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Rules or Handbooks or Guidelines

ITER Fire Protection Approach

This document provides a summary of the approach for fire protection of ITER Project. This approach bases on the Project Requirements and other related documents.
Fire protection of ITER Project has the following objectives: Prevent fire and fire damage that could lead to the loss or jeopardize of nuclear safety functions; Ensure human safety; Limit damage to ITER Structures, Systems and Components for investment protection This document focuses on these objectives.
This project-level document specify more detailed fire safety provisions permitting to prevent, detect, retard and/or extinguish fire that could threaten or degrade workers safety, Safety Important Components (SIC) and other ITER Structures, Systems and Components important for ITER Investment Protection.

Approval Process			
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Change Log			
ITER Fire Protection Approach (25SDBD)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	25 Sep 2007	
v1.1	Approved	28 Sep 2007	
v2.0	Approved	26 May 2008	
v3.0	In Work	28 Jul 2010	Changes for consistency with RPrS as submitted in March 2010.
v3.1	Approved	28 Jul 2010	Editorial changes.
v4.0	Signed	09 Oct 2025	LIST OF CHANGES General changes 1. Changing the document design in line with the new ITER template – whole document 2. Changing the content in line with the new ITER template – whole document 3. Bringing the whole text in line with the new ITER_D_27ZRW8 - Project Requirements (PR), including the links for specific PR (traceability) – whole document 4. Updating of the terms everywhere: firefighting systems, Fire Hazard Analysis, ITER Project, fire zones, etc. Local changes (Updated and new provisions) 5. Section 1. Purpose (1.1 – 1.5) 6. Section 2. Scope (2.5 – 2.7) 7. Subsection 3.1. Definitions (Fire Zone is added) 8. Subsection 3.2. (Acronyms are added: DBA, DBC, DEC, DS, HVAC, SSC, SIC, V&V) 9. Section 4. Reference documents (New ones were added/updated: 1, 3 – 6, 10 – 13, 15, 16. Obsoleted were removed) 10. Section 5. General Fire Protection Requirements (5.1 – 5.12. The most significant changes: 5.2 – statements regarding to emergency response, 5.3 – 5.6 – statements regarding to “fire zones” (“fire cells”), 5.8 – identification of criteria for the fire hazard identification) 11. Section 6. (6.1 – 6.2) – only bringing the whole text in line with new ITER_D_27ZRW8 - Project Requirements (PR) and minor corrections 12. Section 7. (7.1 – 7.13. The most significant changes: 7.2 – 7.4 – identification of clearer criteria for the equipping of the rooms with fire detection and alarm systems, 7.7 – the actions initiating by fire detection systems are updated, including operation of DS in the burning fire sector and DS sectors) 13. Section 8. (8.1 – 8.16, 8.18 – 8.25. The most significant changes: 8.8 – 8.16 – identification of the clearer criteria for the equipping of the rooms of firefighting systems, table with standards was removed) 14. Section 9. (9.1 – 9.3. The most significant changes: 9.1 – Emergency Control Building (B7S) is mentioned, 9.2 – description of DS operation). 15. Section 10. (10.1 – 10.5. The most significant changes: Whole text of the section - removing of information duplicated with FHA General Methodology and Guidelines (with links in 9.4 and 9.5); adding of the key assumptions for the design and Fire Hazard Analysis) 16. Appendix A Fire sectors (A.1 – A.4. The most significant changes: Whole text of the section - removing of information duplicated with ITER_D_ASWMDA - Guideline to Fire hazard analysis methodology : #F4: Fire sectorization and [RPrS 1-9.6] RPrS chapter 1-9.6 Zonage incendie ITER_D_2WACDZ (with links in A.3);

			17. Appendix B Control of combustibles and ignition sources (B.1. B.3, B.5, B.10, B.11, B.14, B.15. The most significant changes: B.12 – links on the documents for batteries rooms are identified in line with Page Information - External LL from 2023 Fire in a Lithium metal polymer batteries storage warehouse - ITER Lessons Learned - Science & Integration Department) 18. Appendix C Fire Detection and Alarms (C.1, C.2, C.3, C6, C.9 – C16. Only minor updates) 19. Appendix D Fire Suppression (D.1 – D.5, D.7, D.8, D.10 – D.21. The most significant changes: D.19 –focus on the proper fixed automatic firefighting systems in line with Page Information - External LL from 2023 Fire in a Lithium metal polymer batteries storage warehouse - ITER Lessons Learned - Science & Integration Department) 20. Appendix E Fire Mitigation in Design (E.1.1 – E.1.5, E.2.1 – E.2.6, E.4.1 – E.4.11, E.5.1 – E.5.5, E.6.1 – E.6.3, E.7.1: The most significant changes: E.4.11 – requirement for batteries storages in line with Page Information - External LL from 2023 Fire in a Lithium metal polymer batteries storage warehouse - ITER Lessons Learned - Science & Integration Department) 21. Appendix D Bibliography. Most of the documents were deleted as obsoleted. The TF-F - Fire Protection Design Plan (B7RKEW) has been added to link as the source of the applicable regulation, standards and project documentation and requirements 22. Appendix Integrated Approach to Confinement and Fire Protection has been deleted for the simplification of the document of ITER Fire Safety Approach (25SDBD v3.1), other appendixes have been simplified with adding of minor updates
v4.1	Revision Required	14 Oct 2025	The version of the RCC-F in the references is corrected on 2024 Fire load density (wording corrections)
v5.0	Signed	14 Nov 2025	1. Updates, clarifications and simplifications for some of the wordings have been done. 2. Updates in regard to fire protection and operation of MCR and ECR in case of fire have been made 3. New reference documents have been added to simplify and justify the sections 3, 8 and 10 of the document 4. List of examples of the buildings in the section has been reduced 5. The provisions regarding HVAV and DS operation in case of fire have been clarified 6. Section 10 has been simplified with reference to the relevant methodology and guidelines 7. Some definitions in section 3 have been updated/removed
v5.1	Approved	17 Nov 2025	1. Nuclear buildings in several provisions replaced by SIC buildings 2. Human error considered for the design and construction (if it is required)

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Table of Contents

1 Purpose

1.1 This document provides a summary of the approach for fire protection of ITER Facility. This approach is based on the Project Requirements document [1] and other related documents.

1.2 Based on the [PR1280], the fire protection of the ITER Facility has the following objectives:

- Prevent fire and fire damage that could lead to the loss or jeopardize of nuclear safety functions, mainly:
  - the inability to bring and maintain ITER Facility in a safe state (including intervention of emergency response teams),
  - the release of radioactive/toxic substances within the facility and/or to the Environment,
  - workers exposure to ionizing radiations.
- Ensure human safety,
- Limit damage to ITER Structures, Systems and Components for investment protection.

1.3 This document focuses on these objectives.

1.4 Based on the [PR1191], this document specifies more detailed fire safety provisions permitting to prevent, detect, retard and/or extinguish fire that could threaten or degrade workers safety, Safety Important Components (SIC) and other ITER Structures, Systems (SSC) and Components important for ITER Investment Protection.

1.5 This document is a Complementary Applicable Document to the PR, and as such is applicable to the entire ITER Project. As it is a guideline/textbook, it is possible to use alternative ways to provide fire protection of the ITER Facility based on world best practice and in line with the French legislation. Deviations from this document will be verified and justified by Fire Hazard Analysis.

2 Scope

2.1 A fire is a chemical reaction, started by an ignition source, that consumes fuel and oxygen and produces heat and light; if this chemical reaction is stopped the fire tetrahedron (presence of fuel, oxidant, ignition source and exothermal chemical chain reaction) is broken.

2.2 A fire can cause the degradation of systems contributing to:

- ITER safety functions, including the degradation of confinement systems, resulting in the release and spread of toxic/radioactive products, and the risk of internal and external exposure,
- ITER Investment Protection, including the loss of critical SSCs and ITER operation time.

This abstract describes the concept of fire protection applied in the design of ITER Facility.

2.3 This abstract describes the concept of fire protection applied in the design of ITER Facility.

2.4 These measures are compliant with applicable French legislation, namely the enactment of 31 December 1999 amended by the enactment of 31 January 2006 [Order 1999], as well as DGSNR guideline 7/01 (Direction générale de la Sûreté nationale (France)) concerning the prevention, detection and propagation of fire [DGSNR guidelines].

2.5 This document mostly focuses on the fire protection of the buildings where fire can lead to violation of the safety functions defined in Decree No. 2012-1248 [2]. That means these are the building containing radioactive/toxic substances, SIC and/or personal performing safety functions, for example:

- Tokamak Building – B11
- Tritium Building – B14
- Hot Cell Facility Building – B21
- Tokamak Assembly Preparation Building – B22
- Emergency Power Supply Building (Train A) – B44
- Emergency Power Supply Building (Train B) – B45
- ESP Generator Building (Train B) – B57
- ESP Generator Building (Train A) – B58
- Control Building South (PIC for DT) – B71S (Emergency Control Building – B7S)

In general, all these buildings are protected against external and internal fires in line with fire safety requirements for nuclear facilities, PR and associated documents.

Requirements of non-nuclear French regulations (Labor Code) and standards are also applied to all these buildings.

In case of a conflict between nuclear and non-nuclear fire protection requirements, priority is given to the nuclear requirements. In such cases the justification of fire safety should be provided to compensate the deviations from non-nuclear fire protection requirements. The example of such cases is irrationality of installation of smoke removal systems in the rooms with radioactive/toxic inventories.

2.6 The provisions of this document can be also applied to other buildings of ITER Facility if fire in these buildings can create impacts (for example, due the explosion, fire propagation, collapse, etc.) on the buildings mentioned in the item 2.5 of this document. Examples of such buildings include:

- Assembly Building – B13,
- RF Heating Building – B15,
- RF Heating Building 2 (ECH & CST) – B18,
- Fuel Cycle Cylinder Gases Compound – B25,
- Magnet Power Conversion Building 1 – B32,
- Magnet Power Conversion Building 2 – B33,
- NB Power Supply Building – B34,
- NB High Voltage Power Supply Building – B37,
- Cryoplant Compressor Building – B51,
- Medium Voltage Distribution Building LC/1A – B46,
- Medium Voltage Distribution Building LC/2B – B47,
- Cryoplant Coldbox Building – B52

The full and precise list of such buildings can be identified after full Fire Hazard Analyses has been prepared. Until this analysis is done, only requirements of non-nuclear French regulations (Labor code) and standards are applied to these buildings.

2.7 For other buildings only requirement of non-nuclear French regulations (Labor Code) and standards are applied, for example for office buildings.

2.8 The list of the building mentioned above, as well as screening criteria is updating on the regular basis and presenting in the document ITER_D_B7RT78 - Fire Protection Database for buildings of ITER Project.

3 Definitions

3.1 Definitions

Fire Barrier	Fire walls, ceilings, floors, doors, dampers, penetrations sealing, cable wraps, etc., used to limit the consequences of a fire. A fire barrier is characterized by a fire resistance rating
Fire Sector	A building or part of a building comprising one or more rooms or spaces, constructed to prevent the spreading of fire to or from the remainder of the building for a given period of time. A fire sector is completely surrounded by a fire barrier
Fire Zone	Volume delimited by boundaries (geographical separation, fire screens, fire wrapping, or other fire protection means) such that afire occurring inside cannot spread to the outside, or that a fire occurring outside cannot spread to the inside for sufficient time to allow it to be extinguished
Fire Damper	A device which is designed to prevent the passage of fire (flame, temperature, smoke, etc.) through a duct, under given conditions
Fire Load	The sum of the calorific energies which could be released by the complete combustion of all the combustible materials in a space, including equipment, the facings of the walls, partitions, floors and ceiling, consumables, etc.
Fire Resistance	The ability of an element of building construction, component or structure to fulfil, for a stated period of time, the required load bearing function, integrity and/or thermal insulation and/or other expected duty specified in standards for fire resistance tests
Fire Retardant	The quality of a substance for suppressing, reducing or delaying of the combustion of certain materials
Fire Stop	Physical barrier designed to limit the spread of fire along cable routes or other combustible systems, structures, and components
Non-combustible Material	A material that, in the form in which it is used and under the conditions anticipated, will not ignite, support combustion, burn or release flammable vapour when subject to fire or heat

3.2 Acronyms

DBC	Design Basic Conditions
DEC	Design Extension Conditions
DS	Detritiation System
HVAC	Heating, Ventilation, and Air Conditioning

SSC	Systems, structures and components
SIC	Safety Important Components
PIE	Postulated Initiating Event
PFL	Possible Fires Remaining Localised
PFG	Possible Fires Remaining Generalized
V&V	Verification and validation

For a complete list of ITER abbreviations see: ITER_D_2MU6W5 - ITER Abbreviations

4 Reference documents

[1] [PR] Project Requirements ITER_D_27ZRW8
[2] Decree No. 2012-1248 dated 9 November 2012 authorising IO to create a nuclear facility called « ITER » ITER_D_CZK7M5
[3] NUREG-2178, Vol. 1 Refining And Characterizing Heat Release Rates From Electrical Enclosures During Fire (RACHELLE-FIRE).Volume 1: Peak Heat Release Rates and Effect of Obstructed Plume. Final Report (+ Appendix E)
[4] Design And Construction Rules For Fire Protection of PWR Nuclear Plants. RCC.F – 2024 Edition (*Only in the scope applicable for the ITER Project*)
[5] Method for the justification of fire partitioning in water cooled nuclear power plants (NPP). ISO 18195:2019. Edition 1, 2019. (O*nly in the scope applicable for the ITER Project*)
[6] [SIC guidelines] The safety important functions and components criteria and methodology, ITER_D_347SF3
[7] [RPrS 1-10] RPrS chapter 1-10 Domaine de fonctionnement autorisé ITER_D_3F8ZBA
[8] Order dated 7 February 2012 relating to the general technical regulations applicable to INB ITER_D_7M2YKF
[9] Décision no 2014-DC-0417 de l'Autorité de sûreté nucléaire du 28 janvier 2014 relative aux règles applicables aux installations nucléaires de base (INB) pour la maîtrise des risques liés à l'incendie ITER_D_TZYR3J
[10] Fire hazard analysis – General methodology ITER_D_9WZH42
[11] Accident Analysis Safety Rules ITER_D_9CGERR
[12] Guidelines to Fire hazard analysis methodology ITER_D_9UBC4B
[13] Load Specifications (LS) ITER_D_222QGL
[14] [RPrS 1-9.6] RPrS chapter 1-9.6 Zonage incendie ITER_D_2WACDZ
[15] ITER_D_DJQXMD - OHS Design Requirements: Battery Rooms
[16] ITER_D_5PQBJP v1.3 - Explosion - Defined requirements for all phases prior to D/T phase
[17] [Layout description] Layout description and guidelines for routing of plant systems in the Tokamak complex building ITER_D_2UZ9WX
[18] [RPrS 1-6.4.8] Protection incendie ITER_D_33G46A
[19] [RPrS 2-3.1] Risques externes ITER_D_32HQW9
[20] [General Safety Principles] Principes Généraux de Sûreté ITER_D_3BNKW5
[21] [NFS 62-200] Norme AFNOR NFS 62-200: Matériel de lutte contre l'incendie - Poteaux et bouches d'incendie - Règles d'installation, de réception et de maintenance
[22] ITER_D_FAERY5 - Internal Hazard Analysis Guide
[23] ITER_D_4B6ZNP - Fire Load Assessment for Tokamak Complex - Buildings 62.11, 14 & 74

5 General Fire Protection Requirements

5.1 Based on [PR1280] to implement the objectives of Fire Protection, the ITER Facility applies the following "Defense-in-Depth" approach:

- Fire prevention,
- Fire detection and suppression,
- Fire mitigation, to prevent spread and to limit the consequences of a fire,
- Fire incident response.

5.2 It is possible to maintain ITER Facility in a safe condition during and following a fire, based on the following principles:

- For each radioactive/toxic inventory, at least one confinement system remains intact during and following a fire in line with [PR1288],
- An adequate degree of fire protection is provided by a "Defense-in-Depth" approach in the design:
  - Preventive measures which aim to avoid or limit the occurrence of the four prerequisite conditions (fire tetrahedron) for a fire to occur,
  - Fire detection and firefighting measures suited for the type of fire considered,
  - Reduction measures, intended to:
    - Limit or prevent fire propagation, particularly through adequate fire sectorization/fire zoning of buildings and appropriate routing of DS and HVAC,
    - Ensure the integrity of SIC systems and components, and their associated safety functions (e.g. confinement, radiation protection), particularly through design, e.g. separation of redundant equipment into different fire sectors, fire-fighting and personnel protection measures,
    - Ensure personnel evacuation by means of emergency exit routes throughout the facility, accessible from every room within a time and distance in accordance with the applicable regulations. The evacuation routes include fire protected corridors and staircases,
    - Provide emergency response by involvement of fire teams to extinguish or reduce a fire, to contribute to the evacuation of personnel and to assist the wounded or the specialized fire control teams when they arrival at the scene.

Moreover, in line with [PR1280], [PR1390], [PR1146]:

- To the extent practicable, fire sectors are established in order to limit the risks associated with fires (See Section 9 and Appendix A). Based on IAEA standards it is a fire containment approach,
- Fire sector inventories at risk shall be as low as practicable, for example,
- In a fire sector where the impact of a potential release due to a fire represents a significant risk for the project safety objectives, additional controls shall be established to limit fire risk. These additional controls may include: precluding ignition sources, and/or further restricting fire loading and/or increasing fire resistance,
- For a specified time period, fire sectorization prevents the propagation of a fire or the effects of a fire from one sector to another, as well as from the outside into buildings. This is achieved by maintaining the fire resistance of the boundary of the sector during postulated fires which could occur on either side of the boundary. The fire load is controlled in order to ensure that the duration of the fire will not exceed the duration specified for the fire sector walls or boundaries [PR1195]. In case of increasing of fire loads it should be verified by Fire Hazard Analysis.

These functions are accomplished through a combination of design features, procedural controls, and automatic or manual response actions.

5.3 Based on [PR6114] and [PR2260] when fire sectorization cannot be provided to manage an identified fire risk, other compensatory measures are implemented to prevent the occurrence of that risk or to mitigate its consequences to an acceptable level. These are “fire zones” in line with French regulations (“fire cells” in line with IAEA standards). Based on IAEA standards it is a fire influence approach.

5.4 In case of application of fire influence approach, the following means can be used to avoid fire spreading in or out a fire zones:

- The limitation of combustible materials,
- The separation of equipment by distance, without intervening combustible materials,
- The provision of local passive qualified fire protection such as fire shields or cable wraps,
- The provision of fire detection and firefighting systems.

5.5 Fire zones provide protection of SSC in case of fire at least for two hours but not less than:

- Real fire curve: fire temperature and fire duration (that means it is not obligatory to apply ISO curve),
- Time which is necessary for performance of the required safety function of this SSC in line with safe state criteria.

5.6 The proper implementation of “Defense-in-Depth” is verified by Fire Hazard Analysis (Section 10) for postulated fires with consideration of key assumptions. Fire Hazard Analysis consists of the identification of fire hazards in the different rooms of the buildings. For each room, the consequences of fires are analyzed, and measures are implemented as necessary to reduce the likelihood, duration and consequence of a fire.

5.7 The following criteria can be used for the fire hazard identification, as well as for the further design of fire protection and for the Fire Hazard Analysis for ITER Facility:

- Fire load density (MJ/m^2),
- Availability and location of the ignition sources,
- Fire kinetics of material, substances,
- Local concentration of fire loads (e.g. large oil equipment’s, many cables without fire protection, diesel tanks, etc.),
- Pool fire risks (e.g. flammable liquid, plastic, etc.),
- Explosion risks (e.g. flammable liquid, gas, dust, etc.),
- Other criteria (e.g. ZOI, PFL and PFG [3 – 5]).

5.8 A postulated fire in a building will not lead to the loss of safety functions or radiological/toxic consequences exceeding acceptable limits, considering single failure criteria for DBC and other criteria for DEC.

5.9 Releases could most significantly occur upon breach of confinement barriers; hence, protection of confinement is needed, and the following functions need to be evaluated considering the safety characteristics of ITER Facility:

- Control coolant enthalpy to prevent damage to barriers from overpressure or underpressure,
- Control chemical energy to avoid energy release and pressurization threats to confinement barriers,
- Heat removal to protect against mobilization (e.g. by evaporation or melting) of hazardous materials and damage to confinement barriers,
- Control magnetic energy to avoid damage to confinement barriers from electric arcs, pressurization by cryogens, or mechanical impact in the event of failures,
- Provide required auxiliary services to achieve the above,
- Provide reliable information on all operational events and accidents, and for monitoring the performance of the confinement, and its protection during accidents.

5.10 Safety requirements and Safety Important Classes for SSC to achieve this for ITER Facility are elaborated in the Project Requirements document [1] and the criteria and methodology is described in [6] and in [7].
5.11 Safety important systems, structures and components (SIC equipment) are listed in [6].

6 Fire Prevention

6.1 The design and operation of ITER Facility limit the likelihood of a fire [PR1195, PR6111, PR2268, PR2271].
6.2 The main preventive measures taken with regard to the risk of internal fire are described in Appendix B. Some general measures are given in this section:

- The quantity of combustible materials and loads in each room or area is limited to minimum process requirements by using non-combustible, non-flammable or low flame propagation materials whenever possible (M0 or M1 materials, C1 cables, etc.) in SIC buildings,
- Halogen-containing products are prohibited in rooms/areas/volumes deserved by ITER Detritiation System (DS) as they reduce the efficiency of the DS. Otherwise, their introduction require specific project approval,
- The fire risk due to the use and installation of combustible materials in rooms containing SIC components (or adjacent rooms) is minimized, particularly by:
  - Separating or increasing the distance between potential fire sources and SIC components or systems,
  - Protecting SIC components (diesel generators, cables, electrical panels, etc.) against the effects of a fire, by separation, minimizing fire loads, etc.
- The design and construction of the facilities are based - as far as possible - on rules that prevent fires caused by the use or malfunction of equipment, or potential human error (where it is required),
- Operations with a risk of fire (e.g. cutting, welding, etc.) require specific permits and associated protection measures, particularly in rooms with confinement systems,
- The on-site use and storage of combustible materials in areas adjacent to or containing SIC items will be controlled and accounted for and kept to a practicable minimum; combustible materials not required to be immediately available for operational purposes will not be stored close to SIC items,
- Areas with fire risk for nuclear safety containing flammable materials (such as gloveboxes, for example) or a hot spots (such as cutting, for example) will be inerted with a non-reacting (e.g. nitrogen) gas,
- Due to the high risk of fire and/or explosion, maintenance activities in rooms housing systems/components containing explosive substances (for example, tritium, hydrogen, diborane, etc.) shall be limited to periods when the processes using such substances are shut-down and these substances are appropriately isolated or removed,
- Potential ignition sources shall be prevented or limited, and where an ignition source is present in a room, area or component, the appropriate protection measures shall be taken.

7 Fire Detection

7.1 The design and operation of the ITER Facility ensure early detection and fast alarm in case of fire.

7.2 Each room of nuclear buildings and/or buildings containing SIC are equipped with a fire-detection and alarm system appropriate to that risk and to the environmental conditions of the room [PR2272].
7.3 Rooms of other building are equipped with fire detection systems in line with requirement of non-nuclear French regulations (Labor Code) and standards.
7.4 Fire detection and alarm system can be not required in the areas with low fire risks and without risks of radiological/toxic consequences in case of fire. For example, for the rooms if all the criteria below are met:

- Negligible or low fire load density [23],
- Absence of SIC, radioactive/toxic inventory, material/substances with high fire kinetics (e.g. flammable liquid, gases, etc.), local concentration of hight fire loads,
- No risks of pool fires, explosions (due to availability of combustible liquids, gases, etc.),
- No risks for firefighters intervention,
- No additional requirements of non-nuclear French regulations (Labor Code) and standards for the installation of firefighting systems.

7.5 In nuclear buildings and/or buildings containing SIC, the fire detection systems remain operational during and following SL-2 earthquake [PR6112]. Based on the results of Fire Hazard Analysis the requirements for SL-3 can be applied in some cases, for example for rooms with ITER Hard Core Components.
7.6 The fire detection systems operate during all operation modes of ITER Facility.
7.7 In the event of a fire, the following actions could be initiated by fire detection:

- Fire alarm is activated to ensure fast evacuation of personnel. (Personnel providing control of safety functions moves to ITER Emergency Control Room (ECR, in B71S) in case of fire in ITER Main Control Room (MCR, in B71N). The necessary measures are implemented in MCR to provide safety of personnel for evacuation period. Vehicles delivering items (entering, loading, or unloading) leave the building quickly). This detection and alarm function will be provided by fire detectors and fire notification appliances
- The HVAC supply and extraction to the burning fire sector is isolated [PR2274], except for operation of smoke removal system or in case of ventilation management for pressure mitigation,
- The DS in the burning fire sector is isolated (in line with confinement and HVAC strategies for the specific building),
- Smoke protection systems (smoke extract or/and air overpressure) are activated (where such systems are installed),
- Automatic fixed firefighting systems are activated. (The delay in the activation of automatic fire extinguishing systems is provided to ensure the safe evacuation of personnel, if it is necessary). Manual firefighting systems are activated by personnel based on needs.

7.8 Suitable audible and visual alarms are provided within each area equipped with potentially dangerous automatic firefighting systems (for example, carbon or nitrogen). In addition, adequate written procedures are provided to ensure the safety of personnel entering such areas.
7.9 The detection and alarm systems are operations at all times. These systems are capable of being energized by the non-interruptible emergency power supplies, so that in the event of loss of normal power, they still provide early warning of a fire.
7.10 Where the extinguishing agent is detrimental to the ITER Facility, its systems and components in case of spurious activation, the fixed automatic firefighting system is activated by two means of detection (two different technologies or special certified detectors). The fire detection systems initiate the transition to a safe state by taking actions on the ventilation system (HVAC), for example, fire detectors will trigger the closure of the air supply or extraction.

7.11 Fire detection and alarm systems are designed to comply with French regulations and recognized international standards such as for example, EN, ISO and IAEA standards.
7.12 Safety classification of fire detection and alarm systems are based on the principles identified in the classification document [6]. This classification will be verified by Fire Hazard Analysis.
7.13 Further guidance on fire detection systems is provided in Appendix C.

8 Fire Suppression

8.1 The design and operation of the ITER Facility ensure early suppression of fires by active firefighting systems or passive fire containment techniques.
8.2 Each room of nuclear buildings and/or buildings containing SIC have firefighting systems/equipment (fixed or mobile, automatic or manual) appropriate to the fire risk, the response time of the fire detection system, the potential presence of contamination sources and the need to protect workers (including firefighters) and SIC against the fire and associated secondary hazards (including those resulting from the type of firefighting system used) [PR2273].
8.3 In nuclear buildings and/or buildings containing SIC, the firefighting systems remain operational during and following SL-2 earthquake [PR6113]. Based on the results of Fire Hazard Analysis the requirements for SL-3 can be applied in some cases, for example for rooms with ITER Hard Core Components.
8.4 Firefighting systems are designed and located to ensure that their operation, damage, or spurious or inadvertent actuation does not impair the performance of the required safety functions and lead to unacceptable radioactive/toxic consequences. Potential for errors in operating firefighting systems are considered in the design. Consideration is also given to the effects of operation of firefighting systems in adjacent areas.
8.5 The firefighting systems operate during all operation modes of ITER Facility.
8.6 In the design of firefighting systems, events which could credibly occur simultaneously and independently of a fire are considered. For example, consideration is given to the effects of system maintenance outages, and the single failure criterion.
8.7 The type of firefighting system is adapted to the type of fire identified in the particular room considered. Consideration is given to speed of operation, the type of combustible material present, the possibility of thermal shock, the impact on room pressure, the potential for spread of contamination, the potential for developing and managing waste and the consequences on human beings (e.g. asphyxiation) and on items important to safety.
8.8 Firefighting systems/equipment are not required in the areas with low fire risks and without risk of radiological/toxic consequence. For example, for the rooms if all the criteria below are met:

- Negligible fire load density [23],
- Absence of SIC, radioactive/toxic inventory, material/substances with high fire kinetics (e.g. flammable liquid, gases, etc.), local concentration of hight fire loads,
- No risks of pool fires, explosions,
- No risks for firefighters intervention,
- No any additional requirements of non-nuclear French regulations (Labor Code) and standards for the installation of firefighting systems.

8.9 Mobile manual firefighting equipment (e.g. fire extinguishers) are installed in each area with access and low risk for the manual firefighting in line with relevant requirements of non-nuclear French regulations (Labor Code) and standards.
8.10 Fixed manual firefighting systems (e.g. internal hydrants with fire hose lines or dry risers) are installed in all levels of the building with free access and without risk for the firefighters

intervention in such a way to provide firefighting for each point of rooms, if one of the criteria is met:

- Medium or hight fire load density [23],
- Availability of local concentration of hight fire loads,
- Availability of SIC, radioactive/toxic inventory,
- Risks of pool fires, explosions,
- Relevant requirements of non-nuclear French regulations (Labor Code) and standards.

8.11 Fixed automatic firefighting systems are installed in areas with the risks that safety functions (for safe state) will be lost and limits for radioactive/toxic releases in environment will be exceeded in case of fire and fire associated events if one of the criteria is met:

- firefighting is used as a fire zone (fire cell) in line with item 5.4 (for example, for the cooling of the SIC),
- firefighting is used to prevent the propagation of fire between fire sectors in case of failures of fire protection component in the wall openings (for example, fire dampers, fire doors, etc.),
- no access for firefighters or high risk for firefighter in case intervention.

Examples of such cases are areas with:

- SSC related to PIE and redundant safety systems (SIC train A, SIC train B) with safety functions for associated PIE which are not physically separated by fire sectorization, distances and passive fire protection,
- Gloveboxes and other SSC with large radioactive/toxic inventory, such as transmission lines with huge radioactive/toxic inventories which are not physically protected by fire sectorization or passive fire protection,
- Hight fire loads (>1200 MJ/m^2) with risk of generalized fire and collapse of load bearing structures,
- Medium fire loads (>400 MJ/m^2) but with explosive substances/materials, hight kinetic combustible substances/materials (e.g. flammable liquid, gases, etc.)or with local concentration of fire loads in the room, etc. with risk of explosion of intensive fire (exceeded standard ISO curve) and collapse of load bearing structures.

8.12 Each SIC-1 electrical enclosure that are located in SIC rooms are equipped with automatic fire detection and firefighting system within its enclosure. When located in the same room than a SIC-1 electrical enclosure, each SIC-2 electrical enclosure are also equipped with an automatic fire detection and suppression system within its enclosure [PR2179].

8.13 Fixed automatic firefighting systems are also installed in the areas in line with relevant requirements of non-nuclear French regulations (Labor Code) and standards.

8.14 Other rooms also can be equipped with fixed automatic firefighting systems based on results of Fire Hazard Analysis.

8.15 Fixed automatic firefighting systems are installed/activated for whole room area or locally depending on the location of fire loads and safety targets.

8.16 Auxiliary measures for firefighting are provided in the form of:

- Access for firefighting is available in case of fire whenever possible or remote fire extinguishing devices will be operable from outside the room,
- Evacuation routes and emergency exits allow safe personnel evacuation,
- Ventilation ensures smoke free evacuation routes providing pressurization in emergency exits, when appropriate,
- Suitable fixed emergency lighting at appropriate locations and portable lighting, as appropriate, is provided for all fire sectors,
- A fixed wired emergency communication system with a reliable power supply is installed at pre-selected stations,

- Alternative communication equipment such as two-way radios is provided in the control room and at selected locations,
- Self-contained breathing apparatus is available for the immediate action fire-fighting team and is positioned at appropriate locations.

8.17 The Fire Protection Water System (FPWS) supplies and distributes water for the purpose of firefighting. It is configured as two independent feeds, so that water can be delivered at any point by at least two independent means.

8.18 Liquid effluents generated by fire extinguishing media are collected to prevent dispersion of radioactive/toxic material by specific drainage systems.

8.19 Gas/Aerosol firefighting systems are used in locations containing control cabinets and other electrical equipment where water may cause electrical short circuits and impair functionality leading to an impairment of the required safety functions or to lead to unacceptable radioactive/toxic consequences.

8.20 The use of fixed total-flooding gas firefighting systems is generally confined to uninhabited spaces. Activation delay is provided for such systems for evacuation (in case of human presence).

8.21 Where fixed automatic firefighting system is selected, provisions are made for manual initiation and shutoff

8.22 Firefighting systems are designed to comply with French regulations and recognized international standards such as for example, EN, ISO and IAEA standards.

8.23 Safety classification of firefighting systems are based on the principles identified in the classification document [6]. This classification will be verified by Fire Hazard Analysis.

8.24 Detailed provisions for fire suppression is specified in the Appendix D.

9 Fire Mitigation

9.1 The mitigation measures associated with the risk of internal fire and intended to protect SIC and prevent or limit fire propagation include:

- The overall fire loading in a building complies with the required fire resistance of that building in order to prevent its collapse in case of fire [PR6111],
- Measures taken in terms of layout and fire sectorization [PR1396, PR1390, PR1396, PR2062] are intended to prevent the spread of fire and fire effects from one fire sector to another or from outside to:
  - Keep an internal fire (within the volume) from spreading outside (or to keep an external fire from spreading inside) for a duration that is sufficient to extinguish the fire,
  - Prevent common mode of failure that could jeopardize the required safety functions, and/or to protect workers and investments,
  - Segregate fire loads and/or inventories/equipment at risk, for extinguishing the fire within the required response time, etc.,
  - Mitigate the risks that a fire occurring in such sectors could lead to radioactive/toxic releases with unacceptable consequences to workers, the Public and/or the Environment.
- Redundant equipment of SIC systems and components are segregated and installed in different fire sectors in line with [PR6115, PR2052, PR2367, PR2058]:
  - When a SIC component is required to perform a safety function during/after a fire occurring within its fire sector, provisions are implemented (as needed) to ensure that the SIC component can perform its credited safety function,
  - For SIC systems that have redundant SIC trains, the redundant SIC components are located in independent and separate fire sectors. However, this

independence/separation may not be possible in some cases, and when it is required to locate both redundant SIC components in the same fire sector, at least one of these components are protected against fire in order to maintain its required functionality,
    - For the SIC auxiliary systems that have redundant SIC trains (including power supply, I&C, fluid & gas), the redundant SIC trains providing the same safety function are routed through independent and separate fire sectors. However, this independence/separation may not be possible in some cases, and when redundant trains are required to go through the same route, the intrusive train are protected against fire to maintain its required functionality,
    - In any given room containing SIC components of a SIC train, all the SIC components are connected to the same SIC train for their required services (like power supply, I&C, gas & fluid) – for example Train A SIC electrical enclosures only connected to Train A SIC services.
- Maintaining the fire resistance of the sector boundary against postulated fires that may occur on either side of the boundary. The main characteristics in line with [PR1404, PR1405, PR1410] are as follows:
    - Fire sectors prevent fire propagation at least for 2 hours in line with ISO curve, but not less than real duration and temperature conditions of fire (it should be verified by Fire Hazard Analysis),
    - The fire resistance rating of the penetrations sealing through fire sector boundaries (such as fire dampers, fire doors, pipes, ducts, etc., including if any the filling material used to seal the penetration opening) is equivalent to that of the crossed boundary.
- Specific measures (fire detection and firefighting systems, sufficient distance with respect to SIC components, etc.) are implemented in fire sectors where the risk of fire propagation within the sector needs to be reduced,
- Fire sectors requiring fire suppression are equipped as far as possible with fire detection and firefighting systems, and other support systems such as smoke removal, ventilation and drainage (if it is necessary),
- Specific measures are implemented to prevent fire propagation via the vertical shafts.
- Potential sources of fire initiation and fire load are located in separate fire sectors segregated where practical from SIC components and systems.

9.2 The mitigation measures taken to reduce the secondary effects of a fire in a fire sector (e.g. smoke, heat, overpressure, contamination transfer) are as follows:

- Burning fire sectors are isolated by fire dampers, fire valves, etc. upon detection of a fire and necessary measures are taken to enable manual isolation of valves or fire dampers whenever necessary,
- For other rooms HVAC (depending upon location) remain operational during and after a fire (in line with confinement and HVAC strategies for the specific buildings) to ensure smoke extraction and overpressure suppression,
- In case of detection of tritium leaks the DS is activated in all rooms (except the burning fire sector) which are considered as DS sector (in line with confinement and HVAC strategies for the specific buildings).

9.3 The mitigation measures for personnel protection include:

- Early detection and fast alarm in case of fire,
- Providing safe escape routes for personnel with permanent emergency lighting systems installed in emergency exits used for personnel evacuation,

- Staircases are free of combustible materials and other provisions are taken to avoid smoke ingress and facilitate evacuation (for example, self-closers for fire doors and S-requirements in addition to EI, smoke protection systems, etc.).

10 Fire Hazard Analysis

10.1 The aim of the Fire Hazard Analysis is to justify the sufficiency of the protection provisions against fire retained by the operator of a basic nuclear installation (INB). The Fire Hazard Analysis is based on a demonstration proportionated to the stakes as required by the regulations [8, 9].
10.2 The main goal of Fire Hazard Analysis is the V&V that the safety requirements are implemented in the proper way and that safety is provided for all postulated fires and failures.
10.3 Fire Hazard Analysis is performed in line with General Methodology [10] and associated documents [11, 20, 22].
10.4 The following guidelines [12] are also used ass supported instructions to perform Fire Hazard Analysis.
10.5 In case of lack of safety identified by Fire Hazard Analysis the additional measures will be implemented with repetition of Fire Hazard Analysis.
10.6 Fire Hazard Analyses will be updated systematically on all lifecycle stages of ITER Facility, including configuration changes of design, temporary modifications during operational stage, etc.

Appendix A Fire sectors

A.1 Based on [PR1390] the effects of fires that could occur within a building are mitigated by establishing a fire sectorization of the whole building volume, in line with the following guidelines:

- A fire sector is a volume that is composed of a room or group of rooms that are delimited by walls/slabs (including their penetrations sealing) and are designed to keep an internal fire (within the volume) from spreading outside (or to keep an external fire from spreading inside) for a duration that is sufficient to extinguish the fire,
- A building has at least one fire sector covering its entire volume. The subsequent division of this overall fire sector into several fire sectors and their layout depends on the identified fire risks, design choices and Fire Hazard Analysis. This includes (but is not limited to):
  - The need to prevent common mode of failure that could jeopardize the required safety functions,
  - For fire sectors containing mobilizable radioactive/toxic substances, the need to mitigate the risks that a fire occurring in such sectors could lead to radioactive/toxic releases with unacceptable consequences to workers, the Public and/or the Environment
  - The available options for segregating fire loads and/or inventories/equipment at risk, for extinguishing the fire within the required response time, etc.

A.2 The following measures are implemented in the fire sectors of the buildings:

- Radioactive/toxic inventory is controlled by physical means, administrative means, or both in order to limit the radioactive/toxic inventory potentially vulnerable to a fire,
- Fire loading and fire resistance within SIC buildings containing radioactive/toxic materials are implemented and controlled in the building fire sectors, to ensure - in case of fire - that at least one confinement barrier remains intact for any radioactive/toxic inventory [PR1403],
- Openings through fire barriers are filled with components (doors, dampers, etc.) and material guaranteeing the same degree of fire resistance as the rest of the fire barrier, using a process verified by an approved organization,
- Ventilation ducts (or DS pipes) opening into a fire sector are equipped with fire dampers (fire valves). These fire dampers (fire valves) are installed as near as possible to the fire sector boundaries. The parts of ducts (pipes) between the fire damper and the fire sector boundary are protected by a fire-resistant material,
- Ventilation ducts running through a fire sector are protected by a fire-resistant material (if there are not fire dampers in the fire sector boundaries)
- The mobilizable tritium inventory in a fire sector are limited to 70 g, with some exceptions that are individually authorized [PR1146].

A.3 Identification of fire sectors is done in line with [12] and [14].

A.4 Fire sectorization/fire zoning will be verified by Fire hazard Analysis.

Appendix B Control of combustibles and ignition sources

B.1 This Appendix provides the more specific provisions in addition to Section 6 (Fire Prevention).

B.2 The main preventive measures taken with regard to the risk of internal fire are listed below.

B.3 The personnel is informed of fire hazards in the buildings and measures to prevent a fire.

B.4 The quantity of combustible materials stored internally and normally exposed to risks of fire (e.g. oils) is reduced by supplying only the minimum necessary for ongoing operations and by providing an external storage area.
B.5 The quantity of combustible materials in rooms or areas is monitored and measures are taken to limit quantities. This includes (but is not limited to):

- Paints and coatings are avoided in most cases, since they contribute to the fire loading and can absorb the tritium; in cases where wall or floor lining is required, low-flammability products are used,
- Halogen-containing products are prohibited in rooms/areas/volumes deserved by the Detritiation System (DS) as they reduce the efficiency of the DS. This includes (but is not limited to):
    - Electrical insulating materials such as terminal blocks, moulded circuit breakers cable terminations, etc.,
    - Teflon sealants, Teflon lubricants, Teflon based seals and other fluorinated materials,
    - PVC based caps, tubing connectors etc.
- The use of combustible materials in air filters and their frames is minimised,
- As far as is practicable lubricating oil is only used in a fire protected design,
- Preference is given to a low flammable hydraulic fluid,
- Inside buildings, dry indoor transformers are used where appropriate,
- The use of plastics that produce corrosive combustion products is kept as low as reasonably practicable,
- Precautions are taken to prevent insulating materials that have the capability of absorbing oil or other combustible fluids from accumulating flammable or explosive mixtures.

B.6 The from the use and installation of combustible materials in rooms containing SIC components (or adjacent rooms) are minimized, particularly by:

- Separating or increasing the distance between potential fire sources and SIC components or systems,
- Protecting SIC components (diesel generators, cables, electrical panels, etc.) against the effects of a fire, by minimizing fire loads, separation, etc.

B.7 Ignition sources are controlled (metallic equipment grounded, electrical equipment in conformity with legislation, non-spark creating electrical equipment, physical separation between electrical components, protection against external aggressions (lightning, external fire etc)).
B.8 Electrical equipment is turned off after use.
B.9 The design and construction of the facilities is based as far as possible on rules that prevent fires caused by the use or malfunction of equipment (e.g. restriction of fluid pipes in electrical rooms, routing fluid lines below cables, power supply shutdown, arc protection, protection against external hazards, etc.).
B.10 Operations with a risk of fire (e.g. cutting, welding, etc.) require specific permits and associated protection measures, particularly in rooms with confinement systems, SIC and/or radioactive/toxic materials.
B.11 Specific measures are taken for rooms containing flammable liquids or gases (hydrogen, deuterium, tritium, etc.) that can be potentially released into the rooms during a fire or other abnormal events, for example:

- Systems are designed with a high degree of integrity and protected from vibration or other destructive effects to prevent leakage of such materials. Safety devices should be provided for limiting the leakage of combustibles, for example by using flow limiting devices, flow limiting valves and automatically controlled shut-off and isolating valves.

Similarly, drainage facilities are provided for combustible or flammable liquids in case they leak.

- Supply lines are drained or purged with a non-reacting gas (e.g. nitrogen) when not in use or during maintenance phases,
- Priority is given to low-flammability hydraulic fluids, oil lubrication is only used in systems designed with suitable fire protection,
- Tritiated hydrogen is confined in an additional confinement when needed with a non-reacting gas to prevent tritium leakage and air ingress,
- Processes are operated slightly below atmospheric pressure to prevent release and permit detection of failures,
- Rooms containing flammable gases are ventilated,
- Rooms with a risk of tritiated hydrogen leakage are equipped with a tritium detection system. In case of detection of tritium leakage, the process is placed in a safe state, and the DS is activated as necessary,
- Hydrogen supply cylinders (or special containers) and associated distribution manifolds are kept well-ventilated and are stored outside of areas containing SIC components and/or radioactive/toxic materials,
- In the event that additional ventilation is required in these storage areas, the system is designed to maintain the hydrogen concentration below flammable limits in the volume,
- Lithium batteries are not located in the rooms where fires can impact on the SIC components, except the location of single batteries. In case of location of more than one battery, the specific robust fire protection measures are developed to prevent radioactive/toxic releases and impacts on safety functions in case of fire,
- Batteries that can produce hydrogen (which has a higher than safe concentration) are placed in well-ventilated areas to limit the risk of hydrogen accumulation. In case of a risk of exceeding the safe concentration of hydrogen, a hydrogen detection systems connected to the charge shutdown systems (or to other necessary systems) are installed in the rooms. All measures are consistent with ATEX requirements,
- Fire protection measures for battery rooms and storages are implemented in line with [15, 16],
- Process monitoring systems can detect abnormal conditions that could indicate leakage,
- Tritiated hydrogen systems are designed, as far as possible, in such manner that their operation (or potential failure) does not trigger a fire-initiating mechanism.

B.12 The on-site use and storage of combustible materials in areas adjacent to or containing SIC items will be controlled and accounted for and kept to a practicable minimum; combustible materials not required to be immediately available for operational purposes will not be stored close to SIC items.

B.13 Components comprising a significant quantity of combustible materials (transformers, diesel tanks, etc.) are installed away from PIC buildings to prevent risks of fire propagation.

B.14 Inertization of gloveboxes is provided.

B.15 Detection of loss of inertization or detection of oxygen in gloveboxes and in some areas of the Hot Cell Facility (pressure and oxygen concentration sensors) is provided.

B.16 Dry transformers are used whenever possible.

B.17 Removal of electrical enclosures from the rooms with systems containing radioactive/toxic materials. Electrical enclosures are closed by instruction.

Appendix C Fire detection

C.1 This Appendix provides the more specific provisions in addition to Section 7 (Fire Detection).

C.2 In designing fire detection and alarm systems, it is assumed that both these systems and their individual components are sufficiently reliable to perform their intended functions at all times. For fire detection systems, this reliability may be affected by, for example, a reduction in sensitivity of the sensing devices leading to the non-detection or late detection of a fire, or the spurious operation of an alarm system when no smoke or fire hazard exists.

C.3 Detectors are selected based on the nature of products released by the heating up, carbonization or initial bursting into flame of the materials present in the fire sector.

C.4 "Fire alarms" may be activated by personnel present inside the buildings (during operating phases where access to the buildings is permitted), independently of the automatic alarms generated by the fire monitoring system.

C.5 Fire detection system is designed in closed loops.

C.6 The detection and alarm systems are operational at all times. They are capable of being energized by the non-interruptible emergency power supplies, so that in the event of loss of normal power it will still provide early warning of a fire.

C.7 Automatic system connected with fire detection system is provided to protect the filtration system and control the closure of fire dampers.

C.8 Visual and audible alarm signals associated with the fire detection systems are transmitted to the control rooms and are distinct from other alarm signals.

C.9 For the purpose of providing a warning to personnel who may enter or who may be working in an area equipped with potentially hazardous automatic firefighting systems (e.g. carbon dioxide, nitrogen, freon, etc.), suitable audible and visual alarms are provided within, and at each entrance to, the area and there are adequate written procedures to ensure the safety of personnel entering such areas.

C.10 Fire Detection status (fire alarms, technical alarms, faults, activations, monitoring status) is permanently monitored and reported to the Main and Emergency Control Rooms, and the Command Post.

C.11 Fire detectors allow early detection of fires and specific identification of fire outbreaks (addressability of detectors).

C.12 The individual detectors are placed within a fire area such that the flow of air due to ventilation or pressure differences dictated by contamination control will not cause smoke or heat to flow away from the detectors and thus unduly delay actuation of the detector alarm.

C.13 Fire detectors are also placed in such a way as to avoid spurious signals due to air currents generated by the operation of the ventilation system. This should be verified by in-place testing.

C.14 The Selection of fire detection equipment takes into account the environment in which the equipment must function, e.g. radiation fields, humidity, temperature and air flow. Where the environment (e.g. increased radiation level, magnetic field, high temperature, etc.) does not allow detectors to be placed immediately in the area to be protected, alternative methods, such as sampling of the gaseous atmosphere from the protected area for analysis by remote detectors with automatic operation, could be considered.

Appendix D Fire suppression

D.1 This Appendix provides the more specific provisions in addition to Section 8 (Fire Suppression).

D.2 The choice of firefighting systems installed (e.g. fire suppression systems, dry risers, internal fire hydrants with fire hose lines, fire extinguishers, etc.) is based on several criteria, including the following ones:

- Potential impact on SIC components and operators present,
- Fire suppression system activation time,
- Type and quantity (fire loads) of combustible materials present in fire sectors,
- Potential presence of contamination sources (radioactive/toxic materials or substances),
- Possibility of external intervention for manual firefighting.

D.3 Manual and portable firefighting systems are provided in areas accessible to personnel. The location of these systems is clearly indicated, and they are maintained in good operating condition.

D.4 Electrical control and power supply circuits for firefighting systems are fire protected or located outside fire sectors.

D.5 In case of loss of electric power supply of the firefighting systems, a permanent power supply is provided an alarm is transmitted to the control room.

D.6 Generally, water systems are preferred in areas containing a high fire load of electrical cable material and other combustibles where the possibility exists for deep seated fires. Water systems may also be used for large quantities of oil, e.g. lubrication or transformer cooling. The selection of the system for each case depends on the possibility for electrical difficulties and/or spreading of oil fires.

D.7 Depending on fire load concentration and fire kinetic of combustibles water spray or sprinkler systems are used.

D.8 Water automatic firefighting systems are designed according to specific criteria (e.g. quantity, location, activation temperature, water flow, etc.).

D.9 A local water flow alarm is provided on water extinguisher systems to indicate operation capabilities and transmitted to the control room or emergency control station.

D.10 The water firefighting system is designed according to the following criteria:

- The firefighting water network is designed according to reference NFS 62-200 related to fire fighting with 2 independent feeds. Routing is such that leaks will not affect systems important to safety. A pump is associated with each line when gravity is not sufficient,
- The maximum flow required corresponds to the consumption of the water fixed automatic system in the fire sector with the largest water demand (considering type of the system), plus the consumption of the fixed manual firefighting systems (internal and external hydrants),
- The system can deal with extreme climatic conditions defined for ITER Facility,
- Means are be provided for the collection of water in areas where water is used for firefighting,
- Water firefighting systems are continuously connected to an adequate supply of firefighting water. These systems may be actuated automatically or manually depending on various factors including: risk to personnel, need for prompt action, potential for contamination, type of potential contamination, potential damage to equipment, etc.

D.11 Where an automatic firefighting system is selected, provisions are made where practicable for manual initiation if needed (except in the case of fuse bulb type sprinkler systems) and shutoff.

D.12 In the case of water spray systems which are only manually initiated, the systems are designed to withstand fires for a period established to be sufficient to allow time for the manual initiation.
D.13 Dry risers are located to ensure protection of fire sectors. The length of the hose lines/water jet ensures fire extinguishing at every point in the fire sector.
D.14 Dry risers are installed in the staircases, airlocks and on the protected areas in the vicinity on the floor access.
D.15 Gas firefighting systems take the following into account: type of fire, reactions with other materials, effects on equipment, and toxic and corrosive characteristics of decomposition products, potential pressurization in the rooms.
D.16 The use of halon type extinguishing agents is prohibited in areas served by the DS.
D.17 In rooms containing electrical equipment, the local aerosol/gas/powder firefighting systems are used. In case of using the overall gas firefighting systems the following characteristics are considered:

- The quantity of gas to be injected is determined as a function of the leak tightness of the rooms, the necessary concentration (with respect to the fire risk), and the fire suppression time,
- The potential effects on room structures of a pressure increase during gas injection are evaluated and ventilation systems are planned accordingly,
- Personnel protection measures are taken with regard to the access to rooms equipped with gas extinguisher systems (audible and visual alarm, as well as written procedures posted in rooms and entrances).

D.18 For pumps, etc., which contain a large inventory of combustible lubricating oil, a fixed automatic firefighting system is provided (e.g. inert gas purged gloveboxes on tritium plant) and the hydrocarbon based lubricating oil is replaced by a less flammable fluid to reduce the potential for a fire. In all cases, an oil collection system will be provided. A mobile oil collection system is capable of collecting oil from all potential leakage points and safely draining oil to a closed container.
D.19 Access to rooms with potential fire risk is provided for firefighting personnel whenever possible. In case of absence of such access, firefighting systems may be activated automatically or from outside the rooms.
D.20 Local emergency response teams must be available within a very short time and be ready to extinguish or reduce a fire, to contribute to the evacuation of personnel, or to assist the wounded or the specialized fire control teams when they arrival at the scene.
D.21 In case of failure of access control in the event of a fire allowing inadvertent entry (for example of fire-fighters) into dangerous areas, physical measures (such as interlocks, wearing of protective clothing, etc.) and/or administrative measures (warning signs, sound messages, etc.) will be set up to restrict access to these rooms. These measures will fail safe (i.e. locked) on loss of power or signal. Emergency exit from inside the hazardous zones will use mechanical devices such as crash bars that are independent of power, control and other services and are not operable from outside.

Appendix E Fire mitigation in design

E.1 Layout

E.1.1 Layout is affected by the approach to fire mitigation:

- A fire containment approach assumes that all combustibles within a fire sector can be consumed during a fire,

- In a fire influence approach, redundant elements of SIC systems are not necessarily separated by fire barriers, but the effect of a fire is limited by a combination of distance to other items important to safety, protection features such as an active extinguishing system (e.g. water sprinkler) or passive features such as structural elements (e.g. fire stops, fireproof coatings, etc.). Such measures are called fire zones.

E.1.2 Each approach has certain advantages and disadvantages. The ITER Facility facilities may contain areas that use the fire containment approach and other areas within which the fire influence approach is employed. The approach that is most suited for a particular location is determined on an area by area basis.

E.1.3 The approach to be taken within the ITER Facility facilities is not a matter of choice on the merits of fire protection alone. The fire containment approach may not easily be applied in some areas because of the need to locate redundant safety trains in the same fire sector. Consequently, the fire influence approach is used in these locations.

E.1.4 Where the fire containment approach is applicable, the design considers the balance with fire protection needs against other safety concerns. The use of structures to form fire barriers does not interfere unduly with maintenance and in-service inspection needs. For example, the design of the ITER Facility provides that fire barriers between closely spaced equipment does not block access doors to electrical panels or prevent removal of mechanical devices for maintenance purposes or impede adequate ventilation to vital components. Enclosing high pressure components in fire barriers may also influence missile impact problems.

E.1.5 In general, the fire containment approach is preferred since it emphasises passive protection and thus the protection of SIC systems does not depend on the operation of fixed firefighting systems.

E.2 Ventilation systems

E.2.1 Ventilation systems are designed to prevent the spread of fire and smoke between sectors. The capability to isolate portions of the ventilation system, for example via fire dampers are provided where necessary to prevent the spread of fire. Fire dampers have the same fire resistance rating as the sectors they are isolating. Portions of ventilation systems (e.g. connecting ducts, fan rooms, filters) situated outside the fire sector have the same fire resistance as the sector unless they can be isolated by fire dampers, in which case they may not require fire resistance.

E.2.2 High Efficiency Particulate Air (HEPA) filters at fire sector boundaries shall be fire-resistant (minimum efficiency of 99.9% during a fire) [PR1412].

E.2.3 Change of temperatures and pressures within the ventilation system and the affected fire sector due to temperature rise, smoke production or equipment failure caused by the fire-are also taken into account.

E.2.4 Wherever possible, non-combustible or fire resistant filters are used in any application where radioactive/toxic materials release is being controlled. Where combustible filters are used in ventilation systems whose subsequent malfunction or failure could result in unacceptable releases of radioactive/toxic substances, the following measures are implemented:

- The filter banks are separated from other equipment by adequate fire barriers,
- Appropriate methods are used to protect the filters from the effects of fire,
- Fire detectors are installed inside the ducts before and after the filter bank.

E.2.5 The fresh air supply and extraction to fire sectors shall be located away from the exhaust air outlets and smoke vents of other fire sectors to the extent necessary to prevent intake of smoke or combustion products and malfunctions of items important to safety which could lead to unacceptable releases of radioactive/toxic substances.

E.2.6 Staircases which serve as access and escape routes are kept free of all combustibles, and the overpressure ventilation relative to adjacent areas is provided in order to keep the staircase free of smoke. It is advisable to make provision for smoke removal from corridors and rooms leading to staircases. For high multi-storey staircases consideration are given to subdividing the staircase.

E.3 Electrical systems

E.3.1 Electrical portions of systems important for safety (SIC), as far as is reasonably achievable, are designed to neither cause nor support a fire. Equipment such as cable circuits, switchgear and diesel generators associated with SIC systems important for safety are protected against the consequences of fire such that safety functions are maintained. Cable insulation and jacketing materials when present in significant quantities are fire retardant and of low smoke, low fume and low corrosion construction. Use of halogenated materials are avoided in tritium areas.

E.3.2 Cables are laid on trays of steel, steel conduits or other structurally acceptable and non-combustible cable supports. The distance between power cables on the trays are sufficient to prevent an unacceptable influence between cables due to heat generated in them. The electrical protection system are designed so that the cables will not overheat under normal load and transient short circuit conditions.

E.3.3 Cabling associated with a train of redundant SIC systems runs in individual specifically protected routes (the most preferable locations are in the different fire sectors) and no cables crossing between redundant trains of systems. Exceptions to these recommendations may be necessary in certain locations such as control rooms, cable spreading rooms and process building rooms. In this case the cables are separated by appropriate means (fire zones). Such exceptions are minimised.

E.3.4 Electric cables that run through a fire sector boundary are not contribute to the spread of fire by design and/or protection with a flame-retardant material, in order to comply with one of the equivalent standards listed below [PR1407]:

- IEC 60332-3 and IEC 60332-1,
- NF C320-70 C1,
- For cables in SIC buildings: Euroclass with minimum class Cca-1sb-d1a1 according to EN50757,
- For cables in non-SIC buildings: Euroclass with minimum class Cca-1sb-d2-a2 according to EN50757.

E.3.5 Electric cables, that run through a fire sector, and that are required to operate in the event of fire, are fire-resistant, by design and/or protection with a fire resistant material, in order to comply with the NF C 32-070 (that is, CR1 Class) or IEC 60331 [PR1408].

E.3.6 In all buildings containing SIC and/or radioactive/toxic substances, all cable trays have a metallic cover to minimize the risk of fire propagation. In addition, if necessary, a 2-hour fire protection envelope implemented on cable trays depending on the level of risk, in case of fire [PR2379].

E.3.7 Large oil filled transformers are not situated where their burning could cause undue hazards. They are preferably located in separate buildings or external compounds situated away from buildings containing SIC equipment.

E.3.8 The following additional recommendations are considered:

- Areas containing heavy fire loads from electrical cables are separated from other equipment by fire barriers or even contained in a separate fire sector,
- Switch gears are separated from other equipment by fire barriers or contained in a fire sector,
- The use of combustible material in all switches, circuit breakers and control and instrumentation enclosures is kept to a reasonably acceptable minimum.

E.3.9 The main SIC electrical enclosures for centralized control/power supply of SIC components are located in dedicated SIC rooms, which don't include any non-SIC electrical enclosures [PR2053].
E.3.10 Considering the dangerous of lithium batteries fires, to provide low fire propagation and effective firefighting in the battery rooms and storages the following fire protection measures are defined (for each specific case):

- maximum quantities of batteries per battery group,
- minimum safe distances (between battery groups, as well as between batteries and fire walls/slabs,
- maximum storage heights,
- specifics of fire protection systems.

E.4 Special location requirements

E.4.1 Emergency control building in some cases contains equipment of different SIC systems in close proximity. Consequently, in such cases all structural material used for the electrical cabinets, and any fire stops within them are non-combustible. Redundant equipment used to perform the same safety function are housed in separate electrical cabinets with sufficient distance between cabinets. If, however, this is not possible, fire stops of non-combustible material are used for separation. Every effort are made to keep the fire load in the building as low as reasonably practicable at all times.
E.4.2 Emergency control room is placed in another building (fire sector) than building with main control room. Sufficient physical separation between these two building is provided. There are no common ventilation systems or any fire/smoke propagation routes between these two building.
E.4.3 The area immediately surrounding the tokamak is a fire sector in which generally the equipment of more than one redundant SIC system is located. Consequently, all structural material within this fire sector and any fire stops or fire barriers between redundant SIC equipment shall prevent damage for both of redundant SIC system.
E.4.4 For pumps, which contain a large inventory of combustible lubricating oil, a fixed automatic firefighting system are provided. As an alternative to an extinguishing system, the hydrocarbon based lubricating oil should be replaced by a less flammable fluid to reduce the potential for a significant fire, or an oil collection system may be provided. The oil collection system is capable of collecting oil from all potential leakage points and safely draining oil to a closed container.
E.4.5 Filter banks containing high fire loads from charcoal are taken into consideration in determining fire protection requirements. A fire in a filter bank can cause severe consequences owing to the presence of radioactive/toxic materials. Passive and active measures can be provided to limit the effects of fires in a filter bank: for example, the filter may be contained within a fire sector fitted with a fixed water sprinkler system, or monitoring of temperature rise in the connecting ducts could be provided to enable the timely isolation of the filter banks and the diversion of the air flow to a reserve filter. If necessary, manual fire-fighting techniques can then be activated.

E.5 Fires of external origin

E.5.1 The ITER Facility is designed, and appropriate measures taken, to minimize the risk of external fire around buildings and the ITER Site, and if such an event were to occur, to prevent its propagation inside the SIC buildings [PR2035].

E.5.2 The design of ITER Facility prevents smoke or heat from fires of external origin from impairing the accomplishment of necessary safety functions. For example, the ventilation system are designed to prevent such smoke and heat from affecting redundant elements of systems important for safety (SIC) so as to cause a loss of a necessary safety function. This can be accomplished by isolation of the ventilation systems from outside air by dampers, with reliance on alternative systems to accomplish the ventilation system functions. It can also be accomplished by separating the inlet and exhaust hoods of one ventilation system serving one SIC system from the inlet and exhaust hoods serving other redundant SIC systems. For example, emergency diesels require normal air for combustion. Therefore, the ITER Facility ensures the adequate supply of normal air to that number of diesels required to perform necessary safety functions. In these ways a fire of external origin will not prevent the accomplishment of a necessary safety function.

E.5.3 Where the ITER Facility site requires consideration of the effects of aircraft crashes at or near the site, a fire hazards analysis of this accident will be made [PR2036, PR2037]. This analysis will consider that fires may occur at several locations because of the spread of the aircraft's fuel and may lead to the failure of fire sector boundaries as a result of missile impact. Smoke may also be produced at several locations. Special equipment such as foam generators and entrenching tools, as well as specially trained on-site and off-site fire-fighting personnel could be required to prevent such fires from penetrating structures containing SIC items.

E.6 Secondary effects of fires and firefighting

E.6.1 The secondary effects of fires and of firefighting systems are considered. Design of ITER Facility ensures that these secondary effects will not have an adverse impact on safety. Examples of secondary effects are as follows:

- Thermal effects as a result of thermal expansion of air,
- Transfer of radioactive/toxic material due to water spray which may lead to the contamination of other areas and drain systems,
- Unavailability of a firefighting system subsequent to its discharge (genuine or spurious),
- Actuation of a second fire protection system due to the actuation of the first one, with subsequent significant deleterious effects and unavailability of fire protection,
- Deleterious effects from heat, smoke, steam from evaporating water spray, flooding by fire materials, and corrosives on equipment and structures,
- The presence of corrosive products of combustion from the burning of electric cable insulation. These products may be transported into areas remote from the original fire, where, in the presence of atmospheric moisture, they can cause general corrosion of equipment and structures or electrical failures many hours or days following the initial fire incident,
- The release of halogenated products of combustion, which are detrimental to the DS,
- Dry chemical extinguishing agents causing failures of electrical switching devices as a result of insulation or corrosion of contacts,
- Sudden temperature drop or pressure impact due to carbon dioxide extinguishing system discharge causing malfunction of sensitive electronic equipment,
- Water intrusion into electrical systems causing failures due to short circuits or earth circuits,
- Electrical breaks, short circuits, earth circuits, arcing and additional energy input due to failure of equipment and piping,
- Mechanical damage due to deformation and collapse of structures, possibly aggravated by (secondary) explosions which can cause the generation of missiles, additional loading

on items important to safety, release of high temperature fluids, and blockage of access and escape routes,

- Deleterious effects on operating personnel from heat, smoke, fire extinguishing materials and toxic gases originating from insulating materials.

E.6.2 Specific provision will be taken to avoid forest fire around the facility (clearing around INB perimeter).

Appendix D Bibliography

The following documents are listed for information only. Design decisions may be based on these or other sound engineering practice and judgement.

[D.1] Safety of Nuclear Power Plants: Design: IAEA Specific Safety Requirements No. SSR-2/1 (Rev. 1), – IAEA, Vienna, 2016.
[D.2] Safety of Nuclear Power Plants: Commissioning and Operation: IAEA Specific Safety Requirements No. SSR-2/2 (Rev. 1), – IAEA, Vienna, 2016.
[D.3] Protection against Internal Hazards in the Design of Nuclear Power Plants: IAEA Safety Standards No. SSG-64, – IAEA, Vienna, 2021.
[D.4] Protection Against Internal and External Hazards in the Operation of Nuclear Power Plants: IAEA Safety Standards No. SSG-77, – IAEA, Vienna, 2022.
[D.5] Safety Classification of Structures, Systems and Components in Nuclear Power Plants: IAEA Safety Standards Series, No. SSG-30, – IAEA, Vienna (2014).
[D.6] Preparation of Fire Hazard Analyses for Nuclear Power Plants. Safety Reports Series No 8 IAEA, Vienna, 1998.
[D.7] ASSEMBLEE PLENIERE DES SOCIETES D'ASSURANCES CONTRE L'INCENDIE ET LES RISQUES DIVERS, 'Recueil des regles et documents techniques relatifs a l'incendie.
[D.8] Appendix C – Applicable regulation, standards and project documentation and requirements of the TF-F - Fire Protection Design Plan (B7RKEW)