GUIDANCE NOTES ON

QUALIFYING NEW TECHNOLOGIES

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American Bureau of Shipping
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ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA

Foreword

The marine and offshore industries regularly develop new technologies that have no service history in the proposed application or environment. Often, governing industry codes and regulations do not develop at the same pace as technology. These new technologies have little or no precedent and may be so different from existing designs that the requirements contained in class Rules may not be directly applicable.

These Guidance Notes describe the ABS approach for qualification of new technologies to confirm their ability to perform intended functions in accordance with defined performance requirements. This document also provides details regarding the required submittals and the key interaction points with ABS during the new technology development to benefit from ABS involvement as a trusted advisor.

A systems engineering approach to qualification is introduced in this document that allows for systematic and consistent evaluation of new technologies as they mature from a concept through confirmation of operational integrity in their intended applications. The approach is divided into a five stage process that is aligned with the typical product development phases of a new technology:

- Feasibility Stage
- Concept Verification Stage
- Prototype Validation Stage
- System Integration Stage
- Operational Stage

Completion of qualification activities within each stage of the new technology qualification process results in a Statement of Maturity issued to the client attesting to the maturity level of the new technology. Upon completion of the Prototype Validation Stage, the new technology may be "Type Approved" under the ABS Type Approval Program to limit repeated evaluation of identical designs for eligible products. During the Prototype Validation Stage, if all the engineering evaluations have been completed, a Product Design Assessment (PDA) can be issued prior to further consideration for ABS Type Approval.

The integration of the new technology qualification process with the Novel Concept Class Approval process (as presented within the ABS *Guidance Notes on Review and Approval of Novel Concepts*) provides end users of the qualified technologies with the added benefit that the transition from new technology qualification to Class Approval will be seamless. It provides regulatory agencies with the confidence that all hazards associated with the introduction of the new technology to the market has been systematically identified and mitigated. It is to be noted that when applying these Guidance Notes for certification or classification purposes in conjunction with Novel Concept Class Approval process, the primary driver for classification acceptance will be safety even though there may be additional functional requirements (e.g., reliability) defined by the client.

These Guidance Notes become effective on the first day of the month of publication.

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GUIDANCE NOTES ON

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SECTION 1 Introduction

1 Overview

These Guidance Notes describe the ABS approach for qualification of new technologies to confirm their ability to perform intended functions in accordance with defined performance requirements. They also provide details of the required submittals, the ABS review process and the key interaction points with ABS during the new technology development.

This document introduces a systems engineering approach to qualification that allows for systematic and consistent evaluation of new technologies as it matures from a concept through confirmation of operational integrity in its intended application. The approach is divided into a multi-stage process that is aligned with the typical product development phases of a new technology. The qualification activities within each stage employ risk assessments and engineering evaluations that build upon each other in order to determine if the new technology provides acceptable levels of safety in line with current offshore and marine industry practice. The qualification efforts by all stakeholders including the vendor, system integrator and end-user at each stage are recognized and captured within a new technology qualification plan (NTQP). Completion of qualification activities as identified within each stage of the NTQP results in a Statement of Maturity being issued by ABS attesting to the maturity level of the new technology.

The process is also compatible with approaches based on technology readiness levels (TRLs), (e.g. API RP 17N/Q, ISO 16290/NASA, and US DoD); and can be tailored to projects that require the use of multiple pathways to qualification. The comparison of ABS Qualification Stages with industry TRLs can be found in Appendix 2.

It is to be noted that when applying these Guidance Notes for certification or classification purposes in conjunction with Novel Concept Class Approval process, the primary driver for classification acceptance will be safety even though there may be additional functional requirements (e.g., reliability) defined by the client.

3 Background

The marine and offshore industries regularly develop new technologies that have no service history in the proposed application or environment. Often, governing industry codes and regulations do not develop at the same pace. These new technologies have little or no precedent and may be so different from existing designs that the requirements contained in class Rules may not be directly applicable.

Marine vessels and offshore units which contain new technological features or designs that are not currently governed by Rules, Guides and existing industry standards may still be qualified and/or approved by ABS through the process described in these Guidance Notes. This qualification is on the basis that the Rules, Guides, and existing industry standards, insofar as applicable, have been complied with, and that special consideration through appropriate risk assessments and engineering evaluations has been given to the new features through the application of these Guidance Notes.

These Guidance Notes are structured to provide a general procedure for vendors/system integrators/end-users to guide them through the process of obtaining Statements of Maturity attesting to the maturity level of new technologies. The process can be applied to technologies seeking qualification independent of class approval or installation on ABS classed assets.

The integration of the new technology qualification process and the Novel Concept Class Approval process provides end users of the qualified technologies with the added benefit that the transition from new technology qualification to Class Approval will be seamless. It provides regulatory agencies with the confidence that hazards associated with the introduction of the new technology has been systematically identified and mitigated.

5 Application

These Guidance Notes are in general applicable to all new technologies for offshore units and marine vessels that do not follow typical Rules, Guides, or industry codes or standards. This document provides guidance to parties seeking recognition for the maturity level of a proposed new technology.

A new technology for the purpose of these Guidance Notes is defined as any design (material, component, equipment or system), process or procedure which does not have prior in-service experience, and/or any classification rules, statutory regulations or industry standards that are directly applicable. It is possible to categorize the type of "novelty" in one of four categories:

i) Existing design/process/procedures challenging the present boundaries/envelope of current offshore or marine applications

ii) Existing design/process/procedures in new or novel applications

iii) New or novel design/process/procedures in existing applications.

iv) New or novel design/process/procedures in new or novel applications

An asset such as a marine vessel or an offshore unit becomes a novel concept if the incorporation of any new technology(ies) appreciably alters its service scope, functional capability, and/or risk profile. Novel concepts are typically presented to ABS for review and class approval following the process in the ABS *Guidance Notes on Review and Approval of Novel Concepts (Novel Concept Guidance Notes).*

The New Technology Qualification (NTQ) process could be applicable in the following cases:

i) To qualify new technology that may need to be classed or certified at a later date

ii) To simultaneously qualify new technology identified while seeking class approval for a novel concept

iii) To qualify a new technology independent of the need to be classed or certified

If the proposed new technology is intended for incorporation on an asset to be classed by ABS, then it is recommended that the new technology complete up to and including the System Integration Stage of the New Technology Qualification (NTQ) process. In other cases, the level of maturity to which the new technology may be qualified depends on the client's request. New technology qualification could be requested from ABS at any level of indenture as desired such as component, sub-system or system level.

The process is designed to accommodate cases where multiple vendors, system integrators, and/or end-users need to work together to qualify a combination of new technologies. In such cases, it is important for the teams to work together to integrate technologies as early as possible in order to optimize the process. Even though these Guidance Notes are primarily intended for the qualification of new technologies, the approach could also be applied to qualify existing technologies.

7 New Technology Qualification Process

The NTQ process confirms the ability of a new technology to perform its intended functions in accordance with defined performance requirements. The process starts with a comprehensive description of the technology to be qualified, followed by a screening of the technology to reveal the new or novel features that the qualification should focus on.

The process is divided into five sequential stages that progressively qualify the technology from feasible to operational stages as requested. The five qualification stages are:

i) Feasibility Stage

ii) Concept Verification Stage

iii) Prototype Validation Stage

iv) System Integration Stage

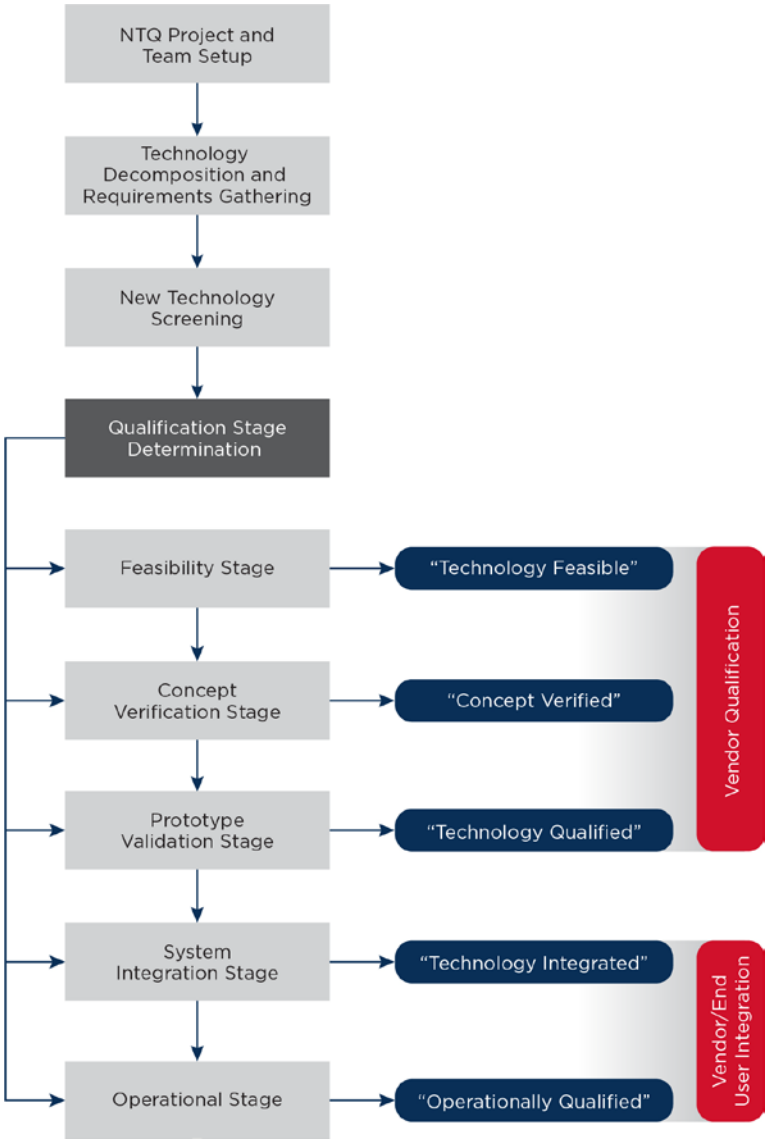
v) Operational Stage

Qualification activities outlined in the New Technology Qualification Plan (NTQP), are to be performed within each stage and should be defined at the end of the previous stage as agreed between the client and ABS. The qualification activities are based on the information available depending on the maturity level and based on the findings and knowledge gained in the previous stages completed. Typically, there are two main sets of activities within each stage, namely, engineering evaluations and risk assessments.

Upon completion of each of the five stages, a Statement of Maturity will be issued to the vendor(s) and the technology can progress to the next stage of maturity. It is envisioned that some vendors may have developed technologies to a level beyond the Feasibility Stage prior to contacting ABS for this qualification service. In such cases, ABS would perform an assessment of the current stage of technology development and endorse the technology with the applicable Statement of Maturity based on this assessment. The technology qualification can then proceed starting at that stage and continuing to the subsequent stages. Additionally, the new technology qualification process can be stopped at any stage, and restarted at an agreed upon time.

Section 1, Figure 1 provides a basic overview of the process along with the Statements of Maturity issued. Further guidance on each topic and deliverables that are to be submitted to ABS for review can be found in later Sections.

FIGURE 1
New Technology Qualification Process



9 ABS Type Approval Program

New technologies that have completed the Prototype Validation Stage of the NTQ process or have been "Technology Qualified", and can be consistently manufactured to the same design and specification may be "Type Approved" under the ABS Type Approval Program. During the Prototype Validation Stage, if all the engineering evaluations have been completed, a Product Design Assessment (PDA) can be issued prior to further consideration for ABS Type Approval. The ABS Type Approval Program is a voluntary option for the demonstration of compliance of a system or product with the defined performance requirements as derived from Rules, Guides, or other recognized standards. It may be applied at the request of the vendor or manufacturer. The suitability of the ABS Type Approval Program for the proposed new technology will be determined on a case-by-case basis.

Specific requirements and details regarding the ABS Type Approval Program can be found in 1-1-4/7.7 and Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1).*

11 Definitions

As Low As Reasonably Practicable (ALARP). Refers to a level of risk that is neither negligibly low nor intolerably high, for which further investment of resources for risk reduction is not justifiable. Risk should be reduced to ALARP level considering the cost effectiveness of the risk control options.

Approval. Confirmation that the plans, reports or documents submitted to ABS have been reviewed for compliance with one or more of the required Rules, Guides, standards or other criteria acceptable to ABS.

Availability. Ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided (ISO 14224).

Boundary. Interface between an item and its surroundings (ISO 14224).

Client. The vendor, OEM, manufacturer, asset owner/operator of the new technology or novel concept, representing any party or parties that have a stake or interest in the design or third party groups working under or for these entities.

Consequence. The measure of the outcome of an event occurrence in terms of people affected, property damaged, outage time, dollars lost or any other chosen parameter usually expressed in terms of consequence per event or consequence amount per unit of time, typically per year.

Controls. The measures taken to prevent hazards from causing undesirable events. Controls can be physical (e.g., safety shutdowns, redundant controls, added conservatism in design, etc.), procedural (e.g., operating procedures, routine inspection requirements, etc.) and can also address human factors (employee selection, training, supervision).

Critical Assumption. An assumption that if found not true will change the conclusions of the study that used such assumption.

Engineering Evaluations. Various engineering analysis tools and testing that may be used to support new technology qualification activities. Typical examples include but not limited to the following: Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Functional and Performance Testing, Model Testing, System Integration Testing, etc.

Failure. The loss of the ability to perform the intended function.

Failure Causes. Circumstances associated with design, manufacture, installation, use and maintenance that have led to a failure (ISO 14224).

Failure Mechanism. A physical or chemical process resulting in a form of damage which will ultimately lead to failure.

Failure Mode. The specific manner of failure that the failure mechanism produces.

Functional Specification. Document that describes the features, characteristics, process conditions, boundaries and exclusions defining the performance and use requirements of the product, process or service (ISO 13880).

Frequency. The occurrence of a potential event per unit of time, typically expressed as events per year.

Global Effects. Total effect an identified failure has on the operation, function or status of the installation or vessel and end effects on safety and the environment.

Hazards. Conditions that exist which may potentially lead to an undesirable event.

Indenture Level. The level of subdivision of an item from the point of view of maintenance action (ISO 14224).

Item. Any part, component, device, subsystem, functional unit, equipment or system that can be individually considered (ISO 14224).

Local Effects. Impacts that an identified failure mode has on the operation or function of the item under consideration or adjacent systems.

Maintainability. Ability of an item under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources (ISO 14224).

Manufacturing Assessment (MA). An inspection of the product during manufacture, an assessment of the quality control system and manufacturing processes that must be satisfactorily completed if the manufacturer wants a product to be labeled "Type Approved" under the ABS Type Approval Program.

Manufacturing Plan. Document setting out the specific manufacturing practices, technical resources and sequences of activities relevant to the production of a particular product including any specified acceptance criteria at each stage (ISO 13880).

Product Design Assessment (PDA). Technical evaluation of a product for potential use on ABS-classed assets. The process involves ABS Engineers verifying product compliance with manufacturers' specifications, applicable ABS Rules and national or international standards.

Quality Assurance and Quality Control. Typical quality plans and related processes for controlling quality during production.

Qualification. The process of confirming, by examination and provision of evidence, that equipment meets specified requirements for the intended use (API RP 17N).

Qualification Activities. Usually in the form of risk assessments, engineering evaluations, and testing that is required to be performed in order to mature the new technology to the next stage.

Qualification Plan. A document containing the qualification activities listed to mature the new technology to the next qualification stage. This is submitted as a New Technology Qualification Plan (NTQP) report.

Redundancy. Existence of more than one means for performing a required function of an item (ISO 14224).

Reliability. Ability of an item to perform a required function under given conditions for a given time interval (ISO 14224).

Risk. The product of the frequency with which an event is anticipated to occur and the consequence of the event's outcome.

Risk Profile. Description of any set of risks (ISO 31000).

Technical Specification. Document that defines technical requirements to be fulfilled by the product, process or service in order to comply with the functional specification (ISO 13880).

Type Approval. A voluntary ABS Program for product certification that is used to demonstrate a product manufacturer's conformance to the Rules or other recognized standards. The Product Design Assessment (PDA) and Manufacturing Assessment (MA) together result in a Type Approval or a "Type Approved" product.

Validation. The process of evaluating a production unit (or full scale prototype) to determine whether it meets the expectations of the customer and other stakeholders as shown through performance of a test, analysis, inspection, or demonstration.

Verification. The process of evaluating a system to determine whether the product of a given development stage satisfy the approved requirements and can be performed at different stages in the product life cycle by test, analysis, demonstration, or inspection.

13 Abbreviations

ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute Recommended Practice
CFD	Computational Fluid Dynamics
FEA	Finite Element Analysis
FMECA	Failure Mode Effects and Criticality Analysis
FTA	Fault Tree Analysis
HAZOP	Hazard and Operability
HAZID	Hazard Identification
HFE	Human Factors Engineering
ITP	Inspection Test Plan
MA	Manufacturing Assessment
MTBF	Mean Time Between Failure
NTQ	New Technology Qualification
NTQP	New Technology Qualification Plan
PDA	Product Design Assessment
PFD	Process Flow Diagram
P&ID	Piping and Instrumentation Diagram
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
RAM	Reliability, Availability and Maintainability
RBD	Reliability Block Diagram
SRDD	Systems Requirements and Description Document
SIT	Systems Integration Test
US DoD	United States Department of Defense

SECTION 2 Getting Started

1 New Technology Qualification Project and Team Setup

Once the client (vendor/system integrator/end-user) requests qualification of a technology using these Guidance Notes, a project kick-off meeting is scheduled. At this meeting, the client presents to ABS a brief overview of their proposed technology along with their expectations, any ongoing qualification activities (if initiated) and project timelines. ABS will advise the client if new technology qualification is the most appropriate path for proceeding and recommend next steps.

The kick-off meeting is followed by the establishment of a new technology qualification team. An important factor for a successful technology qualification is the composition of the qualification team. The qualification process involves the interaction of two teams: the vendor or client team (design team) and the ABS-designated review team.

For each NTQ project, depending on the complexity of the proposed new technology, ABS may establish a special multidisciplinary review team comprised of ABS staff members. The composition of the team will depend on the technical areas involved in the project as well as the physical location of the client's engineering and testing facilities. This will help the client benefit from technical review and comment from our subject matter experts throughout the qualification process. One of the members will be the designated NTQ project lead to act at as the client's main point of contact throughout the NTQ process. All ABS team members will be covered under the confidentiality/non-disclosure agreement that is typically signed between ABS and clients for this type of qualification services.

It is encouraged whenever possible to include ABS, system integrators and end users of the new technology early in the qualification process. This will facilitate the identification and alignment of requirements early in the design process avoiding costly design modifications later. If applicable, input from regulatory agencies (including flag Administration) will also help align the qualification activities with requirements or other expectations.

3 New Technology Decomposition and Requirements Gathering

3.1 Introduction

The NTQ process follows a systems engineering approach to qualifying new technology. This approach focuses on the following elements:

- Defining goals of the new technology
- Identifying the functional requirements to meet the goals
- Identifying the performance requirements for the functional requirements
- Performing qualification activities to verify and validate the performance requirements

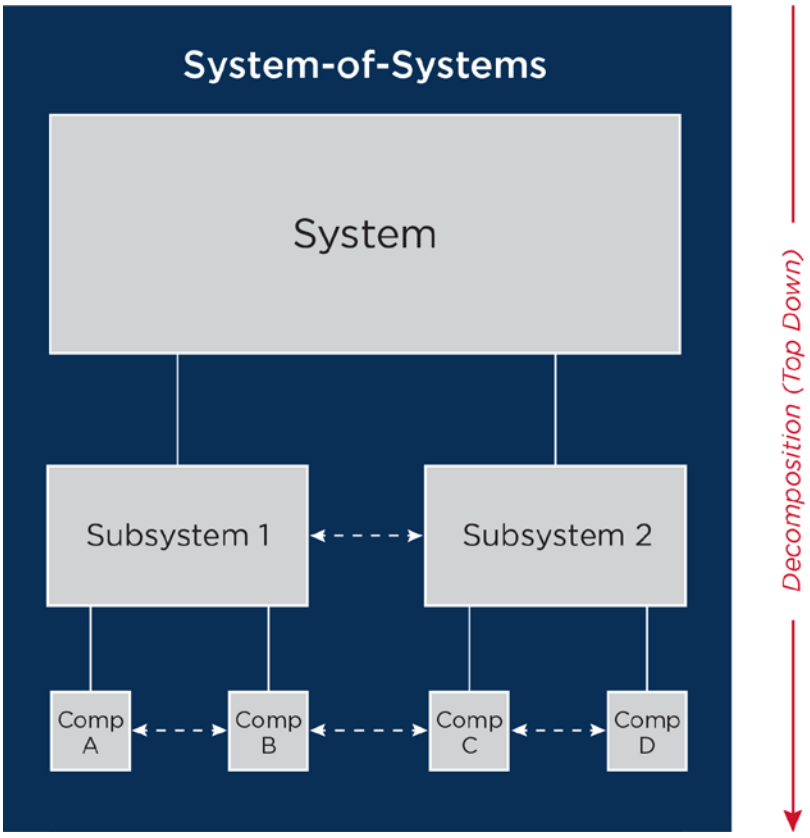
The qualification process starts with a top-down system decomposition, wherein the system is divided into subsystems, which are further broken down into components. This decomposition process is used in order to achieve the following:

- Mapping functional requirements of the system to item(s) (e.g., subsystems or components) identifying ownership of a specific functional requirement,
- Mapping functional requirements to specific performance requirements,
- Confirming that all defined functional requirements can be addressed by configurable items,
- Identifying new technology items prior to determining if qualification is needed and what interactions between items need to be considered.

Depending on the type of item for which the client is seeking qualification, the NTQ process can be tailored. This is applied by considering the different categories of new technology as defined in Subsection 1/5 and understanding what exactly has changed to focus qualification efforts.

The maximum maturity level of the system is based on the individual qualification of each item(s). For example, the overall maturity level of the system is equal or lower than that of the subsystems, which are equal or lower than that of the individual components. The decomposition, system hierarchy and interactions between all items are depicted in Section 2, Figure 1.

FIGURE 1
New Technology System Hierarchy



The item for which new technology qualification is desired could be at any level of indenture within the system hierarchy. System-of-Systems (SoS) refers to the larger system with which integration of the new technology could occur. This SoS could be another system or an asset such as a marine vessel or an offshore unit. The asset becomes a novel concept if the incorporation of any new technology(ies) appreciably alters its service scope, functional capability, and/or risk profile.

3.3 New Technology System Requirements and Description Document

Properly defining a new technology is a critical aspect of NTQ. For this purpose, a system requirements and description document (SRDD) should be developed for the new technology and maintained throughout the NTQ process. This document defines and sets the baseline requirements for the new technology and may be derived from functional and technical specifications. The requirements will be defined for each level within the system hierarchy as applicable. As the design matures through development and more knowledge is gained through qualification, these requirements may be subject to change. The SRDD will need to be updated accordingly.

3.3.1 Defining System Requirements

3.3.1(a) Goals. The goals defined for the new technology should identify the high-level scope, objectives, or requirements that the new technology needs to meet. Goals may be derived from client's needs, mission, measures of effectiveness, environmental or application constraints, program/policy decisions and/or requirements derived from tailored specifications or standards.

3.3.1(b) Functional Requirements. Functional requirements define each function that the system is required to perform. The functional requirements should be mapped to specific items that will perform the function and typically includes a description of the function to be performed, the environment within which the function should be performed, the conditions under which the system should start the function and the conditions under which the system should terminate the function.

3.3.1(c) Performance Requirements. The performance requirements define how well each functional requirement should be accomplished, and the set of performance metrics including identification of critical performance parameters. The performance requirements can be defined qualitatively at early design stages and progressively more quantitatively during subsequent stages of technology maturation. In case where performance requirements are not defined because of the novelty of the technology, the requirements should be extrapolated from existing Rules, Guides, and/or other industry standards. Any relevant requirements from regulatory agencies or Flag Administration should be also considered. The performance criteria is the acceptance criteria against which the results of each qualification activity is evaluated.

The requirements should be defined according to NATO AVT-092 "Qualification by Analysis" and/or ISO 13879 "Petroleum and natural gas industries – Content and drafting of a functional specification". The aspects to consider for inclusion while defining functional requirements and related performance requirements may vary depending on the new technology to be qualified but typical considerations include:

3.3.1(d) Design Conditions. The system design conditions describe all applicable loading requirements under the environmental and operating conditions. This should include, but not be limited to, the natural environment (e.g., temperature and chemical exposure), the induced environment (e.g., vibration and noise), electromagnetic signal environment, and threats. Typical loading and design conditions to be considered include, but are not limited to, the following:

- Pressure and temperature induced loads and fluctuations
- Static and dynamic loads
- Fatigue and fracture effects
- Wear and vibration effects
- Material degradation and associated loss from damage mechanisms
- Accidental loads (as applicable)

3.3.1(e) System Interface Requirements. The system interface requirements define all internal and external physical and functional interfaces (e.g., mechanical, electrical, etc.) relevant to the new technology. Interfaces among system elements should also include interfaces with the human element. The system interface definition confirms that various elements of the system can functionally and physically interact with each other and with all external systems they connect to or communicate with. A graphic description of the interfaces can be used when appropriate for clarity.

3.3.1(f) Human System Integration Requirements. Human factors play an important role for the system to work safely and effectively in achieving required functions and goals, and should be considered throughout the design life of the new technology. Human factors requirements (ergonomics) define the characteristics of human system interaction in terms of usability, safety, human reliability, performance, effectiveness, efficiency, maintainability, and health. It is important that human factors be considered during early design stages.

Human Factors Engineering (HFE) is a specialized engineering discipline that integrates human behavioral and physical capabilities and limitations with traditional engineering disciplines to produce a human-system interaction that maximizes the best of both, allowing both the human and system to work together in achieving functional and performance requirements.

The focus of HFE is the design of the human-system interface. This includes interfaces between personnel and the hardware, software, and physical environments associated with systems. It also involves the interfaces between personnel, individual tasks, and the overall work system (e.g., its structure, management, policies, and procedures). A good starting point is defining usability requirements which identify user needs and expectations. Usability requirements define the appropriate allocation of functions between users and the technology as well as the measurable effectiveness, efficiency, and satisfaction criteria in specific contexts of use.

During the design process, specific areas, stations, or equipment arrangement that would require concentrated human engineering attention should be defined. Any special requirements, such as constraints on allocation of functions to personnel and communications and personnel/equipment interactions, should be specified. Successful application of HFE depends on a proper process of conducting the appropriate activities in the various stages of the development lifecycle of the system.

Further guidance on Human Factors Engineering can be found in the following references:

- ABS *Guide for Ergonomic Notations*
- ABS *Guidance Notes on the Implementation of Human Factors Engineering into the Design of Offshore Installations*
- ABS *Guidance Notes on the Application of Ergonomics to Marine Systems*
- ABS *Guidance Notes on Ergonomic Design of Navigation Bridges*
- *Standard Human Engineering Program Requirements for Ships and Marine Systems, Equipment and Facilities, Standard 1337. American Society of Testing and Materials (ASTM) (2010)*
- *Common Requirements, Architectural Components & Equipment (C-CR-002). Norwegian Oil Industry Association and the Federation of Norwegian Engineering Industries (NORSOK). (1996)*
- *Working Environment (S-002). Norwegian Oil Industry Association and the Federation of Norwegian Engineering Industries (NORSOK). (2004)*

3.3.1(g) Maintainability. Specify the quantitative maintainability requirements that apply to maintenance in the planned maintenance and support environment. Examples are as follows (ISO 29148):

- Time (e.g., mean and maximum downtime, reaction time, turnaround time, mean and maximum times to repair, mean time between maintenance actions)
- Rate (e.g., maintenance staff hours per specific maintenance action, operational ready rate, maintenance time per operating hour, frequency of preventative maintenance)
- Maintenance complexity (e.g., number of people and skill levels, variety of support equipment, removing/replacing/repairing components)
- Maintenance action indices (e.g., maintenance costs per operating hour, staff hours per overhaul)
- Accessibility to components within systems and to parts within components

3.3.1(h) Reliability. Reliability describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability requirements determine the robustness, consequences of, and redundancy of the system. Reliability requirements are best stated as quantitative probability statements that are measurable by test or analysis, such as the mean time between failures (MTBF) and the maximum acceptable probability of the failure during a given time period.

3.3.1(i) Safety and Environment. Safety and environmental requirements applicable to eliminating or minimizing hazards related to people, environment, and asset.

3.3.1(j) System Life Cycle Sustainment. The system life cycle sustainment requirements include activities that relate to sustaining the quality or integrity of the system. Typical requirements include, but are not limited to, support, sparing, sourcing and supply, provisioning, technical documentation, personnel support training for all modes of operation (e.g., installation, hook-up, commissioning, and decommissioning) throughout the life cycle of the system. These requirements should be updated as needed in order to sustain performance.

3.3.1(k) Data Management and System Security. For data-intensive systems, the management of information should be defined. The information management requirements should define the information the system receives, stores, generates and exports as well as the backup of the information.

System security requirements define both the surrounding environment (i.e., location) of the system and the operational security requirements. For example, to protect the system from accidental or malicious access, use, or destruction, some protection methods (e.g., access limitations, use of passwords, or the restriction of communications between some areas of the system) can be used. For control systems that govern multiple critical aspects of the assets, insights should be provided for operations, maintenance and support of cyber-enabled systems, to improve security in those systems.

The ABS CyberSafety™ program addresses cyber-enabled systems protection in an extended set of engineering processes that emphasizes human and systems safety. For further guidance on this program refer to the following documents:

- ABS *Guidance Notes on Application of Cybersecurity Principles to Marine and Offshore Operations – ABS CyberSafety™ Volume 1*
- ABS *Guide for Cybersecurity Implementation for the Marine and Offshore Operations – ABS CyberSafety™ Volume 2*
- ABS *Guidance Notes on Data Integrity for Marine and Offshore Operations – ABS CyberSafety™ Volume 3*
- ABS *Guide for Software Systems Verification – ABS CyberSafety™ Volume 4*
- ABS *Guidance Notes on Software Provider Conformity Program – ABS CyberSafety™ Volume 5*

3.3.2 System Description

The SRDD is also to include a detailed technology description. This involves additional documentation that could help provide evidence or demonstrate the ability of the technology to meet defined system requirements. The description of the technology typically includes the following:

i) Equipment list

ii) Comparison with existing similar technologies

iii) Lessons learned from similar technologies

iv) Possible applicable standards, codes, or industry practices

v) Relevant engineering documents as applicable:

- Piping and Instrumentation Diagrams (P&IDs)
- Heat and material balances
- Block diagrams
- Design schematics
- General arrangements
- Material specifications including material properties
- Design analysis methodology and related reports
- Installation analysis
- Test reports

vi) Control and safety system details

vii) Operational, maintenance, and inspection strategies

viii) New or unproven manufacturing, assembly, transit, storage, installation, hook-up, testing, commissioning, and decommissioning details

ix) Quality, health, safety, and environmental philosophies

The SRDD needs to be submitted for ABS review. The SRDD is not intended to be a single consolidated document but a design review package that compiles the relevant documents.

It is recognized that the requirements definition and the supporting description documentation is developed throughout the NTQ process. The submittal only needs to include the information available based on the design maturity of the new technology.

5 New Technology Screening

Once the technology has been described, a systematic screening process is needed in order to identify the new or novel elements, characteristics, or environment for which qualification is needed. The decomposed system should be reviewed to identify which of those items are considered new technology, as defined in Subsection 1/5, and which ones are not. The level of effort involved in qualification increases from categories *i)* through *iv).* Items that are not considered new technology could follow the conventional ABS certification process.

For new technology items, it is useful to identify whether similar technology exists and whether relevant Rules, Guides, and/or standards apply wholly or partially for this technology. Identifying the new technology items provides a basis for reducing the qualification scope to only those items that need to be addressed through the NTQ process. The vendors could perform the screening process independently or in a workshop setting with ABS, which will help support/guide the process. Section 2, Table 1 below, is a sample table that can be used for a systematic screening.

TABLE 1
Systematic Screening Table

Item	*Description*	*Similar Technology Exists?*	*Relevant Rules, Guides, or Industry Standards for This or Similar Technology?*	*New Technology (Yes/No)*	*New Technology Category (i, ii, iii, iv)*	*Notes*
1		Technology 1, Technology 2…	Standard 1 (partially) Standard 2 (No)…	Yes	*i*	
2		No	Standard 1 (partially) Standard 2 (partially)…	Yes	*iii*	
3		This technology exists	N/A	No	N/A	

Columns:

Description: Description of elements of the new technology item(s) (e.g., subsystems)

Similar Technology Exists?: Identify whether similar technologies exist, for example, technologies in other industries (e.g., onshore, aerospace, etc.). If existing technology exists, list them in this column.

Relevant Standards for This or Similar Technology: List of any standards applicable to the new technology with short explanation about applicability.

New Technology (Yes/No): Decide which technologies are new and which are not.

New Technology Category: As defined in Subsection 1/5:

i) Existing technology challenging current boundary/envelope

ii) Existing technology in new applications

iii) New technology in existing applications

iv) New technology in new applications

Notes: Other information or justification relevant to the screening process (e.g., conditions for applicability of standards, recommendations for qualification, etc.).

The systematic screening results and supporting information is to be submitted for ABS review.

7 New Technology Stage Determination

Based on the results from the new technology screening process and review of the SRDD, ABS and the client will agree on a maturity level determination. An appropriate qualification stage will be assigned to proceed, with qualification activities. A detailed questionnaire for determining the technology maturity level and qualification stage can be found in Appendix 3.

A more mature design could result in the ability to start at a later qualification stage, thus minimizing the level of effort and time it takes to complete qualification of the new technology. Once credit has been given to the design maturity and the appropriate qualification stage is determined, the client can proceed through the qualification process outlined in the following Sections:

- Feasibility Stage (Section 3)
- Concept Verification Stage (Section 4)
- Prototype Validation Stage (Section 5)
- System Integration Stage (Section 6)
- Operational Stage (Section7)

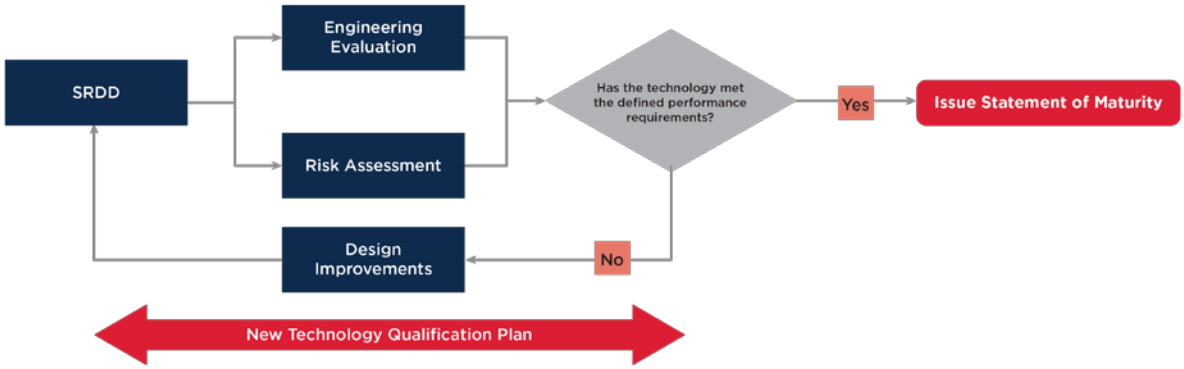
9 New Technology Qualification Plan and Activities

The New Technology Qualification Plan (NTQP) defines a roadmap for progressing the new technology through the appropriate qualification stages. The objective of the NTQP is to provide a summary of qualification activities that need to be performed at each stage in order to demonstrate the ability of the new technology to meet the requirements specified in the SRDD.

The initial NTQP should be developed based on the findings in the screening process in Subsection 2/5. The NTQP for each subsequent stage is updated based on the findings from the previous stage activities and discussions between the client and ABS. A NTQP template is provided in Appendix 4.

Qualification within each stage is comprised of a set of iterative activities that include engineering evaluations and risk assessments to verify new technology design. Results of these activities could lead to design improvements or modifications to the requirements specified in the SRDD. All design improvements and/or modifications should be documented in the NTQP with necessary technical justification. Section 2, Figure 2 summarizes the iterative NTQP activities.

FIGURE 2
New Technology Qualification Stage Iterative Process



9.1 Risk Assessment Requirements

As stated in Subsection 2/9, a risk assessment is to be prepared and submitted to ABS for review.

For a new technology requesting qualification through the NTQ process, a risk assessment is to be performed/updated at each stage as applicable. The risk assessment within the NTQ process will vary from qualitative to quantitative depending on the maturity level and information available at that stage. The primary objective of the risk assessment is to identify technical risks and uncertainties associated with the proposed design and document all foreseeable hazards, their causes, consequences, and potential risk control measures considering the new technology in its proposed application and operating environment. All possible interfaces, and known integrations are to be evaluated as part of this assessment.

All risk assessments performed must consider the following areas:

i) Personnel safety

ii) Asset protection

iii) Environmental protection

It is recommended that the risk assessment be carried out by a multidisciplinary team that includes the design team (vendor) and the end-user. ABS' participation in the risk assessment is also recommended. Appendix 2 of the ABS *Guide for Risk Evaluations for the Classification of Marine-Related Facilities* provides an overview of how to assemble an appropriate risk assessment team.

Prior to performing the risk assessment, a risk assessment plan should be prepared and submitted to ABS for review. The risk assessment plan should include the following information:

i) Scope of the Assessment

- *a)* Description of the proposed new technology including physical and operational boundaries
- *b)* Intended service application of the new technology

ii) Assessment Team

- *a)* Subject matter experts/participants/risk analysts, including their background and areas of expertise

iii) Assessment Preparation

- *a)* All available new technology information (e.g., design basis, drawings, procedures, etc.),
- *b)* Proposed risk assessment method (e.g., FMECA)
- *c)* Proposed risk assessment criteria for evaluation (e.g., risk matrix)

After the risk assessment has been completed, a report that includes the following information should be submitted to ABS for review:

i) Scope

- *a)* Description of the proposed new technology including physical and operational boundaries
- *b)* Intended service application of the new technology

ii) Risk Assumptions and Data References

iii) Supporting Engineering Documents

- *a)* Technical drawings

iv) Risk Assessment Worksheets (Hazard Register) that

- *a)* Identifies hazards associated with the new technology in its current boundary conditions (application and operating environment),
- *b)* Identifies scenarios associated with each identified hazard,
- *c)* Identifies causes of the hazardous scenario,
- *d)* Identifies consequences of the hazardous scenario,
- *e)* Identifies existing risk control measures for each hazardous scenario,
- *f)* Estimates the likelihood (frequency) and the severity of the consequence,
- *g)* Evaluates the risk of the hazardous scenario by measuring it against the acceptable risk criteria agreed upon by the analysis team,
- *h)* Identifies and evaluates the need for any recommendations to lower the risk to acceptable levels (design improvements through risk control measures)

v) Conclusions and Recommendations

- *a)* Action items and/or recommendations

Further guidance on developing basic and detailed risk assessment plans can be found in Section 5 and Section 6, respectively of the ABS *Guide for Risk Evaluations for the Classification of Marine-Related Facilities.*

It is recognized that each new technology may be unique in terms of design, operating environment, and application, therefore it is difficult to provide precise guidance on which risk assessment techniques should be used in a given situation. Therefore the selection of risk assessment methodology should be considered on a case-by-case basis and discussed with ABS prior to performing a risk assessment. Some typical recommended risk assessment techniques and their common uses can be found in Section 2, Table 2.

TABLE 2
Recommended Risk Assessment Techniques

Type of Study	*Description*	*Common Uses*
HAZID	A method to rapidly identify hazards, assess potential consequences, and evaluate existing safeguards of the system. Methods draw upon a highly experienced multi-disciplinary team using a structured brainstorming technique to assess applicability of potential hazards.	• Used for all types of systems and processes.
FHA	A functional hazard assessment (FHA) is used to identify and assess the functional failures of a system or subsystem.	• Used for all types of systems and processes.
FMEA (Failure Mode and Effects Analysis)	An FMEA is a reasoning approach best suited to reviews of mechanical and electrical hardware systems. The FMEA technique (1) considers how the failure modes of each system component can result in system performance problems and (2) makes sure the proper safeguards are in place. A quantitative version of FMEA is known as failure modes, effects and criticality analysis (FMECA).	• A design FMEA/FMECA can be used for reviews of mechanical and electrical systems (e.g., fire suppression systems, vessel steering and propulsion systems) to identify design related failures. • A process FMEA is often used to identify failures while performing steps within a given process or procedure (e.g., manufacturing, assembly).
Hazard and Operability (HAZOP) analysis	The HAZOP analysis technique uses special guide words for (1) suggesting departures from design intents for sections of systems and (2) making sure that the proper safeguards are in place to help prevent system performance problems.	• Used for finding safety hazards and operability problems in continuous process systems, especially fluid and thermal systems. It can also be used to review procedures and other sequential or batch operations.

Further guidance on risk assessments techniques can be found in the following references:

- ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries*
- ABS *Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification*
- *Petroleum and Natural Gas Industries – Offshore Production Facilities – Guidelines on Tools and Techniques for Hazard Identification and Risk Assessment, ISO 17776*
- *Risk Management – Risk Assessment Techniques, ISO 31010*
- *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, SAE ARP 4761*

9.3 Engineering Evaluation

Engineering evaluations are used to verify and validate that the new technology is capable of performing acceptably with respect to intent and overall safety according to the requirements of each stage. This is achieved gradually for each qualification stage through specific qualification activities as the technology matures and can be found in the NTQP. The types of activities for engineering evaluation are:

i) *Review Engineering Design Requirements.* As the technology matures, and more detailed design information becomes available, the functional and performance requirements are reviewed/updated as needed.

ii) *Technical Analyses and Simulations.* Engineering design analyses and simulations are used to verify the technology at the earlier qualification stages

iii) *Validation Testing.* Functional, model testing, and prototype testing are used to verify that the new technology satisfies all the specified functional and performance requirements.

iv) *Interface Analyses.* Interface analyses of the technology with existing systems are required and system integration testing is needed in order to fully understand all interactions between the new technology and surrounding systems, including people and the environment.

v) *Verification of Operability.* Operational testing and the collection of test data are required to verify the new technology satisfy the operational requirements.

vi) *Verification of Inspectability and Maintainability.* The various components of the new technology must be reviewed to confirm that they can be monitored, inspected and maintained in a manner consistent with existing practice.

vii) *Quality Assurance and Quality Control (QA/QC) Program.* Establish and maintain an effective quality control procedure(s) and quality acceptance criteria at each stage in accordance with recognized industry standard.

9.5 Design Improvements

Based on the results of the engineering evaluation and risk assessment activities, design improvements may be necessary to enhance reliability and safety of the design. The opportunities to improve safety could be through changes or modifications that make the design inherently safer or implementation of appropriate risk control measures. Example design changes include, material changes, reconfiguration, redundancy, and loading requirements.

Any design improvements that are identified and determined necessary as part of further refinement of the new technology is to be re-evaluated against the functional and performance requirements outlined in SRDD. The updated qualification activities should aim to meet these new requirements. Design improvements should be tracked in the NTQP.

The following sections should be considered when improving the design of any new technology.

9.5.1 Hierarchy of Risk Control Measures

Inherently safe design exists in something as a permanent and inseparable element. In other words, the risk control measures in place are “built in”, not “added on”. Identification of measures to control risks identified throughout the qualification process can be summarized in the following list:

i) *Elimination or Substitution.* Elimination of the design element, or the hazard associated with it should always be the first consideration. Careful evaluation may indicate that the functional requirements may be accomplished by another design element.

ii) *Engineering.* Engineering controls are mechanical or physical features added to the equipment, systems, subsystems, and/or components in order to remove or control the hazard, either by initial design specifications or by applying methods of substitution, minimization, isolation, or ventilation.

iii) *Administrative.* Administrative controls rely more actively on human action and behavior. Examples of administrative controls include written operating procedures, maintenance and inspection strategies, checklists, safety meetings, alarms, signs, training of personnel.

iv) *Personal Protective Equipment.* Personal protective equipment (PPE) creates a barrier between the person wearing the PPE and the hazard associated with the job. PPE such as hearing protection, protective clothing, safety glasses, respirators, gloves, welding aprons, and hardhats are methods of controlling hazards.

In general, inherently safe design is more of a philosophical way of thinking rather than a specific set of tools or methods. For example, a hazard might be considered “safe” because it has specific risk reducing measures in place. Inherently safe design asks the question, “can it be safer?”

The goals of inherently safe design can be summarized by the following:

- Fewer and smaller hazards
- Fewer causes that initiate hazardous events
- Reduced severity and consequences (e.g. fatalities, lost time incidents, asset damage, etc.)
- More effective management of residual risk

The inherently safe design approach to achieve goals of safer design should consider elimination or substitution to significantly reduce hazards. The following questions should be asked when considering the design of new technologies with hazardous potential:

1. Can the hazard be eliminated by design improvements?
2. If not, then can the magnitude of the hazard be reduced?
3. Do the alternative designs identified in question 1 and 2 increase the magnitude of other hazards or present new hazards?
4. What other risk control measures (engineering or administrative) are required to manage hazards that remain?

An inherently safe design approach to design improvements is recommended in order to eliminate design elements that are limiting the new technology from meeting defined functional and performance criteria. This philosophy should shift focus on improving design by implementing elimination, substitution, or engineering risk control measures.

9.5.2 Management of Change

Design improvements are inevitable during the course of technology design and development and are integral to the process, especially during the early design phases. These improvements can potentially have an impact on risk, and on previously performed qualification activities during the NTQ process. For this reason, it is important that clients establish an appropriate Management of Change (MoC) program. It is recommended that a MoC program be developed to confirm that design improvements are reviewed in a responsible manner by appropriate personnel.

A MoC program is a combination of policies and procedures used to evaluate the potential impacts of a proposed design improvement so that it does not result in unacceptable risks. Developing an effective MoC strategy requires establishing, documenting, and successfully implementing formal policies to evaluate and manage both temporary and permanent modifications including equipment, materials, procedures and conditions.

The techniques used to evaluate the improvement, the people available for review, the time frames for reviewing and implementing the improvement will differ between the design phases. During the early phases, there may be many design improvements, but there will be fewer records to update than if the improvement occurs at a later stage. Tools such as software simulations and preliminary risk analysis can prove extremely valuable when determining design improvements at early stages and are less labor intensive than in later stages.

An effective MoC program requires preparation beyond defining and documenting a policy to outline the system. The following factors are important to successful implementation of a MoC program:

i) Clear roles and responsibilities

ii) Appropriate organizational preparation

iii) A written MoC program manual that includes MoC forms

iv) Pilot roll-out before the full-scale deployment, training of affected personnel, and

v) Close attention when integrating MoC with existing programs.

The following references provide more details on Management of Change processes:

- ABS *Guidance Notes on Management of Change for the Marine and Offshore Industries*
- *API RP 750, Management of Process Hazards, American Petroleum Institute, Washington, DC, 1990*
- *API RP 75, Recommended Practice for Development of a Safety and Environmental Management*
- *Program for Offshore Operations and Facilities, American Petroleum Institute, Washington, DC, 2004*
- *Guidelines for Management of Change for Process Safety, Center for Chemical Process Safety CCPS, 2008*

SECTION 3 Feasibility Stage

1 Introduction

A new technology considered for qualification in the Feasibility stage is at an early concept maturity level, where basic research and development activities to identify engineering principles are complete; and a concept formulated along with its functional requirements. A high-level design analysis is performed to verify the concept in the intended application and that the overall proposed level of safety is comparable to those established in Rules, Guides, other recognized industry standards and recommended practices.

In cases where multiple concepts are submitted for ABS review, the overall objective is to work with ABS to identify a concept that proves most feasible for the application with respect to safety and reliability.

3 Qualification Activities

3.1 Engineering Evaluation

The engineering evaluation at the Feasibility Stage involves a high-level design verification of the proposed concept. All goals, functional requirements, and performance requirements submitted as part of the SRDD in 2/3.3 are reviewed along with any available high-level engineering design analysis to verify that the proposed concept is feasible.

3.3 Risk Assessment

A high-level risk assessment should be carried out during this stage to identify any preliminary technical risks and uncertainties associated with the proposed concept. The risk assessment should focus on documenting all foreseeable hazards, their causes, consequences, and potential risk control measures considering the new technology in its proposed application and operating environment. Additionally, all possible interfaces and known integrations should be considered. This risk assessment should set the basis for any subsequent qualitative/quantitative assessments that may need to be performed to completely understand the new technology's risk profile. Subsequent assessments may be in the form of additional engineering evaluation or risk assessments.

The results of the risk assessment should be documented and tracked in a hazard register for assessment and implementation in future qualification stages. The primary function of the hazard register should be to demonstrate that hazards and appropriate risk control measures have been identified. Recommendations for additional risk assessments and engineering evaluations are to be documented and submitted as part of the NTQP.

An appropriate risk assessment technique should be selected for this high-level risk assessment and submitted to ABS for review in the form of a risk assessment plan as discussed in 2/9.1. The engineering evaluation documents that support the risk assessment should be available and at an appropriate level of maturity before the risk assessment is performed. The following high-level risk assessment techniques are recommended as options for identifying preliminary technical risks:

i) HAZID identifying possible hazards, events, and outcomes related to the impact on personnel, asset, environmental, and reputation

ii) Functional FMEA identifying possible failure modes, effects (local and global), causes, and preliminary safeguards including all interfaces (i.e. system to system, system to subsystem, etc.)

iii) Functional Hazard Analysis (FHA) identifying system/sub-system functions and hazards associated with those functional failures

A risk assessment report including the hazard register should be prepared. The risk assessment report and the NTQP should be submitted to ABS for review.

There may be specific cases where the information available at this maturity level is limited and a risk assessment technique may not be possible. This scenario will be treated on a case-by-case basis, and ABS will recommend an alternative approach as needed to meet the new technology Feasibility Stage requirement.

5 Summary of Submittals

The following qualification activities along with future activities for the Concept Verification Stage should be highlighted in the NTQP and submitted to ABS for review:

5.1 Engineering Evaluation

i) SRDD

- Design basis, functional specification and/or technical specification of the new technology
- System and function architecture details such as functional flow block diagram
- Design details such as basic engineering drawings and engineering principles associated with further development
- Design analysis methodology and any available preliminary results
- Details regarding physical and functional interface requirements (mechanical, hydraulic, electronic, optical, software, human, etc.)
- Applicable design references, codes, standards and guidelines, and technical justification for any proposed deviations (may be identified independently or during the new technology screening process)
- Lessons learned, references and examples of comparable designs

5.3 Risk Assessment

i) Risk assessment plan in accordance with 2/9.1

ii) The appropriate risk assessment report identified in 3/3.3

iii) Hazard Register complete with an action tracking system

7 Feasibility Stage Completion: Technology Feasible

Once the above deliverables have been submitted to ABS for review and all specified performance requirements have been verified, then a Statement of Maturity will be issued stating that the technology is feasible. The technology is now ready to proceed to the Concept Verification Stage.

SECTION 4 Concept Verification Stage

1 Introduction

The second stage of the NTQ process is the Concept Verification Stage. The new technology is verified as performing its functions in accordance with defined performance requirements. This is accomplished by performing more detailed engineering studies and physical (or virtual) model testing. Reliability testing of select items may be performed. The operating conditions and the relevant environment are further refined. The functional and performance requirements outlined in the SRDD are re-evaluated, verified, and updated (as needed). The interfaces between configurations are verified against functional and performance requirements.

In addition, the production strategy is developed in the form of a preliminary manufacturing plan. A design risk assessment is carried out to identify technical risks related to design failures. Risk assessments from the Feasibility Stage are reviewed and updated (as needed) based on the design development in this stage.

3 Qualification Plan Activities

3.1 Engineering Evaluation

3.1.1 Engineering Design Review

At the Concept Verification Stage, the concept is confirmed and the engineering design is performed to verify that the functionality and performance of the new technology can be satisfied. The subsystem and component level requirements following the systems engineering approach should be defined if not specified at the Feasibility Stage. The objective is to define complete and consistent requirements that an item should have and confirm that the design correctly and completely captures each specification in the system requirements.

The performance requirements should state how the technology will perform its function and how the system requirements will be met. The performance requirements are to be established and should be detailed enough that the technology can be evaluated against the expected performance criteria. In addition, the requirements for the integration of subsystems and components into system prototypes should be defined. The overall configuration of the system should be provided and a preliminary interface analysis should be performed to verify the interfaces between configurations.

Design constraints should be identified and incorporated into the system requirements and design documentation. At this stage, the system requirements should be stated in quantitative measures that can be verified by subsequent numerical or analytical models and model tests. The overall system requirements defined at the Feasibility Stage should be reviewed to confirm continued relevance. Any change should be reviewed and documented with technical justification.

A preliminary manufacturing plan should be developed and should include the manufacturing methods and processes, the facilities, the production schedule, and the quality assurance requirements. The materials used in the system should be determined and reviewed during the qualification process. The technology design documentation is to be submitted for ABS review.

3.1.2 Functional and Model Testing

Tests are an essential part of the NTQ process and they can demonstrate the performance of the new technology. The types of tests required depend on the novelty of technology itself and pre-existing experience with similar concepts.

Functional and model tests are used to verify the functionality of the system and its ability to meet the defined functional requirements. Testing is to be performed in the technologies anticipated environment and operating conditions. The objectives of the functional testing are to verify that the system meets the performance and reliability requirements, as well as to verify the results obtained from the analytical models. The functional testing should consider and address the critical failure modes identified during the risk assessments.

For the new materials or those that can have a significant effect on the performance of the system, destructive or non-destructive testing should be used to identify the relevant failure modes and mechanisms or to explore the critical parameters and their effects. The same raw materials or components stated in the material specification for the actual product should be used in the tests. For materials that will degrade over time, materials degradation testing should be performed. Accelerated testing methods may be used to test the lifetime performance of the materials in a shorter time. Additionally, reliability testing for select items may be required.

Before performing any testing, a test plan should be developed and submitted to ABS. The test plan should document the test setup and strategy that will be used to verify that a product meets its design specifications and other requirements. The specific test plans should include the assumptions and constraints, input data, test procedures, expected test results, the parameters to be measured, instrumentation system specifications, and the acceptance criteria for evaluating results. For certain tests, it may be required for an ABS Surveyor to witness the testing activities to verify that it meets performance requirements and confirm the presence of an effective quality control program. Further guidance on function and model testing can be found in references [10], [11], [12] and [13] listed in Appendix 1.

3.3 Risk Assessment

The objective of the risk assessment in this stage is to identify technical risks associated with the new technology design to the lowest level of indenture as practicable. The updated concept level design engineering documentation from the Feasibility Stage and the additional engineering documents developed in this stage serve as input to the risk assessment. This design risk assessment should take into account the following:

- Any design modifications from the Feasibility Stage
- Updated functional and performance requirements
- Updated configurations
- Possible interfaces and integrations
- All potential failure modes, failure causes and failure mechanisms in all expected operational modes and life cycle stages
- The effectiveness of existing risk control measures and the need for any additional or more reliable measures
- Closing out any action items (qualification activities) as agreed in the Feasibility Stage

Based on the findings of this risk assessment, additional qualification activities in the form of risk assessments or engineering evaluation may be required to further assist in identifying and assessing the full potential ranges of failure causes, failure mechanisms, consequences and any related uncertainties. These additional studies may be coarse, detailed, or a combination depending on the objective of the study. The results of the risk assessment should be documented and tracked in a hazard register for assessment and implementation in future qualification stages. The resulting qualification activities should be documented within the NTQP. A risk assessment report including the hazard register should be prepared. The risk assessment report and the NTQP should be submitted to ABS for review.

A risk assessment technique that is appropriate for reviewing the new technology design should be selected and submitted as part of the risk assessment plan to ABS. Potential design related failure events in all anticipated operational modes should be evaluated. Typically, for hardware or mechanical systems, a Failure Mode Effects and Criticality Analysis (FMECA) is recommended. The FMECA performed can help evaluate failure modes and corresponding failure causes, failure mechanisms, and the local and global effects of failure. It also includes a criticality analysis which is used to estimate the probability of failure and the severity of the associated consequence. The probability can be qualitative if lacking historical quantifiable data, but quantitative probabilities are preferred. The method of assigning criticality should be included within the risk assessment plan and agreed by ABS prior to the study. Results from the FMECA should be relayed back to the design process of the new technology to facilitate any design improvements or FMEA verification activities. Further guidance on FMECA and related verification activities can be found in the ABS *Guidance Notes on Failure Mode and Effects Analysis for Classification.*

The following risk assessments verifying all technical risks are to be performed and submitted to ABS for review.

i) Design risk assessment (e.g., FMECA) as described above.

ii) Update Feasibility Stage risk assessments as needed based on updated design documentation.

iii) Perform any additional risk assessments identified while verifying the design and/or updating previous risk assessments.

If reliability, availability and maintainability (RAM) targets are defined as part of the functional requirements then a preliminary system RAM analysis should be carried out in this stage. System modeling techniques such as reliability block diagrams (RBD), fault tree analysis (FTA), Markov state diagrams or other established methods should be used to demonstrate the ability of the system to meet the defined performance requirements. The FMECA serves as input to the system reliability models along with the other engineering documentation developed at this stage. A RAM analysis should be prepared and submitted for ABS review. The data sources used, their applicability and any related assumptions should be documented within this report.

5 Summary of Submittals

The following qualification activities along with future activities to be addressed in the Prototype Validation Stage should be highlighted in the NTQP and submitted to ABS for review:

5.1 Engineering Evaluation

i) SRDD

- *a)* Documents that describe the concept verification design requirements
- *b)* Design documents that include but not limited to the configuration, drawings, PFD/P&ID, analytical models, etc.
- *c)* Functional and model test plans, test data (as requested), and test results

ii) Preliminary manufacturing plan

5.3 Risk Assessment

i) Updated risk assessments from the Feasibility Stage (as applicable)

ii) Updated Hazard Register with updated action items closed out

iii) Preliminary design risk assessment (e.g., FMECA) report

iv) Preliminary system RAM analysis report (as applicable)

7 Concept Verification Stage Completion: Concept Verified

Once the above have been submitted to ABS for review and all specified performance requirements have been verified, then a Statement of Maturity will be issued stating that the concept has been verified. The technology is now ready to proceed to the Prototype Validation Stage.

SECTION 5 Prototype Validation Stage

1 Introduction

The third stage of the NTQ process is the Prototype Validation Stage. New technology that has matured to this stage has previously completed conceptual functional, performance, and reliability testing in nonspecific environments. The main objective in this stage is to validate with a prototype what was verified in the Concept Verification Stage.

During this stage, the technology is further developed to the point where a prototype or full scale production unit can be manufactured. All engineering studies and design risk assessments are completed and the design is refined to the detailed design. Engineering documents such as detailed drawings, product specifications, manufacturing plan and qualification test procedures are all fully developed. A preliminary system-of-systems interface analyses may be performed and system integration testing plan developed. Process risk assessments may be carried out (as needed) to evaluate relevant procedures and further refine them.

A prototype or full scale production unit is manufactured and all necessary qualification testing is carried out to validate the design. After completing this stage, the new technology has demonstrated that it can perform within the established performance requirements in a simulated or actual environment for an extended period of time.

3 Qualification Plan Activities

3.1 Engineering Evaluation

3.1.1 Engineering Design Review

At the Prototype Validation Stage, the engineering design is to confirm that the overall system, down to the lowest component level, has satisfied all system requirements. The performance requirements a technology must meet should be finalized and measurable. In addition, the requirements for system integration, installation, commissioning, operation, maintainability, and decommissioning should be established.

At this point the system has reached the necessary level of maturity to start fabricating, integrating, and testing. Changes in the requirements defined for any items during the previous stages should be reviewed and documented with technical justification.

At this stage, all design analyses and configuration definitions are completed and all design decisions that are outstanding are to be finalized. It is noted that there may be a need to revisit certain analytical and other relevant studies based on results of the prototype test. Detailed drawings including all dimensional requirements, process and instrument details, safety features and ancillary systems are completed as applicable. For load bearing components, all relevant loading and the uncertainty in that loading are analyzed. For process and electrical systems, all associated potential system failure/breakdowns and their associated failure frequencies (if applicable), as well as the consequence and impact on the system from each failure are identified.

In addition, all information (e.g., drawing and data) required for the production of the system are to be finalized. The actual performance of the new technology should be evaluated during prototype testing and compared against existing designs if available. The aforementioned design engineering documents are to be submitted to ABS for review. A preliminary system-of-systems interface analyses and system integration testing plan may be developed at this stage and submitted to ABS for review before the System Integration Stage.

3.1.2 Prototype Testing

Prototype testing is intended to prove that the interactions between the systems/subsystems/components under relevant loading and environmental operating conditions can perform reliably as intended. Prototype tests can identify potential failure modes and mechanisms as well as the critical parameters, especially when operational experience in relevant environments is limited or unknown.

Prototype testing can be used to verify the analytical models and the assumptions made during the engineering design process. A test plan which details test techniques, test limits, expected test data, quality assurance requirements should be developed and submitted to ABS for review before prototype testing. Calibration of measuring devices is to be current with manufacturer's quality management system. Calibrations should be traceable to a recognized national standard (e.g., NIST, ANSI, etc.).

For certain new technologies, it may be very difficult to perform prototype testing in the actual environment. In this case, virtual prototype testing in a simulated environment can be performed. However, the virtual prototype testing must be reviewed by ABS to assess that the simulated environments are commensurate with expected operational practices. Analysis tools, such as finite element analysis (FEA) and computation fluid dynamics (CFD), and other methods used should be qualified for application. The prototype testing documents should include inputs, assumptions, boundary conditions, the computational models and appropriately conditioned/reported test results. Prototype test results should be documented and analyzed to determine whether the prototype satisfies specified functional and performance requirements in its actual environment. A prototype test report is to be submitted to ABS for review. Further guidance on prototype testing can be found in references [10], [12], [13] and [14] listed in Appendix 1.

3.1.3 Manufacturing

A manufacturing plan should be finalized that includes the manufacturing methods and processes, the facilities, the production schedule, and quality assurance requirements. Quality assurance of the manufacturing process should confirm that the product meets the required specifications. The manufacturing plan should be submitted to ABS for review. Further guidance on developing a manufacturing plan can be found in references [15], [16] and [34] listed in Appendix 1.

3.1.4 ABS Survey

Survey during the manufacturing process and prototype testing may be required. The vendor should submit an Inspection Test Plan (ITP) to ABS for review. The ITP should define witness points and hold points as agreed between the vendor and ABS. The ABS Surveyor should witness the manufacturing process and prototype testing to verify that proper manufacturing and prototype testing processes are followed and it meets the quality assurance requirements.

3.3 Risk Assessment

The main objective of the risk assessments performed in the Prototype Validation Stage is to validate the final design of the new technology. The design risk assessment (e.g., hardware design FMECA) from the Concept Verification Stage should be reviewed and updated to evaluate changes made to the design and/or other aspects of the new technology description. Changes made to one part of the design or new technology design requirements could have the potential to introduce new technical risks to other previously evaluated parts. The results of other qualification activities in this stage may also serve as input to the updated design risk assessment. Follow-on qualification activities determined from the results of the updated design risk assessment should be included within the NTQP.

For certain new technologies with high consequence severity levels upon failure, if not already addressed by other risk assessments, ABS may recommend that an additional process risk assessment (e.g., process FMECA or HAZOP) is performed. The objective of this risk assessment is to evaluate the potential failures that could occur during specific steps as listed within the procedures. This process risk assessment typically evaluates procedures related to manufacturing (as defined within the final manufacturing plan), testing (prototype and systems integration), installation/integration, commissioning, operations and decommissioning. A risk assessment technique that is appropriate for reviewing these procedures should be selected and

submitted as part of the risk assessment plan to ABS for review. Typically, a process FMECA or HAZOP study is recommended. It is recognized that the scope of this risk assessment depends on the availability of relevant procedures. All interfaces should also be considered when performing this assessment. The recommendations from the study should be used by the engineering design team and the operations team to determine any design improvements or procedural changes necessary before finalizing the design and manufacturing.

Based on the findings of the final design risk assessment and process risk assessment (if applicable), a re-evaluation of all previous risk assessments should be considered. All previous risk assessments should be reviewed against any newly identified failure modes or hazards. Changes made to the design due to findings in these risk assessments should also be checked against the final functional and performance requirements.

Finally, all identified technical risks from the Prototype Validation Stage and risk assessments from previous stages should be appropriately managed through any necessary design improvements. All corresponding action items should be closed in order for the new technology to complete this stage of the NTQ process.

The following final design level risk assessments verifying all technical risks are to be performed and submitted to ABS for review:

i) Final design risk assessment (e.g., design FMECA)

ii) Final process risk assessment (e.g., process FMECA or HAZOP) if applicable

iii) Update all previous risk assessments as needed based on updated final design level documentation

iv) Final hazard register based on the final design with all actions items closed out

If applicable, the preliminary RAM analysis should be re-evaluated and finalized. The final RAM analysis report should be submitted for ABS review.

5 Summary of Submittals

The following qualification activities along with future activities for the System Integration Stage should be highlighted in the NTQP and submitted to ABS for review:

5.1 Engineering Evaluation

i) SRDD

- Review engineering documents that describe the component requirements and the interaction between components, subsystems, and the overall system if applicable.
- Detailed design documents including detailed drawings, product specifications, process and instrument details, detailed calculations, etc.
- Prototype test plans, test data (as requested), and test results summarized in a report.
- Additional qualification testing, data, and results identified in the design risk assessment (e.g., FMECA).

ii) Inspection Test Plan (ITP)

iii) Detailed manufacturing plan.

5.3 Risk Assessment

i) The final updated risk assessment reports from the Concept Verification Stage (as applicable).

ii) The final design risk assessment (e.g., FMECA) report.

iii) The process risk assessment (e.g., process FMECA) report (as applicable).

iv) The final system RAM analysis report (as applicable).

v) Final hazard register with all action items closed out.

7 Prototype Stage Completion: Technology Qualified

Once the above deliverables have been submitted to ABS for review and all specified performance requirements have been verified, then a Statement of Maturity will be issued stating that the technology has been qualified. The technology is now ready to proceed to the System Integration Stage.

9 ABS Type Approval Program

Upon completion of the Prototype Validation Stage of the NTQ process, the new technologies that are consistently manufactured to the same design and specification may be Type Approved under the ABS Type Approval Program to limit repeated evaluation of identical designs. During the Prototype Validation Stage, if all the engineering evaluations have been completed, a PDA can be issued prior to further consideration for ABS Type Approval.

SECTION 6 Systems Integration Stage

1 Introduction

The fourth stage of the NTQ process is the Systems Integration Stage. In this stage, discussions between the vendor and end-user are held to understand the compatibility of the technology with final operating system and operating environment. An interface analysis is performed to confirm the compatibility of the item. The technical risks during operations that have not been addressed during previous risk assessments are evaluated and relevant reports updated. All necessary risk control measures are implemented.

The "Technology Qualified" item is then integrated (by installation) with the final intended operating system. All functional and performance requirements of the integrated system as outlined in the SRDD are validated through testing before (or during) commissioning. Plans for in-service survey, inspection, monitoring, sampling and testing (as applicable) are determined.

3 Qualification Plan Activities

3.1 Engineering Evaluation

3.1.1 System Interface and Integration Requirement

At this stage the overall technology goals and requirements may remain unchanged. However, specific requirements for system-of-systems functionality and interfaces should be finalized. In addition, the detailed operational performance parameters should be defined and operational procedures should be developed. System interface and integration requirements are to be submitted to ABS for review.

3.1.2 Interface Analysis

It should be analyzed that the addition or incorporation of the new technology does not negatively affect the integrity of the surrounding systems and components. All necessary functional and physical interfaces (e.g., mechanical, electrical, environment, data, human, etc.) and other systems should be reviewed and verified that the new technology does not adversely affect those systems. At this stage, the interfaces should be specified in quantitative limiting values, such as interface loads, forcing functions, and dynamic conditions. The use of tables, figures, or drawings is recommended as appropriate. The vendor/end-user should provide detailed interface control methods or other engineering solutions so that the new technology is compatible with the integrated systems. The complete interface analysis and necessary engineering solutions are to be submitted to ABS for review.

3.1.3 System Integration Testing (SIT)

The operational prototype is built and integrated into the final system. Full interface and function test programs are performed in the intended (or closely simulated) environment. The impact of the new technology on the performance and integrity of other systems as well as the impact of other systems on the new technology itself should be addressed. An initial operational test and evaluation should be performed to assess the operational effectiveness and suitability in the intended environment. The operational test must demonstrate that the operational aspects associated with placing the application in a marine or offshore environment are commensurate with typical operational practice for these facilities. Changes to the technology design or operational procedures may be necessary to address any issues encountered during operational testing. A test plan which details test techniques, test limits, expected test data, quality assurance requirements should be developed and submitted to ABS for review before the system integration testing. All test procedures and test results are to be summarized in a report and submitted to ABS for review.

3.1.4 ABS Survey

Survey during the system integration testing may be required as agreed upon in the system integration test plan. ABS Surveyor will witness the system integration testing to verify that proper testing processes are followed and it meets the quality assurance requirements based on the witness points as agreed between the vendor/end-user and ABS.

An In-Service Inspection Plan (ISIP) to address in-service survey, inspection, monitoring, sampling and testing (as applicable) during operations should be submitted for ABS review.

3.3 Risk Assessment

The main objective of the risk assessments performed in the System Integration Stage is to evaluate any technical risks resulting from system integration and operations that have not been previously evaluated as part of the design risk assessment, process risk assessments or other risk assessments in the previous stages. The end-user should manage any additional/residual risks identified through appropriate risk control measures.

An appropriate risk assessment technique should be selected and submitted as part of the risk assessment plan to ABS for review. The use of a process FMECA, HAZOP or HAZID are recommended. The scope of this risk assessment typically includes installation, SIT, commissioning, operations and decommissioning. The assessment should consider all interfaces between the validated prototype and the connected system (system-of-systems). Follow on qualification activities may be determined from the results of the risk assessment such as engineering evaluation, testing, design improvements or procedure changes. These activities should be addressed within the NTQP. All risk control measures should be implemented and any outstanding action items from the risk assessment closed before proceeding with system integration testing and commissioning.

The need for updates to any previously submitted risk assessments or RAM analysis should be evaluated and addressed as appropriate. Updated risk assessment reports including hazard registers, RAM analysis (if applicable) and the NTQP should be submitted for ABS review.

5 Summary of Submittals

The following qualification activities along with future activities for the Operational Stage should be highlighted in the NTQP and submitted to ABS for review:

5.1 Engineering Evaluation

i) SRDD

- All documents that describe requirements for system-of-systems functionality and interfaces.
- All documents that describe detailed operational procedures and performance parameters.
- System integration test plans, test data, and test results summarized in a report.
- Plans for in-service survey, inspection, monitoring, sampling and testing (as applicable) during operations or ISIP.

5.3 Risk Assessment

i) Updated risk assessment reports from the previous stages (as applicable)

ii) Other applicable technical safety studies (e.g., RAM).

7 System Integration Stage Completion: Technology Integrated

Once the above deliverables have been submitted to ABS for review and all specified performance requirements have been verified, then a Statement of Maturity will be issued stating that the technology is integrated. The technology is now ready to proceed to the Operational Stage.

SECTION 7 Operational Stage

1 Introduction

The last stage of the new technology qualification process is the Operational Stage. New technology categorized as "Operationally Qualified" denotes that it has been integrated into the final system and has been operating successfully in service in the relevant operational environment.

Once the technology has been qualified at the Prototype Stage, it must be confirmed that the knowledge gained by the engineering and risk assessment tests and studies is fed into the operational stage, in order to monitor prior assumptions and predictions through in-service field verification. In other words, the first implementation of any new technology should be treated as a first time application to some extent. This Section will outline the necessary activities that must be completed and the information to be supplied to ABS during this stage. It is recommended that the qualification process involves members with operational background in this stage of the project. These members should become familiar with the results of all the previous qualification stages, if they had not participated from the start of the qualification process.

At this stage, the operational objectives, operating environment and the performance requirements established during design are reviewed and applied to define goals for in-service operation. Following successful operation and performance achievement of the goals in the actual operational environment, the technology can be granted a Statement of Maturity.

The activities of the Operational Stage are as follows:

i) Implementation of in-service survey, inspection, monitoring, sampling and testing plans

ii) Collection and analysis of reliability, availability, maintainability (RAM analysis) and other operational performance data as needed

iii) Comparison of operational data above with previously specified performance requirements, goals and criteria

iv) Performance of root cause analyses for any observed failure and using feedback to introduce modifications for improvement

v) Comparison of observed parameters with any critical assumptions made during the previous qualification stages and updating calculations as necessary

It is to be noted that when applying these Guidance Notes for classification or certification purposes, the primary driver for classification acceptance will be safety even though there may be additional functional requirements (e.g., reliability, ability to perform as per operational design specification) defined by the client.

3 Qualification Plan Activities

The need and extent of special in-service qualification requirements are dependent upon the justifications and risk assessment results during the design and qualification process. System requirements have been started to be defined in the Feasibility Stage of qualification, and they have been updated in later stages as the design evolved. Such requirements have to be translated into specific and quantifiable performance requirements to be attained during operations. Additionally, any critical assumptions made in the risk assessment and engineering evaluations during the four previous qualification stages should be monitored to confirm that operational experience does not disprove them. Taking all the above into consideration, the vendor and/or end-user together with ABS should outline the necessary elements of in-service survey, inspection, monitoring, sampling and testing needed to gain confidence in the real world application of the new technology.

These special requirements can be integrated in the end-user's Asset Integrity Management program. Advanced inspection and maintenance approaches like Reliability Centered Maintenance (RCM) and Risk Based Inspection (RBI) are appropriate strategies to follow since they are based on reliability and risk goals. Data collection and management are very important activities to consider for the in-service qualification stage.

The amount of operational history that is sufficient to verify performance requirements during operations depends on several factors, including actual equipment run time, failure rate and exposure time to failure. Therefore, the time to reach the "Operationally Qualified" status for the proposed new technology will be determined on a case-by-case basis.

All records related to the inspection, monitoring, sampling and testing of the new technology as established by the agreed-upon operational qualification plan or ISIP should be kept and made available for review upon request by ABS at any time. These records will be reviewed periodically to establish the scope and content of the required surveys that should be carried out by ABS.

The following references contain additional guidance for in-service monitoring, sampling, testing and inspection plans:

- ABS *Guidance Notes on Equipment Condition Monitoring Techniques*
- ABS *Guidance Notes on Reliability-Centered Maintenance*
- ABS *Guide for Surveys Using Risk-Based Inspection for the Offshore Industry*
- ABS *Guidance Notes on the Investigation of Marine Incidents*
- ABS *Guide for Hull Condition Monitoring Systems*
- ABS *Guide for Hull Inspection and Maintenance Program*
- ABS *Guide for Building and Classing Subsea Pipeline Systems*
- API RP 17N *Recommended Practice Subsea Production System Reliability, Technical and Integrity Management*

5 Summary of Submittals

The output of this stage is a report reviewing the operational data collected, and demonstrating how the specified performance requirements and criteria have been met.

The following items are typical submittals that ABS would expect to receive annually in order to conduct an Operational Stage audit:

- Summary report of results of the inspection, monitoring, sampling and qualification testing activities
- Failure data analysis of critical components
- Non-conformance reports and corrective actions taken.

Note: In case of a non-conformance report for a critical component, ABS should be notified as soon as practical.

7 Operational Stage Completion: Operationally Qualified

Once the operational experience of the new technology has proven to be successful (i.e., according to the expected performance, for a satisfactory amount of time in the actual operating environment, and meeting criteria acceptable by ABS), then a Statement of Maturity stating the operational qualification of the technology will be issued.

APPENDIX 1 References

1. API RP 17N Recommended Practice Subsea Production System Reliability, Technical and Integrity Management. American Petroleum Institute, 2009.
2. ISO 16290. Space systems – Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment. International Organization for Standardization, 2013.
3. IEC 60300-3-4. Dependability Management: Application Guide- Guide to the Specification of Dependability Requirements. International Electrotechnical Commission, 2007.
4. NATO AVT-092. Qualification by Analysis. Technical Report. RTO-TR-AVT-092, North Atlantic Treaty Organization (NATO), 2009.
5. ISO 13879. Petroleum and natural gas industries -- Content and drafting of a functional specification. International Organization for Standardization, 1999.
6. ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries*. Houston, TX.
7. ABS *Guide for Risk Evaluation for Classification of Marine-Related Facilities*. Houston, TX.
8. ISO 17776. Petroleum and Natural Gas Industries – Offshore Production Facilities – Guidelines on Tools and Techniques for Hazard Identification and Risk Assessment. International Organization for Standardization, 2000.
9. ISO 31010. Risk Management – Risk Assessment Techniques. International Organization for Standardization, 2009.
10. Department of Defense Test & Evaluation Management Guide, December, 2012.
11. ISO 17025. General requirements for the competence of testing and calibration laboratories. International Organization for Standardization, 2005.
12. Military Handbook 781A (MIL-HDBK-781A), Handbook for reliability test methods, plans, and environments for engineering, development qualification, and production, 2015.
13. Military Standard 810G (MIL-STD-810G), Environmental engineering considerations and laboratory tests, 2012.
14. IEC 60068. Environmental Testing. International Electrotechnical Commission, 2013.
15. Waid, M. (2011). Manufacturing Planning Guide.
16. Department of Defense. Defense Manufacturing Management Guide for program managers, 2012.
17. ABS *Guidance Notes on Equipment Condition Monitoring Techniques*. Houston, TX.
18. ABS *Guidance Notes on Reliability-Centered Maintenance*. Houston, TX.
19. ABS *Guide for Surveys Using Risk-Based Inspection for the Offshore Industry*. Houston, TX.
20. ABS *Guidance Notes on the Investigation of Marine Incidents*. Houston, TX.
21. ABS *Guide for Hull Condition Monitoring Systems*. Houston, TX.
22. ABS *Guide for Hull Inspection and Maintenance Program*. Houston, TX.
23. ABS *Guide for Building and Classing Subsea Pipeline Systems*. Houston, TX.
24. ABS *Guide for Ergonomic Notations*. Houston, TX.

25. ABS *Guidance Notes on the Implementation of Human Factors Engineering into the Design of Offshore Installations*. Houston, TX.

26. ABS *Guide for Crew Habitability on MODUs*. Houston, TX.

27. ABS *Guide for Crew Habitability on Offshore Installations*. Houston, TX.

28. ABS *Guidance Notes on the Application of Ergonomics to Marine Systems*. Houston, TX.

29. ABS *Guidance Notes on Ergonomic Design of Navigation Bridges*. Houston, TX.

30. American Society of Testing and Materials (ASTM). Standard Human Engineering Program Requirements for Ships and Marine Systems, Equipment and Facilities, Standard 1337, 2010.

31. Industry Association and the Federation of Norwegian Engineering Industries (NORSOK). Common requirements, architectural components & equipment (C-CR-002), 1996.

32. Industry Association and the Federation of Norwegian Engineering Industries (NORSOK). Working environment (S-002), 2004.

33. ISO 9001. Quality management systems – Requirements, 2015.

34. API Specification Q1. Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry. American Petroleum Institute, 2014.

35. AS 9100 Revision C. Quality Management System – Requirements for Aviation, Space and Defense Organizations, 2009.

36. ABS *Guide for Marine Health, Safety, Quality, Environmental and Energy Management*. Houston, TX.

37. ABS *Guidance Notes on Review and Approval of Novel Concepts*. Houston, TX.

38. INCOSE 2015. Systems Engineering Handbook – A Guide for System Life Cycle Processes and Activities, version 4.0. Hoboken, NJ, USA: John Wiley and Sons, Inc., ISBN: 978-1-118-99940-0.

APPENDIX 2 Comparison of ABS Qualification Stages with Industry TRLs

1 Introduction

Technology Readiness Levels (TRLs) are a method of estimating the maturity level of new technology. There are a wide variety of scales in industry based on the ISO 16290 standard. This standard uses a numerical scale one through nine, with nine representing the most mature. The American Petroleum Institute (API) uses a scale ranging from zero to seven. Although the definitions of these levels differ slightly (space systems vs oil and gas), the fundamental philosophy remains the same. ABS has developed a stage gate process compatible with the wide range of TRLs (API, US DoD, ISO 16290). However, the numbers levels presented have now been replaced by a series of qualification stages. Comparison of the ABS definition and the industry TRLs are provided in the table below.

TABLE 1
ABS Qualification Stages Comparison with Various Industry TRLs

ABS Qualification Stage	*API RP 17N/Q TRLs*	*US DoD TRLs*	*ISO 16290 TRLs*
Feasibility Stage	0	1	1
	1	2	2
Concept Verification Stage	2	3	3
		4	4
Prototype Validation Stage	3	5	5
	4	6	6
System Integration Stage	5	7	7
	6	8	8
Operational Stage	7	9	9

APPENDIX 3 New Technology Stage Determination

1 Introduction

In order to estimate the current qualification stage of a proposed a new technology, the following table should be used. These questions serve as general guidance to understand the design maturity of the technology based on completed qualification activities and hence determine the corresponding qualification stage. The client's design team, ABS, and other identified stakeholders should agree upon the qualification stage identified. All supporting documentation justifying affirmative answers are to be submitted to ABS for review. Negative answers will be reviewed on a case-by-case basis in order to determine applicability of the question to the technology.

Qualification Stage	*Item #*	*Question*	*Yes/No/NA*	*Evidence to support?*
Feasibility Stage	1	Has what is specifically new and/or unique about the concept been clearly identified?		
	2	Has what specifically needs qualification been defined?		
	3	Have potential applications been identified?		
	4	Have fundamental objectives and requirements (e.g., RAM) for the identified application been identified?		
	5	Have basic functionality and durability of the technology been analyzed?		
	6	Have basic principles been observed and reported?		
	7	Have lessons learned from similar technology been reviewed and documented?		
	8	Have basic design calculations been performed?		
	9	Have conceptual research and development been completed?		
	10	Has a preliminary list of reliability drivers been prepared?		
	11	Has a preliminary fitness assessment (physical interfaces, human etc.) been performed?		
	12	Can engineering drawings (basic configurations, interfaces, and/or PFD's or flow charts) and calculations be submitted for review?		
	13	Have any early stage risk assessment and mitigation studies been performed and documented?		
Concept Verification Stage	14	Has the concept functionality been demonstrated by physical models or "mock-ups"?		
	15	Have laboratory scale material testing and degradation mechanisms been performed?		
	16	Have all conceptual design engineering studies been completed?		
	17	Have preliminary function/performance/reliability engineering studies been completed?		
	18	Have reliability drivers been confirmed?		
	19	Is there documentation that RAM requirements can likely be met?		
	20	Has durability been confirmed by testing or calculation?		
	21	Has a viable manufacturing or fabrication scheme been documented?		
	22	Has preliminary qualitative design risk analysis (e.g., FMECA) been documented?		
	23	Have the initial risk assessments been reviewed/updated to identify any additional technical risks?		

Qualification Stage	*Item #*	*Question*	*Yes/No/NA*	*Evidence to support?*
Prototype Validation Stage	24	Have all items in the manufacturing of the technology been specified?		
	25	Has the manufacturing and assembly process been accepted?		
	26	Has a prototype or full scale production unit been manufactured?		
	27	Has the manufacturing and assembly defects been removed by stress screening?		
	28	Has the technology passed basic functionality testing of prototype (physical or virtual) or full scale product to demonstrate fitness and function capability in a simulated or actual operating environment?		
	29	Has a performance data collection system been established and properly documented?		
	30	Has the technology passed performance, durability, and accelerated life tests?		
	31	Is the degradation of function/performance within expected acceptable limits?		
	32	Has the technology passed system reliability analyses?		
	33	Has the operating/destruct limits been established or confirmed?		
	34	Has the degradation limits and rates been established or confirmed?		
	35	Has the required in-service monitoring needs and means been identified?		
	36	Has a process risk assessment (e.g., process FMECA) been performed and documented (if applicable)?		
	37	Has the final design risk assessment (e.g., FMECA) been completed for all life cycle modes (including assembly, transit, storage, installation, hook-up, commissioning, operation, decommissioning) for all interface permutations and properly documented?		
	38	Have the residual risk and uncertainty been estimated and properly documented?		
	39	Has the reliability study been updated and properly documented?		
System Integration Stage	40	Has the design risk assessment (e.g., FMECA, HAZOP) considering full system interfaces been updated and properly documented?		
	41	Have all other technical risks been identified/addressed and properly documented?		
	42	Has the technology been deployed into a full prototype and fully integrated with the intended system?		
	43	Has the function/performance when connected/integrated into a wider system been fully tested?		
	44	Have all mechanical, hydraulic, optical, electronic, software, etc. and human interfaces been fully addressed and documented?		
	45	Have all system integration requirements been confirmed?		
	46	Has installation/hook-up/testing/commissioning with a wider system been completed as per specifications?		
	47	Is there a data collection system in place to document performance and reliability?		
	48	Has a detailed in-service inspection/monitoring/sampling plan been defined and properly documented?		
	49	Can inspection/monitoring/sampling functionality be validated?		
Operational Stage	50	Has the technology demonstrated acceptable reliability and availability in the targeted operating environment?		
	51	Has the in-field service monitoring, sampling, and inspection plan been successfully implemented?		
	52	Has reliability and integrity performance data been properly collected, analyzed, and documented?		
	53	Have any underperforming components of the technology been identified?		
	54	If so, then has there been any reliability improvements for failed or underperforming components?		

Qualification Stage	*Item #*	*Question*	*Yes/No/NA*	*Evidence to support?*
Operational Stage (continued)	55	Has there been any performance feedback from projects or suppliers?		
	56	Have any unexpected aspects (e.g., interdependencies or influences on performance) or safety concerns been observed?		
	57	Has the technology been reliable for at least one survey (or maintenance or planned replacement) cycle or agreed upon time period as indicated in the SRDD or in-service inspection plan (ISIP)?		
	58	Has the design risk assessment (e.g., FMECA) been updated with in-service performance data?		
	59	Has the system reliability assessment been updated and properly documented?		

APPENDIX 4 New Technology Qualification Plan (NTQP) Template

1 Introduction

The New Technology Qualification Plan (NTQP) should be a high level document that tracks the maturity level and status of qualification activities. These activities help verify and validate the new technology's ability to qualify all desired NTQ stages. The document is not meant to be a collection of engineering reports, methodologies, test data, or plans. The NTQP is to be updated throughout qualification process.

The following sections provide a recommended template for submitting an NTQP as part of the new technology qualification process.

3 New Technology Qualification Plan (NTQP) Template

Executive Summary

1.0 Introduction

- Summarize the project objectives.
- Provide an overview of the new technology and its application.
- Describe current status of design and qualification activities.
- Provide key points of contact.

2.0 New Technology Screening and Stage Determination

2.1 System Requirements Overview

- Summarize defined system goals, functional and performance requirements (with reference to appropriate SRDD document(s)).

2.2 New Technology Screening

- Summarize the new technology screening results.

2.3 New Technology Stage Determination

- Summarize the results of the new technology stage determination process.

3.0 New Technology Qualification Activities

- For each new technology item being qualified, list all qualification activities including the following details for each activity
  - Summarize the qualification activity (scope, objective and method)
  - Performance Requirement and its source.
  - Identify the stage in which this qualification activity was determined.
  - Provide reference to appropriate engineering evaluation report or risk assessment report (include corresponding hazard register nodes) from which this activity was determined.
  - Scheduled Timelines (start/finish).

- Provide reference to appropriate engineering evaluation or risk assessment reports that documents the results of the qualification activity.
- Comments from the Client & ABS

4.0 References

Appendices:

Appendix 1 Summary of Previous Qualification Activities

List all previously completed qualification activities prior to NTQ process with references to appropriate reports.