

Recommended Practice on Subsea Equipment Qualification

API RECOMMENDED PRACTICE
17Q SECOND EDITION, MAY 2018

REAFFIRMED, APRIL 2023



AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to ensure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

Copyright © 2018 American Petroleum Institute

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows:

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the standard.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the standard.

May: As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, “can” denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

	Page
1 Scope	1
2 Normative References	1
3 Terms, Definitions, Acronyms, and Abbreviations	1
3.1 Terms and Definitions	1
3.2 Acronyms and Abbreviations	4
4 Document Outline and Application	4
4.1 Process Application	4
4.2 Equipment Applicability	5
4.3 Supplier and End User Role in Qualification Programs	5
5 Qualification Program	6
5.1 General	6
5.2 Overall Qualification Program Process	6
5.3 Requirements Planning (STEP 1)	9
5.4 Technology Maturity Assessment (STEP 2)	10
5.5 Qualification Program Selection (STEP 3)	11
5.6 Qualification Failure Modes, Effects, and Criticality Analysis (Q-FMECA)(STEP 4)	14
5.7 Qualification Plan (STEP 5)	16
5.8 Qualification Execution (STEP 6)	17
5.9 Results Evaluation and Residual Risk/Uncertainty (STEP 7)	21
5.10 Implement Improvements and Modifications (STEP 8)	21
5.11 Qualification Assurance (STEP 9)	22
5.12 End User Qualification Process (TRL 5–7) (STEP 10)	23
6 Assessing Technology Readiness	25
6.1 Technology Readiness Levels (TRL)	25
6.2 Performing the Technology Readiness Level (TRL) Assessment	25
6.3 Risks in Advancement of Technology Readiness Level (TRL)	29
Annex A (informative) Statistical Analysis of Test Data	31
Annex B (informative) Example Technology Maturity Assessment	41
Bibliography	45
Figures	
1 Example of Technology Development Link to End User Application/Project Development	6
2 Overall Process for Qualification Programs	7
3 TRC/TRL Correlation Matrix	12
4 Top Down System Hierarchy and Bottom Up TRL Assessment	29
5 TRL Assessment Question Sequence	30
A.1 Weibull Probability Plot with 2-sided 90 % Confidence Interval (Data from Table A.1)	33
A.2 Results of Example at 50 % Confidence	37
B.1 Diagram of a Vertical Xmas Tree with Key	41
B.2 System Breakdown Example for 15K 350F VXT	42
B.3 Component Breakdown Example for 5" Gate Valve	44
Tables	
1 TRL Definition, Descriptions, Supporting Information, and Achieved Level	26

Contents

	Page
A.1 Example of Sorted Failure Data	31
A.2 Confidence Levels vs Chi-Square Values	34
B.1 Technology Maturity Assessment for a Gate Valve.	43
B.2 Technology Maturity Assessment for a Connector Gasket	43

Recommended Practice on Subsea Equipment Qualification

1 Scope

This recommended practice (RP) provides suppliers, contractors, and operators with process-level guidance to qualify equipment intended for use in subsea applications. This document is intended to provide high-level guidance only, so that the industry will have a common set of principles to follow for equipment qualification. It is not intended to replace existing company processes or procedures. The application of this recommended practice is dependent on the stakeholder companies (qualifier and end user) accepting its use. Although developed for application to subsea equipment, the process described by the RP can be applied to non-subsea equipment as well.

2 Normative References

The following referenced documents are required for the application of this recommended practice. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

API RP 17N, *Recommended Practice on Subsea Production System Reliability, Technical Risk, and Integrity Management*, 2nd Edition (2017)

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this recommended practice, the following terms and definitions apply:

3.1.1

component

Collection of subcomponents which when brought together function as a unit. (e.g. connector, gate valve, pressure transducers).

3.1.2

cut set

Unique combination of component failures that can cause a system failure.

NOTE A system can have multiple, different cut sets.

3.1.3

environment

Internal, external, and operational conditions to which equipment is exposed.

NOTE This includes physical, chemical, biological, and usage conditions (i.e. seawater environment, water depth, seabed conditions, reservoir conditions, pressure, temperature, etc.).

3.1.4

failure mode

Effect by which a failure is observed on the failed item (i.e. the loss of a required functionality; e.g. the loss of containment).

3.1.5

field proven

Technology or equipment that has been through the entire qualification process and is classified as TRL 7.

NOTE See Table 1 for the definition of TRL 7.

3.1.6**first article**

First of a product produced using the “normal processes” as will be used to make multiple numbers of the same product.

3.1.7**hazard rate**

Instantaneous failure rate of a component.

NOTE When the hazard rate is constant, the hazard rate = failure rate.

3.1.8**limit state**

State beyond which an item no longer satisfies the requirements.

NOTE The following categories of limit states are of relevance for structures: ULS = ultimate limit states, FLS = fatigue limit states, ALS = accidental limit states, SLS = serviceability limit states.

3.1.9**prototype**

Trial product produced to test a concept or process.

3.1.10**production model**

Product manufactured using the “normal processes” and intended for normal use.

3.1.11**qualification**

Process of confirming, by examination and provision of evidence, that equipment meets the specified requirements for the intended use; the combination of verification and validation activities.

3.1.12**qualification FMECA****Q-FMECA**

Integrated FMECA with the purpose of identifying and prioritizing qualification activities for a technology (see 5.6).

3.1.13**specification**

Document in which function, performance, design, and operating requirements are defined, together with associated reliability and integrity goals and requirements.

3.1.14**standard qualification program****SQP**

Qualification program that uses qualification activities prescribed within existing standards applicable to the technology (see 5.4).

3.1.15**technology**

Component, product, physical process, or system used to perform specific functions and/or to achieve specific goals.

3.1.16**technology qualification program****TQP**

Qualification program that utilizes a Q-FMECA to identify qualification activities necessary to qualify the technology in line with the identified goals and requirements (see 5.4).

3.1.17**uncertainty**

State of having limited knowledge where it is impossible to exactly describe the existing state or future outcome(s).

3.1.18**validation**

Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.

NOTE 1 Validation activities are intended to answer the following type of question:

- did we design/build the right thing? (i.e. confirmation that 'the thing' will work in a specific application)
- are we doing the right tests?
- did we build/use the right model with the right data?

NOTE 2 Design validation can include one or more of the following (this is not an all-inclusive list):

- prototype tests,
- functional and/or operational tests of production products,
- tests specified by industry standards and/or regulatory requirements,
- field performance tests and reviews.
- finite element analysis
- system reliability analysis

3.1.19**verification**

Confirmation, through the provision of objective evidence, that the specified requirements have been fulfilled

NOTE 1 Verification activities are intended to answer the following type of question:

- did we design/build the thing right? (i.e. does 'the thing' conform to the specified requirements)
- did we undertake the test/analysis correctly?

NOTE 2 Design verification activities can include one or more of the following (this is not an all-inclusive list):

- confirming the accuracy of design results through the performance of alternative calculations,
- review of design output documents independent of activities of design and development,
- comparing new designs to similar proven designs.

3.2 Acronyms and Abbreviations

For the purposes of this recommended practice, the following acronyms and abbreviations apply:

ALT	accelerated life testing
CFD	computational fluid dynamics
ESS	environmental stress screening
FAT	factory acceptance testing
FEA	finite element analysis
FMECA	failure modes, effects, and criticality analysis
GOR	gas-to-oil ratio
HALT	highly accelerated life testing
HASS	highly accelerated stress screening
HPU	hydraulic power unit
MCS	master control station
MCTF	mean cycles to failure
MTTF	mean time to failure
RCFA	root cause failure analysis
R&D	research and development
RDT	reliability demonstration testing
RGT	reliability growth testing
RP	recommended practice
SIT	system integration test
SQP	standard qualification program
TQP	technology qualification program
TRC	technical risk categorization
TRL	technology readiness level

4 Document Outline and Application

4.1 Process Application

A qualification program is typically a multi-dimensional process that consists of a number of interrelated steps—from requirements setting, planning activities, executing tests and analyses, reviewing results against expectations, and preparing documentation. This recommended practice is written to simplify the qualification process and to align associated expectations within individual organizations and within the industry. It is recognized that there are many methods for qualifying technology and that each company may have specific motives or constraints preventing full adoption of the process described in this document. However, it is recommended to use as much of the process as possible to increase efficiency within the industry.

This recommended practice is not intended to replace the qualification and testing philosophies defined in existing standards (i.e. flexible pipe and ancillary equipment). Existing equipment standards shall be used for detailing qualification test plans, while this recommended practice can be used as a process guide to plan, execute and evaluate a qualification program.

The document is organized based on the process described in 5.1. Section 5 is made up of subsections which represent each step of the process. Although the process is linear in nature, it does not necessarily mean that a qualification program must follow the steps in perfect sequence. Often, programs work on several steps at one time, or iterate between two steps until progress is made. The process is simply a guide for planning, executing, and evaluating a technology qualification.

This qualification process tailors recommendations depending on the assessed technology maturity and technical risk. Technology readiness levels (TRL) are used to assess technology maturity, and the technical risk categorization (TRC) tool is used to assess the technical risk. TRLs are defined in this document in Section 6 and are a means of assessing and communicating the maturity of technology and equipment relative to a set of predefined criteria. TRCs are defined in API 17N and are a means of assessing technical risk across a set of change categories. The TRL and TRC are combined into a matrix to guide the user to the appropriate qualification activities for that specific phase of development. A key feature of the qualification process is to continually reassess the technology maturity and technical risk as the program progresses, and the plan of the appropriate qualification activities for that stage based on the recommendations in this document.

4.2 Equipment Applicability

4.2.1 General

This RP can be applied to all subsea oil and gas related equipment including:

- subsea equipment, including related control systems,
- non-permanently installed facilities and tools, and
- system interfaces (e.g. chemical injection interface with a production system).

4.2.2 Subsea Equipment

From wellhead equipment to the top of the riser, plus the hydraulic power unit (HPU)/master control station (MCS) (and other subsea-specific, surface equipment) and typically including: wellheads (both subsea and mud line casing suspension systems) and trees; pipelines, jumpers, flow lines, and end connections; processing equipment; controls, control lines, and control fluids; instrumentation; templates, manifolds, and production (including water injection) risers (both rigid and flexible).

4.2.3 Non-permanently Installed Facilities and Tools

Equipment and tooling required to install, commission, and operate subsea wells and equipment included in 4.2.2. Includes well access systems, drilling equipment, specialized tooling for facility intervention, etc.

4.2.4 System Interfaces

Hardware interfacing risks, especially those that also represent boundaries between different organizations, should be considered in equipment qualification programs.

4.3 Supplier and End User Role in Qualification Programs

The technology development and project development processes are often managed independently but are complementary in nature. Each has a distinct role within a qualification program and associated TRL progression. Figure 1 represents this relationship and how each process may interact with the other. Figure 1 depicts the role a supplier typically has in each process and the role the end user typically has in each process. The assumed role of a supplier in a technology/project development is to deliver TRL 4 rated component/equipment that may be assembled into an assembly or sub-system. The end user then typically takes that assembly/subsystem and integrates it with

their subsystems or systems to ensure broader interfaces are validated. A supplier may deliver a component or system to a TRL other than 4, depending on the product, end user needs, supplier strategic objectives, etc. The supplier can deliver a TRL 5 component if fully integrated into a supplier-delivered system.

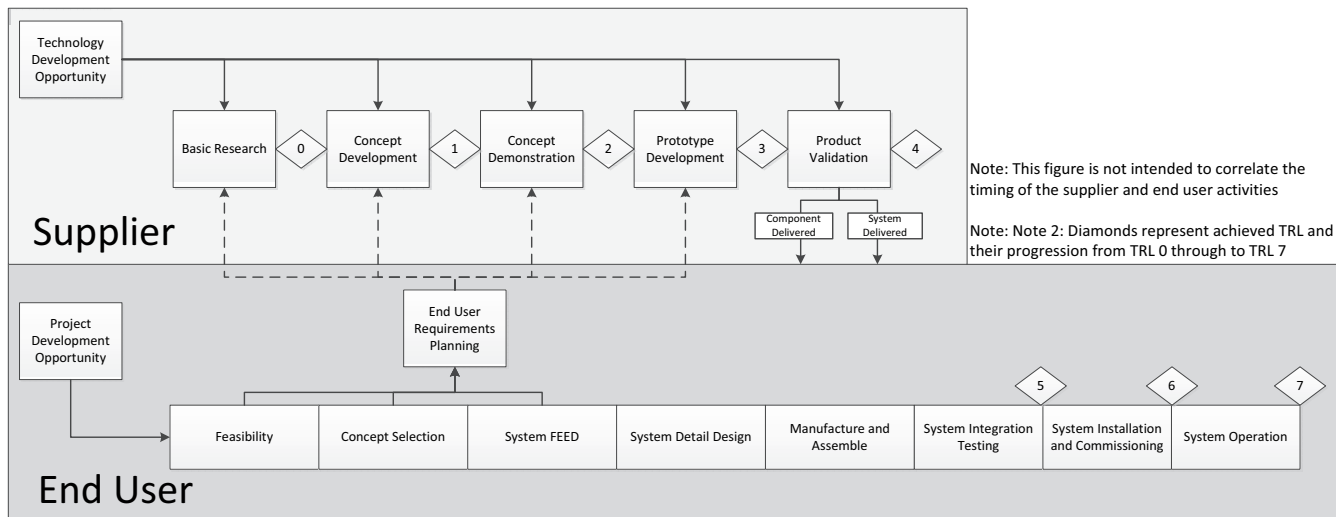


Figure 1—Example of Technology Development Link to End User Application/Project Development

NOTE A technology development is not always associated with a project development or specific field application. A technology development can be, and often is, undertaken as a standalone endeavor by a supplier and/or end user.

5 Qualification Program

5.1 General

It is recommended that all equipment to be used subsea, regardless of system design or application, be subject to qualification to ensure they meet defined reliability, integrity, and operational requirements. The need for executing a technology qualification should be assessed by performing a proper technology maturity assessment (see 5.4).

5.2 Overall Qualification Program Process

The overall aim of a qualification program is to provide evidence that a selected technology or equipment will meet functional and performance requirements, within specified operational limits, and with an acceptable level of confidence. Each step of the qualification program is a process in its own right. The overall qualification program process is shown schematically in Figure 2, described briefly below, and detailed in the following sections.

STEP 1 Requirements planning: The requirements planning process is undertaken early in the technology development program to define the goals and requirements for the technology and its application together with qualification requirements. If a specific application is unknown at the time of qualification, assumptions should be defined as part of the requirements planning process.

STEP 2 Technology maturity assessment: The technology maturity assessment uses TRC/TRL tools to (a) evaluate the technical risk and maturity of a concept in line with specified goals and requirements, (b) compare technologies, (c) determine if a research and development program is appropriate and, (d) identify the appropriate qualification path for the selected technology.

NOTE The level of detail in the technology maturity assessment depends on why the assessment is being conducted. If qualification is conducted as part of a field development, high-level assessments are often performed at an overall equipment level to assist with technology identification and concept selection, while detailed assessments at a component or part level are conducted to identify and focus qualification effort where it is needed.

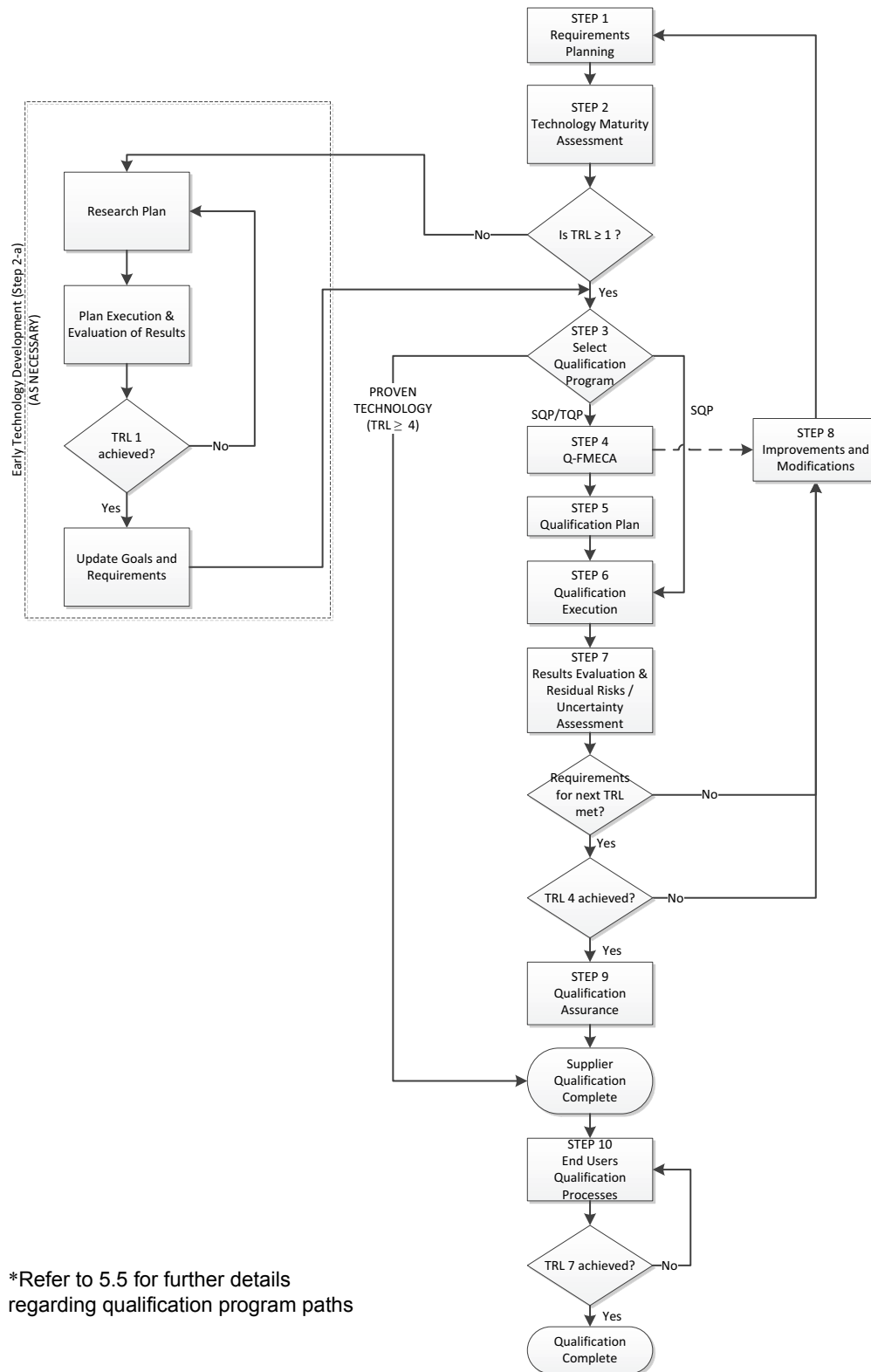


Figure 2—Overall Process for Qualification Programs
(Rectangle = Process; Diamond = Decision; Oval = End)

STEP 3 Select qualification program: The output from a technology maturity assessment is used to select one of three paths available for qualification:

- technology qualification program (TQP),
- standard qualification program (SQP), and
- proven in use (prior qualification program completed).

The recommendations for qualification path decision are described in 5.4. Which of the three paths is appropriate is dependent on the initial TRC and TRL assessed for the technology. It is recommended that a detailed maturity assessment be performed in advance of selecting the qualification program.

STEP 4 Qualification FMECA (Q-FMECA) is a critical activity in the planning stages of a qualification. Its primary purpose is to support identification and development of the qualification plan (Step 5). The Q-FMECA output may also identify design improvements to be made before testing commences. Although a Q-FMECA is recommended for all qualification programs, organizations should consider mandating Q-FMECA where a TQP is selected at the end of Step 3.

STEP 5 Qualification Plan: A qualification plan is a document which comprises the activities required to qualify a technology to an acceptable level in line with the program goals and requirements. The plan should be directly informed by the Q-FMECA, as well as the detailed TRL assessment, industry standards, and other resources relevant to the subject technology. The plan generally includes a combination of physical testing activities and modelling and assessment activities. The plan should address the qualification activities to be undertaken at each TRL to achieve TRL 4.

STEP 6 Qualification Execution: The execution of qualification test plans typically involves running physical testing activities and performing modeling activities, including simulations, engineering analyses, and reliability/availability analyses in accordance with the plan and specified testing conditions. Qualification execution will generate results that provide the basis for evidence of function and performance. A key element of this stage is data analysis, which may require the application of statistical analysis techniques.

STEP 7 Results Evaluation: Following the qualification execution stage, the results of the tests and data analyses should be evaluated against the initial goals and requirements. If the qualification results indicate that the technology is not meeting the specified requirements for TRL advancement, then design improvements or modifications may be required (Step 8).

STEP 8 Improvements and Modifications: Design improvements or an evaluation of requirements can be performed at any point in the qualification program. It is most common to consider design improvements or requirement modification during the Q-FMECA (Step 4) or during results evaluation (Step 7). For example, if it is found during results evaluation that predicted reliability performance is less than specified, then design improvements may be necessary. The principle in Step 8 applies wherever the design is found not to meet the specification during qualification testing.

STEP 9 Qualification Assurance: The final step in the supplier qualification program is the qualification report. Assurance reports may be written at any stage in the qualification program but are specifically recommended once a technology achieves TRL 4. The qualification report is used to document the qualification claims together with associated arguments and evidence of qualification achievements throughout the technology qualification process.

STEP 10 End Users Qualification Program: The TQP steps outlined above are those generally undertaken by a technology developer or equipment supplier. Once equipment has achieved TRL 4, the technology is ready for an end user's application. The end users qualification program involves testing and monitoring to progress the equipment TRL through TRLs 5, 6 and 7. In addition to the guidance provided in this document, further considerations for this phase can be found in API 17N, Annex C.

5.3 Requirements Planning (STEP 1)

5.3.1 General

The definition of performance goals and requirements within a qualification program is the process which leads to the development of the application specification which typically includes goals, requirements and acceptance criteria. If a specific product application is unknown at the time of qualification, assumptions should be defined and agreed upon among stakeholders, and associated requirements should be developed based on these assumptions.

The requirements planning process involves the following activities and procedures:

- develop a plan for identifying goals and requirements from stakeholders,
- elicit and validate goals and requirements,
- prepare a draft application specification document and issue to stakeholders for comment and approval,
- issue a final draft of the application specification with approved goals and requirements, and
- agreed-upon criteria for adapting the general TRL definitions to the specific technology to be qualified. Recommended only if the anticipated qualification scope warrants this level of detail.

The procedure is applicable for components, equipment and assemblies, which can be defined as new or modified technology.

5.3.2 Application Specification

The output of the requirements planning activity is the application specification which contains the goals, requirements, and technical risk acceptance criteria. The purpose of the application specification is to provide a common set of criteria against which all qualification activities should be assessed. The application of technology should be unambiguously and completely described through text, calculation data, drawings, and other documents. It is important that the functional and performance requirements and limitations of the technology are stated and that all relevant interfaces are clearly defined.

The application specification should be a living document which is updated as the technology maturity progresses and achievable goals and requirements become better defined.

The goals and requirements should address, but not be limited to, the following areas:

- regulatory requirements;
- function and performance requirements;
- technical requirements:
 - life cycle stages to be addressed;
 - design standards to be used;
 - operational and process conditions;
 - internal and external environmental conditions;
 - equipment life;

- reliability and integrity performance;
- limit states; and
- technology readiness level required for the program.

NOTE New technology may not be covered by established codes and procedures and thus it may not be clear how to qualify against existing standards or requirements. If this is the case, this document can be used to help guide the new technology development process.

5.4 Technology Maturity Assessment (STEP 2)

5.4.1 General

There are various qualitative and semi-quantitative approaches to assess technology maturity. The tools described below—technical risk categorization (TRC) and technology readiness level (TRL)—are tools commonly used to compare technologies, to develop appropriate qualification plans, and to communicate the status of a specific technology as development programs are executed.

The TRCs and TRLs assigned during the technology maturity assessment are used to select the appropriate path for the technology qualification. Each of the available qualification paths makes specific recommendations suitable for the state of technology maturity indicated by the assessed TRC and TRL.

End users often perform technology maturity assessments in early stages of subsea development projects, specifically during feasibility studies and concept selection (see Figure 1). These assessments are typically preliminary and aid in technology identification, concept down-selection, and field development planning. It is not recommended to select a qualification path based solely on these high-level assessments.

A detailed technology maturity assessment is required to identify specific components and/or parts where qualification effort is needed. These detailed technology assessments are typically performed by suppliers (with end user participation) who possess the requisite knowledge of each technology and product. It is recommended that the detailed TRC and TRL assessments be conducted at a low enough level where discrete components and/or parts with low maturity for the specific application can be identified. This level of detail in the assessment ensures that qualification effort is focused only where it is needed and that qualification activities can be properly sequenced. For example, when qualifying assemblies, individual components may need to be qualified separately before the assembly can embark on its own qualification (i.e. a valve may be ready for final testing, assessed at TRL 3, except for a new seal design which is at TRL 1. If practical, the seal could be qualified independently of the valve until it reaches TRL 3 or 4). The qualifier should determine the appropriate level of detail to assess/qualify depending on component level maturity.

5.4.2 Technology Readiness Levels (TRLs)

Technology readiness levels (TRLs) are sets of defined levels of maturity to which technology and equipment can be assessed and their maturity clearly communicated. A TRL indicates a technology's current state of readiness, i.e. a "snapshot" in time, as intended for a specific application.

Performing TRL assessments, either on new technology or in response to a change to existing technology, helps clarify communication and facilitate qualification planning. The assessed TRL, when combined with an assessed TRC, determines the recommended qualification path for a specific technology. It is recommended to periodically reassess and track TRLs throughout a qualification program to monitor progress, communicate status, and adjust qualification activities. Monitoring and tracking TRLs is especially useful when multiple technologies are being qualified in a single program.

See Section 6 for TRL definitions and extended guidance on TRL assessments.