

NORSOK STANDARD

**CONDITION MONITORING
OF
LOADBEARING STRUCTURES**

N-005
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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Standards Institution).

The purpose of NORSOK standards is to contribute to meet the NORSOK goals, e.g. by replacing individual oil company specifications and other industry guidelines and documents for use in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, the NORSOK standard will be withdrawn.

Annex A and B are informative. Annexes C, D, E and F hereof are normative.

INTRODUCTION

This NORSOK standard focuses on adopting life cycle approach considering safety and cost related issues throughout the design, construction, operation and final disposal of offshore structures. The requirements specified hereof are however not necessarily applicable for the phases beyond decommissioning of an installation. The effects on DFI activities, including cost increases due to efforts to reduce IMR expenditure, should be considered against the IMR related aspects in operation phase. A key issue in this context is to retain the possibility of using safe and cost effective inspection methods.

This standard describes principles of how condition monitoring of loadbearing structures should be planned, implemented and documented to maintain a safe installation and to comply with the NPD regulations including the requirements in the relevant standards.

1 SCOPE

This NORSOK standard describes principles, functional requirements and guidelines for condition monitoring of the loadbearing structures throughout their operative lifetime until the decommissioning. The standard is applicable to all types of offshore structures used in the petroleum activities, including bottom founded structures as well as floating structures.

The standard is applicable to condition monitoring of complete structures including substructures, topside structures, vessel hulls, foundations, and mooring systems.

The standard covers all aspects related to condition monitoring, including in-service inspection and maintenance planning, implementation, structural integrity evaluation, condition monitoring documentation. Assessment of offshore structures, when the initiators exist, is also addressed.

2 NORMATIVE REFERENCES

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced below.

ISO 13819-1	Offshore structures part 1: General requirements
EN 473	Qualification and certification of NDT personnel - General principles
NORSOK N-001	Structural design
NORSOK N-002	Collection of metocean data
NORSOK Z-001	Documentation for operation (DFO)

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Acceptable damaged condition	Acceptable damaged condition is a condition where there may be for example damage to the installation's loadbearing structures, but which based on a detailed evaluation or assessment may be justified for further operation on certain conditions, such as monitoring, repairs within a stipulated time limit or with operational limitations.
Atmospheric zone	That part of the loadbearing structures which normally is not subjected to repeated sea water wetting and drying.
Can	Can requirements are conditional and indicates a possibility open to the user of the standard.

Company	The operating company of an offshore installation.
Condition monitoring	Systematic examination and evaluation of the overall structural condition ensuring that an acceptable level of structural integrity and safety is maintained.
Condition report	Documented results from condition monitoring.
Condition summary	Description of the condition of the loadbearing structures in the operational phase.
Contractor	The company to design, fabricate or install complete or parts of an offshore installation.
Deviation	Lack of accordance between actual condition and regulatory requirements, industry requirements, internal Company requirements, the design condition, or the intended use.
DFI resumé	Design, fabrication and installation resumé, developed in accordance with the Company condition monitoring philosophy and Norsok Z-001 DFO.
General damages	Corrosion, visible cracks, dents, gouges, abrasion, deformations, etc.
Gross damages	Large deformations, severed joints, missing member, etc.
Informative references	Shall mean informative in the application of Norsok standards.
Loadbearing structures	Those part of an installation that have transfer of actions as their main objective, such as substructure of bottom founded structures, gravity base structures, hull of floating units, bridges, deck structures, drilling derricks, flare booms, crane pedestals, helideck structures, lifeboat platforms, riser support systems, mooring systems, etc.
May	May indicates a course of action that is permissible within the limits of the standard (a permission).
Normative references	Shall mean normative in the application of Norsok standards.
Norwegian petroleum activities	Petroleum activities where Norwegian regulations apply.
Operator	A company or an association which through the granting of a production license is responsible for the day to day activities carried out in accordance with the license

Periodic activities	The activities to be performed on a regular basis.
Petroleum activities	Offshore drilling and production, treatment, and storage of hydrocarbons.
Phase	The relevant stage applicable to each individual installation: design, construction, operation, decommissioning and final disposal.
Recognized classification society	A classification society with recognized and relevant competence and experience from the petroleum activities, and established rules and procedures for classification/certification of installations used in the petroleum activities.
Shall	Shall is an absolute requirement which shall be followed strictly in order to conform with the standard.
Should	Should is a recommendation. Alternative solutions having the same functionality and quality are acceptable.
Signs of gross damages	Gaps, spalling of marine growth or surface coating, etc.
Splash zone	That part of the loadbearing structures which is subjected to repeated sea water wetting and drying.
Structural integrity	Structural soundness and strength, stability, buoyancy in so far as they are relevant to life safety, the environment, and substantial economic values.
Submerged zone	That part of the loadbearing structures which normally is submerged in sea water and exposed to the constant influence of this element.
Unacceptable damaged condition	Unacceptable damaged conditions is a condition which involves major damages significant to the structural integrity and which, throughout different levels of assessment, has been identified as noncompliant to the prevailing regulations. This condition is not acceptable for further operation.

3.2 Abbreviations

ACFM	Alternating current field measurement
ACPD	Alternating current potential drop
CP	Cathodic potential
CSU	Column Stabilized Unit
DFI	Design, fabrication and installation
Dff	Design fatigue factor
DP	Dynamic Positioning

EC	Eddy current inspection
IBCM	Instrumentation Based Condition Monitoring
IMR	In-service Inspection, Maintenance and Repair
ISO	International Organization for Standardisation
MPE	Magnetic particle examination
NDE	Non-Destructive Examination
NPD	Norwegian Petroleum Directorate
PDO	Plan for Development and Operation
ROV	Remotely Operated Vehicle

4 GENERAL

4.1 Objectives

The objectives of condition monitoring for loadbearing structures are to ensure that an adequate level of structural integrity is maintained at all times.

4.2 Regulations, standards and premises

Loadbearing structures used in petroleum activities shall throughout their lifetime comply with relevant national and international regulations. The loadbearing structures should be inspected, evaluated, assessed and maintained, in line with this standard and ISO 13819-1 "Offshore structures, Part 1: General requirements".

The loadbearing structures shall at all times meet the intent of the standards to which they were originally designed.

The condition monitoring philosophy provided by the Company shall be applied as a part of the design premises.

A certificate granted by a recognised classification society, based on the classification rules and offshore survey may be accepted as a verification of the condition, provided that the classification rules applied satisfy requirements as specified in the regulations, the normative standards inclusive this standard, and other applicable documents. The same requirements are also applicable to re-qualification of fitness for an offshore installation dependent on if the installation fulfils the requirements at the date of PDO.

When the verification of structural condition is based on the rules and services of a classification society without issuance of maritime certificates, the requirements to structural condition monitoring and documentation should be in accordance with the regulations and this standard. The Classification society will in this case be regarded as a technical consultant for the Operator. The Operator has the responsibility towards the authorities.

4.3 Condition monitoring principles

The Operator shall throughout the lifetime of the installation ensure that the loadbearing structures are suitable for the intended purpose.

The Operator shall monitor the condition of the operated offshore installation in a systematic manner. This may include development of an overall philosophy and strategy for condition

monitoring, establishing in-service inspection systems and long term inspection programs, in-service inspection planning, offshore execution, data logging, evaluation and assessment, implementation of repair and mitigation measures, emergency preparedness, etc.

The structural integrity may be considered based on component check, system capability assessment or / and system safety assessment.

Note: For petroleum activities on the Norwegian Continental Shelf, the systems' loadbearing capabilities shall be in accordance with the Regulations related to loadbearing structures. Deviations from the above-mentioned regulations, e.g. the use of system capability assessment or/and system safety assessment methods, is regarded as a deviation from the regulations and requires an exemption from the NPD.

In order to achieve the objectives as described in subclause 4.1, the condition monitoring shall determine, within a reasonable level of confidence, the existence, extent and consequence of:

- degradation or deterioration due to fatigue or other time dependent structural damage
- corrosion damage
- fabrication or installation damage
- damage or component weakening due to strength overloading
- damage due to man-made hazards
- excessive deformations

and for floating units specially:

- violating requirements to intact stability
- defects on watertight doors, hatches, automatic shutting functions, onboard warning system
- defect on ballasting system, tank sounding, valves, pumps, etc.
- damage of mooring system

Areas of concern shall be:

- human life and health
- the environment
- properties, operating interests and other economic aspects.

The condition monitoring programme is subject to continuous updating as it involves many factors in the nature of uncertainty such as environmental conditions, failure probabilities, damage development, etc. In addition, a revision of the programme may also be necessary as a result of development of tools and methods.

In case the condition of an offshore installation is monitored adopting other principles, the Operator shall be able to document that requirements to structural integrity and other functional requirements are met.

4.4 Technical documentation

The Operator shall be able to document the system and acceptance criteria applied to in-service inspection planning, offshore execution, result evaluation and assessment, and emergency

preparedness for structural damage in connection with extreme conditions and accidents, and reporting routines. The documentation, including relevant procedures of different levels, shall be available to the authorities as requested.

Computer programs to be used in condition monitoring of offshore loadbearing structures shall be documented to show that they are suitable for their intended purposes and that they are properly verified.

For mobile installations registered in a state's shipping register and certified by a recognized classification society, it should be documented that condition of the structure, during its use in the petroleum activities, complies with the requirements of the legislation enforced by the national authorities. In case of non-conformance, the deviation, its significance and plan for implementation of necessary corrective measures shall be reported to the authority as required.

4.4.1 IMR design requirements

A condition monitoring philosophy document shall be provided by the Company as stated in subclause 4.3.

This document shall contain the Operator's condition monitoring philosophy, applied inspection methods, access requirements, limitations of inspection related to safety and operations, and corresponding design requirements such as corrosion allowance, corrosion protection, specific fatigue requirements, etc. Any additional requirements regarding DFI information may also be addressed in this document.

This philosophy document shall be used as a part of the design basis for the loadbearing structure.

4.4.2 IMR design brief and design report

The design Contractor shall in the design brief implement Operator's IMR design requirements and requirements in this standard and demonstrate how the requirements can be met by the design. The design brief shall cover, as a minimum, the areas such as overall structural redundancy, provisions of critical areas and components, consequences of failures, accessibility, possible repair methods, extent of inspection and inspection methods which are premised for the design.

An IMR design report shall be prepared by the design Contractor accordingly.

4.4.3 DFI resumé

A summary document containing key technical information and with reference to all relevant DFI documents shall be prepared in parallel to the other works during the design and construction. The information should include design basis, condition monitoring concept, areas of vital importance to the structural integrity and functional performance, deviations, and the other as-built data significant to developing condition monitoring programme and to the uses in the operation phase.

Requirements to the DFI resumé, are detailed in NORSOK Z-001 "Documentation for operation (DFO)", Annex A.7 DFI resumé and Annex C DFI resumé for loadbearing structures.

Regarding deviations, distinction should be made between deviations from the regulations, Company's project specific requirements, relevant codes and standards, professional publications, construction non-conformance, and other deviations from the conditions reported in the design reports. Particular attention should be given to any parts of installation's loadbearing structures that

have been damaged or repaired during construction phases and which may be significant to the structural integrity and installation's functional performance.

4.4.4 Periodic framework programme

The Operator shall establish a periodic framework programme for condition monitoring.

The inspection results and condition evaluation of these shall be reported in the condition report. Characterization of damage significant to the structural integrity and functional performance shall provide user groups with opportunity to assess the condition of the loadbearing structures and initiate corrective measures, in order that an adequate level of safety can be maintained.

History outline of damage or defects revealed, repairs and major modifications carried out in the operation phase should be included in a condition resumé. The mentioned outline should together with main results from structural studies, evaluations and assessments completed in this period be included in the condition summary which should be subject to continuous updating.

5 PROGRAMME FOR CONDITION MONITORING

5.1 Condition Monitoring Philosophy

The detailed condition monitoring programme of loadbearing structure depends on the design and maintenance philosophy, the current condition, the capability of the inspection methods available and the intended use of the structure. The focus should be put on the identified safety critical components, in addition to improving the accuracy and reliability of prediction of structural performance and in-service inspection methods.

Condition monitoring of the loadbearing structures includes the following major activities:

- Establishing a condition monitoring system comprising strategy, acceptance criteria, in-service inspection philosophy, evaluation and assessment methodology and a report routine. Necessary tools and software should also be defined in the system.
- Development of a long term condition monitoring programme (periodic framework programme) which is subject to continuous updating and revision.
- To carry out detailed inspection planning on a regular basis, e.g. annually.
- To execute the inspection work packages in accordance to the requirements specified.
- To record, evaluate and report inspection results.
- To monitor environmental conditions and the structural behaviour such as dynamic motions, foundation behaviour, erosion, strain of key components, etc. if the value or characteristics are highly uncertain. See also NORSOK N-002 "Collection of metocean data".
- Initiation of fitness for purpose assessments if initiators are revealed during routine evaluation of the inspection results.
- Consideration and conception of prevention and mitigation measures.
- Development of emergency preparedness systems including procedures for mobilisation of duty engineers, evacuation plan, system for unscheduled inspection on special occasions, post event assessment, production re-start after the events.

It should be noticed that operational aspects, such as inspection vessel management, use of ROVs, etc., are as important as the structural aspects with respect to life cycle cost and operational safety.

5.2 Requirements to a programme for condition monitoring

A programme for condition monitoring shall comply with the regulation requirements relating to planning of this type of activity. Structural design, technical solutions and areas requiring particular attention, for example accepted deviations from the presumptions described in and dealt with in the DFI resumé and the condition summary or the structural components significant to structural integrity and functional performance, should be focused when requirement specifications for condition monitoring are prepared.

Loadbearing structures on new installations shall be reviewed in order to get a picture of possible damage, defects deterioration and deviations revealed during the design and construction phases. This review should be carried out in the light of the design criteria of the installation. Knowledge of any damage and defects may enable the Operator to initiate necessary measures in time, and assess the need for monitoring, repairs or operational limitations for the installation.

When operational limitations are introduced as a part of the mitigation measures resulting from fitness for purpose assessment, the limitations may be included considering an overall safety level of the installation in question.

For floating structures a stability monitoring system shall be installed onboard.

5.3 Intervals for condition monitoring

5.3.1 Periodic framework programme

The first of the framework programmes should have an extent which as far as possible provides a description of the overall condition of the loadbearing structures. This framework programme shall be evaluated in relation to stipulated acceptance criteria for operation and deviations which is described and dealt with in the DFI resumé.

The first of the framework programmes should also be planned in connection with the condition monitoring which is to be performed after the installation is positioned, or in connection with putting the installation into operation.

Practice from the Norwegian petroleum activities indicates that the first framework programme should be completed within 3-5 years, depending on for example platform exposure, structural redundancy and extent of inspection during DFI phases. Based on information gained in the first period of operation and knowledge about the application of new analysis techniques and methods within condition monitoring and maintenance, the interval may be altered. A change in the duration of the framework programme should be based on maintaining an adequate level of safety and proper documentation of this.

The Operator should give emphasis to systematization of previously acquired data in subsequent planning and implementation of condition monitoring.

The framework programme and any changes on these shall be reported according to the regulations.

5.3.2 Initial condition survey

During the first year of operation of the installation, an initial condition survey should be carried out in order to enable an overall assessment of the ability of the loadbearing structures to meet the redefined acceptance criteria. The condition survey will be able to disclose damage or defects if any at an early stage such that corrective measures can be initiated as needed.

This activity may be included as part of the first periodic framework programme.

5.3.3 Periodic condition monitoring

Condition monitoring of the loadbearing structures shall be carried out regularly. Condition monitoring is assumed to be carried out according to the prepared periodic framework programme.

Requirements on condition evaluation will be specified as a part of condition assessment in subclause 6.5 which covers both routine evaluation of in-service inspection results and fitness for purpose assessment.

5.4 Unscheduled inspection on special occasions

Inspection should be conducted after extreme/accidental events or as a result of operational changes. The unscheduled inspection may also be conducted to monitor repair or other remedial programs. Any further actions to maintain an adequate level of structural integrity should then be based on results of the inspection and the other information available.

An unscheduled inspection may, subject to evaluation, be advanced or delayed to coincide with a scheduled inspection program.

5.5 Updating of programme for condition monitoring

The framework programme should be subject to review within the period of time for which it is applicable.

If the results from condition monitoring indicate deviations of significance to the structural integrity of loadbearing structure, the intervals for condition monitoring as well as the condition monitoring philosophy should be reconsidered and the framework programme should then be updated accordingly.

6 IMPLEMENTATION OF CONDITION MONITORING

6.1 Safety for inspection personnel

Safety for personnel engaged in inspection and maintenance activities should be considered in the design phase.

Diving operations should be avoided where possible.

It is the Operator's responsibility to ensure that:

- inspectors have received the necessary training and skills with respect to safety in inspection work

- safety requirements stipulated in international and national safety regulations are known, implemented in company procedures and adhered to
- personal protective equipment in compliance with international and national regulations is available and is being used.

Safety can be increased by planned methods and equipment, by procedures, and, not least, by alertness paid by the individual inspector.

6.2 Qualification of inspection personnel

Visual inspections, pressure testing and NDE shall be carried out by personnel holding practical experience and theoretical knowledge enabling them to discover and to assess defects found on the structure or equipment under examination.

Personnel responsible for offshore inspection by NDE shall be qualified according to EN 473/NORDTEST Level 3 or equivalent.

The NDE inspectors shall be qualified according to EN 473/NORDTEST Level 2 or equivalent.

Personnel to carry out control of surface treatment shall be qualified according to FROSIO, NACE or equivalent.

Personnel responsible for the assessment of the condition of the structure or equipment to be monitored shall have relevant engineering competence and comply with the Operator's requirements to practical experience in condition monitoring of offshore loadbearing structures.

Assessment personnel shall monitor the work carried out by inspection personnel.

6.3 Detailed inspection planning

The condition monitoring should primarily be concentrated on discovering serious damage or defects on the loadbearing structures. Also the potential defects and deterioration which may escalate into damage significant to structural integrity and functional performance shall be inspected.

It may, when appropriate, be practical to differentiate between condition monitoring in the atmospheric zone and in the submerged zone, as accessibility and the extent of inspection differs between these zones. The splash zone may be covered under one of them or under both categories. It should however be noted that the practical possibility of performing in-service inspection in the splash zone, deploying surface air diving or ROV, may strongly be affected by the weather condition. Needs for splash zone inspection should therefore be reduced to a minimum.

It should be noted that there may be several sets of values defining splash zone with respect to corrosion allowance, wave slamming, fatigue due to repeated sea water wetting and drying, in-service condition monitoring and repair, etc. The term splash zone hereof is related to the condition monitoring. The Operator may, as appropriate, define the splash zone altering from the physical splash zone, dependent on types of structure and condition monitoring philosophy.

An important part of condition monitoring is detection and a characteristic description of any damage/defects, as well as detailed information of corrosion protection and condition.

The Instrumentation Based Condition Monitoring, IBCM, may be used as an alternative to the conventional inspection methods. The IBCM is particularly suitable to the areas with limited accessibility for performance of condition monitoring and maintenance.

If the IBCM is included as part of the condition monitoring programme, criteria for use should be enclosed with the condition monitoring programme. The criteria should specify to what extent the IBCM is used for monitoring of existing condition, or for detection and characterization of damage or defects.

6.3.1 Atmospheric zone

The condition monitoring is carried out in order to detect possible damage or defects due to the negative effects including the following parameters:

- structural design
- air humidity
- condensation
- sea spray
- temperature variations
- mechanical loads
- wave loads
- other environmental conditions
- static and dynamic loads
- altered operational conditions

The programme for condition monitoring of the atmospheric zone should in particular take into account areas with restricted accessibility for condition monitoring and maintenance.

6.3.2 Splash zone

Condition monitoring in the splash zone should in addition to the parameters mentioned in 6.3.1 in particular consider the effect of:

- the alternating effects of wet and dry surface.
- denting of the structure
- missing or deformed structural members
- pitting
- marine growth

6.3.3 Submerged zone

With regard to submerged loadbearing structures the condition monitoring should, in addition to the parameters mentioned in 6.3.1 consist of a visual survey to detect, particularly, possible damage/defects or conditions that may cause an obstacle to effective condition monitoring, including:

- marine growth
- damage to the hull
- scouring of the sea bed under or in the immediate vicinity of the installation or build-up of seafloor substance/ sediments
- build up of cuttings or sediments if such build-up covers a significant part of the structure

- composition of the sea water and pH values
- temperature variations
- specific conductivity of sea water and bottom sediments
- biological activity
- movement in bottom sediment
- mechanical loads including anchoring
- cathodic protection conditions

6.3.4 Areas requiring special attention with regard to cathodic protection

Based on the evaluations of criticality and consequences as a result of deviations, the Operator should give emphasis to identifying areas requiring particular attention. This applies also to areas with restricted accessibility for condition monitoring and maintenance.

The protection level for the loadbearing structures shall be described and monitored. For installations without corrosion protective coating, such survey should be completed at the latest 3 months after installation at the field. For installations with corrosion protective coating, such survey should be completed at the latest 12 months after installation at the field.

The location of measuring points in respect of cathodic protection or corrosion monitoring should be selected on the basis of knowledge of the structure from the design, construction and operation phase.

6.4 Inspection record

The Operator shall maintain an up to date filing system for results and evaluations from the condition monitoring programme throughout the lifetime of the installation. The data may include video tape, inspection log, first hand inspection report, evaluation and recommendations.

Such data records should also include tools/techniques employed, planned and actual scope of work and description of findings and any anomalies discovered.

The data should preferably be collated and recorded in an electronic data base.

6.5 Condition assessment

It is of importance that the overall risk of the installation are focused during the assessment process.

When inspection data becomes available or when an inspection work package needs to be revised, a routine evaluation shall be conducted to:

- confirm that the acceptance criteria are met or that the ongoing inspection is suitable to the use.
- recommend any remedial measures or a revision of the inspection plan
- initiate fitness for purpose assessment

The following factors may be included in the evaluations:

- DFI documentation including environmental criteria and other premises, design and analysis results, construction record, extent of inspection during the construction,
- historical findings,
- modifications and repairs,

- historical extreme events,
- performance of corrosion protection system.

If the condition monitoring reveals an extent of damage of such serious nature that the safety level may not be maintained, the consequences for the structural integrity of the installation shall be assessed. Upon results of the assessment any remedial measures including operational limitations of the installation shall be considered and initiated according to the regulations.

The fitness for purpose shall also be initiated when significant deviations from the design, for example significantly increased loading due to addition of facilities, are present.

The remedial measures to be initiated should then be considered relative to the risk so that an adequate safety level is maintained as is reasonably practicable. The remedial measures may be prevention measures such as structural strengthening, load reductions, change of condition monitoring procedures, etc. or mitigation measures such as demanning, evacuation procedures, etc.

ANNEX A INSPECTION METHODS (INFORMATIVE)

A.1 General

This annex describes different in-service inspection methods/techniques which are widely used in condition monitoring of offshore structures.

In general, all inspection methods/techniques available for fabrication inspection are also applicable for above water in-service inspection. See also NORSOK M-101 “Structural Steel Fabrication”

Examination by destructive methods, e.g. core drilling, are used to detect hidden damage or defects of concrete structures. The methods are also used to assess the mechanical strength or parameters significant to concrete durability.

A.2 Selection of inspection methods

For a given task, appropriate inspection method(s) should be selected considering both motivations of the inspection, reliability of the methods, result presentation, ROV applicability, weather dependency, equipment accessibility and offshore time consumption.

It is recommended to select the methods which allow use of ROV, as long as they are applicable and appropriate.

In general, visual inspection with cleaning, highly accurate electronic NDE and Ultrasonic will only be applied to selected locations or as a follow-up of the other inspection methods.

For certain purposes, The Instrumentation Based Condition Monitoring, IBCM, can be used as a cost effective alternative to the conventional inspection methods, particularly for monitoring areas with limited accessibility, or as a supplementary mean to e.g. verify novel design solutions. Typical applications of IBCM can be strain monitoring of jacket structures, foundation behaviour during extreme storms, propeller shaft and rudder systems of ship shaped units, turret, riser and mooring systems, etc.

The quality of visual examination is very dependent on professional quality of the inspector, who must know:

- where to look
- what to look for; and
- how to report

A.3 Actual in-service inspection methods

A.3.1 Above water inspection methods

A.3.1.1 General visual inspection

General visual inspection is the most commonly applied inspection method to reveal gross and as well as general damages. Visual inspection requires a satisfactory ambient light level and additional tools like halogen lamps, torches, etc.

A.3.1.2 Close visual inspection

Critical areas or areas with high probability of crack occurrence will be subject to close visual inspection. Close visual or close-up inspection is normally defined to “within the reach of the arm’s length”. Note that when light colour paintings are used, very small fatigue cracks may be detected by this method due to paint cracking and rust. Close visual inspection should always be carried out before NDE work is started.

A.3.1.3 Non-destructive Examination, NDE

Thickness measurements are carried out by ultrasonic methods. Thickness measurements need not to be carried out as long as paint systems are maintained.

Corrosion protection level for impressed current systems, CP measurements are normally to be carried out at regular intervals to confirm the proper working of any impressed current system.

Crack detection. Surface breaking defect due to fatigue may be detected by means of MPE or by EC.

MPE requires removal of paint, and it is often difficult to reinstate the original corrosion protection level by touch-up painting. This may in turn lead to future corrosion attack and deteriorated fatigue properties. This is mainly a problem for semi submersible and mono hull (ship) structures. Provided sufficient fatigue life has been accounted for in design, the better method would be to carry out a careful close visual inspection. Areas where the fatigue resistance needs to be confirmed by NDE or where the consequence of a developing fatigue crack is unacceptable may be examined by means of EC. MPE should only, if necessary, be used to further assess a confirmed indication, either from the EC or the close visual examination.

A.3.1.4 Pressure testing/tightness testing

Tanks are to be hydraulically tested to verify structural integrity of the boundaries to adjacent tanks and compartments. The tank shall be 100 % filled with water up to the top of its air pipe level.

Air may be used for tightness testing, in which case the overpressure is to be kept at a minimum by means of a watertube and shall not exceed the design pressure of the tank. However, for personnel risk reasons, in no case the overpressure must exceed 2000 mm water gauge.

A.3.2 Below water inspection methods

The most widely used methods, their capabilities, features, and limitations are briefly discussed and included in Table A.1 on the next page.

Table A.1 - Below water inspection methods

Methods/techniques		Capability	Technical description	ROV applicability	Cost related aspects
Visual	Without cleaning	Scour, sea floor instability, gross damage, signs of gross damages, existence of anodes	Video based reporting.	ROV	Fast
	With cleaning	Follow-up investigation of general damage	Video based reporting	Work class ROV	Time consuming
Electronic	MPE	Fatigue damage	Existence and length of surface crack.	Work class ROV	Cleaning required. Time consuming
	EC	Fatigue damage	Length of surface crack, may also be used for depth measurement. Independent evaluation possible	ROV	Relatively fast. Through coating up to ca. 10mm.
	ACPD	Fatigue damage	Depth of surface crack. Supporting MPE.	Work class ROV	Cleaning required. Time consuming
	ACFM	Fatigue damage	Both length and depth of surface crack. Independent evaluation possible.	ROV	Relatively fast. Through coating up to ca. 10mm.
Ultrasonic		Wall thickness, corrosion, fatigue and fabrication defect, post-repair inspection	Embedded defects.	Work class ROV, Usually performed by diver	Cost level depends on different applications.
FMD		Fatigue damage and post-event damage	Through thickness crack. Excellent tool for rapid screening.	ROV	Fast No cleaning necessary.
Cathodic Potential		Corrosion	Anode performance. Often combined with visual inspection.	ROV	Field calibration necessary, but the readings can be taken quickly
Other	Dimensional measurement	Scour, subsidence, marine growth, dent, out-of straightness, corrosion pit size, etc.	For special purposes.	May be performed by ROV, but with limited capability	
	Stress&def. monitoring	Structural behaviour monitoring	For special purposes.		
	Radiography	E.g. testing of hyperbaric welds	Internal defects		

ANNEX B SAFETY PROCEDURES FOR IN-SERVICE INSPECTION (INFORMATIVE)

B.1 General

The Contractor to execute in-service inspection shall have safety procedures which in principle include the following routine:

- A safety meeting is to be held before any inspection is started to discuss all aspects of safety with special attention to gas testing procedures, command and communication lines, and rescue arrangements.
- A senior officer is to be appointed to be in charge of operations.
- The inspection team, in case of internal structure inspection, shall always comprise a minimum of two persons, however normally not more than four persons for easy escape/rescue.

B.2 Lifting appliances used for survey

For some inspections, use of mobile lifting appliances may be the only alternative. Such inspections shall only be carried out by personnel that have received special training and qualification in such techniques. The following safety aspects shall be assessed as applicable:

- if crane is based, the qualification of the crane operator,
- availability and condition of safety harness,
- facility of emergency stop,
- technical condition of lifting appliances (periodical inspection records),
- stability/capacity of barge,
- barge anchoring/mooring,
- lifting appliance's supporting to the barge,
- means of communication between lift platform and crane operator/barge personnel,
- unexpected relative motions of the lift platform caused by external forces like wind, waves, currents,
- attachment facilities for absailing equipment.

B.3 Inspection of Internal structures

For inspection in crude oil tanks, ballast tanks and void spaces, the following safety aspects shall, as a minimum, be controlled

- The tank/space shall be thoroughly ventilated. As many open exits as possible shall be provided.
- Gas testing before tank entry:
 - Oxygen contents shall be not less than 21 per cent by volume.
 - Hydrocarbon gases shall be not more than 1 per cent of LEL (Lower Explosion Limit)
 - Benzene (C₆H₆) shall be not more than 5 ppm (by multigas detector, Draeger or similar),
 - Hydrogen Sulphide (H₂S) shall be not more than 5 ppm
 - Limits for other toxic components from chemical products, as applicable, shall be available on board.

For tanks connected to Inert Gas Systems:

- max. carbon monoxide (CO): 35 ppm (by Draeger Tube or similar)
- max. nitrogen dioxide (NO₂): 2 ppm (by Draeger Tube or similar)
- max. nitrogen monoxide (NO): 25 ppm (by Draeger Tube or similar)
- max. sulphur dioxide (SO₂): 2 ppm (by Draeger Tube or similar)
- Tank preparations
 - Continuous forced tank ventilation, if possible ducted down to the bottom of the tank.
 - Do not use inert gas fans due to possible contamination.
 - Blank off inert gas branches or remove sections of same.
 - Cargo branches leading to, or passing through tanks to be drained off and flushed with water.
 - Valves in all pipelines leading to tank during inspection to be closed and sign posted.
 - All adjacent tanks to be in the same gas free condition as the tank being inspected. As a minimum, it shall be confirmed that there are no structural leakage or valve leakage.
- Safety watch and safety equipment
 - No one shall enter a tank or void space without a safety watch stationed at the tank hatch throughout the inspection.
 - The safety watch has the authority to order evacuation of a tank and is responsible to register personnel entering the tank.
 - Communication shall be maintained between safety watch and inspection personnel by means of walkie-talkie certified intrinsically safe.
 - Rescue equipment, including breathing apparatus, resuscitators, smoke masks, rescue lines, stretcher(s), etc. to be available.
- Tanks must be sufficiently clean and free from water, scale, dirt and oil residues to allow safe and reliable inspection.
- No inspection must take place as long as ballast is being pumped in or out of that tank.
- Use of ultrasonic, MPE or EC equipment should in general require a “hot work certificate”.
- Free climbing above bottom or stringers represents a danger and should be evaluated.
- Natural lighting to be provided by opening up all tank hatches, supplemented by suspended lighting. Each inspector shall carry a torch of high intensity beam type. Use of torches and light in flammable atmosphere should be subject to approval by the Company.
- Inflatable or rigid rafts shall have sufficient compartmentation to provide adequate buoyancy and stability with one compartment ruptured.

ANNEX C JACKET STRUCTURES (NORMATIVE)

C.1 General

This annex contains additional requirements specific to condition monitoring of the jacket structures.

C.2 Jacket integrity

Jacket structures are usually designed with an in-built structural redundancy so that the acceptance level of structural integrity of a such structure may be significantly higher than strength of first failed component, dependent on manning and operation of the installation.

The alternative approaches for quantitatively assessing the structural integrity may for example be based on design condition, component failure probabilistics, reserve strength ratio, structural reliability, overall quantitative risk etc.

To predict and to determine with a reasonable level of confidence the existence, extent and consequences of deterioration, damages and defects of the structural components are essential to maintain structural integrity of a jacket structure.

C.3 Classification of the installations and their structural components

C.3.1 Purpose

Purpose of classification is to identify the needs of different levels of in-service inspection and thereby to plan a cost effective condition monitoring programme maintaining structural integrity of the installation.

An Operator may, in line with its condition monitoring philosophy, classify the installations and their structural components according to some or all of the criteria described in the following sections. Based on the specified requirements, classification information shall then be included in the DFI resume, which will form the basis for inspection planning, inspection execution, inspection results evaluation and assessment of structural integrity and fitness for purpose. Reference is also made to NORSOK standard Z-001 "Documentation for Operation", Annex A.7 "DFI Resume".

It should be noted that uncertainties associated with different analyses and failure modes may not be the same so that these uncertainties should be considered and reflected in the condition monitoring programme.

C.3.2 Classification of a jacket structure

An offshore jacket structure may be classified according to:

- Personnel safety, environmental exposure and criticality to field operation
- Design code applied
- Present structural condition
- Reserve strength of the platform

C.3.3 Classification of structural components on a jacket

A structural component on jacket may be classified according to:

- Member redundancy (relative to jacket system capacity)
- Residual strength of tubular joint
- Design fatigue life of joint
- Utilisation of structural component
- Accessibility

C.4 In-service inspection planning

In-service inspection plan shall, as a part of condition monitoring process, be developed and revised for each installation soon after receiving DFI resumé, and be periodically updated throughout its service life. The inspection planning shall focus on condition verification of the structural components so that the structural integrity at any time will effectively be secured.

In general, a jacket structure may, during its in-service life, have the following defects, damage or deterioration:

- Joint degradation due to repeated actions
- Corrosion damages
- Component failure due to overloading
- Component damages due to accidental actions
- Other irregularities, such as marine fouling, scouring, etc.

The damages / failure due to overloading or accidental actions will usually be taken care of by inspections on special occasions, whilst existence and extent of the other damages / defects should be determined during regular offshore inspections.

There are as described in Annex A "Inspection Methods" several methods applicable to jacket inspection with different level of accuracy. For the key components with low redundancy, high level inspection method, for example one of the NDE methods should be used. The high level inspection method should generally also be applied for further examination when an indication was detected using lower level inspection method such as visual inspection without cleaning.

Special attention should be given to the joints of major importance to the structural integrity of the jacket in and just below the splash zone.

It should be noted that Flooded Member Detection is a cost effective method for jacket structures, particular when a joint has an adequate residual strength (cracked strength) or / and the incoming brace has sufficient redundancy.

To be able to identify critical areas and key components which are of major importance for structural integrity, ultimate strength analyses such as pushover type analysis are recommended to be performed for the jacket structures, preferably already during the design.

C.5 Assessment process

Inspection results shall be evaluated against prediction and accumulated experience in operation of the field. The evaluation shall be directed to:

- Verifying if the requirements for assuming on-going structural integrity of the jacket overlong term are met.
- Improvement of condition monitoring (precision, appropriate method to the potential damages / defects, reasonable inspection interval, etc.).
- Revealing any assessment initiators for further structural assessment.

When initiators for assessment occur as a result of the evaluation or due to operational changes, the structural assessment shall be performed to verify platform's fitness for purpose, which may, for example when the jacket violates the design code, imply some restrictions for its normal operation, such as requirements for production shut down during extreme conditions.

The following data / information may be required for assessment of jacket structures:

- General information:
 - Original and current platform use and functions
 - Location, water depth and orientation
 - Manning level
 - Platform configuration, piles, conductors, risers, etc.
- DFI information:
 - Regulations, design codes and other specifications applied
 - Environmental data and wave kinematics
 - Deck elevation
 - Foundation data
 - Material properties and traceability record
 - Design actions including weight information
 - Drawings
 - Other "as-built" and "as-installed" information
- Historical information:
 - Extreme events and the structural performance during the events
 - Deviations, defects, damage significant to structural integrity and functional performance
 - Analyses and as-built information of modifications, repairs and other remedial measures
 - Scour at foundations

- Other studies and assessments conducted in operation phase

- Survey and instrumentation

The analyses to be applied in such an assessment may be design code check, non-linear push over analysis, low fatigue cyclic analysis, structural reliability assessment, and quantitative risk assessment dependent on the current condition and exposure of the installation.

The structures which are classified as low consequence installation with respect to personnel safety and the environment may also be justified fitting for purpose by cost benefit analysis and use of As Low risk As Reasonably Practicable (ALARP) principle.

C.6 Remedial measures

Prevention measures (reduction on probability of hazardous events) and mitigation measures (reduction on severity of the consequences) should be considered at all stages of assessment for a structure which violates the code or standard to which the structure was originally design to.

Remedial measures to be considered are for example:

- Load reductions
- Strengthening
- Change to operational mode and procedures
- Intensification of and change to condition monitoring
- Removal of facilities exposed to the environmental pollution

ANNEX D COLUMN STABILISED UNITS (NORMATIVE)

D.1 General

This annex contains aspects which are specific to condition monitoring of column stabilized units.

Column stabilized units (CSU) of steel are well proven designs for use as mobile drilling platforms. For such use they are classified with a Classification society and according to normal practice they are periodically inspected and maintained inshore when out of service. These structures are normally designed with minimum fatigue life of 20 years. However, experience has shown that many of these platforms are fatigue sensitive and have to be repaired and modified several times during their service life. This has, however, normally not been considered as a safety or economic problem due to the characteristic of structural redundancy and good accessibility and opportunity for inspection and maintenance when the unit is out of service between drilling assignments.

Column stabilized units intended for permanent installation over a long service life will normally not be planned with inshore inspection and maintenance. The condition will be that the CSU will be inspected and maintained on site, in production and under short revision stops. Due to the economic consequences related to a possible unintended production stop and/or requirement for inshore repair work, the probability of failures due to fatigue, corrosion etc. should be suitably low.

Another problem with offshore inspection is reduced accessibility due to weather and operation. Due to these aspects the design and documentation requirements should be especially considered when selecting and developing the concept.

Properties to be aimed for are:

- Structural redundancy
- Low overall dynamic stress level
- Avoiding complex details sensitive to fabrication quality
- High fatigue endurance and few fatigue sensitive areas
- Good accessibility for inspection, maintenance and repair (avoid need for divers)

With respect to fatigue endurance the operator should define minimum Design fatigue factors (Dff) for the different areas of the CSU dependent of consequence of failure, accessibility for inspection, inspection method, maintenance philosophy etc., When considering consequence of failure also economical consequences with respect to possible maintenance and repair should be included. From a life cycle cost consideration it may be beneficial to design for higher Dff's than the minimum requirements according NPD. The cost consequences of increased Dff's may be relatively low compared with the gained reduction in IMR cost.

D.2 Platform integrity

The overall integrity of a CSU is related to different aspects such as structural strength, floatability, stability and position keeping.

CSU's are designed with a variety of structural configurations giving differing degrees of structural redundancy.

The reduction in structural integrity of a CSU with a failure such as a local crack, a missing element or a local damage from an accidental load, is to be considered for each specific case. The possible reduction of structural integrity will depend on, location, size and type of failure and the structural configuration of the unit. A robust concept is characterized by an ability to maintain structural integrity for a wide range of local failures.

Another aspect of structural failure may be leakage which can threaten integrity with respect to floatability and stability.

Considerations regarding the consequence of different possible failures should be undertaken as a part of the design work for the purpose of categorization of the structural elements.

Integrity related to floatability and stability is dependant on the condition of the ballast system including sea chests, ballast lines, valves, pumps and the operation and control system. The latter includes the function of different systems such as power supply , hydraulics, automation, etc.

The integrity of the position keeping system, normally consisting of mooring lines, is important with respect to avoiding escalating events such as riser failures. The integrity is normally secured by a redundant design which include allowance for a certain number of line breakages. This is documented in the design of the system.

D.3 Catergorization of structural areas and joints

The purpose of classification of areas, components and connections is to identify the requirements for in-service inspection and thereby to plan a cost effective condition monitoring programme.

A CSU consists of a buoyant steel hull and a deck structure which is either a plate box design or a space frame design or a combination.

The internal structure may include dry void spaces and different types of tanks.

The external structures can be divided in 3 zones.

- A submerged zone that can be inspected under water from outside.
- A splash zone that is difficult to inspect and repair from the outside due to disturbance from waves.
- The area above the splash zone that can be inspected under dry conditions.

The categorization is related to the following aspects.

- Strength and fatigue utilization
- Consequence of failure
- Accessibility for inspection, maintenance and repair

- Inspection method

Probability of failure is normally related to fatigue endurance and/or corrosion. Normally large areas of a CSU have relatively low probability of failure and also low consequence of failure. Such areas can be panels in pontoon, columns and deck.

The highest fatigue exposed details are normally related to end connections of bracings and certain transition areas between pontoons, columns and decks. The highest consequence of failure is normally related to braces and their end connections.

Also details with high stress concentrations in other areas can be critical with respect to fatigue. Examples may be cut outs for doors, pipe and cable penetrations, air ducts etc..

Accessibility for inspection is dependent on different aspects such as submerged areas, splash zone, special arrangement in dry areas required for access and safety, internal access dependent on opening of watertight hatches, gasfreeing, air support, light, permanent or temporary scaffolding. Access can also be prohibited by equipment, pipes, cable racks, fire-insulation etc..

Inspection methods will depend on accessibility, dry or submerged, structural categorization etc. General inspection of submerged areas should not depend on use of divers, use of ROV or similar should be aimed for.

Floating structures are especially suited for crack monitoring of the external submerged surface by leakage detection. The condition for use of this method is, however, that a through thickness crack is acceptable with respect to safety and that it is acceptable from an operational and repair point of view. The leakage detection system should be automatic and maintained and tested regularly.

D.4 In-service inspection planning

All structures and systems which are of importance for the overall safety and function of the unit shall be included in the inspection programme.

The In-service inspection program should be made flexible with respect to inspection activities. This means that different areas and systems may follow different schedules dependent on the opportunity for access and acceptable working conditions, as follows:

- Unlimited access
- Access limited by Operation
- Access limited by Weather
- Inspections that requires special preparations, as cleaning, scaffolding etc.

Some inspections may have to be undertaken under revision stops and have to be planned accordingly.

Other Inspections will be weather sensitive and should be planned for favourable times of the year. For such inspections a certain preparedness for utilizing the best possible conditions should be considered.

In addition to an overall visual inspection and a general awareness of leakages etc. the following should be systematically monitored.

- Close up inspection (including NDE) in defined critical connections
- Component and connection failure due to overloads
- Corrosion damage, especially in susceptible areas
- Corrosion protection, function of system, condition of paint etc.
- Damages from wave impacts
- Marine fouling
- Damages from accidental loads such as local dents on columns etc.
- Condition of seachests
- Condition and function of ballast system
- Condition of Mooring systems including lines, fairleads, winches, stoppers etc.
- Check of stability, i.e. deck loads, vertical centre of gravity

For the mooring system a separate document describing inspection, maintenance and replacement philosophy should be established. This should include inspection methods and frequencies, fabrication and installation data, acceptance data and replacement procedures.

D.5 Assessment process

Inspection results shall be evaluated against prediction and accumulated experience in operation. The evaluation shall be directed to:

- Verifying that the condition satisfies the requirements for continued service
- Modification/Improvement of condition monitoring (methods, intervals etc.)
- Need for further and more detailed structural and system assessment

For a CSU the integrity is related to structural strength, position keeping system, floatability and stability. All aspects shall be included in the monitoring program and in assessment of condition after inspections.

Normally the unit is designed to remain intact and within the design requirements for its entire service life. Certain components and systems may, however, be designed with limited service life. In this case changing or upgrading will be a planned activity. (ex. pumps, valves etc.).

Irregularities which represent a deviation from prediction shall be assessed with respect to possible reasons and be documented. Further it shall be evaluated if the irregularity is a local phenomena or if it may be symptomatic and influence other areas and details. If this is the case an overall assessment shall be undertaken.

Damages resulting from accidental actions shall be inspected immediately and the integrity evaluated accordingly. Uncertainty with respect to the integrity before assessment has been performed may require temporary shut down.

When functional and operational conditions are changed compared with the original design assumptions, necessary assessment to document the units integrity shall be performed.

Important basis for the assessment is; Original documentation of structure and systems, reanalyses model, DFI-information, historically experience from monitoring and operating the unit.

D.6 Remedial measures

Remedial measures can be of both temporary and permanent character.

Temporary measures shall be used to secure necessary integrity until a permanent repair or modification has been planned and carried out.

Temporary measures may include drilling of crack stoppers, temporary strengthening, operational limitations and changes (draft, trim, ballast, mooring pretension etc.), increased inspection activity and use of specific monitoring equipment.

Permanent measures should be taken as soon as possible considering time required for planning, criticality, availability of resources, requirements to environmental conditions, operational and economical aspects.

ANNEX E SHIP-SHAPED UNITS (NORMATIVE)

E.1 General

This annex contains additional requirements specific to condition monitoring of the ship shaped unit.

Ships shaped units are used for a variety of offshore applications such as drilling, production, storage and offloading. The environmental loads acting on a floating offshore installation and the modes of operation at sea differ significantly from the loads acting on a merchant vessel. This leads to stricter requirements in design. The philosophy with respect to condition monitoring and maintenance of the load bearing structures will depend on function, field life, safety requirements, and operational and economical considerations.

Maintenance and assessment of merchant vessels are normally based on periodical dry-docking and reclassification every 5 years. Repairs and modification due to local damages caused by corrosion, fatigue or overload are not unusual for such vessels and this is normally considered as part of the owners' maintenance procedures with acceptable safety consequences and life cycle costs.

A project specific approach with respect to design and maintenance philosophy may be required for ship shaped units used for offshore activities due to, e.g.,

- requirement to long service life on location with a minimum of production stops for inspection, maintenance and repairs, IMR,
- limited access for inspection when the unit is operating on the field,
- high environmental loads (weather vaning, side shell fatigue loads, etc. should also be considered)
- special operating conditions related to filling and emptying of tanks, sloshing effects in slack tanks, etc.,
- increased economical risk,
- increased safety standards,
- special design areas with limited operational experience like e.g. turret, turret area, fairleads, thrusters, topside supports.

Life cycle cost considerations will often lead to stricter requirements in design than those following from safety considerations alone. The requirements to condition monitoring will depend on the Operator's choice of operating philosophy and design basis. The design Contractor shall document the design solutions that are basis for condition monitoring requirements and that the various condition monitoring activities can be performed in practice.

Design solutions that will influence the requirement to inspect and do maintenance work will be, e.g.,

- increased overall hull strength due to environmental loads, (see E.2.1)
- how important load effects are compensated for in design or operation, (See E.2.1)
- increased fatigue endurance, implementation of fatigue and maintenance friendly design, (See E.2.2)

- corrosion protection and corrosion allowance, (See E.2.3)
- inspection availability, including e.g., inspection methods, tools and permanent staginess for access, (See E.3.2)
- safety and risk to inspection and maintenance personnel. (See 6.2, B.3 and E.3.2)

In the light of life cycle costs, investments in the design phase to reduce risk of damages and inspection needs will normally be worth while, since inspection and repair costs offshore may show to be excessive.

E.2 Structural integrity

E.2.1 Overall hull strength and categorisation of structural components

Site specific environmental loads, station keeping characteristics (weather vaning) and loading/discharging conditions on the field will, together with limit state considerations, be dimensioning for the overall structural strength of a ship shaped unit for offshore production or storage.

The condition monitoring activities shall concentrate on the safety critical components identified in a quantitative or qualitative risk assessment of the structural integrity. Alternative approaches for quantitatively assessing the structural integrity may for example be based on design conditions, component failure probabilistics, structural reliability, overall quantitative risk, etc. Operating restrictions and limitations will be used in the analyses to achieve an adequate level of safety and reliability.

It is essential to predict and to determine with a reasonable level of confidence the existence, extent and consequence of deterioration, damages and defects of structural components in order to ensure maintenance of the structural integrity of the ship structure. Inspection and maintenance activities may used to compensate for shortcomings in design efforts related to life cycle cost analyses, as long as the safety of the unit is not compromised.

Ship structures are usually designed with an implicit structural redundancy so that the acceptance level for structural integrity of the hull as such may be significantly higher than the strength of the first failed component.

In order to provide for a cost effective condition monitoring program in compliance with requirements stipulated in this standard and the other relevant normative standards the Operator may classify the hull structure and as well as structural components in structural categories. These may be used for the purpose of planning inspection levels, extent and methods both during fabrication and in the operating phase.

The hull structure may be classified according to:

- Personnel safety, environmental exposure and criticality to field operation
- Design code applied
- Current structural condition

The structural components may be defined as “special areas”, “primary structures” and “secondary structures” (according to class rules), or as decided by the Operator. The structural components may be categorised according to

- Importance to the structural integrity
- Level and type of applied stress
- Loading rate
- Presence of stress concentrations and critical load transfer points
- Accessibility for inspection and maintenance
- Construction non-conformance and inspection findings

Information regarding structural categorisation should be given in the DFI resumé and will be subject to revisions.

E.2.2 Fatigue aspects

Fatigue problems can be related to different factors such as,

- high overall dynamic stress level
- local dynamic effects like side shell loads and tank sloshing,
- global and local stress concentrations,
- vibrations,
- structural details (design or workmanship),
- riser and mooring loads.

Many of these factors can be adequately compensated for in design by means of careful planning with minor cost consequence. However, fatigue aspects related to the overall dynamic load level will depend on the section modulus of the hull beam. Improvement of these fatigue properties will lead to e.g. increased plate thickness and dimensions of longitudinals in deck and bottom. The increased investment will have to be balanced against reduced cost of inspection and possible repairs in the operations phase. The additional cost can be minimised by early planning in design.

In order to account for difficult access for inspection and repairs as well as for the importance of the component/consequence of damage, the design fatigue factors specified in the NORSOK N-001 “Structural Design” or higher may be used.

Design fatigue factor 1 and a design fatigue life of 20 years, as may be qualitatively assumed for many structural components of a ship, are normally not compatible with continuous service on location for the lifetime of the field without dry docking or interruption due to repair. Where life cycle cost considerations are made, the design factor may often be increased to 3.

Simplified inspection efforts can be justified if the design fatigue factors are increased. Increased design factors can also be called for due to economical consequences of preparation for hot work to repair defects. The cost of shut down of production / off hire contributes significantly to the total picture.

Such considerations should be taken by the Operator during design and recorded in the DFI resume.

E.2.3 Corrosion protection of the hull

Corrosion protection systems may consist of a combination of paint systems and sacrificial anodes or impressed current systems. Corrosion allowance may also be provided for in design. Special care shall be made to design corrosion protection systems in areas of limited access and in areas where sacrificial anodes have no or little effect.

The lifetime of the corrosion protection system is to be decided during design, depending of the planned continuous service time before dry-docking and repair.

Personnel in charge of follow-up during construction shall be qualified in the requirements to painting procedures.

Facilities for renewal of anodes to be planned, e.g. by installing fixing lugs, etc. Condition monitoring activities and methods of assessment will depend on the actual design solutions and may consist of visual inspection of painting systems, measurement of anode consumption, thickness measurements, CP measurements, etc. Assessments (forecasts) of the expected remaining lifetime of paint systems and anodes shall be made, compared to the design lifetime and recorded for follow-up.

Regarding corrosion resistant materials in propellers, shafts, glands, etc., the galvanic effect of corrosion resistant materials is to be accounted for in design. The condition is to be monitored by permanently installed instrumentation devices.

A combination of sacrificial anodes and paint system may give rise to substantial stray currents through thrusters and shafts, propellers, etc. It must be ensured that the items in question have the required resistance to such currents.

E.3 In-service inspection planning

E.3.1 Inspection frequency

Inspection frequency of the various elements and parts is to be determined as a function of design solutions, based on risk considerations.

E.3.2 Accessibility

E.3.2.1 Internal Structures

Based on the Operator's inspection philosophy and requirements to close-up inspection and NDE the design Contractor should plan for safe and cost effective means of access to all parts of the structures. Consideration should be made to the fact that access to certain areas can be difficult when the ship is operating. Temporary access by means of rafts, absailing techniques or by building staginess may be restricted by the ship's movements, may be expensive, and may represent risk to personnel.

Procedures for gas freeing and monitoring of tank atmospheres to be established.

E.3.2.2 External hull

a) Underwater parts marking

The underwater parts should be permanently marked by welding and paints in order to identify tanks, sea chests, anodes, echo sounders, etc. The marking is to be documented by means of drawings and colour photographs.

Sea chests are to be provided with means of reliable closure in order to allow inspection and maintenance. Due consideration to be made to safe manhole covers for dry access from the interior of the ship.

Longitudinal propellers and shafts, and rudders are normally not dismantled at sea for inspection and repair and must be designed to operate for the planned time to first dry docking. Means for condition monitoring will depend on the design. For rudders, this will typically be by means of monitoring shaft and pintle clearances. Propeller shafts shall be equipped with means to monitor leakage and clearance / shaft bearing deterioration.

Means and procedures for mounting and dismantling of thrusters at sea should be provided, unless design and monitoring systems compatible with the expected continuous service life has been accounted for.

Fairleads and fairlead housings may contain areas and weld connections that are not accessible for inspection when the vessel is at sea. This must be taken into account by means of mounting and dismantling, or alternatively, by an appropriate design fatigue factor combined with increased requirements to material properties and general stress level.

b) Splash zone

Floating production vessels do not have a typical “splash zone”, since this zone can be made accessible for inspection and maintenance by ballasting to a lesser draft (weather permitting). Inspection will normally be limited to a general visual inspection for deformations and a closer inspection of weld seams for corrosion. Access by boat will normally be satisfactory both for inspection and touch-up painting. The space between turret and circum turret can be made available down to the light ballast line by means of permanent staging (platforms and walk ways), but due consideration should be made to the risk of swell in this area before entering. The space from this waterline down to the bottom of the turret are generally less accessible while the vessel is on location, hence precautions should be made during design to avoid the need for inspection and maintenance in the area.

c) Above water parts

Above water parts will normally be accessible for inspection and should be planned and confirmed during design. Consideration should be made in the design phase to access overboard to the shipsides by temporary staging.

Special fatigue and corrosion considerations should be made to structural areas above deck that are covered by Passive Fire Protection (PFP). Topsides support connections to deck should be included in the inspection programme and it should be considered to terminate the PFP above these connections on the basis of a fire load assessment.

E.3.3 Turret and Mooring Systems

E.3.3.1 Turret Structures

Design considerations related to bearing system:

- deformation of hull and the circum turret shall not leave the turret in stuck position (clearance required)
- friction of bearing in stuck position shall be sufficiently low to allow rotation within operating envelope (depending on design)
- bearing material shall not deteriorate beyond acceptable limits, i.e. future performance to be considered and requirements to shop testing established. Since a variety of turret designs are available, the resulting monitoring requirements will have to be established for each individual project.

Special features / Submerged turret loading:

Structural parts of the submerged turret and its swivel, mooring system and risers must be designed with the view of realistic condition monitoring. Lack of accessibility for inspection and repairs must be compensated for in design by means of relevant fatigue life, corrosion protection, etc.

E.3.3.2 Mooring lines

A mooring analysis is to be carried out in design in which hazards and consequences of failures are established. Operational hazards will also depend on which disconnection philosophy that has been assumed for risers and mooring lines and if the vessel's mooring system and structures are designed to withstand beam sea in case of a mooring failure. Here, the reliability of any DP system is to be taken into account.

Inspection and testing of mooring equipment and lines are to be planned on the basis of these analyses.

Depending on the type and material of mooring lines, the lifetime to renewal and/ or possible intermediate inspection is to be established. Inspection can be planned to take place on a rotational basis, whereby one line is disconnected and brought to surface for inspection at the time. The need for a replacement line to be connected to the mooring system during inspection must be considered.

Individual inspection records to be made for each mooring line.

E.3.3.3 Anchors

Record of mooring system behaviour to be maintained. If drag of any of the anchors is experienced, the situation is to be evaluated before further compensating measures are decided.

E.3.3.4 Risers

Damage to the outer sheathing of the risers may allow seawater to enter into the tight annular space housing the steel reinforcing wires. Corrosion in this area may significantly reduce the fatigue life of the risers. The integrity of risers' outer sheathing, the buoyant elements, as well as anchoring to the seabed to be monitored by e.g. remotely operated vehicles (ROV) at regular intervals. Any debris found is to be removed.

E.3.4 Other aspects

E.3.4.1 Measurement of wear in propeller shafts and rudders

The design solutions must reflect the planned service life before dry-docking. Facilities for condition monitoring of wear of propeller shafts and rudders to be accounted for in design.

E3.4.2 Marine growth

Marine growth will not have any significant effect on drag or wave forces and will normally only have to be removed from the ship sides in order to allow for inspection of weld seams, etc. The cleaning requirement will depend on the inspection method (visual, MPE or eddy currents). In most cases cleaning by high pressure water jetting or brushing will be sufficient. ROV operation is possible. Outside hinged or bolted covers are recommended in order to allow for cleaning and inspection of sea chests from the inside. Chlorine systems are often used within sea chests to reduce the marine growth.

E.4 Assessment process

Inspection results shall be evaluated against acceptance criteria, prediction and accumulated experience in operation of the field. The evaluation shall be directed to

1. Verifying if the requirements for assuming on-going structural integrity of the unit over long term are met.
2. Improvement of condition monitoring (precision, appropriate method to the potential damages/defects, reasonable inspection interval, etc.) Improvement in this context may include increased but also reduced efforts.
3. Revealing any cause for further structural assessment. Besides general deterioration within acceptable limits, any modification, renewal or repair carried out that may have led to increased or decreased utilisation shall be accounted for. Operational limitations or restrictions may be considered as a consequence of such assessment.

The following data / information may be required for assessment of ship structures in conjunction with inspections:

- General information:
 - Original and current installation use and functions
 - Location, water depth and mooring, risers and DP configuration
 - Manning level
- DFI information
 - Regulations, design codes and other specifications applied
 - Environmental data
 - Material properties and tractability record
 - Design actions
 - Accepted non-conformities in design and fabrication
 - As built drawings

- Historical information
 - Deviations, defects, damages significant to the structural integrity and functional performance
 - Extreme events and structural behaviour during such events
 - Inspection records
 - As-built documentation of modifications, renewals and repairs
 - Other studies and assessments conducted in the operational phase
 - Inspection records
 - Structural analyses results and associated computer models
 - Damage and intact stability computer models
- Survey and instrumentation

Analyses required in connection with assessment of the structural condition will depend on inspection findings and changes in the operational conditions.

E.5 Remedial measures

If the assessment concludes that the acceptance criteria given in the design code or specification by the owner or authorities are not met, then remedial measures are to be considered.

The objective of remedial measures can be prevention measures (reduction on probability of hazardous events) or mitigation measures (reduction on severity of the consequence).

Remedial measures to consider may be, e.g.

- load reductions,
- strengthening,
- change in operational mode and procedures
- intensification of and change in condition monitoring.

Mitigation measures will typically be to repair to as built condition (or better).

ANNEX F CONCRETE STRUCTURES (NORMATIVE)

F.1 General

This annex contains additional requirements specific to condition monitoring of the concrete substructure.

F.2 Concrete structure integrity

Concrete structures are normally designed with an in-built structural redundancy such that the acceptance level of structural integrity of such structures may be significantly higher than the strength of first failed component.

The alternative approaches for quantitatively assessing the structural integrity may for example be based on design condition, component failure probabilistics, reserve strength ratio, structural reliability, etc.

It is essential to predict and to determine with a reasonable level of confidence the existence, extent and consequences of deterioration, damages and defects of the structural components in order to maintain structural integrity of the concrete structure. This includes also possible defects on operational systems, the failure of which may inflict critical loads to the structure.

F.3 Classification of the installations and their structural components

F.3.1 Purpose

The purpose of classification is to identify the needs of different levels of in-service inspection and thereby to plan a cost effective condition monitoring programme maintaining structural integrity of the platform.

An Operator may, in line with its condition monitoring philosophy, classify the platform and their structural components according to some of the criteria described in the following sections. The designer shall then, based on the specified requirements, provide classification information in the DFI resume, which will form the basis for inspection planning, inspection execution, inspection results evaluation and assessment of structural integrity and fitness for purpose. Reference is also made to NORSOK standard Z-001 "Documentation for Operation", Annex A.7 "DFI Resume".

It should be noted that uncertainties associated with different analyses and failure modes may not be the same. The different uncertainties should be considered and reflected in the condition monitoring programme.

F.3.2 Classification of concrete structure

An offshore concrete structure may be classified according to:

- personnel safety, environmental exposure and criticality to field operation
- design code applied
- present structural condition
- reserve strength of the platform

F.3.3 Classification of structural components on a concrete structure

A structural component may be classified according to:

- importance to structural integrity
- component redundancy (relative to structural system capacity)
- residual strength of structural component
- design fatigue life of structural component
- utilisation of structural component during operational conditions
- accessibility

F.4 In-service inspection planning

In-service inspection planning, as a part of condition monitoring process, shall be developed and revised for each platform soon after receiving DFI resume, and be periodically updated throughout its service life. The inspection planning shall focus on condition verification of the structural components so that the structural integrity at any time will effectively be secured.

During the service life of an offshore concrete structure various kinds of defects, damages or deterioration may develop.

- degradation due to repeated actions.
- corrosion damage and cracking.
- component failure due to overloading.
- component damages due to accidental actions.
- other irregularities, such as marine fouling, scouring, etc.

Damages / failure due to overloading or accidental actions will usually be taken care of by special inspections resulting from the event, whilst existence and extent of the other damages / defects should be determined during regular offshore inspections.

There are, as described in Annex A "Inspection Methods" , several methods applicable to concrete structure inspection with different level of accuracy. For key components with low redundancy, high level inspection methods should be used. High level inspection method should, in general, also be applied for further examination when an indication is detected using lower level inspection methods, or found likely on the basis of special investigations, e.g. thermal load effects.

Special attention should be given to structural joints and D-regions of major importance to the structural integrity. Corrosion monitoring should be considered for the atmospheric and splash zones where the risk of corrosion is high.

The D-regions are complex connections such as wall-dome connections, cell joints, beam-column connections, where the assumption of plane sections remain plane does not apply.

To be able to identify critical regions and key components which are of major importance for the structural integrity, ultimate strength analysis such as thermal cracking analyses and/or pushover type analysis are recommended performed for the concrete shafts including the deck structure, preferably already during design.

In addition to considering different negative effects which may cause damage or defects, such as listed in subclause 6.3, the following parameters should also be included for the concrete structures:

- construction joints
- penetrations
- embeddments
- subsidence
- chloride ingress
- internal defect such as leakage, biological activity and other effects on oil storage

Typical defects for concrete structures may be:

- deformation/structural imperfections
- cracks
- reinforcement corrosion
- damaged coatings
- freeze/thaw damage
- spalls and delaminations
- local impact damage
- impact damage

F.5 Assessment process

Inspection results shall be evaluated against prediction and accumulated experience in operation of the field. The evaluation shall be directed at:

- Verifying if the requirements for assuming on-going structural integrity of the concrete structure over long term are met.
- Improvement of condition monitoring (precision, appropriate method to the potential damages / defects, reasonable inspection interval, etc.).
- Revealing any assessment initiators for further structural assessment.

When initiators for assessment occur as a result of the evaluation or due to operational changes, structural assessment shall be performed to verify structural fitness for purpose, which may, for

example when the structure violates the design code, imply some restrictions for its normal operation, such as requirements for production shut down during extreme conditions.

The following data / information may be required for assessment of concrete structures:

- General information:
 - Location, water depth and orientation
 - Manning level
 - Platform Configuration, piles, conductors, risers, etc.
- DFI information:
 - Regulations, design codes and other specifications applied
 - Environmental data and wave kinematics
 - Deck elevation
 - Foundation data
 - Material properties
 - Design actions including weight information
 - Drawings
 - Other "as-built" and "as-installed" information
- Historical information:
 - Extreme events and the structural performance during the events
 - Deviations, defects, damage significant to structural integrity and functional performance
 - Analyses and as-built information of modifications, repairs and other remedial measures
 - Other studies and assessments conducted in operation phase
- Survey and instrumentation

F.6 MITIGATION MEASURES

Inspection of items that are determined to be of less importance as information and knowledge is updated should be rescheduled.