



OFFSHORE SERVICE SPECIFICATION
DNV-OSS-302

OFFSHORE RISER SYSTEMS

OCTOBER 2003

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:

- A) Qualification, Quality and Safety Methodology
- B) Materials Technology
- C) Structures
- D) Systems
- E) Special Facilities
- F) Pipelines and Risers
- G) Asset Operation
- H) Marine Operations

Amendments and Corrections

This document is valid until superseded by a new revision. Minor amendments and corrections will be published in a separate document on the DNV web-site; normally updated twice per year (April and October). To access the web-site, select short-cut options "Technology Services" and "Offshore Rules and Standards" at <http://www.dnv.com/>

The electronic web-versions of the DNV Offshore Codes will be regularly updated to include these amendments and corrections.

Comments may be sent by e-mail to rules@dnv.com

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INTRODUCTION

General

These new rules were approved by the Executive Board in September 2003.

The rules come into force 1 october 2003.

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SECTION 1 GENERAL

A. General

A 100 Introduction

101 DNV provides various services related to dynamic riser systems, where the word dynamic is referring to a non-stationary riser. In the notation dynamic riser systems, the following are included:

- Metallic risers (i.e. steel, titanium)
- Composite risers
- Flexible pipes
- Umbilicals (i.e. individual or piggy-back)
- Loading hoses.

102 The DNV services include technical advice/assistance (consultancy activities) research and development services, in addition to more traditional design verification/product certification. The verification and certification services are carried out with basis in Rules, Standards, Regulations and customer requirements.

103 This Offshore Service Specification (OSS) provides criteria for and guidance to the above-mentioned services for either complete dynamic riser systems, or for separate/self-contained components of riser systems.

104 DNV is a recognised provider of technical advisory services, which can be directly connected with the development and design of deepwater riser systems.

105 For verification and certification, this Offshore Service Specification for dynamic riser systems aims at using the same principles/approaches as used in the Offshore Service Specification for submarine pipeline systems (DNV-OSS-301).

A 200 Objectives

The objectives of this document are to:

- describe DNV's overall competence and experience related to dynamic riser systems.
- describe DNV's technical advisory-, verification- and certification services for dynamic riser systems.

Guidance note:

DNV will use this Offshore Service Specification as a reference document in writing bids/proposals to the Clients. This will provide a clear and uniform understanding of the scope of work to be carried out.

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A 300 Organisation of DNV-OSS-302

301 This document consists of three Sections and two Appendices:

- Section 1; providing general scope of the present document, informative background information, definitions, abbreviations and references.
- Section 2; providing information about DNV's competence, experience and technical approach used in their dynamic riser services.
- Section 3; providing information/specifications about DNV's services to dynamic riser systems.
- Appendix A; provides examples of verification/certification documents.
- Appendix B; provides an overview of applicable software programs used by DNV.

A 400 Structure of riser-related DNV documents

401 Reference is made to the foreword to this document. From the document structure described therein, documents relating to riser systems consist of a three-level hierarchy with these main features:

- Principles and procedures related to DNV's Offshore Services are separate from technical requirements and are described in DNV Offshore Service Specifications.
- Technical requirements are issued as self-contained DNV Offshore Standards.
- Associate product documents are issued as DNV Recommended Practices.

Guidance note:

Product documents issued under previous document structures may be termed "Classification Notes" or "Guidelines".

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402 The 3-level hierarchy is designed with these objectives:

- Offshore Service Specifications present the scope and extent of DNV's Offshore Services.
- Offshore Standards are issued as neutral technical standards to enable their use by national authorities, as international codes and as company or project specifications without reference to DNV's Offshore Services.
- The Recommended Practices convey DNV's interpretation of safe and sound engineering practice for general use by the industry.

Guidance note:

The latest revision of all official DNV publications may be found on the document list on the DNV's web site: www.dnv.com.

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A 500 DNV applicable standards and specifications

501 The following DNV standards and specifications relevant for dynamic risers apply (not limited to):

DNV Offshore Service Specifications (OSS):

- DNV-OSS-101 Rules for Classification of Drilling and Support Units
- DNV-OSS-102 Rules for Classification of Floating Production and Storage Units
- DNV-OSS-301 Certification and Verification of Pipelines

DNV Offshore Standards (OS):

- DNV-OS-F201 Dynamic Risers
- DNV-OS-F101 Submarine Pipeline Systems
- DNV-OS-C102 Structural Design of Offshore Ships
- DNV-OS-C103 Structural Design of Column Stabilised Units (LRFD Method)
- DNV-OS-C104 Structural Design of Self-Elevating Units (LRFD Method)
- DNV-OS-C105 Structural Design of TLPs by the LRFD Method
- DNV-OS-C106 Structural Design of Deep Draught Floating Units (LRFD Method).
- DNV-OS-E101 Drilling Plant
- DNV-OS-E201 Hydrocarbon Production Plant

DNV Recommended Practice (RP):

- DNV-RP-A203 Qualification Procedures for New Technology

- DNV-RP-B401 Cathodic Protection Design
- DNV-RP-C203 Fatigue Strength Analysis
- DNV-RP-F101 Corroded Pipelines
- DNV-RP-F104 Mechanical Pipeline Couplings
- DNV-RP-F105 Free Spanning Pipelines
- DNV-RP-F106 Factory Applied Pipeline Coatings for Corrosion Control
- DNV-RP-F201 Titanium Risers
- DNV-RP-F202 Composite Risers
- DNV-RP-F203 Riser collision (drafting in progress, planned issued 2004)
- DNV-RP-F204 Riser fatigue (drafting in progress, planned issued 2004)
- DNV-RP-F205 Coupled Analysis (drafting in progress, planned issued 2004)
- DNV-RP-H101 Risk Management in Marine- and Subsea Operations
- DNV-RP-O501 Erosive Wear in Piping Systems

DNV rules:

- DNV Rules for Certification of Flexible Risers and Pipes, 1994
- DNV Rules for Planning and Execution of Marine Operations

DNV Classification Notes (CN):

- DNV CN 7 Ultrasonic Inspection of Weld Connections
- DNV CN 30.4 Foundations
- DNV CN 30.5 Environmental Conditions and Environmental Loads
- DNV CN 30.6 Structural Reliability Analysis of Marine Structures

DNV Standards for Certification:

- 1.2 Conformity Certification Services, Type Approval
- 2.9 Approval programmes – 100 series (Type Approval)
- 2.9 Approval programmes – 300 series (Approval of Manufacturers)

502 The Offshore Standard DNV-OS-F201 Dynamic Risers covers all aspects related to design and analysis of metallic and composite dynamic risers. DNV-OS-F201 is a result of the Joint Industry Project “Design Procedures and Acceptance Criteria for Deepwater Risers”. DNV-OS-F201 applies to all new-built all-metallic riser systems and may also be applied for modification, operation and upgrading of existing corresponding risers. The Standard is applicable for both permanent operations (e.g. production and export/import) as well as temporary operations (e.g. drilling and completion/workover). DNV-OS-F201 for Dynamic Risers is compatible with DNV-OS-F101 for Submarine Pipeline Systems. The main benefits of DNV-OS-F201 are:

- Consistent safety level
- Flexible modern design principles (LRFD method, which is recommended for optimal design of deep water riser systems)
- Cost effective design
- Guidance and requirements for efficient global analyses
- Allowance for use of innovative techniques and procedures.

503 The DNV Offshore Standards are subject to continuous development to reflect the state-of-the-art consensus on accepted industry practice.

A 600 Other applicable standards and specifications

601 DNV Offshore Services can be carried out by using our own standards and or specifications or any other applicable recognised standard or project specific specification and or requirements.

602 Mixing of codes or standards for each system and equipment is in general to be avoided due to the possible differences in safety philosophies. Deviations from the code must be specially noted and approved (if necessary).

Guidance note:

Most standards are a coherent collection of requirements for all the relevant aspects of a riser system. These aspects, e.g. load and resistance, are normally among themselves adjusted to give an overall acceptable safety level. To pick requirements from different standards can then easily result in unpredictable (low) levels of safety.

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603 The following API publications are applicable to risers (not limited to):

API Recommended Practice:

- API RP 2RD, Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
- API RP 17B, Recommended Practice for Flexible Pipe
- API RP 17C, Recommended Practice on TFL (Through Flow Line)
- API RP 17I, Installation Guidelines for Subsea Umbilicals
- API RP 16Q, Recommended Practice for Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems.

API Specifications:

- API SPEC 17J, Specification for Unbonded Flexible Pipe
- API SPEC 17G, Design and Operation of Completion Workover Riser Systems
- API SPEC 17K, Specification for Bonded Flexible Pipe
- API SPEC 7K, Specification for Drilling Equipment
- API SPEC 16R, Specification for Marine Drilling Riser Couplings
- API SPEC 17E, Specification for Subsea Production Control Umbilical.

604 For material and test methods, the American Society for Testing and Materials (ASTM) has a list of relevant specifications.

605 The following ISO standards are applicable (not limited to):

- ISO/FDIS 2394 General Principles on Reliability for Structures
- ISO/CD 13628-2 Petroleum and natural gas industries – Design and operation of subsea production systems – Part 2: Flexible pipe systems for subsea and marine applications
- ISO/CD 13628-5 Petroleum and natural gas industries - Design and operation of subsea production systems -- Part 5: Subsea umbilicals
- ISO/CD 13628-7 Petroleum and natural gas industries – Design and operation of subsea production systems – Part 7: Completion/workover riser systems.

606 In addition to the above mentioned standards or specifications, relevant ASME (American Society of Mechanical Engineers) standards or codes apply.

B. Background

B 100 Introduction

101 The DNV multidisciplinary competence throughout the company is located at different sections or departments and even in different countries. The main objective of this document is to present the overall DNV competence and experience

and to describe how DNV applies these assets in the services offered in relation to dynamic riser systems.

102 DNV is actively involved in Joint Industry Projects (JIP) and Research and Development (R&D) projects. The experience and knowledge gained from these projects are of great value for the DNV services rendered.

103 DNV can through its multidiscipline competence directly engage in technology development and assessment of various riser concepts. This is outlined in some more detail in Section 2 of this OSS.

104 New challenges arise when moving into deeper waters. DNV has been heavily involved in and gained valuable experiences from several developments in the Gulf of Mexico and West of Africa since the mid 1990's. DNV is thus qualified to assist operators and designers to manage the risk associated with the new deepwater challenges through early project involvement.

B 200 Examples of Dynamic Riser Systems

201 The transport of hydrocarbons from a subsea well to or via a production / storage unit positioned at the sea surface may be conducted by a variety of riser configurations depending on key field parameters, such as environmental conditions, platform concept, production rates, well pressure/temperature, water depth, flow assurance, installation issues etc. Also for other applications like injection of gas or produced water into the well or for export of hydrocarbons, riser systems similar to the production riser may be used. The following categories of risers are typically used for exploitation of hydrocarbons:

- Production riser
- Injection riser
- Gas lift riser
- Service riser
- Export / import riser
- Completion / Workover riser
- Marine Drilling riser system
- Subsea Control Umbilical
- Integrated Production Umbilical.

These categories differ with respect to typical dimensions, cross-sectional composition, type of operation, functional requirements and design load conditions.

202 Some of the following characteristic riser designs can be identified to cover the above mentioned applications:

203 *Top tensioned riser (TTR)*; Vertical riser supported by a top tension in combination with boundary conditions that allows for relative riser/floater motions in vertical direction, i.e. by use of heave compensation system. The intended (idealised) behaviour is that the applied top tension should maintain a constant target value regardless of the floater motion. The capacity of relative riser/floater motion in vertical direction (stroke) in addition to applied top tension is the essential design parameter governing the mechanical behaviour as well as the application range. TTR's are applicable for all functional purposes as mentioned above (excl. umbilical) and will hence represent an attractive alternative for floaters with rather small heave motion.

204 *Compliant riser*; Compliant riser configurations are designed to absorb floater motions by change of geometry, without use of heave compensation systems. Compliant risers are mainly applied as production, export/import and injection risers. The required flexibility is for conventional water depths normally obtained by arranging unbonded flexible pipes in one of the 'classical' compliant riser configurations: Steep S, Lazy S, Steep Wave, Lazy Wave, Pliant Wave or Free Hanging (catenary). An example of a "non-classical" riser configuration is the Compliant Vertical Access Riser (CVAR). In deep water it is also possible to arrange metallic pipes in compliant riser

configurations. Critical locations on compliant risers are typically the wave zone, hog –and sag bends, touch down area at seafloor and at the terminations to rigid structures, e.g. I- or J-tubes.

205 *Hybrid riser*; The hybrid riser configuration is a combination of the tensioned and the compliant riser in an efficient way. A typical configuration is a vertical/free hanging riser from a submerged buoy to seabed with a compliant riser from the buoy to the FPS. Hybrid risers are mainly applied as production, export/import and injection risers. A riser tower is an assembly of vertical risers from seabed connected to the FPS with compliant risers. The vertical riser assembly is kept upright by various methods (e.g. truss support structure, distributed buoyancy on the risers, buoyancy tanks).

C. Definitions

C 100 General

101 The definitions in DNV-OS-F201 section 1 C200 also apply to this OSS.

102 The most important definitions from DNV-OS-F201 applied in this OSS are repeated. They are marked "(DNV-OS-F201)" between the word and its definition.

C 200 Verbal Forms

201 The terms *will*, *can* and *may* are used when describing DNV's actions or activities, and the terms *shall*, *should* and *may* are used when referring to other parties than DNV.

202 "*Shall*": Indicates requirements strictly to be followed in order to conform to this OSS and from which no deviation is permitted.

203 "*Should*": Indicates that among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required. Other possibilities may be applied subject to agreement.

204 "*Will*": Indicates a mandatory action or activity to be undertaken by DNV. (Ref. "shall" for other parties.)

205 "*Can*": Indicates an action or activity that DNV not necessarily does unless specifically requested by the Client. (Ref. "should" for other parties.)

206 "*May*": Verbal form used to indicate a course of action permissible within the limits of the OSS.

C 300 Definitions

301 *Buoyancy modules* (DNV-OS-F201): Structure of light weight material, usually foamed polymers, strapped or clamped to the exterior of riser joints, to reduce the submerged weight of the riser.

302 *Certification*: Used in this document to mean all the activities associated with the process leading up to a Certificate.

Guidance note:

In this OSS when *Certification* is used it designates the overall scope of work or multiple activities for the issue of a *Certificate*, whilst *Verification* is also used for single activities associated with the work. This in essence means that *Certification* is *Verification* for which the deliverable includes the issue of a *Certificate*.

Other (related) definitions are:

BS 4778: Part 2: *Certification*: The authoritative act of documenting compliance with requirements.

EN 45011: *Certification of Conformity*: Action by a third party, demonstrating that adequate confidence is provided that a duly identified product, process or service is in conformity with a specific standard or other normative document.

ISO 8402: 1994: *Verification*: Confirmation by examination and

provision of objective evidence that specified requirements have been fulfilled.

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303 Client: DNV's contractual partner. It may be the purchaser, the owner or the contractor.

304 Completion/workover riser (DNV-OS-F201): Temporary riser used for completion or workover operations and includes any equipment between the subsea tree/tubing hanger and the workover floaters tensioning system.

305 Compliant riser: A riser designed to absorb floater motions by change of geometry, without use of heave compensation systems.

306 Consulting: Technical advisory service offered during any phase of a project.

307 Design: All related engineering to design the riser including structural as well as material and corrosion protection.

308 Design phase: An initial riser phase that takes a systematic approach to the production of specifications, drawings and other documents to ensure that the riser system meets specified requirements (including design reviews to ensure that design output is verified against design input requirements).

309 Design checks (DNV-OS-F201): Design checks are investigations of the structural safety of the riser under the influence of load effects (design load cases with respect to specified limit states, representing one or more failure modes, in terms of resistance of relevant structural models obtained in accordance with specified principles).

310 Design Verification Report (DVR): A document issued to confirm that the product/process has been completed in accordance with specified requirements.

311 Drilling riser (DNV-OS-F201): A riser utilised during drilling and workover operations and isolates any wellbore fluids from the environment. The major functions of drilling riser systems are to provide fluid transportation to and from the well; support auxiliary lines, guide tools, and drilling strings; serve as a running and retrieving string for the BOP. Drilling risers may also be used for well completion and testing.

312 Effective tension (DNV-OS-F201): The axial wall force (axial pipe wall stress times area) adjusted for the contributions from external and internal pressure.

313 Export/import riser (DNV-OS-F201): Export/import risers transfer the processed fluids from/to the floater (structure to/from another facility, which may include another platform/floater or pipeline).

314 Fabrication: Activities related to the assembly of objects with a defined purpose.

315 Fatigue (DNV-OS-F201): Cyclic loading causing degradation of the material.

316 Flex joint (DNV-OS-F201): A laminated metal and elastomer assembly, having a central through-passage equal to or greater in diameter than the interfacing pipe or tubing bore, that is positioned in the riser string to reduce the local bending stresses (typical installation at connection to floater/seafloor).

317 Flexible riser: Risers used to take large motions. The flexible riser combines low bending stiffness with high axial tensile stiffness by use of helical armouring layers and polymer sealing layers.

318 Floater (DNV-OS-F201): Buoyant installation, which is floating or fixed to the sea bottom by mooring systems in temporary or permanent phases, e.g. TLP, Ship, Semi, Spar, Deep Draft Floater etc.

319 Global analysis (DNV-OS-F201): Analysis of the complete riser system.

320 Hybrid riser: A combination of tensioned riser and com-

pliant riser.

321 Installation (DNV-OS-F201): The operation related to installing the riser system, such as running of riser joints, landing and connecting or such as laying, tie-in, etc. for a dynamic riser.

322 Limit State (DNV-OS-F201): The state beyond which the riser or part of the riser no longer satisfies the requirements laid down to its performance or operation. Examples are structural failure (rupture, local buckling) or operations limitations (stroke or clearance).

323 Load (DNV-OS-F201): The term load refers to physical influences which cause stress, strain, deformation, displacement etc. in the riser.

324 Load and Resistance Factor Design (LRFD) (DNV-OS-F201): Design format based upon a Limit State and Partial Safety Factor methodology. The partial safety factor methodology is an approach where separate factors are applied for each load effect (response) and resistance term.

325 Low frequency response (DNV-OS-F201): Motion response at frequencies below wave frequencies or near surge, sway and yaw eigenperiods for the floater. LF motions typically have periods ranging from 30 to 300 seconds.

326 Manufacture: Making of articles or materials, often in large volumes. In relation to risers, refers to activities for the production of riser joints, end terminations, components and application of coating.

327 Ovalisation (DNV-OS-F201): The deviation of the perimeter from a circle. This has the form as an elliptic cross section. The numerical definition of out of roundness and ovalisation is the same.

328 Permanent riser (DNV-OS-F201): A riser, which will be in continuous operations for a long time period, irrespective of environmental conditions.

329 Production/injection riser (DNV-OS-F201): Production risers transport fluids produced from the reservoir. Injection risers transport fluids to the producing reservoir or a convenient disposal or storage formation. The production riser may be used for well workover, injection, completion and other purposes.

330 Riser component (DNV-OS-F201): Any part of the riser system that may be subjected to pressure by the internal fluid. This includes items such as flanges, connectors, stress joints, tension joints, flex-joints, ball joints, telescopic joints, slick joints, tees, bends, reducers and valves.

331 Riser joint (DNV-OS-F201): A joint for metallic risers consists of a pipe member mid section, with riser connectors at each end. Riser joints are typically provided in 30 ft. to 50 ft. (9.14m to 15.24m) lengths. Shorter joints, "pup joints", may also be provided to ensure proper space-out.

332 Riser system (DNV-OS-F201): A riser system is considered to comprise the riser, all integrated riser components and corrosion protection system.

333 Riser tensioner system (DNV-OS-F201): A device that applies a tension to the riser string while compensating for the relative vertical motion (stroke) between the floater and riser. Tension variations are controlled by the stiffness of the unit.

334 Risk analysis (DNV-OS-F201): Analysis including a systematic identification and categorisation of risk to people, the environment and to assets and financial interests.

335 Slender Structures: Slender structures are used as a collective term for risers, tendons and mooring lines.

336 Stress joint (DNV-OS-F201): A specialised riser joint designed with a tapered cross section, to control curvature and reduce local bending stresses.

337 Technical Report: A document describing background, theory, methodology, input and results from analyses or other

work carried out.

338 Tensioned riser (DNV-OS-F201): A riser, which is essentially kept straight and tensioned in all parts, by applying a top tension to it.

339 Temporary riser (DNV-OS-F201): A riser which is used intermittently for tasks of limited duration, and which can be retrieved in severe environmental conditions, essentially marine/drilling risers and completion/workover risers.

340 Umbilical: An umbilical is used for example for subsea control, data communication and transportation of production system service fluids and/or utility supplies. The umbilical consists of a group of cables (e.g. electrical, optical fibre) and hoses cabled together for flexibility, over sheathed and or armoured for mechanical strength.

341 Verification: An examination to confirm that an activity, a product or a service is in accordance with specified requirements.

342 Verification Comments Sheets (VerCom): is regarded as a systematic way of documenting the resolution process between the parties involved. An example of VerCom is given in Appendix A.

343 Wave frequency response (DNV-OS-F201): Response at the frequencies of incident waves.

344 Working stress design (WSD) (DNV-OS-F201): Design method where the structural safety margin is expressed by one central safety factor for each limit state. The central safety factor is the ratio between a resistance and the load effect.

D. Abbreviations

ALS	Accidental Limit State
API	American Petroleum Institute
ASME	The American Society of Mechanical Engineers
ASTM	The American Society for Testing and Materials
CAPEX	Capital expenditure
CFD	Computational Fluid Dynamics
CVAR	Compliant Vertical Access Riser
DNV	Det Norske Veritas
DVR	Design Verification Report
FD	Frequency Domain
FE	Finite Element
FEA	Finite Element Analysis
FLS	Fatigue Limit State
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Mode, Effect and Criticality Analysis
FPS	Floating Production System
H	Involvement level High (risk based verification / certification)
HAZID	Hazard Identification
HAZOP	Hazard and Operability Studies

HF	High Frequency
IPU	Integrated Production Umbilical
ISO	International Organization for Standardization
L	Involvement level Low (risk based verification / certification)
LF	Low Frequency
LMRP	Lower marine riser package
LRFD	Load and Resistance Factor Design
LRP	Lower riser package
LTD	Linear Time Domain
M	Involvement level Medium (risk based verification / certification)
MMF	Multitube Moment Factor
MPS	Manufacturing Procedure Specification
NDT	None Destructive Testing
NLTD	Non-Linear Time Domain
OPEX	Operational expenditure
OS	DNV Offshore Standard
OSS	DNV Offshore Service Specification
QRA	Quantitative Risk Analysis
R&D	Research and Development
RFC	Rain Flow Counting
RP	Recommended Practice
SCF	Stress Concentration Factor
SCR	Steel Catenary Riser
SHE	Safety, Health, Environment
SLS	Serviceability Limit State
SRA	Structural Reliability Analysis
TCR	Titanium Catenary Riser
TD	Time Domain
TTR	Top Tensioned Riser
ULS	Ultimate Limit State
VerCom	Verification Comment Sheet
VIV	Vortex Induced Vibrations
WF	Wave Frequency
WIO	Wake Induced Oscillations
WSD	Working Stress Design

E. Other References

E 100 General

101 References not fully referred in the text in Section 1, Chapter A are given below:

102 ISO 8402 Quality – Vocabulary, 1994, International Organization for Standardization, Geneva.

103 En 45011 General Criteria for Certification Bodies Operating Product Certification, 1998, European Committee for Standardization, Brussels.

104 BS 4778 Quality Vocabulary, Part 2 Quality Concepts and related Definitions, 1991, British Standards Institute, London.

SECTION 2 TECHNICAL APPROACH

A. General

A 100 Objective

101 The objective of this section is to give an overview of the basic technical approach applied in DNV's riser services. The described competence and experience are gained through many projects including Joint Industry Projects (JIP) and Research & Development (R&D) projects.

102 The basic technical capabilities described in this Section are referred in the Service Specification outlined in Section 3.

B. Global Analysis

B 100 Global load-effect analysis

101 Global load-effect analyses form the basis for the design of all types of riser configurations (metallic, flexible, umbilicals, top tensioned, compliant, hybrid, loading hoses etc.).

102 The purpose of global riser system analyses is to describe the overall static and dynamic structural behaviour by exposing the system to a stationary environmental loading condition. A global cross sectional description in terms of resulting force/displacement relations is applied. The following response quantities may be given directly as output from global riser analyses:

- Cross-sectional forces/moments
- Global riser deflections
- Global riser position
- Support forces (reactions) at termination to support structures
- Stroke etc.

103 The external loads considered in global load effect analyses are:

- 1) Functional loading due to self-weight, buoyancy, applied top tension in nominal floater position etc.
- 2) Current loading on the riser
- 3) Direct wave loading on the riser. Diffraction effects due to floater motions may be included if relevant (e.g. TLP risers)
- 4) Hydrodynamic loading in moon-pool (relevant for e.g. Spar riser systems)
- 5) Forced floater motions (mean position and dynamic motions). Dynamic motions will normally be given in terms of floater motion transfer functions (RAO's) obtained by Frequency Domain (FD) radiation/diffraction hydrodynamic analyses. Time series of combined WF/LF floater motions obtained by e.g. coupled analyses may alternatively be applied. Simultaneous excitations from several floaters may be considered if relevant (e.g. loading hoses or flow-lines between two floaters).

Items 1. and 2. represent static load cases while items 3. to 5. represent combined static (mean) loads as well as dynamic loads on the riser system.

104 A basic understanding of important nonlinearities of riser systems is of vital importance for system modelling as well as for selection of adequate global analysis approach. Important nonlinearities can be summarised as:

- Hydrodynamic loading (drag force, splash zone effects)

- Geometric stiffness
- Large rotations in 3D space
- Material nonlinearities
- Contact problems, e.g. seafloor contact and hull/slender structure contact.

The relative importance of these nonlinearities is strongly system and excitation dependent. It should be noted that external hydrostatic pressure is not considered to be a nonlinear effect as hydrostatic pressures will be handled by the effective tension or effective weight concept in computer programs tailor made for slender structure analysis.

105 A Finite Element (FE) approach shall be applied in static- and dynamic analyses. FE modelling and model verification (i.e. mesh, time step, load representation etc.) shall be carried out in accordance with principles outlined in DNV-OS-F201.

106 It is recommended to apply computer codes allowing for representation of hydrostatic pressure by the effective tension or effective weight concept.

107 Static load-effect analyses considering static load conditions (i.e. weight, buoyancy, applied top tension, mean floater positions) shall be conducted using a full nonlinear solution scheme.

108 Treatment of nonlinearities is the distinguishing feature among available dynamic analysis techniques. Commonly used dynamic FE analysis techniques, treatment of nonlinearities and main area of application are summarised in the following:

- **Nonlinear time domain (NLTD)** analysis. This approach allows for consistent treatment of load- as well as structural nonlinearities. Nonlinear simulations will typically be needed for systems undergoing large displacements, rotations or tension variations, or in situations where description of variable touch-down locations or material nonlinearities is important.
- **Linearised time domain (LTD)** analysis based on structural linearization at static equilibrium position. Nonlinear hydrodynamic loading according to the Morison equation is, however, still included. A typical application is analysis of tensioned risers with moderate transverse excursions.
- **Frequency domain (FD)** analysis based on structural and load linearization at static equilibrium position (i.e. structural and load linearization). Frequency domain analysis will always give a Gaussian response and is therefore in general not recommended for extreme response prediction. The main application area is fatigue calculations and screening studies.

109 Any use of simplified analysis methodology should be verified by NLTD analyses for a selected number of representative load cases.

110 For further details on methodology for global load-effect analysis, reference is made to DNV-OS-F201.

B 200 Eigenvalue analysis

201 Eigenvalue analysis should be performed to determine the eigenfrequencies and eigenmodes of the riser system. This analysis represents a fundamental check of the dynamic properties of the riser system and should always be considered as the first step in the dynamic system analysis. Eigenvalue analyses shall be based on a complete FE model of the riser system applied in the global load-effect analysis.

202 Eigenvalue analysis is of particular importance for iden-

tification of possible resonance dynamics. Special attention should be given to deep water top tensioned risers operated from Tension Leg - and Spar platforms with complex support conditions (e.g. moon-pool and truss area of Spar platforms).

203 Eigenvalue analysis also forms the basis for assessment of possible vortex induced vibrations (VIV). Computed modes and eigenfrequencies can be used as input to subsequent VIV analysis based on modal FD solution techniques.

B 300 Coupled analysis

301 Floater, risers and mooring lines constitute an integrated dynamic system responding to environmental loading due to wind, wave and current in a complex way. The floater motion response may be decomposed into the following components:

- Static (mean) response due to steady current, mean- wind and wave drift
- Low Frequency (LF) response due to wind, 2nd order wave excitation and viscous drift
- Vortex Induced Vibration (Hull VIV) due to steady current (Spar platforms)
- Wave Frequency (WF) response due to 1st order wave excitation on the floater
- High frequency (HF) response due to higher order wave loading (e.g. springing and ringing response of TLP's).

302 Floater motions for deep water applications will in general be influenced by coupling effects (i.e. restoring, inertia and damping) from slender structures. Current loading and damping due to the slender structures may significantly influence the LF floater motions of deep water floating installations. Consistent treatment of these coupling effects is decisive for adequate prediction of floater motions and slender structure responses for deep water concepts.

303 The importance of coupling effects is strongly dependent on the overall system layout as well as the environmental excitation level.

304 The main purpose of coupled analyses is accurate prediction of floater motion with due regard to floater / slender structure coupling effects (i.e. global performance analysis).

305 Floater motion records produced by coupled analyses can be applied as forced motions in subsequent detailed analysis of selected mooring lines and risers. Alternatively, it is possible to include detailed models of assumed critically loaded mooring lines and risers directly in the coupled model. The latter approach is termed selective slender structure modelling.

306 All relevant coupling effects can be consistently represented using a coupled analysis where the floater force model is introduced in a detailed FE model of the complete slender structure system including all mooring lines and risers. NLTD analyses considering irregular environmental loading are generally required to give an adequate representation of the coupled floater to slender structure response. This approach yields dynamic equilibrium between the forces acting on the floater and the slender structure response at every time instant. Floater to slender structure coupling effects will therefore be automatically included in the solution scheme.

307 Coupled analysis is applicable to all types of floating systems. This includes complex systems consisting of several floaters connected to each other by for instance mooring lines, loading hoses or fluid transfer lines. Pronounced coupling effects have been identified for several deep-water concepts (e.g. TLP, Spar, Semi, FPSO etc.).

308 Combined irregular WF and LF loading should always be included in coupled analyses. Hull VIV may in addition be included in coupled Spar analyses. HF excitation may be considered for TLP's.

309 For further details on coupled analyses, reference is made to DNV-OS-F201.

B 400 VIV Analysis

401 Riser systems exposed to ocean currents may experience in-line as well cross-flow Vortex Induced Vibrations (VIV). The main effects of VIV of relevance to riser system design are:

- The riser system may experience significant fatigue due to VIV.
- VIV may increase the mean drag coefficient to be applied in global load effect analyses and riser interference analyses.
- VIV may influence Wake Induced Oscillations (WIO) of riser arrays (onset and amplitude of WIO).
- VIV may contribute significantly to the relative collision velocity of two adjacent risers (relevant only if structural riser interference is a design issue).

402 VIV is a key design issue for a wide range of riser systems exposed to ocean currents. VIV evaluation is of particular importance for deep water top-tensioned risers.

403 VIV fatigue analyses may be carried out by state-of-practice tailor made software for engineering applications. The main features of such software are:

- Semi-empirical parametric cross-flow VIV load / response formulation based on model test results
- Linear structural model
- Direct FD solution based on linearised dynamic equilibrium equations at static equilibrium position, or
- Modal solution based on eigenmodes and eigenfrequencies computed from FE model of the riser system
- FD fatigue damage calculation.

404 The main limitations of the state-of-practice approach are:

- Linear structural model (e.g. constant effective tension) may give inaccurate results in e.g. touch-down area of SCR's.
- In-line VIV is ignored, which will generally give non-conservative fatigue damage estimates (especially if high in-line modes are excited by VIV).
- Axial stress due to cross-flow VIV is not included (this would require a NLTD VIV analysis).

405 Numerical TD simulation of the turbulent fluid flow around one- or several pipes can in principle be applied for VIV assessment to overcome the inherent limitations of the state-of-practice engineering approach. This approach is commonly termed 'Computational Fluid Dynamics' –CFD. The application of CFD for VIV assessment is presently severely limited by the computational efforts required as indicated in the following:

- 3D – CFD model linked to LTD or NLTD structural model. Presently not applicable due to the enormous computational efforts involved.
- Simplified 2D CFD approach (e.g. vortex in cell method) applied as strip model in a LTD or NLTD structural model. May be applied for verification of selected critical conditions of some riser systems. Demanding to apply for cases where high modes are excited by VIV (e.g. deep water risers) as a large number of strips will be needed to give an adequate load and response representation.
- 2D/3D CFD models applied for single/multiple cylinder sections with flexible supports. May be applied for screening purposes.

B 500 Interference and Collision

501 Riser interference in arrays of TTR's operated from TLP's and Spar platforms exposed to ocean currents is a key design issue for deep water installations. Riser top tension and riser spacing may be increased to avoid riser clashing. Such ac-

tions may however lead to an unacceptable floater design. More cost optimal designs can be achieved by allowing for some riser interference (e.g. in accidental scenarios). This will require dedicated analyses to document sufficient capacity of the riser with respect to collision.

502 The main requirements to riser collision analyses are:

- The riser interference analyses should be based on a FE model of two adjacent (critical) risers. A NLTD approach should be applied.
- Rebound effects from structural interference should be included.
- Local pipe stress/strain due to collision should be established in separate FE analyses. Local pipe stress/strain may be expressed as a function of relative pipe impact velocity. Structural details such as connectors, coating etc may be included as relevant for the actual case.
- Hydrodynamic interaction effects shall be included (shielding, VIV, WIO, proximity effects etc).
- Coefficients for mean lift- and drag shall be based on model tests or state-of-the-art CFD analyses for the actual pipe configuration and Re-number.
- Effect of VIV shall be evaluated and incorporated in the analyses in a conservative way. Increase in mean drag coefficients due to VIV shall be included (of particular importance for the up-stream cylinder).

503 For further details including acceptance criteria for riser collision evaluations, reference is made to DNV-RP for Riser collision (will be issued in 2004).

B 600 Regularity studies

601 Offshore installations are often subjected to constraints limiting normal operation of the system. Such constraints may be given in terms of:

- Environmental conditions (e.g. wave height, current velocity)
- System response (e.g. stroke, floater offset, heave/roll motions etc.)
- Combined environmental/ system response criteria.

602 Typical examples of offshore systems with operational constraints are drilling and well intervention, pipe laying, operation of offshore loading systems etc.

603 The main purpose of regularity analyses is to predict the operability of the system; i.e. the percentage of time that the system is expected to be able to perform normal operations.

604 Regularity analyses are based on joint, long-term, statistics of relevant environmental variables. Annual or seasonal conditions may be considered, dependent on the planned duration of the operation. Measured or hind cast data may be utilised.

605 Regularity analysis with respect to a single environmental constraint may be based on the long-term distribution of the corresponding variable.

606 Regularity analysis with respect to multiple environmental constraints requires organisation of constraint checks for a full range of short-term environmental conditions, followed by integration of the long-term operability. The integration may be achieved by summation over the cells of a scatter diagram, Monte Carlo techniques, or structural reliability methods, dependent on the specific problem.

607 Regularity analysis with respect to system response constraints requires adequate load-effect analyses for a full range of short-term environmental conditions. Interpolation between calculated responses for a limited set of short-term conditions, using a response surface technique, can be efficient when the response calculations are demanding.

C. Detailed component analysis

C 100

101 Examples of general structural components of riser systems requiring special design / analysis considerations are:

- tensioner systems
- landing blocks
- taper joints, keel joints
- tension joints, tension ring
- telescopic joints
- connectors and couplings
- flex-joints, ball-joints
- receptacles
- J-lay collars / buckle arrestors
- buoyancy cans/modules
- sub-sea arch
- VIV suppression devices (e.g. strakes)
- I-tubes / J-tubes
- bell-mouths
- tethers, anchoring elements
- clamps
- termination head / pull-in head
- weak links
- bend restrictor / bend stiffener for flexible risers and umbilicals.

102 The appropriate method for local component analyses spans from a simple analytical approach (e.g. hand-calculations, spread-sheet) to advanced FE analyses depending on the complexity of the actual component of concern.

103 FE analyses shall be carried out using a recognised general purpose FE program offering the required modelling capabilities (e.g. shell-, solid- and beam elements, contact formulation, material models etc.).

104 Recognised principles for modelling and verification of the FE model shall be applied. (e.g. modelling of discontinuities, mesh verification etc). Guidance on FE analysis / modelling of riser components is given in ISO/CD 13628-7 and DNV RP-C203 "Fatigue Strength Analysis of Offshore Steel Structures" for modelling of Stress Concentration Factors (SCF) for fatigue analyses.

105 When carrying out FE analysis for strength, leakage and fatigue (SCF's) assessment the worst combination of specified tolerances shall be used.

106 The calculated stress from the FE analysis can be evaluated according to the acceptance criteria as described in DNV-OS-F201.

107 The stress through the most critical cross-sections shall be linearised when evaluated according to the acceptance criteria's as described in ASME VIII, Division 2, Appendix 4.

108 Local FE analyses are typically applied to:

- Extreme stress / deformation evaluation considering loads from global load-effect analyses as boundary conditions.
- Establishment of component strength in terms of maximum applicable external loads / deformations (e.g. moment, tension, internal/external pressure, bend radius, angular deformation etc.).
- Establishment of response surfaces expressing local component responses as a function of applied loads (e.g. fatigue evaluation by expressing hot-spot stress as function of applied bending moments and tension).
- Evaluation of SCF's to be applied in global fatigue analyses (e.g. SCF due to misalignment of adjacent riser joints) and fracture mechanical crack growth analyses.
- Evaluation of effects from impact loading (e.g. dropped objects on buoyancy cans, sub-sea arch arrangements etc.).

109 The effect of local non-linearities (e.g. weld defects) should be analysed through local FEA and deterministic or probabilistic fracture mechanical analyses of fatigue crack growth and unstable fracture. For assessments of defects subjected to plastic loads, a Level 3 analyses in accordance with BS7910 should be utilised.

D. Structural Reliability Analysis (SRA)

D 100

101 In-depth competence within the field of SRA is essential for qualification of new concepts and new materials with limited field experience, for reliability based design, code calibration, decision support, re-qualification, inspection and maintenance planning.

102 SRA is used in the development of calibrated Load and Resistance Factor Design format (LRFD), which is the preferred design format in DNV-OS-F201.

103 Structural Reliability Analysis allows for comparison of alternative designs. It can be directly used in design and operation of novel structural concepts, or may be used to calibrate partial safety factors in design equations. Key application areas of SRA are:

- Development of cost optimal design
- Development of novel designs in the absence of applicable empirical design rules and limited field experience
- Utilisation of novel materials with absence of applicable empirical documentation of properties
- Sophisticated design of critical components taking advantage of accurate modelling of the inherent uncertainties of relevant failure modes (limit states) and the corresponding resistance
- Development of designs with acceptable reliability
- Re-qualification by rational utilisation of additional information obtained during the installation phase or service life
- Inspection and maintenance planning for rational allocation of resources.

E. Special Analyses

E 100 Pipe-in-pipe analysis

101 Multi-pipe cross sections built up of 2-3 concentric metallic pipes are frequently applied. Spacers may be applied to maintain the required spacing between the pipes.

102 An equivalent beam model of the multi-pipe cross section should be applied in global load effect analyses.

103 The State-of-practice simplified approach of multi-pipe modelling in global load-effect analyses can be summarised as:

- The equivalent axial stiffness is found by summation of the axial stiffness of all tubulars. It is hence implicitly assumed that all tubulars undergo the same axial deformation.
- The equivalent bending stiffness is found by summation of the bending stiffness of the individual tubular of the cross section. In this model it is implicitly assumed that the multi-pipe cross section remains concentric during bending.

The corresponding principles for stress recovery from the global analyses using an equivalent beam model are:

- The resulting (true) axial force of the composite beam model is distributed to each tubular according to the axial stiffness in the individual tubular.

- The resulting bending moment of the composite beam model is distributed to each tubular according to the bending stiffness of the tubular. A multi-tube moment factor – MMF (typically 1.2) may be included on the inner tubular to account for possible pipe interaction effects.

104 Dedicated multi-pipe analyses may be applied for a more in-depth evaluation of the behaviour of pipe-in-pipe cross sections. Such analyses should be carried out by use of a State-of-the-art general purpose FE computer code allowing for detailed modelling of pipe interactions. The FE model should comprise detailed modelling of all tubulars and possible spacers for a representative riser section. Due regard shall be given to modelling of boundary conditions as well as possible individual pre-tensions of the pipes. The multi-pipe analyses are typically applied to:

- Calculation of equivalent stiffness properties to be applied in global load-effect analyses
- Stress recovery from global load-effect analyses
- Evaluation of pipe interaction effects (e.g. relative motions, MMF, local stresses at spacers etc.).

E 200 Pipe erosion analysis

201 Detailed erosion analysis, applying the DNV recommended practice DNV-RP-O501, ensures safe operation criteria's without imposing unnecessary restrictions to the flow rate. DNV-RP-O501 is based on years of experience with erosion testing and simulations. The standard accounts for a wide range of material grading, and is a world standard regarding safe design with respect to erosive wear. For complex geometrical details, erosion simulations may be performed utilising Computational Fluid Dynamics (CFD).

E 300 Heat transfer coefficients and heat loss

301 The temperature drop along the tubular will depend on the degree of insulation and multi-phase flow characteristics.

302 The effect of insulation is characterised by the over-all heat transfer coefficient.

303 For tubular with concentric insulation, the over-all heat transfer coefficient may be determined from standard textbook formulas.

304 For more complex geometries (e.g. multi-pipe cross sections) FE element analysis has to be performed in order to determine the over-all heat transfer coefficients.

305 For new insulation materials or new application of well known insulation materials, qualification is needed. Some main issues in a qualification process are:

- Thermal conductivity
- Effect of external pressure
- Long term properties
- Durability of joints/welds
- A combination of all of the above.

306 Most of these issues have to be done by testing. The DNV laboratories have the equipment and knowledge to carry out the needed testing in a qualification process of insulation materials.

E 400 Multi-phase flow characteristics

401 The multi-phase flow characteristics in the tubulars depend on the tubular dimension and geometry, the degree of insulation, environmental conditions, fluid characteristics, flow rate etc.

402 Analysis of the multi-phase flow characteristics in a piping system requires use of general multi-phase programme systems. The most general programmes systems have the capacity to perform both steady state and transient analysis.

403 The results from such analysis will give information of

pressure drop and temperature drop along the pipe/tubular. Further, also slugging characteristics will be obtained.

E 500 Slug flow analysis

501 Slug flow characterised by an alternating flow of liquid slugs and gas pockets, may cause significant dynamic loading on compliant deepwater riser systems.

502 Global load-effect analysis considering slug effects will generally require tailor-made software for FE riser analyses. A parameterised slug flow description is applied in terms of velocity, length and density of each slug as well as the time intervals between successive slugs. NLTD analyses shall be applied.

503 Reference is made to DNV-OS-F201 for further details.

F. Fatigue Assessment

F 100

101 Normally, the fatigue assessment methods based on SN-curves are used during metallic riser fatigue life evaluation.

102 The total fatigue damage using these methods, is found by accumulation of partial fatigue damage in a number of stationary environmental conditions representative for the long-term environmental climate. A conservative approach shall be applied to obtain the discrete representation of the long-term environmental climate.

103 All relevant cyclic load effects shall be considered in fatigue damage analyses. Fatigue stress calculations shall be based on adequate load-effect analyses in each short-term condition.

104 Applicable SN-curve and Stress Concentration Factor (SCF) shall be evaluated for the actual structural component of concern.

105 TD fatigue damage assessment should be based on a recognised cycle counting approach, typically 'Rain Flow Counting' – RFC.

106 Fatigue stress calculations should generally be based on NLTD global load effect analyses considering stochastic environmental excitations. Any use of simplified assessment of WF and LF fatigue damage (e.g. FD, LTD) should be verified by NLTD analyses considering RFC for fatigue damage accumulation.

107 Consistent assessment of fatigue damage due to WF, LF and Hull VIV will generally require coupled analyses.

108 Fatigue damage due to riser VIV should be assessed in separate dedicated analyses.

109 Fatigue assessment of components containing defects should be performed through fracture mechanical fatigue crack growth analyses.

110 Fatigue resistance of novel materials shall be established through testing.

111 Reference is made to DNV-OS-F201 for further details on fatigue analyses.

G. Drilling, Completion and Workover

G 100

101 In addition to the technical approach described in this section, the global load effect analysis should also consider the static and dynamic structural behaviour caused by the following operational and accidental loading conditions during drilling, completion and workover operations:

- Disconnect of Lower Marine Riser package (LMRP) (emergency or planned)
- Drive or drift off situations (dynamically positioned drilling and intervention units)
- Loss of anchor (moored drilling and intervention units)
- Hang-off modes for riser systems
- Completion and workover riser operations inside the drilling riser
- Effects of riser anti recoil systems
- Loss of riser tensioner or top tension system
- Compensator lock-up
- Specific Gravity of mud and completion fluids
- Running and retrieval of Blow-Out-Preventer, X-mas trees and Lower Riser Package (LRP) and LMRP.

102 The evaluation of the total fatigue damage described in Section F, shall include loads induced during relevant running and retrieval operations as well as hang-off modes.

H. Flexible Risers and Umbilicals

H 100 General

101 Flexible risers (flexible pipes) are either of the bonded type or the unbonded type. Both types consist of segments of a flexi-pipe body with end fittings attached to both ends. Common for both types is the fact that they are both multilayer constructions where each layer serves a special purpose.

102 The individual layers in a flexible riser are being applied one-by-one, starting with an inner layer and completed with a protective layer for an over-all protection of the riser. Unbonded pipes have no bonding effect between the various layers, whereas the bonded types are bonded together through the use of adhesives or by applying heat and or pressure to fuse the layers into a single construction. Unbonded pipes are by far the most preferred type of flexible risers.

103 An umbilical is normally understood to be a bundle of helically or sinusoidally wound small diameter chemical, hydraulic, and electrical conductors for power and control systems. The umbilicals may carry electrical services only, hydraulic or chemical functions only, or a combination of these. Other functions such as gas lift and optical fiber data communications may also be included.

H 200 Design Criteria – Flexible Risers

201 The design criteria for flexible pipes generally can be given in terms of the following design parameters:

- Strain (polymer sheath, unbonded pipe)
- Creep (internal pressure sheath, unbonded pipe)
- Strain (elastomer layers, bonded pipe)
- Stress/load (reinforcement layers and carcass, bonded pipe)
- Stress (metallic layers and end fittings)
- Hydrostatic collapse (buckling load)
- Mechanical collapse (armour layer induced stresses)
- Torsion
- Crushing collapse and ovalisation (during installation)
- Compression (axial and effective)
- Service life factors.

202 The criteria specified apply to the materials currently used in flexible riser applications. Where new materials are proposed or used, the design criteria for the new materials should give at least the safety level specified in the relevant standard, e.g. API Specification 17J (unbonded) or API Specification 17K (bonded). The design criteria should consider all material characteristics, such as susceptibility to creep, fatigue, excessive strain, cracking, aging etc.

H 300 Design Criteria – Umbilicals

301 The design criteria for control umbilicals are shown below:

- Strain (elastomer hoses)
- Strain (steel tubing)
- Stress and or load (reinforcement layers and carcass)
- Stress and or load (steel tubing)
- Stress and or load (end fitting)
- Hydrostatic collapse (buckling load)
- Mechanical collapse (carcass induced stresses)
- Crushing collapse and ovalisation (during installation)
- Compression (axial and effective)
- Service life factors.

302 The criteria specified apply to the materials currently used in subsea control-umbilical applications. Where new materials are proposed or used, the design criteria for the new materials should give at least the safety level specified in the relevant standard, e.g. API Specification 17E. The design criteria should consider all material characteristics, such as ageing, fatigue, excessive strain, etc.

H 400 Load cases

401 Both flexible risers and umbilicals are to be designed to satisfy its functional requirements under loading conditions corresponding to the internal environment, external environment, system requirements, and service life defined by the end-user.

402 All potential load cases for the pipe system, including manufacture, storage, transportation, testing, installation, operation, and accidental events are to be defined by the manufacturer in the design premise. The design premise should specify the load case matrix which defines all normal, abnormal, installation, and fatigue loading conditions according to requirements specified by the end-user.

H 500 Local cross section analysis

501 Because of the composite layer structure of flexible risers and umbilicals, local cross-section analysis is a complex subject, particularly for combined loads. Local analysis is required to relate global loadings to stresses and strains in the different layers of the riser / umbilical cross section. The calculated stresses and strains are then compared to the specified design criteria for the load cases identified in the project design premise.

502 The global load effects on flexible risers and umbilicals are established by the approach described previously in this section.

503 Different approaches exist for calculation of the riser and umbilical characteristics, and for calculating loads, stresses and strains in the individual layers or materials.

504 Simplified approaches: Simplified formulas are given in some handbooks for the calculation of the riser/umbilical characteristics and for calculating loads in the individual layers or materials. The simplified methodologies may be used for preliminary comparison of design loads with design criteria.

505 Numerical calculations: For detailed design, more refined analysis techniques that account for all relevant effects are required. Any program selected for use must be capable of modelling the riser and or umbilical appropriately (including axial, bending, and torsional effects where relevant) and verified as to its accuracy and dependability of results. The program needs to account for interaction and for load sharing between the different layers/components. There are a number of proprietary computer programs for flexible riser analysis, but the number of proprietary computer programs for umbilical analyses is limited.

506 Testing: Load effects in riser or umbilical wall sections may be documented by prototype testing. Under numerical

analysis, the analysis results may be validated by prototype testing. Due to the limited number of software, testing is the most important approach in the design of umbilicals. The DNV laboratories are well equipped for testing of flexible risers and umbilicals. The testing may have different purposes:

- Full scale testing of cross section including end termination to establish pipe characteristics and stresses and strains in the different layers or materials of the riser or umbilical
- Testing of components of the cross section (e.g. one armour wire, hose) to establish e.g. material characteristics, fatigue curves
- Full scale testing of flexible riser/umbilical in temporary phases (e.g. reeling installation).

507 The analysis of the pipe wall environment of a flexible riser is an important consideration, particularly for the determination of gas release requirements and metallic material failure modes. The flexible riser wall for either bonded or unbonded construction is the space occupied by the primary reinforcement elements. The following flexible riser wall environment characteristics should be considered for the design of the flexible pipe:

- Permeated gas and liquids
- External fluid ingress (seawater).

508 Flexible risers and umbilicals are complicated structures, particularly from a fatigue and wear point of view. There are several potential fatigue and wear mechanisms that may be critical. Therefore each application should be carefully evaluated. Fatigue calculations for flexible risers and umbilicals involve substantial uncertainties because of simplifications in the long-term load data and mathematical models, and complexities in the wear and fatigue processes.

I. Material Technology and Failure Investigation

I 100 Material selection

101 DNV has extensive experience within material technology gained through years of research and project experience.

102 The materials selected shall be suitable for the intended use during the entire service life.

103 Moving into deeper waters, the application of new materials in riser design becomes adequate. The most pronounced benefit of selecting other materials than steel (i.e. composites, titanium) is that the same structural capacity is obtained with reduced weight. The reduced weight gives more flexible concept solutions.

104 A joint industry project managed by DNV and with partners from the titanium industry, engineering companies and oil companies has resulted in a recommended practice on design of titanium risers (DNV-RP-F201).

105 Another joint industry project managed by DNV has resulted in a recommended practice on design of composite risers (DNV-RP-F202).

106 Experience feedback of component failures is also systematically recorded and used to avoid similar incidents in future designs. Experience from failure analyses and component testing is utilised in identification of failure modes for novel solutions.

I 200 DNV Laboratories

201 The laboratories of DNV are extensively equipped, and are internationally recognised for their reliability and high quality of work. The laboratories are cost-effective tools in the service of the international industry when needs are:

- Research and development
- Full-scale structural testing
- Testing of mechanical equipment
- Material qualification
- Corrosion control
- Trouble shooting and repairs
- Fitness for purpose verification
- Failure investigation
- Flow- and multiphase flow investigation.

202 The DNV work mode is to work together with the Client, and to tailor the involvement to the needs of the Client.

I 300 Testing

301 DNV has personnel, facilities and equipment for performing different types of testing and validation of risers and related components. Tests of global and local strength, fatigue capacity combined with assessment of material and corrosion can be undertaken. Damage detection (rupture, leakage, etc.) to identify failure modes may also be performed. Potential weak areas of flexible pipes are the terminations and end fittings and these should be verified and tested for real conditions.

I 400 Failure investigation

401 Well equipped metallurgical laboratories with special aim towards materials trouble shooting and service failure investigations are available at the DNV offices in Høvik and Bergen in Norway and in DNV Singapore.

402 The investigations cover a wide spectrum ranging from major breakdowns to failures or cracking of small individual components. Practically every field of technical activity is represented, with special attention to materials selection, corrosion, welding, etc.

403 The investigations normally include fracture analysis to detect the type and nature and the possible reason for a fracture. Metallographic examinations and hardness testing are performed to state the microstructure and heat treatment condition of the material. Evaluation of corrosion type and -pattern, and abnormal wear of components is also part of the activity. Fracture mechanical calculations are utilised to establish the load conditions at and prior to the time of failure.

I 500 Fracture mechanics

501 Materials testing is utilised to determine fracture toughness in terms of e.g. CTOD or J and crack growth parameters, and to determine the effect of these from applied environments. Analyses are typically performed for assessment of the effects of defects, optimization of inspection intervals, extended lifetime or fitness for service analyses and for determination of the probability of crack growth or unstable fracture.

502 Calculations may be performed using conventional deterministic or probabilistic methods.

I 600 Fitness for service

601 Fitness for service assessments are performed in order to document that a component or system meets the over-all requirements to reliability and probability of failure under conditions where one or more design requirement are not fulfilled.

602 The product in question may not meet the specified codes, standards and requirements, or the service conditions may differ from the specified design conditions. Typical conditions are: occurrence of defects or cracks, degradation of material properties, changes in environmental exposure, re-qualification after occurrence of accidental loads.

603 Fitness for service assessments may include all the following expertise:

- Metallurgical evaluation
- Corrosion and corrosion protection evaluations

- Materials testing
- Inspection, vibration measurements and metallurgical field examination
- Linear and non-linear finite elements analyses
- Probabilistic and / or deterministic fracture mechanics calculations.

J. Marine Operations

J 100 General

101 Marine operations shall be planned and prepared to bring an object from one defined safe condition to another according to safe and sound practice, and according to defined codes and standards.

102 Based on three decades of varied experience in complex marine operations, DNV has developed the "DNV Rules for Planning and Execution of Marine Operations", a world-wide recognised reference.

103 A joint industry project managed by DNV and with partners from oil companies, contractors and insurance companies has resulted in a recommended practice on Risk Management in Marine – and Subsea Operations (DNV-RP-H101).

J 200 Operational aspects and limiting criteria

201 An important aspect of marine operations is the limiting criterion under which the operation can take place. The limiting criterion for a marine operation is given as a weather window for a defined period of time (i.e. acceptable wave, wind and current).

202 For a marine operation with a reference period less than 72 hours, the start of the operation is conditional to an acceptable weather forecast. Installation of dynamic risers is usually carried out within this reference period.

203 For operations with a longer reference period, more sophisticated calculations and analyses are needed to find an acceptable weather window and start time of the operation. These calculations are based on statistical data of the environment at the actual site.

204 Examples of tasks carried out by DNV when verifying or calculating limiting environmental criteria are:

- Review of Operational procedures
- Calculations using formulas and methods given in the DNV Rules for Planning and Execution of Marine Operations
- Installation analyses (ref. J 400)
- Statistical analysis of the environment
- Advanced analysis using probability methodology (e.g. calculating the probability of waves exceeding the limit during an operation given the seastate at the start of a time-consuming operations).

205 DNV uses a combination of review and independent calculations and analyses to verify the limiting criteria and that the planned operation is in accordance with the DNV Rules for Planning and Execution of Marine Operations or any other applicable rules or requirements.

J 300 Surveillance

301 DNV can attend a marine operation to confirm acceptable environmental conditions for start and or commencement of a marine operation, performance according to accepted procedures and evaluate and accept necessary minor alterations or modifications to accepted procedure.

J 400 Installation analysis

401 The main purposes of installation analyses are:

- Documentation of integrity of the structure during all relevant phases of the installation operation
- Establishment of limiting criteria (e.g. waves, current, offset,) for the installation operations
- Documentation of residual capacity of in-place structure. (e.g. in-place fatigue capacity considering fatigue damage during installation, e.g. tow-out)
- Support evaluation of marine operations needed during the installation.

402 Examples of typical installation analysis scenarios are:

- Laying analyses of pipelines and SCR's
- Up-ending analyses (Spar's, Riser towers)
- Surface or sub-surface tow-out analyses of e.g. pipe bundles
- Lowering of sub-sea modules from installation vessels to final location on seafloor
- Detailed analyses of stress/strain/pipe ovality etc due to reeling pipe installation

- Riser transfer analysis (e.g. transfer of riser from installation vessel to permanent location)
- Pull-in analyses (e.g. I-tube/J-tube pull-in)
- Engineering Criticality Assessments for fracture mechanical calculation of critical weld defect sizes for all installation methods introducing 0.3% accumulated strain or more. To be performed in accordance with DNV-OS-F101.

403 Installation analyses may require use of several software packages such as: global load-effect analyses, analysis of complex marine operations, general purpose FE software - see Appendix B for detailed software specification.

J 500 Testing

501 For operations where experience is lacking, testing can be necessary to understand the effect from the operation on the riser or umbilical (e.g. reeling installation). The DNV laboratories can assist in planning and/or carry out various tests. The DNV laboratories are further described in Section J 200.

SECTION 3 SERVICE OVERVIEW

A. General

A 100 Objective

101 The objective of this section is to give an overview of the services related to riser systems offered by DNV.

102 The DNV activities are categorised into four main service groups:

- Technical Advisory Services
- Verification Services
- Certification Services
- Research and Development (R&D) Services.

103 Technical advisory services are often provided during early phase projects (e.g. qualification, testing, feasibility, design etc) or during the operational phase (e.g. inspection, monitoring, reassessment etc.).

104 Verification services are activities carried out to confirm that a given design fulfils the specified requirements during installation and operation.

105 Certification can be carried out on either parts of the riser system (i.e. components) or on the total riser system.

106 DNV finds R&D projects necessary to obtain up-to-date knowledge. DNV has therefore strong interests in carrying out or participating in R&D projects.

B. Technical advisory services

B 100 General

101 Technical advisory services are typically offered in early phase projects. DNV has been involved in many projects and gained wide experience with many different riser systems and configurations. Hence, DNV can contribute with expertise in several fields on several levels to assist in the concept evaluation process or the design process.

B 200 Feasibility studies

201 If a client has a riser design for which it would like someone to evaluate its feasibility, DNV can use its technical experience / expertise to give a valuable evaluation.

202 The main purpose of a feasibility study is to identify any technological “stoppers” for a concept and indicate the solution or solve these to the degree necessary to confirm the feasibility of the system.

203 The scope of work for typical feasibility studies covers technical review of the design basis, preliminary design (i.e. configuration, cross section, material) and analyses carried out. Independent global analyses can be included, and HAZID's during installation and operation phase are usually assessed.

204 The result from a feasibility study is usually a report / letter summarising the work carried out by DNV including advice for improvements of the specified design.

B 300 Qualification of new technology

301 DNV can through its multidiscipline competence engage in the technology assessment of new concepts.

302 A new concept can be a field development where the riser system is part of a more complete system or it can be a new riser system concept (e.g. configuration, application, material etc.).

303 For a new product or solution (new technology) it is important to have it qualified to ensure that customers are confident that it works functionally as well as safely. DNV can assist in developing qualification criteria and qualification program, perform laboratory testing and analyses as well as contribute to optimisation of the design.

304 New technology covers both proven technology in a new environment and unproven technology under known environmental conditions.

305 The DNV strategy for qualification is helping the Client to identify the optimal balance between use of experience, theoretical analyses and physical testing.

306 The DNV Recommended Practice (RP) for Qualification Procedures for New Technology (DNV-RP-A203) provides a systematic approach to the qualification of new technology, ensuring that the technology functions in a reliable way within specified limits. The RP specifies the philosophies, principles and methods to be used in the process to prove that the technology is fit for purpose.

307 Concept evaluation implies phases of repeated assessment of technological solutions and their required qualification scope. A concept qualification program would typically contain the following steps:

- Identify and define alternative concepts
- Evaluate the concepts with respect to Revenue, CAPEX and OPEX elements
- Identify relevant failure modes and effects of these (i.e. risk assessment)
- Identify improvement measures and assess effect of these measures (improvement of reliability, cost efficiency, sensitivity analysis)
- Define test programs and or measurement campaigns
- Testing of key components.

308 The result of a qualification scheme can be a statement and documentation of fitness for purpose.

309 The result from a qualification exercise can be used:

- as an acceptance for implementation of new technology
- for comparison between alternative technologies as input in the evaluation of the reliability of a larger system that the qualified new technology may be a part of.

B 400 Risk Assessment

401 It is often required that a systematic review is performed in order to identify critical scenarios and evaluate the consequence of single failure or series of failures of riser systems such that remedial measures can be taken.

402 A methodology for such a systematic review to assess the overall risk to human health and safety, environment and assets, is Quantitative Risk Analysis (QRA) comprising:

- Hazard identification (HAZID / HAZOP) or Failure Mode and Effect Analysis (FMEA) to evaluate the possible causes and consequences of hazardous events
- Assessment of failure probabilities
- Accident developments
- Consequence and risk assessment.

403 DNV has extensive experience in work with offshore safety and applied risk analysis within:

- Assessment of acceptance criteria
- Qualification schemes

- Evaluation of riser accidents and critical scenarios in conjunction with the total risk picture of the installation
- Concepts and design evaluations
- Cost-benefit analysis
- Operational considerations
- Definition of risk reducing measures / recommendations in close cooperation with the client.

B 500 Technical risk assessment

501 Technical risk assessment is a subset of general risk analysis to identify and rank the failure modes based on their risks as a function of both probability of failure and consequence of failure.

502 For new designs, DNV has multidisciplinary competence in defining and assessing the prevailing failure modes for the actual riser system or component based on previous experience, fundamental physical understanding and sound engineering judgement.

503 The probability of failure of a component (or system) may be based on failure statistics or calculated by structural reliability analysis using physical understanding and mathematically formulation of the failure mode and associated uncertainties.

B 600 Design Assistance

601 DNV can assist in specific issues during the design process of a riser system to obtain an optimal design. Examples of DNV's special competences which will be added value for a designer are:

- advanced analyses (e.g. coupled analyses, structural reliability analyses, riser collision)
- detailed component FE analyses
- material evaluation and testing
- technical risk assessment
- expertise on fatigue
- verification of functional requirements (i.e. design, manufacture, installation, operation and abandonment)
- identification and interpretation of formal requirements
- assist in the development of a qualification strategy
- evaluation of design conditions (e.g. ALS)
- develop acceptance criteria
- contribute to optimisation of the design
- develop/review test program
- execute testing in DNV's laboratories
- interpretation of test results and reporting.

B 700 Reassessment

701 Sometimes products do not comply with the specification, code or standard. The component may also have suffered sustained damage, exceeded its service life, or subjected to altered service conditions. A fitness-for-service assessment can help to establish whether the component can still be safely operated or used depending on factors such as its residual strength, occurrence of defects, material degradation and operating conditions. Probabilistic analyses are used as a tool to document the over-all safety level.

702 DNV also looks at installations which have been in service for some time to assess whether the operational conditions could be changed or whether the lifetime of the facility can be extended. This work includes site inspection and measurements, laboratory testing and technical calculations.

703 For lifetime extension, SRA can be used for documenting that the reliability is acceptable.

B 800 Marine Operation Service

801 DNV offer services and support to clients as third party marine advisor in combination or as an alternative to a marine verification scope. The practical experience, the insight with the Rules, combined with the close interface to other DNV

competencies is used as a solid and independent basis to provide advice and support for critical project decisions.

802 Typical Marine Advisory scope includes:

- independent feasibility assessments and studies
- assessment and input to principles of methods and design
- review and assistance in preparation of project specifications
- technical support during tender evaluations
- environmental studies and definition of design conditions
- independent analysis
- vessel surveys (suitability, condition and on-, off hire surveys)
- direct support to project organisations
- Risk Management and Evaluations.

803 When a company has obtained an insurance cover for a marine operation, a DNV Warranty Surveyor can be engaged. The purpose of the Warranty Survey is to ensure that the marine operation is performed within defined risk level and that the terms of the warranty as laid down in the Insurance Policy are complied with.

804 A DNV Warranty Surveyor applies the DNV Rules for Planning and Execution of Marine Operations.

C. Verification Services

C 100 General

101 Verification is the activity carried out to confirm that the riser system satisfies the requirements for the specific location and method of installation and operation, taking into consideration the design, including material selection and corrosion protection, and the analysis methods used.

102 DNV recommends an involvement in the verification activities at an early stage in a project to avoid large impact on cost and/or schedule if errors or failures are uncovered.

103 Review of design, installation or fabrication documentation is based on the assumption of documents for approval being submitted in conclusive self-contained packages per subject/area. DNV allows for one review cycle if not otherwise agreed with the Client, i.e. initial review, issue of comments and review of next revision to confirm incorporation of comments. Possible additional work will be subjected to mutual agreement between DNV and the Client.

C 200 Purpose of Verification

201 Verification constitutes a systematic and independent examination of the various phases in the life of a riser system to determine whether it has (or continues to have) sufficient integrity for its purpose.

202 Verification activities are expected to identify errors or failures in the work associated with the riser system and to contribute to reducing the risks to the operation of the riser system and to the health and safety of personnel associated with it or in its vicinity.

203 Verification is primarily focused on integrity and (human) safety, but business risk (cost and schedule) may also be addressed.

C 300 Verification as a complementary activity

301 Verification shall be complementary to routine design, construction and operations activities *and not a substitute for them*. Verification will take into account the work, and the assurance of that work, carried out by the Owner and its contractors.

302 Verification shall be developed and implemented in such a way as to minimise additional work, and cost, but to

maximise its effectiveness. This development of verification shall depend on the findings from the examination of quality management systems, the examination of documents and the examination of production activities.

C 400 Verification management

401 To ensure satisfactory completion of verification the verification methods used will be described.

402 These methods will ensure that the verification process:

- has a consistent and constructive approach to the satisfactory completion and operation of the riser system
- is available world-wide wherever the Owner or his contractors operate
- is employing up-to-date methods, tools and procedures (if required)
- is employing qualified and experienced personnel.

403 All verification activities will be carried out by competent personnel. Competence includes having the necessary theoretical and practical knowledge and experience of the activity being examined. An adequate verification of some activities may require access to specialised technical knowledge.

404 As well as demonstrating competence of individuals, the verification organisation also will be able to show competence and experience in riser verification work.

C 500 Risk Differentiated Levels of Verification

501 The level of verification activity is differentiated according to the inherent risk to the riser and platform or floater. If the risk (i.e. failure consequence) to the riser is higher, the level of verification involvement is higher. Conversely, if the risk to the riser is lower, the level of verification activities can be reduced, without any reduction in their effectiveness.

502 It is emphasised that the activity level describes the depth of the verification involvement. It follows, therefore, that an increase in the level of involvement above that considered necessary, based on an evaluation of the risks, involves minimal extra risk reduction for increased cost. This practice is unlikely to be cost-effective.

503 Verification of riser systems is categorised into *Low*, *Medium* and *High*. This categorisation is based on the same principles as used in DNV-OSS-301, Certification and Verification of Pipelines. A summary of the levels of involvement is given in Table C1.

Medium is the customary level of verification activity and is applied to the majority of risers.

High is the level of verification applied where the risks to the

riser are higher because, for example, it is in unknown environmental conditions, it is technically innovative or the contractors are not well experienced in the design and construction of similar risers.

Low is the level of verification applied where the risks to the riser are lower because, for example, it is located in benign and well known environmental conditions, or the contractors are well experienced in the design and construction of similar risers.

504 It is the privilege of the Owner of the riser system to choose the level of verification. The selection should consider the factors given in Sec.C200 to C500.

505 Different levels of verification can be chosen for different phases of the riser system, or even within the same phase if necessary. For example, riser design may be innovative and considered high risk whereas the installation method is well known and considered low risk. The converse might be true also.

506 Different levels of verification can also be chosen for different components of a riser system. For example, a component may be innovative and considered high risk whereas the riser pipe and other components are standard joints and considered low risk.

507 The level of verification can be reduced or increased during a phase if the originally chosen level is considered too rigorous or too lenient, as new information on the risks to the riser system becomes available.

508 Verification should be planned in close co-operation with the Owner and each of its contractors, to provide a scope of work that is tailor-made to the schedule of each production process activity, i.e. to make the verification activities, monitoring and witness points, an integrated activity and not a delaying activity.

509 Verification will direct greatest effort at those elements of the riser system whose failure or reduced performance will have the most significant impact on safety as well as project risk.

C 600 Selection of Level of Verification

601 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 riser system. This is illustrated by Figure 1 overleaf.

602 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.

Table C1 Levels of Verification - Summary of Involvement

Level	Description of involvement	Guidance for application on the level of involvement
Low	Review of General Principles and production systems during design and construction. Review of principal design documents, construction procedures and qualification (e.g. MPQT) reports.	Proven riser designs installed in well known environmental conditions Straightforward risers designed, manufactured and installed by experienced contractors Low consequences of failure from a commercial, safety or environmental point of view. Relaxed to normal completion schedule
Medium	Review of General Principles and production systems during design and construction. Detailed review of principal and other selected design document with support of simplified independent analyses.	Projects with a moderate degree of novelty Medium consequences of failure from a commercial, safety or environmental point of view. Ordinary completion schedule
High	Review of General Principles and production systems during design and construction. Detailed review of most design document with support of simplified and advanced independent analyses.	Riser designs in un-known environmental conditions Projects with a high degree of novelty or leaps in technology Inexperienced contractors or exceptionally tight completion schedule Very high consequences of failure from a commercial, safety or environmental point of view.

603 Experienced DNV surveyors are available to follow up and witness the manufacturing and testing of riser components.

The objective is to assure that the testing/manufacturing is performed in accordance with specified procedures and require-

ments.

604 Site attendance/fabrication follow-up may be included in verification and is mandatory in certification. The DNV attendance will vary for the different involvement levels low, medium and high.

605 Selection factors for the level of verification are the:

- *overall safety objectives for the riser system.*
An overall safety objective covering all phases of the riser system from design to operation should be defined by the Owner. The safety objective should address the main safety goals as well as establishing acceptance criteria for the level of risk acceptable to the Owner.
- *assessment of the risks associated with the riser and the measures taken to reduce these risks.*
A systematic review should be carried out to identify and evaluate the probabilities and consequences of failures in the riser system. The extent of the review shall reflect the criticality of the riser system, the planned operation and previous experience with similar riser systems. The result of the systematic review of the risks (e.g. QRA, FMEA, HAZOP) is measured against the safety objectives and used in the selection of the appropriate verification activity level.
- *degree of technical innovation in the riser system.*
The degree of technical innovation in the riser system shall be considered. Risks to the riser are likely to be greater for a riser with a high degree of technical innovation than with a riser designed, manufactured and installed to well-known criteria in well-known waters.
- *experience of the contractors carrying out similar work.*
The degree of risk to the riser system should be considered where contractors are inexperienced or the work schedule is tight.
- *quality management systems of the Owner and its contractors.*
Adequate quality management systems shall be implemented to ensure that gross errors in the work for riser system design, construction and operations are limited.

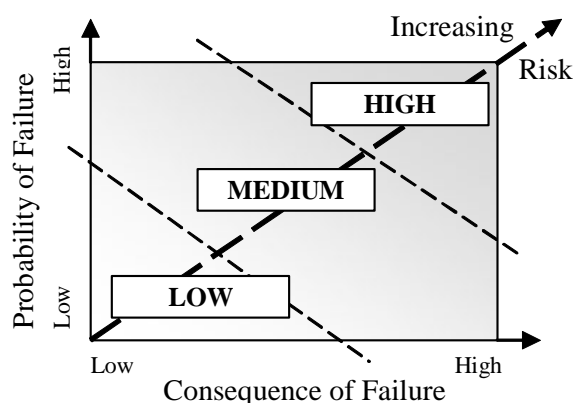


Figure 1
Selection of the Required Level of Verification

C 700 Verification during design

701 Design verification is the examination of the assumptions, methods and results of the design process and is performed to ensure that the specified requirements of the riser system will be achieved.

702 Scope of work for verification of design based on mutual agreement between DNV and Client may include the tasks as given in:

- Table C2 for the Review part
- Table C3 for Independent Analyses

- Table C4 for design checks of metallic risers
- Table C5 for design checks of flexible risers
- Table C6 for design checks of umbilicals.

703 The scope is described for each of the involvement levels low(L), medium(M) and high(H), ref. Table C1.

Guidance note:

Low, medium and high used in this Specification (OSS) shall not be confused with the safety classes low, medium and high used in DNV-OS-F201.

Table C2 Scope of Work for verification of design – Review			
Verification activity	Level		
	L	M	H
<i>Review of specifications for design by</i>			
— Review of design basis (i.e. evaluation of design criteria, environmental data, riser system and interfaces, analysis methods and load cases)	X	X	X
<i>Review of design reports and drawings by</i>			
Review of main documentation to ensure that	X	X	X
— The selected design philosophies are in accordance with specified codes and standards			
— Main load conditions are accounted for			
— Governing conditions are identified			
— Adequate computer software used (tested and documented)			
— Drawings are in accordance with calculations and specifications			
— Corrosion-, wear- and erosion protection measures are adequate			
— Proper materials selected			
— Flow assurance is acceptable			
— Evaluation of main methods used (in accordance with specification?)	X	X	X
— Spot checks of the input data and the calculation results (i.e. riser joints and components)		X	X
— Detailed Review of main design reports and drawings			X

Table C3 Scope of Work for verification of design – Independent Analysis			
Verification activity	Level		
	L	M	H
Simplified global load effect analysis (e.g. frequency domain, time domain with regular waves)		X	X
Advanced global load effect analysis (e.g. non-linear time domain with irregular waves, sensitivity studies)			X
Coupled analysis (if appropriate)		X	X
Eigenvalue analysis		X	X
Simplified fatigue analysis, several fatigue conditions are run for spot checking (frequency or time domain)		X	X
Advanced fatigue analysis, significant number of fatigue conditions are run for calculation of total fatigue damage due to float-er motions and riser dynamics (time domain)			X
VIV analysis (fatigue and interaction) (if appropriate)			X
Simplified Interference analysis (if appropriate)		X	X
Advanced Interference and collision analysis (if appropriate)			X
Installation analysis			X

Special analysis (e.g. pipe in pipe analysis, slug flow, thermal expansion)			X
Soil-riser interaction (if appropriate)			X
Flow assurance analysis/calculations			X
Detailed analysis (FEA) of riser components of significance to the overall safety (e.g. flex-joint, bend stiffener, stress joints, sub-sea arch, spool piece, tensioner system, terminations/fittings etc.)			X

Table C4 Scope of Work for verification of design – Design Checks, metallic risers

Verification activity	Level		
	L	M	H
<i>Serviceability Limit State (SLS)</i>			
— ovalisation		X	X
— riser stroke (if applicable)		X	X
— clearance (if applicable)		X	X
<i>Ultimate Limit State (ULS)</i>			
— deflections within allowable limits		X	X
— Combined loading criteria due to bending moment, axial force and pressure		X	X
— Bursting (internal overpressure)		X	X
— system hoop buckling / collapse (external overpressure)		X	X
— propagating buckling		X	X
— overall column buckling (i.e. no negative effective tension)		X	X
<i>Fatigue Limit State (FLS)</i>			
— calculation of partial fatigue damage due to floater motion for a few fatigue sea states (simplified analysis)		X	X
— evaluation of selected SN-curves, thickness correction factors and SCFs		X	X
— calculation of riser fatigue life due to floater motion and riser dynamics (based on SN-curves, advanced analysis, rain-flow counting)			X
— calculation of riser fatigue damage from temporary phases (e.g. transportation, towing, installation) (if appropriate)			X
— calculation of riser fatigue damage due to VIV (if appropriate)			X
— fatigue assessment using crack propagation calculations (if appropriate)			X
<i>Accidental Limit State (ALS)</i>			
— Resistance against direct accidental load			X
— Ultimate resistance and consequence assessment due to exceeding of a SLS			X
— Post-accidental resistance against environmental loads			X

Table C5 Scope of Work for verification of design – Design Checks, flexible risers

Verification activity (ref. API Spec.17J)	Level		
	L	M	H
<i>Functional Requirements</i>			
— Internal Fluid Parameters		X	X
— System Requirements		X	X
<i>Design Requirements</i>			
— Loads and Load Effects		X	X
— Pipe Design Methodology		X	X
— Pipe Structure Design		X	X
— System Design Requirements		X	X
<i>Pipe Layer Design Check</i>			

— Creep in internal pressure sheath, reduction in wall thickness due to creep in the supporting structural layer		X	X
— Bending Strain in internal pressure sheath		X	X
— Stress buckling in internal carcass		X	X
— Stress buckling in carcass/pressure armour		X	X
— Stress in tensile armours		X	X
— Stress in pressure armours		X	X
— Bending Strain in outer sheath		X	X
<i>Composite cross section design check</i>			
— Collapse of carcass/pressure armour due to external forces		X	X
— Burst due to internal pressure		X	X
— Tensile/compressive/torsional failure		X	X
— Minimum bending radius		X	X
— Fatigue of armour layers (dynamic)		X	X
— Erosion and corrosion evaluation of steel components			X
— Capacity of terminations/-end fittings			X
<i>Materials</i>			
— Material Requirements		X	X
— Qualification Requirements			X
— Quality Assurance Requirements			X
<i>Documentation</i>			X

Table C6 Scope of Work for verification of design – Design Checks, Umbilicals

Verification activity (ref. ISO 13628-5)	Level		
	L	M	H
<i>Functional Requirements</i>			
— Umbilical		X	X
— End Terminations and Ancillary Equipment		X	X
<i>Design Requirements</i>			
— Loads and Load Effects		X	X
— Design Methodology		X	X
— Analysis		X	X
<i>Component Design</i>			
— Electric cable		X	X
— Optical Fibre Cable		X	X
— Hoses		X	X
— Metallic Tubes		X	X
<i>Terminations and Ancillary Equipment Design</i>		X	X

C 800 Verification during construction

801 Verification during construction is carried out by means of attendance, audits, inspection or spot checks of the work, as appropriate, in sufficient detail to ensure that the specified requirements of the riser system will be achieved.

802 Scope of work for verification of manufacture and fabrication specifications / procedures can include the tasks as given in Table C6 for each of the involvement levels low (L), medium (M) and high (H).

Table C7 Scope of Work for verification of manufacture and fabrication

Verification activity	Level		
	L	M	H
<i>Review of manufacture/fabrication specifications by:</i>			
— Review of Manufacturing Procedure Specification (MPS)	X	X	X

— Are manufacture/fabrication specifications in accordance with public regulations/provisions and safety requirements?	X	X	X
— Review of material and welding procedure specifications	X	X	X
— Review of qualification records (if relevant)	X	X	X
— Review of quality plans and manufacturer's quality system manual		X	X
<i>Review of manufacture / fabrication procedures:</i>			
— Are work instructions and procedures satisfactory?	X	X	X
— Review of Non Destructive Test (NDT) procedures		X	X
— Are personnel qualified?		X	X
— Are methods and equipment with regard to control of dimensions and quality of riser pipe, components and materials satisfactory?		X	X
— Are dimensions in accordance with the basic assumptions made during design?	X	X	X
— Adequate deviations procedures?		X	X
— Adequate transportation and storage of materials and fabricated assemblies?		X	X
<i>Surveillance during fabrication by</i>			
— Visit-based attendance during testing, to ensure, based on spot checks, that the delivered products have been produced in accordance with the manufacturing specification		X	X
— Visit-based attendance during manufacturing and fabrication to ensure, based on spot checks, that the delivered products have been produced in accordance with the manufacturing specification			X

C 900 Verification during installation

901 Scope of work for verification of the installation of a riser system can include the tasks as given in Table C2 for each of the involvement levels low (L), medium (M) and high (H).

Table C8 Scope of Work for verification of installation			
Verification activity	Level		
	L	M	H
<i>Review of installation procedures by:</i>			
— Review of the operational plans and procedures (e.g. handling, running, operation, emergency disconnect, hang-off)	X	X	X
— Review of Failure Mode Effect (and criticality) Analysis (FME(C)A) and HAZOP studies carried out	X	X	X
— Review of installation and testing specifications and drawings	X	X	X
— Review of riser installation manuals	X	X	X
— Review of contingency procedures	X	X	X
— Review of operational criteria from analyses carried out	X	X	X
— Review of analyses and strength calculations	X	X	X
— Review of equipment certificates	X	X	X
— Review of personnel qualifications	X	X	X
— Review of contractor Quality system manual	X	X	X
<i>Independent analyses</i>			

— Installation analysis		X	X
<i>Surveillance before installation activities by:</i>			
— attendance during important testing		X	X
— perform inspections of essential equipment and structural elements		X	X
<i>Surveillance during installation activities by:</i>			
— Visit-based attendance during start up or first of several equal operations		X	X
— Full time attendance during the off-shore operation			X

C 1000 Verification documents issued

1001 The level of reporting is dependent on the tasks carried out in the verification project. One or a combination of the below listed type of reports can be issued as documentation of the verification service carried out.

1002 Technical Report: A technical report will typically give a description of the independent work carried out during the verification process. The report will include description of models used, assumptions/simplifications, methodology, results obtained and comments.

1003 Design Verification Report (DVR): Verification reports are issued to confirm that the relevant product or service has been completed in accordance with specified requirements. The DVR will always be dated and have two signatures, the originator and the DNV project sponsor. The DNV internal verifier will also be named. The report will include information such as:

- Product description
- Application (operational limitations and conditions of use) for which the product or service is intended
- Codes and standards with which the product or service has been verified against
- Clear statement of the conclusion from the verification (does it or does it not meet the specified requirements)
- Codes and standards used as reference
- Documentation on which the verification report is based (documents, drawings, correspondence, including revision numbers)
- Any comments
- Identification of any non-conformances

An example of a typical DVR is shown in Appendix A.

1004 Verification Comment Sheets (VerCom): Review of documents can be reported using Verification Comment Sheets. These documents give details to the client of aspects of riser design and construction that DNV:

- Considers do not meet the specified requirements
- Does not have enough information to make a decision
- Offers advice based on its own experience.

Only in the first two instances does DNV expect a response from the owner or its contractors. A typical Verification Comment sheet is shown in Appendix A.

1005 Visit Report: If visit or attendance during manufacturing or fabrication is part of the verification, DNV will issue a report to document the witnessing (e.g. purpose of visit, status, comments).

1006 Marine Operation Declaration: When the marine operational procedures comply with the Marine Operation Rules, DNV can issue a Marine Operation Declaration. In order to issue a Marine Operation Declaration for a complex or particularly sensitive operations, attendance of DNV surveyor will normally be required.

D. Certification services

D 100 Introduction

101 Certification describes the totality of verification activities leading up to the issue of a DNV Certificate.

Guidance note:

The essential difference between the terms Certification and Verification is that Certification is used only where DNV's scope covers the integrity of the entire riser system and may then result in the issue of a DNV certificate.

Verification is used where DNV's scope applies to the verification of only a single (or more) phase of the project. Verification results in the issue of a DNV Design Verification Report, or alternatively, Verification Comment Sheets (VerCom).

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102 For the certification services for risers, DNV distinguish between:

- Classification related Certification
- Non-class related Certification.

D 200 Classification related Certification

201 A production riser system that shall be installed and operated from a floating production unit or a marine riser from an offshore drilling unit will require a product certificate if the vessel is given the special facility class notations **PROD** or **DRILL**.

202 The principles and methodology described for the verification service, ref. Section 3 Chapter C, apply also to the certification.

Guidance note:

To obtain a certificate, all phases need to be verified with the scope of work as described for the different involvement levels low, medium and high, i.e. design, fabrication/manufacture and installation.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

203 A complete description of applicable class notations and technical basis for offshore classification is given by the offshore service specifications, see Table D1.

Table D1 Offshore Service Specifications	
No.	Title
DNV-OSS-101	Rules for Classification of Drilling and Support Units
DNV-OSS-102	Rules for Classification of Floating Production and Storage Units

204 Classification procedures and requirements specifically applicable in relation to the technical provisions for Dynamic Riser Systems are given in Chapter 3 in the standards:

- Offshore Standard DNV-OS-E101 Drilling Plant
- Offshore Standard DNV-OS-E201 Hydrocarbon Production Plant.

D 300 Non-Class related Certification

301 Type Approval is defined as Approval of conformity with specified requirements on the basis of systematic examination of one or more specimens of a product representative of the production.

Guidance note:

The definition is based on ISO / IEC Guide 2 (1991)

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

302 The objective of Type Approval is to certify that the design of a product type or group of products (system) is in con-

formity with defined technical specifications.

303 The policy of Det Norske Veritas towards achieving the above objective is to operate the service with the following features:

- Availability world-wide
- Use of up-to-date methods and recognised rules, standards and codes
- Use of qualified and experienced specialists
- Efficient co-ordination and updating of the Type Approval Scheme.

304 The scope of the Type Approval is to assess that a specific material, design of a product type or system are in conformity with defined technical specifications. Type Approval can be applied to a wide range of materials, products and systems. Type Approval may be a self-contained and independent service or an element in a Product Certification.

305 If the Type Approval process is successful a Type Approval Certificate is issued.

306 Det Norske Veritas reserves the right to decide for which product types the Type Approval scheme may be applied.

307 The technical specifications used as basis for the assessment are normally part of Det Norske Veritas' Rules for Classification and other parts of Det Norske Veritas Rules including those Regulations, Codes, Standards, etc. accepted within the framework of these Rules, on the basis of which Det Norske Veritas is authorised to grant approvals.

308 Common to all these specifications are their ability to secure fitness for the intended application on board ships rigs, which has been evaluated by Det Norske Veritas and found to be satisfactory.

309 A Product Certificate states that the *manufactured products* are in conformity with specified requirements and the Type Approval 1 Type Examination granted. A Product Certificate is issued for each manufactured product or product batch and is stating conformity with specified requirements at the time of issue. Each product unit must be possible to identify and trace back to the certificate by means of the product marking. (Serial No., Batch No., etc.).

310 The Type Approval scheme consists of the following three elements:

- Assessment of Conformity of Design to verify that the design of the product conforms to specified requirements
- Type Testing to verify that the characteristic of a material, product or system has the ability to meet specified test requirements
- Certificate Retention Survey to verify that the conditions stated when the certificate was issued are complied with at any time during the validity period of the certificate.

311 Type Testing may be waived for certain products that cannot be subjected to a realistic test.

312 In addition to the analytical capabilities of DNV, experienced surveyors are available to follow up and witness the manufacturing and testing of riser components as required in a certification process. The objective is to assure that the manufacturing is performed in accordance with specified procedures and requirements.

313 Type Approval of a system is issued for the system design. The Type Approval Certificate (for the system) is based on the Type Approval of important components or materials being an integral part of the system, i.e. a system may comprise a varying number of Type Approval Certificates.

314 Detailed information on the Type Approval process may be found in Certification Note 1.2 Type Approval.

E. Research and Development (R&D) Services

E 100 General

101 DNV's objective is to have a highly technically skilled staff to make the work interesting and to serve the clients in a best way.

102 One way to obtain this is to be actively involved in R&D projects. In addition to internally financed R&D projects, DNV has been and is actively involved in many Joint Industry Projects.

103 In addition to increased experience and knowledge, some main results from JIPs carried out are development of standards, recommended practices, guidelines and software.

E 200 Development of Rules, Guidelines and Specifications

201 DNV has a long tradition in development of Rules and guidelines. The work with the new Offshore Codes started in 1999. Many of the offshore standards and recommended practices are results of JIPs, and the main codes directly applicable for risers are:

- DNV-OS-F201 Dynamic Risers
- DNV-RP-F201 Titanium Risers
- DNV-RP-F202 Composite Risers

- DNV-RP-F203 Riser collision (drafting in progress, planned issued 2004)
- DNV-RP-F204 Riser fatigue (drafting in progress, planned issued 2004)
- DNV-RP-F205 Coupled Analysis (drafting in progress, planned issued 2004).

E 300 Development of Software

301 DNV use technical analyses as a mean to predict and understand behaviour and assumption, and as an active design tool. Significant resources are invested together with the industry to develop software. Own developed as well as externally developed software are used actively to assist our Clients in finding cost effective solutions to existing and coming challenges.

302 DeepC for mooring, riser and floater coupled analysis is the result from the JIP Deeper. The development is carried out in close co-operation between Marintek, DNV software and the analysis team in DNV. This gives the analysis team an active role in the prioritising of new functionality. This again gives DNV a unique position and flexibility to solve the demanding and complicated problems the Clients need solutions to moving into deeper waters.

303 A self-standing computer program for capacity checks according to DNV-OS-F201 will be commercially available in 2003. Link to any global analysis software is provided by a simple, well defined file interface.

APPENDIX A

EXAMPLES OF DOCUMENTS

A. Introduction

A 100 General

101 This appendix includes example forms for use by DNV in the verification and certification of riser systems.

102 The following forms are included:

- Verification Comment Sheet (A 200)
- Design Verification Report (A 300)
- Product Certificate (A 400)
- Type Approval Certificate (A 500).

A 200 Verification Comment Sheet

Project Title:				DNV Project No.:
Document title:	Prepared by:	Date:	Sign:	Document No.:
	Verified by:	Date:	Sign:	Revision:
Have all previous comment to this document been satisfactory solved or repeated below? ...				
VERIFICATION COMMENTS:				
VerCom. No.:	Description:	Category ¹	Status ²	
	<i>Section ?</i> <i>DNV recommends ..</i>	TQ	O	
		TQ	O	
		A	C	
		A	C	

¹ NC = Non-Conformance TQ = Technical Query A = Advice (reply not needed)

² O = Open C = Closed (requires a reference)

A 300 Design Verification Report (DVR)

DESIGN VERIFICATION REPORT

(Independent Review Certificate)

MANUFACTURER : Drill Company, ,
SALES ORDER NO. :

INSTALLATION : Platform
ID NO. : 73000000
ARCHIVE NO. :

REGULATORY BODY : DNV

This is to certify that the design of:

Drilling Riser

has been reviewed and found to comply with:

[1] DNV Offshore Codes

The following design codes/standards were used as references:

—

The verification is related to the following operational limitations:

- Maximum Working Pressure : 1034 bar (15000 psi)
- Minimum Design Temperature : -29 °C (-20 °F)
- Maximum Design Temperature : 107 °C (225 °F)
- Maximum “As-built” Weight : 6.8 T 150000 lb.
- Service : Standard/ Sour/ H₂S

—

—

The verification is based on the following documentation:

A. Design Specifications

<u>Doc. No.</u>	<u>Rev.</u>	<u>Date</u>	<u>Title</u>
-----------------	-------------	-------------	--------------

<u>Drwg. No.</u>	<u>Rev.</u>	<u>Title</u>
------------------	-------------	--------------

B. Correspondences

– None

C. Fabrication Procedures

Test Procedures:

1.

NDE Procedures:

2.

Welding Procedures:

3.

D. Comments

1.

E. Conditions

1.

Høvik, 28 February 2002

for DET NORSKE VERITAS AS

XX
Head of Section

YY
Project Engineer

Verified by: ZZ

Distribution:

Orig: Drill Company, att.: Client[Fax:]

CC: DVR Log,

A 400 Product Certificate

DET NORSKE VERITAS

Certificate No.:



PRODUCT CERTIFICATE

THIS IS TO CERTIFY THAT:

Product description:

Type designation:

Serial No:

Marking:

Manufactured by:
(manufacturer and location)

Ordered by (customer):

Customer reference:

Intended for:

Conforms with the following specification/standard:
(if necessary use Appendix to certificates form no. 40.91a)

Remarks/test results:

☐ If marked x, see encl.

For **Det Norske Veritas AS**

Place

Date

Surveyor

Declaration by manufacturer (when applicable)

The undersigned manufacturer declares that the specified product has been built and tested in conformity with the specification/standard stated above and the conditions referred to in:

Type Approval Certificate No.:

Quality System Certificate No.:

Manufacturing Survey Arrangement No.:

This Product Certificate is valid only when endorsed by a DNV Surveyor. The endorsement is a statement that the conditions stipulated in the Manufacturing Survey Arrangement for the product in question have been complied with.

Manufacturer:

Place

Date

Name

If any person suffers loss or damage which is proved to have been caused by any negligent act or omission of Det Norske Veritas, then Det Norske Veritas shall pay compensation to such person for his proved direct loss or damage. However, the compensation shall not exceed an amount equal to ten times the fee charged for the service in question, provided that the maximum compensation shall never exceed USD 2 million. In this provision "Det Norske Veritas" shall mean the Foundation Det Norske Veritas as well as all its subsidiaries, directors, officers, employees, agents and any other acting on behalf of Det Norske Veritas.

A 500 Type Approval Certificate

DET NORSKE VERITAS
TYPE APPROVAL CERTIFICATE

CERTIFICATE NO.

This Certificate consists of x page

This is to certify that

with type designation(s)

Manufactured by

is found to comply with

Application

Max Working Pressure:

Min Design Temperature:

Max Design Temperature:

Max Allowable Tension:

Min Bending Radius:

Depth rating:

Place and date

Høvik, 20yy-mm-dd
for DET NORSKE VERITAS AS

This Certificate is valid until

20yy-mm-dd

Discipline Manager

Local Office

Surveyor

Reference Standards

-

Product Description

Application/Limitation

- Maximum Working Pressure
- Minimum Design Temperature
- Maximum Design Temperature
- Maximum Allowable Tension
- Minimum Bending Radius
- Depth rating
- Weight in air full of fluid

Type Approval documentation

<u>Doc. No.</u>	<u>Rev.</u>	<u>Date</u>	<u>Title</u>
-----------------	-------------	-------------	--------------

<u>Drwg. No.</u>	<u>Rev.</u>	<u>Title</u>
------------------	-------------	--------------

Tests Carried Out

-

Marking of Product

1.

Documents, signboards etc. which are to accompany each product/delivery:

-

Production Survey Arrangement

-

Other Conditions/Comments

-

END OF CERTIFICATE

APPENDIX B APPLICABLE SOFTWARE

A. General

A 100 General

101 This appendix gives an overview of the software used by DNV on different riser analyses.

A 200 Floater motions and or station keeping

201 To establish floater motions used as boundary conditions in global riser analyses, DNV uses the following software:

- **Sesam Program Package** (Prefem, Preframe, Wadam/Wamit)
- **Simo**: Simulation of complex marine operations and global performance of floating structures
- **MIMOSA**: Stationkeeping analysis of moored offshore structures
- **Swim-Motion-Lines (SML)**: Time domain program for calculation of global performance of floating structures taking into account wind, waves and current
- **DNV/Marintek software DeepC**: Analysis tool for global performance of floating structures using coupled/de-coupled time domain analyses (SESAM Product based on RIFLEX/SIMO).

A 300 Global Load Effect Analysis

301 Global riser analyses are used to calculate resulting cross-sectional forces, global riser deflections, global riser position, support forces at termination to rigid structures, stroke etc. DNV uses the following software:

- **MCS software Freecom-3D**: Three dimensional finite element frequency domain analysis program
- **MCS software Flexcom-3D**: Three dimensional finite element time domain analysis program
- **Marintek software Riflex**: Finite element computer program for slender structure analysis
- **DeepC** (ref. A 200).

A 400 VIV Analysis

401 DNV use the following software for running VIV analyses:

- **Shear-7**: VIV response prediction tool for risers, which uses mode superposition methods
- **VIVANA**: VIV program for slender marine structures based on empirical hydrodynamic coefficients.

A 500 Interference analysis

501 DNV use the following software for checking of interference between mooring lines - risers or risers-risers:

- **MCS Clear-3D**: Three dimensional riser clearance analysis (Compatible with FLEXCOM-3D)
- **DeepC** (ref. A 200).

A 600 Components and Detail Analysis

601 DNV use the following software for component analyses:

- **Ideas**
- **Advance/Abaqus**: General purpose nonlinear finite element structural analysis program
- Program for weldability and weld cracking evaluations
- **CRACKWISE** and **FATIGUEWISE** for fracture mechanics assessments
- Spread sheet for cathodic protection design calculations
- Program "COMCAPS" for calculating the performance of designed cathodic protection systems
- Program "CORROLINE" for prediction of material loss in pipeline.

A 700 Structural Reliability Analysis

701 For structural reliability analyses, DNV use the following software:

- Proban
- Proinsp.

A 800 Capacity checks of steel risers

801 DNV uses the following postprocessors for calculation of utilisation and fatigue life:

- DNV postprocessor Riser life (ULS, FLS)
- DNV postprocessor Casper (capacity checks based on DNV-OS-F201)
- MCS Flexcom-3D Database/Timetrace Postprocessor
- MCS Life-3D (FLS, frequency domain).

A 900 Capacity checks of flexible risers or umbilicals

901 Cross section analyses are carried out with the software:

- **Caflex**: Cross-sectional analyses of composite cross-sections (flexible risers, umbilicals, wire ropes etc).

