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MQP Level 3

Instructions for ITER System Load Specifications

This document provides requirements and recommendations for the preparation of load specifications to be used in the design of ITER System Structures and Components (SSCs).

Approval Process			
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Change Log			
Instructions for ITER System Load Specifications (33TTPJ)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	15 Dec 2009	
v1.1	Signed	23 Dec 2009	Scope of each reviewer was specified in chapter 1.1. Some editorial changes, some changes in the relaxed requirements for conceptual or preliminary design review.
v1.2	Signed	12 Feb 2010	Comments of Reynard and Taylor are considered in this version. Other editorial changes.
v1.3	Approved	01 Apr 2010	Relaxed Requirements for quality class > 1 were added. Relaxed Requirements for preliminary and conceptual design review were modified. Other small changes.
v2.0	Disapproved	22 Nov 2012	· The chapters are reordered. · Some phrases are reworded. · The chapter Introduction is replaced by the chapters 1 Purpose of this Guideline · In the chapter 2, request for a system to be exempted from writing a SLS is added. · In the chapter 3, the following reviewers are added: T Schioler, V. Rozov, JJ. Cordier, C. Alejaldre, M. Kondoh. · In chapter 4, some abbreviations are added. · In the chapter 5, references [6],[8],[14],[15],[16] are added in replacement of obsolete references. · In the chapter 8.1, the generic template is updated. · In the chapter 8.2, the reference [14] is added. · In the chapter 8.3, the list of reviewers and the approver are updated. · In the chapter 8.4, list the components SIC or SR and list the design codes are added. Figure 8.1 is updated. · In the chapter 8.4, the figure 8-2 is updated. · In the chapter 8.6, the text is updated. · Chapter abstract and load reference document is replaced by chapters 9.1 and 9.4 · In the chapter 9.2, the scope of SLS is better defined and the type of design review is added. · In the chapter 9.8, the references regarding French regulation are updated. · In the chapter 9.9.2, the figure 9-1 is modified (toroidal direction). · In the chapter 9.9.3, SL-1, SL-2, SMHV are added. · In the chapter 9.10, specific loads are added. · In the chapter 9.13.3, the DIN reviewing is added · In the chapter 9.15.2.5 the text is updated, SMHV is added. · The chapter 9.15.5 is added.
v2.1	In Work	19 Mar 2013	The comments from the previous version are taken into account.
v2.2	Signed	12 Apr 2013	Modification of the chapter 3 : scope of the reviewers of this guideline
v2.3	Signed	29 May 2013	Comments from reviewers taken into account.
v2.4	Signed	31 May 2013	Comment from reviewer taken into account in chapter 9.5
v2.5	Approved	03 Jun 2013	Chapter 9.9.2 Coordinate systems: The direction of the poloidal arrow is changed on the figure 9-1, and the definition of the Tokamak Global Coordinate System is improved.
v3.0	In Work	10 Mar 2021	As per approved MQP doc request 2PW8CK the changes are: Major update of the content to reflect the current baseline and organization scheme. Extended applicability of requirements.

v3.1	Approved	11 Mar 2021	Technical change to correct conversion error. Also the changes forgotten to specify in the rev. 3.0: - Document moved in MQP - The title changed to «Instructions for ITER System Load Specifications» (guidelines before)
v3.2	Approved	12 Apr 2021	Under same MQP doc request https://user.iter.org/default.aspx?uid=2PW8CK this version is to integrate the comments from F4E as following: - Made minor corrections to definitions. - Added acronyms for IEA and EPNS that were missing. - Aligned the definition of Approver to the design review procedure. - Made the definitions of roles self-consistent and removed the reference to the Sign-off Authority. The SoA will be updated to point directly to these instructions. - Added "Assessment of operation conditions…" to the list of sub-tasks in §5.1. - Added units for Particle flux. - Minor correction in the list of Types of Loads under §LS 8. - Clarified applicability of [SLS155-R] in §LS 13.3. - Specified dose units under [SLS161-R] in §LS 13.3.2.
v3.3	Approved	27 Nov 2024	As per communication CS9VQR and tracked changes version the changes are: - Reorg change: Safety Responsible Officer replaced the role of EPNS representative - Reorg change: The roles of SMDA and EVDA removed - Reorg change: RSG member removed - Design Coordinator replaced the role of System RO - Representative of System replaced the role of member of Section/Division - SIRO role introduced - Chapter Records developed - Some minor corrections

Table of Contents

1 Purpose

This document provides requirements and recommendations for the preparation of load specifications to be used in the design of ITER System Structures and Components (SSCs). According to [1] a system load specification is the basis of the Structural Integrity Report presented during the Design Review of a system.

These instructions provide:

- The general requirements for the preparation of a system load specification.
- The template with a table of contents and sample text of a system load specification.
- The required content of each paragraph.

[SLS001-R] The requirements given in this document are for a Load Specification to be used in a final design review. If a Load Specifications is prepared for conceptual or preliminary design reviews, some requirements are relaxed as stated in §5.2.

2 Scope

[SLS003-R] This document applies to the ITER Organization (IO) involved in the preparation of Load Specifications for ITER SSCs. It also applies to Domestic Agencies (DA) or external contractors who are asked to prepare Load Specifications for the ITER project, see [1]. The rules governing the propagation of the requirements specified in these Instructions to external contractors or interveners are specified in [9], and shall be followed.

These instructions cover the activities associated with planning, preparing, issuing, and revising Load Specifications.

[SLS004-R] These instructions apply to the development of Load Specifications of ITER SSCs of Quality Class (QC) 1 and 2. The instructions are not mandatory for QC3 SSCs.

These instructions do not cover spot-checking or surveillance activities on Protection Important Activities (PIAs). Requirements for these activities are specified in [1].

This document is generated from [1].

Some of the recommendation provided by these Instructions might need to be adapted to some SSCs based on their specificity.

3 Definitions and Acronyms

3.1 Definitions

Term	Definition
System	The system for which this load specification is written.
Component	A part of the system for which this load specification is written.
Part	A part of a component.
Load combination	Superposition of single loads.
Single load	Comprises all loads acting on the system that have the same origin or cause, e.g. all dead weight loads act due to gravity.
Design driving load	It is the most severe loading condition related to one or more failure modes. As a consequence, the structural elements that prevent this or these failure modes will be designed primarily against this load.
Damage	It means that a part has separated into two or more pieces; has become permanently distorted, thus ruining its geometry; has had its reliability downgraded; or has had its function compromised, whatever the reason. Examples of damages are excessive deformation, plastic instability, progressive deformation, cracking, fatigue, fast-fracture, etc. Please note that some standards use the expressions failure or failure mode instead of damage. In the context of this document, all of these terms are considered as having the same meaning.

Table 1 – Definitions.

3.2 Abbreviations

The list of abbreviations used in this document is given in Table 2. For a complete list of ITER abbreviations see ITER_D_2MU6W5 - ITER Abbreviations.

AAR	Accident Analysis Report
CDR	Conceptual Design review
DA	Domestic Agency
DDD	Design Description Document, see list in IDM
EM	Electromagnetic
FDR	Final Design review
ICD	Interface Control Document
IEA	Integrated Engineering Analyses Section
IS	Interface Sheet
PBS	Plant Breakdown Structure
PDR	Preliminary Design review
PIC	Protection Important Component
PR	Project Requirements
PSD	Power Spectral Density
RO	Responsible Officer
SIRO	System Integration Responsible Officer
SLS	System Load Specification
SSC	System, Structure, Component
SRD	System Requirement Document

Table 2 – Abbreviations.

4 References

[1] Procedure for Analyses and Calculations (ITER_D_22MAL7)
[2] Template for ITER System Load Specifications (ITER_D_2PW74P v1.4)
[3] Load Specifications (LS) (ITER_D_222QGL)
[4] Accident Analysis Report, ITER_D_2ZTMLF
[5] Codes and Standards for ITER Mechanical Components (ITER_D_25EW4K)
[6] Project Requirements (PR) (ITER_D_27ZRW8)
[7] Design Review Procedure (ITER_D_2832CF)
[8] Quality Classification Determination (ITER_D_24VQES)
[9] Safety Important Functions and Components Classification Criteria and Methodology (ITER_D_347SF3)
[10] ITER Seismic Nuclear Safety Approach (ITER_D_2DRVPE)
[11] DIRECTIVE 2014/68/EU of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment - EN (ITER_D_RZ6PAK)
[12] Arrêté du 20 novembre 2017 relatif au suivi en service des équipements sous pression et des récipients à pression simples - EN (ITER_D_W2C32X)
[13] Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN (ITER_D_7M2YKF)
[14] Arrêté du 30 décembre 2015 relatif aux équipements sous pression nucléaires - ([TRANSLATION]-[EN]) (ITER_D_SMP384)
[15] ASN Guide #19 - Application of the French Order dated 12/12/2005 on Nuclear Pressure Equipment - Version of 21-02-2013 - EN (ITER_D_FXQ9NZ)
[16] IO Generic Template (ITER_D_34BAZX)
[17] Instructions for Structural Analyses (ITER_D_35BVV3)
[18] Instructions for Seismic Analyses (ITER_D_VT29D6)
[19] Instructions for EM Analyses (ITER_D_TSZ9KQ)
[20] Instructions for Computational Fluid Dynamics Analyses (ITER_D_VUEEDB)
[21] Instructions for Nuclear Analyses (ITER_D_R7XRXB)
[22] Instructions for the Storage of Analysis Models (ITER_D_U34WF3)
[23] Procedure for ITER CAD Data Exchanges (ITER_D_2NCULZ)
[24] Assignment of the System Integration Responsible Officers (SIROs) (ITER_D_8E6WQ9)
[25] Design Development Procedure (ITER_D_U34DDZ)

5 General Principles

5.1 Planning and Preparing

The task of writing a system load specification can be split into the following sub-tasks:

1) List the components which are Protection Important Components (PIC) or safety relevant classified.
2) List the design codes and standards selected for each component (RCC-MR, ASME…) and justification of adequacy of the selected code for SIC components.
3) Assessment of available data, i.e. collection of existing reference documents that contain load assessments, e.g. electromagnetic (EM) analysis reports, structural analysis reports with load and mass assumptions, presentations, design description document(s), etc. The scope of this assessment should be to identify which existing reference documents are out of date, incomplete or missing. The outcome should be the arrangement of the preparation of all required reference documents.
4) Assessment of all the operating conditions (nominal, off-set, faults, etc.) of the SSCs during their lifetime (§LS 12).
5) List of damages. With the help of the system RO and the individual responsible for the structural integrity report, identify all damages of the system. The scope of this discussion should be the identification of the design driving loads and their structural consequences.
6) General organization, i.e. definition of the scope, identification of reviewers, draft structure of topics of contents, discussion of planned schedule with RO.
7) System Description, preliminary preparation of §LS 11
8) Specification of Load, preparation of §LS 13 and §LS 14.
9) Completion of System Load Specification
10) Review
11) Approval

Depending on the complexity of the system load specification and the allocated resources the preparation time of the system load specification varies. See below a typical schedule and note that the duration of the review usually is substantial.

Note: The preparation of the required load assessment reports represents a high risk of delay for the design of the system. The same reports are also critical for the preparation of interface loads, and therefore impact the schedule of surrounding systems as well. Their preparation should therefore be started early, and followed attentively.

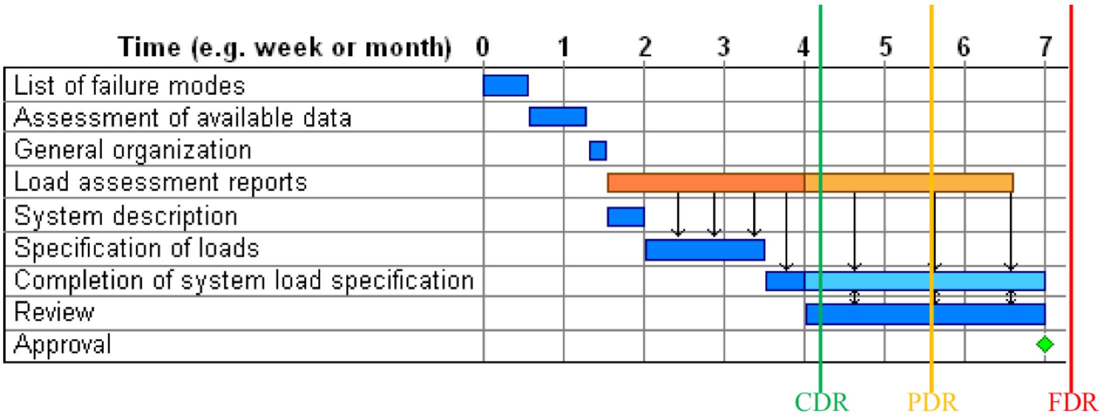

Figure 1 – Typical schedule for preparation of a system load specification

A close collaboration between the Author and all contact persons and in particular with the reviewers of the load specification is essential:

- Interface loads should be agreed with the related reviewers before submitting the load specification for review. This helps to prevent the need for time-consuming revisions.
- The author of a SLS may request the support of IEA for the preparation of a SLS.

5.2 Relaxed requirements

This appendix relaxes some requirements depending on the design maturity of the SSCs. All relaxed requirements given for the preliminary design review also apply for the conceptual design review.

5.2.1 Preliminary Design Reviews

The number of occurrence does not need to be given for loads that are not design driving.

The load category does not need to be given for loads that are not design driving.

Loads that are not design driving are not required to be specified. Neither is it required to specify an envelope load for such loads as described in §LS 13.6.

Interface loads that are not design driving to the interfacing systems do not need to be specified.

[SLS053-R] The assessment of the masses and of the centre of gravity (§LS 13.1.1) can be simplified by not considering details in the design such as bolts, nuts, fillets, and other relatively light parts of the system. Such simplification in the assessment shall be stated. In this case a mass uncertainty factor shall be specified, which can be used to scale the specified masses. It is important to be aware that many structural assessments made for the preliminary design review of a system would require revision for the final design review in case the masses change.

5.2.2 Conceptual Design Reviews

[SLS054-R] References are not required for loads which are not defined in the baseline. In other words, if baseline loads exist, they shall be used as input to the SLS. If such loads do not exist, it is acceptable at the CDR level to define the loads without providing references.

States of the system and components during which no design driving loads occur, do not need to be described.

Single loads and load combinations that are not design driving for the design concept of the system and its components are not required to be specified.

The number of occurrence for loads that clearly do not contribute significantly to fatigue damage are not required to be given.

Types of Loads are not required to be described (§LS 8).

The Path of the Main Loads is not required to be described (§LS 9).

Description of System, Components, Parts is not required (§LS 11.2.1).

Interfaces that have no influence on the design concept of each interfacing systems and its components do not need to be described (§LS 11.2.4) and the associated Interfaces Loads (§LS 13.5) do not need to be specified.

[SLS062-R] The assessment of the masses and of the centre of gravity (§LS 13.1.1) can be rough and based on appropriate hand calculations. The mass assessment shall nonetheless be documented and a mass uncertainty factor shall be specified to multiply or divide the specified masses.

5.3 QA for System Load Specifications

[SLS008-R] The system load specification propagates information from higher-level load specifications, mainly [3]. All information given in the system load specification shall be consistent with all higher-level load specifications.

[SLS009-R] A *Revision* chapter shall exist in the system load specification at the beginning of the document. In each revision of the load specification all changes made since the previous version shall be listed strictly and precisely. If the IO IDM in-built feature is used, the changes will be logged directly in IDM and this paragraph is generated automatically.

[SLS011-R] For each value specified in the load specification, either a reference shall be given or a comprehensive derivation of this value must be shown in the system load specification.

[SLS012-R] All referenced analysis reports that are used to define loads in the load specification shall be prepared following [1] and the relevant instructions [[17]-[22]].

6 Workflow

The workflow for the processes related to the preparation of a load specification is shown in Figure 2.

The diagram shown in Figure 3 identifies only the role of the author of the load specification and focuses more on the preparation of the content and the global inputs required. This approach is retained as it is more useful and practical for the purpose of this document.

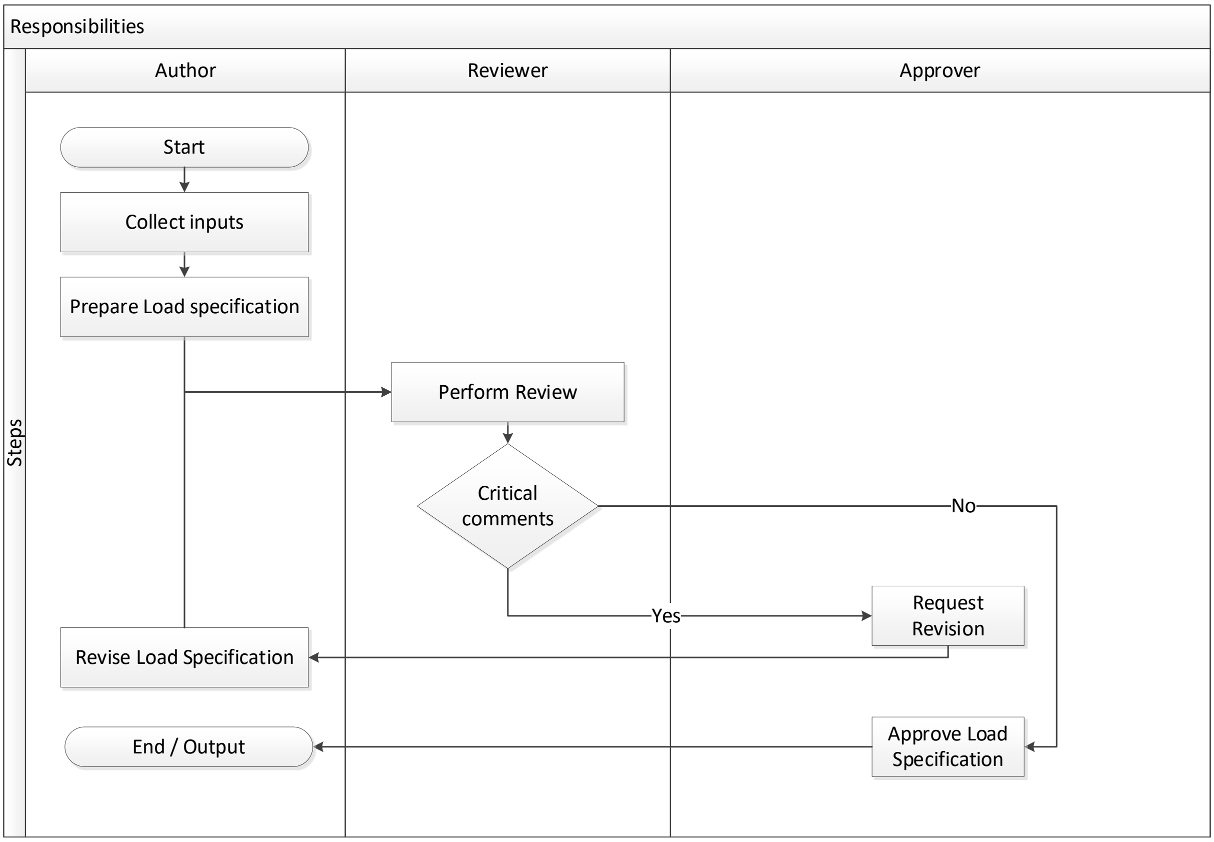

Figure 2 – Workflow of the preparation of a load specification.

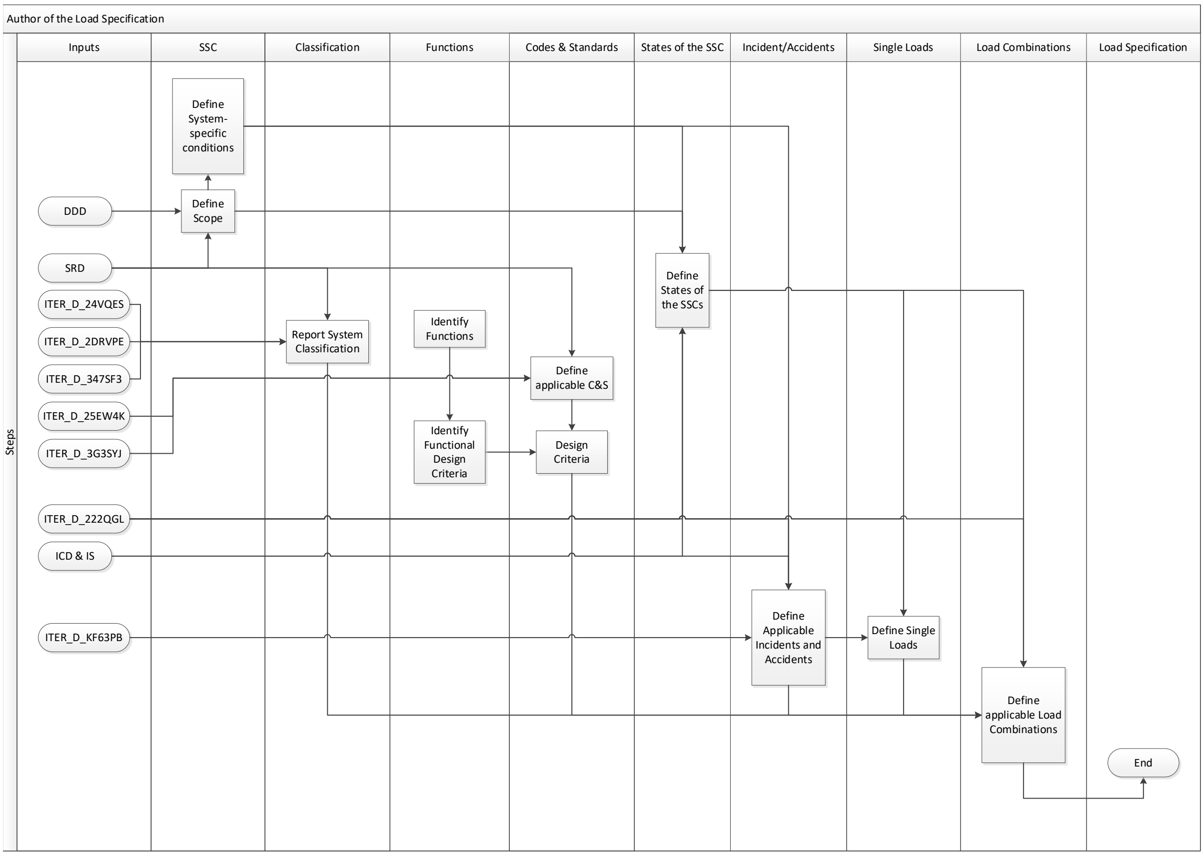

Figure 3 – Global input and information flow in a Load Specification.

7 Responsibilities

7.1 Author

[SLS015-R] The Author(s) have the role of preparing the load specification. The author(s) of the system load specification document shall be selected by the person who has the responsibility of the completion of the design, with the approval of the person having the authority to approve the final design of the system (see §7.3).

7.2 Reviewers

[SLS019-R] The Reviewers have the role of reviewing the load specification, checking for mistakes and compliance with higher level requirements.

[SLS018-R] The list of reviewers shall, at least, include:

- The Design Coordinator, see [25] for details.
- One representative of each system with an interface to this component. Note that this shall include the assembly team when applicable.
- One member of the Science Division if needed, as agreed with the Head of the Science Division.
- One member of the Quality Assurance Division, as agreed with the Head of the Quality Assurance Division, to ensure that the Quality Assurance requirements are met.
- One reviewer assigned by the IEA Section Leader, for general review and compliance with these Instructions. If required, IEA shall assign additional reviewers to cover specific disciplines like electromagnetics, seismic and neutronics loads.
- One reviewer assigned by the Design Integration Section (DIS), as agreed with the head of DIS.
- The System Integration Responsible Officer (SIRO). Note that the list of SIROs can be found in [24].
- The Safety Responsible Officer of the SSC, to control the implementation of safety requirements. If no safety requirements apply to the SSCs covered by the SLS, the Safety Responsible Officer review is limited to confirming that no safety requirements apply.

[SLS020-R] The scope of the reviewers of the system load specification shall be clearly assigned, ideally specifying the chapter numbers or contents to be reviewed by each individual.

7.3 Approver

[SLS021-R] The Approver of the system load specification is the Design Approver, which is the duly authorized person to approve the system design on behalf of his/her organization [7].

8 Interactions with Other Processes

The interactions with other processes are defined in [1].

9 Records

Record	Author(s) (R)	Reviewer(s) (C)	Approver (A)	Informed (C)
Load Specifications	See Section 7.1	See Section 7.2	See Section 7.3	

Record	Template, UID	Place to store, UID, if available	Doc type and UID, if available	Naming convention	Retention period
Load Specifications	**[SLS006-R]** Load specifications shall be written in Microsoft Word using the template [2], which is based on [16].	See [1]	**[SLS010-R]** Load Specifications shall be uploaded in IO IDM as document type “Load Specification”, i.e. Document Codes DM-F0-01, DM-F0-02 or DM-F0-03.	**[SLS022-R]** Load Specifications shall be titled such that their scope (Component, PBS) is described as well as possible within the confines of a reasonable number of characters.	See [1]

Appendix A Technical Requirements

Appendix A.1 Overview over the Content

[SLS026-R] It is recognised that each system can have its own peculiarities and that a fixed list of section headings is not always appropriate. The list of headings covered here is appropriate in most cases. If any of the sections listed here are not applicable for a particular scope, the sections shall be included, along with the text “Not applicable” underneath it. The author can add additional sections if these are required.

The headings in this section are capitalised and have the «LS» prefix to indicate that they correspond directly to headings in the template for System Load Specifications.

LS 1 PURPOSE

This section of the document outlines the reason the Load Specification has been written. The template for load specifications [2] includes the typical content of this section.

LS 2 SCOPE

[SLS031-R] This section shall list the parts of the ITER Project that are affected by this document, including at least the detailed definition of the geometry covered and its maturity.

An SLS document can be written for a system (PBS level 1) or lower PBS levels (subsystems and components). If the scope is defined in the "system description" chapter (see §LS 11), a reference can be made to this chapter.

[SLS032-R] A proper definition of the scope boundary shall be provided specifying which SSC of the reference PBS are not under the scope of the SLS. If no exclusion is defined, it will be assumed that the SLS is intended to cover all parts or components belonging to the reference PBS.

[SLS193-R] The components that will need integrity justification a-priori shall be clearly identified.

LS 3 SCOPE OF THE REVIEWERS

[SLS034-R] This chapter shall include the scope of each reviewer of the SLS. This chapter is mandatory when a proper definition of the reviewers' scope is not practical on IDM, which is normally due to limitations on the number of characters allowed to define the scope of a reviewer on IDM.

Reviewer (Affiliation)	**Scope**
Reviewer 1 (IEA)	Compliance with ITER_D_33TTPJ.
Reviewer 2	Interfaces with PBSxx and associated interface loads.
Reviewer 3	Interfaces with PBSyy and associated interface loads.
Reviewer 4 (IEA)	EM Loads
Reviewer 5 (IEA)	Seismic Loads
Reviewer 6	Overall review as System RO
Reviewer 7 (EPNS)	Safety Requirements
Reviewer 8 (QA)	Quality Requirements

LS 4 REFERENCES

[SLS036-R] All the references for the system load specification shall be listed here.

[SLS039-R] All the documents from which loads are propagated (namely ITER_D_222QGL and, if any, upper level load specifications), shall be included among the references. Additional load conditions that are peculiar to single components (and therefore are not propagated from ITER_D_222QGL or upper level load specifications), shall be defined and referenced, as required by ITER_D_222QGL.

[SLS040-R] References shall be stored in IO IDM or be publicly available (e.g. design codes or engineering handbooks).

[SLS042-R] References shall be approved.

[SLS043-R] References to external resources like suppliers' websites are volatile and shall be avoided.

[SLS044-R] When referencing external sources like codes and standards, textbooks and publications, full details about the edition shall be specified.

[SLS045-R] When a reference is not related to the design status defined in §LS 11.1, this shall be stated in the chapter where the information of this reference is used and the author shall also consider the need of defining an uncertainty factor to account for the inconsistency related with the design status. The value of the uncertainty factor can be selected based on the qualitative evaluation of the possible impact of the inconsistencies and on the future evolution of the design.

[SLS046-R] When baseline loads are available, these shall be propagated to the system load specification document. The following documents provide inputs that are applicable at project level at the time of writing these instructions. Since the applicability of these documents is subject to changes through the configuration management processes, the author is strongly recommended to contact IEA to check the current status of the baseline.

- Load Specifications (LS) (ITER_D_222QGL)
- Global Tokamak Seismic Analysis Report (ITER_D_33W3P4)
- Design Seismic Floor Response Spectra in the Tokamak Complex (ITER_D_SVBRJZ)
- SL-3 Floor Response Spectra for Tokamak Complex (ITER_D_SFSN7Q)
- Seismic Relative Displacements between the Building Floors (ITER_D_KWXL6B)
- EU-DA Report – PA 6.2.P2.EU.02 - Methodology to be Used to Generate the Seismic Floor Response Spectra for Ancillary Buildings at ITER – F4E-D-229SKE (ITER_D_PN36V6)
- Model 2010 new baseline Intermediate thick BM, IDM Folder (ITER_D_2PN3CN)
- Magnetic Field Maps (MFM) (ITER_D_XMCQMZ)
- Safety requirement Roombook (ITER_D_KF63PB)

[SLS188-R] Additional references to the calculations used to derive any load prescribed in the document shall be defined in this chapter.

LS 5 SYSTEM CLASSIFICATIONS

[SLS063-R] The safety, seismic and quality class classifications shall be reported in this chapter.

[SLS064-R] A reference to the SRD (or equivalent) shall be provided to justify the system classification.

Although the classifications are also given in the SRD of the system it is preferable to also list them in the system load specification in order to avoid that the users need to follow the link to the SRD.

[SLS190-R] When reporting the classification, each single part that has a unique classification shall be distinguished. This is especially important for the SSCs for which structural assessments are foreseen.

The following documents are the basis for the classification:

- Quality classification of the system, see [8].
- Safety classification of the system, see [9].
- Seismic classification of the system, see [10].

[SLS065-R] Systems and equipment that are classified in accordance with French regulations related to pressure and nuclear pressure equipment shall be identified. For this specific case, the applicable French regulations are:

- For pressure equipment:
    - DIRECTIVE 2014/68/EU of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment - EN [11]
    - Articles R. 557 and L. 557 of the French Environmental Code
    - Arrêté du 20 novembre 2017 relatif au suivi en service des équipements sous pression et des récipients à pression simples - EN [12]
- For nuclear pressure equipment:
    - Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN [13]
    - Arrêté du 30 décembre 2015 relatif aux équipements sous pression nucléaires - ([TRANSLATION]-[EN]) [14]
    - ASN Guide #19 - Application of the French Order dated 12/12/2005 on Nuclear Pressure Equipment - Version of 21-02-2013 - EN [15]

LS 6 CODES AND STANDARDS

[SLS194-R] The applicable codes and standard shall be specified in this chapter.

[SLS195-R] The codes and standards shall be consistent with the prescriptions given in [5]. Any amendment or addition to the codes prescribed in [5] shall be documented and endorsed by the IO RO and, if the scope includes PICs, the SRO.

LS 7 DEFINITIONS

A reference to §LS 11.2.1 should be made where the identifying names of all components and single parts are defined.

LS 7.1 Units

[SLS067-R] All loads shall be provided using the International System (SI) base and derived units. The only exception to this rule is that degrees Celsius may be used instead of Kelvin.

[SLS068-R] To avoid misinterpretations, load values shall be given with their units, even though a global specification is made in this chapter.

Additional explanations may be provided for the units that the user of this load specification is not expected to be familiar with.

Table 3 lists common units used for structural analyses.

[SLS071-R] Units for additional disciplines shall be added depending on the content of the load specification.

Units that are not used may be removed from the table.

Quantity	**Unit name**	**Unit symbol**	**In SI base units**
Length	Meter	m	
Mass	Kilogram	kg	
Time	Second	s	
Temperature	Kelvin	K	
	Celsius	°C	
Acceleration			m/s^2
Angular acceleration			rad/s^2
Angular velocity			rad/s
Density			kg/m^3
Energy, Work	Joule	J	N·m
Entropy			N·m/K
Force	Newton	N	$kg \cdot m/s^2$
Frequency	Hertz	Hz	1/s
Moment			N·m
Second moment of area			m^4
Power	Watt	W	N·m/s
Pressure	Pascal	Pa	N/m^2
Stress	Pascal	Pa	N/m^2
Young´s Modulus	Pascal	Pa	N/m^2
Thermal flux density			W/m^2
Velocity			m/s
Particle flux			$1/m^2/s$

Table 3 – List of SI Units

LS 7.2 Coordinate systems

[SLS072-R] The coordinate system with respect to which the loads are prescribed shall be defined here.

[SLS073-R] The relevant coordinate system corresponding to a particular load shall be indicated in the related single load chapter.

When the majority of loads are specified in the same coordinate system, the remark *«Unless stated otherwise all, loads are specified in this coordinate system»* can be added.

The ITER Tokamak Global Coordinate System, which is a cylindrical coordinate system mostly used in structural analyses, can be specified as in Figure 4. The axes/directions of this coordinate system are named: radial, toroidal, and vertical. The identifier of the toroidal angle is φ counter clockwise when viewed from above. Also the directions "poloidal" and "toroidal" are often used for load directions.

Note that as stated in [6], [PR464-R], the reference plasma current and toroidal field directions in ITER are negative with respect to the Tokamak Global Coordinate System defined above.

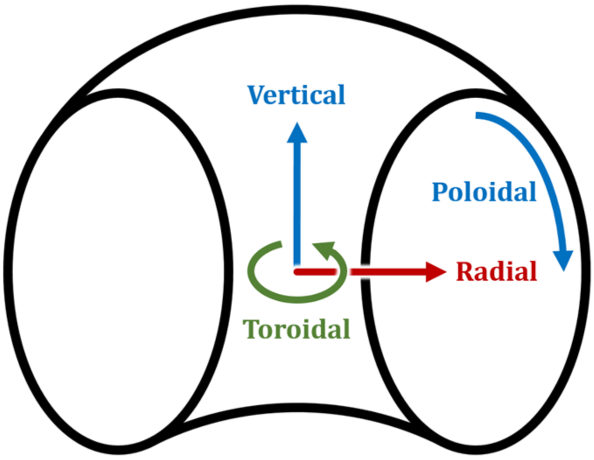

Figure 4 – Definitions of tokamak directions and global cylindrical coordinate system.

LS 7.3 Abbreviations

[SLS074-R] All abbreviations used in the document shall be defined.

For a complete list of standard abbreviations see ITER Abbreviations (ITER_D_2MU6W5). An example of common abbreviations is given in Table 4.

ANB	Agreed Notified Body
AVDE	Asymmetric Vertical Displacement Event
CS	Central Solenoid
DA	Domestic Agency
ELM	Edge-Localized Mode
EM	Electromagnetic
ICE	Ingress of Coolant Event
LOCA	Loss of Coolant Accident
LOFA	Loss of Forced Flow Accident
MD	Major Disruption
PA	Procurement Arrangement
PF	Poloidal Field
SL-1	Seismic Level 1
SL-2	Seismic Level 2
SMHV	Séismes Maximaux Historiquement Vraisemblables
TF	Toroidal Field
TPF	Toroidal Peaking Factor
VDE	Vertical Displacement Event
VS	Vertical Stability
VV	Vacuum vessel

Table 4 – Abbreviations.

LS 8 TYPES OF LOADS

[SLS075-R] The loads acting on the system shall be classified depending on their type.

This classification allows the definition of the physics involved and therefore helps identifying the type of analyses that will be involved in the design process.

An example of possible types of loads is provided below. This list is not exhaustive. If required, the list should be complemented according to the specific characteristic of the scope of the load specification.

- Inertial loads: these are caused by accelerations of masses due to gravity and seismic events.
- Electromagnetic (EM) loads: volumetric forces and moments generated by the interaction between electric currents flowing through conductive materials and magnetic fields or by the presence of ferromagnetic materials.
- Pressure loads: forces distributed over surfaces, typically due to coolant fluid or atmosphere acting on evacuated volumes.
- Thermal and nuclear loads, due to direct irradiation from the plasma or due to the presence of radioactive/irradiated materials, coolant temperature or temperatures imposed by interfacing components.
- Assembly or installation loads, e.g. pretension and live loads.
- Manufacturing loads, e.g. residual stresses produced by brazing or welding procedures.
- Specific loads (e.g. corrosion, wearing, vibration).

LS 9 MAIN LOADS

[SLS077-R] This chapter shall help the coordinator as well as the reviewers of the structural integrity report of the system and its components to get a qualitative and quantitative overview over the loads acting on each component.

All single loads in the scope of the load specification should be summarized here.

Each item in the list should have a reference to the chapter where the loads are described.

For each item in the list, the maximum magnitude expected of the load should be provided.

Additional information on how to describe the Main Loads is provided in Appendix B.4.

LS 10 PATH OF THE MAIN LOADS

Showing the path of the loads helps the user of the load specification, as well as its reviewers, to judge the complicity of the loads specified.

[SLS081-R] A figure or schematic view shall be added to show where each load is applied and through which parts of the component it is transferred to the supports or to other interfaces.

If appropriate, i.e. for systems that are sufficiently simple and have few interfaces, a textual description of the load paths can be used, instead of a picture.

LS 11 SYSTEM DESCRIPTION

LS 11.1 Design Status and Geometry

[SLS082-R] The design phase to which the Load Specification applies (CDR, PDR or FDR) shall be stated here.

[SLS083-R] The system load specification shall be consistent with the design state of the actual phase.

The design of the system may not yet be final at the time of writing the system load specification, especially if the system load specification is prepared for CDR or PDR. The author of the load specification may choose to specify some loads taking into account design changes that are planned (not hypothetical) to be made in the future. This is usually beneficial in the design process of the system if the anticipated design changes will increase the loads.

[SLS084-R] The geometry of the scope of the load specification shall be unambiguously traceable. This can be achieved by:

- Providing references to the relevant approved CAD files, drawings or Data Exchange Task (DET) [23].
- Refer to chapter LS 11.2 for a description of the design.

LS 11.2 System Design Description

[SLS086-R] This chapter shall provide information of the design of the overall system under the scope of the SLS (§LS 2) in order to allow a clear understanding of how the loads act and are applied to the single parts.

Although it would improve the quality of the load specification, it may be chosen not to write a complete design description. Instead, here the author of the load specification could refer to an (approved and up-to-date) design description document.

A clear understanding of the design description is often difficult if no pictures are provided and therefore it is recommended to add figures that show the scope and its parts.

In addition to figures showing the system itself, pictures of the context of the system should be provided as well. For example, if the scope of the load specification is a set of cubicles located in the Tokamak Complex, a picture of the general view of the relevant level of the building should be added to show where the cubicles are located.

LS 11.2.1 System, Components, Parts

Components and parts that are under the scope of the SLS should be listed in this chapter. This can be of great help for the author of the load specification and for the overall coordination of all load specifications.

One or more pictures, possibly with an exploded view, should show all components and parts.

All components and parts should be labelled with their official identifying names, which are exclusively used in this load specification.

It is recommended to highlight the parts and surfaces of the system where loads are applied.

The official identifying names of all components and parts can be found in the DDD of the system. It is however recommended to reconfirm the choice of identifying names with the responsible officer of the system, since inconsistencies with identifying names can cause confusion and misunderstandings.

[SLS092-R] The materials used for each component and part shall be provided.

The definition of the build-up of the system is strongly linked to the definition of the interfaces.

LS 11.2.2 Fabrication and Assembly

[SLS094-R] The description of the fabrication process of the SSCs under the scope of the load specification shall be provided here.

A full description of the fabrication process is not required. Only the processes that cause significant loading conditions need to be addressed, based on the knowledge available at the time of preparing or updating the load specification. Additional information and recommendations are given in Appendix B.5.

LS 11.2.3 Functions

[SLS095-R] The functions of the system under the scope of the load specification shall be described here, insofar as they affect the assessment of the SSC.

Additional information is provided in Appendix B.6.

LS 11.2.4 Interfaces

[SLS101-R] All the interfaces that result in or may affect loading conditions for the scope of the load specification shall be identified and listed here.

[SLS097-R] All the relevant Interfaces Control Documents (ICD) and Interface Sheets (IS) shall be listed under §LS 4 and shall be referenced here.

[SLS196-R] All Interface sheets shall be signed, reviewed and approved.

[SLS102-R] For interface loads that are identified but that are not documented in the ISs available during writing the load specification, alternative sources shall be identified and properly referenced and additional reviewers shall be added as necessary to ensure that the references are relevant to the scope of the load specification.

[SLS098-R] The specification of interface loads that are applicable to the scope of the load spec shall be given in §LS 13.5.

LS 12 STATES OF SYSTEM AND COMPONENTS

A State of a system/component is a continuous condition under which a certain set of loads act on the system itself. This must not be confused with an Event, which is a condition of relatively short duration (compared to the duration of a state) that happens at a specific point in time, while the system is in a specific State.

Examples of states are Fabrication, Commissioning and Operation.

[SLS103-R] The different States that the components of the system will experience shall be listed and briefly described.

[SLS105-R] If during a certain state the loading conditions can change, the state shall be subdivided into sub-states, each of which represented by a unique set of loading conditions. One typical example is the state Operation, which could be divided in sub-states likes Cool-down, Warm-up, Plasma Operation, and so on…

[SLS104-R] The description shall mention which events (typically incidents or accidents) are expected to happen during a certain state. A typical case is Plasma Disruptions during Plasma Operation.

Additional information is given in Appendix B.8.

LS 13 SINGLE LOAD CASES

[SLS106-R] The loads occurring during all States and Events listed in §LS 12 and that are relevant to the design of the scope of the load spec, shall be specified in this chapter.

[SLS107-R] Loads that are not applicable or negligible for the scope or states in which no design-driving loads occur, shall be covered in §LS 13.6.

[SLS109-R] The loads shall always have numerical values.

[SLS110-R] If the values of some loads are not available at the time of writing the load specification, this shall be stated and a remark shall be made that such loads will be detailed in future revisions.

[SLS108-R] All load values shall be specified including their units, their spatial distributions and their time functions.

[SLS016-R] The loads specified in the Load Specification shall be a conservative envelope of the loads that will occur during the foreseen operation of ITER.

[SLS111-R] The number of load cycles and the load category shall be specified.

[SLS113-R] The category of the loads shall be prescribed in a manner that is consistent with §4 of [3].

[SLS112-R] The loads (test loads, load category) shall be specified in a manner that is consistent with the codes and standards selected for the components [5].

LS 13.1 Mechanical Loads

LS 13.1.1 Dead Weight

[SLS115-R] The configuration of components and parts that are assembled in each state of the system (see §LS 12), shall be identified. This information allows identifying the components whose mass needs to be listed separately.

[SLS116-R] The detailed assessment of the masses and the centre of gravity shall be reported or referenced.

[SLS117-R] If dynamic analyses are performed, the moment of inertia of the components shall be reported or referenced.

[SLS118-R] The coordinate system used to provide the coordinates of the centre of gravity and the moment of inertia shall be defined in §LS 7.2 and specified here.

[SLS120-R] A load decrease or increase factor shall be specified to scale the mass taking into account the mass uncertainty in order to be conservative. This decrease or increase factors could be respectively 0.9 or 1.1.

LS 13.1.2 Assembly and Pretension Loads

[SLS121-R] Assembly loads shall be specified in this chapter. These include:

- List of parts and potential temporary assembly structures attached to the component.
- Temperature or temperature range at which assembly is performed.
- Accelerations applied to the parts during assembly.
- A picture of the supporting system of the component.
- Reference to documents that describe the assembly steps and procedures.

[SLS122-R] The temperature at which pretension/compression loads are applied shall be specified.

Pretension loads can be specified either by providing directly their values or by referring to the design rules of the applicable codes and standards.

Information that is not available at CDR and PDR is not required to be specified, but a placeholder should be created saying that the information will be included the latest at FDR.

LS 13.1.3 Test Loads

[SLS125-R] Test conditions shall be specified here.

[SLS126-R] All circumstances that influence the analysis of the test(s) shall be specified, e.g. temperature(s), state of assembly, support conditions and internal/external pressure.

LS 13.1.4 Coolant Pressure

[SLS127-R] The operating and design coolant parameters shall be specified for each state of the system (as defined in §LS 12) that is characterized by a unique set of values.

[SLS128-R] If relevant to the structural integrity assessment, non-uniform spatial distribution or transient fluctuation of the coolant pressure and temperature shall be defined. Examples of such non-uniform pressure could be water hammer, or pressure gradients due to high velocity flows (especially through bends).

The pressure values should be consistent with those given in the interface sheets with PBS 26. Conservativism can be added if deemed necessary.

LS 13.1.5 Seismic Loads

[SLS132-R] Seismic loads shall be specified by the definition one or more of the following:

- Static equivalent accelerations of the components. These accelerations can be either uniform or non-uniform. Combinations of static equivalent accelerations in different directions are typically required.
- Spectra at the structural supports of the system and its components. These are typically Floor Response Spectra (FRS), but Power Spectral Density (PSD) may also be used.
- Time-histories of the displacements or accelerations of the supports.

If static equivalent accelerations are specified, the conditions of applicability of such accelerations should be justified. One way to accomplish the justification is to run modal analyses of the SSCs and to show in which parts of the applicable FRSs the dominant natural frequencies fall.

[SLS133-R] Any relevant relative displacement between the structural supports of the system shall be specified.

[SLS134-R] Unless a detailed dynamic analysis is performed and the number of cycles per event is directly calculated, 10 equivalent maximum stress cycles shall be considered for each seismic event whenever a fatigue or a cyclic load analysis is required (Note 2 in Appendix B of [3]).

All acceleration values for an SL-1 event can be derived from those specified for an SL-2 event by dividing by a factor of 3. Similarly, as a first approximation, all acceleration values for an SMHV event can be derived from those specified for an SL-2 event by multiplying by a factor of 0.73 [2].

The main reference documents for seismic loads are provided in §LS 4.

LS 13.1.6 EM Loads

EM Loads are mechanical loads or environmental conditions caused by the interaction of a non-zero magnetic field in the space occupied by a system with ferromagnetic materials or current-carrying components.

[SLS138-R] The EM loads acting on the scope of the load spec shall be specified in this chapter.

Electromagnetic loads can be static or transient, depending on the causes that generated them. An example of static EM load is the outward pressure in an energized coil. An example of dynamic EM loads are the forces and moments induced during plasma transients.

Mechanical EM Loads include volumetric forces, but also accelerations and relative displacements of surrounding structures. The typical cases are:

- An in-vessel component attached to the vacuum vessel. This component will be subject to volumetric forces. Also the vacuum vessel will be subjected to volumetric forces and therefore it will move, thus accelerating the parts attached to it. These accelerations are in most cases defined in the same fashion as seismic loads (i.e. using FRSs) and therefore the same consideration and requirements made in §LS 13.1.5 about using static equivalent accelerations apply here.
- An ex-vessel component that has a connection both with the vacuum vessel and the tokamak building. The vacuum vessel will be subject to volumetric forces and will move, thus causing a relative displacement with respect to the building.

[SLS197-R] If a system is subject to dynamic EM loads, either a full transient structural analysis shall be performed, or suitable dynamic amplification factors (DAF) shall be included in a static calculation.

[SLS139-R] The specification of EM loads shall cover all the project phases that are relevant to the SSCs in the scope of the load specification.

[SLS140-R] The specification of EM loads shall cover all the States of System and Components (§LS 12) that are relevant to the SSCs in the scope of the load specification.

[SLS141-R] The specification of EM loads shall cover all the applicable events (operating scenarios, plasma disruptions, magnet fast discharges and static stray fields) that produce electromagnetic loads and that are relevant to the SSCs in the scope of the load specification.

Note that when EM loads are not negligible, different methodologies are used to assess them, depending on the SSCs being in-vessel or ex-vessel. Specific instructions are given in [19].

[SLS144-R] The mechanical loads (forces, pressures, moments) generated by the EM events/conditions and acting on the SSCs in the scope of the load specification shall be specified. If at the time of writing the load specification the mechanical loads due to EM events/conditions are not yet available, the prescription of the input to the EM analyses only shall be prescribed and a sentence shall be added to specify that the resulting mechanical loads will be added at a later stage.

[SLS192-R] If non-uniform distributions of EM Loads are prescribed, the following requirements apply:

- A reference to the files that define the spatial distribution of non-uniform electromagnetic loads shall be provided.
- The methodology for interpolation of non-uniform load distributions in the structural models shall be described.
- The integral forces and moments acting on each single parts shall be reported, including the definition of the point about which the moments are calculated, and the methodology used to perform the integration.

In case of systems located in proximity of the plasma, the EM loads are likely design drivers. For systems that are located outside the bioshield, the EM loads are often negligible from the mechanical point of view, but can have an important role from the point of view of EM Compatibility (EMC). Additional sources of EM loads can be the interaction between stray magnetic fields and currents of various nature flowing through conductive materials, e.g. current through large conductive loops and grounding connections.

[SLS145-R] Electromagnetic loads due to additional causes that are specific to the SSCs in the scope of the load specification shall be identified and prescribed here in agreement with the system TRO.

The definition of the load due to EM transients is often a difficult task in the preparation of a load specification for components and parts surrounding the plasma. The support and revision of members of the Science Division (SCD) and IEA is recommended.

LS 13.1.7 Structural Loads due to Component Operation

[SLS148-R] Loads that are triggered by the operation of active components shall be specified in this chapter.

Loads due to component operation are those triggered internally by active components, for example actively driven currents. These need to be distinguished from loads that are externally triggered, like seismic events, and that act equally on both passive and active components.

LS 13.2 Loads in Incident and Accident Events

Accidental events in ITER are described in [4].

[SLS186-R] Incidental and Accidental Loads shall be considered for any component where any of the following is true:

- The component has a Safety Importance Class (SIC).
- Investment protection requirements apply, i.e. if the replacement cost is high or if failure of the components can cause a long machine shutdown or loss of machine performance.

[SLS150-R] Loads in incident and accident events considered for safety reasons shall be agreed with the Safety & Quality Department. This may include potential loads or events due to the surrounding systems, like impact of missile objects or jet impingement during high-energy line breaks (HELB).

[SLS152-R] Loads in incident and accident events considered for investment protection reasons shall be agreed with the RO of the SSCs in the scope of the load specification.

LS 13.3 Thermal and Nuclear Loads

[SLS153-R] The Thermal and Nuclear Loads due to plasma scenarios that are applicable to the SSCs in the scope of the load specification shall be specified in this chapter (Thermal and nuclear loads). This includes stating the applicability to the different staged approach plasma phases.

[SLS155-R] If thermal and nuclear loads are applicable, the implications of the 700 MW Flexibility Scenarios (§4.3.1.2 and [PR2098-R] of [6]) shall be considered in the Load Specification.

[SLS156-R] The different plasma operation phases shall be distinguished (e.g. start-up, steady-state, ramp-down), as defined in §LS 12, when providing the applicable thermal and nuclear loads.

[SLS160-R] If non-uniform distributions of Thermal and Nuclear Loads are prescribed, the following requirements apply:

- A reference to the files that define the spatial distribution of non-uniform thermal loads shall be provided.
- The methodology for interpolation of non-uniform load distributions in the thermal and structural models shall be described.

[SLS198-R] The integral power applied on each single parts shall be reported, including the description of the methodology used to perform the integration.

Additional information about Thermal and Nuclear Loads are provided in Appendix B.9.

LS 13.3.1 Thermal Loads

[SLS157-R] Thermal loads that are applicable to the scope of the load specification shall be prescribed in this chapter.

Thermal loads can exist for example during assembly, plasma operation, maintenance, baking.

When the detailed prescription of non-uniform distributions of thermal loads results in extensive datasets, calculation reports prepared, reviewed and approved according to [1] can be referenced, instead.

[SLS159-R] When prescribing thermal loads, the following information shall be specified, where applicable:

- The configuration of the SSCs (i.e. which parts are present in a specific state).
- The number of occurrences of a specific thermal configuration.
- The thermal loads and boundary condition, which can be: surface heat fluxes (e.g. plasma heat); internal heat generation (e.g. Joule heating); imposed temperatures; convection parameters (bulk temperature and heat exchange coefficient or the relevant flow parameters).
- The range of thermal loads. This is because thermal stresses are usually secondary stresses, which are typically verified taking into account the stress range (the difference between the minimum and the maximum occurring stress).
- The time functions of the heat loads, if transient effects play a role.

LS 13.3.2 Nuclear Loads

[SLS161-R] The following loading conditions due to nuclear radiation that are applicable to the SSCs in the scope of the Load Specification shall be specified in this chapter.

- Energy deposition due to neutrons and gammas (dose in Grey, W/m^3).
- Decay heat.
- Helium production (alpha particles per million, appm)
- Lattice damage (dpa).

Note that whilst energy deposition is often negligible outside the Cryostat (except for cryogenics), material degradation may still be relevant.

[SLS163-R] If any of the conditions listed above do not apply or is deemed not significant, appropriate justifications shall be provided.

LS 13.4 Specific Loads or Conditions

[SLS165-R] Loads due to additional causes that are specific to the SSCs in the scope of the load specification (e.g. corrosion, wearing, vibration, humidity) shall be identified and prescribed here in agreement with the system TRO.

LS 13.5 Interfaces Loads

[SLS166-R] All the loads that are relevant to the interfaces identified in §LS 11.2.4 and defined in the relevant interface sheets shall be specified here.

LS 13.6 Not Significant Load Cases

A load is not significant either because its magnitude is negligible or because it is not applicable to the scope.

[SLS167-R] All the loads that are considered not applicable shall be listed here and justifications shall be provided as to why these loads are not applicable.

[SLS168-R] It shall be demonstrated that the loads that are considered negligible are enveloped by the loads prescribed in the load specification. Appendix B.10 provides additional guidance on this topic.

LS 14 LOAD COMBINATIONS

LS 14.1 Categorization of Load Combinations

[SLS170-R] A description of the load categorization in ITER shall be reported here. This can be achieved by simply referring to the description already given in §4 of [3].

[SLS171-R] The damage limits that are applicable to each component and load category shall be prescribed here.

[SLS172-R] A table shall be added showing the correlation between the damage limits prescribed for the SSCs and the design rules (service levels/states) in the applicable codes and standards defined in §LS 6.

[SLS199-R] Damage limits for every single part subject to integrity assessment (identified in §LS 2) shall be defined consistently with the safety and other classifications and role of the component/part.

[SLS200-R] The damage limits shall be endorsed by the IO RO and, if the scope includes PICs, the SRO.

[SLS173-R] The definition of the applicable damage limits shall be consistent with the requirements provided in §4 of [3].

[SLS174-R] Load combinations that are propagated from [3] without modifications shall maintain their original categorization. Any load combination that is peculiar to the scope of the load specification shall be categorized using the requirements given in §5 of [3].

LS 14.2 List of Load Combinations

[SLS175-R] All load combinations to be considered in the structural integrity assessment shall be listed in this chapter.

[SLS177-R] The definition of the load combinations shall be consistent with the provisions in §5 of [3].

[SLS178-R] Each load combination shall refer to one of the States defined in §LS 12, combined with any applicable event.

[SLS179-R] The number of occurrences of each load combinations shall be specified. Category III load combinations should be specified to occur once in the life of ITER. Category IV load combinations are expected not to occur in the life of ITER and therefore no number of occurrences needs to be specified.

LS 14.3 Fatigue Cycles

A separate specification for fatigue analyses should be provided depending on the complexity of the load combinations. This can be necessary for the following reasons:

- The number of occurrences of an event is not necessarily the same as the number of load cycles. For example, 10 cycles are considered for each SL-1 event when detailed dynamic analyses are not available (see §LS 13.1.5).
- The single loads in a load combination could have different number of cycles within the same time interval, thus requiring the application of special rules (e.g. rainflow) to assess the component useful life.

A table with a detailed definition of the applicable transient cases and the number of cycles should be provided to define the cyclic loading conditions. The definition of the transient cases should include at least the two limiting load conditions in between of which the load is varying monotonically. An example of such specification is provided in Appendix B.11.1.

Appendix B General Guidance and Advice

It is recommended to read these instructions completely.

Identify tasks that involve the work of your ITER or DA colleagues or could be done independently by someone who supports you (e.g. assessing the dead weight of a component). To initiate these tasks as early as possible is most likely time saving.

For the same reason as stated in the previous point, identify the required reference documents for the load specification (with the help of the responsible officers of the system and its components, your colleagues and the contact person from CID/IEA).

A template for the preparation of the system load specification document is provided [2]. If helpful, chapters may be added, based on the peculiarities of the specified system.

Write the chapter "Scope" as early as possible. You may find it necessary to discuss its contents with the responsible officers of the system and its components.

Be aware of *all* possible damages of the components. All damages are listed in the structural integrity report of the system. If the structural integrity report of the system does not exist at the time of writing the load specification, it may be useful to discuss the damages of the system and its components with the person in charge of the analyses. (A damage is the manner in which a system fails. A damage is always triggered by a load. The structural integrity report verifies that each damage does not occur under the specified loads.)

Appendix B.1 Preparation

Frequently remind yourself of the aims of the system load specification.

Be aware that the preparation of the system load specification may require a significant amount of time. It is easy to underestimate the amount of work required to write a SLS. This can often cause the SLS to be written in a rush at the last minute, increasing the probability of ending up with a poor-quality document.

Be aware that you were chosen to write the load specification because of your knowledge of the loads. It is likely that your knowledge of the loads on the system and its components is better than that of the users of this load specification. Do not assume that the users of this load specification have your detailed knowledge.

Keep in mind that the main purpose of writing the system load specification is to provide clear input for the analysis of a system and its components.

The users of a load specification often assume that the specified load values are final and will not be changed in the future. If in a new version of the load specification load values are changed it often causes analyses to become inconsistent. Be aware of the amount of effort that is required to update analyses and therefore do not specify preliminary load values if possible. If you do so, clearly state this in order for the users of the load specification to be prepared for changes.

As you write a specification always be specific, and avoid being generic. It is often difficult and time consuming to be specific, e.g. when describing precisely how a load is to be applied.

For transient events, remember to either specify the dynamic amplification factor to be used in analyses, or else specify the time-function of the load.

Avoid generic expressions like:

- *This load is rather low.*
- *This effect causes high stresses.*
- *Dynamic amplification is small.*
- *This load has little influence on the overall stress state and deformation.*

And be more specific using expression as:

- *Smaller than 5% of the total load.*
- *< 3 MPa.*
- *The effect of load A can be considered enveloped by load B* and specify how this effect has to be considered, e.g. by applying a dynamic amplification factor.

When specifying factors to increase certain loads over and above what is required by the codes, careful use of terminology helps to avoid confusion. Specifically:

- A factor used to account for uncertainties in load analyses is known as an *uncertainty factor.*
- A factor used to ensure a margin against the criteria is known as a *safety factor*.
- Factors accounting for known effects that are too complex to specify more precisely should be clearly named, e.g. *streaming factor* or *dynamic amplification factor*.

Good figures and examples help to clarify the explanatory text and load formulas. When adding figures show the essential, and ensure that embedded text has appropriate size.

Appendix B.2 Presentation

The process of writing a load specification should include one or more presentations where the specified loads are explained to concerned people allowing them to provide comments.

Each ITER department involved with at least one of its members in the review of this load specification and the DAs may be invited to this presentation. External collaborators and other ITER colleagues may also be invited. The video conference system may be used to allow remote participation.

All the presentations may be stored on IDM and made available to all ITER and DA participants.

Appendix B.3 Scope

In some cases, it is recommended to split the SLS in several documents. This is especially practical for systems where the nature of the design drivers can differ significantly, for example because the parts are located in different places where the characteristic loads are different. This is typical for systems that are both in-vessel and ex-vessel. If this split of the scope is not performed, the individual loads and load combinations become different, which increases the risk of producing a misleading specification and even missing some loads/load combinations.

It is strongly recommended to identify in the scope, with the highest possible detail, the specific components for which the SLS is defining loads. This can be accomplished by providing detailed lists with detailed part references or even producing separate “Information Records”. The latter also permits the concise identification of classifications for individual parts and the further definition of damage limits.

Appendix B.4 Main Loads

This list will help the coordinator as well as the reviewers of the structural integrity report of the system and its components to get a qualitative and quantitative overview over the loads acting on each component. An example if shown in Table 5:

Load case	**Chapter**	**Loads**
Baking	8.3.2	Coolant at 200°C and 3.0 MPa.
LOCA during normal operation IV	8.4.1	Differential pressure between the two VV cooling loops: 1.3 MPa, decay heat of SS structures (15.9 kW) to be removed by the remaining cooling loops.
VDE III		Peak force 1.6 MN. Peak moment 3.1 MN m. 3 mm relative displacements at the interface with the VV.
Seismic loads		Peak accelerations *aa* m/s² at *ff* Hz during SL-2

Table 5 – Main loads acting on the system/components

Appendix B.5 Fabrication and Assembly

The aim of §LS 11.2.2 is to give to the user of the load specification a general understanding of the fabrication and assembly processes that are foreseen to be used.

The description of the fabrication processes can be very simplified (e.g. bolted structure) or a reference document can be given. The SRD of the system may include a description of the fabrication processes. The focus should lie on loads that may occur on single components during fabrication, e.g. during testing of components, stresses in parts due to thermal expansion of other parts.

The fabrication method often plays a role in the selection of criteria and analysis assumptions used to verify each component of the system. For example, welds often need to be treated differently from the parent material, and certain cases require manufacturing tolerances to be taken into account. It may therefore be useful to discuss this with an experienced analyst or expert in the code selected for each component.

Appendix B.6 Functions

The functions are described with the aim to identify potential loads that may compromise them and to derive acceptance criteria, additional to the structural ones, by respecting which the functions of the system are preserved.

Be aware that each component and part may have different functions in different states during the life cycle of the system (see §LS 12).

When describing the function(s) of the components and parts focus on:

- Brief - if possible quantitative - description of the "active" function(s) fulfilled, unless it is obvious. Be aware of the possibly different functions of one part in different states (see §LS 12). The aim of this explanation is to help the user of the load specification to understand the purpose of component. Unclear or complicated explanations should be avoided in order not to confuse the user.
- Brief - if possible quantitative - description of the "passive" (and often not intended) function(s) fulfilled, e.g. heating up or cooling down of water in pipes passing through, function as counter-weight, function as electrical conductor/insulator, neutron / thermal / magnetic shielding properties of this component. The shielding properties of this component are parameters considered in the design of components that are shielded by this component. It may not be obvious which other components rely on the shielding properties of this component. It may be useful to discuss this with the IEA contact person.
- Sensitivity to certain circumstances that challenge the functional requirements, e.g. temperature, vibration, clearance, friction, radiation, activation, pre-stress.
- Possible effects on other parts generated by the operation of one part, e.g. heat load, induced currents / caused magnetic field, insulation, magnetic shielding, neutron shielding, vibration.

Appendix B.7 Interfaces

ICDs describe all interfaces of a system A to another system B. Each ICD contains a list of ISs, each of which describes a single interface of system A with system B.

§LS 11.2.4 provide the description of the interfaces, while the specification (the actual values) of the interface loads is given in §LS 13.5.

Typical interfaces can be - amongst others:

- A structural connection, e.g. support. Typically transfers forces and/or moments.
- A thermal contact, e.g. proximity (radiation) or physical contact (thermal conductance). Typically transfers heat flux.
- A bellow. Typically accommodates relative displacement and minimises the interface loads.
- A rupture disk. Typically transfers a differential pressure between inside this component and outside, but - during an incident/accident - may not.
- Magneto-mechanical coupling, e.g. VV/Magnet coupling.

Interface loads are specified in the load specification of system A as well as in the load specification of system B. This is to ensure that each user of the system load specification has one document containing all necessary load information.

Appendix B.8 States of the Systems and Components

A discussion with the responsible officer of this system is recommended to ensure that the list of states is complete. The following is a possible list of states that covers the entire life of a system. Please note that this list does not cover all possible cases:

- Fabrication, transportation, assembly and testing
- Commissioning
- Operation

    - Cool-down
    - Warm-up
    - Magnet charging and discharging
    - Standby between plasma pulses
    - Normal plasma operation
    - Baking
    - Shut-down for maintenance and upgrade
- Decommissioning

The description of each state or sub-state should focus on circumstances…

- …that are special compared to other states regarding parameters like temperature, external/internal/differential pressure, radiation, non-uniform heat load and conditions during transients that influence one or more possible failure modes of the system and its material;
- …that represent different support conditions of the system (e.g. during assembly, remote handling, or when in certain circumstances one or more supports releases or constrains the system);
- …during which the masses of the system are special compared to other states (e.g. no cooling water, shielding plates not yet assembled, exchange of parts);
- …during which the orientation in space of the system is special compared to other states (e.g. during assembly, remote handling).

The description of each state or sub-state should include an explanation of the reasons that lead to this state or sub-state to occur. The objective of this explanation is to give to the user of the load specification a general understanding of the overall situation of the system in the moment the related loads occur. This explanation should be made as simple and clear as possible. This is especially important when explaining the reasons for plasma scenarios. The scope of a description of plasma events should always be to prevent that the user makes non-conservative assumptions. If possible, a reference document describing this state or sub-state in a different context should be given.

Appendix B.9 Thermal and Nuclear Loads

During plasma operation, neutron and gamma irradiation of many ITER SSCs occurs. Neutron irradiation often causes damage to materials.

The most common consequences are listed below, and their effect should be specified:

Neutron and gamma energy deposition causes non-uniform volumetric (W/m^3) heat load in the component. The total absorbed dose gives the energy per kilogram absorbed by this component in Gray. (1 Gy = 1 J/kg).

Note that even though the neutron energy deposition outside the VV is usually negligible (with the exception of cryogenic components), changes to properties of various sensitive materials or components can still happen. Furthermore, significant gamma dose may be received outside the bio-shield and at times other than during plasma operation, for example during cask movement.

Decay heat will be present in the irradiated structures after a shutdown. This can have a role during accidental conditions and should be taken into account.

Helium production (appm, alpha particles per million) in materials subjected to neutron radiation increase progressively during the life of ITER. Helium concentration after irradiation affects the ability to re-weld affected components, as well as the welding methods that can be used. This is especially important for the VV and in-vessel components. Helium production also deteriorates material properties and causes expansion, although usually not significantly.

Lattice damage (dpa, displacements per atom), deteriorates material properties depending on the dpa level, irradiation conditions and the material in question. Typical effects include increases of the yield and ultimate strengths of steel and copper alloys, decreases of ductility and irradiation creep leading to stress relaxation. The latter is important for bolting, and needs to be considered for In-Vessel components. Neutron damage also leads to degradation of the insulation properties of some materials used in in-vessel components. Neutron fluxes are also responsible for degrading the properties of the insulation of the superconducting magnets.

Appendix B.10 Not Significant Load Cases

A load is considered not applicable when it does not act on the system for physical reasons (for example EM loads on a non-conductive/non-ferromagnetic material) or for geographical reasons (for example the event happens in a different location from where the SSCs are located).

A single load, A, acting on the system or its components may be considered not significant if its effects are less severe, yet similar in type, to another single load, B. In this case it may be specified that *«load B is assumed to account for load A»*. In other words, load B envelopes load A. When specifying an existing single load B as an envelope load:

- Consider that the number of load cycles of the loads A and B must be added when defining the envelope. If the magnitude of the load A is very low when compared to load B, the life of the component might not be affected significantly and therefore adding the number of cycles might result in an excessively conservative definition. In these cases, adding the cycles is not required, assuming that the appropriate justifications are given.
- Be aware that the load combinations that include load A may not have the same load category as the load combinations that include load B.
- Be aware of parameters that are different during load A and load B that influence the analysis criteria, e.g. temperature, material degradation, pretension, etc.
- Point out that it is conservative to assume load B instead of load A and justify this statement, if necessary with an approved and appropriate reference document.

Appendix B.11 Load Combinations

The load combinations chapter can be divided in separate sub-chapters if deemed necessary. The following is an example:

- Overview. Contains a list of all load combinations, specifying the load category of each.
- Design Loading Conditions. This sub-chapter is not required in all load specifications. In case it is general practice for this type of systems to specifically list the design loading conditions (as for pressure vessels), they should be listed in this sub-chapter.
- Test Loading Conditions. If this component is tested before, during or after the operation phase, list the test load combinations.
- Category I and II
- Category III
- Category IV
- Specification for Fatigue Analysis

Appendix B.11.1 Specifications for Fatigue Analysis

This paragraph reports an extract from «Cryostat load specification document (ITER_D_34HHUG v3.0)» that shows an example of how to prescribe the load cycles for fatigue analysis. The specification consists of several parts:

- The definition of thermal states and magnet states, providing the applicable temperature of the components and interfaces, which are necessary to determine both thermal stress and material properties to be used in the assessments.
- Individual fatigue cycles, where the limiting conditions (begin-end) of each relevant load combination is prescribed and associated to the applicable thermal state.
- Master cycles, where the individual fatigue cycles are grouped together to define a limited number of envelope cases, with the aim to reduce the number of individual assessments.

Note that the thermal states are defined in a different chapter of the original document and the tables reported here are an extract, therefore not all the information is reported here. For a complete overview of how this detailed specification is prepared, refer to ITER_D_34HHUG v3.0.

Table 6 and Table 7 respectively define the individual fatigue cycles and master fatigue cycles for the Cryostat. The fatigue cycles have been compiled based on a number of assumptions:

- *One magnet cool-down per cryostat-pump down.*
- *Cr ICE II can only happen during normal operation, i.e. the situation modelled in the Accident Analysis Report.*
- *The VV is baked every time is it Assume that the VV is baked every time it is brought up from RT. In other words, the cycle RT → 100 C → RT will never happen.*

The fatigue damage for each master cycle is the damage caused by the worst of the given options. The total fatigue damage is the sum of damage for each master cycle.

To determine the fatigue damage for the cryostat:

- *Determine the fatigue damage D for each of the individual fatigue cycles listed in Table 6*
- *For each of the master fatigue cycles, work out which of the combinations listed in Table 7 gives the worst fatigue damage. E.g:*

$$D_c = max\ (\ 500 \times D_{c1}\ ,\ 500 \times D_{c1}\ ,\ 500 \times D_{c1}\ )$$

- *The total fatigue damage for the Cryostat is the sum of the damage for the seven master cycles, i.e.:*

$$D_{total} = D_a + D_{bf} + D_{bg} + D_c + D_d + D_e + D_g + D_h$$

ID	***Start state***		***End state***	
	LC	*Thermal state*	*LC*	*Thermal state*
a1	*0*	*1*	*NO + VDE II + Magnet (f-3.i)*	*6*
a2	*0*	*1*	*NO + SL-1 + Magnet (f-3.i)*	*6*
…	…	…	…	…
a5	*0*	*1*	*DW + P1 + VV Baking + SL-1*	*9*
b1	*DW*	*1*	*DW + P1*	*3*
b2	*DW*	*1*	*DW + P1 + VV Baking*	*8*
…	…	…	…	…
b5	*DW*	*1*	*NO + Magnet (f-4)*	*6*
bg1	*DW*	*1*	*DW + P1 + SL-1*	*3*
bg2	*DW*	*1*	*DW + P1 + VV Baking + SL-1*	*8*
…	…	…	…	…
bg10	*DW + SL-1*	*1*	*DW + P1 + Magnet (f-4)*	*6*
c1	*DW*	*1*	*DW + VV Baking*	*7*
…	…	…	…	…
h2	*DW + P1*	*1*	*DW + P1 + VV Baking*	*9*

Table 6 – Definition of individual fatigue cycles for the cryostat.

Master cycle	*Damage for master cycle is worst of...*
a	*1 × a1*
	1 × a2
	…
bf1	*100 × b1 + 382.5 × f1*
	100 × b2 + 382.5 × f1
	…
bf2	*100 × b5 + 2500 × f2 (1)*
bg	*5 × bg1*
	5 × bg2
c	*500 × c1*
	500 × c2
	…
d	$100 \times d1 + 1000 \times d2 + \sum_{j=1}^{j=8}(30\,000 \times d3.j)$
e	*15 × e*
g	*45× g*
h	*100 × b1+500 × hi*

Table 7 – Fatigue master cycles for the Cryostat. The worst combination for each master cycle must be considered for the assessment. Individual fatigue cycles are defined in Table 6

End of extract from ITER_D_34HHUG v3.0.