Risk Based Qualification of New Technology - Methodological Guidelines

April 2020

Guidance Note
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BUREAU VERITAS MARINE & OFFSHORE

GENERAL CONDITIONS

1. INDEPENDENCE OF THE SOCIETY AND APPLICABLE TERMS

1.1 The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.

1.2 The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.

1.3 The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, designer, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of them above listed being relieved of any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 The Society only is qualified to apply and interpret its Rules.

1.5 The Client acknowledges the latest versions of the Conditions and of the applicable Rules applying to the Services' performance.

1.6 Unless an express written agreement is made between the Parties on the applicable Rules, the applicable Rules shall be the Rules applicable at the time of entering into the relevant contract for the performance of the Services.

1.7 The Services' performance is solely based on the Conditions. No other terms shall apply whether express or implied.

2. DEFINITIONS

2.1 **"Certificate(s)"** means classification or statutory certificates, attestations and reports following the Society's intervention.

2.2 **"Certification"** means the activity of certification in application of national and international regulations or standards, in particular by delegation from different governments that can result in the issuance of a Certificate.

2.3 **"Classification"** means the classification of a Unit that can result or not in the issuance of a classification Certificate with reference to the Rules. Classification is an appraisement given by the Society to the Client, at a certain date, following surveys by its surveyors on the level of compliance of the Unit to the Society's Rules or to the documents of reference for the Services provided. They cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

2.4 **"Client"** means the Party and/or its representative requesting the Services.

2.5 **"Conditions"** means the terms and conditions set out in the present document.

2.6 **"Industry Practice"** means international maritime and/or offshore industry practices.

2.7 **"Intellectual Property"** means all patents, rights to inventions, utility models, copyright and related rights, trade marks, logos, service marks, trade dress, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database rights, topography rights, moral rights, rights in confidential information (including know-how and trade secrets), methods and protocols for Services, and any other intellectual property rights, in each case whether capable of registration, registered or unregistered and including all applications for and renewals, reversions or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.

2.8 **"Parties"** means the Society and Client together.

2.9 **"Party"** means the Society or the Client.

2.10 **"Register"** means the public electronic register of ships updated regularly by the Society.

2.11 **"Rules"** means the Society's classification rules and other documents. The Society's Rules take into account at the date of their preparation the state of currently available and proven technical minimum requirements but are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.

2.12 **"Services"** means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to: ship and company safety management certification, ship and port security certification, maritime labour certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board. The Services are carried out by the Society according to the applicable referential and to the Bureau Veritas' Code of Ethics. The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

2.13 **"Society"** means the classification society **'Bureau Veritas Marine & Offshore SAS'**, a company organized and existing under the laws of France, registered in Nanterre under number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.14 **"Unit"** means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

3.1 Subject to the Services requested and always by reference to the Rules, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enter the Unit's class in the Society's Register;
- survey the Unit periodically in service to note whether the requirements for the maintenance of class are met.

The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

3.2 The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

4.1 The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit for surveys; and (iii) inform the Society in due time of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates are only valid if issued by the Society.

4.3 The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

4.4 The Society may at times and at its sole discretion give an opinion on a design or any technical element that would 'in principle' be acceptable to the Society. This opinion shall not presume on the final issuance of any Certificate or on its content in the event of the actual issuance of a Certificate. This opinion shall only be an appraisal made by the Society which shall not be held liable for it.

5. ACCESS AND SAFETY

5.1 The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawing, etc. required for the performance of the Services must be made available in due time.

5.2 The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

6.1 The provision of the Services by the Society, whether complete or not, involve, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.

6.2 Without prejudice to any other rights hereunder, in case of Client's payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interests equal to twelve (12) months LIBOR plus two (2) per cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold Certificates and other documents and/or to suspend or revoke the validity of Certificates.

6.3 In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to solve the dispute.

7. LIABILITY

7.1 The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:

- Indirect or consequential loss;
- Any loss and/or deferral of production, loss of product, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case whether direct or indirect.

The Client shall defend, release, save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

7.2 Except in case of wilful misconduct of the Society, death or bodily injury caused by the Society's negligence and any other liability that could not be, by law, limited, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cents (150%) of the price paid by the Client to the Society for the Services having caused the damage. This limit applies to any liability of whatsoever nature and howsoever arising, including fault by the Society, breach of contract, breach of warranty, tort, strict liability, breach of statute.

7.3 All claims shall be presented to the Society in writing within three (3) months of the completion of Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

8.1 The Client shall defend, release, save, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services (including for damages arising out of or in connection with opinions delivered according to clause 4.4 above) except for those claims caused solely and completely by the gross negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

9.1 The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2 In such a case, the Classification granted to the concerned Unit and the previously issued Certificates shall remain valid until the date of effect of the termination notice issued, subject to compliance with clause 4.1 and 6 above.

9.3 In the event where, in the reasonable opinion of the Society, the Client is in breach, or is suspected to be in breach of clause 16 of the Conditions, the Society shall have the right to terminate the Services (and the relevant contracts associated) with immediate effect.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible or liable for any failure to fulfil any term or provision of the Conditions if and to the extent that fulfilment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2 For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contaminations, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts.

11. CONFIDENTIALITY

11.1 The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, are treated as confidential except where the information:

- is properly and lawfully in the possession of the Society;
- is already in possession of the public or has entered the public domain, otherwise than through a breach of this obligation;
- is acquired or received independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure.

11.2 The Parties shall use the confidential information exclusively within the framework of their activity underlying these Conditions.

11.3 Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

11.4 Without prejudice to sub-clause 11.1, the Society shall have the right to disclose the confidential information if required to do so under regulations of the International Association of Classifications Societies (IACS) or any statutory obligations.

12. INTELLECTUAL PROPERTY

12.1 Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.

12.2 The Intellectual Property developed by the Society for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain the exclusive property of the Society.

13. ASSIGNMENT

13.1 The contract resulting from to these Conditions cannot be assigned or transferred by any means by a Party to any third party without the prior written consent of the other Party.

13.2 The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14. SEVERABILITY

14.1 Invalidity of one or more provisions does not affect the remaining provisions.

14.2 Definitions herein take precedence over other definitions which may appear in other documents issued by the Society.

14.3 In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

15.1 These Conditions shall be construed and governed by the laws of England and Wales.

15.2 The Parties shall make every effort to settle any dispute amicably and in good faith by way of negotiation within thirty (30) days from the date of receipt by either one of the Parties of a written notice of such a dispute.

15.3 Failing that, the dispute shall finally be settled under the Rules of Arbitration of the Maritime Arbitration Chamber of Paris ("CAMP"), which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be Paris (France). The Parties agree to keep the arbitration proceedings confidential.

16. PROFESSIONAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, economic and trade sanctions (including but not limited to US sanctions and EU sanctions) and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption, copyright and trademark protection, personal data protection (https://personaldataprotection.bureauveritas.com/privacypolicy).

Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for hereunder, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official, or candidate.

16.2 In addition, the Client shall act consistently with the Bureau Veritas' Code of Ethics. https://group.bureauveritas.com/group/corporate-social-responsibility

GUIDANCE NOTE NI 525

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SECTION 1 GENERAL

1 Introduction

1.1 Application

1.1.1 The purpose of this note is to provide a methodological guideline to qualify a technology using a risk based approach.

The objective is to identify failure modes for the technology and to ensure the associated risks are reduced to an acceptable level thanks to a number of qualification activities.

In the case of technologies which are not covered by existing recognized requirements (e.g. rules, standards, codes of practice), technology qualification can be used to demonstrate that are given technology provides an acceptable level of confidence.

1.1.2 The methodology for qualification of technologies given by this Note may be used to qualify, for example:

- unproven equipment or system
- unproven integration of equipment into a system
- system with unproven parts
- technology not covered by recognized requirements
- technology without relevant experience history.

1.1.3 Other use of technology qualification may typically be:

- to confirm feasibility and absence of show-stoppers that may prevent the technology from being developed to maturity
- to confirm readiness of the technology to go to the next stage of development
- to confirm readiness of the technology for specific application
- to support testing phases of a technology.

1.1.4 Bureau Veritas should be involved in the qualification process at the earliest stage, typically at the initial concept phase. However we consider that it should be possible to be involved in the qualification of a technology during advanced stages of its development.

1.1.5 Statement issuance

Statements may be issued at intermediate stages of the qualification or at completion of the technical development stages:

- Statement further to technology assessment
- Endorsement of qualification plan
- Approval in principle or statement of compliance (i.e. Third Party Attestation).

1.1.6 Technology qualification plan

The Applicant/Inventor and the Society will agree on the most suitable course of actions to be followed for validating the qualification process depending on the maturity of the technology.

Qualification activities identified through the process are gathered into a Technology Qualification plan.

1.2 Regulatory context

1.2.1 General

In the case of a technology, usually a product or a system, which is intended to be placed on board a Marine Unit, the Regulations and Rules applicable to that Unit have to be taken into consideration during the qualification process. Typical Regulations and Rules may be:

- International Rules:
  - International Conventions of the International Maritime Organisation like SOLAS or MARPOL and associated circulars or guidelines
  - Specific Rules of the Unit's Flag Administration
  - Recognized Rules for industrial installations
- Bureau Veritas Rules for Classification:
  - NR467 Rules for Steel Ships
  - NR445 Rules for Offshore Units
- Standards and Guidance notes:
  - ISO/IEC
  - API
  - EN
  - BS
  - OCIMF
  - SIGTTO
  - NORSOK

1.2.2 Technology and alternative design

When a technology comprises innovations that deviate from applicable prescriptive statutory regulations (e.g. SOLAS Convention), the provisions of the relevant IMO Guidelines have to be followed to run an approval process to the satisfaction of the concerned vessel's Flag Administration. Reference is made to IMO Guidelines MSC.1/Circ.1002, MSC/Circ.1212, IMO MSC.1/Circ.1455 and amendments thereto as applicable.

1.3 Definitions

1.3.1 Acceptance criteria

Acceptance criteria mean a set of statements, each one specifying functional and/or non-functional requirements with a clear pass/fail result, applied at a given stage of the qualification process

1.3.2 New technology

New technology means a technology which is not yet experienced or proven such as:

- a significant improvement over an already proven technology and/or a specific historical context
- a well proven production technique being used for a different purpose than the one for which it has been developed
- a totally new technology
- other cases as agreed with the Society.

1.3.3 Qualification

Qualification means confirmation by assessment and documented evidence (including tests records) that the new technology is able to satisfy acceptance criteria for the specific use in the specified environment.

1.3.4 Reliability

Reliability means the probability of an item or system to adequately perform a required function under stated conditions of use and maintenance for a stated period of time.

2 General methodological approach

2.1 General principle

2.1.1 The basic principle of qualification is to simulate, as realistically as possible, the service conditions for which a new technology is designed and to verify that its use or its results provide a sufficient level of confidence.

2.1.2 The design, manufacturing, testing, quality controls, and product quality and reliability assessment necessary to demonstrate that the product initially and continuously meets the specified requirements are to be addressed and included in the qualification requirement. In addition, to the greatest extent possible, intended applications and operating environments must also be understood and considered.

In order to accomplish these objectives, product design, manufacturing materials, workmanship, conformance testing, and surveillance should be evaluated. Each of these elements should be reviewed and considered for applicability to the technology and products being considered for qualification.

2.1.3 Optimisation

The time frame and the costs are also important parameters: it is often impossible to perform tests for the duration of the entire expected life of the product that uses a new technology and the qualification is to be optimised with regards to the expected results.

2.2 Qualification process

2.2.1 Basic qualification process

In principle, and unless otherwise stipulated by the Society, the methodological approach consists, but not limited to 4 main steps as follows:

a) Technology qualification basis, see Sec 2.

This first step aims to define the qualification scope by describing the new technology.

b) Technology assessment, see Sec 3.

This second step aims to identify risks while evaluating the maturity of the new technology.

c) Qualification plan, see Sec 4.

This third step aims to define the qualification program scheme to be implemented on a case by case basis.

d) Execution of qualification plan, see Sec 5

This last step aims to adopt and execute the qualification program.

In addition, an optional benchmarking step may be considered to compare new technologies, see Sec 6.

Flowchart on the approach is shown in Fig 1.

2.2.2 Qualification process during project development

The level of uncertainties is to be lowered to a minimum during the project development phase and the qualification process should be used to assess the uncertainties, to eliminate doubts or to identify miss outs if any, considering the identified requirements and Applicant/Inventor's specifications.

The technology qualification may be used to support the development of the technology:

- along the entire project from the beginning to the end; or,
- partially, at different stage of maturity to update and verify the design at different stages.

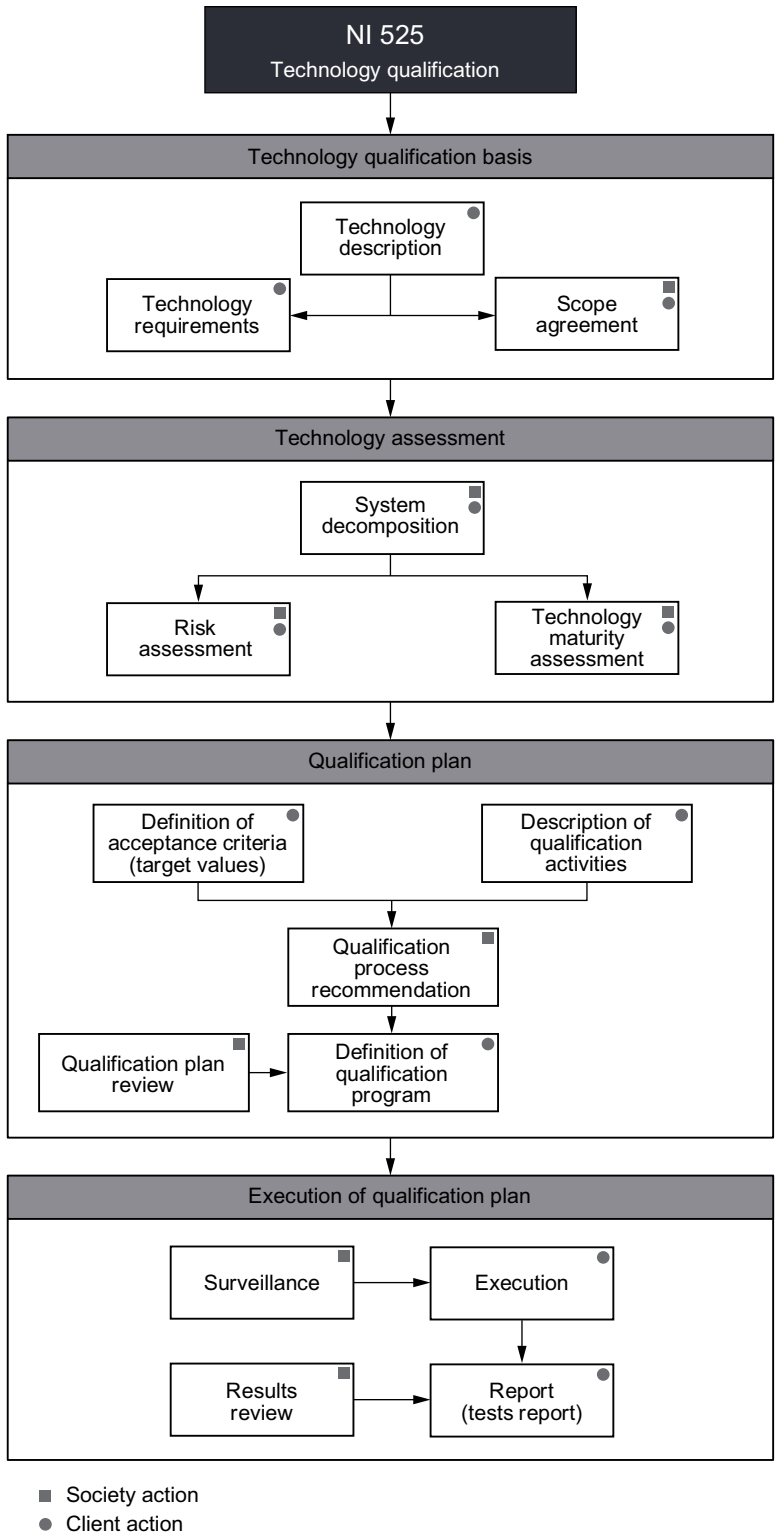
2.2.3 Iterative process

Whenever the technology needs to be redesigned during the project development, a re-qualification may be necessary depending on the extent and nature of the change and the iteration process.

In any case, the qualification procedures necessary to assure the quality targets are to be maintained and duly defined for the design changes; particularly when the complexity of the technology requires a new baseline or redefinition of parameters in terms of criticality, performance, quality and reliability of the technology.

Depending on the criticality of the change, the re-qualification process can range from simply validating the change by performing discrete or particular tests, to a full re-qualification if so considered necessary by the Society.

Figure 1 : Basic qualification process



SECTION 2 TECHNOLOGY QUALIFICATION BASIS

1 Introduction

1.1 General

1.1.1 To establish the basis of technology qualification it is necessary to set the provisions for qualification through the technology description and finding the requirements for its assessment by identifying:

- intent of technology development
- environment of technology
- the expected life cycle of technology
- the specific use of the technology in any specified condition
- the responsibility matrix
- the acceptance criteria:
  - non functional (Design, Conformity & QA/QC)
  - functional (Performance, Set of objectives).

1.1.2 The technology qualification basis typically includes:

- the technology description, see [2]
- the technology requirements, see [3]
- the scope agreement, see [4].

1.2 Supporting documents

1.2.1 The technology qualification basis is supported by the following documents, when relevant:

- project description documents:
  - design briefs
  - general arrangement
  - basis of design
- system description documents:
  - process and instrument drawing (P&ID)
  - process flow diagrams (PFD)
  - design criteria
- operation and service description documents:
  - installation documentation (procedures, tolerances)
  - operation documentation
  - maintenance documentation (procedures, maintenance requirements for servicing and repair).

2 Technology description

2.1 General

2.1.1 The technology qualification basis is to cover a complete technology description capable for demonstrating the ability of technology to meet the objective.

2.1.2 The performance, quality and reliability aspects of the products are to be fully understood and taken into consideration for completing the qualification program.

2.1.3 Depending of the type and the relevance of the considered technology, the following information are to be given:

- description of the intent of technology development
- description of design (equipment list, properties, fabrics, materials environment, system interface...)
- description of material properties and manufacturing:
  - manufacturing techniques
  - requirements for controlling the manufacturing processes
  - restraints and trouble-shooting found to industrialization
- description of operational modes and functional principles
- stage of development, whether in a status of concept, prototype, patented, market recognition and life cycle of technology
- description or requirements for maintenance philosophy
- list of relevant standards, codes or other relevant documents
- existing certifications, if any in other contexts or use
- description of the Research & Development Methodology selected by the Applicant/inventor
- similarities with other technology.

3 Technology requirements

3.1 General

3.1.1 The technology requirements are defined by functional and non functional characteristics required by:

- adopted standards of reference
- market needs
- environmental and operational constraints as applicable, depending on:
  - design
  - manufacturing and quality controls
  - testing
  - finished product reliability
  - business opportunity assessment demonstrating the suitability of the technology in the market.

3.2 Functional requirements

3.2.1 The functional requirements are to be defined by the acceptance criteria against which the results of the qualification activity is evaluated, whereas performance criteria may be given by a qualitative and/or quantitative means.

4 Scope agreement

4.1 General

4.1.1 For each qualification of technology, the process should be agreed at the beginning between Applicant/Inventor and the Society with:

- technology description
- general arrangement of the technology
- applicable documents and parts of standards - design basis
- description of technology requirements, goals and process
- description of each party obligations
- description of deliverables
- project time line.

SECTION 3 TECHNOLOGY ASSESSMENT

1 General

1.1 Application

1.1.1 The purpose of the technology assessment is to identify the uncertainties associated to the new aspects of the technology in order to help to identify the technology qualification activities required.

1.1.2 For the purpose of this note, the technology assessment comprises three modules:

- system analysis, see [2]
- technology maturity assessment, see [3]
- risk assessment, see [4].

1.2 Supporting documents

1.2.1 The technology assessment is supported by the following documents, when relevant:

- documents from qualification basis as defined in Sec 2
- technology items drawings
- system decomposition report with functional description
- technology maturity assessment report
- risk assessment reports.

1.3 Technology assessment report

1.3.1 At the end of this step, a technology assessment report is issued by the Applicant/Inventor indicating the results of the three modules mentioned in [1.1.2].

2 System analysis

2.1 General

2.1.1 When designing a qualification program, the technology and the individual products are to be carefully examined.

The technology and/or the products are to be examined in order that, the Society and the Applicant/inventor have a common understanding on the intent of the considered technology.

This process consists of a bottom-up approach, thus making the systems and sub-systems to emerge from the whole so the processing of information can be identified as incoming data being objectively and clearly perceived.

2.2 Functional description

2.2.1 Functional description aims at identifying all the functions performed by the system and the necessary inter-relations between them to properly perform a given task. So, the Society and the Applicant/Inventor can clearly understand the purpose of the system and the interactions of the various components when running the risk assessment.

2.2.2 Operational modes

The analysis focuses on the operation phase only. Failures or human errors occurring during previous phases are to be established.

2.2.3 Functions description

For the purpose of the present note, functions may be classified as follows, depending on the type of technology or product:

- Principal Functions (PF):

  The basic functions for which the system has been designed, being sub-classified as:

  PF1 : first Principal Function

  PF2 : second Principal Function

  see Tab 1 for general reference.

- Auxiliary Functions (AF):

  Function which is essential for the completion of principal functions, being sub-divided as:

  AF1 : first Auxiliary Function

  AF2 : second Auxiliary Function

  see Tab 2 for general reference.

- Constraint Functions (CF):

  Functions made necessary by the conditions to which the system is exposed due to the combination of different factors and includes only one category identified as:

  CF1 : first Constraints Function

  see Tab 3.

2.2.4 Functional description table

The spreadsheet format as shown in Tab 4 can be adopted to collect the information and define the system by function type when applicable.

Table 1 : Associated detailed principal functions and components

Function type	Component	Function
PF1	X	first Principal Function
PF1	Y	first Principal Function
PF2	Z	second Principal Function
Note 1: The same function can be associated to several components. **Note 2:** The same component can have several functions.		

Table 2 : Associated detailed auxiliary functions and components

Function type	Component	Function
AF1	T	first Auxiliary Function
AF2	U	second Auxiliary Function
Note 1: The same function can be associated to several components. **Note 2:** The same component can have several functions.		

Table 3 : Associated detailed constraints functions and components

Function type	Component	Function
CF1	J	first Constraints Function
CF1	K	first Constraints Function
Note 1: The same function can be associated to several components. **Note 2:** The same component can have several functions.		

Table 4 : Functional analysis table

Function **(1)**	Component **(2)**	Connection from **(3)**	Connection to **(4)**	Comment **(5)**
First function	X	Y	Z	-
First function	Y	S	X	-
Second function	Z	Y	T	-

(1) Function : A concise statement of the function performed by the item, including both the inherent function of the part and its relationship to interfacing items is indicated
(2) Component:This column deals with the name of component
(3) Connection from:This column identifies the component (under analysis or not) that is physically linked to and located upstream the current component
(4) Connection to:This column identifies the component (under analysis or not) that is physically linked to and located downstream the current component
(5) Comment: Any pertinent remarks pertaining to and clarifying any other column in the worksheet line can be recorded here.

3 Technology maturity assessment

3.1 General

3.1.1 Through the technology maturity assessment the level of development of the technology will be considered.

The uniqueness and acknowledgment of technology in the industry is ranked according to Tab 5 taking into account both the level of maturity and the proposed conditions of operation of the technology.

This ranking defines the need for qualification depending on the potential risks of failure.

3.1.2 Ranking is classified herein as a function of three main aspects:

- application conditions experience, see [3.2]
- technical maturity (TRL), see [3.3]
- integration maturity (IRL), see [3.3.4]

The ranking means the following:

- 0: No new uncertainties

  Proven methods, tests, analysis can be used to provide evidence of the technology. No technology qualification activity is needed for these elements, but it is important to take them into account as they may be critical for the overall technology. A criticality assessment against existing standards or codes is normally sufficient.
- 1: New uncertainties

  Light qualification activities are required, based on engineering studies.
- 2: New challenges

  Moderate qualification activities are required, based on tests in addition to engineering studies.
- 3: New risks

  High qualification activities are required, based on combination of different tests and engineering studies.

3.1.3 When all of new technology elements are ranked at level 0, qualification process is not the considered the most appropriate to assess the technology. In general, classic certification (or classification) process may be applicable.

3.1.4 Integration of equipments and sub-systems

For each system, the maturity level can be found at different level:

- System level

Note 1: Example: side-by-side offloading by rigid arm in offshore conditions is new.

- Sub-system level

Note 2: Example: liquefied gas tandem offloading by flexible hoses in offshore conditions. In this case the sub-system “flexible hose” is not proven.

- Equipment level.

In this case the rating should first be done at each level (one rating per new equipment, new sub-system, new system), and consider the integration level as defined in [3.3.4].

Note 3: For example, with a liquefaction process, we will have a different rating:

- for the system (need for a pilot)
- for each sub-system considered as new
- for main equipments.

3.2 Application maturity

3.2.1 The application maturity is defined by the application conditions of the new technology and by two categories:

- Similar:

  The conditions of operation are regarded as the same or not significantly different or not more severe from the conditions for which the technology is proven

- Different:

  The conditions of operation are regarded as significantly different or more severe from the conditions for which the technology is proven or has been used.

Note 1: Thus an onshore system will be considered as "different condition of application" as well as a proven system for floating units in protected area.

3.3 Technical maturity (TM)

3.3.1 General

Technical maturity (TM) is defined as a measure of the development state of the technology.

The following information is necessary:

- a brief description of the technology to be addressed and evaluated, on a technology qualification point of view (see qualification basis in Sec 2
- the operating references (field experience and conditions of operation (site conditions)) for this technology
- the qualifications (studies and/or tests and/or pilots…) already or currently performed for this technology and possible gaps with the operating conditions and parameters stated in Design Basis.

For integrated subsystem or equipment/components, level of maturity of the technology should reflect the degree of uncertainties associated with their integration into the system. The technical maturity is to be adjusted to consider integration maturity level (see [3.3.4]).

Interface analysis is to confirm the compatibility of the item integration. Both functional and physical interfaces should be analyzed.

3.3.2 Technical maturity levels

Globally, four main levels may be considered:

- Proven:

  documented operational references with the applicable conditions of operation (Field proven)

- Limited references:

  Few or short term operational references

- Extrapolated from proven:

  System design based on known and proven technologies with the aim to improve the performance or to adapt it to the new conditions of operations but with no or few operational references

- Unproven:

  Completely new design system or equipment without any reference that is to say systems or equipment ranked 3 according to Tab 5.

Note 1: Examples:

- A technology commonly used onshore would be ranked as proven in different condition.
- A technology with 2 offshore references in more severe conditions of operations would be ranked as limited references in similar conditions.

3.3.3 Technology Readiness Level (TRL)

The technical maturity is in practice generally assessed by using Technology Readiness Level (TRL) which are a measure of the technology development state. Various scales are adopted depending on the domain, for example:

- US DoD: Technology Readiness Assessment deskbook (2009)
- API 17Q: Recommended Practice on Subsea Equipment Qualification (2018)
- US DoE: Technology Readiness Assessment Report (2010)
- EARTO Recommendations: The TRL Scale as a Research & Innovation Policy Tool (2014).

An alternative TRL scale is proposed in Tab 6.

Table 5 : Technology rating

Technology maturity	Application conditions	
	Similar	Different
Proven	0	1
Limited references	1	2
Extrapolated from proven	2	3
Unproven	3	3

Table 6 : Example of Technology Readiness Level scale

TRL		Description
Unproven	1	Basic research: basic principles are stated
	2	Concept developed: concept is proven by analysis
	3	Concept demonstrated: concept is validated by physical model, functionally tested in laboratory, material is tested on key components.
Limited references	4	Prototype developed: prototype is reliability tested in relevant laboratory environments.
	5	Product validated: full scale technology is reliability tested in relevant operating and environmental conditions.
	6	System interface tested: technology is interface and functional tested into relevant operating system (outside the intended operating field)
Proven	7	System installed and commissioned: technology is interface and functional tested in the relevant environment
	8	System operated: technology is operating in intended environment
	9	System operated for a sufficient length of time: technology is operating over full range of intended conditions.

3.3.4 Integration maturity (IM)

When integration maturity (IM) is to be considered to adjust the technology maturity, different approaches may be adopted (e.g. quantitative, qualitative) depending on qualification goals and quality of interaction. The present Note gives an example of general approach which could be followed.

a) As a guidance, technical maturity adjustment should follow the following principles:

- when integration maturity is low (i.e. high uncertainties), technology maturity should be decreased
- when integration maturity is high (i.e. low uncertainties), technology maturity doesn't need to be modified
- when multiple integration maturity with different levels are assigned, the technology maturity should be adjusted taking into account the lowest integration maturity.

Note 1: Applying these general principles on the overall system and considering the rating given in Tab 5:

- a new system designed with at least one new equipment should be considered as new
- a new system designed only with proven equipments should be considered as extrapolated from proven
- a proven system designed with new equipments should be considered as extrapolated from proven.

b) As an example for linear system, the Integration Maturity should modify the TRL according to the following equation:

$TM = \alpha_{IM} .TRL$

where:

TRL : Technology Readiness Level as defined in [3.3]

α_{IM} : Reduction factor depending on integration maturity level.

Note 2: Considering the IM scale given in Tab 7 and TRL is halved when IM is the lowest (i.e. IM = 1), the reduction factor may be expressed by the following linear formula:

$\alpha_{IRL} = 0,17\ IM + 0.33$

Table 7 : Example of integration maturity scale

IM	Description
1	Interface is sufficiently identified to characterized the relationship
2	Interface is sufficiently controlled to established the integration
3	Integration is demonstrated into the system environment
4	Integration is proven

4 Risk assessment

4.1 General

4.1.1 Before establishing the qualification plan and in order to optimize it, criticality of the technology and its items should be assessed.

The criticality analysis makes it possible to highlight the most critical points of the technology under consideration and to decide on which points more effort is to be made as well as the types of tests that are needed to further investigate them.

4.1.2 Risk assessment is to include at least the followings:

- failure identification
- criticality determination.

4.1.3 Unproven items

For items with low technology rating (i.e. less than 2), criticality assessment should be based on a risk assessment method to analyze the possible failures of the technology and their possible consequences, see [4.2].

The design and failure modes that would contribute to reduced performance, quality, and reliability is to be addressed in the qualification program to ensure that failures do not occur in field applications.

4.1.4 Proven items

For proven items, a criticality assessment against existing standards or codes is normally sufficient.

4.1.5 Risk assessment method

Risk assessment method should be adapted to the technology and the purpose of the qualification.

Techniques such Failure Mode, Effect and Criticality Analysis (FMECA) can be used to structure failure analysis. Other techniques may also be accepted, such as HAZOP (recommended for new services), HAZID, SWIFT, FHA, FTA, ETA,

See App 1 for more guidance on risk analysis.

Guidance on HAZID and HAZOP are given in ISO 17776 and IEC 61882 respectively,

Guidance on risk assessment method is given in ISO 31010.

Definition of risk analyses are given in NI 635 Index on applicable risk analysis for Marine and Offshore.

4.2 Failure identification

4.2.1 It can be useful at first to set up a generic hazard list to be applied on each case. This list is not exhaustive as specific hazards could be relevant of specific systems only.

The potential hazards that exist on ships or offshore facilities are well known and documented. In order to ensure that all of the potential accident events are identified, the generic list will be used as a checklist, against which the facilities will be examined to identify the specific hazards for the facilities

Table 8 : Typical failure modes

1	Structural failure (rupture)	12	Fails out of tolerance (low)	23	Delayed operation
2	Physical binding or jamming	13	Inadvertent operation	24	Erroneous input (increased)
3	Vibration	14	Intermittent operation	25	Erroneous input (decreased)
4	Fails to remain (in position)	15	Erratic operation	26	Erroneous output (increased)
5	Fails to open	16	Erroneous indication	27	Erroneous output (decreased)
6	Fails to close	17	Restricted flow	28	Loss of input
7	Fails open	18	False actuation	29	Loss of output
8	Fails closed	19	Fails to stop	30	Shorted (electrical)
9	Internal leakage	20	Fails to start	31	Open (electrical)
10	External leakage	21	Fails to switch	32	Leakage (electrical)
11	Fails out of tolerance (high)	22	Premature operation	33	Other unique failure conditions as applicable to the system characteristics, requirements and operational constraints

4.2.2 Hazard groups

The Hazard Group describes the type of event which if realized, has the potential to cause serious injuries or fatalities. Typical Hazard Groups are as follows:

- Structural Failure
- Equipment Failure
- Dropped Objects
- Containment Failure
- Helicopter Crash
- Control/Safety System Failure
- Fire/Explosion
- Toxic release
- Loss of propulsion
- Loss of steering gear
- Flooding
- Loss of buoyancy
- Loss of stability
- Loss of station keeping
- Grounding
- Stranding
- Collision
- Smoke
- Occupational Incidents
- Excessive ship motions.

4.2.3 Failure modes

Typical failure modes are as listed in Tab 8.

Refer also to IEC Publication: IEC 60812 (2006), Analysis techniques for system reliability–procedure for failure mode and effects analysis (FMEA).

4.3 Safety criticality determination

4.3.1 Determination of the safety criticality (considering structure integrity, health and environment) of each item is derived via simple combination of the determined severity and failure probability factors and by reference to Tab 9 for which five critical zones are proposed.

Table 9 : Safety criticality rating matrix

F - Factor		S - factor				
	5	C3	C4	C5	C5	C5
	4	C3	C4	C4	C4	C5
	3	C2	C3	C3	C4	C4
	2	C1	C2	C2	C3	C3
	1	C1	C1	C2	C2	C3
		1	2	3	4	5

Note 1:

C1 : Non critical equipment
C2 : Low critical equipment
C3 : Moderately critical equipment
C4 : Critical equipment
C5 : Highly critical equipment

Safety criticality ratings form the basis for deciding which items of equipment should be subject to more detailed qualification activities and for providing guidance concerning the scope and level of qualification activities that should be undertaken. Recommendations on qualification assessment activities according to criticality levels are given in Sec 4, [4].

4.3.2 Criticality rating

The criticality (C) is defined as the product of the probability of occurrence or frequency (F) of the event and the potential consequences or severity (S).

$C = F \times S$

or in logarithmic format:

$\log C = \log F + \log S$

Typically examples of rating are given in Tab 11 and Tab 10.

Frequency is defined with respect to the mode of failure taking into account the failure effects on the system itself.

4.3.3 Evaluation of functional failure probabilities and allocation of the appropriate frequency factor will be based upon an assessment of input data from various relevant sources such as, for example:

- recognized generic reliability databanks, reference books etc

- advices from Engineering/Procurement/Construction (EPC) contractor
- advices from Operator
- information from Vendor/Manufacturer.

4.3.4 Consequence of failure (Severity - S)

Consequence of failure provides a qualitative measure of worst potential consequences impacting for example:

- operation and availability of the technology
- environment
- health and safety
- property
- economical aspects.

Typical example of severity ratings are given inTab 10.

4.3.5 Failure probability (Frequency - F)

Failure probability provides a ranking of probability of occurrence of a failure. Probability may be assessed by a qualitative or quantitative way.

Typical example of frequency ratings are given in Tab 11.

Table 10 : Severity factor S

F	Severity	Definition
1	Negligible	No damage to personnel, safety functions fully available Non significant spill, minor environment impact No off-site impact/damage No economic loss, negligible effect on production performance
2	Minor	Light injuries to personnel and/or local damage to safety functions A few barrels of pollution to sea, moderate environment impact, Minor off-site impact Minor economic loss, partial loss of production performance where maintenance is not required outside maintenance plan
3	Severe	Serious injuries to personnel and/or large local damages to safety functions A few tonnes of pollution to sea. significant environmental impact, Situation is manageable Moderate off-site impact limited to property damage or minor health effects Severe economic loss, partial loss of production performance where maintenance is required in addition to maintenance plan
4	Critical	One fatality, or less than 10 on-site permanent disabling injuries, impairment of safety functions Serious environment impact, Significant pollution demanding urgent measures for the control of the situation and/or cleaning of affected areas Significant off-site property damage or short term health effects to public Critical economic loss, total loss of production performance
5	Catastrophic	Multiple fatalities and/or 10 or more on-site permanent disabling injuries also outside the event area, total impairment of safety functions Extensive environment impact. Major pollution with difficult control of situation and/or difficult cleaning of affected areas Extensive off-site property damage, fatalities or short term health effects to public Major economic loss, total loss of production performance where major repair is needed

Table 11 : Frequency factor F

F	Annual frequency	Definition
1	$< 10^{-4}$	Extremely improbable: not expected in the system life Simple design; proven reliable design; simple production techniques; standard infrequent or no maintenance; insignificant levels of operating conditions
2	10^{-4} to 10^{-3}	Improbable: not anticipated in the system life Standard design; minimal modification to reliable design; standard production techniques easy verification; standard frequent maintenance; low level of operating conditions
3	10^{-3} to 10^{-2}	Remote: should not happen in the system life Design with no external interfaces; significant modifications to proven design; difficult production techniques with easy verification; complex and frequent maintenance; high levels of operating conditions
4	10^{-2} to 10^{-1}	Reasonably probable: expected a few times in the system life Complex design with few interfaces; the new design is based upon established design techniques not easy verification; complex production techniques; extremely limited maintenance possibility; very high levels of operating conditions
5	$> 10^{-1}$	Extremely probable: expected several times in the system life Complex design with significant external interfaces; new design/new design techniques; new production techniques; no possible maintenance; severe levels of operating conditions

SECTION 4 QUALIFICATION PLAN

1 General

1.1 Application

1.1.1 A qualification plan is established to provide evidence that risks identified during the technology assessment (see Sec 3) are adequately addressed.

1.1.2 The purpose of the qualification plan is threefold:

a) To finalize selection of equipment items that are to be subjected to qualification activities.

b) To develop an integrated qualification work program, in which specified assessment activities are pre-planned and scheduled so as to minimize costs and interruption to normal fabrication operations during subsequent program execution.

c) To define the extent and detail of the qualification activities that are to be undertaken on each selected item to assess the qualification program.

1.2 Qualification plan set up

1.2.1 General

Qualification plan includes the followings main steps:

- qualification activities definition, see [2]
- acceptance criteria for each qualification activity, see [3]
- qualification recommendations, see [4]
- qualification plan schedule, see [1.2.2].

1.2.2 Qualification plan schedule

Qualification plan schedule aims to:

- identify qualification activities to validate
- give acceptance criteria
- describe tests to be performed
- describe the planning
- identify the responsibilities
- specify the surveillance and inspection requirements.

1.2.3 Update of qualification plan

During the qualification process and during the development of the technology, iterative process may be followed to take into account feedback from the different development stages. To reflect this iterative process, qualification plan is to be revised as necessary to incorporate the improvements and modifications of the technology (see [2.1.3]).

1.3 Supporting documents

1.3.1 The qualification plan is supported by the following documents:

- technology items specification, see Sec 3
- criticality assessment report, see Sec 3
- qualification program report with description of qualification activities and acceptance criteria, see [1.2.2].

1.4 Deliverables

1.4.1 Qualification plan endorsement is issued upon satisfactory review of the qualification plan.

2 Qualification activities

2.1 General

2.1.1 First step to establish the qualification plan is the definition of qualification activities: the qualification plan is to select the required activities to be performed in order to address the key issues resulting from the technology assessment (see Sec 3). Selected activities are to be adapted to the criticality level as defined in Sec 3, Tab 9. They consist in combining both engineering analysis and test programs, including evaluation of design, manufacturing materials, workmanship, conformance testing and surveillance.

Note 1: As a guidance, qualification recommendations are given in Article [4].

Each of these elements should be reviewed and considered for applicability to the technology and products being considered for qualification.

2.1.2 Qualification activities may generally be grouped into the following different categories:

- engineering analysis, see [2.2]
- testing, see [2.3]
- manufacturing, see [2.4.2]
- surveys and inspections, [4.1]
- quality system.

2.1.3 Iterative activities

When considered technology is subjected to improvements (e.g. design changes), qualification plan is to be updated to reflect these modifications and to identify the required associated qualification activity to check the improvements.

2.2 Engineering analysis

2.2.1 Engineering analyses are one of main type of activity to provide qualification technology evidence. They include, but not limited to, the following analysis:

- recognized experience analysis, see [2.2.2]
- analytical analysis, see [2.2.3]
- numerical analysis, see [2.2.4].

2.2.2 Recognized experience analysis

Recognized experience can be available for sub-system or parts of the technology and thus be a valuable source of qualification evidence. Even if the existing experience is not directly applicable to the considered technology, recognized experience can support the qualification of the technology by adaptation to fit the new technology and comparison to take differences into account.

Recognized experience analysis may be based on documented experience, including:

- damage experience related to the considered technology
- operational data
- experience from previous survey
- service experience in similar field of application
- background information on similar types of technology operated in similar conditions.

2.2.3 Analytical analysis

Analytical analysis may include when relevant:

- Empirical formulas or solutions
- Existing methods from standards or good practice
- Prediction methods:

  Prediction methods are based on an analytical assessment of behavior of materials of the product taking into account a specified design environment and a specified design lifetime.

  The definition of adequate prediction methods requires the analysis and knowledge of Environmental Stress Factors (ESF) (Elevated temperature, oxygen, mechanical load, water, ozone, UV radiation, etc) and the corresponding aging mechanisms (physical, chemical, combined) which lead to the reduction of lifetime of the product in the specified environment.

  Prediction methods are generally based on assumptions and theoretical simplification of real physical or chemical degradation phenomena. When they exist they need sometimes to be re-calibrated by tests to fit with a particular or new application.

When analytical analysis deemed not satisfactory to be sufficiently confident, tests are generally to be performed to validate the predicted behavior or parameters.

2.2.4 Numerical analysis

Numerical analysis may include when relevant:

- direct calculation
- Finite Element Model (FEM) analysis
- Computational Fluid Dynamics (CFD) calculation
- simulation models
- corrosion models.

Note 1: Numerical analysis may concern different category of analysis, such as electrical analysis, stress analysis, buckling analysis, vibration investigation, fatigue analysis, flexibility analysis, deformation analysis.

When numerical analysis deemed not satisfactory to be sufficiently confident, tests are generally to be performed to validate the predicted behavior or parameters.

2.3 Testing

2.3.1 The specific testing qualification requirements should be clearly specified and documented.

The testing (compliance, quality, and reliability assessments) should be developed to detect and eliminate early failure modes. It should also demonstrate that the system/equipment meets the performance and reliability requirements.

2.3.2 Regarding the physical tests, the model's size and the test's duration should be as close as possible to the size and the design life time of the equipment. Since it is not always feasible to come close to these conditions, reduced models can be used as well as accelerated time testing procedures

2.3.3 Materials testing

The materials and processes used in the system/equipment should be understood to determine the type of incoming inspection, testing, and traceability provisions that need to be reviewed and controlled during the qualification process.

Certain materials could be sufficiently critical to the ultimate performance of the system/equipment that a baseline may need to be established, just as was required for design and manufacturing.

The process and materials used in the system/equipment become an integral part of the actual qualification program.

2.3.4 Repeated testing

The use of repeated tests is a means to reduce the uncertainty on the results and on the extrapolation to real systems by using statistical methods. However, this is only possible for component produced in important series or at low cost.

2.3.5 Long term testing

The purpose of tests could be threefold:

- recalibration of theoretical prediction methods
- empirical determination of degradation laws
- confirmation of prediction.

Repeated long term testing in the expected environmental conditions is generally considered as the most efficient qualification method but for practical and financial reasons this type of testing is not always possible.

These considerations lead to the necessity to define and use accelerated tests methods.

2.3.6 Accelerated tests methods

The determination of accelerated tests consists of four steps:

a) Definition of environment in which the product/material will evolve (elevated temperature, oxygen, mechanical load, water, ozone, UV radiation, etc).

b) Identification of degradation mechanisms (physical, chemical, combined).

c) Identification of accelerating factors: combined loads (fatigue, static); temperature (isothermal, cyclic); hygrothermal; oxygen, etc..

d) Identification of indicators (residual strength, stiffness, fatigue life, etc.).

Once these steps have been performed it is necessary to define a level of application of accelerating factors and a duration of accelerated test representative of the product lifetime.

The methods development to determine the time reduction in function of the level of application of the accelerating factor could be either empirical using as input the ESF in tests protocols or analytical using as input the controlling variables (geometry, loading history, material properties, etc.).

2.3.7 Working test

Working test includes, but is not limited to, when relevant checking of:

- alarms and safety devices
- power supply
- proper condition of the technology items and their protection from water, ice formation and mechanical damage
- operation of main and auxiliary machinery.

2.3.8 Pressure test

Pressure test includes for example, but is not limited to, when relevant checking of:

- integrity of pipings
- main and auxiliary engines and turbines components
- pumps and other machinery items (air compressors, heat exchangers, ventilation fans for boilers and other equipment used for essential services, piston pumps and centrifugal pumps, screw pumps, gear pumps)
- refrigerating installation
- rudder
- hydraulic device
- independent tank, integral tank and membrane containment systems
- air cooler and coils
- pressure relief valve
- watertight and semi-watertight doors
- boilers and other pressure vessels including their associated fittings which are under internal pressure
- mechanical joint
- hydrostatic jacking unit
- casing of the housing.

2.3.9 Performance test

Performance test includes, but is not limited to, when relevant checking of:

- operation is in accordance with the requirements specified (automatic systems or equipment)
- self-monitoring features
- protection against specified conditions.

2.3.10 Power supply test

Power supply test includes, but is not limited to, when relevant checking of:

a) Variation

b) Failure:
   - specified action of the equipment on loss and restoration of supply in accordance with the system design
   - possible corruption of program or data held in programmable electronic systems, where applicable.

2.3.11 Onboard tests

a) Trials at mooring

   Trials at the moorings include, but are not limited to, when relevant:
   - satisfactory operation of the machinery
   - quick and easy response to operational commands
   - protection of the various installations (mechanical parts, safeguards for personnel).

b) Sea trials

   Sea trials includes, but is not limited to, when relevant checking of:
   - response of mechanical, hydraulic, electronic system as predicted for intended operational modes (e.g. integration tests for electronically controlled engines)
   - proper operation of the control system of propulsion machinery
   - satisfactory performance of the deck installations, main propulsion system and essential auxiliaries, including safety devices, monitoring and alarms
   - anchoring
   - steering gear
   - automation systems
   - dangerous vibration
   - proper functioning of the devices for emergency operations
   - wireless data communication equipment

     (radio-frequency transmission not to cause failure of any equipment and its self-fail as a result of electromagnetic interference during expected operating conditions).

2.4 Quality assurance and quality control

2.4.1 Quality assurance and quality control (QA/QC) ensure capability and performance against proven quality principles and ensure the processes are followed and acceptance requirements are met during multiple phases of technology qualification, which include inspection, repair, assembly function testing, load-out, completion.

QA/QC includes, but not limited to, when relevant:

- audit of works (product control, dimensional conformance, process control, good manufacturing practice,...)
- quality management system
- QA manual
- certification
- fabrication surveillance and inspection
- traceability system
- personnel qualification (especially welders, NDT operators, heat treatment...).

QA/QC may concern the global supply chain (the manufacturer, the factory, the mill, the shop, the yard, the project site location, the laboratory...) and encompass the different phases (design, construction, assembly, testing, load-out, completion, in-service, asset integrity management).

Note 1: The key criteria are policies, procedures and records that would indicate the ability to deliver consistent quality management over time, rather than at one given time or only for certain products.

2.4.2 Manufacturing

The manufacturing process should be assessed to determine which steps are most critical and must be monitored, tested, and controlled to assure continuous system/equipment performance, quality and reliability.

The manufacturing process may be complex enough to actually require that a baseline be established.

Any changes to it would require notification and possible re-qualification.

3 Acceptance criteria

3.1 General

3.1.1 For each qualification activity described in [2], the acceptance criteria should be defined in accordance with the purpose of qualification.

The acceptance criteria is generally expressed in quantitative way (target values as: maximum pressure, temperature, speed,...).

4 Recommendations for qualification assessment activities

4.1 General

4.1.1 Surveillance, surveys and inspections

The qualification plan should also determine the type, extent, scope and frequency (initial or periodic) of the assessments that will be necessary for verification taking into account the system/equipment life cycle, complexity, and criticality should be reviewed to determine the frequency of the assessments that are needed.

4.1.2 During construction

Intervention during construction includes, but is not limited to, when relevant:

- examination of parts of the technology covered by the qualification
- check of quality system
- examination of construction methods and procedures
- check of selected items covered by the qualification
- attendance to tests and trials when deemed necessary.

4.1.3 After construction

Intervention after construction includes, but is not limited to, when relevant:

- external and /or internal examination of relevant items and parts
- attendance to running tests
- check of condition monitoring records
- check of measuring instruments, which are to be re-calibrated or replaced if inaccurate
- check of deflection readings, clearances, witness marks, cracks, conditions of selected items
- dismantling of selected items for inspection
- verification of connection assemblies, locking device.

4.2 Guidance on qualification assessment activities levels

4.2.1 As a guidance, the Society's interventions in relation with qualification activities according to criticality level are given in Tab 1 and described hereafter.

4.2.2 Non-critical equipment (SHE Criticality C1)

No detailed qualification assessment activities are considered necessary for non-critical equipment. Action specified to such equipment will thus be restricted in practice to the review of manufacturer certificate.

Table 1 : Qualification assessment activities levels summary

Qualification Assessment activities		Critically level				
		C5	C4	C3	C2	C1
Quality System						
1	Quality System			X	X	
2	Certified quality system (e.g. ISO 9001)	X	X			
3	QA Manual review	X	X			
4	Audit of Works (frequent: 1/y)	X	X			
5	Audit of Works (moderate: 2-3 y)			X		
6	Quality /IT plans review	X	X	X	X	
Engineering & Design						
1	Design review	X	X	X		
Qualification tests witnessing						
1	Materials	X	X			
2	Prototype tests	X	X	X		
Survey at works						
1	Materials	X	X			
2	During fabrication	X	X			
3	After completion	X	X			
4	Checking or tests	X	X	X		
5	Running tests	X	X	X		
6	Traceability	X	X	X	X	
Documentation						
1	Construction dossier	X	X			
2	Test records and qualification	X	X	X		
3	Manufacturer certificate				X	X

4.2.3 Low critical equipment (SHE Criticality C2)

Detailed qualification assessment activities of low critical equipment will be limited to assessment of manufacturer Quality Assurance (QA). A Standard quality system will be regarded as sufficient. The Quality/IT plans will be reviewed, and assessment work scopes / checklists will be utilized, aiming at providing moderate fault detection confidence for the most probable equipment failure modes mechanisms only.

4.2.4 Moderately critical equipment (SHE Criticality C3)

In general, detailed qualification assessment activities of moderately critical equipment will follow similar lines to that for low critical equipment. In this instance, however, extended application/coverage of Non Destructive Testing (NDT) measurement will be employed for static equipment, aiming at providing the necessary enhanced level of defect detection confidence.

4.2.5 Critical equipment (SHE Criticality C4)

Detailed qualification assessment activities for highly critical equipment will be tailored to each individual item, taking due account of all potential failure modes/degradation mechanisms.

4.2.6 Highly critical equipment (SHE Criticality C5)

In general, detailed qualification assessment activities of super critical equipment will follow similar lines to that for highly critical equipment. In this instance, however, the qualification process will involve a combination of assessment techniques aiming at providing a very high level of fault detection and life durability confidence.

SECTION 5 EXECUTION OF QUALIFICATION PLAN

1 General

1.1 Purpose

1.1.1 Execution of qualification plan consists on performing the qualification activities according to the established qualification plan (see Sec 4) and document the performance of the technology for the concerned activities compared to the acceptance criteria.

1.2 Supporting documents

1.2.1 The execution of the qualification plan is supported by the following documents, when relevant:

- Reports relative to the qualification activities (see [4]), such as:
  - tests reports
  - engineering reports
  - fabrication reports
  - inspection reports
  - Quality Assurance/Quality Control (QA/QC) reports.
- Qualification plan (see Sec 4).
- Performance report to demonstrate compliance of the technology with the technology qualification basis (see Sec 2), including when relevant:
  - margins against target specifications
  - sensibility analysis
  - assumptions and limitations.

2 Execution of qualification activities

2.1 General

2.1.1 Qualification activities are executed in accordance to the qualification plan (see Sec 4) and recorded accordingly (see [4]).

2.2 Identification of deviation or failures

2.2.1 When deviation or failures are detected during the execution of qualification activities, they are to be documented in reports (see [4]) and they are to be investigated in relation to their occurrence.

At least the following cases should be considered:

- Failure is identified by the qualification plan and occurs in accordance with expected target:

  no further action is needed
- Failure is identified by the qualification plan but occurs in conflict with expected target:

  failure should be reevaluated by the qualification process. Modifications of the technology may be needed to mitigate the risk. In this case, qualification plan should be updated consequently.
- Failure is not identified by the qualification plan:

  failure is to be considered by the qualification process, (i.e. qualification plan needs to be updated to implement the failure, when deemed relevant).

3 Surveillance

3.1 General

3.1.1 Where defined by the qualification plan, surveillance of the qualification activity may be required (see Sec 4, [4]).

4 Data collection and Reports

4.1 General

4.1.1 For each activities, outcomes should be reported into appropriate documents as identified by the qualification plan, such as:

- test report (testing activities)
- analysis report (design review)
- inspection report (surveillance, surveys and inspection).

4.1.2 Test report

For each item of the test program, the test report is to indicate at least the following information:

a) Identification data:
   - identification of the concerned technology item (serial number, type, technical data, etc.)
   - date and place (port, voyage log, test laboratory, site,...) of the test with relevant external conditions (measured wind speed, estimated wave height, temperature, pressure...)
   - numbering of test according to qualification plan.

b) Test conducted:
   - test specification (description, type)
   - results of the test
   - inspection findings if any
   - maintenance and repairs carried out and parts replaced, if any.

c) Supporting documentation such as sketches, photos, measurement reports, are to be attached to the report.

Note 1: The report may be provided in hard copy or using a computerized recording system.

4.1.3 Analysis report

For each analysis performed, an analysis report is to indicate at least the following:

a) Identification data:
- identification of the technology/equipment, system or sub-system, and mode of operation
- identification of probable failure modes and acceptable deviations from the intended or required function

b) Analysis conducted:
- standards used for analysis
- objectives of the analysis
- any assumptions made in the analysis
- conclusions of analysis (calculations and evaluations)
- identification of trials and testing needed to prove conclusions

Note 1: When deemed necessary to validate the conclusion of simulations, a validation report should includes:
- a clear description of the input and output data, along with explanations on how the output data are obtained/calculated (e.g. by the software)
- comparisons between simulation results and full scale and/or model test results.

The analysis report may be submitted in two parts:
- preliminary analysis, as soon as the initial arrangements of technology can form the basis of discussion
- final analysis detailing the final design with a detailed assessment.

4.1.4 Survey report

Each survey is reported in a detailed survey report listing all observations and comments raised by the surveyors. The survey report is to indicates at least the following information:

a) Identification data:
- identification of the concerned technology item
- date and place of inspection and name of the person under whose responsibility the inspection has been carried out.

b) Survey conducted:
- type of inspection carried out (visual external examination, internal examination after dismantling, overhaul,...)
- readings performed, when applicable (clearances, thickness measurements, working pressure, or other working parameters of the technology)
- findings during the inspection (corrosion, fractures, pieces of equipment worn out, broken or missing)
- results of tests performed (such as working tests, pressure test).

c) Supporting documentation such as sketches, photos or other documentation when this is deemed necessary to clarify the findings are to be attached to the report.

Note 1: For example:
- photos may be used to show the condition of the pieces of equipment, the coating condition of piping, or the extent of corrosion
- sketches may be used to indicate fractures and deformations, clearances taken, or other measurements performed.

4.1.5 Thickness measurement report

The report thickness measurement report includes at least the followings:

a) Identification data:
- date when the measurements were carried out
- type of measuring equipment
- names and the qualification of the operators and their signatures

b) Measurement conducted:
- location of measurements
- thickness measured and corresponding original thickness, if relevant

c) Supporting documentation such as sketches, photos or other documentation when this is deemed necessary to clarify the findings are to be attached to the report.

5 Results review

5.1 General

5.1.1 For each qualification activities, outcomes should comply with the acceptance criteria as defined in the qualification plan, see Sec 4, [3].

Results should be within the limits which are appropriate for the characteristics of the concerned technology.

SECTION 6 BENCHMARKING METHODOLOGY

1 General

1.1 Introduction

1.1.1 The aim of this Section is to define a methodology and examples of criteria according which shall be benchmarked, from a Technology Qualification point of view, the Technologies and, finally, the Concept Designs defined by the Applicant/Inventor.

1.2 Definitions

1.2.1 Applicant/Inventor

Means the party which is in charge of the product development.

1.2.2 MAJOR EQUIPMENT

Means main pieces of equipment (machinery, pressure vessels, structure, etc.) involved directly in the SYSTEM's TECHNOLOGY and which, thereby, is tagged in most of the documents, e.g. exchanger, turbine,…

1.2.3 SYSTEM

Means any facility of the Product to fulfill a required functionality

1.2.4 TECHNOLOGY

Means the scientific study, its use in applied sciences and its application to a SYSTEM or a MAJOR EQUIPMENT.

1.2.5 SHOWSTOPPER

Means an issue, activity, event or feature of the project which causes the level of one or more acceptance criteria to exceed acceptable values, and which cannot be mitigated and consequently kills the project.

1.3 Systems benchmarking criteria

1.3.1 The criteria which have been identified for benchmarking, from a qualification point of view, the technologies proposed by the Applicant/Inventor are the followings:

- Showstoppers
- Maturity Level
- Qualification Process Complexity
- Qualification Duration
- Qualification Cost
- Qualification Probability of Success.

The below questions might be related to the system, the sub-system and to equipment using a new technology; the questions at equipment level will be the same as those at system level.

1.3.2 The Show-stoppers

This is the most important criterion as if there is any show-stopper identified in the qualification process of the proposed technology the technology should be, by the fact, rejected.

The show-stoppers search should be performed in the first steps of the benchmarking study in order to prevent useless work if show-stopper is identified.

This criterion has only two values: Yes or No.

Project budget or schedule may also lead to show-stoppers.

1.3.3 The Maturity Level

This criterion will define the need for qualification: the more the technology is new the higher are the risks of failure to be fit for purpose.

The proposed values of the criterion are listed in Sec 3, Tab 5.

1.3.4 The Qualification Process Complexity

This criterion will allow comparing the proposed technologies with regards to the qualification process complexity which is linked with the duration, the costs and the probability of success of the qualification process.

The proposed values of the criterion are listed in Tab 1.

The following information is necessary:

- Types of studies or tests are needed to qualify the equipment/system which remain to be qualified:
  - qualification needing real size models, tests or pilot
  - complex analysis needing support of model tests
  - complex analysis using sophisticated computer programs and high level analysts
  - simple Analysis using standard engineering methodology and tools and/or feedback experience.
- Who is supposed to perform the technology qualification (suppliers, partners…).

Table 1 : Qualification Process Complexity rating

Qualification Complexity	Rate
Qualification needing: • real size models tests or • pilot	3
Complex analysis needing support of model tests	2
Complex analysis using sophisticated computer programs and high level analysts	1
Simple Analysis using standard engineering methodology and tools and/or feedback experience	0

It should be supported by the list of codes and norms to be applied and the corresponding qualification program.

Note 1: Some codes require project specific analyses to define the criteria to be applied.

Note 2: Some codes or norms are more stringent than others and their mention with both the knowledge of the actual qualification level or compliance stage of the competing technologies with these codes and norms will help to estimate the difficulty to reach the final qualification and will help to rank the technologies with regard to this criteria.

Note 3: In general, the comparison should not be based only on codes or norms used, but also on:

- Maintenance and operating conditions and cross-checking of information.
- Cross-checking of condition of application of norms and conditions stated in design basis.

In case of several sub-systems or equipments needing qualification the overall system rating will be the lower rating of all separate rating. It should be noted that a rating of 0 will generally be applied only for a complete system qualification.

1.3.5 The Qualification Duration

The duration of the qualification process is important for the viability of the project as a too long duration of qualification will delay out of the acceptable range the completion of the studies and /or equipment procurement.

The proposed values of the criterion are listed in Tab 2.

Table 2 : Qualification Duration rating

Qualification Duration	Rate
More than 18 months	3
7 months to 18 months	2
1 month to 6 months	1
Less than 1 month	0

The estimation of the qualification duration should be supported by adequate qualification plan schedule.

the schedule of qualification should be part of the Technology Qualification Plan issued by Applicant/Inventor. In case of several sub-systems (or equipments) requiring qualification the Applicant/Inventor schedule should take into account the qualifications that can be done in parallel and those than have to be done in series. In general the system qualification duration is the duration of the longest system to qualify

1.3.6 The Qualification Cost

The qualification cost is also an important parameter as a too high cost could not satisfy the project budget limitations.

The proposed values of the criterion are listed in Tab 3.

Table 3 : Qualification Cost rating

Qualification Cost	Rate
> 1000 k Euros	3
< 1000 k Euros	2
< 100 k Euros	1
< 10 k Euros	0

The qualification cost estimation should be supported by adequate qualification plan budget.

The cost of qualification should be estimated in the Applicant/Inventor Technology Qualification Plan, taking into account both the need for sub-system qualification and for the whole system qualification. The overall cost of qualification is the sum of all separate costs.

1.3.7 Qualification Probability of Success (Fitness for Service)

This criterion will allow comparing the proposed technologies with regards to their probability of success to meet expected system purpose in project conditions.

The proposed values of the criterion are listed in Tab 4.

Table 4 : Qualification Probability of Success (Fitness for Service) rating

Qualification Probability of Success	Rate
Qualification Uncertain	3
Qualification expected with restrictive conditions for maintenance and operation	2
Qualification expected with non restrictive conditions for maintenance or operations	1
Full Qualification ascertained without specific maintenance or operating conditions	0

This criterion should be supported by adequate qualification plan, including how will be defined either the limiting conditions of operations, either the constraining maintenance procedures

However a good understanding of the system is necessary to be able to evaluate if restriction of use of one equipment/sub-system can be extrapolated to the whole system. A duplication of the equipment or a procedure may reduce its impact on the overall system; on the contrary the separate restrictions on equipments may escalate lead to more severe operating conditions for the overall system.

2 Benchmarking methodology

2.1 General

2.1.1 Systems benchmarking

Based on the information (answers to questions and documentation) collected from Applicant/Inventor the rate values obtained for each system-related criterion will be plotted on a graph shown in Fig 1 for each proposed subsystem.

This will allow a visual comparison of several Concept Design regarding one system.

Note 1: Any system without any related technology qualification activity shall be rated the maximal value for each criterion.

Table 5 : Systems benchmarking example

Criteria	Technology 1	Technology 2
Maturity level	1	2
Qualification duration	1	1
Qualification cost	3	2
Qualification process complexity	1	2
Fitness for service	2	3
Total for project benchmark	8	10

2.1.2 Concept designs benchmarking example

Regarding concept designs benchmarking a similar approach will be used. For each sub-system of the Concept Design, the benchmarking results for each criterion will be added to obtain a global rate from 0 to 15 of the sub-system which then will be plotted on a Concept Design graph as shown in Fig 2.

A global Concept Design criteria can then be created by adding the criteria for all sub-systems and dividing by the number of sub-systems ranked.

2.1.3 Systems benchmarking example

For the system A, two technologies have been proposed (Technology 1 and Technology 2) as shown in Tab 5.

Corresponding graph is shown in Fig 3.

Figure 1 : Rate value graph

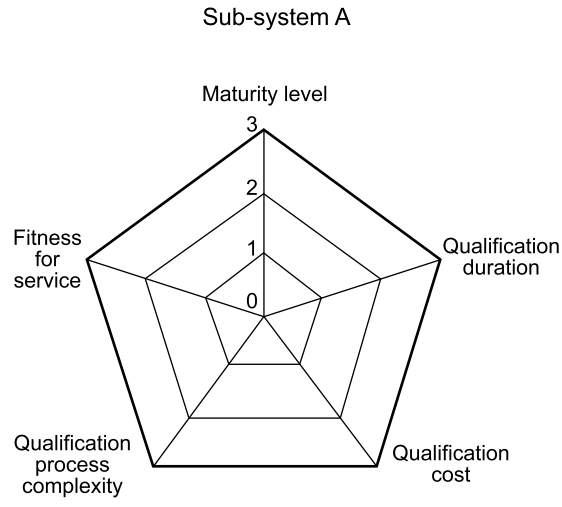


Figure 2 : Concept Design graph

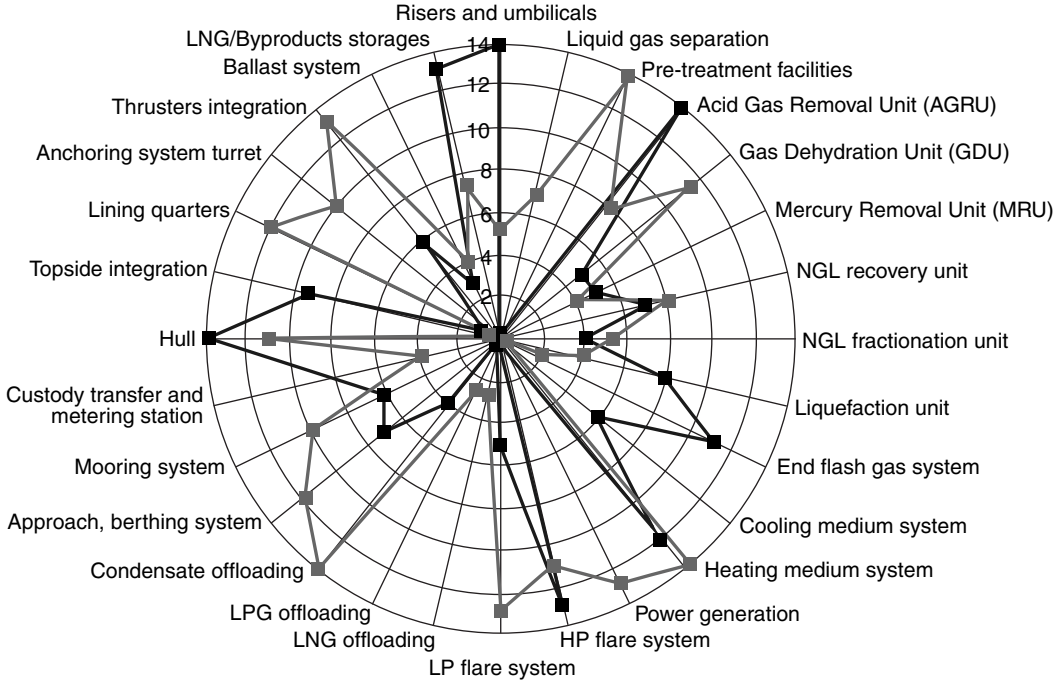
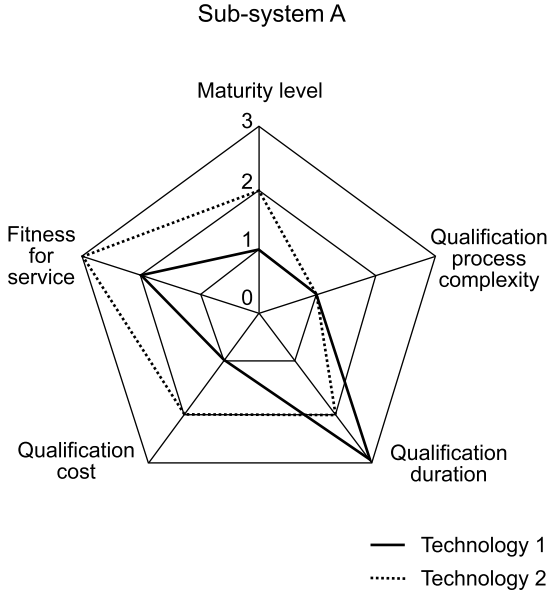


Figure 3 : System benchmarking graph



2.1.4 Reference documentation

As a minimum, the following list of documents should be provided:

- outline for novel aspects and the proposed approach to be taken for establishing engineering justification on these features.
- concept level engineering calculation dossiers demonstrating suitability of the novel features for the proposed service
- life and operational envelope
- supporting test results and data sources used in the engineering analysis
- preliminary qualification plan(s) and associated schedule and budget
- concept Approval Certificates, Type Approval Certificates, Design Review Certificates, Tests Certificates, etc.

Others justifications as required.

APPENDIX 1 FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS (FMECA)

1 Introduction

1.1 General

1.1.1 Failure Mode Effect and Criticality Analysis (FMECA) is a reliability and integrity analysis where each individual failure is considered as an independent occurrence with no relation to other failures in the system, except for the subsequent effect that it might produce.

1.1.2 FMECA is a common used risk analysis performed to support the technology assessment.

1.2 Definitions

1.2.1 Availability

Percentage of time where an item or a system can adequately perform a required function for which it has been designed.

1.2.2 Consequence

The resulting effect of a physical event causing safety, environmental damages and/or unavailability.

1.2.3 Criticality

The product of the probability of occurrence or frequency of the event and the potential consequences or severity.

1.2.4 Escalation

An increase in the consequences of a hazardous event or a sequence of events.

1.2.5 Frequency

Number of occurrences of the event per unit of time.

1.2.6 Hazard

The potential to cause safety, environmental damages and/or unavailability.

1.2.7 Probability

The likelihood of occurrence of a specific event.

2 Methodological approach

2.1 Method

2.1.1 A Failure Mode, Effects and Criticality Analysis (FMECA) study considers each mode of failure for every component of a system, and determines local effects and end effects on system operation, on personnel safety and environment protection.

Failure modes are classified in relation to likelihood of the failure occurring and severity of failure effects. Likelihood in combination with severity will generate a criticality rating for each failure mode, which is based upon a predetermined risk matrix.

Starting from the basic failure characteristics of elements and functional structure of the system, FMECA systematically documents the ways equipment can fail, the possible causes, the effects these failures can produce on system performance and ranks each potential failure according to the combination of its severity, its probability of occurrence and the possibility that it can be detected.

These three parameters are qualitatively evaluated referring to defined levels. Five levels for probability, consequences and non-detection are defined. The combination of these three figures (probability, consequences, and non-detection) provides the criticality score associated to the considered failure mode.

The FMECA is carried out on a series of worksheets, where the results are listed in a tabular format, equipment item (or function) by equipment item (or function), following a systematic bottom up approach starting from the lowest level of component failure and rising through the next level of system hierarchy up to the overall system level.

In that specific case, FMECA is performed on the basis of the functional analysis.

2.2 Generic hazards list

2.2.1 Anyway, it is strongly recommended to explore the hazards listed in the following during the performance of the FMECA by identifying the causes and the consequences of the associated component failure.

2.3 Generic failure modes

2.3.1 Generic failure modes are given in Sec 3, [4.2].

2.4 Specific hazard identification

2.4.1 The development of the hazard register will ensure that all types of hazard associated with the facilities will be identified and assessed. The method and level of detail of assessment will depend on the type of hazard, the degree of risk associated with it and the methods available to minimise the risk.

2.5 FMECA procedure

2.5.1 FMECA worksheet

The FMECA is performed using the standard worksheet format shown in Fig 1.

Figure 1 : FMECA standard worksheet

FMECA Worksheet							Report n° XXX					
			Operational Mode :				Date :					
N°	Item Description		Failure Description		Failure Effect		Risk Reducing	Rating				Action /
	Function	Comp	Mode	Cause	Local	End	Measures	F	S	D	C	Remarks

N° : A number for the univocal identification of the item within the worksheet is recorded.

Function : A concise statement of the function performed by the item, including both the inherent function of the part and its relationship to interfacing items is indicated.

Each function identified in the Functional Analysis Table is considered.

Component: Name of component.

The same names as the ones adopted in the Functional Analysis Table should be used.

Failure Mode: All predictable failure modes, that are consistent with the considered equipment, are identified and described. Considering the item's normal operating condition, potential failure modes are determined by examination of item connections identified in the Functional Analysis Table.

Failure Causes: The most probable causes associated with the postulated failure modes are identified and listed.

Failure Effects: For each considered failure mode, both immediate effect of failure at the failure location (Local effect) and the final effect (End effect) impacting availability, are identified, evaluated and recorded.

Risk Reducing Measures: For each identified failure mode, possible risk reducing measures so as to reduce the likelihood of effects associated with the failure mode, are identified and recorded. They can deal with design safety factors, redundancy, inspection, monitoring, …

Probability of Failure (F): A probability category is assigned to each item to provide a qualitative ranking of its probability of occurrence (see frequency classification below).

Severity Category (S): According to the failure effect (End effect), a severity category is assigned to each item, to provide a qualitative measure of the worst potential consequences impacting availability and resulting from considered item failure (see damage classification below).

Criticality Level (C): Each potential failure mode is ranked according to the combination of its severity classification, its detection capability and the probability of its occurrence.

Actions / Remark: In this column, for each item, are listed:

- any suggested corrective actions for reducing the likelihood of effects associated with the failure mode
- any pertinent remarks pertaining to and clarifying any other column in the worksheet line
- notes regarding recommendations for operative procedure improvements.

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