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In-service integrity management of structures and maritime systems

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Foreword

NORSOK N-005:2017, was adopted as NORSOK Standard in October 2017.

NORSOK N-005:2017, replaces NORSOK N-005, rev. 1, December 1997.

NORSOK is an acronym for the competitive position of the Norwegian continental shelf and comprise petroleum industry standards in Norway. The collaboration initiative in 1993 between the authorities and the petroleum industry initiated the development of NORSOK standards.

Reducing the project execution time and developing and operating cost for petroleum installations on the Norwegian shelf was the target.

The intention for the Petroleum industry is to develop and use standards providing good technical and cost effective solutions to ensure that the petroleum resources are exploited and managed in the best possible way by the industry and the authorities. The industry will actively contribute to the development and use of international standards in the global market.

The NORSOK standards shall:

- bridge the gap based on experiences from the Norwegian continental shelf where the international standards are unsatisfactorily;
- replace oil company specifications where possible;
- be available as references for the authorities' regulations;
- be cost effective;
- promote the Norwegian sector as an attractive area for investments and activities.

Developing new NORSOK standards and regular maintenance of existing standards shall contribute to maintain the competitiveness both nationally and internationally for the Norwegian petroleum industry.

The NORSOK standards are developed by experts from the Norwegian petroleum industry and approved according to the consensus principles as laid down by the guidelines given in this NORSOK directive.

The NORSOK standards are owned by the Norwegian Oil and Gas Association, the Federation of Norwegian Industries and the Norwegian Shipowners' Association. They are managed and published by Standards Norway.

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Introduction

This NORSOK standard aims to support activities relating to the safety and integrity management of structures and marine systems until final removal.

It describes the principles and practices of how the integrity management of structures and marine systems should be planned, implemented and documented to ensure fitness for service, and to comply with the PSA regulations and relevant NORSOK standards.

This update of NORSOK N-005 includes marine systems, and broadens the scope to cover the entire integrity management process (previously limited to inspection and monitoring). This has resulted in a total restructuring and rewriting of the standard.

This revision addresses the overall integrity management process for the safety of structures and marine systems in operation.

The principal standard for offshore structures is NORSOK N-001, Structural design.

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1 Scope

This standard contains principles, practices, functional requirements and guidelines for the integrity management of offshore structures and marine systems throughout their life, including time until decommissioning and final removal.

This standard is applicable to all types of offshore load-bearing structures used in petroleum activities, including substructures, topside structures, vessel hulls, foundations, mooring systems and marine systems such as water and weather tight systems, stability systems and station keeping systems.

This standard covers all aspects of integrity management, including the management of data, inspection and/or monitoring strategies, inspection and/or monitoring execution, integrity evaluation and integrity assessment.

The assessment of existing offshore structures to be operated beyond original requirements is addressed in NORSOK N-006. Initiators for when such assessment is needed are covered in that standard, in accordance with NORSOK N-001.

2 Normative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines 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 the requirements of the referenced standards.

NORSOK M-101, *Structural steel fabrication* (Rev. 5 October 2011)

NORSOK M-501, *Surface protection and protective coating* (Rev. 6, February 2012)

NORSOK N-001, *Integrity of offshore structures* (Rev. 8, September 2012)

NORSOK N-004, *Design of steel structures* (Rev. 3, February 2013)

NORSOK N-006, *Assessment of structural integrity for existing offshore load-bearing structures* (Edition 2, April 2015)

NORSOK Z-001, *Documentation for operation DFO* (Rev. 4, March 1998)

NORSOK Z-008, *Risk based maintenance and consequence classification* (Rev. 3, June 2011)

ISO 19901-5:2003, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 5: Weight control during engineering and construction*

IACS Recommendation 87, *Guidelines for Coating Maintenance & Repairs for Ballast tanks and Combined Cargo/Ballast tanks on Tankers* (Rev. 1, June 2006)

NACE-SP0108-2008, *Corrosion Control of Offshore Structures by Protective Coatings, Maritime, 2008*

3 Terms and definitions

For the purposes of this NORSOK standard, the following terms and definitions apply.

3.1

air gap

vertical distances measured from still water level (still water air gap) or top of wave crest (air gap) to bottom of steel of deck structure

3.2 assessment

a further evaluation by specialist engineers which may include analysis

3.3 as-built documentation

documentation that includes as-built documentation

3.4 as-is documentation

documentation that includes as-built documentation and information collected during in-service

3.5 as-is analysis models

analysis models representing the as-is condition

3.6 can (possibility and capability)

1: expression in the content of a document conveying expected or conceivable material, physical or causal outcome

2: expression in the content of a document conveying the ability, fitness, or quality necessary to do or achieve a specified thing

Note 1 to entry: Possibility and capability is expressed using the verbal forms specified in Table 6 .

3.7 design service life

the period during which a structure is to be used for its intended purpose

3.8 defect

an imperfection, fault, or flaw in a component that needs to be evaluated

3.9 deviation

lack of agreement between actual condition and regulatory requirements, industry requirements, internal company requirements, the design condition, or the intended use

3.10 DFI resumé

the design, fabrication and installation resumé is a project as-built deliverable

Note 1 to entry: e.g. in accordance with NORSOK Z-001

3.11 evaluation

evaluate if changes need further assessment

3.12 facility

offshore petroleum installation, or plant for production of oil and gas

3.13 freeboard

vertical distances measured from still water level to main deck

3.14 gross errors

human error, mistakes and omissions that may cause defects and failures (from e.g. design, fabrication, transportation, installation and operation)

3.15**hazards**

accidental events, deterioration (e.g. corrosion, fatigue, wear and tear) and extreme actions to structures and marine systems that can threaten their integrity

3.16**inspection**

examination for conformity by measuring, observing, or testing the relevant characteristics of an item

Note 1 to entry: Examples of relevant findings: cracks, coating breakdown, corrosion, dents, buckled items etc.

3.17**integrity**

a state of being fit for service, with an acceptable level of safety against failure

Note 1 to entry: I.e. the ability of structures and marine systems to perform their required function in accordance with NORSOK N-001

3.18**integrity management**

integrity management is a continuous process to manage all changes that will occur during service life (from fabrication until decommissioning) that may affect the integrity of structures and marine systems

3.19**integrity management strategy**

a plan for how the integrity management objective is achieved

3.20**may (permission)**

expression in the content of a document conveying consent or liberty (or opportunity) to do something

Note 1 to entry: Permissions are expressed using the verbal forms specified in ISO/IEC Directives Part 2 clause 7.4 Table 5 .

3.21**monitoring**

use of electrical or mechanical instruments to collect data for integrity assessment of the as-is condition

3.22**operator**

company or an association that through the granting of a production licence is responsible for the day to day activities carried out in accordance with the licence

3.23**shall (requirement)**

expression in the content of a document conveying objectively verifiable criteria to be fulfilled and from which no deviation is permitted if compliance with the document is to be claimed

Note 1 to entry: Requirements are expressed using the verbal forms specified in ISO/IEC Directives, Part 2 clause 7.2 Table 3 .

3.24**should (recommendation)**

expression in the content of a document conveying a suggested possible choice or course of action deemed to be particularly suitable without necessarily mentioning or excluding others

Note 1 to entry: Recommendations are expressed using the verbal forms specified in ISO/IEC Directives, Part 2 clause 7.3 Table 4 .

Note 2 to entry: In the negative form, a recommendation is the expression that a suggested possible choice or course of action is not preferred but it is not prohibited.

4 Abbreviation

ACFM	alternating current field measurement
ALS	accidental limit state
CFL	calculated fatigue life
CoG	centre of gravity
CP	cathodic potential
CSU	column stabilized unit
CVI	close visual inspection, normally within arm's length
DFE	design fatigue factor
DFI	design, fabrication and installation
DFO	Documentation for Operation
EC	eddy current
FCS	fixed concrete structures
FLS	fatigue limit state
FMD	flooded member detection
GVI	general visual inspection
ICCP	impressed current cathodic protection
KG	vertical centre of gravity
MPI	magnetic particle inspection
NCS	Norwegian continental shelf
NDT	non-destructive testing
ROV	remotely operated vehicle
SSU	Ship-shaped units
STL	submerged turret loading
STP	submerged turret production
TLP	tension leg platform
ULS	ultimate limit state
UT	ultrasonic testing

5 Integrity management of structures and marine systems

5.1 Objective

The objective of integrity management of structures and marine systems is to ensure and document that the safety level specified for all limit states in NORSOK N-001 is met during the service life. Both the physical condition of the facility and new knowledge relevant for the structural integrity shall be evaluated regularly and if necessary assessed.

5.2 Integrity management process

Integrity management of structures and marine systems is the process to ensure that changes which may affect the integrity are managed in a systematic manner throughout the service life. Examples of changes are listed in [Annex A, A.2](#).

The integrity management process described in this standard is illustrated in [Figure 1](#). For more details see the different sections referred to in the figure. Shaded boxes indicate continuous activities. Other equivalent processes which ensure the integrity of structures and marine systems may also be used, e.g. as described in NORSOK Z-008 (specifically relevant for marine systems, see [8.5.5](#) and [Annex I](#)).

The specific integrity management strategy for each facility shall be documented and shall describe the process to meet the objective as described in [5.1](#).

An integrity management strategy shall be developed for each facility. The strategy document shall include necessary requirements to the integrity management organization. The strategy document shall define regulations and standards to be used as basis for integrity assessments. Necessary operational limitations of the facility shall be defined. Furthermore, a strategy plan for inspection and/or monitoring of the condition of the facility shall be included in this document.

Control of the as-is condition in [Figure 1](#) is illustrated by a grey area with boxes starting with a data register. Then the working process continues with an evaluation of relevant data for assessment of the integrity. This evaluation may lead to developing inspection and/or monitoring programmes with a following execution of these programmes. Thereafter the results from the performed inspection and/or monitoring shall be transferred into the data register ready for a new evaluation. An evaluation of relevant data can also trigger a further integrity assessment as indicated in the boxes below the loop for control of as-is condition.

If it is assessed during the integrity assessment that the requirements to integrity are fulfilled, the information from this assessment shall be transferred into the data register. Otherwise compensating measures shall be implemented and the documentation shall be transferred into the data register. If the work with compensating measures implies requirements to changes in the integrity management strategy, the strategy document shall be revised accordingly. This may for example be related to operational limitations and modified requirements to control of the as-is condition.

The operator shall arrange for necessary transfer of experience gained through the service to new employees.

New experience and new knowledge will be gained during the operation of a facility. This can be positive or negative experience from the actual facility, but it can also be experience from other similar facilities and significant changes in design standards which shall be used as basis for maintenance of a sound integrity management document as indicated in [Figure 1](#).

Integrity management shall be subject to quality assurance and verification as described in NORSOK N-001, Clause 5.

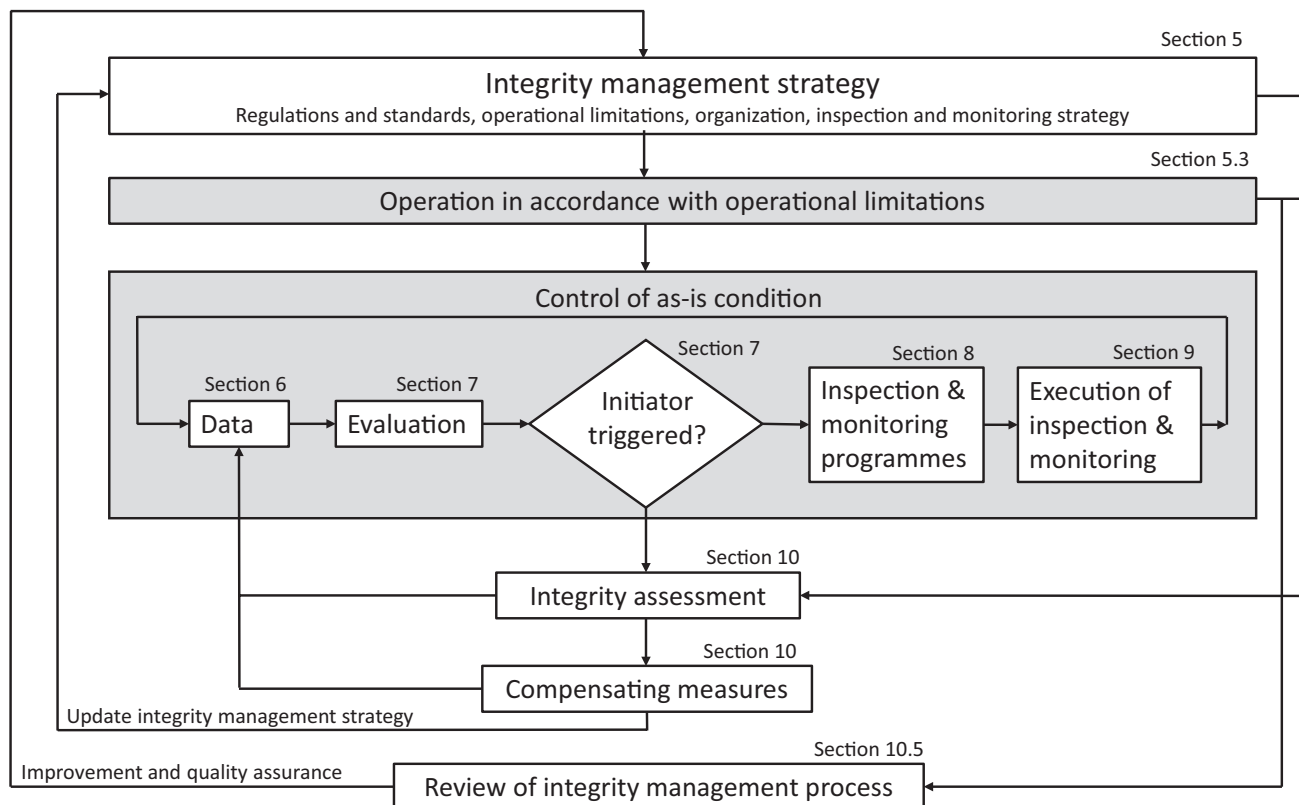


Figure 1 - Integrity management process

5.3 Operation in accordance with requirements

Operational limitations for the specific facility may originate from requirements and limitations in the structural and marine system integrity analysis and evaluations. Operations shall be in accordance with these limitations.

Operational procedures should as a minimum comprise:

- size of allowable visiting supply vessels and requirements for these to enter the safety zone;
- limitations in weight and centre of gravity;
- load plans;
- crane operational limitations;
- special considerations for drilling operations, if any;
- de-manning requirements, if relevant;
- de-ballasting restrictions for storage cells in fixed concrete structures.

Additional operational procedures for floating facilities comprise:

- stability limit curves for intact and damaged condition;
- still water limit curves;
- operational and survival draft;
- operational restrictions with regards to draught and trim;

- tank filling restrictions; and
- weight management curves for TLPs.

5.4 Integrity management organization and qualifications

5.4.1 Management organization

The operator shall establish an organization for integrity management where the organisation of roles and responsibilities throughout the integrity management process shall be clearly defined and adequately manned by competent resources. This includes also descriptions of work processes.

5.4.2 Competence requirements

The operator shall define the necessary requirements to competence for the responsible engineers involved in the integrity management in accordance with NORSOK N-001, relevant PSA regulation and this standard.

5.4.3 Resources

The operator is responsible to provide the resources necessary to supporting the integrity management process.

5.4.4 Qualification of engineers

The engineers should have the following qualifications:

- structural and marine engineers shall have relevant education;
- be familiar with relevant information about the facility;
- have knowledge of ageing effects for structures and marine systems;
- be experienced in offshore inspection and maintenance planning of structures and marine systems;
- have knowledge regarding inspection tools and techniques;
- be aware of general in-service inspection findings in the offshore industry;
- be familiar with offshore inspection and maintenance execution;
- be experienced in evaluation of inspection findings;
- understand the hazards and failure modes of structures and marine systems;
- understand how the structures and marine systems are intended to be protected against and withstand these hazards; and
- be familiar with the archive systems and tools supporting the integrity management process.

5.4.5 Qualification of inspection personnel

Visual inspections, pressure testing and NDT shall be carried out by certified personnel holding practical experience and theoretical knowledge enabling them to discover and to assess defects as specified:

- Personnel responsible for offshore inspection by NDT shall be qualified in accordance with requirements given in NORSOK M-101 or equivalent.

- The NDT inspectors shall be qualified in accordance with requirements given in NORSOK M-101 or equivalent.
- Personnel to carry out control of surface treatment shall be qualified in accordance with NORSOK M-501 or equivalent.

Personnel to carry out cathodic protection (CP) inspection should be certified to minimum NACE qualifications, cathodic protective tester-1 or equivalent.

6 Data

Essential aspects of integrity management are the validity, extent and accuracy of the structure's data and inspection history. Accordingly, records of all relevant original design documentation such as drawings, specifications, analyses, and information from fabrication, transportation, installation and in-service inspections, engineering evaluations, repairs, and incidents shall be retained by the owner.

Projects for new and modified facilities, their structures and marine systems are delivered with as-built DFO documentation (Documentation for Operation) in accordance with NORSOK Z-001 and any additional company requirements.

A system to ensure that computer models reflect the as-is condition at any time shall be in place, and all relevant analyse files shall be readily available in case of need for re-analyses.

A change register shall be established and kept updated. This register may include changes in the condition, modification of the facility, change to the mode of operation, changes in design standards etc. All changes shall be logged and followed up.

A weight database shall be used to monitor all permanent dry weight changes (the lightship weight for floating facilities). It shall be updated and the following data shall as a minimum be reported:

- bulk weight and corresponding centre of gravity;
- equipment weight and corresponding centre of gravity;
- discipline code;
- area code;
- installation code.

More details are provided in ISO 19901-5 Weight control during engineering and construction. All input data to the weight database shall be traceable with reference to design drawing and/or tag. In most cases, it is desirable to also include the content weight in equipment and piping per system as part of the weight database as these weights may not be readily accessible otherwise. If there is a modification project with large weight increase, a separate weight report shall be issued.

Metocean and geophysical data shall be updated when found necessary.

New knowledge shall be acquired and assessed as found necessary.

New techniques for improved inspection and monitoring and best practices shall be implemented, when relevant.

The data necessary for integrity management shall be archived and made readily available for assessments throughout the service life of the facility. An overview of relevant data is given in [Annex A](#).

7 Evaluation

7.1 General

The evaluation activity shall consider all changes that might affect the integrity of the facility. The purpose of the evaluation activity (see process in [Figure 1](#)) is to decide if:

- these changes imply further inspection or repairs;
- the existing inspection programmes are adequate and properly executed;
- assessments are needed (see [7.3](#) and 10);
- immediate compensating measures are needed (see [10.4.1](#)).

If assessment is triggered, it shall be ensured that this is initiated and followed up by compensating measures, if needed.

7.2 Evaluation of inspection and monitoring results

In the evaluation of inspection and monitoring results, reporting and acceptance criteria can assist the evaluation process:

- reporting criteria used during inspection execution (see [8.10](#));
- assessment triggers (see [7.3](#));
- engineering judgement.

7.3 Triggers

Typical assessment triggers are found in NORSOK N-001 Subclause 4.4 and NORSOK N-006 Subclause 4.2. The main triggers listed in N-006 are:

- changes from the original design or previous assessment basis;
- damage or deterioration of a primary structural component or a mechanical component;
- exceedance of design service life;
- new knowledge;
- insufficient documentation of structural integrity.

Assessments shall be performed in accordance with NORSOK N-001 and N-006.

8 Inspection and monitoring programmes

8.1 General

Some of the changes in the condition of the structures and the marine systems can be estimated at the design stage like that of anode consumption and fatigue damage accumulation. However, in general there are significant uncertainties related to these estimates and to the other changes of the condition of structures and marine systems during service. Therefore, it is necessary to control that these changes will not result in unacceptable safety. This shall be controlled by inspection and/or monitoring.

Gross errors may remain from the design, fabrication and installation phases. Errors may also occur during the operational life of the facility. Even with high quality DFI document it is not possible to predict where such errors might be hidden. Therefore, when planning inspection, it is important

to first consider items that are associated with the largest consequences of failures. Guidance on assessment of consequence of failure can be found in NORSOK N-004 Section 5.1. If significant changes to the structure or the marine systems are planned or detected during inspection, a reassessment of the consequence of the failure shall be made, see also [8.5.2](#).

A general overview of the condition of the structure and the marine systems is important and this should be achieved by general visual inspection (GVI). Items with high consequence of failure should be prioritized with respect to inspection. Depending on the condition and consequence of a failure further close visual inspection (CVI) or NDT should be performed.

Inspection for surface fatigue cracks requires a cleaned surface. Below water this implies cleaning of the area to be inspected. Inspection for surface fatigue cracks can be performed by use of Eddy Current (EC) or Alternating Current Field Measurement (ACFM). Ultrasonic Testing (UT) can be used for detection of internal defects in for example girth welds in tethers. For further information about inspection methods see [Annex B](#).

8.2 Inspection and monitoring strategy

The detailed inspection programme of loadbearing structure and marine systems 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 directed to the identified components with high consequence of failure.

Developing of an inspection and/or monitoring plan of structures and marine systems includes the following major activities:

- Developing an inspection strategy with the purpose to detect changes. Changes comprise unforeseen errors from design, fabrication and installation in addition to degradation mechanisms such as corrosion, fatigue, wear and scour.
- Establishing a system for reporting routines and handling of data in a data register. Necessary tools, archives and registers should also be defined in this system.
- Development of a long-term inspection and monitoring programme (periodic framework programme) which is subject to continuous updating and revision.
- Development of detailed inspection plan on a regular basis, e.g. annually.
- Execution of the inspection and/or the work packages in accordance with the specified plan.
- Recording of inspection results and storing these into the data register.
- Evaluation of inspection findings and changes in condition and trends.
- Monitoring of environmental conditions and the structural behaviour such as dynamic motions, foundation behaviour, erosion, strain at key components, etc. if the values or characteristics of these are considered highly uncertain.

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

8.3 Types of inspection programmes

The following types of inspection programmes shall be established:

- baseline inspection programme used to establish an as-is status shortly after installation to provide a basis against which subsequent inspection findings can be compared;
- framework inspection programme used for presentation of the long-term inspection strategy;

- annual inspection programme used for presentation of the detailed inspection and monitoring plan.

Monitoring may be used for control of the condition where considered relevant.

In addition to the programmes listed above, the following programmes may be needed depending on the actual condition:

- special inspection programme used for ad-hoc additions to the framework programme, pending the next update of the long-term programme;
- unscheduled inspection programme used for investigation of damages resulting from an unexpected or exceptional event.

8.4 Baseline inspection programme

During the first year of operation of the installation, preferable after the winter season, an initial inspection of the as-installed condition should be carried out to enable an overall assessment of the ability of the structures and marine systems to meet the defined acceptance criteria. The inspection should be performed in such a manner that it can disclose anomalies due to gross errors, early occurring damages or defects (e.g. from transport and installation, etc.) at an early stage such that corrective measures can be initiated as needed. In addition, an evaluation of the functionality of the CP system should be verified.

8.5 Framework inspection programme

8.5.1 General

The first framework inspection programme should have an extent which as far as possible provides a description of the overall condition of the loadbearing structure.

The first of the framework programmes should include the inspections which are to be performed after the installation of the facility, i.e. the base line programme.

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 during the first period of operation, the inspection interval may be altered.

The Operator shall give emphasis to systematization of previously acquired data of significance for evaluation of the condition in subsequent planning and implementation of inspection and/or monitoring.

The framework inspection programme shall include:

- structures covered by the programme;
- inspection location;
- extent of inspection;
- method of inspection;
- frequency of inspections: timetables established based e.g. on fixed intervals (calendar based plans) or structural risk or reliability based intervals.
- procedures for the use of inspection methods and competency requirements of inspectors.

8.5.2 Identification of components to be inspected

Identification of components to be inspected shall be based on:

- the consequence of component failure (the ability to withstand actions in ALS);
- the accumulated fatigue damage;
- the corrosion protection (coating condition and anode potential);
- the deficiencies, misalignments and non-conformances reported in the DFI résumé;
- the inspection history;
- the access and preparations to facilitate access for inspection, maintenance and repair;
- any monitoring results;
- the inspection method suitability and reliability.

Classification of structural components are performed in the design in accordance with design class as described in N-004 Clause 5. This classification is based on joint complexity and the consequences of failure. Some details may need a different classification after installation such as pad eyes which have served their intended function. Other items exposed to deterioration and changes during in-service life may also need to be classified differently from that at design. Where relevant, a re-evaluation of consequence identification of components shall be performed for purpose of inspection and/or monitoring.

8.5.3 Special consideration for corrosion

Maintenance of corrosion protection (coatings and CP) systems is important to prevent accelerated fatigue crack initiation and growth and to maintain structural strength. Light coloured and flawless coatings enhance the effectiveness of visual inspection for e.g. crack and corrosion detection, and should be preferred for repaint after inspections. Specification of areas where surface corrosion is unacceptable (i.e. high quality surface protection is required) shall be provided in the inspection programme.

It shall be verified at regular intervals that the corrosion protection system (coating and CP) is performing within design assumptions. Such criteria will typically be given for the specific facility, e.g. for coating (damage), anodes (consumption), and for testing of cathodic potential.

A maintenance strategy for maintaining the coating and cathodic protection system should be developed.

In case a structure has general corrosion, thickness control shall be performed to document the remaining thickness of the structure. This may be recommended even if corrosion allowance is included in the design to establish trends of thickness diminution.

8.5.4 Special consideration for fatigue

Due to the nature of the fatigue phenomena minor changes in basic assumptions can have significant influence on the predicted fatigue lives. Calculated fatigue lives and calculated probabilities of failure are sensitive to input parameters. It is thus recommended to provide as accurate calculated fatigue lives as possible before the inspection is planned.

For design purpose, it is appropriate to use conservative methods and parameters required for the analyses. However, for planning inspection it is recommended to use relevant (expected or best estimate) values and associated uncertainties to predict accurate results that allow the inspections to be directed to hot spot areas where the fatigue cracks are most likely to occur first. Thus, it is recommended to base planning of in-service inspection of offshore structures on fatigue analysis that has been performed in a consistent way. By consistent is understood that all joints or potential

hot spots are analysed based on a similar methodology such that any inherent conservatism in the analysis methodology is similar for the different hot spots. Use of inconsistent assumptions in analyses may direct inspection to areas with long fatigue lives and one might thus get a false impression of the reliability of the structure with respect to fatigue.

Design of offshore structures with respect to fatigue is normally based on S-N data (test data) derived from constant amplitude testing. In-service inspection for variable amplitude fatigue loading is normally performed to assure that possible cracks in the structure, which may have been present from the initial delivery or have initiated at a later stage during the service time, do not exceed a critical size.

For the S-N fatigue approach, the inspection results cannot be used directly to update the failure probability, as no direct relationship between the crack size and the damage accumulation in the S-N approach is available. A calibration of the S-N fatigue life to a fracture mechanics fatigue crack growth life is therefore required. The resulting extent of required in-service inspection is dependent on how this calibration is performed. An analysis methodology with calibrated initial defects is presented in DNVGL-RP-C210[6] to make inspection planning less time consuming and less complex.

The reliability of a non-destructive examination is described by the ability to detect an existing crack as a function of the crack size and by the uncertainty associated with the sizing of an identified crack. Regardless of the inspection outcome (detection or no detection), each inspection provides additional information to that available at the design stage. Thus, this information can be utilised to update the estimated fatigue reliability.

When planning inspection, it is recommended to assess the consequence of a potential fatigue crack at a considered hot spot. One may select different activities to achieve an optimal inspection plan. Engineering assessment of the different methods and suitability of method for each hot spot is recommended. Some further guidance is provided in [A.3](#) in [Annex A](#) and in DNVGL-RP-C210[6].

Where the integrity of a structure is based on fatigue crack monitoring by leakage detection, it shall be documented that a through thickness crack can be detected and repaired before it grows to a critical crack size. The leakage detection system shall give an alarm if leakage is detected. It shall be automatic, maintained and tested regularly.

8.5.5 Special considerations for TLP tendons

8.5.5.1 Evaluation

General requirements for evaluation of changes are described in [Clause 7](#) of this standard. Reference is also made to [Annex H](#).

For a TLP tendon system, the integrity is closely related to accumulated fatigue damage in the tendon system including girth welds of connectors, and to the extreme tendon tension and compression (slack tendon) response and the corresponding weight and ballast distribution and centre of gravity of the TLP. Considerations concerning these aspects shall be included in the monitoring programme and in the assessment of the condition after inspections.

For a TLP the weight management curve is the primary tool for operating the platform in a safe manner with respect to tendon tensions. The weight management curve defines (see NORSOK N-004) the relationship between the allowable platform mass and the (horizontal) centre of gravity. As long as the TLP is operated below the boundary curves, the tendon loading is within allowable limits for all relevant operating and survival conditions. The weight management curves shall regularly be assessed and safe tendon condition shall be verified by means of updated and related weight and ballast distributions and horizontal and vertical centre of gravity. The weight management curve shall be developed for intact and damaged conditions, and shall in addition be developed for maximum tendon actions (light platform) and for minimum tendon actions (heavy platform). In order to develop the weight management curve, issues like pretension including water-level variations (tide and storm surge), static and dynamic environmental actions, tendon capacity and miscellaneous allowances shall be included.

8.5.5.2 TLP tendon inspection

Due to the high consequence of a potential tendon failure, inspection for fatigue cracks shall be performed of tendon girth welded connections also if the $DFF \geq 10$.

If the TLP tendons are designed based on an assumption of “leak before break” they will be equipped with suitable measures for crack detection or leakage detection. The condition for use of this method is, however, that a through thickness crack is acceptable with respect to structural integrity and that it is acceptable from an operational and repair point of view. Relevant documentation of acceptable safety level should be based on fracture mechanics calculations in combination with site-specific metocean data. It shall be documented that a crack can be detected before growing to a critical size and necessary measures taken, taking into account a relevant weather window for execution and necessary time for preparation and mobilization, see [8.5.4](#) and NORSOK N-006.

For leakage system, reference is made to [8.5.4](#).

8.5.5.3 Execution of inspection and monitoring

TLP tendons are applied with measures for monitoring and adjustment of the prescribed level of tension of the tendons. This monitoring system shall be maintained and tested regularly and records of the tension level shall be evaluated and filed.

Inspection methods are further described in [Annex B](#).

Tendon girth welds identified in [Annex H](#), [H.4.2](#) shall be subject to NDT. It shall be demonstrated that the NDT method used is suited for its intended purpose (surface and embedded defects).

In addition to system elements or details given in [H.4.2](#), the following shall be included as part of the inspection programme:

- An overall periodical internal and external visual inspection of the tendon system.
- The condition of the corrosion protection system (coating and cathodic protection) shall be verified.
- Thickness measurements shall be performed at regular intervals in case of corrosion or breakdown of the corrosion protection systems in areas that could affect the structural integrity. Acceptance criteria for allowable thickness diminution and trending for future corrosion rates shall be established.
- Evaluation of potential field subsidence and related influence on tendons.
- Evaluation of potential foundation settlement and uplift.
- Evaluation if marine growth is outside design assumptions.

8.5.6 Special considerations for marine systems

8.5.6.1 Methods for maintenance

Marine systems are in general designed with built-in redundancy and barriers such that local damage or individual technical or operational faults should not result in unacceptable consequences. Reference is also made to [Annex I](#).

Marine systems that are normally regarded as safety critical are the bilge and ballast systems, the watertight integrity systems, the weight and stability monitoring systems and station keeping

systems. This includes items that are part of station keeping systems, miscellaneous marine systems and watertight integrity systems as listed in the following:

- Station keeping systems:
 - mooring systems;
 - turret and swivel;
 - heading control and thruster assistance.
- Miscellaneous marine systems:
 - cargo systems;
 - inert gas systems and HC blanketing;
 - ballast systems;
 - control systems (including weight management);
 - marine utilities.
- Watertight integrity systems:
 - sea chests (including caissons);
 - overboards;
 - watertight items;
 - weathertight items.

All these systems shall be subject to maintenance as applicable during the service life, based on either method A or B as described in the following:

Method A:

Method A implies that the extent and related intervals of maintenance during the service life of the following equipment is based on the principles of NORSOK Z-008:

- mechanical equipment:
 - static and rotating equipment;
 - piping.
- instrumentation;
- electrical equipment.

However, the minimum extent and related intervals of maintenance during the service life of the equipment shall not be less than specified by DNVGL-RU-OU-0102 Chapter 3 (or equivalent standard with the same safety level).

Where relevant, maintenance of pipes subject to a corrosive environment can be performed based on DNV-RP-G101 (Risk Based Inspection of Offshore Topsides Static Mechanical Equipment) [7].

Method B:

The minimum extent and related intervals of maintenance during the service life of the equipment shall not be less than specified in DNVGL-RU-OU-0102 Chapter 3 (or equivalent standard with the same safety level). Additional requirements are given in this standard.

8.5.6.2 Station keeping systems

Important subsystems and items in the station keeping system that shall be subjected to inspection, and maintenance during the service life are given in [Table I.1](#).

The instrumentation of the line tension shall have alarms for low and high line tension. Regular verification of the alarm settings should be carried out.

Alarms for offset position shall be activated if critical offset is exceeded to ensure integrity of flexible risers. Regular verification of the alarm settings should be carried out.

The position keeping system shall enable the floating installation to maintain position and heading within given operational limits. The position keeping system shall be verified at regular intervals when the weather is calm (no wind, waves and current) as follows:

- 1) Heading, position and mooring line pretensions are acceptable if they are within the limits that are documented in sensitivity studies in design or re-analyses.
- 2) The mooring line tension shall be within $\pm 10\%$ of the design pretension (sensitivity studies of expected pretension range shall be covered in analyses).

For the NCS provisions given in the NMD regulation 998/09 Section 15 should be followed as a minimum.

8.5.6.3 Weight and stability monitoring systems using Method B

Loading computer:

The loading computer on floating facilities is normally divided into the following main weight groups:

- lightship weight;
- risers including content and marine growth;
- drilling weights (cement, mud, hook load, marine riser, etc.);
- mooring lines including marine growth;
- piping content per system;
- equipment content per system;
- ballast, freshwater, fuel, and other tanks with online level indicators;
- storage tanks, sludge tanks, slop tanks;
- other tanks without online level indicators;
- marine growth on hull;
- temporary weights on laydown areas;
- temporary weights on other areas (personnel, supplies, etc.);
- snow and ice loads.

The riser and mooring loads that enter the loading computer shall be determined with the facility in origo position without any environmental forces.

The actual loading condition shall be checked against the KG limit curves daily by a person responsible for the stability on board. In the winter season the effect of snow and/or ice weights shall be accounted for by reducing the KG limit curve. The ghost weight should be limited to less than 1 % of the light ship weight and a reasonable corresponding moment arm. The ghost weight is defined as the weight