RP O401

SAFETY AND RELIABILITY OF SUBSEA SYSTEMS

APRIL 1985

(Note: The present Recommended Practice is identical to Guideline NO 1-85 and will be subject to reprint in correct RP format when the document is subject to revision)
SAFETY AND RELIABILITY OF SUBSEA PRODUCTION SYSTEMS

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Foreword
In January 1984, Veritas published «Tentative Rules for Certification of Subsea Production Systems», which has been the basis for this publication.

The changes mainly concerns the name of the publication and the intention to issue a «Statement of Compliance» for each separate phase of a project development.

This publication is split in two parts, A and B. Part A give a brief description of Veritas services related to the Guidelines, which is outlined in part B.

Any written comment to this publication will be appreciated and assessed for possibly incorporation in the next revision.
PART A

SECTION 1
SERVICES OFFERED BY VERITAS

1.1 General.

1.1.1 Application.

1.1.1.1 These Guidelines apply to the design, fabrication, transportation, installation, and maintenance of Subsea Production Systems for which a Safety/Reliability assessment (see 1.2) is requested.

1.2 Use of the Guidelines.

1.2.1 Issuance of Statement of Compliance.

1.2.1.1 Upon request Veritas is prepared to issue a Statement of Compliance for a Subsea Production System found to be built in accordance with these Guidelines.

1.2.1.2 The Statement of Compliance may be issued upon satisfactory completion of the respective phases for development projects with Subsea Production Systems.

1.2.1.3 The respective phases (1.2.1.2) may be:

- conceptual phase
- engineering phase
- fabrication (of materials and components) phase
- construction (site and field) phase
- operational phase.

1.2.1.4 The Statement of Compliance may contain statements and information relevant for the respective phase:

- a statement that the Guidelines are complied with
- description of the main particulars for the Subsea Production System
- the geographic location and orientation of the Subsea Production System
- description of main operational limitation and basic assumptions.

1.2.1.5 The Statement of Compliance is valid upon the date of issue. The validity of the Statement of Compliance, Operational Phase may, however, be retained provided the requirements in 1.2.2 are followed. Then the Statement of Compliance will be renewed every fifth year.

1.2.2 Operational Phase.

1.2.2.1 In order for a Subsea Production System to retain its Compliance status, it is to be subjected to surveys of the frequency and extent stipulated in Sec. 1.5. The term «survey» in this context may cover various types of accepted methods that can be used to assure the surveyor about operability, reliability or safety of the system. In most cases direct visual inspection will not be practical. As an alternative, features may be built into the system allowing testing or condition monitoring.

1.2.2.2 If it is found that the structure or equipment which is covered by the Statement of Compliance, Operational Phase, does not meet the Guidelines, the owner should be requested to perform the necessary repairs, modifications, tests or measures. Veritas should request this by a recommendation on any improvements, new surveys or other measures found necessary in order to retain the Compliance status, regardless of whether the conditions referred to have previously been approved.

1.2.2.3 If Veritas by significant justification deems it necessary to survey the Subsea Production System or to have technical measurements or other examinations carried out to ascertain whether damages have been sustained or are imminent, a recommendation hereon should be given.

1.2.2.4 Recommendations and memoranda related to Certificate of Compliance Operational Phase are as follows:

- Recommendations to be carried out, are recommendations to the effect that specified operations (e.g. repairs, adjustments, reinforcements) should to be carried out within specified terms (if necessary immediately).
- Memoranda for Operators, is information to the Operators that, for example, a damage has been surveyed and recorded. It has, however, not been considered necessary to call for repairs.

Note:
Recommendations may be issued on behalf of National Authorities.

1.2.2.5 Recommendations and memoranda should be sent in writing to the Operators. Recommendations for immediate repairs can be made verbally, provided the representative of the Operators accepts the recommendation and will take immediate steps to carry it out.

1.2.2.6 Veritas may at any time alter a recommendation or memorandum if this is considered necessary.

1.2.2.7 The Operators may request that a decision by Veritas be reconsidered on the basis of a new survey by one or more Surveyors specially appointed by Veritas.

1.2.2.8 A written recommendation or memorandum will be deleted when Veritas by survey or other means has established that the requirements have been fulfilled. A verbal recommendation is revoked when a subsequent survey proves that the repair is satisfactory.

1.2.3 Withdrawal of Compliance Status, Operational Phase.

1.2.3.1 Veritas should withdraw the validity of the Statement of Compliance, Operational Phase, if the Operator does not comply with his duty to request surveys and to give information, his obligations in connection with the survey, or if he does not rectify defects in accordance with the requirements of Veritas. Such withdrawal should be notified by a letter to the Operator and/or other bodies as relevant.

1.2.3.2 The withdrawal may be made conditional in that it will come into effect only if the Operator, within a stipulated time, has not rectified the conditions leading to the withdrawal.

1.2.3.3 If the conditions leading to withdrawal of the validity of the Statement of Compliance, Operational Phase no longer exist, Veritas may upon request reinstate the validity of the Compliance Status. As a condition hereto, Veritas can demand that the Subsea Production System be subjected to a survey or certain specified improvements.
1.3 Surveillance.

1.3.1 General.

1.3.1.1 The work carried out by Veritas should ensure that the Subsea Production System is designed, fabricated, transported, tested, installed, and operated in accordance with this publication. This work comprises appraisal of drawings, procedures and specifications, and inspection. The surveillance by Veritas is additional to, and not a replacement of quality control carried out by the contractor or manufacturer.

1.3.2 Surveillance during Fabrication Phase.

1.3.2.1 The contractor should provide necessary access to the Subsea Production System for the Veritas Surveyor and the necessary assistance required for carrying out the inspection work.

1.3.2.2 When a Subsea Production System is fabricated under the surveillance of Veritas, Veritas should examine:

- that the dimensions, strength and safety and control functions of the Subsea Production System comply with the Guidelines and the approved plans, and that the prescribed materials are used,
- that the materials and the systems which are used have been tested in accordance with the Guidelines,
- that the work is carried out in compliance with the Guidelines, and to the satisfaction of Veritas, and in accordance with normal good practice,
- that satisfactory tests are carried out to the extent and in the manner prescribed in this publication.

1.3.3 Surveillance during Construction Phase.

1.3.3.1 Surveillance during transportation should be required when found necessary.

1.3.3.2 The installation, testing and commissioning should take place under the surveillance of Veritas, in accordance with approved plans and specifications.

1.3.4 Surveillance during Operational Phase.

1.3.4.1 The subsea production system should be subject to surveillance in accordance with the Guideline. (See Sec. 12.)

1.4 Documentation.

1.4.1 General.

1.4.1.1 The total documentation should consist of both documentation which has to be submitted to Veritas before commencement of fabrication or any other specific phase, and of such documentation (reporting) which will be worked out during the various phases.

1.4.1.2 Depending on the nature of the documentation some should be subject to approval by Veritas, and some will not. Receipt of the latter will still form a basis for the approval of the Subsea Production System.

1.4.1.3 It should be the Operators responsibility to keep complete files of all documentation relevant to safety and durability of the Subsea Production System. It should also be his responsibility to keep complete files of reports regarding operation, surveys, repair, damages, and abnormal functions.

1.4.2 Documentation which should be submitted before each respective phase.

1.4.2.1 The documentation listed in 1.4.2.2 up to and including 1.4.2.4 should be submitted to Veritas in ample time before commencement of fabrication, transportation, installation or operation, whichever is relevant. The documentation is should be submitted in triplicate through the local Surveyor, unless otherwise agreed.

1.4.2.2 For a description of the conditions which are decisive to the design of the Subsea Production System, information should normally be required on environment, product, use and treatment as follows:

**Environment**
- Water depth.
- Maximum and minimum seawater temperature.
- Maximum wind speed.
- Current and wave conditions.
- Ice conditions.
- Seismic activity.
- Marine growth.
- Soil properties.
- Bottom topography.

**Product**
- Hydrocarbon description.
- Maximum pressure.
- Maximum temperature.
- Production rates.
- Contaminants produced and their possible effect on corrosion rate, wear and clogging such as water, H2S, CO2, sand, wax, etc.

**Use and treatment**
- Design life.
- Functional loads during the various phases, as relevant.
- Transportation and installation procedures.
- Maintenance system and re-entry systems.
- Main operation characteristics.

1.4.2.3 For the purpose of verification that the proposed Subsea Production System satisfies the applicable requirements regarding strength, durability and serviceability, calculation and other analytical material should normally be required as follows:

- Necessary calculations for the determination of functional and environmental loads.
- Failure effect analyses.
- Structural analyses, including analyses of pressure containing components, and foundation analysis.
- Sea bottom stability analysis if applicable.
- Analyses regarding corrosion protection systems.

1.4.2.4 For description of the proposed Subsea Production System, information on design, materials, fabrication, procedures, corrosion protection, and testing procedures including proposed acceptance criteria should normally be required as follows:

- Situation drawing showing the location of the Subsea Production System relative to platforms, shore, ship lanes, fishing areas and other installations or activities affecting the safety of the system.
- General layout drawings of the Subsea Production System including location of related equipment and systems on surface installations.
- Drawings showing supporting structures, pressure containing components, and protecting structures.
- Drawings showing piping systems, including valves and other piping components.
- Drawings showing flowlines and risers.
- Drawings and descriptions of control and safety systems.
- Drawings and descriptions of electrical systems.
- Drawings and description of test equipment.
- Drawings of main maintenance equipment.
- Material specifications.
- Welding specifications, welding procedures and other fabrication procedures as applicable.
- Fabrication procedure qualification reports for welding, metal spraying etc.
- Description of the main principles of the Manufacturers' quality assurance and quality control system.
- Qualification records for welders.
- Test program and procedures for non-destructive testing.
of major components.
- Test programmes for factory tests of individual sub-assemblies.
- Test programs for pressure and leakage testing of systems, testing for possible contamination in essential pip­
ing systems, and functional testing of control and safety systems.
- Test program for final tests upon completion. The pro­gram should include instructions related to shut down, start up, controlled by normal and redundant systems, remote and local, during simulation of failure condi­tions.
- Manuals for transportation, installation, and operation.

1.4.3 Documentation which should be available during each respective phase.

1.4.3.1 During fabrication the following documentation should be made available for examination and possible re­tention by the surveyor:
- Material certificates.
- Dimensional control reports.
- Non-destructive examination reports.
- Test reports according to the test programs in 1.4.2.4 as applicable.

1.4.3.2 During installation the following documentation should be made available for examination and possible re­tention by the surveyor:
- Orientation and alignment reports.
- Photos or video tape of the main components after in­stallation.
- As-built drawings of the main system showing the loca­tion of each main subsystem and main component with a reference for traceability to certificates and reports.
- As-built drawings of main subsystems.
- Reports on:
  - non-destructive testing,
  - post weld heat treatment,
  - dimensional control when relevant,
  - pressure- and leakage testing.
- Reports on:
  - cleanliness of hydraulic systems,
  - functional testing of control- and safety systems,
  - insulation resistance of electrical systems,
  - performance of corrosion protection system.
- Reports on excavation/protection.
- Final inspection report.

1.4.3.3 During the operational phase documentation relat­ed to in-service inspection should to be made available for examination and possible retention by the surveyor accord­ing to Sec. 12.

1.4.4. Operational phase, Manuals

1.4.4.1 The operation manuals (see 1.4.2.4) should be sys­tematically prepared and should include information on the subsea production system, its installation and structure as well as on operation and maintenance.

1.4.4.2 Manuals for operation should be kept at the con­trol stand.

1.4.4.3 A system description is that part of the documenta­tion which explains the design, function and mode of opera­tion. The system description should cover such items as:
1. Definition of symbols and nomenclature.
2. Functional description.
3. Operating instructions, normal condition.
4. Operating instructions, failure condition.
5. Man/machine communication system.
7. Monitoring.

1.4.4.4 In addition to the self-explanatory items in 1.4.4.3 the items under the following headings should cover:
Functional description:
- The different functions including back-up functions should be explained in detail.
- Description of the most probable critical failure modes should be included.

Operating instructions
- Description of the normal operation of the equipment, including adjustments and change of limit values, possi­ble modes of presentation, start up and shut down.
- Description of operation of the Subsea Production Sys­tem in different operational modes including emergency.
- Description of transition from one operational mode to another.

Back-up systems
- In addition to hardware systems, this may also include a plan for use of service and maintenance vessels includ­ing specified availability of these.

Fault-finding procedures:
- Description of fault symptoms with explanation and re­commended corrective actions.
- Instructions for tracing faults back to functional blocks or sub-systems.

1.4.4.5 Other particulars regarding operation and mainten­ance should also be included for information, such as:
- overall testing philosophy
- list of maintenance tools
- lists of spare parts
- lists of suppliers' service network.

1.5 Compliance status operational phase.

1.5.1 Operators' duty.

1.5.1.1 The Retention of validity for the Statement of Compliance Operational Phase, requires that the Subsea Production System is subjected to periodical surveys, that it is operated, inspected and tested in accordance with the parts of the Operations Manuals related to safety and ap­proved by Veritas, and that the operator promptly notifies Veritas of conditions, events or planned actions that may make it necessary to perform a special survey. «Survey» and «inspection» in this context may differ from surface practice. A definition of survey is given in 1.2.2.1.

1.5.1.2 The operator should carry out maintenance, in­spection and testing as required to maintain the Subsea Pro­duction System in a safe condition.

1.5.1.3 The operator should maintain files of the mainten­ance, inspection, testing and remedial measures taken, and make these files available to the Veritas' surveyors upon re­quest. The operator should to make trend analyses based on the findings for possible correction of maintenance, inspec­tion and test frequency.

1.5.1.4 The operator should submit a summary report of the findings in 5.1.1.3 in relation to safety of the Subsea Pro­duction System prior to the survey with Veritas.

1.5.1.5 The operator should arrange for means accepted by the Veritas' surveyor to carry out inspection.

1.5.2 Manuals for operator's inspection.

1.5.2.1 Manuals for the operator's inspection, testing and maintenance should:
- Identify tasks
- Describe procedures, sequences and frequency of the in­spection, testing and maintenance
Identify the means by which inspection and maintenance should be carried out.

Note:
The frequency of these items may vary and some may be due depending on other findings or after abnormalities or accidental loads.

The inspections described in the manual may include:
- Testing of standby systems
- Testing of safety systems
- Testing of emergency systems
- Testing of possible communication systems
- Pressure testing
- Leakage testing
- Check of condition monitoring systems
- Check of corrosion protection system
- Check of the hydrocarbon for possible alteration of its corrosive and erosive properties
- Check for possible material deterioration and incipient cracking
- Check for possible damage by accidental loadings
- Check amount of marine growth and presence of debris in contact with the structure
- Check the foundations for scouring or buildup of seabed substances.

The manuals should be submitted for approval as a part of the Operations Manual.

1.5.2.2 The method described in the manuals should be based on generally recognized practice by reference to recognized codes/standards or by recognized testing carried out.

1.5.2.3 The frequency, items and systems for the owner's inspection and testing should be selected according to the failure effect analysis, failure history and trend analysis from condition monitoring systems.

1.5.3 Surveys with Veritas.

1.5.3.1 The operator should notify Veritas in advance when periodical surveys are to be carried out and make all arrangements for a Veritas Surveyor to inspect to the extent necessary for completion of the survey in accordance with the Guidelines.

1.5.3.2 The frequency of the periodical survey by Veritas will depend on the system design, operation and maintenance plans. The owner should propose a frequency as part of a survey arrangement. This arrangement is subject to approval by Veritas and may later be altered by Veritas depending on the findings and the owners reports.

Note:
Within a 5 year period it should be demonstrated to Veritas that all systems and structural members related to safety are in order. This may be achieved by annual summary reports according to 1.5.14 and by surveys with a Veritas Surveyor during safety assurance of the most significant systems or items. These surveys should be carried out at least twice within the 5 year period.

1.5.2.3 In the event of accident, discovery of damage or deterioration, modifications or any other noted or possible change in the condition or operation of the Subsea Production System that may affect its safety, an additional special survey may be required.

1.5.4 Repairs.

1.5.4.1 Repairs or rework (apart from planned maintenance) to parts that are subject to compliance statements should be approved and surveyed by Veritas.

1.5.4.2 The operator should notify Veritas in advance of any such action and submit the necessary plans and specifications for approval. The exact documentation that should be submitted for approval or information purposes should be decided in each particular case.

1.5.5 Conversion.

1.5.5.1 Conversion should normally be subject to approval in accordance with the Guidelines for new constructions.
PART B

SECTION 1

SCOPE

1.1 General.

1.1.1 Application.
1.1.1.1 These Guidelines apply to the design, fabrication, transportation, installation, and maintenance of Subsea Production Systems for which a Safety/Reliability assessment is requested.

1.1.2 Definitions.
1.1.2.1 Subsea Production Systems including Subsea Completion Systems are systems on or buried in the seafloor and related to production of hydrocarbons.

1.1.2.2 In this publication various references are given to other Veritas publications. These publications are in three levels, defined as follows:

Rules lay down basic requirements in connection with the certification defined in the Rules.

Appendices to the Rules, describe examples of accepted approaches in application of the Rules.

Technical Notes (TN) give guidelines on various problems related to fixed offshore installations.

Reference made in this publication concerns the technical contents and should be regarded as guidelines.

Note given in this publication concerns examples; explanation or possible practical arrangements that might be of interest concerning the text above the Note.

A surveyor verifies that items and systems are satisfactorily manufactured or are in a satisfactorily status.

1.1.3 Scope.
1.1.3.1 The following parts and systems are covered in this publication for Subsea Production Systems:
- Parts and systems surrounded by water or enclosed in a dry environment.
- Downhole completion equipment related to well safety such as downhole safety valves, downhole pumps and artificial lift devices.
- Well heads.
- Christmas trees.
- Subsea manifolds and valves.
- Subsea storage tanks.
- Surrounding, supporting and protecting structures and foundations.
- Production risers and flow lines.
- Control and safety systems.
- Maintenance equipment and systems including Through Flowline Pumpdown Systems (TFL).

1.1.4 Alternative design methods.
1.1.4.1 Alternative methods of design, fabrication, transportation, installation and maintenance to those given in this publication should provide a standard of safety and serviceability equivalent to that of this publication.

1.1.5 Assumptions.
1.1.5.1 It is assumed that the Subsea Production System will be operated by adequately skilled personnel familiar with the system and according to the operation manuals.
SECTION 2
GENERAL DESIGN GUIDANCE

2.1 Design Principles.

2.1.1 Safety principles.

2.1.1.1 Subsea Production Systems should offer acceptable safety against loss of life or health, significant environmental pollution and major economic loss. When this publication is compiled with, safety of the Subsea Production System should be considered acceptable.

2.1.1.2 A failure effect analysis is to be carried out. This analysis is to deal with the most probable failures, their probability and consequences. Such failure types may be technical, operational or due to accidental loading. The result of this analysis should govern the design and the content of the operation- and in-service inspection and testing manuals. The extent of the analysis should depend on the complexity of the Subsea Production System and should in general contain the following:

- A breakdown of the Subsea Production System into functional blocks should be carried out to an agreed level of detail. This level is to deal with failures in sub-systems and functions and their effect on the main system and its functions.
- A description should be made of each physical and functionally independent item and the associated failure mode with their failure causes related to normal operational modes of the item.
- A description of the effects of each failure mode alone on other items within the system and on the overall Subsea Production System performance.

The results from the failure effect analysis should be presented on recognized forms. Guidance is given in Appendix 1.

2.1.1.3 Whenever practical, Subsea Production Systems should be so designed that the effect of a single failure cannot develop into a situation that may cause loss of life or health, significant environmental pollution, and major economic loss.

2.1.1.4 The most probable failures, e.g. loss of power, failure in control systems, should result in the least critical of any possible new condition (fail to safety).

2.1.1.5 Switch-over to stand by systems is to be simple, also in the event of failure in the control and monitoring system. Indication should be given to the operator when redundant systems are activated.

2.1.2 Layout of the Subsea Production System.

2.1.2.1 The layout of the Subsea Production System should ensure accessibility for:

- Safe operation.
- Maintenance.
- Inspection.
- Testing.

Note:
This may include space for access by divers, remote operated vehicles or special dedicated tools.

2.1.2.2 For drilling templates, due space for cutting return should be provided.

2.1.2.3 Where high pressure piping is guided through a closed compartment, the compartment should be designed either to resist the over-pressure caused by a possible leakage or to permit release of the over-pressure without damaging the structure, or provide adequate pressure monitoring and control to isolate pressure sources, thereby limiting compartment over pressure potential.

2.1.2.4 If the system needs a minimum internal pressure, (gas or liquid) to withstand the external pressure at a required safety level, the pressure system safety should be included in the failure effects analysis.

2.1.3 Materials.

2.1.3.1 Materials should be selected with due consideration regarding the environment and for possible repair procedures. In particular this concerns the weldability under hyperbaric conditions when applicable.

2.1.4 Corrosion protection.

2.1.4.1 Structures should be protected in order to avoid corrosion problems during their lifetime.

2.1.4.2 Methods, designs, materials, fabrication and installation of the corrosion protection system are subject to approval. Special precautions should be taken to protect steel members in areas where accessibility for inspection and maintenance is limited.

2.1.4.3 Guidance to materials and welds with respect to environmentally induced cracking such as hydrogen induced pressure cracking (hydrogen blistering), sulphide stress corrosion cracking and chloride stress corrosion cracking are given in Veritas' Rules for Submarine Pipeline Systems.

2.1.4.4 Steel members in contact with seawater or mud/bottom sediments should be protected by cathodic protection with sacrificial anodes or alternatively with impressed current. The cathodic protection system may be combined with a suitable coating. Other protective systems may be accepted upon special consideration.

2.1.4.5 Internal corrosion control should be provided for pipeline systems conveying and storing corrosive hydrocarbons. Internal corrosion control may be achieved by one or more of the following methods:

- Application of corrosion inhibitors.
- Use of corrosion allowance.
- Use of internal coating.
- Application of corrosion resistant alloys or linings.

2.1.4.6 Detailed guidance for the corrosion protection system (2.1.4.3—2.1.4.5) are given in the following Veritas' Rules and Technical Notes:

- Rules for Submarine Pipeline Systems.
- TN B 111 Corrosion Control of Equipment and Piping Systems Handling Hydrocarbons.

2.1.5 Physical protection.

2.1.5.1 Subsea Production Systems should be protected against accidental damage which might reasonably be expected to occur by minimizing both the probability for and the consequences of the damage.
Installation and maintenance procedures should be made for reducing the probability of damage. The design should reduce the consequences of the possible operational errors during installation and maintenance and facilitate replacement of possible damaged components. It may be practical to provide protection against lighter objects dropped from the surface anchor chains and trawling boards. Larger objects from which it may be unpractical to protect should not prevent the shut down of the system by the downhole safety valve(s).

2.2 Marking.

2.2.1 Identification.

2.2.1.1 Structural parts should be marked in order to facilitate identification during inspection.

2.2.1.2 Supervisory and control equipment should be marked in order to facilitate identification. Manually operated valves should be equipped with position indicators, alternatively the position of the handle may serve as indicator.

2.2.1.3 All units, terminals, cable ends, pipe ends and test points should be permanently marked. Transducers and actuators should be marked with their system functions so that they can be clearly identified on plans and instrument lists.

2.3 Well-System Barriers

2.3.1 Safety Requirements.

2.3.1.1 Subsea wells should be equipped with sufficient individual valves for shut down of each conduit capable of producing hydrocarbons. The valves should be fitted in series and installed so that testing of the sealing capacity of each of the valve required is assured. The minimum number of valves should be established by aid of the failure analysis.

Note: By this approach some wells might be fitted with only one downhole safety valve and one X-mas tree valve for a conduit when safety principles are sufficiently documented by the failure effect analysis.

2.3.1.2 The system for killing of the wells should be documented by the failure effect analysis.

2.3.1.3 The down hole safety(s) valve should be installed at a safe depth underneath the seabed in each production, gas and water injection tubing. (Specific minimum depths are required by some national Authorities.)
SECTION 3
ENVIRONMENT

3.1 General.

3.1.1 Environmental phenomena.

3.1.1.1 All environmental phenomena which may impair the proper function of the system or cause a reduction of the system reliability should be considered. Such phenomena include waves, currents, ice, seismic, geological, and geotechnical conditions, temperature, fouling, biological activities, chemical components of water, and internal system conditions.

3.1.2 Acceptable environmental data.

3.1.2.1 The environmental conditions should be described using adequate data for the areas in which the system should be installed.

3.1.2.2 Data supplied by generally recognized source should normally be accepted as a basis for design. Background information on data collection and derivation should be submitted at request.

3.1.2.3 The various environmental factors should be described by characteristic parameters based on statistical data or long term observations. If sufficient data directly applicable to the location in question are not available, conservative estimates based on relevant data for other relevant locations might be used.

3.1.2.4 Statistical data should be utilized in describing environmental parameters of a random nature (e.g. waves). Proper care should be exercised in deriving such parameters in a statistically valid manner, and generally accepted methods should be used.

3.2 Environmental conditions.

3.2.1 General.

3.2.1.1 Possible effects of the various environmental actions should be taken into account to the extent relevant to the situation considered.

3.2.2 Tide.

3.2.2.1 Tides should be taken into consideration when applicable.

3.2.2.2 The assumed maximum tide should include both astronomical tide and storm surge. Minimum tide estimates should be based on the astronomical tide and possible negative storm surge.

3.2.3 Waves.

3.2.3.1 The effect of waves should be taken into consideration for design of Subsea Production Systems. Examples of such effects are direct forces due to drag, lift and inertia effects, and forces due to vortex shedding and other flow induced instability phenomena. Possible liquefaction and transportation of sea bed material due to wave action should also be considered.

3.2.3.2 If some parts of the system are positioned adjacent to other structural parts, possible effects due to disturbance of the flow field should be considered when determining the wave loads. Such effects may either be caused by changes in the wave particle kinematics, or by dynamic excitation caused by vortexes shed from the adjacent structural parts.

3.2.4 Current.

3.2.4.1 The effect of current should be taken into consideration in design of subsea systems.

3.2.4.2 The assumed current velocities should include possible contributions from tidal current, wind induced current, storm surge current, density current and possible other current phenomena.

3.2.4.3 The tidal current may normally be determined from analyses of recorded data, while wind induced, storm surge and density currents may be determined either from statistical analyses of recorded data, or from numerical simulations in lieu of specific studies.

Normal wind induced surface current speed correspond to 2 per cent of the 1 hour mean wind speed.

3.2.4.4 In regions where bottom material may erode, special studies of the current conditions near the bottom including boundary layer effects may be advisable.

3.2.5 Corrosivity.

3.2.5.1 For the evaluation of the corrosion protection system the following properties, with seasonal variations of the sea water and soil representative for the actual location, should be considered:

- temperature
- salinity
- oxygen content
- pH-value
- resistivity
- current
- biological activity (sulphate reducing bacteria etc.)

3.2.6 Ice.

3.2.6.1 In the case of an installation to be located in an area where ice may develop or drift, consideration of ice conditions and their possible effects on the Subsea Production System should be made. The ice conditions should be studied with particular attention to possible:

- ice forces due to floating ice
- potential scour due to grounding icebergs
- ice problems during the installation operations.

3.2.7 Sea temperature.

3.2.7.1 Maximum and minimum sea temperatures should be identified.

3.2.8 Marine growth.

3.2.8.1 The effect of marine growth on the subsea installation should be considered, taking into account all biological and environmental factors relevant to the site in question.

3.2.8.2 For determination of the hydrodynamic loads special attention should be paid to the effective diameter increase and the equivalent roughness of accumulated marine growth when determining the hydrodynamic coefficients.
3.3 Internal system condition.

3.3.1 Installation conditions.

3.3.1.1 A description of the internal conditions during storage, installation, pressure testing and functional testing should be prepared. Of special concern is presence of contamination in hydraulic systems, the duration of exposure to sea water and moist air, and whether inhibitors and/or biocides should be used.

3.3.2 Operational conditions.

3.3.2.1 The physical and chemical composition of the product, flow rates, the pressures and pressure gradient and temperatures in any part of the system should be specified.

3.3.2.1 Limits of temperatures and pressures, and maximum design concentrations of corrosive components for the product should be specified. Of special concern is the content of:

- sulphur compounds
- water and water soluble salts
- oxygen (O₂)
- carbon dioxide (CO₂)
- hydrogen sulphide (H₂S)
- sand
- wax
- hydrates.

3.3.2.2 Other chemicals used for completion, treatment, injection etc. may have influence on corrosion and aging of polymer seals and should be specified.
4.1 General.

4.1.1 Scope.
4.1.1.1 All loads that may influence the dimensioning of the Subsea Production System or parts thereof should be considered in the design. This applies to all phases of the installation and life of the system.

4.2 Functional loads.

4.2.1 General.
4.2.1.1 Functional loads are loads which are natural consequences of the existence, use and treatment of the system in the various situations under ideal conditions. Ideal conditions means no waves, current etc. i.e. no dynamic environmental loads acting.

4.2.2 Functional loads during operation.
4.2.2.1 Functional loads during operation will normally be those due to
- weight
- pressure
- thermal expansion and contraction
- prestressing
- reaction from mechanical functions (actuators, mechanisms).

4.2.2.2 Weight include:
- weight of structures, including coating, all attachments, and marine growth,
- weight of contents,
- buoyancy and ballast.

4.2.2.3 Pressure include:
- internal fluid pressure,
- dynamic behaviour of the fluid in the system during normal, abnormal and emergency operations,
- thermal expansion of an enclosed fluid,
- external hydrostatic pressure,
- soil pressure.

4.2.2.4 Thermal expansion and contraction loads should include the effect of product temperature on material temperature. Possible other causes of changes in material temperature should also be considered. The temperature difference to be considered is that between material temperature during operation and material temperature during installation, shutdown and maintenance.

4.2.2.5 Thermal expansion or contraction loads may not be taken into account when they do not influence the capacity to carry other loads. Fluctuation in temperature may contribute fatigue and should be taken into account when checking fatigue strength.

4.2.2.6 Pre-stressing, such as permanent curvature or a permanent elongation introduced during installation, should be taken into account to the extent it affects the capacity to carry other loads.

4.2.3 Functional loads during transportation, installation and maintenance.
4.2.3.1 The functional loads during installation and maintenance, may be grouped as
- weight
- pressure
- installation forces.

4.2.3.2 Installation forces should include all forces occurring during installation operations. Typical installation and maintenance forces are hook up forces and other forces associated with entry or retrieval of parts of the Subsea Production System in normal and planned emergency modes.

4.3 Environmental loads.

4.3.1 General.
4.3.1.1 Environmental loads are loads due to waves, current and other environmental phenomena. Loads due to human activities independent of the Subsea Production System are also included, e.g. loads from fishing gear.

4.3.1.2 The environmental loads are random in nature and should in principle be evaluated by means of probabilistic methods. Natural, simultaneous occurrence of different environmental phenomena should be determined by proper superposition of their individual effects, taking into account the probability of their simultaneous occurrence.

4.3.1.3 The environmental loads during normal operation should not to be taken less than the probable severest load in a time period of 100 years for the actual ocean area. If risers or other items are designed for disconnection at specified weather conditions, the probable severest loads in a time period of 100 years should apply to the disconnected state.

4.3.1.4 For temporary phases the probable severest load in this period should normally be evaluated based on three times the expected duration of the phase.

4.3.1.5 The environmental parameters for determination of environmental loads in temporary installation and maintenance phases lasting 5 days or less, and which can be interrupted with a safe margin may be based on reliable weather forecast.

4.3.2 Wave loads.
4.3.2.1 Wave induced loads should be determined by use of generally recognized methods taking proper account of water depth and the size, shape and type of installation.

4.3.2.2 In the analytical determination of wave loads, the hydrodynamic coefficients used in the analysis may be determined on the basis of published data, model tests, or full scale measurements.

For details on analytical determination of wave loads, see Rules for the Design, Construction and Inspection of Offshore Structures.
4.3.2.3 For structures of complex shape for which analytical determination of wave loads may not yield sufficient accuracy, the wave loads should be determined by use of reliable and adequate model tests.

4.3.3 Current loads.
4.3.3.1 The current induced drag and lift forces on the subsea system should be taken into account.

4.3.3.2 Where Morison's equation (Defined in «Rules for the Design Construction and Inspection of Offshore Structures. Appendix B) is applicable, the effects of current may be accounted for by a vectorial addition of the orbital water particle velocity due to the waves and the steady current velocity.

4.3.3.3 The possibility of flow induced cyclic loads caused by the current should be considered. Guidance pertaining to this phenomenon is given in Rules for Submarine Pipeline Systems.

4.3.4 Ice Loads.
4.3.4.1 In areas where ice may develop or drift, the possibility of ice scouring and impact loads from drifting ice should be considered.

4.3.5 Loads from fishing gear.
4.3.5.1 In areas with fishing activity, the possibility of loads due to impact from or hookup of fishing gear such as bottom trawl, pelagic trawl, purse seine etc. should be considered.

Note: In the North Sea Area, impacts from trawl doors with a mass up to 2000 kg and with a velocity up to 3 m/sec. may be expected. The maximum breaking strength of double trawl wires may be up to 1000 kN.

4.3.6 Earthquake loads.
4.3.6.1 The effects of earthquakes should be considered: see Veritas Rules for the Design, Construction and Inspection of Offshore Structures.

4.3.7 Accidental loads.
4.3.7.1 Accidental loads should be taken into consideration for those parts of the system where such loads are likely to occur. Examples of accidental loads are given in the following sections.

4.3.7.2 Impact loads from dropped objects associated with the different activities in the installation and operation phases of the system should be considered.

4.3.7.3 The possibility of load effects due to dragging of anchors should be considered.

Note: A large support ship might have a breaking strength of one anchor chain up to 1000 kN and drilling rig up to 7000 kN. Mass of their anchors might be 3000 kg and 20 000 kg.

Protection philosophy is also described in Sec. 2.
SECTION 5
FOUNDATIONS

5.1 General.

5.1.1 Application.
5.1.1.1 This section applies to the foundation of Subsea Production Systems and is limited to a general presentation of some of the problem areas which should be considered in the design. For more detailed guidance, reference is made to Veritas Rules for the Design, Construction and Inspection of Offshore Structures, its Appendix F and Technical Notes for Fixed Offshore Installations TN A 300.

5.2 Site Investigation.

5.2.1 General.
5.2.1.1 Site investigation should always be carried out. The investigation should at least include:
— a site geology study
— a bottom topography study
— a soil exploration programme with determination of relevant geotechnical properties of the foundation soils.

5.2.1.2 The physical extent of the site investigation is dependent upon type of structure, uniformity of the soil and the seabed conditions. The investigation should be sufficiently extensive to reveal all seabed features and soil deposits of importance to the structure.

5.2.1.3 Special attention should be paid to the characteristics of the seabed surface material in the area and the potential risk of mudslides and scouring phenomena.

5.3 Foundation Design.

5.3.1 General.
5.3.1.1 A Subsea Production Structure may be supported by piles, by the casings themselves (casings acting as piles), directly by the seabed, or combinations thereof.

5.3.2 Pile/casings supported Structures.
5.3.2.1 The foundation piles of a pile supported structure should be designed for compression, tension and lateral loads, as applicable.

5.3.2.3 The structure should be properly connected to the pile/casings. This may be made by a mechanical device or by grouting the annulus between pile and sleeve.

5.3.3 Seabed supported Structures.
5.3.3.1 The foundation of a seabed supported structure should be designed to have sufficient vertical and horizontal bearing capacity for the loads in question.

5.3.3.2 Depending on seabed conditions high contact stresses may develop. This should be considered in the design. Underbase grouting may have to be used to achieve the required stability and load distribution.

5.3.4 Buried Structures.
5.3.4.1 In the case of buried structures, the stability of the excavation should be considered.

5.3.4.2 Buried structures should be designed to resist the earth pressures.
SECTION 6
STRUCTURES

6.1 General.

6.1.1 Application.

6.1.1.1 This section applies to structures surrounding, supporting and protecting the main items of the Subsea Production System. The structures dealt with in the following are designed of steel or concrete. Other materials should be subject to special considerations.

6.1.2 Materials and design.

6.1.2.1 For detailed guidelines reference is made to the following Veritas Rules:

6.1.2.2 A structural analysis of main members should be carried out. The analysis should include static and dynamic evaluations of safety against excessive yielding, fatigue, fracture, collapse and excessive displacement as applicable.

6.1.2.3 Significant yielding of protective structure due to accidental loads of small probability might be acceptable when supported by the failure effect analysis.

6.1.2.4 Sufficient space for:
   - deposits from drilling
   - drilling equipment
   - maintenance and inspection
should be provided.
SECTION 7
RISERS AND FLOWLINES

7.1 General.

7.1.1 Application.
7.1.1.1 Section 7 applies to the connecting piping system between the Subsea Production System and the surface installation for conveying hydrocarbons or injection fluids, or used for maintenance.

7.1.2 Definitions.

Supported production riser system — a piping system attached or built into structures.

Marine production riser system — a piping system suspended from a surface support without lateral supports between surface and seafloor.

Work over riser — a riser used during major maintenance of the well completion system.

Flowlines — a piping system conveying produced or injected fluid between underwater unit and riser, and which normally might be installed by similar methods as submarine pipelines.

7.1.3 Reference.
7.1.3.1 For supplementary guidelines reference is made to the applicable parts of:
— Veritas' Rules For Submarine Pipeline Systems.
— API RP 2Q; Design and Operation of Marine Drilling Riser Systems.
— API RP 2K; Care and Use of Marine Drilling Risers.

7.1.3.2 For design of supported production risers the Rules for Submarine Pipeline Systems.

7.2 Design of Marine Production and Workover Risers.

7.2.1 General.
7.2.1.1 For marine production and workover risers, the motions and corresponding forces should be taken into account. When connected to a floating platform, the interactions should be considered. First and second order motion under wave, current and wind loads and their corresponding static and dynamic effects should be taken into account.

7.2.1.2 The response analysis of the riser under wave and current load should ideally account for dynamic, non-linear stochastic response. However, it may not be possible to account for all phenomena in the analysis. In this case the uncertainties should be resolved through model tests. The type of analysis required is dependent on the design proposed for the riser.

7.2.1.3 The spacings between marine production risers and between risers and anchor systems should be such that physical interference does not result in structural damage.

7.2.1.4 Flexible risers should have properties, documented by verified tests and/or calculations, which show a defined and sufficient safety, during the design life, for the most probable failures due to: excessive loads, fatigue, aging of polymer materials and bonding/vulcanizing, gas diffusion and decompression etc.

7.2.2 Tensioners.
7.2.2.1 Appropriate redundant systems should be designed so as to ensure that the required tension is always applied to the riser. Redundant tensioning system should be designed with a strength to carry the total load under maximum environmental design loads even if one of the redundant systems is out of order.

7.2.4 Buoyancy.
7.2.4.1 If buoyancy elements are fitted, the damage of one element should not influence the buoyancy of others.

7.2.4.2 Buoyancy elements made of synthetic materials and embedded spheres in a synthetic matrix should have documented longterm properties for:
— Density of materials at actual depth
— Compressive strength and creep
— Water absorption

Further specifications on the following are to be given:
— Type
— Method of attachment
— Instructions for storage and handling.

7.2.5 Disconnection and Re-entry.
7.2.5.1 The feasibility of disconnection and re-entry of the riser strings with due respect to safety for the Subsea Production System and the riser itself should be considered in the failure effect analysis.

7.3 Design of Flowlines.

7.3.1 General
7.3.1.1 For general guidance, reference is made to Veritas' Rules for Submarine Pipeline Systems.

7.3.1.2 For flexible flowlines guidance is given in TN A 503.
SECTION 8
PIPING AND MECHANICAL EQUIPMENT

8.1 General.

8.1.1 Application.
8.1.1.1 Section 8 applies to piping and mechanical equipment used in hydrocarbon, utility and auxiliary systems on subsea production installations or related specifically to such systems.

8.1.1.2 Detailed guidance on design, materials, corrosion protection, fabrication and documentation is given in Veritas Technical Notes for Fixed Offshore Installations Volume B. These Notes also refer to applicable API specifications and other standards frequently used.

8.2 Design and fabrication.

8.2.1 Pressure vessels.
8.2.1.1 The TN B 101 gives guidance for pressure vessels and references to recognized codes and standards.

8.2.1.2 In case of permanently manned chambers the pipe penetrations should in general be fitted with internal shut-off valves, which should be mounted directly on the chamber wall or close to the wall, provided the connecting pipe is well protected and has a minimum thickness according to the Rules for Certification of Diving Systems.

8.2.2 Piping.
8.2.2.1 For general guidance, reference is made to Veritas TN B 102, Piping Systems.

8.2.2.2 Flexible pipes and hoses should have properties documented by verified tests and/or calculations, which show a defined and sufficient safety during the design life for the most probable failures. Further guidance is given in TN A 503.

8.2.3 Valves.
8.2.3.1 Design and arrangement of manual valves should to be such that open and closed positions are indicated, alternatively the position of the handle may serve as indicator.

8.2.3.2 Manual valves should be closed with a right-hand motion (clockwise rotation).

8.2.3.3 Shut-off valves for high pressure oxygen and air should be of types which need several turns to shut off. This is mainly applicable to life support systems of manned systems, and is to reduce the risk of internal pipe fires or explosions caused by heat from rapid gas compression and the presence of combustible contaminations or materials.

8.2.3.4 For valves one has to demonstrate (calculations or test results) the functional capability for any normal and emergency operation.

8.2.4 Through flowline (TFL) pump down systems.
TFL systems should generally satisfy the recommendations laid down in API RP 6G.

8.2.5 Wellheads, Xmas trees, Subsurface Safety Valves etc.
8.2.5.1 For guidance, reference is made to TN B 112 and TN B 113 concerning subsurface safety valves and wellhead equipment.

8.2.5.2 Subsea completed wells should be equipped with valves fitted in series according to sec. 2.3

8.2.5.3 For guidance regarding Blow-out Preventers used during completion and workover, reference is made to TN B 106.
SECTION 9
CONTROL AND SAFETY SYSTEMS

9.1 Application.

9.1.1 General.
9.1.1.1 Section 9 applies to Control and Safety systems related to hydrocarbon production, including power supplies.
9.1.1.2 The general safety principles for control and safety systems are given in sec. 2. The following specifies additional principles.

9.1.2 Safety principles.
9.1.2.1 Safety systems should be required when hazardous conditions cannot be expected to be counteracted manually.
9.1.2.2 Those parts of the control systems with essential impact on the safety should have high reliability. This should be documented through the failure effect analysis.

9.1.3 Environment.
9.1.3.1 Possibilities for electro-magnetic interference from external sources should be considered as well as vibrations, humidity, dust, saltmist and temperature that may influence sensitive instrumentation.

9.2 System design.

9.2.1 Control stand.
9.2.1.1 There should be control from at least one stand. From this stand all normal control and production monitoring should be possible. The control stand should give the operator all required status information to allow for safe operation.
9.2.1.2 When there is more than one control stand for remote operation, a system of preference should be applied in order to prevent simultaneous operation from different stands. A communication system should exist between the stands.
9.2.1.3 The control stand should indicate the expected system responses from operations executed. The feedback for this indication should be derived from a point appropriate to the criticality of the operation in question.

9.2.2 Monitoring and alarm.
9.2.2.1 The extent of monitoring should be based on good production practice and the failure effect analysis. This might concern possible parameters related to the production pressure in essential separated cavities such as annulus, position indication, wear and tear and from instrumented riser joints.
9.2.2.2 An alarm should be initiated for abnormal conditions when the consequence of a failure is critical for safety.
9.2.2.3 All alarms should include visual and acoustic signals. For localization of faults, visual signals should be given.
9.2.2.4 Performance tests of the alarm system should be possible during operation.
9.2.2.5 Permanent switch-off of the alarm system should not be possible. In particular cases, however, partial disconnection may be accepted provided a visual warning signal is showing that it is disconnected.
9.2.2.6 The more frequent failures within the alarm system, such as broken connections to measuring elements, should release alarm (normally closed circuit).
9.2.2.7 Display of one alarm should not inhibit display of other alarms.

9.2.3 Safety functions.
9.2.3.1 As far as practicable the design of control systems should be such that no significant reduction in the safety level exists during maintenance and repair of the control systems.
9.2.3.2 Where appropriate the control systems should be designed for automatic shut down for pressure or flow in the Subsea Production System outside a preset level.
9.2.3.3 The control systems should be designed for automatic shut down on request from certain external signals (e.g. major emergency and fire on topside facilities)

9.2.4 Shut down valves.
9.2.4.1 The control systems for shut down of a Subsea Production System should close the valves in case of:
- Shut down command.
- Loss of control from the control stand over a specified period, unless as back-up system is functioning. This also applies to monitoring, but depends on criticality of signals and operation.

9.2.5 Control during maintenance.
9.2.5.1 If control is carried out from a maintenance vessel, extent of the control and safety systems should comply with the failure effect analysis.

9.3 Component design.

9.3.1 Installation.
9.3.1.1 Equipment in one atmosphere submerged instrument chambers with dry environment should be designed to operate with specification in a relative humidity of 100%. Electrical cable penetrations should have seals against liquid (liqued block). This should prevent liquid passing the chamber wall if the liquid has penetrated into the cable.

9.4 Power supply.

9.4.1 General.
9.4.1.1 The capacity of the power supply systems should be sufficient to handle maximum consumption during normal and emergency operations.
9.4.1.2 The power supply arrangements including prime movers should operate satisfactorily under all relevant conditions.
9.4.2 Variations in supply.
9.4.2.1 The equipment should function satisfactorily within prescribed limits. These limits should exceed the tolerances for the power supply and variations due to the system design and operation.

9.4.3 Separation/Insulation.
9.4.3.1 Electric power to Subsea Production Systems should be separated from top-side electrical power equipment by means of isolation transformers in order to reduce possible earth fault currents in case of diver intervention. DC equipment should be special considered (See 10.2).

9.4.4 Hydraulic power.
9.4.4.1 Pressure in hydraulic systems should be kept within prescribed limits with regards to normal operational pressure and transient pressure peaks.

9.4.4.2 Where appropriate hydraulic systems should be fitted with filtering system with prescribed filtering properties, according to specification of applied hydraulic equipment.

9.4.4.3 Flowrates of hydraulic fluid and stiffness of piping systems should be compatible with prescribed time limits between execution of commands and system response.

9.4.4.4 Hydraulic fluids should have documented long time properties (viscosity, corrosity, bacterial growth etc.) and compatibility with materials used.

9.4.5 Emergency Power
9.4.5.1 The automatic safety valves for emergency shut down of production should have adjacent power storage in addition to power supply. This storage may be by mechanical springs, hydraulic or pneumatic accumulators.
SECTION 10
ELECTRICAL SYSTEMS

10.1 General.

10.1.1 Standard.

10.1.1.1 All electrical equipment should comply with a recognized standard relevant for the actual application. A complete list of the standards should be made up. The International Electrotechnical Commission’s (IEC’s) standards are recommended.

10.1.1.2 All components for essential equipment should be designed to operate satisfactorily with documented reliability. The documentation should be made through an identification of the failure modes for the components together with frequency of occurrence of each failure. The data sources also should be given, e.g. types tests, previous experience, manufacturing and quality control data, factory acceptance testing, engineering judgement etc.

Note:
For electronic systems the use is recommended of quality controlled components according to one of the following quality control systems:

a) IEC has put into operation January 1983 an international system, IECQ = «the IEC Quality Assessment System for Electronic Components».

b) A Western European system has been in operation since 1974, CECC = «CENELEC Electronic Components Committee». A CECC «Qualified Products List» is issued annually and updated quarterly.

c) The American system of MIL specifications and standards (which is the oldest of these systems), and the Military Handbook 217D, «Reliability prediction of electronic equipment».

It should be noted that the data presented in these systems are valid only for the specified environmental conditions, e.g. atmospheric pressure in most cases. Components which are designed for atmospheric pressure only should not be used at hyperbaric pressure without verification of suitability.

10.2 Supply systems.

10.2.1 Electric power sources.

10.2.1.1 Electric safety systems should have at least two independent power sources, each of sufficient capacity for the power demand in case one of the sources is out of action. This principle should be deleted in case the redundancy requirement is met by using a non-electric back-up system. Alarm should be given on failure of an electric power source.

10.2.1.2 The voltage and frequency variations should be kept within prescribed limits.

10.2.2 Insulation and Earthing

10.2.2.1 Insulated supply systems should generally be used, whether A.C. or D.C. Earthed systems may be specially considered.

10.2.2.2 When practicable (excluded are subsea systems with cable (umbilical) terminations including inductive couplers), an insulated supply system, including the secondary side of step-down or isolating transformers (or convertors) should be provided with an automatic insulation monitoring device, actuating switch-off and alarm by insulation faults. Alarm only may be used if a sudden switch-off of the equipment may endanger the operation of the production system. This insulation monitoring should be continuous, except that one common instrument with an automatic scanning device may be approved to monitor two or more electric systems.

A value lower than 1000 ohm per volt to initiate an alarm is frequently used above surface.

On earthed supply systems, if approved after special consideration, earth leakage circuit-breakers or relays should be used for this purpose.

10.2.2.3 All exposed metal parts of equipment, which can be touched by personnel, should be earthed.

10.2.3 Maximum Voltage.

10.2.3.1 The operating voltages should be chosen after consideration of the power demand, the voltage drops and variations which can be tolerated, and should not be higher than necessary for the actual application. For permanently installed lighting equipment the voltage should not exceed 250V. If necessary, step-down transformers (or convertors) should be installed for this purpose.

For portable equipment supplied via flexible cables one may use:

D.C. (with max. 10% riple): Max. 120V.
A.C.: Max. 24 V, or
Max. 250 V when supplied via a separate isolating transformer for each piece of equipment.

10.2.4 Wet systems.

10.2.4.1 If enclosures filled with oil or other insulating liquids are used, and the possibility of a short-circuit in the equipment cannot be excluded (e.g. for electric motors or other equipment with windings or coils), it should be ensured that the enclosure will not burst by an internal short-circuit.

Note:
The pressure rise by a short-circuit in a liquid-filled enclosure will depend on the volume and on the energy which is developed, i.e. the magnitude and duration of the short-circuit current.

The insulating properties of such oil or other insulating liquids should be checked either by periodical maintenance and service, or by some kind of continuous monitoring system.

10.2.4.2 If gas-filled enclosures are used for essential equipment, a water leakage alarm system should be installed.

10.2.5 Production systems in atmospheric compartments.

10.2.5.1 The internal space of a dry system may be considered as a hazardous area Zone. For Zone 0 intrinsically safe equipment normally should be the only type of electrical equipment which is allowed (in special cases other equipment which has been specially approved for Zone 0 installation by a recognized testing institution may also be considered), except when:

The internal space is filled with inert gas in normal operation, and with air or other oxygen-containing atmosphere only during maintenance and servicing operations.

In this case other types of explosion-protected equipment suitable for hazardous area Zone 1 or Zone 2 may be considered in each case.

A gas detector installation for continuous monitoring of the hydrocarbon gas content during maintenance and servicing operations should be required in such cases.
10.3 Protection of divers.

10.3.1 General safety principles.

10.3.1.1 If it is intended to use divers for maintenance and servicing, it should be ensured that all enclosures, cable armouring or other parts which may be touched by a diver in the water cannot become live or reach dangerous voltage levels under fault conditions such as by earth faults.

Note:
If possible, the system design and the diver’s suit with accessories should be such that the possible fault current through the diver’s body will not exceed the «perception level» which is about 0.5 mA A.C. or 2 mA D.C. If this is not possible, it should be ensured that the fault current through the diver’s body will not exceed the «let-go level» which is about 9 mA A.C. or 40 mA D.C., unless special types of protective disconnection devices for the power supply are used, see below.

If the fault current through the diver’s body could exceed the «let-go level» (9 mA A.C. or 40 mA D.C.), special protective devices should be used (e.g. earth leakage circuit-breakers), which disconnect the electric supply quickly enough to prevent heart fibrillation. For this purpose time release characteristics, in relation to the magnitude of the possible fault currents, are given e.g. in IEC publication No. 479 (1974), «Effects of currents passing through the human body».

If these conditions cannot be met, divers should not be allowed to operate in the water close to the production equipment when its electrical system is in operation.
SECTION 11
SAFETY OF PERSONNEL

11.1 General.

11.1.1 Application.
11.1.1.1 Section 11 applies to Subsea Production Systems intended for manned intervention for operation, testing, survey or maintenance. When a transfer vehicle for personnel is connected to the system, the Guidelines apply to the system including the vehicle.

11.1.1.2 This Guideline does not include general purpose transfer vehicles for personnel. But concerns such vehicles when the vehicle itself or systems in the vehicle are intended as substitute for systems or components required for the Subsea Production System.

11.1.1. General guidance for the vehicle is given in:
— Veritas’ Rules for the Construction and Classification of Submersibles
— Veritas’ Rules for Certification of Diving Systems.

11.1.2 Arrangement.
11.1.2.1 Moving parts, high voltage components, outlets from vents or safety valves should be located and/or protected so that hazard is minimized.

11.1.2.2 Subsea Production Systems manned when the vehicle itself or systems in the vehicle are intended for safe support of the life of personnel such as systems for maintaining and controlling a breathable atmosphere, temperature, humidity and pressure.

11.2. Life support systems.

11.2.1 Application.
11.2.1.1 11.2 only applies to Subsea Production Systems designed to house personnel inside compartment(s) at atmospheric pressure.

11.2.1.2 Life support systems are defined as the systems intended for safe support of the life of personnel such as systems for maintaining and controlling a breathable atmosphere, temperature, humidity and pressure.

11.2.2 Arrangement of compartments.
11.2.2.1 Subsea Production Systems manned when the transfer vehicle is not connected should have a connected rescue vehicle with sufficient capacity to carry the maximum number of personnel that may be present. And it should have at least two compartments separated by hatches with a diameter of at least 0.60 metres. Compartments and hatches should be designed for possible pressure in the other compartments corresponding to the water depth and possible relief pressure to sea.

11.2.2.2 Hatches and compartment bulkheads intended solely for separation of inert/breathable environments may be designed to withstand the maximum pressure differential possible across the compartment bulkhead or with suitable pressure relief devices to prevent compartment overpressure.

11.2.2.3 Hatches between compartments should be designed for operation from either side, and fitted with a system for equalization of a possible pressure difference between the compartments within reasonable time limits.

11.2.2.4 The size of the compartments closest to the escape hatches should be sufficient to contain the maximum number of personnel that may be present in the Subsea Production System.

11.2.3 Design principles.
11.2.3.1 Life support systems should be designed with systems that can replace each other in such a manner that the effect of a single failure cannot spread from one system to others thus causing a dangerous situation for personnel.

11.2.3.2 There should be emergency life support systems. These systems should have a capacity of at least 96 hours safe life support during normal operations. Emergency life support systems should be independent of a surface support. For Subsea Production Systems installed some distance from a base that may contain rescue facilities, a larger capacity emergency life support system may be required.

11.2.4 Contamination of breathable atmosphere.
11.2.4.1 There should be a mask available for supply of suitable breathing gas for each of the personnel. The masks should be ready for use in case of contamination of the normal breathing gas, and should have a capacity at least sufficient for all personnel during a period sufficient for reestablishing a normal breathing situation. The masks may be connected to either portable or permanent installed supply systems. In addition, and as a minimum one spare mask should be available in each chamber.

11.2.4.2 There should be a system for purifying or changing a contaminated atmosphere intended for breathing. This system should be designed for removal of contaminants due to normal and emergency operations. In emergency the system should be designed in relation to 11.2.4.1 to avoid a significant pressure buildup in the compartment. The maximum allowable pressure will be a function of the design of the vehicle, possible decompression equipment for the personnel and, tolerances of O2 partial pressure.

11.2.4.3 The contaminant level of a compartment should be analysed prior to opening the hatch. While occupied each compartment should have a monitoring, indication and alarm system for the gases that may contaminate the atmosphere intended for breathing due to failures. (O2, CO, H2S, hydrocarbon gases and inert gases etc. as applicable).

11.2.4.4 An indication system should be arranged centrally to indicate contamination of the breathing gas in all compartments when occupied. The indication centre should be in the transfer vehicle and/or in the compartment closest to the normal escape hatch when manned according to 11.2.2.1.

11.2.5 Design.
11.2.5.1 Veritas’ Rules for the Construction and Classification of Submersibles, section for Lifesupport Systems, give further guidance.

11.2.5.2 Veritas’ Rules for Certification of Diving systems give guidance for oxygen systems.

11.3. Access and Egress.

11.3.1 Dry transfer of personnel.
11.3.1.1 It is assumed that the personnel transfer vehicle is continuously connected to a compartment when the Subsea Production System is manned or that an alternative rescue vehicle is continuously connected.
11.3.1.2 Subsea Production Systems as defined in 11.2.2.1, should have more than one access hatch. Each of the hatches and locking systems should be compatible with the same transfer vehicle for alternative use.

11.3.1.3 For transfer systems where the transfer vehicles are locked to a sub-sea compartment, there should be system(s) that indicates to the personnel being transferred correct locking with regard to position, seal, and possible locking mechanism.

11.3.1.4 For transfer systems using a personnel transfer vehicle that is tethered from the surface, the depth dependant mating force or the possible locking systems between the sub-sea compartment and the vehicle and adjoining structures should have a superior strength compared to the tether-system, to assure a broken tether-system before any damage of the connection of the vehicle. Alternatively an automatic yielding and final release system for the tether may be fitted.

11.3.1.5 A possible locking system between the personnel transfer vehicle and the sub-sea compartment should have at least two independent alternative systems for operation, each of which should be able safely to separate the vehicle from the sub sea compartment. At least one of the systems should be independent of the surface supply.

11.3.1.6 The emergency buoyancy of a personnel transfer vehicle should be sufficient to carry out an ascent with maximum payload even when a possible tether is broken in the least favourable manner with regard to its weight.

11.3.1.7 The transfer vehicle should be equipped for internal release of a possible tether.

11.4. Fire protection for atmospheric oxygen containing environments.

11.4.1 Materials.

11.4.1.1 The use of combustible materials should be avoided wherever possible. Combustible materials include materials which may explode, or ignite and burn or smolder independently in the gas environment applicable for the compartments.

11.4.1.2 Structural components, furniture and knobs, paint, varnishes and adhesives applied to these should not be combustible unless satisfactorily protected against fire, as far as practicable.

11.4.1.3 Materials and arrangements should wherever possible to be chosen such as to avoid build-up of static electricity and to minimize the risk of spark production due to electrical failures.

Note: In inner areas without electrical equipment, furniture and floors of electrically conductor material equipment may be used. For inner areas where powerful electrical equipment is used the materials and arrangements may be chosen such as to minimize contact with earthed metalwork. A specific electrical resistance between $10^7$ and $10^{10}$ ohm.m. is considered to be suitable also for avoiding build-up of static electricity.

11.4.2 Fire Fighting Systems.

11.4.2.1 The fire fighting systems should be based on evaluations made from the results of the Failure Effect analysis. (Sec. 2). The analysis should contain evaluations on:

- possibilities for and the effect of fire compared with common accepted offshore surface systems.

Possible items of concern are:

- The most probable fire sources and fire development scenarios.
- Fire detection system principles.
- Alarm system principles.
- Possible failure in detection and alarm systems and warning of faults: e.g. voltage failure, broken line, earth fault etc.
- Fire extinction system principles: coverage, capacity and control of the extinction process.
- Extinguishing agent: efficiency, storage properties and compatibility with the emergency breathing plans.

11.4.2.2 The risk of fires, injuries and fatalities in this context should not be higher than accepted for surface production systems.

11.5. Communication and Location.

11.5.1 Surface/seafloor.

11.5.1.1 Between the Subsea Production System and the surface, at least two communication systems should be arranged for direct voice communication. One of the systems should be for emergency use and of a wireless type, for operation at a recognized frequency.

11.5.1.2 All major alarms should also be given at surface.

11.5.2 Internal Communication.

11.5.2.1 Communication systems should be arranged for direct voice communication between each of the compartments.

11.5.3 Location system.

11.5.3.1 A Subsea Production System manned according to 11.2.2.1. should have two independent system for locating it.
APPENDIX 1
FAILURE EFFECT ANALYSIS

General
This appendix is intended as guidance for one approach for the Failure Effect Analysis as described in 2.1.1.

Failure Effect Analysis
This comprises a systematic overview of the failure modes of the equipment and their effects on the safety of well control, personnel and equipment. Any method of analysis for obtaining the information may be used. Results presented on Failure Mode and Effect Analysis, FMEA, forms (example in table 1) and the total FMEA documentation should provide adequate basis for:

- Assessing the completeness of the FMEA. The FMEA is complete when all failure modes are identified for all main operational modes and at an appropriate level of detail (see below).

- Ensuring compliance with the Guidelines with respect to effects of failures on safety and detectability of failures.

Only failure modes affecting safety and associated system reliability need be included. The level of detail in the FMEA need not be high. Examples of what may be considered as components are:

- main connectors
- valves with actuators
- individual control/monitoring systems

The FMEA should consider the following modes of operation of the well:

- normal production (alternatively: injection) and production testing.
- maintenance by wireline, pumpdown tools or major workover by pulling tubing.
- possible pigging of flowlines
- production logging
- testing of valves
- kill well by mud circulation
- kill well by bull heading
- well pressure measurements on individual annular spaces
- possible disconnection of production riser

Only new conditions brought about by each mode of operation need be considered.

Within the limits stated above all modes of failure should be identified, e.g. technical failures, failures due to operations and accidental loading.

It should be documented how the possibilities for the individual failure modes and/or effects are taken into consideration through design, manuals for installation, operation and testing as well as through design, inservice inspection and maintenance.

Detailed FMEA.
There should be performed a detailed FMEA of dedicated safety barriers against loss of well control and, if applicable, safety measures for personnel in habitat systems. As a minimum, the detailed FMEA should encompass the subsurface safety valve and the wellhead and hanger. Control and Monitoring Systems of these safety systems should be included.

Similar analyses should also be made for other systems of special safety importance, e.g. evacuation systems in manned habitat systems, and riser systems.

The detailed FMEA should be laid out to identify failure modes that will reduce or destroy the safety function(s) of the equipment and in particular:

- failures from a common origin, e.g failures that are caused by the event(s) that make use of the safety barrier necessary
- failure modes introduced during normal operation and testing
- failure modes occurring when the system is in the activated mode
- detection possibilities of individual failures
- effects of the failures on safety.

Within the limitations stated above the FMEA should include all failure modes, e.g. technical failures due to accidental loading and operation.

Classification of Failure Modes
The failure modes of the analysis may be classified according to their effects shown in Table 2.

Failure modes with any effects in class 1 may then be listed separately as Very Critical Events (VCE). Failure modes with any effects in class 2 may be listed separately as Critical Events (CE).

The VCE list may be used as an appropriate document for each new application of the system. The VCE list should contain best estimates on the probability of any VCE occurring once or more during the entire time period during which the system is connected to a pressurized well. Where not satisfactorily statistically materials are available best estimates on probabilities may be obtained by extrapolation from related offshore activity and by justified engineering judgments.

The VCE and the CE should be separately listed in the operation manual along with descriptions of how the various failure modes will or may be detected in the control room during various modes of operation.

The operator should document that the VCE and the CE are known to the platform superintendents and the head of the platform of field operations. This information should be maintained by the operator and be less than one year old.

All common cause failures, i.e. failures of the safety systems having a cause that also results in need for using the safety system, should be treated as Very Critical Events.
Table 1  Typical example of a failure mode, effects and criticality analysis work sheet.

<table>
<thead>
<tr>
<th>Location/Field/Ident:</th>
<th>System:</th>
<th>Date:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Equipment Name</th>
<th>Function Identify No.</th>
<th>Failure Mode</th>
<th>Cause</th>
<th>Failure</th>
<th>Effect Local</th>
<th>Effect End</th>
<th>Detection</th>
<th>Alternative Provisions</th>
<th>Failure Probability</th>
<th>Criticality Ranking</th>
<th>Remarks</th>
</tr>
</thead>
</table>

Table 2  Effect of failure mode

<table>
<thead>
<tr>
<th>Class</th>
<th>Well control</th>
<th>Personnel</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (VCE)</td>
<td>Loss of control</td>
<td>Loss of life</td>
<td>N.A.</td>
</tr>
<tr>
<td>2. (CE)</td>
<td>One barrier remains or two barriers remain and working status of one unknown</td>
<td>Evacuation necessary</td>
<td>Damage to surface platforms/requirement likely; or subsea damage to several wells; or at least one well and manifold damaged</td>
</tr>
<tr>
<td>3.</td>
<td>Reduced safety (but none of above)</td>
<td>Reduced safety (but none of above)</td>
<td>Significant changes in loads on subsea production system</td>
</tr>
</tbody>
</table>

1) Only failure modes occurring when personnel are exposed.
2) Reduced redundancy and/or events destroying fail safe behaviour of any valve.