient instruments shall be included in each component to monitor component performance within the design envelope, and to alert plant operators of the onset of operation outside design margins.

2.9.2 Control

[5304s120-R;Defined Requirement] Each major component or subsystem of the DNB System shall be provided with its own local control cubicle (LCC).

[5304s472-R;Defined Requirement] The DNB System shall be controlled from the CODAC system through the Plant System Host (PSH) as the interface structure [19].

[5304s473-R;Defined Requirement] The control for the DNB System shall comply with the *Plant Control Design Handbook* [4].

[5304s825-R;Defined Requirement] Experimental data and information on NB heating and CD system status shall be copied from the plant network in order to make it available on the ITER general network for analysis and remote collaboration.

[5304s826-R;Defined Requirement] The components of two redundant SIC-1 systems shall be located in independent and separate fire sectors (fire sectors are defined in Section 7.9.7).

[5304s827-R;Defined Requirement] Each train (A and B) of the electrical supply and the I&C cabling of the SIC-1 cubicles shall be routed through independent and separate fire sectors.

[5304s828-R;Defined Requirement] The SIC-1 cubicles shall be located in dedicated rooms that do not contain SIC-2 or SR or non-SIC cubicles.

[5304s829-R;Defined Requirement] The SIC-1 cubicles shall be equipped with automatic fire detection and suppression systems.

[5304s830-R;Defined Requirement] The components of SIC-2 systems for which there is a redundancy requirement shall be located in two independent and separate fire sectors.

[5304s831-R;Defined Requirement] The redundancy of SIC-2 cubicles can be implemented with the SR, and non-SIC cubicles at dedicated and separate places in the same room. The minimum distance between SIC-2 and non-SIC cubicles shall be 2 m. This room (and not the cubicles themselves) shall be equipped with automatic fire detection and suppression systems.

[5304s832-R;Defined Requirement] Each train (A and B) of the electrical supply and of the I&C cabling of the SIC-2 cubicles, shall be routed through different fire sectors.

[5304s833-R;Defined Requirement] Concerning the SIC-2 cubicles for which there is no redundancy requirement, their implementation in the same room as SR and non-SIC cubicles shall be possible if all the cubicles (SIC-2, SR and non-SIC) are equipped with automatic fire detection and suppression systems.

[5304s834-R;Defined Requirement] In any given room, all the SIC-1 cubicles shall be on the same Train (A or B) for power supply and I&C cabling.

[5304s835-R;Defined Requirement] In any given room, all the SIC-2 cubicles shall be on the same Train (A or B) for power supply and I&C cabling.

2.10 Computer hardware and software requirements

[5304s253-I] A Mini-CODAC will be used for factory testing during procurement.

[5304s474-R;Defined Requirement] The control and instrumentation hardware and software for the DNB System shall comply with the *Plant Control Design Handbook* [4].

2.11 HVAC requirements

[5304s246-R;Defined Requirement] The NB cell shall be permanently connected to the De-tritiation System (DS). However, during maintenance periods, the NB cell is served by the HVAC system, to allow personnel access.

It is noted that exhaust from ventilation zones shall be routed to filtration/detritiation systems (as required) in order to limit releases to the outside, and to prevent backdraught phenomena occurring from one area to another. If the atmospheric concentration of tritium exceeds 108 Bq/m3, the ventilation of the affected zone shall be automatically isolated, and its depressurization and exhaust management shall be performed by the Detritiation System until the radiological levels are acceptable again, and the HVAC is running.

The hydrogen atmospheric concentration, in areas with a potential risk of accumulation of tritium, deuterium, protium and/or mixtures of these isotopes, shall be monitored, with appropriate alarm systems provided.

[5304s475-I;Defined Requirement] The level-3 area, above the NB cell, will be served by HVAC, with a back-up by the DS in case of an accidental contamination.

[5304s681-R;Defined Requirement] Temporary access areas for workers, to put on and remove the protective equipment that is required to protect against internal/external radiation exposure, shall be provided as needed, especially for maintenance operations on ventilation and filtration components.

2.12 Vacuum requirements and Vacuum classifications

2.12.1 Allowable leak rates

[5304s162-R;Defined Requirement] A global leak rate shall be specified for the NB Heating and CD System primary vacuum confinement in the *ITER Vacuum Handbook* [2], Section 25.2.

[5304s476-R;Defined Requirement] Individual leak rates limits for each component shall be specified so as to be consistent with the global allowance of less than $1x10^{-10}$ Pam^3/s.

[5304s163-R;Defined Requirement] Welded seals shall be used for the non-circular closure plates that have primary vacuum confinement functions.

[5304s773-R;Defined Requirement] For the circular flanges on the NB Front End Components, the sealing shall be done with a double metallic seals with a monitored interspace.

[5304s164-R;Defined Requirement] In-situ leak tests shall be possible for all metallic seals that are to be installed (and replaced with their components) with RH equipment.

[5304s165-I] No in-situ leak test will be required for full-penetration structural welds.

[5304s166-I] An independent leak test of the beam source, and of each of the beam-line components, should be possible.

[5304s836-R;Defined Requirement] The precision of leak localization shall be such as to minimize component repair/replacement operations and for each leak shall give certainty of position to a single replaceable or repairable section of a component.

[5304s837-R;Defined Requirement] When multiple leaks occur on different components or in different locations these shall also be individually-localizable down to individually-replaceable components or repairable sections.

2.12.2 Vacuum pumping

[5304s168-R;Defined Requirement] The injectors shall be evacuated using the regeneration foreline for roughing and for the regeneration of the cryopumps.

[5304s838-R;Defined Requirement] The DNB vacuum vessel shall be capable of being pumped down from atmospheric pressure to 10 Pa within 24 hours.

[5304s478-R;Defined Requirement] The DNB injector shall be equipped with two cryopumps, that are the same type as for the NB H&CD injectors but with a surface area of 5.5 x 3.0 m and the capture probability is 34%.

[5304s170-R;Defined Requirement] The evacuation of the injectors, prior to cool-down, and the regeneration of the cryogenic pumps to a schedule (provided by the vacuum pumping and fuelling system) shall be compatible with the operation of the NB Heating and CD System, and of the DNB.

[5304s479-R;Defined Requirement] The interspace of the absolute valve shall be pumped by a dedicated pumping line (PBS 31).

[5304s480-R;Defined Requirement] The service vacuum system shall be used for pumping and monitoring of all interspaces.

[5304s481-R;Defined Requirement] Vacuum measurements shall be done in the DNB vessel and duct.

[5304s482-R;Defined Requirement] The temperature of the cryo pumps shall be measured.

[5304s483-R;Defined Requirement] The residual gas pressure in the beam-line vessel shall be monitored.

[5304s484-R;Defined Requirement] The gas flow rates into the ion source and the neutraliser shall be monitored.

[5304s485-R;Defined Requirement] The central vacuum control system shall have the control of the absolute valve.

[5304s839-R;Defined Requirement] All surfaces between the DNB absolute valve, the Bellows and the Drift Duct Liner that are exposed to the primary vacuum shall be baked at a temperature greater than 180°C. Exceptions for lower-temperature baking of components that are at or beyond the vessel ports boundary shall be treated on a case-by-case basis.

[5304s840-R;Defined Requirement] The surfaces between the absolute valve and the duct liner shall be capable of being raised from operating temperature to the baking temperature within 2 days.

[5304s841-R;Defined Requirement] Following baking, the surfaces between the absolute valve and the duct liner shall be capable of being returned to their pre-pulse operating temperature within 24 hours.

[5304s842-R;Defined Requirement] The rate of change of temperature of the surfaces between the absolute valve and the duct liner shall not be faster than +5 K/h during warm-up, and -7 K/h during cool-down, considering thermal stresses.

2.13 Thermal management requirements

[5304s138-R;Defined Requirement] The NB PHTS shall be used to cool the beam source, the beam-line components, the fast shutter, the absolute valve and the drift duct.

[5304s142-I] The NB PHTS will provide ultra-pure or purified grade cooling water with a resistivity greater than 5 MΩ.cm and an inlet temperature of 38°C.

[5304s682-R;Defined Requirement] The Component Cooling Water System (CCWS-2A) shall be used to cool the active compensation and correction coils (ACCC).

[5304s145-R;Defined Requirement] The draining and drying of each injector shall be possible independently.

[5304s146-R;Defined Requirement] The segregation of the hydraulic circuit of each of the beam-line components shall be possible, to allow independent leak tests and to isolate a leaking system.

[5304s683-R;Defined Requirement] The DNB System vessel shall be connected to the NB drain tank via a dedicated draining system that can be connected with Remote Handling. It is noted that it shall be possible to process the water and to clean the safety drain tank(s) to allow the restart of the ITER plant within one year.

[5304s143-I] The cooling water system will be designed to be readily upgraded to accommodate one additional HNB injector during DT phase operation.

[5304s144-I] It is assumed that the ACCC will be powered in all operating scenarios.

[5304s486-R;Defined Requirement] The overall thermo-hydraulic requirements for the NB PHTS for one NB Heating and CD System injector are given in Table 2.13; the DNB shall comply with the specified values. To minimise the power that has to be evacuated, for the scenarios considered in the table below, it is assumed that conditioning and injection into ITER will not be done at the same time, and that only one HNB will be firing into the calorimeter at one time, although all the HNBs may be conditioning; the conditioning HNBs will be operated sequentially; injecting HNBs and the DNB may operate simultaneously.

[5304s555] **Table 2.13: NBI PHTS Thermo-hydraulic requirements**

[5304s630]

Startup phase – H-He phase	
Maximum power to be cooled by 38 °C, 2.0 MPa purified grade cooling water with a resistivity >5 MΩcm For two HNB + DNB injecting	85.6 MW
Power to be cooled by 20 °C, 0.8 MPa cooling water with a resistivity > 0.5 MΩcm For the ACCC of two HNB and DNB injecting	1.9 MW
Total power to Cooling water	87.5 MW
Upgrade – D T phase	
Maximum power to be cooled by 38 °C, 2.0 MPa purified grade cooling water with a resistivity >5 MΩcm For three HNB + DNB injecting	124.7 MW
Power to be cooled by 20 °C, 0.8 MPa cooling water with a resistivity > 0.5 MΩcm For the ACCC of three HNB and DNB injecting	2.5 MW
Total power to Cooling water	127.2 MW

[5304s557-I] Note that, most likely, the ACCC are going to be used even in conditioning mode. It is not assumed that the HNBs will be accelerating beams to the calorimeter in parallel, so the power to be removed with the PHTS will be lower than during injection. The table shows the values for deuterium operation of the HNB and hydrogen operation for the DNB.

2.14 Electromagnetic requirements

[5304s158-I] The stray field from ITER will be reduced by a dedicated magnetic field reduction system.

[5304s159-I] The magnetic field reduction system will not result in a disturbance of the ITER plasma confining fields above the prescribed limits of the ripple, as defined in *Project Requirements (PR)* [7]

[5304s488-R;Defined Requirement] Components whose function is unacceptably influenced by electromagnetic fields at their installation location shall preferably not be used in the design of the DNB System. If usage is unavoidable, such elements shall be shielded so that their performance is not unacceptably affected by the fields.

[5304s489-I] The design of the NB cryopumps will account for the mechanical effects of electromagnetic fields on the structural integrity, and on the heat loads resulting from eddy currents that are induced within the conductive structure of the various components.

[5304s490-R;Defined Requirement] The design of the control and instrumentation components, and their wiring to cubicles, shall account for the environmental electromagnetic fields, both in term of signal degradation and eddy current dissipation, and provision shall be made for mitigation.

[5304s843-R;Defined Requirement] As a general requirement for electromagnetic compatibility and shielding, all ITER electrical components shall be designed to comply with IEC 61000.

2.15 Nuclear shielding requirements

[5304s684-R;Defined Requirement] The NB Heating and CD System ducts and the DNB duct shall have nuclear shielding to limit the nuclear heating, damage to the insulation and to the copper stabiliser of the superconducting magnets.

[5304s149-R;Defined Requirement] The NB Heating and CD System ducts and the DNB duct shall have nuclear shielding to limit the activation of materials in the cryostat structures that surround the NB ducts. (This is to reduce doses, at the relevant positions for hands-on in-cryostat maintenance, less than 100 μSv/hour after 10^6 s from the shutdown of DT plasma operation.)

[5304s150-R;Defined Requirement] The NB Heating and CD System and the DNB shall have nuclear shielding to limit the activation of the NB cell. The NB cell is categorized as a “yellow” zone, and the equivalent dose shall be less than 2 mSv/hour after 24 hours from the shutdown of DT plasma operation. However the dose should also be maintained As Low As Reasonably Achievable (ALARA), in the context of allowing personnel access for limited hands-on maintenance.

[5304s151-R;Defined Requirement] The NB Heating and CD System and the DNB shall have nuclear shielding to limit the dose levels in the area and volumes that surround the NB cell, to be less than 25 μSv/hour. The surrounding zones are categorized as “green” zones.

[5304s152-R;Defined Requirement] The NB Heating and CD System and the DNB shall have nuclear shielding to limit the neutron and gamma-ray flux and fluence to the tokamak building L3 level, to avoid activation of this area.

[5304s685-R;Defined Requirement] Releases of radioactive effluents, substances from the NB Heating and CD System and the DNB, shall be kept As Low As Reasonably Achievable (ALARA) and in all cases within design and operational guidelines.

[5304s844-R;Defined Requirement] Personnel access to the inside of the DNB Vessel shall be prohibited once the DNB vessel becomes activated, and consequently all in-vessel maintenance activities shall be done remotely.

[5304s845-R;Defined Requirement] Before venting the DNB FEC's, the bakeable DNB FEC sub-components shall be baked to remove as much tritium as possible.

[5304s846-R;Defined Requirement] The maximum tritium concentration in the vacuum vessel PHTS cooling water shall not exceed 0.21 mg.m-3 (76 MBq/kg), including measurement uncertainties.

[5304s847-R;Defined Requirement] The maximum tritium concentration in the PHTS cooling water of in-vessel components shall not exceed 0.32 mg.m-3 (114 MBq/kg), including measurement uncertainties.

2.16 Chemical requirements

[5304s155-R;Defined Requirement] The ion sources shall require the supply of caesium, although in rather small quantities (less than 100 mg per 1000 s of operation of one beam source). The exact quantity shall be established in on-going experiments at the ion source testbeds at IPP Garching.

[5304s154-R;Defined Requirement] The DNB HV bushing interspace shall be filled with dry air.

2.17 Material requirements

[5304s173-R;Defined Requirement] The manufacturer shall take appropriate measures to ensure that the material that is used conforms to the required specification.

[5304s174-R;Defined Requirement] Commercial materials shall be utilised to the maximum possible extent.

[5304s175-R;Defined Requirement] Commercial materials shall conform to the applicable standards (ASTM, JIS, DIN) for the definition of their grade, physical, chemical, mechanical and electrical properties and for related testing.

[5304s491-R;Defined Requirement] The design and materials shall conform to the standards that are specified in the Materials Properties handbook [24], see also [5] for information.

[5304s492-R;Defined Requirement] Halogenated materials shall be forbidden in areas that are served by the detritiation systems. Exceptions shall be approved by the tritium system and safety section responsible officers.

[5304s848-R;Defined Requirement] It shall be noted that halogenated materials include all solids liquids and gases that contain fluorine, chlorine, bromine or iodine. In industrial applications, halogenated materials are often present in such items as process gases, electrical cable insulation, floor and wall coatings, paints and cleaning solvents.

[5304s459-I] Halon fire suppression systems will not be used in areas that are served by the detritiation systems.

[5304s176-R;Defined Requirement] All materials, for which a suitable certification from the material supplier is not available, shall be tested to determine the relevant properties.

[5304s850-R;Defined Requirement] The materials and fabrication processes of the in-vessel and the NB duct components shall be selected considering whenever possible the minimization of the error fields.

[5304s558] **Table 2.17: List of materials for one H&CD NB injector and for the DNB**

[5304s582]

Material	Approximately quantity for one HNB (Tonnes)	Approximately quantity for the DNB (Tonnes)	Additional information
Soft iron	501	285	For the passive magnetic shielding and support structure
Copper	128	47	For the active coils
Copper Chrome Zirconium	26	13	For beam source and beam line components
Copper and stainless steel	52	19	For the neutraliser RID and Calorimeter
Aluminium and stainless steel	13	13	Cryo pump panels
Titanium and carbon	TBD	TBD	Coating on cryo pumps
Stainless steel	56	100	Beam line vessel
Stainless steel	37	0	Beam source vessel
Stainless steel and aluminium	52	25	Fast shutter, Absolute valve, VVPSS box, Bellow and drift duct
Gold, Silver and Aluminium	TBD	TBD	For sealing surfaces on the absolute valve
Alumina	20	5	For the bushing
Epoxy	TBD	TBD	For the insulation of the ACCC and the bushing
Kovar	TBD	TBD	For the bushing
Caesium	< 120 g	< 120 g	For the ion source (stored inside 3 ovens in the HNB and 1 oven in the DNB)
Cobalt and Samarium	TBD	TBD	For the permanent magnets in the beam source
Lead	209		Lead wall (for the whole NB cell)

2.18 Manufacturing requirements

[5304s178-R;Defined Requirement] The DNB injector components shall be manufactured with high precision, and strict mechanical tolerances, to guarantee the beam optics parameters in the beam source, and to minimize losses that are due to direct interception of the beam on the beam-line components (with a maximum misalignment of less than 2 mrad).

[5304s179-I] The DNB accelerator components should be manufactured with high quality surfaces and treatments to provide high voltage holding, and be compatible with the vacuum requirement.

[5304s686-R;Defined Requirement] All surfaces shall be compatible with the *ITER Vacuum Handbook* [2].

[5304s493-R;Defined Requirement] The manufacturing shall be done according to the *ITER Vacuum Handbook* [2].

[5304s687-R;Defined Requirement] Part of the manufacturing, in particular the final treatment and assembly, shall be performed in a suitably clean area.

[5304s182-I] The only component that may need special facilities is the HV bushing large bore ceramic insulator, which will possibly require the availability of a suitable sintering furnace.

2.19 Construction requirements

[5304s495-I] The NB cell will withstand an absolute pressure of 0.2 MPa in case of an accident.

[5304s187-I] The NB cell walls will have a gas permeation level that is compatible with a rate of leakage of less than 100% of the NB cell volume per day at 0.2 MPa absolute pressure during over-pressurisation.

[5304s188-R;Defined Requirement] The NB cell walls shall allow simple decontamination procedures.

[5304s851-R;Defined Requirement] The TCWS clients in the NB cell all have the potential to be contaminated with tritium and activated corrosion products. TCWS components that are in contact with the cooling water provide primary confinement of these radioactive inventories.

The methods for controlling the corrosion behaviour during operation shall be established for all systems.

[5304s189-R;Defined Requirement] The NB cell shall allow water containment and drainage, in case of cooling water spillage.

[5304s190-I] The NB cell walls, floor and ceiling will incorporate penetration and flanges that are suitable for all of the service passages.

[5304s735-R;Defined Requirement] Potential liquid effluents generated by the fire suppression substances or a leak of an effluent-bearing component of the Diagnostic Neutral Beam System shall be collected in order to prevent dispersion of radioactive or toxic substances.

[5304s852-R;Defined Requirement] The limitations in size and weight of the components (including packages and frames) shall be as follows:

- Maximum length: 19 m with an exception for crane beams: 47 m on a single line
- Maximum width: 9 m
- Maximum height: 9.1 m
- Maximum weight: 600 t.

[5304s853-R;Defined Requirement] Where traceability is required, as for all SIC systems, structures or components, or for parts whose lifecycle has to be monitored during the life of the project, unique identification of individual items or batches shall be implemented.

2.20 Assembly requirements

[5304s688-R;Defined Requirement] The NB Heating and CD System shall be assembled and tested within the NB cell.

[5304s192-R;Defined Requirement] Particular care shall be taken for the leak testing of the vacuum components of the DNB System during the assembly. The assembly should be done according to the *ITER Vacuum Handbook* [2].

[5304s199-I] Two delivery points have been designated, within the ITER plant for the components of the NB Heating and CD System and DNB System.

[5304s200-R;Defined Requirement] Delivery Point 1 (DP1) is in the NB PS area. The equipment shall be transported, with dedicated trolleys pulled/pushed by tractors, via the intermediate delivery point close to the NB cell north wall.

[5304s201-R;Defined Requirement] Delivery Point 2 (DP2) is a designated cleaning area, outside the lay-down area. The equipment shall be transported, with dedicated trolleys pulled/pushed by tractors, to the lay-down area; then, using the assembly hall crane, to the lift area; finally to the NB cell and the high voltage deck room in L3.

[5304s205-R;Defined Requirement] At the delivery points, a closed space, that satisfies the requirements of cleanliness for the handling of the NB Heating and CD System components and general facilities for unpacking of the components, shall be available.

[5304s202-I] One hatch will be provided above the DNB HV transmission line.

[5304s203-I] During assembly, this hatch will be used as a passage for the transmission line 3.

[5304s206-I] Prior to the start of the assembly operations for the DNB and the NB Heating and CD System, the NB cell civil structures will be completed including:

• All embedded flanges that are provided by relevant systems

• All appropriate finishing on concrete walls, slabs and ceiling

• The NB cell doors

• The NB cell access to the NB corridor between the Tokamak complex and Hot Cell Building

• All conventional equipment and appliances (such as water, compressed air and steady-state electrical power supply) that have their point of supply within the NB cell

• All connections to the NB cell of the de-tritiation system

• All metrology secondary datum points and fiducial target points that are established and marked

• Remote handling crane

• Front section of the manipulator rail that is stored in the ceiling of the NB cell above its final position

• HVAC system ensuring ventilation for a good working environment for the workers

• Fixation points / embedded plates of components fixed to the building, already installed in the floor in accordance with the positioning accuracy that is defined by NB.

[5304s220-R;Defined Requirement] The assembly and testing activities for the two HNB injectors and the DNB injector shall be considered as fully parallel, in the sense that the three systems shall be installed in the NB cell at the same time.

[5304s221-R;Defined Requirement] An assembly sequence for the NB Heating and CD System shall be approved prior to FDR of the assembly.

[5304s222-I] The possibility of installing a third HNB at a later stage, during the ITER operation, will be kept open. A conceptual study has been performed to assess the feasibility of such installation.

[5304s223-I] In principle, the third injector could be installed following the same procedure, as described above. The tools that are used for the assembly of the HNB-1 and HNB-2 will be used for the assembly of HNB-3. The tools will be stored in a suitable location in the meantime.

2.21 Installation requirements

[5304s194-R;Defined Requirement] Each component of the DNB System shall be contained in packaging that provides environmental protection and maintains cleanliness during transport and on-site storage. The work should be carried out according to the recommendations in the *ITER Vacuum Handbook* [2].

[5304s195-R;Defined Requirement] Inside the packaging, the components of the DNB System shall be fixed in a transportation rig that supports the components during shipping and handling.

[5304s689-R;Defined Requirement] The packaging of the DNB System shall be equipped with sensors that monitor excessive forces and environmental conditions during transportation.

[5304s196-R;Defined Requirement] The transportation rig for the DNB System shall have the standard type interfaces (eyebolts, support plates and bracket) for lifting the component, while fixed in the transportation rig, and for connecting the transportation rig on the trolley, for transportation within the ITER plant.

[5304s198-R;Defined Requirement] The transportation rig for the DNB System shall ensure the static stability and protection from accidental damage of the components during the storage periods.

[5304s197-R;Defined Requirement] The transportation rig for the DNB System shall provide protection of the equipment against humidity, dust and other contaminations during short and long term storage periods.

2.22 Testing and inspection requirements

2.22.1 Factory Tests

[5304s228-R;Defined Requirement] The fabrication of the DNB System, and its components, shall be subdivided into a number of sub-components, allowing independent factory testing, to the largest possible extent.

[5304s229-R;Defined Requirement] FAT procedures shall be approved prior to FDR.

[5304s230-R;Defined Requirement] In general, the following types of functionally acceptance tests at the manufacturer shall be performed on sub-components or parts of sub-components:

• Dimensional checks

• Pressure tests

• Vacuum leak tests, following the *ITER Vacuum Handbook* [2]

• Vacuum compatibility tests; mechanical tests (fatigue and reliability)

• Flow tests of the water circuits

• Electrical tests (voltage holding under vacuum / pressurised gas) for isolators, high voltage feedthroughs and beam source assembly.

[5304s497-R;Defined Requirement] During factory tests, where appropriate, the ITER Mini-CODAC control and data acquisition system shall be used for testing of the components.

2.22.2 Weld Tests (on-site)

[5304s690-R;Defined Requirement] On-site weld test procedures shall be approved prior to FDR.

[5304s237-R;Defined Requirement] All on-site welds shall undergo leak tests, and Non-Destructive Examination (NDE) on site, as required by the applicable codes and standards.

[5304s238-R;Defined Requirement] As an intermediate step of the assembly procedure, the DNB vessel that forms the primary vacuum confinement of the DNB System injector (after the on-site seal welds) shall have their welds examined by Non-Destructive Examination and shall be leak tested.

[5304s691-R;Defined Requirement] A global leak test of the DNB vessel shall be performed before installation of the HV bushing and front-end components.

2.22.3 Commissioning

[5304s692-R;Defined Requirement] The commissioning procedure shall be approved prior to FDR.

[5304s498-I] A prototype of the DNB beam-line will be integrated at the Indian testbed and all essential features of the integrated full performance will be tested.

[5304s242-R;Defined Requirement] The DNB injector shall be commissioned to full performance by accelerating the beam on to the calorimeter panels prior to injecting into the tokamak.

[5304s240-R;Defined Requirement] Commissioning of the NB Heating and CD System and of the DNB shall be independent of operation on the tokamak. The Operation Room in Building 34 will be used for commissioning and testing.

[5304s854-R;Defined Requirement] The integrated commissioning of the DNB Vessel shall include a mechanical verification of position and leak testing.

[5304s241-R;Defined Requirement] The injector shall be isolated, either by closing the fast shutter between the NB vessel and the duct if ITER is under vacuum, or by closing the absolute valve. Closing the absolute valve allows an independent vacuum to be created in the injector.

[5304s243-I] During the initial testing and commissioning the injector will be operated by the ITER Mini CODAC command control and data acquisition system.

[5304s244-R;Defined Requirement] The initial testing and commissioning of the DNB System shall include checks of all control software, and shall demonstrate the efficiency of all interlocks.

2.23 Decommissioning requirements

[5304s693-R;Defined Requirement] The decommissioning operations of the DNB System shall be designed so to maintain the safety of the personnel, the public and the environment.

[5304s942-R;Defined Requirement] Residual tritium that is present at the end of ITER operations shall be recovered to secure storage and/or shipping containers.

[5304s934-R;Defined Requirement] ITER deactivation shall include the removal of DNB components and their packaging for long-term storage.

[5304s933-R;Defined Requirement] ITER Organization shall provide the site Host Member with all records, "as-built prints", information and equipment pertinent to dismantling after deactivation.

[5304s255-R;Defined Requirement] Where possible, the design of the DNB System shall use modular components, for ease of dismantling.

[5304s256-R;Defined Requirement] Where possible, the design of the DNB System shall apply segregation of radioactive systems or components.

[5304s257-R;Defined Requirement] Where possible, the design of the DNB System shall avoid incurring contamination.

[5304s258-R;Defined Requirement] Depending on operational conditions (such as maximum expected neutron flux and fluence) and allowable dose rate, the requirements for specific impurities in chemical composition of materials which give significant contribution to activation of materials shall be established. These limits on impurities' concentration shall be technically feasible and reasonably achievable. The requirements for limit of impurities are defined in [48].

[5304s694-R;Defined Requirement] The generation of solid wastes (radioactive, other hazardous and domestic) from DNB System operation and decommissioning shall be limited to the maximum extent possible, in terms of quantity and their toxicity level (as relevant). The volumes and level of radiotoxicity in the solid radioactive waste shall be reduced to the maximum extent possible.

Specific design provisions shall be undertaken to avoid that solid, liquid and gaseous toxic products affect workers during normal operations and to avoid spread of these materials into rooms accessible to workers.

These provisions shall consider potential corrosive, flammable and explosive issues associated with these toxic products.

All solid, liquid and gaseous toxic products needed for ITER construction and operation shall be identified and their quantity and characteristics estimated for normal operation, including maintenance operations.

The inventory for all solid, liquid and gaseous toxic products shall be limited to the maximum extent possible in the design, and their impact maintained As Low As Reasonable Achievable (ALARA) during operation.

[5304s855-R;Defined Requirement] Solid waste packages shall be controlled prior to transport and disposal.

[5304s856-R;Defined Requirement] Waste from a radioactive waste zone shall be processed in a radioactive treatment facility.

[5304s857-R;Defined Requirement] Waste from a non-radioactive waste zone shall be processed in a non-radioactive treatment facility.

2.24 Other services

[5304s260-R;Defined Requirement] It shall be noted that compressed air might be required for the operation of some equipment.

[5304s858-R;Defined Requirement] Compressed Nitrogen shall be required for operation of valves in the NB Gas Introduction System and for the guard gas flow in the manifold going to the Storage and Delivery system.

[5304s859-R;Defined Requirement] The use of nitrogen in any region that is subject to radiation shall be justified by an analysis of the possible generation of C14 through activation and of ozone through radiochemical conversion of trace levels of oxygen.

[5304s860-R;Defined Requirement] No cliff-edge effect: this shall be demonstrated by showing that the magnitude of the consequences of a postulated event is bounded, and that there is no large increase as the safety functions are progressively degraded.

3 SAFETY DESIGN REQUIREMENTS

3.1 Safety design criteria

[5304s737-R;Defined Requirement] The total inventory of tritium within the vacuum vessel and its associated systems, among them the Diagnostic Neutral Beam System, shall be equal or less than 1 kg.

The total site tritium inventory in ITER shall not exceed 4 kg. The tritium inventory in a fire sector (see Section 7.9) shall be limited to 70 g, with some exceptions that are individually authorized.

[5304s937-R;Defined Requirement] ITER shall be designed, constructed, and operated in accordance with the French safety regulations as provided for in Article 14 of the ITER Agreement [37].

[5304s738-R;Defined Requirement] The total inventory of in-vessel, activated dust (such as beryllium dust and tungsten dust) within the ITER vacuum vessel and its associated systems, among them the Diagnostic Neutral Beam System, shall be equal or less than 1000 kg, including measurement uncertainties.

[5304s861-R;Defined Requirement] The inventory of beryllium dust and tungsten dust, on surfaces that become sufficiently hot to be reactive with steam or air during incidents, shall not exceed 11 kg for beryllium dust or 76 kg for tungsten dust, or a linear combination of the two species, taking into account that 11 kg beryllium or 76 kg tungsten is the quantity which, if fully reacted with steam, leads to 4 kg hydrogen in the vessel. Deflagration of more than this quantity exceeds 0.2 MPa peak dynamic pressure, the limit for the first confinement barrier (see Table 7-4).

[5304s862-R;Defined Requirement] There shall be provisions for measuring or estimating the inventory of activation products to assure that inventory limits are not exceeded.

[5304s863-R;Defined Requirement] The level of activated corrosion products in cooling systems shall be minimized, for example through the selection of materials in systems.

[5304s264-R;Defined Requirement] The DNB System shall provide the safety function of confinement of tritium and dust inventory.

[5304s864-R;Defined Requirement] Formal project approval for a single confinement system may be given by ITER Organization if justified by analyses that shall show that the failure of this single confinement system results in small consequences.

[5304s725-R;Defined Requirement] The DNB System design shall be failure tolerant and no single failure of components shall result in severe consequences to the personnel, public and/or environment.

[5304s695-R;Defined Requirement] Safety Importance Class (SIC) components of the DNB System shall be designed to withstand all loads and conditions that are resultant from any design basis situations (including normal operations and any incidental and accidental situations, during and after which SIC elements shall continue in accomplishing their accredited safety functions).

[5304s696-R;Defined Requirement] Any unexpected operation of active components within the DNB System, their failure or damage resulting from an abnormal event, shall not prevent SIC components of accomplishing their safety functions.

[5304s865-R;Defined Requirement] VV blank flanges shall be installed for temporary closure where the systems are not installed as functional. Temporary blanking shall be listed, planned, supplied and commissioned on all open penetrations to the vacuum boundaries (PBS16).

The appropriateness of any temporary provisions shall be demonstrated by systematic safety analysis based on the quantities, location, and operation related to hazardous inventories.

For the confinement of radioactive materials, definitive provisions shall be available for the start of Assembly and Integrated Commissioning phase IV (prior to FPO).

Prior to the definitive provisions being available, the safety functions to be achieved by the intermediate ITER configurations shall be guaranteed using temporary provisions with requirements similar to the definitive provisions (e.g. redundancy, back-up power supply) or with reduced requirements scope (case by case: no redundancy, limited use of back-up power supply, limited resistance to external events...).

[5304s697-R;Defined Requirement] The DNB System shall have two robust confinement barriers.

[5304s268-I] The first confinement barrier of the DNB System consists of the DNB injector module itself, the duct that connects to the vacuum vessel, and all the surfaces of internal components that are exposed to primary vacuum, and all the cooling pipes coming from vacuum vessel internal components up to their isolation valves.

[5304s265-R;Defined Requirement] Each NB injector, as part of the first confinement barrier, shall assure that under any circumstances the maximum leak rate does not exceed 1% of the injector volume per day at 0.2 MPa absolute pressure.

[5304s269-I] The second confinement barrier of the NB Heating and CD System and the DNB consists of the NB cell, and the outer isolator rings of the HV bushing for the HNB injector.

[5304s266-R] The second confinement barrier of the NB Heating and CD System and the DNB shall ensure that, under the assumed reference faults of the first barrier, the leak rate shall not exceed 100 volume% of NB cell volume per day at 0.2 MPa absolute pressure.

[5304s698-R;Defined Requirement] The SIC components of the DNB System shall be protected against the risk that is associated with the potential whipping and missile effects from high energy fluid circuits (pressure greater than 20 bars and temperature greater than 100°C) or other potential sources for missiles (such as internal explosion, failure of a machine with moving parts).

[5304s285-R;Defined Requirement] The use of bellows in the confinement barrier of the DNB System shall be minimized; or, where bellows are needed, double bellows shall be used, to reduce the probability of leakage both under normal operation and in over-pressurisation cases.

[5304s284-R;Defined Requirement] The interspace between the bellows of the DNB System shall be partially pressurised, and monitored by the service vacuum system.

[5304s287-R;Defined Requirement] All the areas of the first confinement barrier of the DNB System that can be intercepted by the beam power shall be protected with actively cooled liners.

[5304s288-R;Defined Requirement] All the cooling water, cryogens and gas lines of the DNB System shall be provided with isolation valves (with a corresponding Safety Importance Classification [16]).

[5304s290-I] In case of spillage of coolant within the NB cell, the NB cell floor will allow drainage of the effluents.

[5304s295-R;Defined Requirement] All of the penetrations through the NB cell and the NB cell door shall be designed to assure that the leakage from the pressurised cell is less than 100% of cell volume per day at 0.2 MPa absolute pressure [22].

[5304s296-R;Defined Requirement] Means shall be provided, to perform maintenance such that contamination is controlled, and to ensure that one confinement barrier of the first confinement system is in place.

The routing/piping of confinement barriers shall be such as to avoid potential damage to confinement systems by movement of equipment during maintenance.

[5304s291-R;Defined Requirement] Any interspace shall be filled with an inert tracer gas, and pressure monitored to provide leak detection and localization.

[5304s292-R;Defined Requirement] There shall be no significant leakage of activity from the DNB System into rooms during or following a SL-2 earthquake.

[5304s699-I] The section of the HV transmission line where it is passing through the floor of L3 will be covered with soft iron shielding.

[5304s294-I] In case of detection of SF6, the ventilation of the level 3 area and the NB cell that is normally connected to the de-tritiation system, will be stopped.

[5304s700-R;Defined Requirement] The DNB Systems and components shall be traceable, and be given a unique identification of their individual items or batches.

[5304s624-R;Defined Requirement] The ITER Organization shall develop and maintain a database that allows securing and accessing all records that are related to any traceable item.

[5304s274-I] The safety procedure in case of a seismic event will cause the immediate interruption of the beam power supplies, and the closure of all isolation valves, by the central safety system.

3.2 Safety limits

[5304s286-R;Defined Requirement] The DNB cryopumps shall undergo periodic regenerations to maintain pumping functionality and to limit the hydrogen inventory such that the pressure in the neutral beam vessel remains below 0.2 MPa in the case of air ingress and deflagration.

3.3 Monitoring requirements

[5304s734-R;Defined Requirement] The potential failure of a vacuum envelope of the Diagnostic Neutral Beam System shall be monitored (usually by measuring pressure within the envelope), with appropriate alarm system.

[5304s526-R;Defined Requirement] Any interspace shall be pressure-monitored to detect a failure of a confinement.

[5304s528-R;Defined Requirement] The hydrogen / deuterium inventory on the cryo pumps shall be monitored.

[5304s866-R;Defined Requirement] The DNB shall comply with the Radiation Protection Program (RPP) that shall be developed and implemented by the ITER Organization. The RPP will include worker classification and access control as well as a system of authorization and associated procedures. The ITER RPP shall be reviewed periodically to check its efficiency, and to optimize it where possible.

For the radiation protection from mobile sources, definitive provisions shall be available the start of PFPO-2 (at the end of Assembly and Integrated Commissioning phase III).

[5304s867-I] ITER Organization will guarantee the security of its "Installation Nucléaire de Base (INB)" as defined in French laws and regulations, including the equipment and facilities required for the operation of this installation and its related installations and equipment, during their construction, operation, deactivation, and in providing for decommissioning, in accordance with the Headquarters Agreement signed between the French Government and ITER Organization [13], [43].

3.4 Safety-specific instrumentation

[5304s617-R;Defined Requirement] Monitoring shall be provided to indicate the DNB system status in all operational states and accident conditions.

[5304s625-R;Defined Requirement] SF6 and O2 levels shall be monitored with appropriate alarm systems for access to the access controlled areas NB cell and L3 level HV Deck room during shutdowns / maintenance periods.

[5304s701-R;Defined Requirement] Safety Importance Class (SIC) components of the DNB System shall be subject to monitoring as needed, to ensure that they will perform their accredited safety functions.

[5304s702-R;Defined Requirement] The Safety instrumentation of the DNB System shall be designed to provide redundant and, where appropriate, diverse systems as necessary to achieve the required reliability.

3.5 Safety related testing and inspection

[5304s703-R;Defined Requirement] Appropriate control, test, inspection and qualification procedures shall be implemented during design, construction, assembly, installation and commissioning of the DNB System in order to ensure that Safety Importance Class (SIC) components will perform their accredited safety functions (including the control/audit, update and keeping of associated records for SIC element).

The DNB shall provide the capability for testing and for monitoring parameters, as necessary, to ensure availability and function, as credited in the safety analysis.

[5304s307-R;Defined Requirement] The testing of all components of the DNB injector vessel that form part of the primary confinement shall be performed according to established design codes.

[5304s308-R;Defined Requirement] The primary confinement barrier shall undergo leak testing prior to first commissioning.

[5304s310-R;Defined Requirement] Provisions shall be made to allow periodic leak checks of all of the penetrations in the primary confinement barrier, to ascertain their performance compared to that specified by the design, and to maintain confidence that, if accidents occur, the corresponding dose limits shall not be exceeded [22].

[5304s311-R;Defined Requirement] Modifications that are made to any part of the confinement barrier shall require re-testing to ensure that the integrated confinement barrier leak rate has not been degraded.

[5304s312-R;Defined Requirement] Penetrations in the secondary confinement barrier, in particular flanges for all penetrations, shall be individually pressure tested at 0.2 MPa absolute pressure.

[5304s313-R;Defined Requirement] The design of flanges shall allow for local pressure testing.

[5304s314-R;Defined Requirement] The NB cell door shall be periodically leak tested.

3.6 Qualification requirements

[5304s500-R;Defined Requirement] Safety Importance Classification (SIC) equipment [16] shall be qualified to function in the seismic and environmental conditions for which their service is required.

3.7 Safety related operations and procedures

[5304s731-R;Defined Requirement] Appropriate procedures to perform the Diagnostic Neutral Beam System operations (including maintenance activities) shall be developed, with the appropriate organization to guarantee their application, the authorization required as well as actions to be taken in event of an emergency such as in case of fire, an equipment failure or ITER On-Site Emergency Plan.

Temporary isolation procedures (e.g. lock off of temporary openings, waveguides, unused bus-bars etc) shall be planned, agreed and safety assessed.

It shall also be possible to maintain ITER in a safe condition during and following a fire.

[5304s704-R;Defined Requirement] The presence and handling of hazardous chemical substances (such as SF6 and beryllium) shall be managed in such a manner as to protect the personnel, the public and the environment.

Both the quantity and level of toxicity of such inventories shall be minimized, controlled and monitored.

[5304s705-R;Defined Requirement] The cooling water for the beam-line components shall be maintained with back-up pumps, in case of a power cut or a spillage of cryogens in the NB vessel, to avoid freeze-up of the cooling water.

[5304s316-I] In the case of a power cut, the needed instrumentation for safe operation of DNB System will be powered by UPS.

[5304s318-R;Defined Requirement] The beam power shall be removed as a first step in any active safety procedure.

[5304s319-R;Defined Requirement] For injector operation, the injectors and their sub systems shall be in the state that is defined in Section 4.1.1.

[5304s320-R;Defined Requirement] The beams shall not be operated below some minimum plasma density, below which shine-through to the opposite wall becomes excessive. This limit is a function of the power handling capability of the injector-facing wall, the beam power, power density and pulse length.

[5304s321-R;Defined Requirement] The beams shall not be operated if the magnetic field in the injector cannot be held below the design value.

[5304s726-R;Defined Requirement] The residual magnetic field in the vertical direction between the grounded grid in the beam source and the entrance of the Neutraliser shall be:

- $|Bz| < 0.5\times10^{-4}$ T and

- $\left|\int_{0m}^{1m} B_z\,dx\right| < 0.5 \times 10^{-4}\ Tm$

[5304s727-R;Defined Requirement] The residual magnetic field in the vertical direction inside the Neutraliser shall be:

- $|Bz| < 0.2\times10^{-4}$ T and
- $\left|\int_{1m}^{4m} B_z\,dx\right| < 0.6 \times 10^{-4}\ Tm$

[5304s322-R;Defined Requirement] If the pressure in the DNB System vessel is larger than a pre-set threshold then the first action shall be to close the fast shutter. The absolute valve shall thereafter be closed. These actions will limit the ingress of gas to the vacuum vessel.

In reverse ITER shall be equipped with appropriate devices to prevent plasma transients from challenging confinement barriers; these can also as a consequence initiate the closure of the fast shutter and the absolute valve.

[5304s501-R;Defined Requirement] The DNB System cryo pump shall undergo regeneration (100 K) at a high enough frequency to keep the hydrogen or deuterium inventory within deflagration safety limits. This allows controlling the injector inventory as all ITER systems shall be designed and operated so that radioactive and hazardous inventories are maintained as low as reasonably achievable and within the limits that are authorized for the site, plants, zones, systems and components.

[5304s706-R;Defined Requirement] The DNB System cryo pump shall be regenerated, and the hydrogen gas evacuated, before opening of the first confinement barrier.

[5304s707-R;Defined Requirement] The design and operation of the DNB System shall take into consideration the human and organisational factors, in order to prevent or minimize risks that are associated with potential human failure [15].

[5304s869-R;Defined Requirement] The DNB shall comply with the Tritium Handbook [26] during maintenance and dismantling operations. Tritium Shipments shall be in B(U) containers capable of storing not more than 70 g of tritium. (B(U) is an IAEA classification for containers qualified for transportation of radioactive material.).

3.8 Occupational safety

[5304s708-R;Defined Requirement] The safety objectives that are defined in the *Project Requirements (PR)* shall be followed when working on the NB Heating and CD System.

Hazard identification and risk assessment (HIRA) process shall be implemented in design phase in order to:

- identify workplace OHS hazards whose control shall have impact on ITER systems design
- assess the level of risk related to them in order to control them.

[5304s324-R;Defined Requirement] Means shall be provided to perform maintenance of the DNB System in such a way that contamination is controlled and doses are ALARA (As Low As Reasonably Achievable). This is foreseen to be achieved by a maintenance procedure that combines remote operation and transportation of activated/contaminated components to the Hot Cell Facility.

[5304s325-R;Defined Requirement] Biological shielding shall be provided to protect personnel by maintaining the equivalent dose rate below 25 µSv/hour, 24 hours after shutdown in the galleries of the NB Heating and CD System.

[5304s326-R;Defined Requirement] Biological shielding shall be provided to protect personnel by maintaining the equivalent dose rate below 2 mSv/hour, 24 hours after shutdown inside the NB cell.

[5304s709-R;Defined Requirement] Appropriate measures shall be implemented to limit to the possible extent of worker exposure to beryllium (including confinement, monitoring, decontamination, exposure limitation, and access control).

3.9 Environmental impact requirements

[5304s736-R;Defined Requirement] The confinement of the principal inventories of radioactive in the Diagnostic Neutral Beam System shall be maintained during all design basis situations (including maintenance).

[5304s328-R;Defined Requirement] Production of activated gases in the air atmosphere of the NB cell shall be limited to the lowest practical amounts.

[5304s330-R;Defined Requirement] The DNB System shall not use substances that are excluded by EU RoHS regulations.

[5304s710-R;Defined Requirement] Volumes of effluents shall be limited to the maximum extent possible (by minimizing the quantity that is generated and/or the toxicity level, by reduction or recycling to the maximum extent possible).

[5304s739-I] The radioactive dust inventory in the NB cell will be determined periodically by measurement, taking into consideration associated uncertainties.

[5304s871-R;Defined Requirement] It shall be noted that there may be a future "safety function" for dust measurements; this is currently under investigation.

[5304s740-R;Defined Requirement] The generation of solid waste (radioactive, other hazardous and domestic) by the Diagnostic Neutral Beam System from ITER operation and decommissioning shall be limited to the maximum extent possible, in terms of quantity and toxicity level.

This shall include inventories of all hazardous substances and fuel that is stored on site, as well as radioactive and hazardous waste and effluents that are generated during ITER operation and decommissioning.

[5304s741-R;Defined Requirement] The volumes and level of radio-toxicity in solid radioactive waste from the Diagnostic Neutral Beam System shall be reduced to the maximum extent possible. No radioactive material processing shall lead to a high-level radioactive waste stream.

[5304s742-R;Defined Requirement] The Diagnostic Neutral Beam System shall be designed, operated and decommissioned to comply with the ALARA radiation exposure requirements to the personnel (individual and collective), the public and the environment, and in all cases within the General Safety Objectives of ITER specified in PR Chapter 7.2.

[5304s872-R;Defined Requirement] Beryllium zones shall be established in accordance with the zoning criteria that are listed in Table 7-8.

[5304s873-R;Defined Requirement] Access to beryllium zones shall be restricted in accordance with Table 7-8.

[5304s874-R;Defined Requirement] Proper signage shall be placed in areas, to be consistent with Table 7-8 beryllium zoning requirements.

[5304s875-R;Defined Requirement] Thresholds and conditions of exposure of personnel to magnetic fields shall be established as per Table 7-9.

[5304s876-R;Defined Requirement] Magnetic field zones and access and control conditions shall be established as per Table 7-11.

[5304s877-R;Defined Requirement] The radiofrequency exposure for personnel who are working in areas that are adjacent to sources of hazard shall comply with the following limits that are recommended by the International Commission on Non-Ionizing Radiation (ICNIR).

[5304s878-R;Defined Requirement] In order to improve safety on the ITER site, all identification, labelling and signage shall be standardised to reduce the likelihood of error.

[5304s879-R;Defined Requirement] All labelling, colour coding and signage installed on the ITER site shall comply with the ITER Site Signage & Graphics Standards [42].

[5304s880-R;Defined Requirement] All DNB components shall also comply with the recommendations of the ATEX - requirements for risk assessment and mitigation [[30] and [32]].

[5304s881-R;Defined Requirement] Ventilation shall provide sufficient air renewal to avoid hydrogen concentration in rooms where there is an explosion risk.

[5304s882-R;Defined Requirement] If there is no potential for an explosive mixture, the area shall be defined as having ”no zoning”.

[5304s883-R;Defined Requirement] Zoning shall be established in the nuclear buildings, to protect people, equipment, and the environment from the effects of perceived hazards during all phases of the facility life cycle. For the ITER facility, zoning shall apply to: Ventilation, Radiological, Anti-deflagration, Beryllium, Magnetic, Radiofrequency, Fire, Waste.

[5304s884-R;Defined Requirement] Ventilation zones shall be established, based on the estimated atmospheric contamination, consistent with Table 7-5.

[5304s885-R;Defined Requirement] Note 1: Recirculation shall be included for enhanced tritium recovery, and does not significantly impact confinement.

[5304s886-R;Defined Requirement] Note 2: Only internal exposure hazard shall be taken into account, the derived atmospheric concentration (DAC) is used as defined in PR1242.

[5304s887-R;Defined Requirement] The radiological zoning shall be based on total dose, as listed in Table 7-6, or on equivalent doses to hands and feet, as also listed in Table 7-6, when the external exposure to hands and feet exceeds the total exposure.

[5304s888-R;Defined Requirement] The radiological zoning shall be defined for each plant operation state, following the criteria of Table 7-6, see also [35], [36], [53], [52].

[5304s889-R;Defined Requirement] The marking (signing) of the radiation zones from greyish blue to red shall follow the norm (ref. MF M 60-101) and shall be clearly posted on all access routes to the zones. The marking of the radiation zones shall be modified according to every change to the zoning.

[5304s890-R;Defined Requirement] Access conditions for the personnel to the radiological zones shall be as given in Table 7-7.

[5304s891-R;Defined Requirement] Note 1: Total dose rate shall be the sum of external dose rate and internal dose rate. Internal dose rate can be calculated, using airborne concentration, as a ratio of “Derived Air Concentration” (DAC) (see definition of DAC in PR1242).

At levels higher than 1 DAC, specific authorization shall be required to enable access of personnel equipped with appropriate individual protections.

[5304s892-R;Defined Requirement] Note 2: In case of exposure of the eye lens (crystalline), these values shall be multiplied by 0.3 (150/500).

[5304s894-R;Defined Requirement] Note 4: Human access shall be forbidden without special authorization.

[5304s895-R;Defined Requirement] Note 1: Under normal situations, with no detectable atmospheric contamination permitted in green or yellow zones, the trefoils shall only indicate the risk of external exposure

[5304s896-R;Defined Requirement] Note 2: French regulations classify workers as Type A and Type B. Type A workers shall include those whose exposure to ionizing radiation may lead to a dose greater than 6 mSv during 12 consecutive months, and Type B workers include those exposed to ionizing radiation and not classified Type A.

3.10 Reliability requirements

[5304s332-R;Defined Requirement] Single failure of an active component of the DNB System shall not prevent implementation of the safety function of the DNB System.

3.11 Other requirements

[5304s711-R;Defined Requirement] The caesium ovens shall be pre-filled with caesium, and sealed before installation on the ion source.

[5304s939-R;Defined Requirement] Counter measures limited in time and space shall be addressed by considering consequences in relation to guidelines such as:

- The avoidance of the need for public evacuation, for which a guideline is 50 mSv of avertable dose in a period of no more than one week, according to IAEA recommendations and French regulations
- The limitation of the need for short-term sheltering, for which a guideline in French regulations is 10 mSv
- The limitation of the need to ban the consumption of food products, by studying the likely contamination levels and predicting the extent (in space and time) of such banning, if any.

[5304s936-R;Defined Requirement] The ITER installations shall be designed to withstand extreme heat conditions; that is, air temperatures up to +45ºC and temperatures of +40ºC for buildings [39].

[5304s935-R;Defined Requirement] The ITER installations shall be designed to withstand extreme cold conditions; that is, air temperatures down to -25ºC and temperatures of -15ºC for concrete structures and isolated structures [39].

[5304s334-R;Defined Requirement] The ovens shall be discarded as waste once they are empty. No re-filling of the ovens is anticipated.

[5304s503-R;Defined Requirement] It shall be noted that the maximum quantity of hydrogen that can be produced from 120 grams of caesium is 1.8 grams. This is much lower than the deflagration limit.

4 OPERATION AND MAINTENANCE

4.1 Operation

[5304s898-R;Defined Requirement] The DNB shall be designed for an operating lifetime of no less than 20 years plus the time for dedicated commissioning.

[5304s899-R;Defined Requirement] ITER shall be designed to meet the requirements of the three reference scenarios. (Upgrade requirements for auxiliary (non-tokamak) systems for the Hybrid Operation and Non-Inductive Operation scenarios which are provided in Section 4.4.4 of the PR).

[5304s900-R] The NB Heating and CD System shall be designed to meet the requirements of the three reference scenarios:

- Inductive operation 500 MW, Q=10, 15 MA operation with heating during ramp-up.
- Hybrid operation
- Non-inductive operation: weak negative shear operation.

The vacuum vessel and in-vessel components including the NB duct shall be designed to accommodate the heat loads specified in the ITER Heat and Nuclear Load Specifications [11].

[5304s901-R;Defined Requirement] The inlet pre-pulse and during pulse coolant temperature of the Vacuum Vessel and Neutral Beam port (up to the torus isolation valve) in-vessel components (unless otherwise specified below) shall be 100°C, within a range of ±10°C, accuracy ±2% at nominal flow rate and pressure.

The inlet pre-pulse and during coolant temperature of all in-vessel components shall be 70°C, within a range of ±5°C, at nominal flow rate and pressure.

[5304s508-I] The DNB System can either be operated in a conditioning mode, or injecting into ITER plasma. In conditioning mode, the beam will be intercepted on the calorimeter.

[5304s712-R;Defined Requirement] The DNB System shall be designed to be operated in accordance with the Operations Handbook.

4.1.1 System operation states

[5304s341-R;Defined Requirement] The DNB System shall always be in a defined common operation state. The design of the NB Heating and CD system shall be designed for an operating lifetime no less than 20 years plus the time for dedicated commissioning.

[5304s510-I] The global operation states as defined in the *Operations Handbook: 2 Operational States* [6] for the DNB System are as shown in the following table.

[5304s560] **Figure 4.1.1: Global Operation States**

[5304s567]

ITER Operation State Plant subsystem	Construction/Long Term Maintenance (LTM)	Short Term Maintenance (STM)	Test & Conditioning State (TCS)	Short Term Stand-by (STS)	Plasma Operation (POS)
Duration	>30 days	1-30 days		<8 hrs	
NB power supply	OFF	OFF	OFF/[ON]	ON	ON
NBI	OFF/Maintenance	OFF/Maintenance	OFF/[Ready for conditioning]	Ready for Pulse	Pulse(Ready for injection, Dwell)
NB Cryo	OFF/Maintenance	OFF/Maintenance	Normal/Slow PRS	Normal	Normal/Fast PRS

4.1.2 Operational conditions

[5304s337-R;Defined Requirement] The operation of the DNB System shall be possible whenever the plasma parameters guarantee that the power that is deposited by the beam on the first wall (shine-through) remains within prescribed limits.

[5304s338-R;Defined Requirement] The DNB System shall be able to operate with hydrogen at a fixed acceleration voltage between 90 kV and 100 kV.

[5304s902-R;Defined Requirement] The plasma control system shall minimize the frequency of events causing damage to the first wall and high heat flux components, whether by localized melting, detachment of tiles, or breaching of water cooling pipes. The NB H&CD system shall therefore be controlled by the PCS to avoid these events.

[5304s903-R;Defined Requirement] The DNB shall be designed to operate with a duty factor of at least 25% for burn duration greater than 450 s.

[5304s904-R;Defined Requirement] The DNB system shall be designed to operate with a pulse period time not exceeding 1800 s for burn duration less than 450 s.

[5304s905-R;Defined Requirement] Electromagnetic loads shall be kept within acceptable limits even in the event of potential failures in control.

4.1.3 Main control room

[5304s906-R;Defined Requirement] The DNB shall be controlled or configured by personnel inside of the Nuclear Installation (INB) perimeter [33], [34]. For this purpose, a Plant Operation Zone (POZ) is defined, which geographically almost equals the perimeter of the INB. In all situations, the Main Control Room (see Section 6.10), or the Backup Control Room, that both have the capability to monitor and to control SIC components and to put the plant in a safe state, shall remain habitable.

[5304s907-R;Defined Requirement] The DNB shall be operated from the Main Control Room. There shall be no other offices or control rooms for the NB heating and CD system within the INB perimeter.

[5304s512-I] The equipment inside the main control room will comply with the requirements by CODAC and its plasma control system.

[5304s586-R;Defined Requirement] For normal operation the NB crew shall consist of one operator for the DNB and one operator for each NB Heating and CD System injector. In addition, one responsible person will be required for all NB Heating and CD Systems and two people for the NB power supplies.

4.1.3.1 *Monitoring requirements*

[5304s299-R;Defined Requirement] The overall power balance of the injector and the power loads on the injector components shall be monitored.

[5304s298-R;Defined Requirement] Beam-line diagnostic equipment shall be used to allow monitoring of the beam power distribution to ensure safe operation of the injector.

[5304s713-R;Defined Requirement] The power density profiles shall be monitored at some relevant locations that allow information to be obtained about beam source segment aiming and alignment. This shall be done both in the DNB System-commissioning mode, when the calorimeter is intercepting the beam, and in an injection mode (open calorimeter).

[5304s301-I] Measurement of the total injected power will be provided to the plasma control system (PBS 47) when the NB Heating and CD System is operated.

[5304s302-I] The temperatures of the most critical points for detection of off-normal operating conditions will be monitored.

4.2 Maintenance

4.2.1 Maintenance plan

[5304s515-R;Defined Requirement] A maintenance plan shall be prepared by the supplier and approved by IO. The minimum information that is required in this maintenance plan is the following (a maintenance plan template is under preparation by IO):

- Scheduled operations (such as controls, checks, adjustments, calibrations, overhauls, and replacements) that are derived from Safety and Security regulations, and that are identified as necessary by the supplier in order to ensure the best operation of the system in its intended operational scenario.

- Critical unscheduled operations (such as replacements and repairs) that may impact ITER availability and / or introduce needs for additional support (such as spares, procedures, training, tools and test equipment, and infrastructure).

[5304s536-R;Defined Requirement] Maintenance tasks are identified from RAMI analysis and Safety Analysis in order to meet the Project's safety and availability requirements. They shall be specified and verified as part of the design process for ITER systems, under the responsibility of their TRO.

The RAMI analysis, once completed, shall provide input data and recommendation for the maintenance plan. In the meantime, the following elements can already be considered:

- The caesium ovens shall be replaced during the long term maintenance periods that are, at present, foreseen every 16 months. The foreseen duration for the replacement is less than 2 weeks.

- The DNB System is connected to the primary vacuum via an absolute valve that provides the isolation between the ITER vacuum vessel and the BLV. The absolute valve metallic seal is being considered as a single barrier. NB maintenance with the NB primary confinement opened shall only be carried out with the absolute valve locked in the closed position.

- NB maintenance with the NB primary confinement closed (in vacuum or not) can be carried out without venting the ITER vacuum vessel, but must be carried out when ITER is not operating.

[5304s596-R;Defined Requirement] The maintenance requirements of the DNB System shall conform to the maintenance periods that are defined for ITER.

[5304s602-R;Defined Requirement] *Short term maintenance* shall be allowed according to the following pattern:

- Daily checks, controls, conditioning of equipment, fluids preparation within less than 8 hours of elapsed time.

- Routine maintenance shall not be required with intervals less than 2 operational weeks. Routine maintenance covers minor adjustments, calibration, replacements of equipment. Routine maintenance shall be performed within less than 2 days elapsed times.
- Short term maintenance must take into account the zoning constraints (access control, environmental conditions) and corresponding time constraints.

[5304s603-R;Defined Requirement] *Major shutdowns shall be* scheduled to allow for major scheduled replacements, overhauls / refurbishments, and repairs of equipment. It shall be noted that ITER requirements for this maintenance interval could be up to two years.

[5304s604-R;Defined Requirement] No scheduled maintenance of the DNB System shall be required outside these defined periods unless it can be performed during normal plasma operation (hidden maintenance).

[5304s714-R;Defined Requirement] During ITER operation, Safety Importance Classification (SIC) components of the NB Heating and CD System [16] shall be periodically controlled, maintained, inspected and tested in compliance with requirements of the ITER Site Maintenance Programme (including the preparation of dedicated maintenance procedures; the control/audit, update and keeping of test and maintenance records for each system).

4.2.1.1 Spares

[5304s599-R;Defined Requirement] Recommendation for spares provisioning shall be provided, both for scheduled and unscheduled maintenance, taking into account operating conditions. The final decision on spares provisioning shall be made by IO. Cubicles and their components must be addressed as a major spare item.

RAMI results shall be taken as a major driver for definition of the list of critical spares.

Spares shall be readily available where the evaluation shows the need.

[5304s600-R;Defined Requirement] To avoid inventory increase, the supplier shall make maximum use of off-the-shelf equipment and components' catalogues that are identified by ITER Organization.

[5304s601-R;Defined Requirement] The supplier shall inform ITER Organization of any risk regarding components' obsolescence, and make all pertinent recommendation to mitigate that risk.

4.2.1.2 Operation and maintenance procedures

[5304s597-R;Defined Requirement] Documents must be provided to IO for operation and maintenance of the system' equipment on site. These publications shall comply with the ITER template for operation and maintenance procedures. Data shall be provided both as paper and electronic media.

[5304s715-I;Defined Requirement] Maintenance procedures for the NB Heating and CD System will contain appropriate measures to be taken to protect vacuum envelopes during maintenance operations.

It will be noted that t536he Maintenance Classification is intended to support the performance of relevant engineering analyses, and an adequate implementation of the ITER limit for annual collective radiation dose exposure, as established in [PR1129-R]. Therefore, this classification is maintenance environment oriented, and will be assigned to any maintenance task that is defined by the ITER Designer or ITER Operator.

[5304s533-R;Defined Requirement] Maintenance procedures for RH Class 1 components shall be developed in detail, and verified on mock-ups, prior to their first assembly.

It is noted that in order to manage the ITER maintenance planning in a proper way, MC1 is divided into three sub-classes as follows:

- Maintenance Class 1-1 (MC1-1) shall be defined for any maintenance task which represents 1% or more of the ITER annual collective radiation dose exposure limit.
- Maintenance Class 1-2 (MC1-2) shall be defined for any maintenance task which is in the range from 0.1% to 1% of the ITER annual collective radiation dose exposure limit.

- Maintenance Class 1-3 (MC1-3) shall be defined for any maintenance task which represents less than 0.1% of the ITER annual collective radiation dose exposure limit.

[5304s534-R;Defined Requirement] Maintenance procedures for RH Class 2 components shall be developed in detail, and verified on mock-ups, where deemed practical and necessary, prior to their first assembly.

It is noted that maintenance Class 2 (MC2) includes any planned or unplanned maintenance activities that must be performed in environment of toxic and/or other hazardous but without risk of radiation exposure or radioactive contamination.

Maintenance Class 2 (MC2) includes any planned or unplanned maintenance activities that must be performed in environment of toxic and/or other hazardous but without risk of radiation exposure or radioactive contamination.

Maintenance Class 2 shall be associated to any maintenance task which is not classified as MC1 and which requires special PPE (Personal Protective Equipment) for workers, such as air suit or breathing mask.

In order to manage the ITER maintenance planning in a proper way, MC2 is divided into two sub-classes as follows:

- Maintenance Class 2-1 (MC2-1) shall be defined for any maintenance task which deals with Beryllium and require Beryllium waste management.
- Maintenance Class 2-2 (MC2-2) includes any other MC2 maintenance tasks that are not classified as MC2-1.

4.2.1.3 Operation and maintenance training

[5304s594-R;Defined Requirement] Initial training shall be provided for the ITER Operation and Maintenance crew. The training shall conform to the training rules that are set up by ITER Organization. The training scope is identical to that of the operation and maintenance procedures.

4.2.1.4 Special tools and test equipment

[5304s591-R;Defined Requirement] Any special tool and test equipment that is needed for maintenance of the system's equipment on site shall be provided to ITER Organization. Any such equipment, that would be additional to items that are delivered as manufacturing means, installation means, test and commissioning means shall be fully justified.

[5304s592-R;Defined Requirement] Special pieces of equipment that are needed for packaging, handling, storage and transportation are in the scope of the requirement. The supplier shall state the degree of protection for any packaging equipment. This degree of protection shall be identified, based on the ITER Organization defined environmental conditions.

[5304s908-R;Defined Requirement] The design of all ITER systems, and subsystems, and the planning of the shipping, storage, construction and machine operation, shall take into account the meteorological conditions, and the risks of abnormal conditions. The meteorological conditions, and some Cadarache-specific criteria that are imposed by French and European norms, are reported in [A20].

[5304s360-I] The cryo pumps will initially be assembled by hand using some of the RH tools and the overhead crane.

[5304s361-R;Defined Requirement] The RH equipment and the operation sequences for RH Class 3 components shall be designed in detail prior to machine operations.

[5304s535-R;Defined Requirement] The RH equipment and the operation sequences for RH Class 3 components shall be designed in detail prior to machine operations.

4.2.1.5 Facility requirements

[5304s589-R;Defined Requirement] The supplier shall identify any facility requirements (such as property class, security, and utilities) of equipment that need to be tested and maintained outside the Hot Cell Facility (control cubicles, for instance).

[5304s343-R;Defined Requirement] The DNB vessel shall be decontaminated, using a ventilation system, before breach or removal of any component.

[5304s348-I] Outside the neutron shield, the dose rate inside the volume of the NB cell will be lower than 2 mSv/hour, at any location, within 10^6 seconds from the end of DT operation.

[5304s349-R;Defined Requirement] At sufficiently low background gamma radiation, limited operations of hands-on maintenance on components, as well as hands-on assistance and preparation for remote-handling tasks, shall be possible.

[5304s350-R;Defined Requirement] The number, duration and procedure of the maintenance interventions shall be defined according to the ALARA principle, reducing the number of components and taking into account the simplicity of maintenance in their design.

[5304s356-R;Defined Requirement] The remote maintenance of the DNB System shall be performed by a dedicated remote maintenance system that is located within the neutral beam cell as provisions for remote maintenance shall be made for all environments where hands-on maintenance would result in ITER administrative limits (less than 100 μSv/h) being exceeded.

4.2.2 Remote handling

[5304s909-I] All DNB components will also comply with the RH Code of Practice [31].

All the RH classified components will be designed as per the RH code of practise for their RH compatibility.

[5304s352-R;Defined Requirement] All of the components that are internal to the neutron shielding, that may require replacement, shall be designed to be compatible with the remote handling maintenance.

[5304s354-R;Defined Requirement] The remote maintenance of the neutral beam injector system shall be performed by a dedicated remote maintenance system that is located within the NB cell. The remote handling approach is to remove the components, and to transfer them inside sealed bags or transfer casks to the Hot cell for maintenance/disposal or directly to radioactive waste.

[5304s537-I] The remote handling equipment will be stored in the NB cell.

[5304s538-R;Defined Requirement] The caesium ovens, beam source, electron dump, neutraliser, RID, calorimeter, exit scraper, vessel lid, PMS and the fast shutter actuator and sealing plate shall be remotely removable and replaceable.

[5304s539-R;Defined Requirement] To the maximum extent possible, protection measures shall be provided to prevent injury to the personnel or minimize damage to the handled equipment and surrounding components in the event of the failure (direct or indirect) of the handling system, or an operation error during the NB maintenance.

The wearing of appropriate individual protection equipment shall be mandatory before access to the NB Cell as it is a zone with safety risks. Appropriate training shall be mandatory before access to a zone that has cryogenics-related safety risks.

Appropriate recorvery procedures shall be specified in the event DNB handling equipment fails.

4.2.3 Hot cell

[5304s519-I] The only components of the DNB System that are required to be regularly replaced are the caesium ovens. These will be removed and transferred to the Hot cell for disposal. All other components that are identified in Section 4.2.2 will be taken to the Hot cell facility or rad waste at their end of life.

4.3 RAMI

4.3.1 Reliability, Availability, Maintainability and Inspectability requirements

[5304s345-R;Defined Requirement] The beam-line components shall avoid maintenance during the operation lifetime of ITER.

[5304s346-R;Defined Requirement] The activities that are related to the design, construction, operation and optimization of the NB Heating and CD System shall be carried out to guarantee, as much as possible, the expected performance of the DNB System in ITER, including the reliability and availability targets that are defined in the *Project Requirements (PR)* [7].

DNB system shall be designed for an operational machine availability of at least 32% on average over ITER H-phase (up to 40% over one month of operation) in a three-shift operating mode with a Mean Scheduled Down Time (MDTS) not greater than 11.3 months over every two-year experimental campaign, taking into account 365 working days per year and 24 working hours per day.

Plasma scenarios for H, He and D operation shall necessarily encompass a wide range of plasma parameters up to the maximum technical capability of the tokamak in order to address:

- Development of the discharge scenario required for full D-T phase reference operation, including features such as plasma current initiation, current ramp-up, formation of a divertor configuration and current ramp-down
- Commissioning of core tokamak systems, such as Poloidal Field system, Correction Coils system, in-vessel coil systems up to the maximum value of plasma current and toroidal field (15 MA / 5.3 T)
- Progressive commissioning of the Plasma Control System, together with interlock and protection circuits and safety-important systems, as required by the technical performance of the tokamak and the level of plasma performance achieved
- Development of the "Progressive Start-up" strategy as per the RPrS [R08] for determination of maximum loads on vessel and in-vessel structures due to disruptions and vertical displacement events (Section 4.3.7)
- Provision of experimental data to validate the ITER licensing assumptions
- Commissioning with plasma of all tokamak auxiliary systems H&CD, diagnostics, fuelling, pumping for which D-T plasmas are not required
- Characterization of hydrogenic retention and dust production, and demonstration of techniques for their control
- Commissioning of appropriate mitigation techniques against the consequences of plasma transients and loss of control
- Demonstration of power handling capabilities of plasma-facing components within the heat load limitations of H, He, and D plasmas including semi-detached divertor operation and low impurity level
    - Achievement of type-I ELMy H-modes for sufficient durations to allow an adequate physics basis for the implementation of full D-T plasma operation including aspects such as H-mode power threshold scaling and energy and particle transport at the ITER scale
    - Finalization of nuclear commissioning with a minimum amount of tritium.

4.3.1.1 Test and validation

[5304s716-R;Defined Requirement] Reliability characteristics shall be demonstrated by the supplier as part of the DNB System qualification process. The warranty period shall also be used as a validation period for the reliability characteristics of the system equipment. Deviations from requirements shall be identified and compensating / correcting actions identified and implemented. Responsibility identification, budgeting and planning shall be established based on a Reliability-Centered Maintenance procedure for the Implementation of necessary actions.

[5304s717-R;Defined Requirement] Maintainability characteristics shall be demonstrated by the supplier as part of the qualification process. Critical on-line controls or replacements shall be realized during integrated commissioning. These demonstrations shall ensure accuracy of elapsed times, and efficiency of support equipment that is needed for task performance.

[5304s914-R;Defined Requirement] Design verification by qualification testing shall be performed as early as possible and prior to the point when related system, structures, and/or components are installed.

[5304s915-R;Defined Requirement] If an alternate calculation method or a qualification test method for design verification of a system, structure or component has not been developed or there is difficulty in its application, then the design review shall be used as the design verification method of the system, structure or component. The design review shall be performed either as specific review by one or more independent reviewers competent in a single discipline or by multi-disciplinary review performed by a multi-disciplinary review team.

[5304s916-R;Defined Requirement] If it is possible to verify the design integrity of a system, structure or component by design verification using only design calculation, and an alternate calculation method has been developed, then the alternate calculation shall be used as the design verification method of the system, structure or component.

[5304s917-R;Defined Requirement] If performance of a related component has not been verified due to application of a new design concept, then the qualification test by model test under conditions that simulate the most adverse design conditions shall be used as the design verification method for the component.

4.3.2 Risk reducing

[5304s570-R;Defined Requirement] The DNB ion source shall be as similar as possible to the ion source of the HNB. The source shall be qualified in the Ion Source Test Facility SPIDER in Padua up to performance parameters common to both systems. The necessary additional DNB specific development shall be carried out at the Indian Test Facility (INTF) at ITER India in Gandhinagar.

[5304s571-I] A prototype of the DNB beam-line will be integrated at the Indian testbed and all essential features of the integrated full performance will be tested.

[5304s541-R;Defined Requirement] A Failure Mode Analysis of the DNB System, and an evaluation of the Severity, Occurrence and Detectability levels of the main failure mode causes, shall be done. Based on the result from this evaluation, some actions shall be taken to reduce the risk level. This can be done either by modification of the design, or the fabrication methods, or by test, operation and/or maintenance procedures.

4.3.2.1 Design recommendations

[5304s614-R;Defined Requirement] RAMI design recommendations shall be provided in review of this SRD when RAMI analyses are completed.

4.3.2.2 Operation recommendations

[5304s608-R;Defined Requirement] RAMI recommendations for DNB System operation shall be provided in review of this SRD when RAMI analyses are completed.

4.3.2.3 Maintenance recommendations

[5304s610-R;Defined Requirement] RAMI recommendations for DNB System maintenance shall be provided in review of this SRD when RAMI analyses are completed.

[5304s613-R;Defined Requirement] RAMI results shall be taken as a major driver for definition of the list of critical spares.

[5304s542-I;Defined Requirement] Spare parts should be readily available where the evaluation shows the need.

[5304s918-R;Defined Requirement] Accessibility to the physical interface points shall be taken into account as a way to improve the maintainability and inspectability of the concerned components, and thus ultimately the availability of the systems.

[5304s919-I] Note *: The Detritiation System will have an availability of 98.72%.

4.3.2.4 Testing recommendations

[5304s612-R;Defined Requirement] RAMI recommendations for DNB System testing shall be provided in review of this SRD when RAMI analyses are completed.

5 QUALITY REQUIREMENTS

[5304s615-R;Defined Requirement] All items and services shall comply with the *ITER Quality Assurance Program* [10].

6 APPLICABLE CODES AND STANDARDS

[5304s368-R;Defined Requirement] All mechanical components shall be designed according to the latest approved version of the *Codes and Standards for ITER Mechanical Components* [1]. Design rules and standards shall be selected for each system or component, in consideration of SIC, using the guidelines in Table 7-2 [7].

[5304s719-I] The applicable manufacturing standards to follow are the following.

[5304s720-R;Defined Requirement] RCC-MR 2007 shall be applied for the vessel components and attachments that serves as the first confinement barrier. These are the DNB vessel, the feedthrough box for the instrumentation, the Fast shutter, the Absolute valve, the drift duct bellows and the gas lines for the ion source between the HV bushing and the isolation valves in HVD2, the neutraliser gas line and the PMS. The DNB vessel is classified as class 2 box structures components (design rules RC 3800).

[5304s721-R;Defined Requirement] SDC-IC [23] shall be applied for the internal components inside the first confinement barrier. These are the Beam source, BLC adjustable beds for the BLCs, the Neutraliser, The electron dump, the RID, the Calorimeter, the Exit scraper, the Drift duct liner and the Duct liner.

[5304s722-R;Defined Requirement] ASME Sec VIII Div 2 shall be applied for the Active Correction and Compensation Coils, the HV transmission line, the cooling water pipes in the HV transmission line and the actuator pipes for the gas valves in the HV transmission line.

[5304s369-R;Defined Requirement] The DNB vessel shall not be classified as a pressure equipment as the absolute pressure will remain below 0.15 MPa. In accidental case category IV the pressure could increase to 0.2 MPa but this case is out of the scope of the regulation. The vessel is consequently classified as PED category 0 and is not submitted to ESPN.

[5304s723-R;Defined Requirement] Piping shall fulfil regulatory requirements.

[5304s370-R;Defined Requirement] Piping and vessels shall comply with French regulation on pressure equipment (decree 99/1046, decree and design) and ESPN Order 30 December 2015 (order on nuclear pressure equipment).

[5304s371-R;Defined Requirement] Specific design, fabrication and test criteria shall be used for the HV bushing and isolators for RID water supply, which includes non-metallic materials (ceramic and fibre reinforced plastic) as part of its vacuum/pressure retaining boundary. The usage of ceramic and fibre reinforced plastic prevents the direct application of the ASME section VIII div. 2 to these parts of the confinement.

[5304s378-R;Defined Requirement] For material that has structural functions, the source of material property information for design analysis shall be either the applicable structural code or the ITER structural design criteria based on the materials assessment report and the latest approved version of the MPH Handbook [24] . In case of conflict, the ITER structural design criteria shall take precedence.

[5304s379-R;Defined Requirement] All components that have vacuum confinement functions shall also comply with the recommendations of the *ITER Vacuum Handbook* [2].

[5304s380-R;Defined Requirement] The fabrication shall follow the general prescriptions of the *ITER Quality Assurance Program* [10] and the specific prescriptions that are given in the applicable standards:

- Codes and Standards for ITER Mechanical Components [1]
- In-vessel Components, SDC-IC [23]
- Material Properties Handbook (MPH) [24]
- List of Codes and Standards for ITER Systems, Structures and Components (MPH) [25].

7 ADDITIONAL REQUIREMENTS FOR THE STAGED APPROACH PHASES

7.1 First Plasma phase

7.2 Pre-Fusion Power Operation 1 phase

[5304s922-R;Defined Requirement] Before the first deuterium-tritium starts, the ITER device and facility shall be capable of being upgraded to provide personnel access to the interior of the ITER vacuum vessel in the presence of Be dust for hands-on maintenance.

[5304s923-R;Defined Requirement] The FPO Deuterium Operation shall aim at achieving 15 MA plasmas in Deuterium with a robust plasma control, and commissioning ITER systems prior to operations with Tritium.

7.3 Pre-Fusion Power Operation 2 phase

7.4 DD-DT phase

[5304s920-R;Defined Requirement] The NB H&CD system shall be installed in stages as stated in the staged approach configuration [28]

[5304s924-R;Defined Requirement] ITER shall be designed to provide an average neutron fluence of 0.30 MW.y.m-2 in the active phase in order to satisfy the overall requirement specified in the Project Specification document [44].

[5304s930-R;Defined Requirement] "For the following safety functions, these definitive provisions shall be implemented before the start of PFPO-1 (at the end of Assembly and Integrated Commissioning phase II):

- the confinement of toxic materials;
- support systems required to enable the confinement of both radioactive and toxic materials;
- prevention of hazards challenging safety functions;
- environmental surveillance;
- crisis management.

[5304s927-I;Defined Requirement] The Overall Strategy to construct and to operate ITER is presented in ITER Research Plan [40]. This strategy has been revised to integrate a staged approach where the following four plasma operation phases will be performed: First Plasma (FP), Pre-Fusion Power Operation 1 (PFPO-1), Pre-Fusion Power Operation 2 (PFPO-2) and Fusion Power Operation (FPO). Each of these plasma operation phases is preceded by an assembly and an integrated commissioning campaign. They correspond to four configurations of the ITER Plant, the FPO configuration being the final one, corresponding to the ITER Baseline, to undertake the full D-T plasma operation

8 APPENDIX

[5304s947-I;Defined Requirement] This appendix lists defined requirements and information from the PR that are identified as applicable For Information to the system. These PR statements must be propagated down the chain of interveners for the system to ensure they are aware of them (there is no need to demonstrate compliance with each statement).

PR defined requirements and informations applicable For Information to the system									
PR2372	PR2364	PR2374	PR2375	PR4955	PR1945	PR2354	PR2085	PR1946	PR1962
PR2376	PR3078	PR3080	PR3081	PR3086	PR3099	PR3215	PR1108	PR2032	PR1349
PR1357	PR1369	PR1438	PR1457	PR4947	PR4948	PR4975	PR4988	PR5000	PR5014
PR5015									

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