OFFSHORE SERVICE SPECIFICATION
DNV-OSS-303

RISK BASED VERIFICATON

APRIL 2001

DET NORSKE VERITAS

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

DNV Offshore Codes consist of a three level hierarchy of documents:

— *Offshore Service Specifications.* Provide principles and procedures of DNV classification, certification, verification and consultancy services.
— *Offshore Standards.* Provide technical provisions and acceptance criteria for general use by the offshore industry as well as the technical basis for DNV offshore services.
— *Recommended Practices.* Provide proven technology and sound engineering practice as well as guidance for the higher level Offshore Service Specifications and Offshore Standards.

DNV Offshore Codes are offered within the following areas:

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SECTION 1 INTRODUCTION

A. General

A 100 Introduction

101 This document provides the basic philosophy and describes the principles, content and implementation of a *risk based verification* (RBV) approach, DNV's role and an outline of the deliverables. The RBV approach aims at balancing the efforts to control the operational and technological risks. It provides for cost and time savings in a verification approach by focusing on criticality and corresponding efforts requiring priority attention. RBV is a complement to, and not a replacement for, the common industry quality measures required to fulfil contractual obligations.

A 200 Background

201 The business today is characterised by the need to balance expected cost and benefits through a better understanding and mastering of the subject assets and their associated risks. The aim is an optimum control of uncertainties from the concept stage to final abandonment of any facility, particularly so for projects characterised by:

— large portion of unproven design and track record
— having a high degree of complexity
— elements being introduced to new operating conditions or applications.

202 This raises questions on the efficiency of "traditional" verification methods which often have requirements derived from a compliance regime based on rules and regulations that appear prescriptive in their approach. Such requirements are often limited to safety, and experience has shown that such verification often has been fragmented. The benefits of a holistic and transparent approach, i.e. maintaining a total overview across discipline boundaries, and paying necessary attention to environmental issues and sound economical performance has, in a number of cases, therefore not been accomplished.

203 As an alternative to this prescriptive approach, risk based assessment methods can be used to identify critical elements and establish performance based requirements (or standards). These standards define the relevant acceptance criteria pertaining to safety, integrity, availability (reliability and maintainability), functionality and environmental impact of a facility throughout the life cycle. The depth and level of involvement will vary with type of engagement, and an evaluation of risk related to project implementation (schedule and cost), *project risk management* (PRM), will normally be an integral part of the RBV scope.

204 The above represents the basis for DNV's RBVscheme, as further described in this document.

A 300 Purpose

301 The purpose of this document is to:

a) Provide the basic philosophy and describe the principles, content and implementation of the RBV service.

b) Outline the integrated service features, premises and proposed involvement to stipulate the basis for a RBV assignment.

c) Illustrate the added value to our customers, such that the service is recognised as a benefit rather than a bureaucratic requirement. This means showing RBV as an efficient tool to obtain confidence by independent verification of own and/or contractor(s) work, and to show financiers, partners, insurers that a plant or facility complies with a relevant basis, even in areas where formal references may be missing or are under development.

d) Serve as a guideline for our customers (owners, operators, EPC contractors, manufacturers) requiring verification services during feasibility evaluations, concept selection, detailed design, procurement, manufacturing, commissioning, operation and abandonment.

A 400 Objectives

401 The RBV service shall:

a) Focus on prioritised efforts, i.e. provide our customers with the ability to focus their verification efforts where the contribution is perceived as cost effective, and adding value by applying the principles, methods and tools further described under Sec. 2 and 3.

b) Install confidence, i.e. demonstrate through independent (see Sec.1 A800) and competent scrutiny that the plant is designed and constructed so that:

— it is fit for its intended purpose
— its level of integrity is as high as reasonably practicable
— the associated risk to health, life, property and environment is as low as reasonably practicable.

402 The advantages for DNV's customers shall be:

a) Improved performance through reduced probability for undesirable events, and by contribution to optimum solutions (with regard to CAPEX, OPEX and RISKEX) for critical areas.

b) Cost and time savings

— by early involvement to ensure correct decisions and minimise rework
— from integration of verification services to ensure co-ordination of activities
— through avoiding undue attention to areas and activities that are not critical.

A 500 Scope and application

501 The scope of RBV as described in this document is primarily aimed at offshore facilities or installations used for the exploration, intervention, production and transportation of hydrocarbons. These principles may, however, also be applied to general industrial developments, i.e. land based plants and equipment.

502 It applies to any features, or elements of a facility, recognised as safety, environmental and/or reliability critical where:

— failure could cause or contribute substantially to a significant incident
— it is crucial to the prevention, control, or limitation of the effect of a significant incident
— the system availability directly impacts the revenue stream as well as the operating cost related to maintenance.

503 RBV may thus be undertaken to confirm that an entire facility, or its elements/components with corresponding activities/processes are in compliance with one, or any combination, of requirements as illustrated in Fig. 1.

504 The scheme may be seen as an integral part of the customers project risk and quality management system.

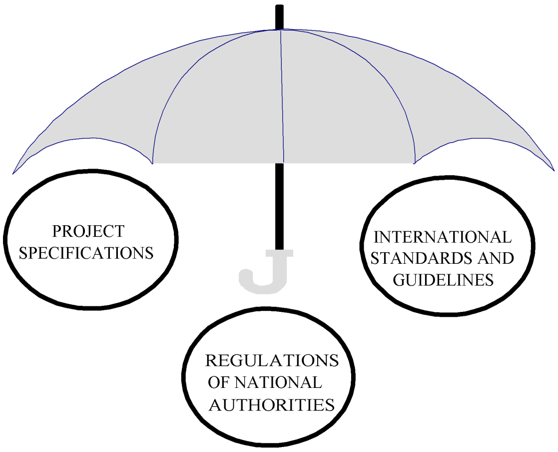

Figure 1
Risk Based Verification compliance coverage

A 600 Deliverables

601 The specific deliverables are to be identified in the contract governing a particular and unambiguous scope.

602 A key feature of the RBV approach is the process leading up to a verification activity plan. The deliverables from this exercise will thus comprise of:

— list of critical elements
— performance standards
— verification activity plan.

This will normally (but optionally) be contained in a database application in order to facilitate the dynamic process of modifications and updates, and also provides for a powerful management tool.

Studies and analysis reports providing the required input to the process may also be part of DNV deliverables depending on the particular scope agreed.

603 The deliverables following implementation of the verification activity plan will typically be a *Statement of Conformity* reflecting that the objectives (i.e. requirements in performance standards) have been met, with relevant qualifications.

604 In practice this statement will be supported by *Design Verification Reports* and *Inspection Release Notes* or *Inspection Release Reports* covering defined elements of the fabrication, transport, installation and commissioning phases as applicable for equipment or plants prior to the operation phase.

605 Similarly, statements and reports will be provided for engagements during the operations phase.

A 700 Terms and conditions

701 The exact scope of work is to be agreed between the customer and DNV on a case by case basis. However, with the specific emphasis on risks related to life, property, environment as well as economic performance, the scope needs to contain relevant elements of risk and reliability based assessments.

702 RBV services are not performed in substitution for other parties' role or obligations, and build on the basic assumption that other parties involved (e.g. designers, manufactures, contractors, clients, operations etc.) fulfil their contractual requirements.

A 800 DNV's role and independence

801 DNV's role in facilitating the RBV approach will typically be through contribution in the following areas:

— assist in development of project SHE approach
— conduct/participate in HAZIDs
— conduct/review risk assessments and detailed studies to identify the critical elements
— assist with, or develop performance standards and requirements
— incorporating requirements in the verification activity plan
— implementation of the verification activity plan
— facilitating efficient management by providing a suitable database application in line with the steps identified and detailed under Sec.3.

802 DNV, being an organisation with a wide range of resources, may become involved with services providing decision support, i.e. assist with studies, analysis and design issues, required as input to the RBV process. This may raise the issue of potential conflict of interest and independence. It is therefore recognised that the level of independence may vary, and will in principle be governed by the contract on the basis of the premises for a particular assignment. The minimum requirement is, however, that no one shall verify their own contribution.

B. Definitions and Abbreviations

B 100 Definitions

101 *Accident:* An event involving harm to personnel, property and/or environment.

102 *Availability:* The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or during a given time interval, assuming that the required external resources are provided. This ability is expressed as the proportion of time(s) the item is in the functioning state.

Note 1: This ability depends on the combined aspects of the reliability, the maintainability and the maintenance supportability.
Note 2: Required external resources, other than maintenance resources do not affect the availability of the item.

103 *Commissioning:* The functional verification of equipment and facilities that are grouped together in systems.

104 *Consequences:* The expected effects of an event occurring, e.g. in risk assessment this could be the size of the zone within which facilities are expected.

105 *Critical elements:* Systems, procedures or products that are identified to be critical by the project specified requirements, e.g. related to safety, reliability, environment, performance, schedule, financial consequences. This includes any items which:

— if they failed, could cause or contribute substantially to a major hazard affecting the installation; or
— are intended to prevent or limit the effect of a major hazard.

106 *Customer:* DNV's contractual partner. It may be the owner, purchaser, or contractor.

107 *Failure:* Termination of an item to perform the required (specified) function.

108 *Failure mechanism:* The physical, chemical or other process which lead or could have lead to a failure.

109 *Functionality:* Defines what the system or product is intended to do and how it does it.

110 *Hazard:* A deviation (departure from the design and operation intention) which could cause damage, injury or other form of loss, i.e. a physical situation with the potential to cause harm to personnel or damage installation/facility integrity.

111 *Incident:* Any event identified by the project as being relevant.

112 *Major accident:* Involves fatality due to fire or explosion, multiple fatalities, severe damage to the installation/facility, or significant negative impact to the environment.

113 *Major hazard:* Potential for causing major accident, i.e. involving fatality due to fire or explosion, multiple fatalities, severe damage to the installation/facility, or major pollution.

114 *Manufacturers quality product assessment (MPQA):* A quantitative rating system with a structured methodical basis for assessment of manufacturers, sub-contractors and suppliers ability to control product quality and to meet specified requirements and expectations. MPQA is also used as an objective comparison of the quality status and progress levels in the different organisations.

115 *Mechanical completion:* The checking and testing of equipment and construction to confirm that the installation is in accordance with drawings and specifications and ready for commissioning in a safe manner and in compliance with the project specifications.

116 *Performance Standards:* A statement which can be expressed in qualitative or quantitative terms, as appropriate, of the performance required of a critical system, item or product, person or procedure. It is used as the basis for managing the hazard and performance. It includes planning, measuring and control throughout the lifecycle of the installation in order to ensure the safety, functionality, availability/reliability and survivability of an entire facility, or selected elements, are “built in” and maintained as appropriate.

117 *Product:* A product may include services, hardware, processed material, software or a combination thereof; or a product can be tangible e.g. assemblies or processed materials; or intangible (e.g. knowledge or concepts) or a combination there of, defined in ISO 8402 (1994) items 1.4.

118 *Reliability:* The ability of the product/element to continue to perform a required function under given conditions for a given time interval.

119 *Risk:* The qualitative or quantitative likelihood of an accident or unplanned event occurring, considered in conjunction with the potential consequences of such a failure, or the combination of likelihood and consequence of a hazard being realised, i.e. the chance of a specific event occurring within a specific period of time.
In quantitative terms, risk is the quantified probability of a defined failure mode times its quantified consequence.

120 *Risk acceptance criteria:* Standards by which the results of the risk assessment can be evaluated. The acceptance criteria represents the acceptable level of safety of the installation/ facility.

121 *Risk assessment:* Estimating and evaluating risks from a particular hazardous activity such as operation of an offshore installation. It involves identifying the hazards which are present, making estimates of the frequencies and consequences, and combining them into overall measures of individual or societal risks. These steps are known as “risk analysis”. Once risk criteria are used to evaluate the results, the process is known as “risk assessment”.

122 *Risk Based Verification:* RBV is a systematic approach, which aims at balancing the efforts to control operational and technological risks. It provides for cost and time savings by focusing on criticality and corresponding verification efforts to strike a sound balance between safety, functionality, availability, survivability and cost.

123 *Significant incident*: Usually equal to major accident.

124 *Verification:* Confirmation by examination, testing, audit or review and provision of objective evidence that specified requirements pertaining to an activity, product or service have been fulfilled (derived from ISO 8702 (1994) item 2.17).

B 200 Abbreviations

201 The abbreviations in Table B1 are used:

Table B1 Abbreviatons

Abbreviatons	In full
CAPEX	Capital expenditure
DNV	Det Norske Veritas
DVR	Design verification report
EIA	Environmental impact assessment
EPC	Engineering, procurement, construction
FAT	Factory acceptance test
FMECA	Failure mode, effect, and criticality assessment
FSA	Formal safety assessment
HAZID	Hazard identification review
HAZOP	Hazard and operability study
IEC	International Electrical Commission
IMO	The International Maritime Organisation
IRN	Inspection release note
ISO	The International Standardisation Organisation
IVB	Independent verifying body
LCC	Life cycle cost
MPQA	Manufactured product quality assessment
NCR	Non-conformance report
NDE	Non-destructive examination
OPEX	Operational expenditure
PRM	Project risk management
QA	Quality assurance
QRA	Quantitative risk analysis
RBI	Risk based inspection
RBV	Risk based verification
RCM	Reliability centered maintenance
R&R	Risk and reliability
RISKEX	Risk related expenditure
SHE	Safety, health and environment

SECTION 2 PRINCIPLES

A. Introduction

A 100 General

101 This section stipulates the principles and requirements which, in combination with Sec.1 A700 and Sec.3 will be applied for *risk based verification* (RBV) engagements.

102 Key elements in the RBV approach is the identification of critical elements and development of performance standards. These activities will normally require input from risk/reliability assessments/studies and from detailed design. DNV will, to varying degrees and pending the nature of the assignment, provide such decision support when implementing a RBV scheme. As a minimum, the following will apply:

— Work concerning risk assessment and detailed design work shall be in accordance with recognised methodology and shall be performed by qualified and competent persons with suitable understanding of risk, and the rudiments of risk assessment.
— The risk assessment methodology, and all assumptions and boundary limits and uncertainties of the risk assessment, shall be clearly documented and made available for review by DNV as deemed required.

DNV's role is further described in Sec. 1 A800.

B. Risk Based Verification Principles

B 100 Purpose and key elements

101 RBV is based on a structured, systematic process of using risk and cost-benefit analysis for the purpose of striking a sound balance between technical and operational issues, and between safety, functionality, availability, survivability and costs. It serves as an integral part of total safety and asset management, and applies to all project lifecycle phases from conceptual development until abandonment.

102 RBV comprise of the following two main elements:

— Identification and administration of critical elements and the corresponding performance standards.
— Verification of the adherence to the corresponding RBV process.

B 200 Complementary activity

201 RBV is complementary to routine design, construction and operations activities and not a substitute for them. While taking into account the work, and the assurance of that work, carried out, RBV will to some extent duplicate previous efforts by other parties involved with the facility.

202 The aim is to minimise additional work and cost, but the total effort will depend on the findings from the examination of quality management systems, the examination of documents and the examination of production activities.

B 300 Management

301 To ensure satisfactory execution of RBV assignments, the philosophy and verification methods used will be described, communicated and closely followed up for implementation.

302 This approach is required to ensure that the assignment:

— has a consistent and sound approach to the satisfactory construction and operation of the facility
— is available where the owner or his contractors operate
— use up-to-date methods, tools and procedures
— use qualified and experienced personnel.

B 400 Differentiated levels of verification

401 The level of verification activity will be differentiated according to the risk associated with the facility/system.

Table B1 Levels of verification – Guidance on involvement at system level

Level	*System Characteristics*	*Description of typical involvement*
Low	Proven designs with relatively harmless content and/or installed in benign environmental conditions	Review of general principles and production systems during design and construction
	State of the art design, manufacturing and installation by experienced contractors	Review of principal design documents, construction procedures and qualification reports
	Low consequences of failure from a commercial, safety or environmental point of view	Site attendance only during system testing
	Relaxed to normal completion schedule	Less comprehensive involvement than level Medium
Medium	Facility in moderate or well controlled environmental conditions	Review of general principles and production systems during design and construction
	Plants with a moderate degree of novelty	Detailed review of principal and other selected design document with support of simplified independent analyses
	Medium consequences of failure from a commercial, safety or environmental point of view	Full time attendance during (procedure) qualification and review of the resulting reports
	Ordinary completion schedule	Audit based or intermittent presence at site
High	Innovative designs in extreme environmental conditions	Review of general principles and production systems during design and construction
	Plants with a high degree of novelty or large leaps in technology	Detailed review of most design document with support of simplified and advanced independent analyses
	Contractors with limited experience or exceptionally tight completion schedule	Full time attendance during (procedure) qualification and review of the resulting reports
	Very high consequences of failure from a commercial, safety or environmental point of view	Full time presence at site for most activities
		More comprehensive involvement than level Medium

402 For this purpose, three levels (as shown in Table B1) have been introduced, and serve as an illustration to this approach.

403 An increase in the level of involvement beyond that derived from the evaluation of the risks, will only involve minimal extra risk reduction – but may unnecessarily increase the cost.

C. Selection of Verification Level

C 100 Selection factors

101 The selection of the level of verification shall depend on the criticality of each of the elements that have an impact on the management of hazards and associated risk levels of the facility. Typical selection factors are:

- overall safety/business objectives for the facility
- assessment of the risks associated with the facility and the measures taken to reduce these risks
- degree of technical innovation in the facility
- experience of the contractors carrying out similar work
- quality management systems of the owner and its contractors.

102 The contribution of each element shall be judged qualitatively and/or quantitatively, and shall use, where possible, quantified risk assessment data to provide a justifiable basis for any decisions made. For further details on this approach, reference is made to Sec.3 in this document, and – as a practical illustration - Appendix B, which reflects the method adopted in DNV-OSS-301, *Verification and Certification of Pipelines*.

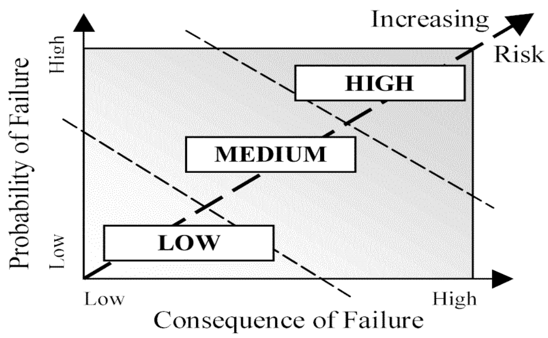

Figure 1
Selection of the required level of verification

C 200 Overall acceptance criteria and assessment of risk

201 Overall project objectives covering all phases of the facility from design to de-commissioning should be defined. These objectives should address relevant parameters, and criteria for the acceptable level of risk are to be established – usually defined by the owner of a facility.

202 A systematic review should be carried out to identify and evaluate the probabilities and consequences of technical or procedural failures pertaining to the facility. The extent of the review shall reflect the criticality of the facility, the planned operation and previous experience with similar facilities.

203 Depending on the type of facility and its location the risk could be measured in terms of health and safety of personnel associated with it or in its vicinity as well as environmental, political and economic consequences.

C 300 Technical innovation and contractor experience

301 The degree of technical innovation and tightness of schedule in a facility development shall be considered, recognising the difference between a high degree of technical innovation and established technology and criteria.

302 Factors to be considered in the selection of the appropriate verification level include:

— degree of complexity in achieving technical requirements
— experience with similar facilities
— contractors' general experience, and experience in similar work.

C 400 Quality management system

401 Adequate quality management systems shall be implemented to ensure that gross errors in the work covering design, construction and operations are limited.

402 Factors to be considered when evaluating the adequacy of the quality management system include:

— whether or not an ISO 9000 or equivalent certified system is in place
— results from external audits
— results from internal audits
— experience with contractors' previous work
— project work-force familiarity with the quality management system, e.g. has there been a rapid expansion of the work force or are all parties of a joint venture familiar with the same system.

Guidance note:

Most organisations have quality management systems certified by an accredited third party certification body. However, when business increases, they expand their staff quickly by taking on contract personnel often for a fixed period or for the duration of a particular contract.

This influx of new personnel can lead to problems of control of both the whole organisation and of particular projects being undertaking. Quality problems may then occur, as these new personnel have no detailed knowledge of the organisation's business methods, its ethos or its working procedures.

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D. Key Issues

D 100 Communication lines

101 Communication lines are illustrated in Fig 2. The actual lines that are to be open for communication depend on the contractual agreements.

102 As an example, in cases where DNV (3rd party) does not have a contract with the owner (1st party), DNV strongly recommends that the owner, through his contract with the 2nd party, secures a communication line from DNV to owner and vice versa.

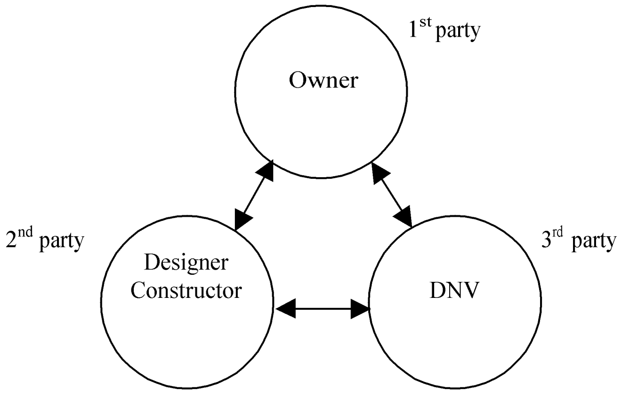

Figure 2
Communication lines

Guidance note:

The recommendation springs from DNV's experience with projects where communications difficulties between the parties have jeopardised the progress of work and release of necessary documentation.

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D 200 Early involvement

201 RBV services shall seek to reduce any uncertainty in the design as early as possible, and if any weaknesses are revealed allow for effective management of necessary changes, see Fig.3. This implies involving operations and maintenance personnel as early as possible in the process.

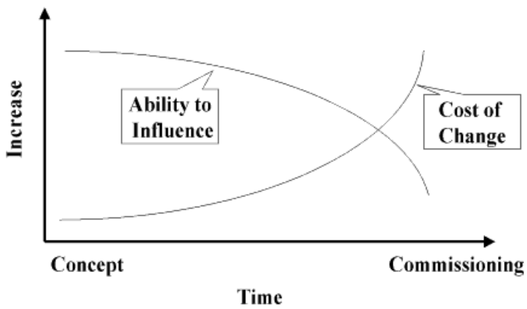

Figure 3
Effect of early involvement

SECTION 3 SERVICE DESCRIPTION

A. Approach

A 100 General

101 The *risk based verification* (RBV) approach consists of the following steps, as indicated in Fig.1:

1) Identification and evaluation of critical elements.
2) Identification and/or development of performance standards.
3) Preparation and implementation of verification activity plan.

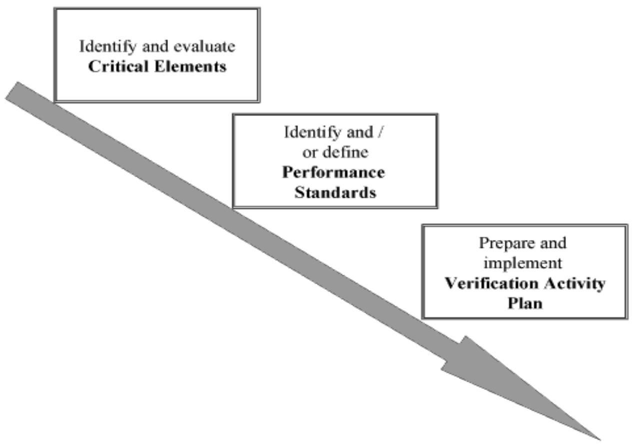

Figure 1
Main elements in RBV

102 RBV is aligned and consistent with current industry risk-based approaches. These include IEC 61508 (Functional Safety of Electrical/Electronic/Programmable Electronics Safety Related Systems - for deciding necessary safety integrity level) which has been widely accepted as basis for design and specification of safety instrumented systems, and the formal safety assessment (FSA) methodology undertaken by the International Maritime Organisation (IMO) in their approach to risk based rules.

103 Key activities in the RBV approach are:

— hazard identification, (step 1, - see 101 and Fig.3)
— risk assessment, (step 1 and 2)
— evaluation of risk-control options, (step 1 and 2)
— cost-benefit assessment, (step 2)
— recommendations for decision-making. (step 2)
— implementation of verification activity plan (design verification and inspection – step 3).

DNV will, in preparation for developing and implementing the verification activity plan (step 3), interact closely with the activities conducted under steps 1 and 2, as also illustrated in Fig.2.

Project risk management (PRM), technical risk and reliability assessment, capability evaluations of suppliers (conducted by means of the manufacturer product quality assessment tool - (MPQA), availability and life cycle cost (LCC) evaluations all constitute decision support activities. Risk based inspection (RBI) programmes and reliability centred maintenance (RCM) are based on principles similar to the RBV approach, and represent tools to achieve cost efficient operation.

104 Fig.3 shows in some more detail the chain of events, with brief activity description and relations. Fig.2 and Fig. 3 reflects the important message of early involvement, and the need for in depth knowledge of the activities required to obtain optimal resource allocation for the verification process. A proactive approach is required and place particular emphasis on roles and responsibilities.

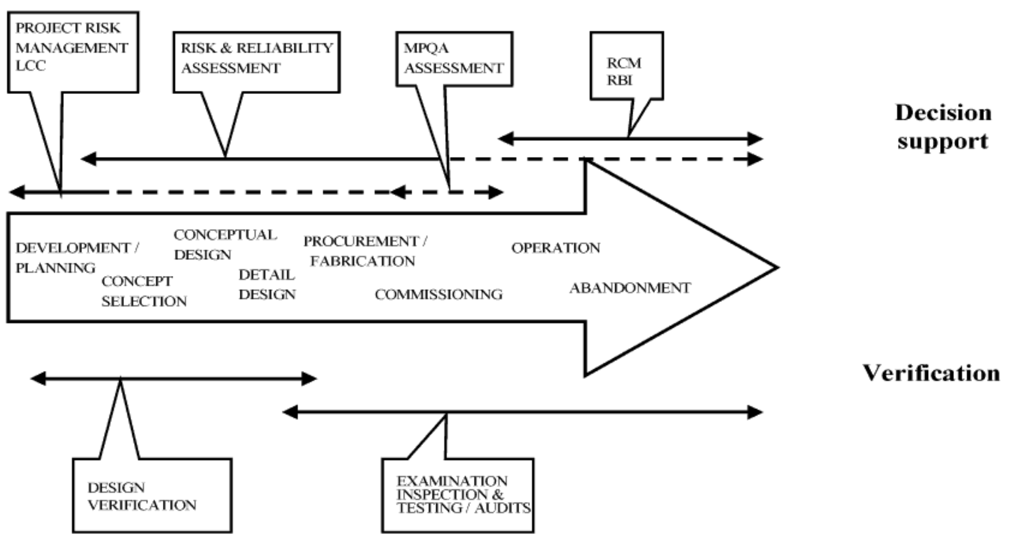

Figure 2
General illustration of phases, elements and activities

B. RBV Scheme Implementation

B 100 Critical elements and ranking

101 Critical elements (see Sec.1 B100) are identified and systems and equipment ranked based on

- design and operation experience of similar existing facilities or products
- engineering judgement/HAZIDSs

and in cases with novel concepts or complicated configurations also the results of risk and reliability assessment work.

102 In the process of the risk and reliability assessment, a criticality ranking will be conducted for each system/product/component, and the ranking will be based upon the following considerations:

- risk – to life, property, and the environment
- production availability
- design maturity
- manufacturing complexity.

B 200 Risk and reliability based assessment

201 It is of vital importance that a comprehensive understanding of the plant's function and service is obtained to conclude a fair evaluation. The input should include a clear definition of scope, functional requirements and safety philosophy, with focus on aspects that may govern various design decisions. Requirements for information will depend on the stage of development (i.e. conceptual or detailed design phase).

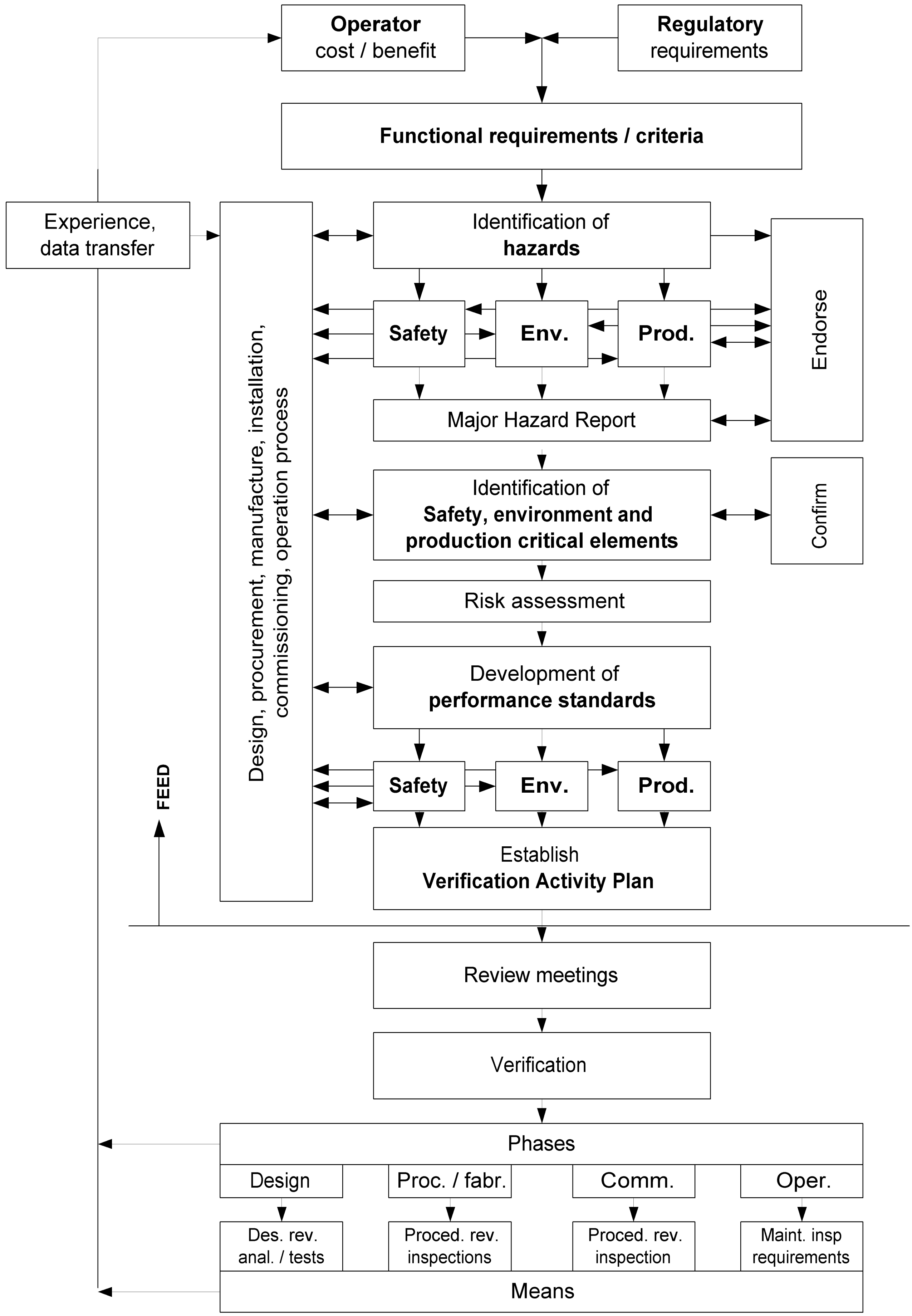

Figure 3
Typical RBV model

202 If presented or in existence, consideration shall also be given to certificates issued under recognised certification schemes. This applies to materials, products, systems and personnel (i.e. type approval/EC type – examination, product, quality system, approval of manufacturer, competence certificates and certificate/declaration of conformity).

203 The type and amount of information required to carry out a risk and reliability (R&R) assessment will vary depending on the system or product subject to analysis and the scope of work. The following is an indication of the type of information required:

— system descriptions, outlining major service and function of systems, product and/or components
— design specifications, including specifications of work medium, material, pressure ratings, minimum/maximum temperatures, corrosion control, environmental and functional loads, where applicable
— redundancy philosophies
— operations manual
— products layout
— qualitative risk and reliability assessments/evaluations, such as FMECA, HAZID or HAZOP of the system, if available
— quantitative risk and reliability assessments, if available
— system block diagram, piping and instrumentation diagram and process flow diagrams
— cause and effects diagrams

204 The content of the R&R assessment must be adapted to the level of detail of the documentation/information available at the respective project stage. Although the content and the purpose of an assessment will vary, there are certain main elements in a risk and reliability assessment that can be put into a generic context with the key element in the process being the assessment loop. The flow diagram presented in Fig.4 illustrates the risk and reliability optimisation process, which will promote acceptable reliability and safety performance at optimum cost. Once the risks have been identified the extent can be reduced to a level as low as reasonably practicable by means of one or both of:

— reduction in the probability of failure
— mitigation of the consequences of failure.

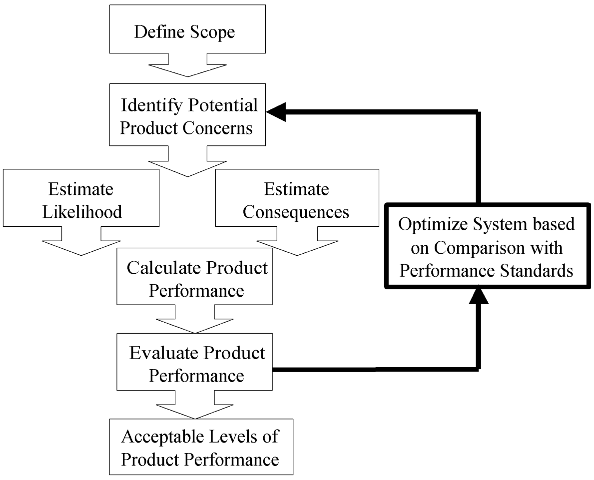

Figure 4
Main elements of the risk and reliability optimisation process

Guidance note:
Reasonable Practicability

The term *as low as reasonably practicable* (ALARP) has come into use through the United Kingdom's "The Health and Safety at Work etc. Act 1974". Reasonable Practicability is not defined in the Act but has acquired meaning by interpretations in the courts.

It has been interpreted to mean that the degree of risk from any particular activity can be balanced against the cost, time and trouble of the measures to be taken to reduce the risk.

It follows, therefore, that the greater the risk the more reasonable it would be to incur substantial cost, time and effort in reducing that risk. Similarly, if the risk was very small it would not be reasonable to expect great expense or effort to be incurred in reducing it.

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205 This implies that measures improving risk and/or reliability should be considered from a cost-benefit point of view, as illustrated in Fig.5. The objective is to arrive at an optimum solution that meet or exceed the performance standard.

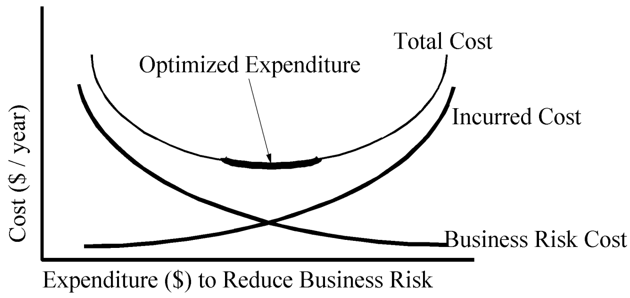

Figure 5
Cost benefit analysis

206 Typical DNV tools and references adopting the risk based approach are:

— EasyRisk - criticality management tool - applied in overall project risk assessments.
— NEPTUNE - integrated quantitative safety risk analysis work-bench for application to offshore installations.
— PAPA - probabilistic assessment of process accidents (fires and explosions) - used to optimise topside design against fires and explosions.
— ORBIT - software for offshore risk based inspection analysis.
— EMDROPS - integrated toolkit for environmental analysis, incorporating oil drift simulations, vulnerable natural resource analysis, environmental risk analysis and contingency planning.
— Offshore standard for pipelines - criteria for design and fabrication of submarine pipelines, where risk assessment is applied to define the acceptance criteria.
— Offshore class rules - criteria for design of offshore units, incorporating an approach for safety assessment.
— Rules for marine operations - adapting risk assessment methods to define criticality of various operations.

B 300 Performance standards

301 Performance standard is a term typically applied for project specific requirements that may have to be customised to meet specific needs of all or individual parts of a plant. Performance standards may also give reference to generic recognised and commonly available industry codes and standards if these satisfy project requirements. The performance standards shall detail the specific goals and objectives and adequately address:

— safety
— functionality

— availability/reliability
— survivability

for each of the critical elements, with the associated systems and equipment, and clearly defined boundaries.

302 The statements made in the performance standards, normally referred to as performance requirements, should be measurable and auditable. The performance requirements are subject to verification. To the extent that the performance of the system or product depends on, or interacts with, the performance of other systems or products in the plant, this dependency or interaction needs to be defined and verified.

303 Performance standards may have to be modified throughout the phases of a plant to cover the differing requirements at each stage.

B 400 Verification and examination

401 Risk and reliability assessment information presented from sources other than DNV will be evaluated for appropriate use in the RBV scheme.

402 It is of the utmost importance to verify that a system or product identified as critical (see B100) is in full compliance with the performance requirements (e.g. those derived from selected codes and standards or project specific requirements).

403 A verification activity plan will be developed to formulate the preceding results and specified requirements.

Typical format for this plan will be:

— introduction - objective, definitions, abbreviations, legislative framework
— hazard management process - approach and objectives
— verification plan framework - purpose, scope, critical elements, performance standards, with activity dossier
— management of verification – responsibilities, communication, points of contact
— selection of personnel – competence, principles of selection
— review and revision plan.

The activity dossier displays the defined extent of DNV's involvement in design review, examination, inspection and testing activities.

404 Design verification is to confirm that a chosen design is in conformity with the performance standard (i.e. project specifications, regulations of national authorities and international standards and guidelines).

405 The criticality ranking will define the level of involvement of the design verification and subsequent examination, inspection and testing, and the content of design verification may vary considerably according to the nature of the product. DNV will review the design information, calculations, dimensional drawings and, if required, carry out independent evaluation/calculations to confirm that all applicable requirements in the selected codes and standards are in compliance.

406 The design verification process shall provide feedback and early identification to the project for the areas of concern and contribute to practical solutions regarding design and construction problems that may arise.

407 The information required for the monitoring and examination of the manufacturing processes will be partly dependent on previous steps in the RBV scheme. Typically, the following information is required to monitor and examine the manufacturing processes and product compliance:

— quality plan
— fabrication specifications including welding, heat treatment, type and extent of NDE, fabrication method, etc.
— tolerances and dimensional control procedures
— bill of materials including material specifications as necessary
— test programs including FAT, mechanical completion and commissioning activities.

408 In the event that the project requirements specify that the manufacturers, sub-contractors and suppliers be evaluated to demonstrate their quality ability to meet specified requirements and expectations, a manufacturer product quality assessment (MPQA) should be performed.

B 500 Verification co-ordination

501 Global procurement activities require long lead times and large capital investments. Once a particular critical delivery has been identified, the supplier will be followed up by close interaction between the manufacturer, local DNV service centres and the project team.

502 The verification co-ordinator shall have the infrastructure support and ability to communicate expediently with all relevant parties the instructions and results from specified activities. When applicable, the early involvement and central role of a verification co-ordinator is an essential part of a successful project procurement process.

APPENDIX A
SUPPORTING SERVICES

A. Purpose

A 100 General

101 The purpose of this appendix is to provide an outline of DNV decision support services closely aligned with the RBV approach.

A 200 Project risk management

201 Project risk management (PRM) is a systematic approach to predict and manage threats and opportunities in executing complex projects.

In the engineering, procurement, construction, installation and commissioning phase of a field development project, the main project target is to deliver on time, within budget and meeting performance and quality criteria. In order to meet the main project target, special focus need to be put on each individual system as well as the complete installation.

PRM is applied continuously to identify, assess and rank threats and opportunities to the main project target throughout the lifecycle of the project. This continuous monitoring enables proactive risk management focusing on the most important threats and opportunities and, thereby, significantly increasing the chances of project success.

PRM is supported by tools and experience databases specially developed by DNV.

A 300 Risk based studies

301 DNV offers a complete range of services to identify and assess risks as well as to evaluate risk control options. These services have been developed in close relation to the offshore industry and authorities.

The services span from coarse qualitative assessments using HAZOP and HAZID techniques to full blown quantitative assessments using the latest tools for consequence assessments and risk estimation.

In the context of RBV, these services may be used to:

- — determine design accidental loads from fires and explosions and avoidance of costly over-design
- — selection of preferable arrangement with respect to escape, evacuation and prevention of accident escalation
- — compliance with authorities requirement
- — focus attention to safety critical areas.

DNV is a competent provider of such services with experienced personnel, a full range of tools and databases and in-house procedures and guidelines.

A 400 Environment

401 DNV may provide environmental impact assessments (EIA) as a multidiscipline and integrated approach for a concept or a project by providing factual foundations on environmental issues for rational decision making.

DNV may participate in major field development project as well as assisting operators in the daily operations.

Environmental risk assessments make the basis for oil spill contingency planning. DNV has the capabilities to establish accounts of total environmental impact using formal life cycle assessments (in accordance with ISO 14040).

Management of the environment requires data and information gathering. DNV has established systems for storing environmental data and information (environmental accounting systems), and have the capabilities to support customers in verifying greenhouse gas emissions.

Finally, DNV assists the clients to establish the environmental status through sampling of marine sediments (tests down to about 1500m water depths have been performed).

A 500 Reliability centred maintenance (RCM)

501 RCM is a tool for developing efficient maintenance plans for all the machinery and utility functions for a ship or a production system. It is in particular important to target the maintenance for the given regime of production requirements, contracts as well as for fulfilling the safety functions. DNV has experience, database and knowledge to undertake such analysis and tailor that to the particular operation.

A 600 Risk based inspection (RBI)

601 RBI is a systematic way of developing a cost efficient inspection plan. RBI uses the results of quantitative risk analyses and production availability analyses to assess the potential failure consequences, and combines materials technology and structural load models to determine the probability of failure. It is based on an assessment of the actual governing damage mechanisms, current status, development with time and the most efficient risk mitigation in terms of inspection, maintenance actions and monitoring. RBI is applied for the main process system and for the structure/hull.

RBI will address the consequence of a failure and the redundancy of the component in question. The consequences are safety impairment, environmental damage and economic losses (repair and loss of production).

A 700 World-wide shelf state compliance studies

701 Exploration and exploitation of oil and gas resources on various continental shelves are not governed by international treaties, and many countries impose their own legislation for such activities.

DNV is well aware of the detailed requirements in such legislative regulation on the shelves where oil and gas exploration takes place, and have developed systematics for verification to existing requirements on most shelves of interest for the oil and gas industry.

In particular, DNV has extensive experience with such verification in Norway, U.K., Canada and Australia. Emerging awareness in developing countries of the particular hazards associated with oil and gas activities on their continental shelves is expected to result in more extensive shelf state requirements in these countries in the near future. DNV is closely following this development with the intention to develop appropriate systematics for efficient shelf state verification to suit new rules and regulations.

A 800 Testing/laboratory facilities

801 DNV has a well equipped laboratory with advanced testing facilities. The laboratory facilities allow for most types of structural large-scale testing, component testing, metallurgical examinations, material testing and welding procedure testing.

The structural strength laboratory is equipped to do full scale fatigue and corrosion fatigue test of ship structures, tubular joints and capacity/load test on components.

The metallurgical laboratory is equipped with facilities for scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDS) and performs all standard tests, fatigue and CTOD testing. The laboratory is recognised for failure investigations, and is fully equipped for laboratory and in-situ investigations.

The welding laboratory is fully equipped for weldability testing, welding procedure, and weld repair procedure development for most of procedures used in offshore and shipbuilding applications.

DNV also has extensive experience with composite materials and is currently writing guidelines for the use of fibre reinforced plastics in the offshore and processing industry, for composite risers and for reinforced thermoplastic pipes. Linked to these activities is prevention of corrosion, adhesive technology and repair of structures using composites and adhesives.

APPENDIX B
EXAMPLE – SELECTION OF VERIFICATION LEVEL (PIPELINE SYSTEM)

A. General

A 100 Principles

101 The selection of the level of certification depends on the criticality of each of the elements that have an impact on the management of risks to the pipeline system.

102 Certification shall direct greatest effort at those elements of the pipeline system where the risk is highest and whose failure or reduced performance will have the most significant impact on:

— safety risks
— environmental risks
— economic risks.

103 Suitable selection factors include, but are not limited to, the:

— overall safety objectives for the pipeline system
— assessment of the risks associated with the pipeline and the measures taken to reduce these risks
— degree of technical innovation in the pipeline system
— experience of the contractors carrying out the work
— quality management systems of the owner and its contractors.

104 Due to the diversity of various pipeline systems, their contents, their degree of innovation, the geographic location, et cetera, it is not possible to give precise guidelines on how to decide what level of certification is appropriate for each particular pipeline system.

105 Therefore, guidance is given as a series of questions that should be answered when deciding the appropriate level of certification for a pipeline system. This list is not exhaustive and other questions should be added to the list if appropriate for a particular pipeline system.

106 It must be emphasised that the contribution of each element should be judged qualitatively and/or quantitatively. Wherever possible quantified risk assessment data should use to provide a justifiable basis for any decisions made.

107 Depending of the stage of the project, the activities may not have taken place yet in which case the questions can also be posed in the form "…. is planned to be?"

B. Trigger Questions

B 100 Relevant areas

101 *Overall safety objective*

a) Does the safety objective address the main safety goals?

b) Does the safety objective establish acceptance criteria for the level of risk acceptable to the owner?

c) Is this risk (depending on the pipeline and its location) measured in terms of human injuries as well as environmental, economic and political consequences?

102 *Assessment of risk*

a) Has a systematic review been carried out to identify and evaluate the probabilities and consequences of failures in the pipeline system?

b) Has this review judged the contribution of each element qualitatively and quantitatively and used, where possible, quantified risk assessment data to provide a justifiable basis for any decisions made?

c) Does the extent of the review reflect the criticality of the pipeline system, the planned operation and previous experience with similar pipeline systems?

d) Does this review identify the risk to the operation of the pipeline system and to the health and safety of personnel associated with it or in its vicinity?

e) Has the extent of the identified risks been reduced to a level as low as reasonably practicable by means of one or both of:

— reduction in the probability of failure?
— mitigation of the consequences of failure?

f) Has the result of the systematic review of the risks been measured against the owner's safety objectives?

g) Has the result of this review been used in the selection of the appropriate certification activity level?

103 *Technical innovation*

a) Has the degree of technical innovation in the pipeline system been considered?

b) Has it been considered that risks to the pipeline are likely to be greater with a high degree of technical innovation than with a pipeline designed, manufactured and installed to well-known criteria in well-known waters?

c) Have factors been considered in the selection of the appropriate certification level such as:

— degree of difficulty in achieving technical requirements?
— knowledge of similar pipelines?
— effect of the new pipeline on the surrounding area?

104 *Contractors' experience*

a) Has the degree of risk to the pipeline system been considered where design, construction or installation contractors are inexperienced?

b) Has the degree of risk been considered where the contractors are experienced but not in similar work?

c) Has the degree of risk been considered where the work schedule is tight?

105 *Quality Management Systems*

a) Have all parties involved in the pipeline system implemented an adequate quality management system to ensure that gross errors in the work are limited?

b) Do these parties include the:

— owner?
— design contractor?
— construction contractors?
— installation contractor?
— operator?

c) Do the factors being considered when evaluating the adequacy of the quality management system include:

— whether or not an ISO 9000 or equivalent certified system is in place?
— results from external audits?
— results from internal audits?

— experience with contractors' previous work?
— project work force familiarity with the quality management system?