idm@F4E UID / VERSION
22FR5T / 3.3

VERSION CREATED ON / STATUS
21 July 2015 / Approved

EXTERNAL REFERENCE

Quality Document

F4E-QA-114: Instructions for Suppliers Performing Design Analysis

The present document provides general instructions applicable to any provider of analyses identified by F4E as protection-important activities (PIA).This instruction is applicable for analysis identified as PIA in conformity with the French INB Order of 07/02/2012. In addition this instruction also applies to Quality Class 1 activities that are not PIA.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Wouters P.**	**21 July 2015:signed**	**F4E-A140**
Co-Authors	**Smith W. (Account Closed)**	**21 July 2015:signed**	
Reviewers	**Chaffard P.- Y.**	**23 July 2015:recommended**	**F4E-A90**
	Combescure D.	**23 July 2015:recommended**	**F4E-A90**
	Fernandez Cano E.	**24 July 2015:recommended**	**F4E-A90**
	Gagliardi M.	**27 July 2015:recommended**	**F4E-A110**
	Jucker P.	**10 September 2015:recommended**	**F4E-A140**
	Leichtle D.	**21 July 2015:recommended**	**F4E-A90**
	Portone A.	**04 August 2015:recommended**	**F4E-A90**
	Puppin S.	**18 August 2015:recommended**	**P-TPI**
	Rodrigues D.	**24 July 2015:recommended**	**P-MSOI**
	Saibene G.	**23 July 2015:recommended**	**F4E-A110**
	Serra G.	**23 July 2015:recommended**	**P-TPI**
Approver	**Filhol J.- M.**	**22 October 2015:approved**	**F4E-A00**
RO: Rodrigues Diogo (F4E)			
Read Access	**LG: EC ITER , LG: F4E Safety, LG: EC UL_NIER Technical Support , LG: EC UL_Extended Design Team, LG: F4E_QAO, AD: IDM_Users, AD: IDM_F4E, AD: F4EN-A90, AD: IDM IE-PE-00-00 Antennas and Plasma Engineering, GG: IAC, project administrator, RO**		

Original Document MD5#: #MD5#

Change Log			
F4E-QA-114: Instructions for Suppliers Performing Design Analysis (22FR5T)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	11 May 2010	
v2.0	Signed	17 February 2015	Major update of the document content and scope.
v2.1	In Work	27 March 2015	Review Comments integrated
v2.2	Signed	07 May 2015	Review Comments Integrated
v3.0	Signed	18 June 2015	Aligned with QA 113
v3.1	Signed	18 June 2015	Typo correction
v3.2	In Work	16 July 2015	Comments included from re-view
v3.3	Approved	21 July 2015	Minor Typo

FUSION FOR ENERGY

WORK INSTRUCTION

Control Page

idm@F4E ref:	F4E_D_22FR5T	Date:	21.Jul.2015

Document title:	Design Analyses by Suppliers (F4E-QA-114)

Areas and functions

Process ownership:	ITER Department HoD
Area(s) concerned:	Contract Implementation
Function(s) concerned:	Operational roles

Purpose

This F4E instruction sets out particular requirements for the performance of calculations and related analysis using computational modelling methods in support of the design of structures, systems and components for F4E.

Scope

These apply to the analysis of the design of all components of Quality Class 1 [6], also to the design of SSC which have PIC and/or Defined Requirements (Safety) and which are classified as Quality Class 2.

This scope includes the;

The requirements for the performance of all calculations supporting design.

Additional requirements for analysis methods using computational modelling processes.

These instructions complement the requirements of F4E-QA-115 [2]; F4E-QA-113 [5] .

Table of contents

Reference Documents

(external links)

[1] French Order 7 February 2012 - *République Française - Arrêté du 7 février 2012 fixant les règles générales relatives aux installations nucléaires de base.* INB Order

[2] Supplier Quality Requirements (F4E-QA-115, F4E_D_22F8BJ)

[3] PIA Guideline (F4E_D_27WDLC)

[4] Guidelines and Templates for Protection Important Design by Analysis Activities (F4E_D_2A7W63)

[5] - Propagation of Generic Safety Requirements in the F4E Supply Chain (F4E-QA-113 - F4E_D_22JRQY)

[6] Quality Classification (F4E-QA-010, F4E_D_22MD99)

1. Introduction

The usual requirements of good practice applicable to any report documenting design analyses need to be kept in mind by the supplier when applying the instructions set forth in this document. In particular, the two following requirements are of prime importance.

<# QA114-REQ-0001

Each report shall be self-supporting. This requirement is related to the understanding of the report by the supplier client. All references in a report shall be supported with clear and self supporting explanation to allow the applicability and purpose of the reference to be understood

#>

<# QA114-REQ-0002

Each report shall be auditable. This requirement is related to the verification of the report, including the traceability of the input data used. The report shall have enough information (text, figures, tables, equations…) to allow its verification by an expert in the field.

#>

2. Definitions

2.1. Suitably Qualified and Experienced Person (SQEP)

A person who has the relevant education standard, the professional qualifications and the experience for a suitable period to guarantee competence in the job role.

2.2. Protection-Important Activity (PIA)

Referring to INB Order Art. 1.3, a Protection-Important Activity *(activité importante pour la protection)* is defined as an activity important for the protection of the interests mentioned in article L593-1 of the (French) Environment Code (public safety, health and welfare, protection of nature and the environment), that is to say, activity contributing to the technical or organizational provisions mentioned at the second paragraph of the article L.593-7 of the Environmental Code or that could affect them. *(Note - The PIAs include the SRAs (Safety Related Activities) defined in the previous French Quality Order of 10 August 1984)*

2.3. Defined requirement

Requirement assigned to a protection-important component so that it may perform the function, with the characteristics expected, provided for in the demonstration mentioned under the second paragraph of Article L.593-7 of the Environmental Code (PIC SDR), or assigned to a protection- important activity so that it may fulfil its objectives as regards this demonstration (PIA SDR). A defined requirement can be attached to a PIC or to a PIA.

3. Requirements for the Performance of All Calculations Supporting Design

3.1. Verification and validation

The reality (physical phenomenon, component…) is never analysed as such but it is abstracted by a conceptual model that describes the reality and from which the mathematical model can be constructed. The mathematical model comprises the conceptual model, mathematical equations, and modeling data needed to describe the reality. The mathematical model may take the form of the partial differential equations, constitutive equations, geometry, initial conditions, and boundary conditions needed to describe mathematically the reality. The computer model represents the software implementation of the mathematical model, usually in the form of numerical discretization, solution algorithms, convergence criteria… The computer model includes the computer program (code), conceptual and mathematical modeling assumptions, code inputs, constitutive model and inputs.

The terms verification and validation are used with different, and sometimes interchangeable meaning, by different authors. The definitions of validation and validation as used in this document are those of ISO 9000.

3.1.1 Verification

Verification is the confirmation, through the provision of objective evidence that specified requirements have been fulfilled (ISO 9000). Confirmation methods for verification can generally be broken into four categories: inspection, analysis, demonstration and testing. Analysis can be sub-categorized into analysis by simulation, analysis by similarity… In particular the following definitions are of interest.

(1) *Model verification* is the process of determining that the software implementation of the mathematical model is accurate. The *model verification* activity focuses on the identification and removal of errors in the software implementation of the *Mathematical Model.*

(2) *Code verification* is the process of determining that the computer code is correct and functioning as intended. The code verification code aims at demonstrating that the computer code can compute an accurate solution.

(3) *Calculation verification* is the process of determining the solution accuracy of a particular calculation. The calculation verification aims at providing evidence that a sufficiently accurate solution is being computed.

3.1.2 Validation

Validation is the confirmation, through the provision of objective evidence that the requirements for a specific intended use or application have been fulfilled (ISO 9000).

Model validation is the process of determining that the model is an accurate representation of the real physical system from the perspective of the intended use of the model. In short, whereas verification deals with the mathematics associated with the model, validation deals with the physics associated with the model. Of course, model validation cannot determine that the model is accurate for all possible conditions and applications, but rather, it can provide evidence that a model is sufficiently accurate for its intended use in a specific application.

3.1.3. Verification and validation

The *verification* and *validation* activities are two independent activities that have to be clearly differentiated. Referring to the modelling, *verification* is the process to determine that a model represents the conceptual description made by its developer. Verification is used to decide whether the model was "built" correctly, i.e. in accordance with the specifications of the developer. *Validation* is the process to determine whether the model is a suitable representation of the real world and is capable of reproducing phenomena of interest. Validation is used to decide whether the right model was "built". For instance, when verifying the mathematical model used for dynamic or seismic analysis, a cross-check of the total mass and/or the mass distribution is a straightforward verification tool. Static calculations with uniform acceleration also help to detect errors in the load path and/or the boundary conditions of the model. Validation of models representing complex phenomena may be done on the basis of experimental results made available through international benchmarks.

Practically, the softwares used in the analyses whether they are commercial softwares or computer codes developed for specific applications, are tailored to build the mathematical model from the conceptual model and to provide the numerical procedure (code) for solving the equations of the mathematical model. Those softwares are referred to in this Work Instruction as *calculation codes* and are subject to verification and validation. The verification concerns both the mathematical model and the code and the validation concerns the mathematical model only.

<# QA114-REQ-0003

Verification and validation shall clearly define the application or range of applications they cover.

#>

3.2. Analysis methods

In addition to the requirement of using verified/validated models and calculation codes when performing analysis, the selection of the analysis method also needs be evaluated.

Validation of an analysis method is the process of ensuring that the analysis method is appropriate for solving the problem from the perspective of its intended use. In particular, the validation shall ensure that the analysis method makes engineering prediction with adequate confidence for the intended use by including appropriate margins.

To this end, the analysis method shall use assumptions and rules suited to the uncertainties and limits of current knowledge on the phenomena involved. The analysis has the objective of providing a quantified solution to a unique problem. Depending on the complexity of the problem, its nature, or the required accuracy of the solution, different analysis methods may possibly be used. Obviously, simplified analysis method contains assumptions and rules. For instance, when seismic analysis is to be performed, an analysis method has to be selected amongst the different available methods: equivalent static analysis, response spectrum analysis, linear dynamic analysis, nonlinear static analysis or nonlinear dynamic analysis, etc…

Or when a seismic analysis method has to be selected amongst the different available methods: equivalent static analysis, response spectrum analysis, linear dynamic analysis, nonlinear static analysis or nonlinear dynamic analysis.More complex analysis methods also contain assumptions and rules. The validation of tools used for modelling of complex phenomena may be done on the basis of the experimental results made available through international benchmarks (SMART, MECOS, CASH for seismic analysis or IRIS for impact analysis, etc.)

<# <# QA114-REQ-0004

Methods of analysis shall be **validated**.

#>

<# QA114-REQ-0005

For every F4E design contract an Analysis Plan shall be produced for F4E approval. The content shall include ;

- *(Topics to be agreed with TSS division specialists proposed topics include)*
- Schedule of Analyses, and for each;
    - Calculation ot Modelling Tools to be employed
    - Analysis Methods,
    - Data Management
    - Codes and Standards justification
    - Verification and Validation
- Explanation of Established Procedures

This document may also include the following aspects or they may be included in the supplier **Quality Implementation Plan**

- the methods and the organizational, technical and documentary means necessary to carry out the analysis.
- the human and material resources necessary to carry out the analysis. For each staff member making part of the organization, his role shall be described and his skills and qualifications shall be provided.
- justifying the adequacy of the methods, means and resources (SQEP) for allowing the analysis to meet satisfactorily the project requirements assigned to it.

#>

<# QA114-REQ-0006

Methods of analysis shall be **appropriate**. The selection of a calculation method by the supplier for a specific application shall be based from the perspective of the intended use of the results and the required accuracy and conservatism.

#>

This requirement means that the analysis method shall be adequate for the intended use. The seismic structural analysis is taken again as an example. When the seismic demand is so high that nonlinearbehaviour is expected, nonlinear dynamic analysis is the most rigorous analysis to represent the behaviourof the structure. It is therefore the analysis method that is capable of producing results with relatively lowuncertainty and may be therefore qualified as appropriate.Nevertheless the non linear analysis (static push-over or transient dynamic analysis) must be performed withqualified tools and fully justified failure criteria.Linear analysis methods may also be used where nonlinear behaviour is expected if a high level of conservatism is not to be avoided. If the conservatism of linear methods needs to be reduced, non linear analysis can be performed.

<# QA114-REQ-0007

The selected calculation method shall be clearly identified in each analysis report.

#>

<# QA114-REQ-0008

The selection of a calculation method for a specific application shall be justified. In particular, the justification shall demonstrate the appropriateness of the selected method to the specific application. The justification shall also consider the uncertainties associated to the predictive values of the outputs as evidenced by the verification/validation process.

#>

<# QA114-REQ-0009

The selection of the calculation method shall be subject to review by F4E. The justification shall either be in the calculation document or in the Analysis Plan. F4E will advise on which presentation of the justification it requires. The use of the calculation method is only permitted after the positive result of the review by F4E-SQEP is forwarded to the supplier.

#>

<# QA114-REQ-0010

Studies shall be carried out to determine the sensitivity of analytical results to the assumptions made, the rules used, and the methods of calculation.

#>

The analysis methods also include the application of codes and standards or established procedures. For instance, the design of structures, systems and components may be performed in accordance with established national or international codes and standards. Some accident scenarios may also performed in accordance with established procedures.

<# QA114-REQ-0011

Methods of analysis shall be **clearly expressed**.

#>

This requirement means that the analysis method shall be clearly identified without any ambiguity. When a well-established and well-documented analysis method is used, the complete identification of the method with the mention, when necessary, of the selected option(s) shall be sufficient. For instance, when a linear dynamic analysis method is selected for a seismic analysis, the type of the analysis shall be mentioned, e.g., the modal time history analysis. For instance, when a linear dynamic analysis method is selected for a seismic analysis, the type of the analysis should be mentioned: modal time history analysis or full transient time-history analysis, eigenmodes and eventually static residual mode considered, etc... When a non-well established and/or poorly documented analysis method is used, a detailed description of the analysis method shall be provided.

When an established code or standard is used, the complete denomination of the code or standard shall be given. For instance, mentioning the ASME B&PV Code is not sufficient but the applied Section and Subsection shall be provided, e.g., Subsection NC of Section III.

3.3. Calculation and Modeling Tools

The analyses cover a wide range of quite different tasks supporting the safety demonstration of the ITER installation, such as the sizing of a structure, system or component, the justification of a required design change, the determination of acting loads under a specified event or the study of a transient event or an accident scenario. For the design of PIC or for the substantiation of Defined Requirements these analyses aim at validating the design of SSC with safety functions defined in the ITER Organisation “Defined Requirements” documents or the SRD or the justification of attributes of the design which relate to the “Defined Requirements (Safety)” of the ITER installation.

This document also applies to analyses which support the demonstration of design of components with investment protection requirements which have no safety requirements but are Quality Class 1.

Although being of different types, all these analyses share the same objective, the assessment of a specific problem that concerns some real physical system, behavior or phenomenon in order to make engineering predictions with the appropriate confidence.

The first step in studying the problem is to define a *conceptual model* that identifies especially the important physical processes taking place and the assumptions to be made. Then the physical system for the problem under consideration is described by a *mathematical model*. For complex problems, the mathematical resolution requires the implementation of the mathematical model in a computer model. More details are provided in paragraph 3.1. above.

Modelling may therefore be defined as the conceptual/mathematical/numerical description of a specific physical system and the code is a computer implementation of algorithms developed to facilitate the formulation and approximate solution of models.

The use of models and calculation codes in the analyses performed for safety demonstration of a design requires very high confidence in the results they provide. To this end, the model and calculation codes used in the analyses have to undergo verification and validation as required by F4E-QA-115 [Ref 2]..

Qualification, could be considered as a substitute to verification and validation.

<# QA114-REQ-0012

Calculation and modelling tools shall be qualified for the specific fields of application, which means that verification and validation could be made from the perspective of the intended use(s) of the models and codes.

#>

3.4. Technical Control of Analyses

A technical control which has the objective of verifying that the requirements assigned to the analysis were met, must be conducted during an analysis.

Note that any discrepancies against input requirements are required to be treated as NCR in accordance with the instructions in F4E-QA-115 [Ref2].

<# QA114-REQ-0013

Verification (self-check) that the contract requirements assigned to the analysis were effectively met shall be performed and documented

#>

<# QA114-REQ-0014

A technical control (independent verification) of each analysis shall be performed. The technical control of the analysis shall be carried out by SQEP persons other than those who performed the analysis, in order to be independent. The content of the technical control shall be recorded and transmitted to F4E for review. This report may be added as an Annex to the final analysis report.

#>

3.5. Codes and Standards

The use of an established code or standard may be imposed by F4E via the contract.

<# QA114-REQ-0015

Where the supplier is making the selection the following instructions apply:

a. Only established national or international codes and standards shall be used for design of structures, systems, and components. The codes and standards shall be used for an application belonging to their scope and their limit of application
b. The combination of different codes and standards for a single aspect of a structure, system or component shall be avoided or justified when used
c. The selection of codes done by the supplier shall be justified on basis of its appropriateness to the specified application. towards F4E and accepted by F4E

#>

<# QA114-REQ-0016

The applicable section, subsection and paragraph of the code shall be clearly specified in the analysis report.

#>

<# QA114-REQ-0017

When codes and standards are used to design a structure, system or component, their appropriateness shall be assessed. In particular, when a specific code or standard is used, its assumptions and the limits and conditions shall be verified and shall be documented in the Analysis Plan which is made available for F4E to review.

#>

<# QA114-REQ-0018

The codes or standards used shall lead to a design that incorporates margins commensurate with the importance of the safety function(s) to be performed. The codes and standards shall be therefore evaluated to determine their applicability, adequacy and sufficiency.

#>

<# QA114-REQ-0019

The codes or standards shall be supplemented or modified to a level commensurate with the importance of the safety function(s) to be performed, as necessary. The combination of different codes and standards for a single aspect of a structure, system or component shall be avoided or if avoidance is not possible they shall be justified when used.

#>

3.6. Use of an Established Procedure

<# QA114-REQ-0020

An established procedure is one that is written and checked by SQEP and is authorised by the management of the organisation responsible and accountable for the activities defined in the procedure. The procedure is recorded in the quality system of the organisation and reviewed and updated at regular intervals by SQEP and these reviews and updates are recorded.

An established procedure shall be used for performing calculations for the design of a protection-important component (PIC) or which are considered PIA (for Quality Class 1 and 2) and also for all Quality Class 1 components.

#>

<# **QA114-REQ-0021**

The use of an established procedure for a specified application shall be justified on basis of its appropriateness. It shall be identified and justified in the Analysis Plan which is subject to F4E review before the calculations or analyses can be undertaken.(Refer to **QA114-REQ-0005**)

#>

<# **QA114-REQ-0022**

The selected established procedure shall be clearly identified in the analysis report (or calculation note).

#>

3.7. Requirements for Management of Input Data

All input data is subject to the following two requirements;

<# **QA114-REQ-0023**

The input data shall be up-to-date and referenced.

#>

<# **QA114-REQ-0024**

For PIC or modelling considered as PIA then any relevant operational feedback from other installations shall be taken into account as well as any relevant information coming from the worldwide research and development programs.

#>

There are basically three types of input data:

(1) data provided by the F4E

(2) data that are results from upstream analyses performed by the supplier itself and referred to as data produced by the supplier

(3) reference data.

The data of **type (1)** provided by F4E are included in the appropriate technical specification (i.e., the Task Order) or in documents referred to in it. Typical input data include the geometry, the materials and the loads. However, it frequently happens that these data are not "cast in stone" since the launch of the task but they are rather "living" data evolving in time with progress made with other related activities. This is mainly due to the fact that the design process is generally iterative and it normally includes several phases.

Type (1) input data also includes the Defined Requirements (Safety) (PIC) which are transmitted to the Supplier (refer F4E-QA-113 [Ref 5]) and the Defined Requirements (Safety (PIA) which are propagated in accordance with F4E-QA-115 [Ref 2].

<# **QA114-REQ-0025**

For data to be considered type (1) only input data provided and validated by F4E in documents issued for application to the task and being the latest current issue having the status "approved" shall be used. Practically, the identification number and index level of the document(s) providing the input data need to be validated by F4E.

The need to validate the type 1 input data every time the analysis is re-performed shall be clarified in the Analysis Plan for F4E approval.

#>

Data of **type (2)** are encountered when a complex task is performed by the supplier as a set of sub-tasks, each of them relating to a specific area. In this case, some input data for a given sub-task may be the outputs of other (upstream) sub-tasks or are determined from these outputs. These input data are referred to as internal input data and are under the responsibility of the supplier. Here also, the different sub-tasks may evolve in time and, as a result, the internal input data may also evolve in phase with progress made with these related sub-tasks. An important consideration to take into account when using *internal input data* is related to the nature of the concerned subtasks with regard to the entire task. Two cases are to be considered: (1) the (upstream) subtask from which is output data are taken is *independent* from the (downstream) subtask in which the output data are used as input data, e.g., a thermal analysis and a stress analysis of a given component are independent subtasks. (2) the upstream and downstream analyses are *dependent*, e.g., stress analysis and fatigue analysis of a given component are dependent subtasks.

<# QA114-REQ-0026

When the upstream subtask and downstream subtask are dependent, the use of the output data of the upstream subtask as input data in the downstream subtask is under the sole responsibility of the supplier.

#>

<# QA114-REQ-0027

When the upstream analysis and downstream analysis are independent, the output(s) of the (upstream) subtask need(s) to be reviewed and accepted by F4E before they are used as input(s) in the downstream subtask.

- The (upstream) analysis report(s) from which outputs are taken as input data for a downstream subtask shall be the latest current issue accepted by F4E. The identification number (including revision index) of the (upstream) analysis report(s) shall be referenced in the analysis report
- When outputs taken from (upstream) analysis report(s) are used directly as input data, justification shall be provided in the analysis report. In particular, justification shall be provided to explain why no multiplying factor is necessary to account for the uncertainties attached to the outputs, if any.
  If the outputs of (upstream) analysis reports are not used directly as input data but the input data are determined from these outputs, the way they (input data) are defined shall be clearly explained and justified in the analysis report which makes use of them
- When necessary, a separate report related to the definition of the input data from the outputs of (upstream) analysis reports may be the preferred solution. In this case the identification number (including the revision index) of this report shall be referenced in the analysis report.
- If the outputs of (upstream) analysis reports are not used directly as input data but the input data are determined from these outputs, the way they (input data) are defined shall be clearly explained and justified in the analysis report which makes use of them

#>

The reference data or **type (3)** input data, are selected by the supplier by reference to established physical data, experiment or other appropriate means. Input data determined by the supplier from an analysis he performed for another contract are also considered as type (3) data.

<# QA114-REQ-0028

Prior to their use in the analysis report, the selected value of these input data as well as their justification shall be transmitted to F4E for review. The use of these input data is only permitted after the positive result of the review by F4E is forwarded to the supplier. They shall be clearly identified in the analysis report

#>

<# QA114-REQ-0029

The selection by the supplier of input data by reference to established physical data, experiment or other appropriate means should be clearly identified, referenced, explained and justified in the analysis report. This includes uncertainties and technical assumptions in the selection of input data which shall be clearly explained and justified in the analysis report. The required justification shall take into account the sensitivity of the results to the input data as identified in the verification/validation process.

#>

<# QA114-REQ-0030

All uncertainties and technical assumptions in the selection of type (2) and type (3) input data shall be clearly explained and justified in the analysis report. The required justification shall take into account the sensitivity of the results to all the input data as identified in the verification/validation process.

#>

Using up-to-date input data for a specific analysis means that the input data are to be the current latest ones made available by F4E (type (1) data) or by the supplier (types (2) and (3) data), and including reference to the applicable version. For Type (1) data using the configured data system eliminates the risk of using obsolete input data. Especially for data of type (3), using up-to-date data also means that the data are conforming to the latest available knowledge.

<# QA114-REQ-0031

The traceability of the input data shall be ensured.

#>

This requirement is important from a safety perspective as it concerns the interfaces between the various analyses, specifically where design covers multidisciplinary disciplines or is spread between various suppliers. Having referenced data, which is traceable, is a pre-requisite for the verification of the consistency between the various analyses.

3.8. Flowchart

A flowchart of the process relating to F4E contracts requiring complex analyses and or computational modeling (such as FEA, CFD models) is attached at Appendix 1.

Appendix 1 : Flow Chart