



GUIDANCE NOTES ON

**LIFE EXTENSION METHODOLOGY FOR FLOATING
PRODUCTION INSTALLATIONS
MAY 2021**

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Foreword (1 May 2021)

The *Guidance Notes on Life Extension Methodology for Floating Production Installations* have been developed to provide guidance for assessment of existing floating production installations when the intended period of operation at the original site or the cumulated operating time at both the original and relocated sites is extended beyond the original design life period. These Guidance Notes supplement the requirements for life extension and relocation of floating production installations in accordance with the *ABS Rules for Building and Classing Floating Production Installations (FPI Rules)*.

These Guidance Notes outline the life extension process that includes a reassessment of the structure, mooring system, stability, and machinery and systems, etc., for the entire installation. This reassessment includes engineering and survey activities.

In the May 2021 edition, a new Appendix 3 introduces a methodology for addressing Remaining Fatigue Life for FPSOs based on Loading Historical Data acquired on board during the vessel's Service Life.

These Guidance Notes become effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

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GUIDANCE NOTES ON

LIFE EXTENSION METHODOLOGY FOR FLOATING PRODUCTION INSTALLATIONS

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SECTION 1 Introduction

1 General (1 May 2021)

Floating production installations (FPIs) are facilities designed for site-specific application based on a design life usually defined by the Owner/Operator. A typical default structural design life is 20 years, though there are installations with other specified design lives. For different reasons, Owner/Operators may seek to keep the unit in operation beyond the original design life, either in the same location or at a different site. In these instances, the Owner/Operator is advised to initiate a life extension process with the assistance of the Classification Society. This process includes a reassessment of the structure, mooring, tendon systems, stability, machinery and systems, etc., for the entire installation. This reassessment includes engineering and survey activities as outlined in Section 2 of this document.

These Guidance Notes highlighting the process and methodology for life extension are applicable to floating production installations of all hull forms (i.e., ship-type installations, column stabilized installations, tension leg platforms (TLPs), Spar Installations (Spars) and hybrid designs, etc.) with the **Floating Production and Storage System, Floating Production, Storage and Offloading System, Floating Storage and Offloading System** and **Floating Offshore Installation** notations. It is not applicable to mobile offshore drilling units.

These Guidance Notes cover the following life extension scenarios:

- i) Life extension for continued services at the same location
 - Option 1: Life extension of up to five years for an installation remaining at the same location. This option presents an abbreviated procedure per 2/3.1.
 - Option 2: Life extension of over five years for an installation remaining at the same location. This procedure is presented in 2/3.3.
- ii) Life extension procedure for continued services at a different area of operation (See 2/3.5)
- iii) **Life extension procedure for continued services based on historical loading information regularly acquired on board from operational data (See Appendix 3)**

The requirements for the Life Extension of an installation that remains at the same site are specified in 1-1-2/5.11.5 of the *ABS Rules for Building and Classing Floating Production Installations (FPI Rules)*. The procedure in these Guidance Notes provides further details regarding the steps to be followed in order to assess an installation for a possible life extension, and also covers those cases where there are changes in the original design parameters or arrangements, for continued operations at the same location.

These Guidance Notes are not intended to serve as a design standard, but rather to highlight the primary activities relating to the life extension procedure for floating production installations.

These Guidance Notes present a methodology that can be applied in the life extension for continued services process. As such, it may be applied to units classed by ABS, not classed by ABS or without class.



SECTION 2 Life Extension Process Overview

1 General

Floating installations designed and built to the requirements in the Rules and maintained in accordance with the applicable ABS requirements are typically intended to have a structural design life of 20 years. Many are designed for uninterrupted operation onsite without any dry docking. When a floating installation exceeds the original design life, an evaluation is to be made and appropriate actions are to be taken to extend the life up to the new operating life of the installation under the site-specific environmental conditions.

3 Life Extension of Floating Production Installations (1 May 2017)

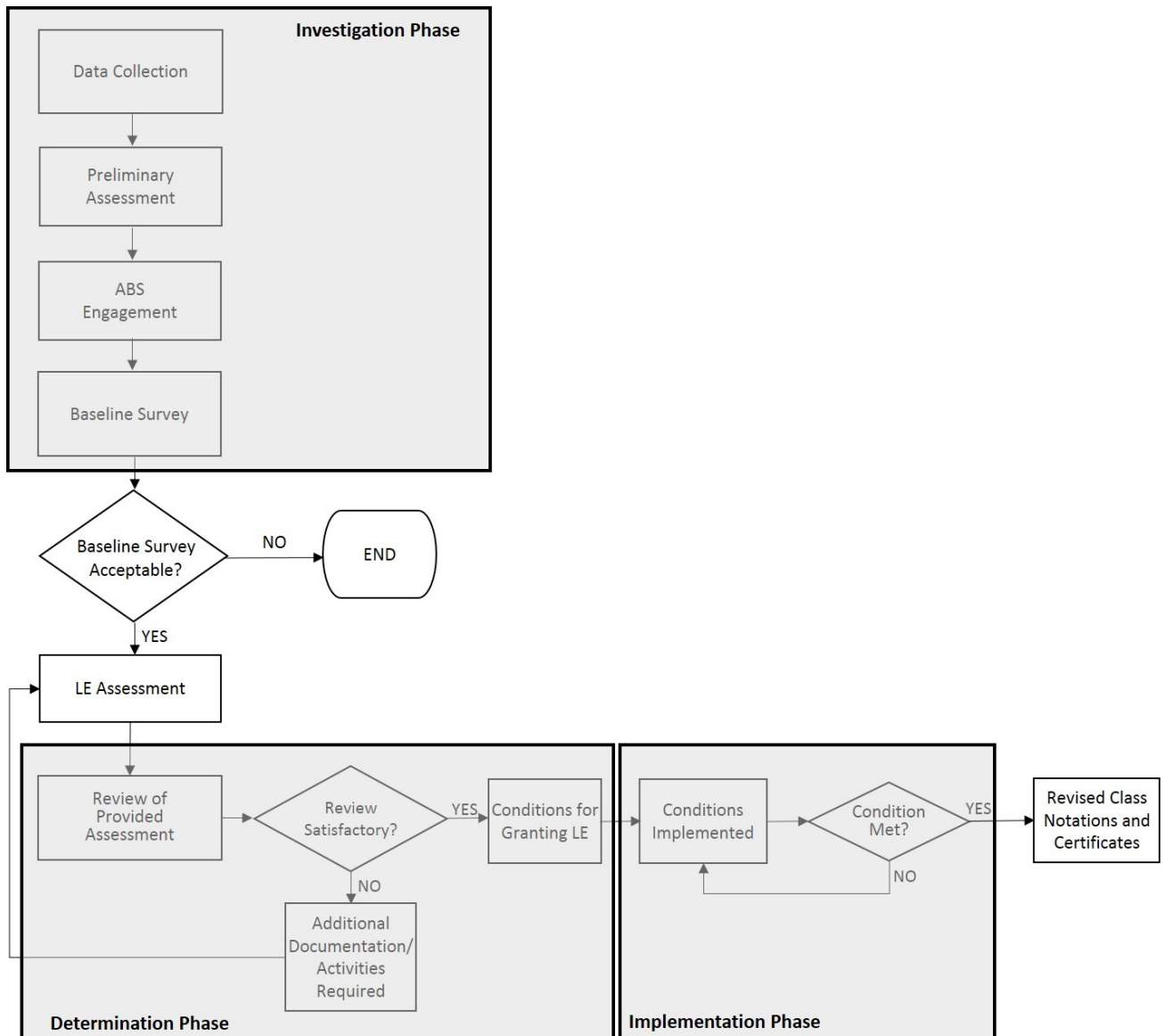
The requirements for the life extension of an installation that remains in the same site are given in 1-1-2/5.11.5 of the FPI Rules. In general, the classification or continuance of classification of an existing installation for extension of service beyond the design life requires special considerations with respect to the review, surveys and structural analyses in order to re-verify the adequacy of the installation for its extended services. The following procedure will provide more details regarding the steps to be followed in order to assess an installation for a possible life extension, in particular for those cases where there are changes in the original design parameters and/or arrangements. The general reviews and surveys procedures are described in 2/3.1 and 2/3.3.

The life extension process generally follows the three phases listed below and is also shown in Section 2, Figure 1A:

- i)* Investigation phase
 - Data collection and engineering assessment
 - Baseline survey
- ii)* Determination phase
 - Reassessment
 - Provision of conditions for life extension
- iii)* Implementation phase
 - Conditions implemented

The detailed life extension process is shown in Section 2, Figures 1B and 1C. Details pertaining to the life extension process are given in Sections 3 through 8.

FIGURE 1A
Life Extension Process Flow Chart Based on Phases (1 May 2017)



3.1 Procedure for Life Extension up to 5 Years at the Same Location (1 May 2021)

If the first life extension request for an installation remaining at the same location is five years or less, the following abbreviated approval procedure is to be followed. If a baseline survey is performed and all required structural repairs are completed, the life extension may be granted without the need for data collection. The life extension process is shown in Section 2, Figure 1B.

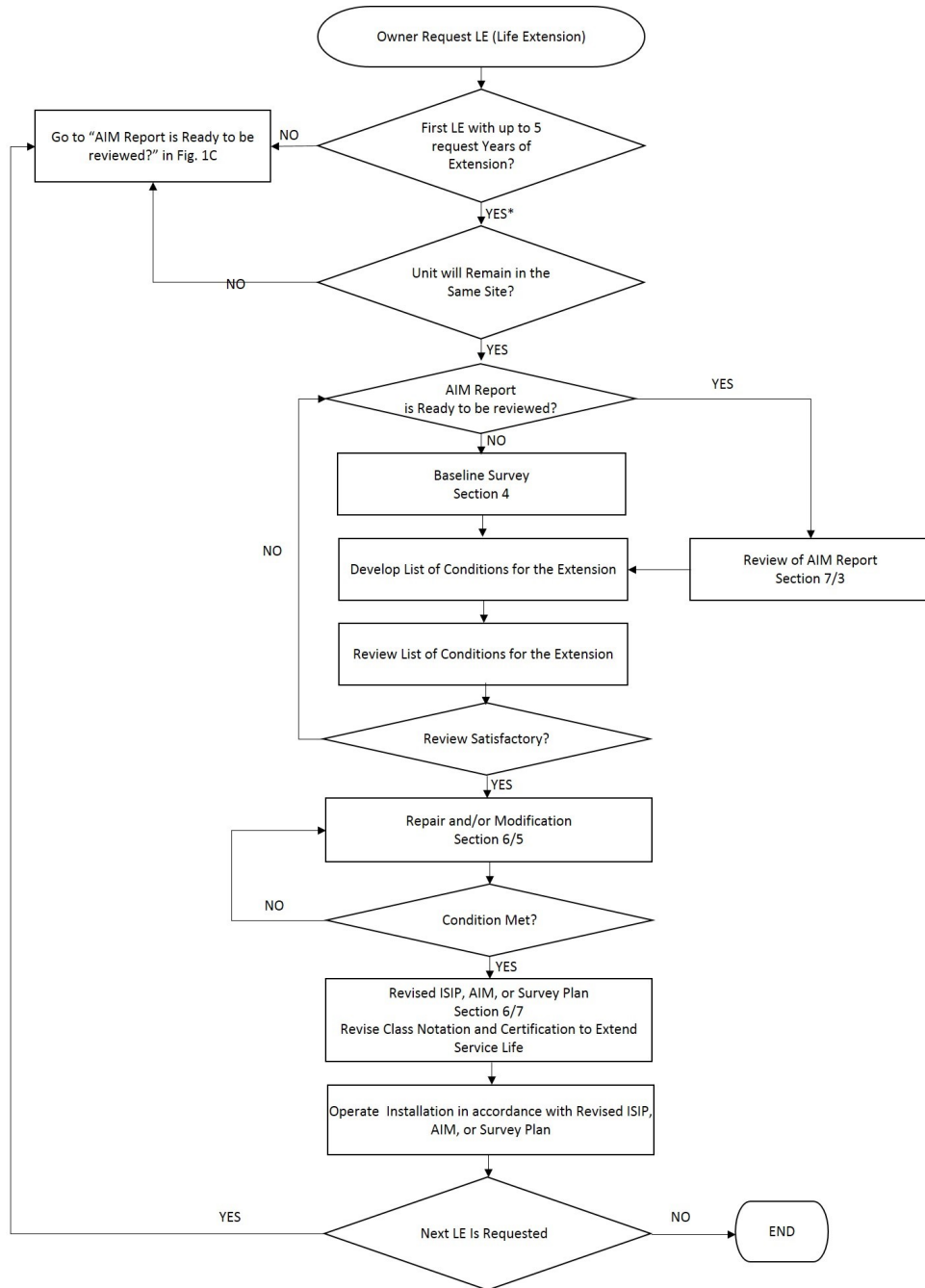
To be granted life extension under these terms, the following conditions are to be satisfied:

- Any modifications to the structure have class approval.
- Critical areas of the original design have been re-examined using NDT techniques and verified to be satisfactory.
- Additional items to be determined on a case-by-case basis during the life extension process have been resolved.

Life extension is a continuous process that extends the original life. This abbreviated process can only be applied once in the lifecycle of a Floating Production Installation. Once a unit has been granted life extension under this option (abbreviated process), additional requests for life extension will be considered as the total additional life beyond the original design life in accordance with the full procedure as described in 2/3.3. For example, if the design life of an installation is 20 years and it receives a life extension of five years, a second five-year life extension will be a ten-year extension to the original design life.

If **FL** or **RFL** notation was granted for the unit under consideration, to use this abbreviate procedure, the original fatigue analysis is to show that the fatigue lives of all joints/critical details are sufficient to cover the extension of use. When the original fatigue analysis shows insufficient remaining fatigue life for the requested extension, the **FL** or **RFL** notation needs to be specially considered.

FIGURE 1B
Life Extension Process Abbreviated Procedure (For life extension up to 5 years at the same location)



* The extension period ends before the first special survey scheduled after the conclusion of the original life

3.3 Procedure for Life Extension Over 5 Years at the Same Location (1 May 2021)

The general procedure, which is shown in Section 2, Figure 1C, for the classification of an existing installation for extended service is as follows:

- i) For life extension, the operator collects and reviews original design documentation, plans, modification records, if any, and In-Service Inspection Plan (ISIP), onboard operation historical loading and environmental data, Risk Based Inspection (RBI), survey reports, etc. Asset Integrity

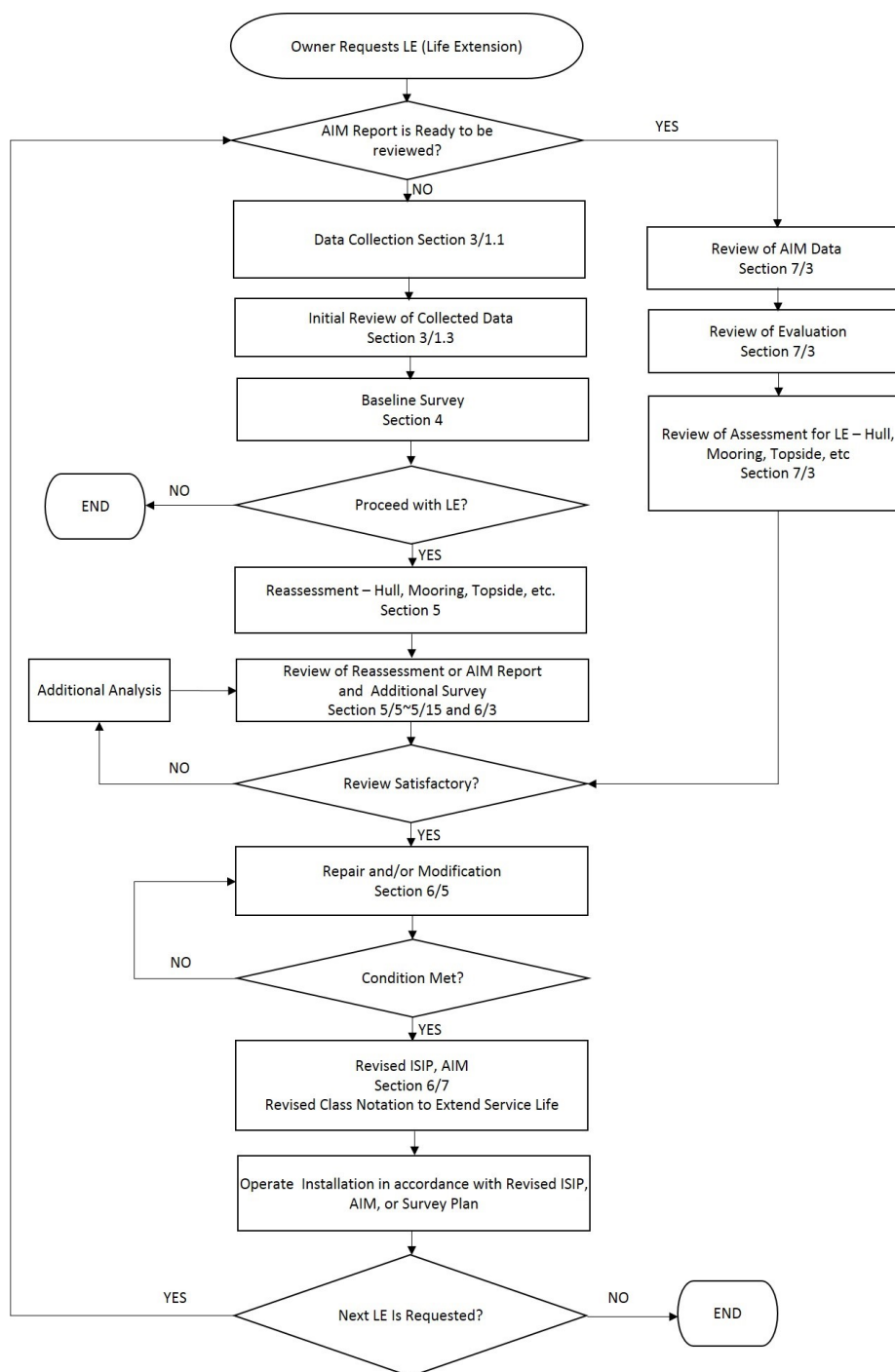
Management (AIM) document, if available, can be submitted in lieu of a data collection, baseline survey, and reassessment for the following items: hull structure, hull interface structure, topside, mooring, riser, systems, and machinery.

- ii)* ABS performs a baseline survey of the structure, mooring and machinery to establish condition of installation. The structural surfaces are to be made accessible and cleaned to the Surveyor's satisfaction to enable inspection.
- iii)* If the baseline survey is acceptable, a reassessment is performed.
- iv)* ABS reviews the submitted AIM documents or the results of the reassessment utilizing results of survey, original plans, metocean data, **onboard historical operational data when available**, and proposed modifications which affect the dead, live, and environmental loads, if applicable, on the structures.
- v)* ABS surveys the installation to verify that any item identified during the review of the AIM documents or reassessment has been addressed.
- vi)* If the review and additional survey are satisfactory, the operator makes any required repairs and modification for extending the service of the installation.
- vii)* ABS verifies completion of conditions for granting the life extension. The operator revises the required documents to reflect any changes for approval (i.e., ISIP, AIM, RBI, Survey Plan, operations manual, loading manual, etc.).
- viii)* ABS reviews the scope of the ISIP, AIM or RBI program to verify the plan modifications as necessary to address results obtained in ii) through v) above that may be necessary to verify the adequacy of the continued service of the installation.

ABS records including ISIP, AIM or RBI are to be updated to reflect the extended life condition. Class certificate is to be issued for life extension. Where applicable, the existing spectral fatigue analysis (**SFA**), fatigue life (**FL**) or remaining fatigue life (**RFL**) notation with year of maturation is to be updated accordingly.

ABS has a tiered set of Structural Integrity Management software tools included in Nautical System (NS) Hull Manager (HM), which allows the operator to manage the condition data of their asset. NS Hull Manager fully integrates structural integrity management into the maintenance, purchasing and repair planning or drydock process. The software has capability of inspection scheduling, anomaly reporting, trending future condition, rapid assessment of hull structures, etc. While the purpose of Hull Manager is to provide lifecycle management, this tool will help and benefit the life extension process for the unit under consideration, since it contains asset specific information required for baseline information and survey, reassessment and re-inspection for hull structures.

FIGURE 1C
Life Extension Process (For life extension over 5 years at the same location)
(1 May 2017)



3.5 Life Extension Procedure for an Installation Relocating to a New Location
(1 May 2017)

If an installation is intended to remain in service beyond its original design life and also be relocated to a new site, the requirements for life extension described in 2/3.3 are to be applied in addition to the requirements for relocation of the unit contained in the *FPI Rules* as follows:

- 1-1-2/5.9.3 for strength requirements for ship-shaped FPIs

- 1-1-2/5.10.2 for strength requirements for other types of offshore installations
- 1-1-2/5.11.4 for fatigue requirements for all types of FPIs
- 1-1-2/15 for significant changes to the operating conditions

3.7 Remaining Fatigue Life (1 May 2017)

The remaining fatigue life can be calculated by means of an analysis as described in A2. This analysis is sensitive to waves encountered and operating loads during the past service and future prediction, therefore the long-term environmental data are to be properly represented.

One or more of the following conditions are to be satisfied by the fatigue assessment:

- i) The original fatigue analysis indicates that the fatigue lives of all joints/critical details are sufficient to cover the extension of use.
- ii) The fatigue environmental data used in the original fatigue analysis remain valid or are deemed to be more conservative.
- iii) No cracks are found during the condition survey or damaged joints, members, and their connections are being repaired.
- iv) Marine growth has been cleaned to the surveyor's satisfaction and corrosion is found to be within the allowable design limits.

A critical area or critical detail is defined in 5A-3-A5/5 and 5A-3-A5/7 of the *FPI Rules*.

3.9 Remaining Fatigue Life Procedure based on Historical Loading Data (1 May 2021)

Accurate and continuous onboard data of historical hydrostatic loading conditions and associated environmental conditions for 5 years or more can be considered for reassessing the Remaining Fatigue Life (RFL), as described in 5A-1-3/3.9.3 of the *FPI Rules*. The *ABS Advisory on Fatigue Monitoring of Floating Production Installations* provides guidance on data acquisition.



SECTION 3 **Baseline Information**

1 **General**

Floating production installation design and operational information is to be collected to allow an engineering assessment of an installation's overall structural integrity. It is essential to have the original design reports, documents, original and as-is plans, specifications, survey records during fabrication, installation and past service. The operator should ensure that any assumptions made are reasonable and information gathered is both accurate and representative of actual conditions at the time of the assessment. If the information cannot be provided, reassessment of the installation is to be required. Actual measurements or testing may be utilized for the reassessment.

1.1 **Documentation to be Provided during Life Extension Process (1 May 2021)**

The documentation listed below is recommended to be provided in order to proceed with the life extension process. The procedure and result of life extension are based on availability and quality of the submitted documentation.

- i) Drawings
 - General arrangements, tank capacity plan, key structural plans, machinery diagrams and system drawings, foundations connected to hull structure along with associated underdeck reinforcement if added, tank vents and overflow arrangement, corrosion protection plan, T & S Booklets and Loading Manuals.
 - Drawings for mooring system and all components, including ropes, chains, connectors and anchoring system (piles or anchors) and mechanical components.
- ii) Design basis containing an assessment of existing design, additional engineering analysis performed in service, and proposed future plan/schedule for life extension, including equipment change out (e.g., mooring chains replacement).
- iii) Existing analyses
 - Scantling calculations, global and local strength analyses, fatigue analyses, stability analysis
 - Mooring analysis, including individual components
 - Tendon analysis if applicable, including individual components
- iv) Existing ISIP or Survey Plan and results/findings, including revision history
- v) Survey and gauging reports
- vi) Owners/Operators reports covering repairs, replacements and operational history
- vii) Record of modifications, including updated drawings
- viii) Records of installation (piles orientation, inclination, etc.)
- ix) Metocean data
 - Updated metocean data of site (if available), metocean history (normal and extreme events) from monitoring system or hindcast analysis
- x) Measured load history of mooring, risers, tendons, etc.

- xi)* Measured historical loading data, and hydrostatic properties applicable to RFL assessments, gathered continuously throughout the vessel's operational life. Owner/Operator should also provide assurance of the data quality which should be validated by ABS.

1.3 Initial Assessment of Baseline Information (1 May 2017)

The following procedure is to be applied for Initial assessment of baseline information:

- i)* Review completeness and extent of original design analyses and determine need for further analyses.
- ii)* Assess condition of the FPI from documentation, ISIP, Survey Plan, survey reports, design basis, or existing analyses, etc.
- iii)* Based on review of data, develop additional items for Survey Plan over and above normal Special Survey activity, including the need of weight verification (deadweight survey or equivalent).



SECTION 4 **Baseline Survey**

1 **General (1 May 2017)**

Surveying an existing installation witnessed and monitored by an ABS Surveyor is necessary to determine a baseline condition upon which justification of continued service can be made. The baseline Survey will include the following activities:

- i) Review of reports of previous surveys and maintenance,
- ii) Development of an inspection procedure, and
- iii) Complete inspection (including underwater inspection) to verify that an accurate assessment of the installation's condition is obtained.

The scope of baseline survey is to be not less than the next upcoming Special Survey.

The baseline survey information can be collected from the surveys leading up to the expiration of the design life. All survey items are to be up to date and examined within the previous 5 years. All anomalies are to be resolved or accounted for in the life extension plan.

3 **Structures (1 May 2017)**

The baseline survey for structures will follow the same scope as the next upcoming Special Survey for Hull.

For additional items from initial review of collected data in Section 3, General Visual Inspection (GVI), Close Visual Inspection (CVI) or Nondestructive Testing (NDT) may be required, as appropriate.

Substantial corrosion areas identified are to be either cropped and renewed or reinforced or have adequate corrosion arresting measures approved and implemented prior to life extension.

The corrosion protection system is to be re-evaluated to verify that existing anodes are capable of serving the extended design life of the installation. If found necessary by the re-evaluation, replacement of the existing anodes or installation of additional new anodes are to be carried out. The condition of protective coatings in the splash zone, if found deficient, are to be rectified and maintained in satisfactory condition.

Nondestructive Examination (NDE) (i.e., thickness measurement and crack detection) is to be carried out according to the survey requirements to establish an accurate assessment of the current condition.

Areas originally designed as non-inspectable are not required to be inspected at this time. At Owner/Operator's request, ABS may consider the reduction of safety factors for fatigue life for past service life if a single inspection is carried out. Extent of such inspection is to be agreed upon between Class and Owner/Operator.

New technologies such as Unmanned Aerial Vehicles (UAV) can be used for baseline survey for structures. Reference can be made to the *ABS Guidance Notes on Using Unmanned Aerial Vehicles*.

5 **Mooring Systems (1 May 2017)**

The scope and schedule of survey as described in 4/1 is applicable to mooring baseline survey. The following steps may be followed for the mooring baseline survey:

- i) Inspect using applicable sections of 7-2-6 of the ABS *FPI Rules* and/or API RP 2I as reference.
- ii) Inspect for cracks, corrosion, dimensional checks, and wear, as accessible. A reasonable length of each mooring chain is to be cleaned to ensure the overall condition of each chain can be satisfactorily verified.
- iii) Inspect wire ropes and synthetic ropes for mechanical damage, twist and sheathing conditions, including anodes, on wire sockets (if installed).
- iv) Carry out general visual inspection (GVI) of mooring components and connectors, and top of piles.
- v) Verify plan for monitoring changes in length of synthetic fiber rope (if applicable) is in place.
- vi) Carry out GVI of fairleads and mooring equipment (i.e., windlasses, chain jacks, chain stoppers, etc.). Additional inspections such as close up visual inspection (CVI) and/or NDE (wet magnetic particle inspection (MPI) or similar) may be applicable for suspect areas identified by the GVI.
- vii) Carry out general visual inspection of turret bearings, bogies, and wear pads. If accessible, bearings and races are to be inspected. Additional/alternative inspection methods can be approved on a case-by-case basis.

Non-accessible areas are to be discussed and agreed upon between Class and Owner/Operator.

7 Tendons (1 May 2017)

The scope and schedule of survey as described in 4/3 is applicable to tendon baseline survey. The following procedure may be followed for Tendon baseline survey:

- i) Visually inspect entire length of all tendons using as appropriate divers/remotely operated vehicles (ROVs).
- ii) Verify condition of coating and anodes.
- iii) Check for flooded tendon sections for entire length of all tendons.
- iv) Carry out visual inspections and surface flaw detection to extent specified by ABS on tendon joints as well as top and bottom tendon connectors.
- v) Carry out thickness measurement of tendons to extent specified by ABS.

Non-accessible areas are to be discussed and agreed upon between Class and Owner/Operator.

9 Machinery and Systems (1 May 2017)

The scope and schedule of survey as described in 4/1 is applicable to machinery baseline survey and may be conducted using the following procedure:

- i) Identify any modifications that were not reviewed/approved.
- ii) Survey non-accessible pipes, valves and cables to the greatest extent possible and practical.
- iii) Survey pipes and valves for critical systems including ballast, bilge, venting, soundings, and firefighting systems.
- iv) Survey critical machinery and electrical system including fire pumps, emergency power, sensors, and alarms. Surveys for ship-type or barge-type installations are to comply with applicable requirements of 7-6-2/1 of the ABS *Rules for Survey After Construction (Part 7)*. Surveys for column-stabilized installations are to comply with applicable requirements of 7-2-4/3 of the ABS *MOU Rules*.

11 Outfitting (1 May 2017)

The scope and schedule of the survey as described in Subsection 4/1 is applicable to the outfitting baseline survey. Personnel access and egress including walkways, gratings and handrails are to be addressed for the baseline survey.

13 Additional Scope of Survey and Analysis

The additional scope of survey and analysis are determined based on reviewing data from existing engineering analyses and surveys and discussing between Class and Owner/Operator.

Any additional analysis to be performed at this stage is to address changes in the original design conditions (loading, structural modifications or significant condition changes such as material loss, etc.).

The extent of any additional analysis in general reflects the extent of the analysis performed at the time of the construction/conversion.

Each request for life extension will be treated on a case-by-case basis and the final extent of the analysis will need to be clarified for each specific project; in some cases the extent of analysis may be increased or reduced.



SECTION 5 Reassessment

1 General (1 May 2017)

The reassessment of an existing installation is to incorporate the results of the baseline survey in Section 4. Specifically, deck loads, wastage, marine growth, scour, and any modifications and damages are to be incorporated into the reassessment. Where available, the original fabrication materials and fit-up details are to be established such that proper material characteristics are used in the reassessment and any stress concentrations are accounted for. Where applicable, the pile driving records are to be made available so that the foundation can be accurately reassessed.

The results of the reassessment are considered to be an indicator of areas needing careful inspection. Possible modifications of structural components to allow continued service of the installation are to be developed.

Strength and/or fatigue reassessment, design review and surveys, when necessary, will be based on the following:

- For structures, systems or equipment not modified and maintained per original design:

Design review will be based on the design codes used in the original design with current environmental data.

- For added or modified structures, systems or equipment:

Design review will be based on the design codes at the time of the contract for the life extension with current environmental data.

- Surveys will be based on the current ABS requirements at the time of the life extension.

3 Environmental Conditions (1 May 2017)

If the current site-specific environmental conditions are more severe than the original design environmental condition, the current site-specific environmental conditions are to be applied.

5 Hull Structures

5.1 Ship-Type Installations (1 May 2017)

Hull structural reassessment of ship-type installations may include strength, fatigue and stability analysis.

5/5.1 TABLE 1 is intended to give an indication of the extent of the strength and fatigue analysis required in case of Life Extension under different scenarios.

Each request for Life Extension will be treated on a case-by-case basis and the final extent of the analysis will need to be clarified for each specific project; in some cases the extent of analysis may be increased or reduced. The decision will be based on extent of life extension, extent of reassessment, condition of the vessel/survey history as well as scope of life extension with respect hull, topsides and position mooring systems, etc.

TABLE 1
Extent of Strength and Fatigue Analysis Scenarios for Life Extension

<i>Basis of Original Design/ Conversion</i>	<i>No Changes on Design Parameters</i>	<i>Change of Design Parameters ⁽²⁾</i>	<i>Reassess scantlings ⁽³⁾ (Longitudinal members only)</i>	<i>Reassess scantlings ⁽³⁾ (Including transverse members)</i>
Tanker Requirement with/ without fatigue analysis	Original Rules ^(1, 4)	ISE ⁽⁴⁾	ISE ⁽⁴⁾	ISE & TSA
SafeHull Phase A	Original Rules ⁽⁴⁾	ISE ⁽⁴⁾	ISE ⁽⁴⁾	ISE & TSA
SafeHull Phase A & B	Original Rules	ISE & TSA	ISE & TSA	ISE & TSA
Eagle FPSO ISE & TSA	Original Rules	ISE & TSA	ISE & TSA	ISE & TSA

Notes:

- 1 In case no fatigue life was assigned during the original conversion, ISE may be required to establish the remaining fatigue life.
- 2 Renewal assessments as per original Rules
- 3 “Reassess Scantlings” involves establishing new Rule required/renewal scantlings due to changes in Rule requirements, or design parameters. Reassess Scantlings is optional and may be performed when requested by the clients.
- 4 Any findings in the baseline surveys for critical areas might require investigation using TSA.

Design parameters include environmental conditions, geographical location of the unit, loading conditions, external loads, pressures, temperatures, etc.

Wastages are to be incorporated into the reassessment model. Detailed procedures for establishing gross and net scantlings taking consideration of wastages are specified in Appendix A2. Detailed procedures for initial scantling evaluation (ISE) and total strength assessment (TSA) are outlined in Appendix A2. Dynamic loading approach (DLA) and/or spectral-based fatigue analysis (SFA) may be performed in accordance with 5A-2-1/5.6.1 of the *FPI Rules*, in addition to TSA. In case of life extension of converted units (where a TSA analysis was performed either during new construction as tanker or during conversion), a cargo block model analysis as defined in 5A-2-1/5.6.1 of the *FPI Rules* or an SFA/DLA can be performed in lieu of TSA.

The possible fatigue-prone areas introduced by modifications are to be identified and assessed.

New critical areas identified based on the reassessment are to be included for additional survey. Furthermore, the ISIP or Survey Plan is to be revised accordingly.

If the fatigue reassessment is not satisfied for the requested years of life extension, the following mitigation measures may be considered on a case-by-case basis:

- Fatigue improvements, if feasible, in accordance with ABS requirements or other recognized standards
- Increased inspection frequency
- Modification of design loading conditions, particularly if the original metocean data has been updated
- Make the originally non-inspectable structure accessible for inspection

5.3 Non-Ship Type Installations (1 May 2017)

Reassessment for non-ship type installations includes global strength, local strength and fatigue strength, corrosion protection and stability analysis.

Structural models for assessing the structural strengths are to be updated to incorporate wastages and changes in configuration and weights.

5.3.1 Strength Reassessment

The global strength reassessment of hull structures is performed for the environment conditions in 5/3.

For US GOM Installations, API Bul. 2Int-Ex (Interim Guidance for Assessment of Existing Offshore Structures for Hurricane Condition) is applied to:

- Design level check
- Survival level check
- Robustness check for critical components.

Alternative approaches such as non-linear FEA for local strength may be considered acceptable on a case-by-case basis.

5.3.2 Remaining Fatigue Strength Reassessment (1 May 2017)

The remaining fatigue strength should be greater than the requested years (L) for life extension multiplied by the safety factors for fatigue life.

The Safety Factors for Fatigue Life are to be as required by the Rules. However, if a Safety Factor for Fatigue Life greater than the Rule requirement was used in the original design, the Safety Factor for Fatigue Life can be reassessed based on the actual criticality and inspectability.

A detailed procedure for remaining fatigue strength assessment can be found in Appendix A1 which includes an example of calculations for non-inspectable critical areas.

If the fatigue reassessment is not satisfied for the requested years of life extension, the following mitigation measures may be considered on a case-by-case basis:

- Fatigue improvements, if feasible, in accordance with ABS requirements or other recognized standards
- Increased inspection frequency
- Modification of loading conditions, particularly if the original metocean data has been updated
- Make the originally non-inspectable structure accessible for inspection

Alternative approaches such as fracture mechanics may be considered acceptable on a case-by-case basis.

The possible fatigue-prone areas introduced by modifications are to be identified and assessed.

5.5 Cathodic Protection Reassessment

If survey shows that anode replacement is required, a plan for replacement is to be submitted for review and approval. Installation is to be surveyed in accordance with Section 6.

If an alternative to anodes is selected (e.g., impressed current), the system details are to be submitted for review and installation is to be surveyed in accordance with Section 6.

5.7 Stability Reassessment

An updated stability analysis is to be carried out using the Rules in effect when the installation was classed with the current deadweight, lightship and loadings. However, if the unit has undergone a major modification during its service, the Rules in effect at the time of major modification are to be applied. The Operations Manual is to be updated accordingly.

5.9 Review of Reassessment Results

If result of reassessment identifies required repairs and/or modifications to achieve life extension, the Owner/Operator is to be advised.

Owner/Operator is to develop and submit such plans required for review and approval.

Alternative approaches (i.e., risk assessment, etc.) may be discussed with ABS on a case-by-case basis.

7 Hull Interface Structures (1 May 2017)

When design loads or modifications have been identified, such as increased weights, metocean environmental condition changes, structural modifications, etc., hull interface structures under as-is condition are to be reassessed.

Reassessment is to include strength, fatigue strength and corrosion protection analysis.

Structural models for assessing the hull interface structural strengths are to be updated to incorporate wastages and changes in configuration and weights (as-is condition).

7.1 Strength Reassessment

The global strength reassessment of hull interface structures is performed for the environment conditions in 5/3.

For US GOM Installations, API Bul. 2Int-Ex (Interim Guidance for Assessment of Existing Offshore Structures for Hurricane Condition) is applied to:

- Design level check
- Survival level check
- Robustness check for critical components.

Alternative approaches such as non-linear FEA for local strength may be considered acceptable on a case-by-case basis.

7.3 Remaining Fatigue Strength Assessment (1 May 2021)

Detailed procedure for remaining fatigue strength assessment can be found in [Appendices 1, 2 and 3](#). The remaining fatigue life should be greater than the requested years for life extension multiplied by the Safety Factor for Fatigue Life. The Safety Factors for Fatigue Life are to be established based on the procedure given in 5/5.3.2.

If the fatigue reassessment is not satisfied for the requested years of life extension, the following improvements may be performed:

- Fatigue improvements, if feasible, to be in accordance with ABS or other recognized standards
- Increase inspection frequency
- Change loading conditions
- Apply enhanced inspection techniques
- Make the originally non-inspectable structure accessible for inspection

Alternative approaches such as fracture mechanics may be considered acceptable on a case-by-case basis.

The areas possibly prone to fatigue that are introduced by modifications are to be identified and assessed.

7.5 Review of Reassessment Results

The review of assessment results follows the procedure given in 5/5.9.

9 Topside Structures

A weight control document reflecting changes in module weights over the unit's service history is to be submitted, if applicable. Topside structures are to be reassessed based on new data including increased weights, metocean environmental condition changes, structural modifications, etc., and incorporating the significant wastages and configuration changes in the structural model.

9.1 Strength Reassessment

The structural strength reassessment of topside structures is performed for the environmental conditions in accordance with 5/3.

Data analysis and reassessment may identify additional review and survey requirements.

9.3 Remaining Fatigue Strength Assessment for Non-Ship Type Installations

The remaining fatigue strength assessment for non-ship type installations follows the procedure given in 5/7.3.

9.5 Review of Reassessment Results

The review of assessment results follows the procedure given in 5/5.9.

11 Mooring Systems

When design loads or modifications have been identified, such as mooring components updates, metocean environmental condition changes, possible seabed changes, any possible changes affecting the mooring responses, etc., mooring systems are to be reassessed.

11.1 Reassessment Analysis (1 May 2017)

Mooring system models are to be developed and updated incorporating wastage in the model while assessing mooring strength and remaining fatigue life.

The mooring strength reassessment is performed for the environmental conditions in accordance with 5/3. For the extended life, the Safety Factors for mooring strength are to be in accordance with 6-1-1/Table 1 of the *FPI Rules*.

Global performance/mooring analysis, with new metocean data and other changes are to be submitted for review. Global performance response such as motion, acceleration, offset, air gap, etc., are to be within the original design criteria.

Applying same corrosion verified for chains to components, detailed calculations for individual components using as-is conditions and actual loads are to be carried out and to be submitted for review.

The Safety Factors for Fatigue Life are to be as required by the Rules. In calculating the accumulated damages or used-up fatigue life, the original Safety Factors for Fatigue Life may be reduced providing that the technical justifications submitted by the Owner/Operator reflect a reduction of the uncertainty in the original design and subject to the following conditions:

- No past findings
- Corrosion rate to be within the original design assumption

- Reliable load/metocean history

However, the Safety Factors for Fatigue Life for the accumulated damage are to be not less than three. For the extended life, the Safety Factors for Fatigue Life are to be in accordance with 6-1-1/5 TABLE 1 of the *FPI Rules* and Section 3, Table 1 of the *ABS Guidance Notes on the Application of Fiber Rope for Offshore Mooring*.

Alternative methodology may be accepted in a case-by-case basis, such as fatigue testing of mooring chain.

For mooring systems with steel wire ropes and polyester ropes, if the life extension period exceeds the warranty period provided by the steel wire rope and polyester rope manufacturer, the requirement of reassessment and in-situ inspection method of the steel wire rope may be considered on a case by case basis.

Where single point mooring systems are installed, mechanical components such as, but not limited to, turret and swivel bearings, driving arms/mechanisms, structural connectors between swivels, and fluid swivels are to follow the same procedure for fatigue analysis. The components may be analyzed using recognized industry standards and published recommended practices such as ISO 281 for bearings, the *ABS Guide for Fatigue Assessment of Offshore Structures*, and ASME Boiler and Pressure Vessel Code.

The anchoring point, such as torpedo piles, are to be re-evaluated in case the mooring lines loads are increased.

11.3 Cathodic Protection Reassessment

The cathodic protection assessment follows the procedure given in 5/5.5.

11.5 Review of Reassessment Results

The review of assessment results follows the procedure given in 5/5.9.

13 TLP Tendons and Tendon Connectors

When design loads or modifications have been identified, such as tendon components updates, metocean environmental condition changes, possible seabed changes, any possible changes affecting the tendon responses, etc., tendons and tendon connectors are to be reassessed.

13.1 Reassessment Analysis

Tendon system models are to be developed and updated incorporating wastage in the model while assessing tendon strength and remaining fatigue life. The strength and fatigue reassessments of tendons, including fracture mechanics, are to be carried out using as-is conditions.

The environmental conditions in accordance with Subsection 5/3 are applied to verify the adequacy of the tendon system based on the design code used for the original design. Robustness check of tendons as per 5B-2-4/1.5 of the *ABS FPI Rules* and or API RP 2T, latest edition is carried out and to be submitted for review.

Global performance/tendon analysis with new metocean data and other changes are to be submitted for review.

Due to the degree of inspectability of tendons and the consequence of tendon failure, tendon fatigue life can only be extended by the fatigue life gained by adjusting the spent fatigue life based on actual service conditions versus the design condition. The fatigue safety factors are to be in accordance with the Rule requirement for both past and future lives. If the fatigue safety factor specified in the Rules cannot be met, a reduced safety factor may be applied to the past fatigue life on a case-by-case basis based on the quality/completeness of the inspection.

In the tendon reassessment, inadvertent disconnect in storm conditions is to be addressed, and consequence analysis of component failure is to be carried out. Alternative methodology may be accepted on a case-by-case basis.

13.3 Cathodic Protection Reassessment

The cathodic protection assessment follows the procedure given in 5/5.5.

13.5 Tendon Connectors with Nonmetallic Components (1 May 2017)

For connectors containing non-metallic components, Owner/Operator is to approach original equipment manufacturer (OEM) to ascertain the following:

- Component original design life
- Expected types of degradation failure (progressive or sudden), and performance consequences
- Possible methods for testing or observing in situ
- Current condition

OEM to demonstrate components suitable for continued use for requested life extension period.

For flex elements, visual examination is to be performed. Owner/Operator needs to prove that the actual conditions of these elements are acceptable to ABS surveyors.

13.7 Tendon Tension Monitoring Systems (1 May 2017)

Tendon tension monitoring system is to be fitted if not currently installed or repaired if not in working order. The requirement for the tendon tension monitoring system follows API RP 2T recommendations.

13.9 Review of Reassessment Results

The review of assessment results follows the procedure given in 5/5.9.

15 Marine and Industrial Machinery and Systems

Previous modifications, if any identified, are to be reviewed along with any upgrades, additions and changes planned during life extension activities.



SECTION 6 Additional Survey/Repairs/ISIP

1 General (1 May 2017)

The initial condition survey in conjunction with structural analysis will form the basis for determining the extent of repairs/alterations which will be necessary to class the platform for continued operation.

A second survey is necessary to further inspect areas which the analysis results indicate locations as being highly stressed regions of the structure. Members and connections found overstressed should be strengthened. Connections with low fatigue lives may be improved either by strengthening or grinding the welds. If grinding is used, the details of the grinding are to be submitted to ABS for review and approval. Interval of future periodic surveys should be determined based on the remaining fatigue lives of these connections.

3 Additional Surveys (1 May 2017)

The new critical areas for inspection are to be identified by comparing the analysis results from the life extension calculation against the critical area locations identified in the previous ISIP or Survey Plan.

The additional survey requirements as a result of the reassessment will be carried out based on the comparison and all outstanding items from the baseline survey are to be completed.

The upgrades, additions and modifications to the marine and industrial machinery and systems are to be re-surveyed.

Non-inspectable areas are to be discussed and agreed upon.

Need for additional or enhanced surveys are to be defined on a case-by-case basis.

5 Repairs and Modifications

Where repairs to the floating production installation or its elements identified by life extension reassessment are planned, a complete repair procedure, including the extent of the proposed repair and the need for the surveyor's attendance, is to be submitted to and agreed upon by the Surveyor reasonably in advance. All repairs found necessary by the Surveyor are to be completed to his/her satisfaction.

Plans of any proposed alteration or modification are to be submitted and approved by an ABS technical office before the work is commenced, and such work, when approved, is to be performed to the satisfaction of the Surveyor.

7 Revision of In-Service Inspection Plan (ISIP) (1 May 2017)

In-Service Inspection Program (ISIP) is a comprehensive program that outlines the procedures to be followed and the inspection frequency of the hull and mooring system of a floating facility. ISIP is to be developed or revised to incorporate the results from surveys, engineering analyses, corrosion protection evaluation and mitigation of structural and equipment damage and/or deficiency.

Upon conclusion of the life extension process, the ISIP needs to be revised and submitted for approval containing the conditions for continued services:

- New inspection intervals
- New critical inspection points identified

- Additional structural elements not previously included in the plan
- Other inspection requirements identified during the process.



SECTION 7 **Asset Integrity Management (AIM)** (1 May 2017)

1 **General**

Asset Integrity Management (AIM) is an ongoing lifecycle process to verify that the hull structure, hull interface structure, topside, mooring and riser have adequate strength to resist the imposed assessment loads. Life extension in AIM is integrated as part of the ongoing maintenance routine for operational installations.

If the installation is under an AIM program, and the AIM report demonstrate that the condition of the installation is fit for service for requested life extension, the process for life extension assessment described in Section 3 to Section 5 for the AIM covered components (hull, hull interface, topside, mooring and riser systems) may be skipped.

To grant life extension for installation under AIM, AIM reports are to be submitted for ABS approval in lieu of reassessment of the hull, hull interface, topside, mooring system and riser system.

3 **AIM Process**

The purpose of AIM is to provide a link between the assessment, inspection and maintenance of the installation. The AIM program should follow recognized industry standards. Reference may be made to API documents, such as API RP 2FSIM (when published), API RP 2MIM and API RP 2RIM, which provide recommended practice for the evaluation, assessment, and inspection of floating installations, including structures, mooring system and riser system, to demonstrate their fitness-for-service.

The AIM process consists of four key components:

- i) *Data Management System.* Create and manage the systems for archiving and retrieving AIM data and other relevant records.
- ii) *Integrity Evaluation of Installations.* Evaluate installation, fitness-for-purpose and propose repairs/modifications if necessary.
- iii) *Integrity Strategy of Installation.* Develop an inspection strategy and metrics for in-service inspection.
- iv) *Inspection Program.* Develop detailed inspection plans and a process for collecting quality data.

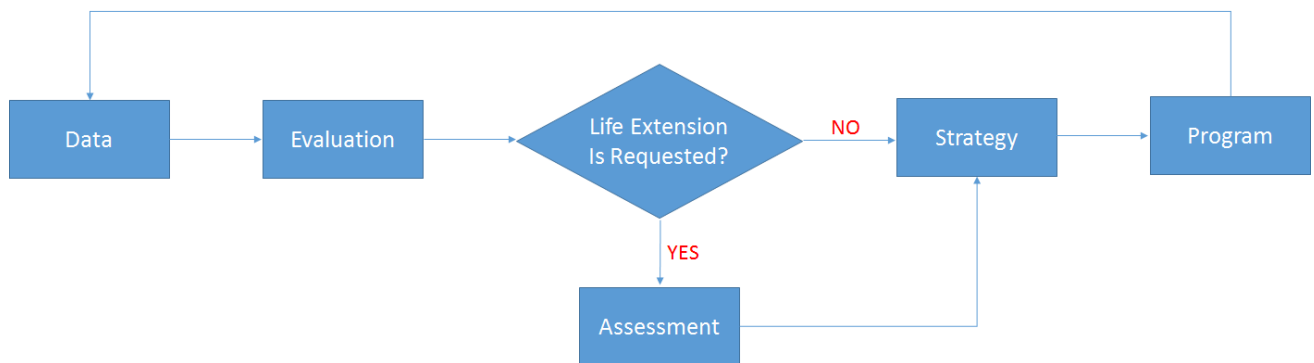
5 **Life Extension in AIM Process**

Since life extension process is integrated within AIM, the following process as shown in Section 7, Figure 1 is to be used in lieu of Section 2, Figures 1B and 1C:

- i) When the remaining design life of an installation is less than or equal to the time before the next special survey and life extension is requested, integrity of an installation is to be confirmed as follows:
 - a) Establishment of the current configuration and physical condition of an installation using existing AIM
 - b) Identification of all hazards and threats to the installation's integrity relevant to extended life using existing AIM

- c) An assessment of an installation for extended service life is to fully account for identified hazards including aging effects such as fatigue, corrosion, and any other issues which may affect the fitness for service of the considered installation. Information from previous assessments and verification reviews should be utilized in planning the assessment process.
 - d) Review the assessment and survey the installation including updates on critical areas and structural modifications deemed necessary based on any assessment performed
 - e) If the review and survey are satisfactory, the operator makes any required repairs and modifications for extending the service life of the installation
- ii) Revision of the inspection strategy based on 7/5i)
 - iii) Revision of the detailed work scopes for inspection activities
 - iv) Continue to manage the integrity of the installation in accordance with the revised AIM plan until the end of operation or when a further life extension is required

FIGURE 1
Assessment for Life Extension within the AIM Process





SECTION 8 Risk Assessment (1 May 2017)

1 Risk Assessment

Risk assessment may be used to supplement the procedure described in previous sections. The risks addressed are primarily those affecting the safety of an installation, facility or operation, but the methods discussed can also be applied to other categories of risk. Risk assessment may be used to identify the various issues and their risk severity associated with a life extension of the asset. Based on the level of risk assigned, a mitigating approach is to be applied in terms of the level of robustness in the approach. The *ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* provides the guidelines for defining the concept of risk, describing the methods available to assess risk associated with life extension, and in setting up and conducting successful risk studies.

Risk assessment techniques may be used to demonstrate that alternatives and novel features provide acceptable levels of safety in line with current offshore and marine industry practice. The *ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* provides guidance to ABS clients on how to prepare a risk evaluation to demonstrate equivalency or acceptability for a proposed life extension of floating production installation.

Risk evaluations for the justification of alternative arrangements or novel features may be applicable either to the installation as a whole, or to individual systems, subsystems or components. ABS will consider the application of risk evaluations for alternative arrangements and novel features in the life extension of the floating production installations, verification surveys during construction, and surveys for maintenance of class.



APPENDIX 1 Procedure for Fatigue Reassessment of Floating Production Installations (Except for Hull Structures of Ship-Type Installations)

1 Remaining Fatigue Strength of Hull Structures and Hull Interface Structures – Non-Ship Type Installations

1.1 Accumulated Fatigue Damage D_p

The accumulated fatigue damage, D_p , that has occurred based on the past service history:

- i) Transit
- ii) Past services
- iii) Site-specific operation at the current environmental criteria

is to be calculated as follows:

$$D_p = \sum_i^n D_{pi}$$

where D_{pi} is the accumulated fatigue damage at the i^{th} past service condition.

1.3 Safety Factors for Fatigue Life of the Accumulated Damages (1 May 2017)

The safety factors for fatigue life of the accumulated damages are determined in the following conditions:

- i) Safety factors for fatigue life (FDF) for the requested extended life (L years) should be taken the same as that used in the original design according to the *FPI Rules* and the *ABS Guide for Fatigue Assessment of Offshore Structures*.

For example:

<i>Safety Factor for Fatigue Life (FDF)</i>		
<i>Structure</i>	<i>Inspectable</i>	<i>Non-inspectable</i>
Non-Critical	3	5
Critical	5	10

- ii) In calculating the accumulated damages or used-up fatigue life, the original safety factor for fatigue life (FDF) may be reduced provided that the technical justifications submitted by the Owner/Operator reflect a reduction of the uncertainty in the original design and subject to the following conditions:

- No past findings
- Corrosion rate to be within the original design assumption
- Reliable load/metocean history

Original safety factor for fatigue life (FDF) for an inspectable critical structure and a non-inspectable structure may be reduced if inspection can be performed examining the current condition of the structure to confirm its structural integrity. The reduction in safety factor will depend on the results of the inspection. Reduced safety factor (α) which reflects a certain extent of the uncertainty in the original design having been removed due to the inspection and thus, is less than the original safety factor for fatigue life (FDF), should be in accordance with the following table:

<i>Visual Inspection</i>		<i>Nondestructive Test</i>	<i>Reduced Safety Factor (α)</i>
<i>General</i>	<i>Close</i>	<i>Magnetic Particle or Dye Penetrant Test, ACFM, UT, etc.⁽¹⁾</i>	
100%	-	-	9
-	100%	-	8
-	100%	20%	7
-	100%	50%	6
-	100%	100%	5

Notes:

- 1 NDT types to be agreed upon on a case-by-case basis.
- 2 % means percent of total weld length.

The reduced safety factor (α) for the accumulated damage is to be not less than the values in the table below:

<i>Reduced Safety Factor (α)</i>		
<i>Structure</i>	<i>Inspectable</i>	<i>Non-inspectable⁽¹⁾</i>
Non-Critical	2	3
Critical	3 ⁽²⁾	5

Notes:

- 1 Reduced Safety Factor, α , can be used
 - If non-inspectable area is checked during Drydocking Survey or Underwater Inspection in lieu of Drydocking (UWILD),
 - For a non-inspectable area if AIM data is available to confirm its current condition and structural integrity.
- 2 Original safety factor for fatigue life (FDF) for an inspectable critical structure can be reduced if inspection can be performed examining the current condition of the structure to confirm its structural integrity.

However, α is to be taken the same as the original safety factor for fatigue life FDF for tendons, tendon porches and tendon connectors.

1.5 Predicted Damage for Life Extension

The predicted annual fatigue damage D_e of the structure in “as-is” condition (as gauged) for the requested extended life is to be calculated at the current site-specific condition using the original wave scatter diagram, or updated scatter diagram if more severe than the original design environmental criteria.

1.7 Remaining Fatigue Strength Check

The remaining fatigue strength is evaluated by using one of the following criteria:

- i) The total factored damage including the accumulated fatigue damage for the past service and the predicted damage for life extension should be less than 1.0:

$$D_p \cdot \alpha + D_e \cdot FDF \cdot L \leq 1$$

ii) The requested life extension L at the current site is to be less than the remaining fatigue life (RFL):

$$L \leq RFL = (1 - D_p \cdot \alpha) / (D_e \cdot FDF)$$

If the remaining fatigue strength is not satisfied, the following improvements may be performed:

- Fatigue improvements, if feasible, in accordance with ABS requirements or other recognized standards
- Increased inspection frequency
- Modification to the loading condition
- Making the non-inspectable structure accessible for inspection

1.9 Calculation Example of Non-inspectable Critical Areas

i) For non-inspectable critical areas, after a one-time inspection, Reduced Safety Factor (α), ranging from five to ten, can be considered for determining the accumulated fatigue damage based on the type (visual, diver, ROV, NDT, etc.) and extent of the one-time inspection.

ii) Fatigue Reassessment Example

- The original Safety Factor for Fatigue Life (FDF) is 10 for non-inspectable critical areas.
- Assume that the Reduced Safety Factor (α) is five based on the one-time inspection and that the calculated accumulated fatigue damage (D_p) for the past service is 0.075.
- Assume that the predicted annual fatigue damage (D_e) for the requested fatigue life is 0.005.
- Assume a life extension (L) of 12 years is requested.
- Fatigue Safety Check:

$$D_p \cdot \alpha + D_e \cdot FDF \cdot L = 0.075 \times 5 + 0.005 \times 10 \times 12 = 0.975 \leq 1$$

Or

$$L = 12 \leq RFL = (1 - D_p \cdot \alpha) / (D_e \cdot FDF) = (1 - 0.075 \times 5) / (0.005 \times 10) = 12.5$$

- The fatigue safety check is satisfied for the requested extended life of 12 years for the check area at the current site.

3 Remaining Fatigue Strength of Topside Structures – All FPIs and Major Hull Interface Structures – Ship-Type Installations (1 May 2017)

The same methodology and procedure for remaining fatigue strength of hull structures in A1/1 of this Appendix is applied for the remaining fatigue strength assessment of topside structures and other major hull structures as identified in 5A-1-4/1 of the *FPI Rules*, except for the original Safety Factors for Fatigue Life ($FDFs$) in the table below in accordance with the *FPI Rules*.

<i>Safety Factor for Fatigue Life (FDF)</i>		
<i>Structure</i>	<i>Inspectable</i>	<i>Non-inspectable</i>
Non-Critical	2	5
Critical	3	10

The reduced safety factors (α) for fatigue life are to be not less than the values in the table below.

<i>Reduced Safety Factor (α)</i>		
<i>Structure</i>	<i>Inspectable</i>	<i>Non-inspectable ⁽¹⁾</i>
Non-Critical	1.5	3
Critical	2 ⁽²⁾	5

Notes:

- 1 Reduced Safety Factor, α , can be used for a non-inspectable area if AIM is available to confirm its current condition and structural integrity.
- 2 Original safety factor for fatigue life (FDF) for an inspectable critical structure can be reduced if inspection can be performed examining the current condition of the structure to confirm its structural integrity.



APPENDIX 2 **Procedure for Strength and Fatigue Reassessment of Ship-Type FPIs**

1 General

The procedures for verifying the hull strength and remaining fatigue strength of the ship-type installations as required by 5/5.1 TABLE 1 are outlined below.

Where the original analysis was performed for the unrestricted wave environment in accordance with the *ABS Rules for Building and Classing Marine Vessels* (using the SafeHull program), a site-specific reassessment may be performed in accordance with the FPI Rules using the ABS Eagle FPSO program. If reassessment of only longitudinal members is desired, it is sufficient to perform the Eagle FPSO ISE analysis. However, if the reassessment is to include transverse members as well, the TSA strength analysis will also be required.

Where the original analysis has been done for site-specific environmental conditions in accordance with the *FPI Rules* (using the Eagle FPSO software program), the strength and fatigue evaluations for site-specific environments have already been performed and may be used as a basis for determining if any further evaluations are necessary.

3 Initial Scantling Evaluation (ISE) for Life Extension

3.1 Strength Evaluation

The original Eagle FPSO analysis may be used for strength verification unless the environmental conditions have been updated or a scantling reassessment is desired. If this analysis is not available or the design parameters have been modified, then the strength is to be verified using the ISE module of the ABS Eagle FPSO software using the standard 20 year NDCV values specified in 5A-3-1/1.7.2(d) TABLE 1 of the *FPI Rules*. The requirements of 5A-2-1 of the *FPI Rules* will be applicable only to reassessed portions of the structure (locations where design, substantial corrosion and renewal scantlings have changed), even in cases where environmental conditions have been updated.

3.3 Simplified Fatigue Evaluation

If the original fatigue analysis has been performed using the ABS Eagle FPSO ISE program, the remaining fatigue life for all longitudinal stiffener end connections may be used to determine whether or not any of the connections need to be renewed/repared, assuming the environmental criteria have not been updated. If the original analysis has been performed using the ABS SafeHull program or is not available, a re-analysis using Eagle FPSO must be performed. The cumulative fatigue damages from the historical route (if originally converted from a trading tanker), the current and historical sites and the expected future fatigue damage for the desired life extension are to be calculated to determine suitability of the end connections. For the detailed procedure for conversions, refer to Part 5A, Chapter 2 of the *FPI Rules*.

5 Total Strength Assessment (Simplified Fatigue Analysis) for Life Extension

5.1 Model Requirements and Assessment Procedures for Life Extension

As minimum requirements for fatigue, at least one three-hold global model within 0.4L amidships in association with the most unfavorable topside loads and selected associated local models should be used to

assess the hull structure fatigue remaining life, according to 5A-3-2 and 5A-3-4/11.5 of the *FPI Rules*. The following steps are to be taken:

- i) For conversions, build Tanker net scantlings model using as-built scantlings and current rules nominal design corrosion values (NDCV) for 20 year period – get stresses ranges for original tanker conditions and obtain fatigue damage due to past service history as tanker;
- ii) Build or modify existing Tanker model considering net scantlings based on as-built or reassessed scantlings at conversion and NDCV from Rules in effect at the construction/conversion. In the absence of those requirements, the NDCV is to be considered not less than the ones indicated in 5A-3-1/1.7.2(d) TABLE 1 of the *FPI Rules* (for a 20-year period) – get stresses ranges and fatigue damage for past service history as a ship-type FPI;
- iii) Incorporate the latest thickness measurements*, and take into consideration topside weight updates and other modifications. The lesser of as-gauged and reassessed scantlings at conversion is to be used as gross scantlings and define net scantlings based on the current Rules NDCV, then calculate the remaining fatigue life. Alternatively the model can be built using the reassessed net scantlings at the life extension. Special attention is to be paid to screening locations according to baseline survey.

Note: * Average of the gauging over each strake for a global model, other methods may be applied.

5.3 Use of As-gauged Scantlings

When considering the use of as-gauged scantlings, it is important to apply the gauging information available to also represent the structures that have not been gauged so as to best represent the hull in its present condition. Several approaches can be used to accomplish this:

- i) *Average wastage by zone.* Take an average value of wastage by zone representing upper/middle/lower thirds of vertical structures, plus added zones for bottom and deck. Apply this information as a wastage percentage to all structures within the zone.
- ii) *Refinement of i) above.* Take same approach as above but apply separate values to plate, stiffener and brackets and also divide the vertical and horizontal zones into groups of three bays each.
- iii) *Use a “gauged neighbor ” approach which can be applied to varying levels of granularity (plate, strake, bay, zone, etc...).* This is applied by denoting the wastage levels of a non-gauged plate or component’s neighbor and taking the average of all adjacent neighbors. For example, if plates on either side of a non-gauged plate have gauged wastages of 5% and 10% respectively, then the non-gauged plate receives a wastage of 7.5%.
- iv) *Apply a known corrosion rate based on a particular service.* In short, this method can be used if an operator is using gauging information to determine wastage rates. In this regard, a total loss can be applied conservatively as the given wastage rate multiplied by x -years of past service and subtracted from the as-built thickness. In this way, future condition can also be predicted for the end of life extension period.

The local fine mesh fatigue models must be built using actual (not averaged) gaugings.

5.5 Loads and Load Cases

- i) *For model built in above A2/5.1.i:* TSA loads and load cases for trading tankers are to be considered. The client is to provide trading history. In the absence of such information, the previous fatigue damage is to be calculated based on unrestricted service environment.
- ii) *For model built in above A2/5.1.ii:* TSA loads and load cases for FPSO are to be applied; if available, the measured environmental condition and the wave heading may be utilized.
- iii) *For life extension model in above A2/5.1.iii:* TSA loads and load cases for FPSO are to be considered. The updated environmental condition and the wave heading are to be taken into

account. Changes/ restrictions in loading conditions about the design draft, permissible still water bending moments and still water shear forces, etc. can be considered on client's request.

5.7 Fatigue Acceptance Criteria

The fatigue acceptance criteria should follow 5A-3-A2 of the *FPI Rules*. When required, strength reassessment is to be in accordance with 5A-3-4/3 and 5A-3-4/5 of the *FPI Rules*.

7 Dynamic Loading Approach and Spectral Fatigue Analyses for Life Extension

7.1 Model Requirements and Reassessment Procedures

On client's request, a full length ship model can be used to reassess the hull structure and fatigue remaining life instead of total strength assessment (TSA), according to 5A-2-1/5.6.1 of the *FPI Rules*. The following steps are to be taken:

- i) For conversions, build tanker as-built model.
- ii) Build or modify existing tanker model to consider: reassessed scantlings at conversion and additions (turret/mooring, topsides modules, cranes, etc.).
- iii) Incorporate life extension gauging* into scantlings, the lesser of the as-gauged and the reassessed scantlings at life extension (gross or net depending on the methodology used), topside weight updates and other modification (turret/mooring, topsides modules, cranes, etc.). Special attention is to be paid to screening locations according to baseline survey.

Note: * Average of the gauging over each strake for a global model, other methods may be applied.

7.3 Loads and Load Cases

- i) *Tanker as-built model in above A2/5.1.i:* The client is to provide the trim and stability booklet for tanker and trade route history for the accumulative fatigue damage calculation for trading tanker. In the absence of such information, the previous fatigue damage is to be calculated based on unrestricted service environment.
- ii) *Reassessed scantlings model at conversion built in above A2/5.1.ii:* The client is to provide the trim and stability booklet for existing FPSO operation and transit cases. The measured environmental condition and the wave heading can be taken into account.
- iii) *Life extension model in above A2/5.1.iii:* The client is to provide the trim and stability booklet for FPSO operation. The updated environmental condition and the wave heading are to be taken into account. Changes/restrictions in loading conditions can be considered on client's request.

7.5 Acceptance Criteria

When required, the strength reassessment is to be in accordance with *ABS Guide for Dynamic Loading Approach for Floating, Production, Storage and Offloading (FPSO) Installations*.

The fatigue acceptance criteria should follow Section 9 of the *ABS Guide for Spectral-Based Fatigue Analysis for Floating, Production, Storage and Offloading (FPSO) Installations*.



APPENDIX 3 Procedure for Fatigue Reassessment of Ship-Type FPIs Considering Onboard Validated Historical Loading Information (1 May 2021)

1 General

The procedures for verifying the hull remaining fatigue strength of a permanently moored ship-type installation as required by Section 5/Table 1 by using validated historical operational and environmental loading parameters are outlined below. Please refer to the *ABS Advisory on Fatigue Monitoring of Floating Production Installations* and the *ABS Advisory on Data Quality for Marine and Offshore Application*.

Where the original analysis has been done for site-specific environmental conditions in accordance with the FPI Rules (using the Eagle FPSO software program), the fatigue evaluations for site-specific environments have already been performed and may be used as a basis for determining whether any further evaluations are necessary in association with the consideration of actual operational historical loading information.

3 Application of Environmental Severity Factors

This section relates to the use of the onboard data acquired for historical loading in the determination of Environmental Severity Factors (ESF) defined in 5A-3-2/1 of the *FPI Rules*.

The proposed adoption of the acquired data impacts the Initial Scantling Evaluation (ISE) phase, addressed in Section 5A-3-2 of the *FPI Rules*, and Total Strength Assessment (TSA), governed by the criteria specified in Section 5A-3-4 of the *FPI Rules*, since it affects the determination of the ESF alpha and beta factors, in accordance with Appendix 5A-3-A1 of the *FPI Rules*. For estimation of Remaining Fatigue Life, only ESF alpha factors are relevant and will be addressed in this Section.

The determination of the environmental severity factors is to be carried out in accordance with Appendix 5A-3-A1 of the *FPI Rules* using the ABS Eagle FPSO SEAS program. The following design input data is needed in order to determine ESF factors:

- Main particulars of the hull
- Draft aft and forward (initially for full load condition)
- Metacentric height
- Radii of gyration
- Critical roll damping
- Mass distribution along hull length
- Hull shape
- Environmental Data

The Initial Scantling Evaluation (ISE) of the *FPI Rules* was based on the 1990's Rules for Tankers (Section 5/2A of the *ABS Rules for Building and Classing Steel Vessels*), and mimics a tanker's operation conditions (i.e., mainly sailing fully loaded on inbound trips and ballasted on outbound trips). Generally, normal ballast loads are defined between 40 and 60% of the fully loaded draft for regular environmental

conditions, and a deeper draft is designed for heavy weather ballast conditions, in order to contain the hull motions in lower drafts with severe weather conditions.

However, this is not the usual operation conditions of a ship-shaped FPSO unit. In order to facilitate the estimation of extreme loads and stresses on the hull, as well as the daily operational ones, some coefficients have been provided in *FPI Rules* to adjust the global behavior of the FPI when in lower drafts. This way, the FPI is designed to operate with a large flexibility of draft range and cargo distribution along cargo tanks but considering the simultaneous action of maximum expected hull girder loads, hull motions, acceleration, and pressures.

While this flexibility is positive for the initial design and building stages of an FPSO, it is a conservative approach to the estimation of the Remaining Fatigue Life. These adopted contingencies impose high stress ranges applied to the hull structure, which results in a greater impact on the fatigue damage and RFL, since the fatigue damage is related to stresses on the hull by a power of 4.5 to 7.5 ($m/0.65$), depending on the S-N curve adopted.

In addition, the absence of data on simultaneous loads occurrence leads to the assumption of maximum positive and negative loadings acting in each of the Dynamic Loading Parameters (DLPs) that are relevant to fatigue calculations, which may lead to a significant increase in damage.

5 Identification of Relevant Onboard Historical Loading Data

When the FPI operates under a regular loading and unloading sequence, the main Static Loading Parameters (SLPs) related to stresses acting on the hull can be identified, regularly measured, validated, and compiled to be considered in the life extension fatigue calculations instead of combining maximum values.

For ready reference, the relevant SLPs are:

- Mean value of minimum, intermediate, and maximum operational draft
- Metacentric height in longitudinal and transverse directions (can be obtained from hydrostatic tables for measured drafts, and tanks sounding/ullage)
- Still Water Hull Girder Bending Moment at each section of the cargo block
- Still Water Hull Girder Shear Forces at each section of the cargo block
- Cargo and ballast tanks filling level – sounding/ullage
- Deadweight mass distribution
- Daily production rate
- Offloading operation start and end time, and offloading volume/weight

The SLPs above mentioned should be measured at the same time, and in a time interval not greater than the following, so that the intermediate filling of each cargo tank can be adequately considered:

$$t_{interval} = v_{smallest} * \gamma_{cargo} * 6 / dp$$

where

$t_{interval}$ = time interval for cargo tanks sounding/ullage measurement (hours)

$v_{smallest}$ = smallest cargo tank volume, in m³ (m³, ft³)

γ_{cargo} = cargo density, in kN/m³ (tf/m³, Ltf/ft³)

dp = daily production, in kN/day (tf/day, Ltf/day)

Additionally, the SLPs data should accumulate continuously for at least five years so that the regular operational loading/unloading sequence can be identified.

From the above data, the maximum and minimum operational drafts can be identified as the average values of associated drafts at the start and end of offloading operations.

Two intermediate drafts should be considered, as close as possible to an even distribution between maximum and minimum operational drafts.

The offloading cycle period can be defined as the average of the different periods between two offloadings, for all the range of time for which the onboard data has been submitted. Then, the total number of offloading cycles for the entire service life of the FPI can be estimated based on this offloading period.

Based on these defined drafts, the other associated SLPs may also be obtained as the average of values for the mean drafts defined as minimum, maximum, and intermediate operational drafts.

7 Identification of Dynamic Loading Parameters Affected by Onboard Historical Data

For the determination of high cycle fatigue stress range loads in the hull structure, the following dynamic loading parameters (DLPs) related to stresses acting on the hull can be identified based on the *FPI Rules* and the *ABS Guide for Spectral-Based Fatigue Analysis for Floating Production, Storage and Offloading (FPSO) Installations (SFA Guide)*, as affected by onboard historical operational and environmental data:

- Environmental wave conditions and relative heading to FPI bow (Subsection 5/3 of the *SFA Guide* and 5A-3-A2/5.7 of the *FPI Rules*)
- Roll and pitch motions, if available (Subsection 5/3 of the *SFA Guide* and 5A-3-2/5.7.1(a) and 5A-3-2/5.7.1(b) of the *FPI Rules*)
- Acceleration at one defined point at main deck level, if available (Subsection 5/3 of the *SFA Guide* and 5A-3-2/5.7.1(c) of the *FPI Rules*)
- Hull girder longitudinal and vertical stresses/deflections at locations along cargo block previously defined as target for allowable Stillwater Values, when available (Subsection 4/3 of the *SFA Guide* and 5A-3-2/3.1, 5A-3-2/5.1 and 5A-3-2/5.2 of the *FPI Rules*).

The above listed information may be derived from hydrodynamic analysis based on the hydrostatic properties calibrated from SLPs identified in A3/5 or can also be obtained from onboard measurements. If onboard measurements are to be used, the method and frequency for taking the measurements along with the data collection and analysis should be agreed to with ABS prior to the start of the measurement program.

If the owner/operator intends to consider the same historical operational and environmental data or any optimized specific loading sequence as applicable to the Remaining Fatigue Life of the unit, the indication of the estimated operational loading sequence should be clearly identified in the Loading Manual, provided that this preferential loading sequence has been successfully implemented into practice by Owner/Operator over the vessel's past operational life, and it is very likely to occur over the vessel's remaining operational life (probability of occurrence over 90%).

The above information should also be measured at the same time, and time interval associated with the relative expected natural period of response. These periods may be obtained from the Response Amplitude Operators, generated by SEAS module of FPSO Eagle Software, or equivalent.

All the associated DLPs peaks' magnitudes may be obtained as the average of observed values for each of the drafts defined as minimum, maximum, and intermediate operational drafts.

9 Procedure for Adjustment of Fatigue Strength Assessment of Ship-Type Installations

The connections to be considered for the Fatigue Strength Assessment are the same ones identified in 5A-3-A2/3 of the *FPI Rules*. Other additional locations may be selected by the client.

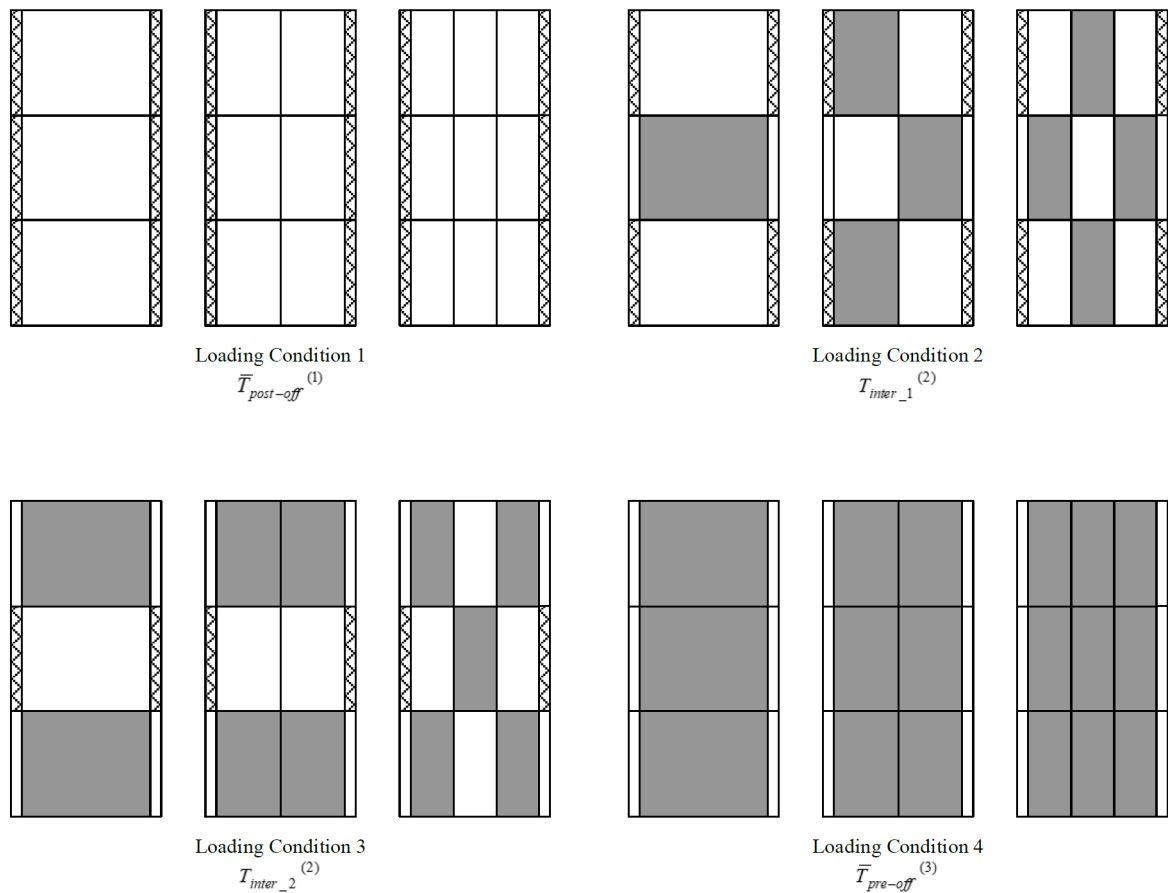
The Long Term Stress Distribution Parameter, identified in 5A-3-A2/5 of the *FPI Rules*, may be replaced by a long term parameter calculated based on measurements and/or hydrodynamic simulations for the specified maximum, minimum, and intermediate operational drafts and conditions, for a probability of occurrence of 1×10^{-4} , according to 5A-1-1/7.5.3 of the *FPI Rules*.

Usually, the typical loading patterns from 5A-3-A2/Figure 2A of the *FPI Rules* for double hulls and 5A-3-A2/Figure 2B of the *FPI Rules* for single hulls should be used. However, for specified regular loading sequences, the designer may submit special loading patterns based on onboard data for the historical loading sequence of each tank and provide an estimation of the Remaining Fatigue Life (RFL) for each tank portion, along with the specific DLPs for the region.

When using historical loading or future planned loading information, namely using the modified loading patterns in Appendix 3, Figure 2A for double hulls and Appendix 3, Figure 2B for single hulls, the load combination factors given in Appendix 3, Tables 2A to 2D can be developed through hydrodynamic analysis for the loading conditions specified in Appendix 3, Figures 2A and 2B. SEAS database and ESF beta and alpha definitions, one single database can still be considered for maximum scantling draft associated with the modified load combination factors in Appendix 3, Tables 2A to 2D below as an example. However, additional SEAS analyses for the specific intermediate drafts can also be processed, and each one can be associated with coefficients for 5A-3-2/Table 1A, as calibrated by the *FPI Rules* for maximum ESF betas and alphas related to maximum draft (requires SEAS analyses). This option, although extensive in hydrodynamic calculations leads to a more accurate remaining fatigue life. The developed Tables 2A to 2D are to be reviewed and approved by ABS.

For computation of percentage of time in each draft, the total time is to be computed based on acquired data on board and submitted for review.

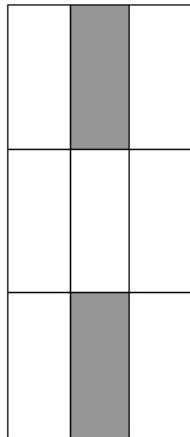
FIGURE 2A
Loading Conditions for Fatigue Strength Assessment – Double Hull and Double Side Single Bottom FPSO/FSO with Loading History Data Submitted



Notes:

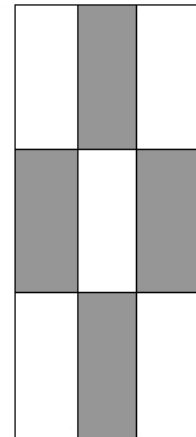
- 1 Minimum operation condition draft – average minimum operational draft of all regular offloadings performed ⁽⁴⁾.
- 2 Intermediate drafts – draft equally divided between Loading Conditions 1 and 4 drafts
- 3 Maximum operation condition draft – average maximum operational draft of all regular offloadings performed ⁽⁴⁾.
- 4 Any abnormal offloading operations, that have resulted in premature offloading or abortion of the regular offloading, should be identified during the historical data capture and submittal.

FIGURE 2B
Loading Conditions for Fatigue Strength Assessment – Single Hull FPSO/FSO with Loading History Data Submitted



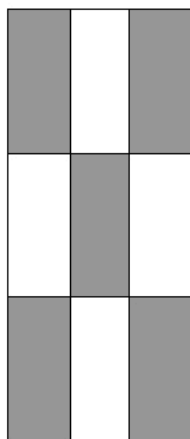
Loading Condition 1

$$\bar{T}_{post-off}^{(1)}$$



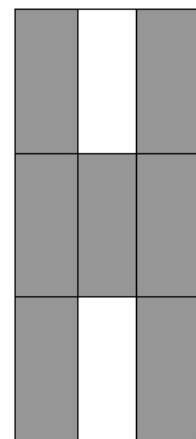
Loading Condition 2

$$T_{inter_1}^{(2)}$$



Loading Condition 3

$$T_{inter_2}^{(2)}$$



Loading Condition 4

$$\bar{T}_{pre-off}^{(3)}$$

Notes:

- 1 Minimum operation condition draft – average minimum operational draft of all regular offloadings performed ⁽⁴⁾.
- 2 Intermediate drafts – draft equally divided between Loading Conditions 1 and 4 drafts
- 3 Maximum operation condition draft – average maximum operational draft of all regular offloadings performed ⁽⁴⁾.
- 4 Any abnormal offloading operations, that have resulted in premautre offloading or abortion of the regular offloading, should be identified during the historical data capture and submittal.

TABLE 2A
Example of Modified Design Fatigue Load Cases
for Fatigue Strength Assessment

(Load Combination Factors for Dynamic Load Components for Loading Condition 1)

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
A. Hull Girder Loads								
Vertical B.M.	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)
k_c	0.90	0.90	0.15	0.15	0.70	0.70	0.80	0.80
Vertical S.F.	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
k_c	0.55	0.55	0.20	0.20	0.40	0.40	0.50	0.50
Horizontal B.M.					(-)	(+)	(-)	(+)
k_c	0.00	0.00	0.10	0.10	0.55	0.55	0.45	0.45
Horizontal S.F.					(+)	(-)	(+)	(-)
k_c	0.00	0.00	0.10	0.10	0.55	0.55	0.45	0.45
B. External Pressure								
k_c	0.50	0.50	0.85	0.85	0.85	0.85	0.85	0.85
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.40	0.40	1.00	1.00	0.75	0.75	0.40	0.40
w_v	0.50	-0.50	0.75	-0.75	0.75	-0.75	0.75	-0.75
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.40	Fwd Bhd -0.40	Fwd Bhd 0.80	Fwd Bhd -0.80
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.40	Aft Bhd 0.40	Aft Bhd -0.80	Aft Bhd 0.80
w_t	—	—	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75
	—	—	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75
c_ϕ , Pitch	-0.15	0.15	-0.10	0.10	-0.30	0.30	-0.45	0.45
c_θ , Roll	0.00	0.00	1.00	-1.00	1.15	-1.15	1.00	-1.00
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes:

- 1 Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 of the *FPI Rules* for M_{ws} and M_{wh})
- 2 Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 of the *FPI Rules* for M_h)
- 3 For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1* & *FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.
- 4 For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM, and Local Pressure Load Conditions.

TABLE 2B
Example of Modified Design Fatigue Load Cases
for Fatigue Strength Assessment

(Load Combination Factors for Dynamic Load Components for Loading Condition 2)

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
A. Hull Girder Loads								
Vertical B.M.	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)
k_c	0.95	0.95	0.25	0.25	0.95	0.95	0.85	0.85
Vertical S.F.	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
k_c	0.55	0.55	0.25	0.25	0.40	0.40	0.50	0.50
Horizontal B.M.					(-)	(+)	(-)	(+)
k_c	0.00	0.00	0.20	0.20	0.70	0.70	0.60	0.60
Horizontal S.F.					(+)	(-)	(+)	(-)
k_c	0.00	0.00	0.20	0.20	0.70	0.70	0.60	0.60
B. External Pressure								
k_c	0.50	0.50	0.90	0.90	0.90	0.90	0.90	0.90
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.55	0.55	0.70	0.70	0.20	0.20	0.40	0.40
w_v	0.50	-0.50	0.75	-0.75	0.75	-0.75	0.75	-0.75
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.40	Fwd Bhd -0.40	Fwd Bhd 0.80	Fwd Bhd -0.80
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.40	Aft Bhd 0.40	Aft Bhd -0.80	Aft Bhd 0.80
w_t	—	—	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75
	—	—	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75
c_ϕ , Pitch	-0.20	0.20	-0.05	0.05	-0.10	0.10	-0.35	0.35

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
c_{θ} , Roll	0.00	0.00	1.00	-1.00	1.15	-1.15	1.00	-1.00
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes:

- 1 Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 of the *FPI Rules* for M_{ws} and M_{wh})
- 2 Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 of the *FPI Rules* for M_h)
- 3 For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1* & *FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.
- 4 For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM, and Local Pressure Load Conditions.

TABLE 2C
Example of Modified Design Fatigue Load Cases
for Fatigue Strength Assessment

(Load Combination Factors for Dynamic Load Components for Loading Condition 3)

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
A. Hull Girder Loads								
Vertical B.M.	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)
k_c	0.95	0.95	0.25	0.25	0.75	0.75	0.85	0.85
Vertical S.F.	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
k_c	0.55	0.55	0.25	0.25	0.40	0.40	0.50	0.50
Horizontal B.M.					(-)	(+)	(-)	(+)
k_c	0.00	0.00	0.20	0.20	0.85	0.85	0.70	0.70
Horizontal S.F.					(+)	(-)	(+)	(-)
k_c	0.00	0.00	0.25	0.25	0.90	0.90	0.75	0.75
B. External Pressure								
k_c	0.50	0.50	0.95	0.95	0.95	0.95	0.95	0.95
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.55	0.55	0.75	0.75	0.10	0.10	0.40	0.40
w_v	0.50	-0.50	0.75	-0.75	0.75	-0.75	0.75	-0.75

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
w_ℓ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.40	Fwd Bhd -0.40	Fwd Bhd 0.80	Fwd Bhd -0.80
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.40	Aft Bhd 0.40	Aft Bhd -0.80	Aft Bhd 0.80
w_t	—	—	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75
	—	—	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75
c_ϕ , Pitch	-0.15	0.15	-0.15	0.15	-0.20	0.20	-0.45	0.45
c_θ , Roll	0.00	0.00	1.00	-1.00	1.15	-1.15	1.00	-1.00
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes:

- 1 Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 of the *FPI Rules* for M_{ws} and M_{wh})
- 2 Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 of the *FPI Rules* for M_h)
- 3 For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1* & *FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.
- 4 For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM, and Local Pressure Load Conditions.

TABLE 2D
Example of Modified Design Fatigue Load Cases
for Fatigue Strength Assessment

(Load Combination Factors for Dynamic Load Components for Loading Condition 4)

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
A. Hull Girder Loads								
Vertical B.M.	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)	Sag (-)	Hog (+)
k_c	1.00	1.00	0.30	0.30	0.80	0.80	0.90	0.90
Vertical S.F.	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
k_c	0.55	0.55	0.25	0.25	0.40	0.40	0.50	0.50
Horizontal B.M.					(-)	(+)	(-)	(+)
k_c	0.00	0.00	0.25	0.25	0.90	0.90	0.75	0.75

	<i>FLC1</i>	<i>FLC2</i>	<i>FLC3</i>	<i>FLC4</i>	<i>FLC5</i>	<i>FLC6</i>	<i>FLC7</i>	<i>FLC8</i>
Horizontal S.F.					(+)	(-)	(+)	(-)
k_c	0.00	0.00	0.25	0.25	0.90	0.90	0.75	0.75
B. External Pressure								
k_c	0.50	0.50	1.00	1.20	1.00	1.00	1.00	1.00
k_{f0}	-1.00	1.00	-1.00	1.00	-1.00	1.00	-1.00	1.00
C. Internal Tank Pressure								
k_c	0.75	0.75	0.80	0.80	0.10	0.10	0.50	0.50
w_v	0.50	-0.50	0.75	-0.75	0.75	-0.75	0.75	-0.75
w_ρ	Fwd Bhd 0.20	Fwd Bhd -0.20	—	—	Fwd Bhd 0.40	Fwd Bhd -0.40	Fwd Bhd 0.80	Fwd Bhd -0.80
	Aft Bhd -0.20	Aft Bhd 0.20	—	—	Aft Bhd -0.40	Aft Bhd 0.40	Aft Bhd -0.80	Aft Bhd 0.80
w_t	—	—	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75	Port Bhd -0.75	Port Bhd 0.75
	—	—	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75	Stbd Bhd 0.75	Stbd Bhd -0.75
c_ϕ , Pitch	-0.30	0.30	-0.15	0.15	-0.10	0.10	-0.80	0.80
c_θ , Roll	0.00	0.00	1.00	-1.00	1.15	-1.15	1.00	-1.00
D. Reference Wave Heading and Motion of Installation								
Heading Angle	0	0	90	90	60	60	30	30
Heave	Down	Up	Down	Up	Down	Up	Down	Up
Pitch	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up	Bow Down	Bow Up
Roll	—	—	Stbd Down	Stbd Up	Stbd Down	Stbd Up	Stbd Down	Stbd Up

Notes:

- 1 Rule vertical bending moment range = $|M_{ws} - M_{wh}|$ (see 5A-3-2/5.2 of the *FPI Rules* for M_{ws} and M_{wh})
- 2 Rule horizontal bending moment range = $2 \times M_h$ (see 5A-3-2/5.3 of the *FPI Rules* for M_h)
- 3 For each load condition pair, the stress range due to local pressure is the difference between the stress values for Local Pressure Load Conditions. For example, for Load Condition Pair *FLC1* & *FLC2*, the stress range due to local pressure is the difference between the stress values for *FLC1* and *FLC2*.
- 4 For each load condition pair, the stress range is the sum of the absolute stress range values due to Vertical BM, Horizontal BM, and Local Pressure Load Conditions.



APPENDIX 4 References

1 Application of Codes and Standards (1 May 2017)

Use of national or international standards or codes other than those listed herein in the life extension of floating production installations is subject to prior approval and acceptance by ABS. The standards or codes being applied are to be adhered to in their entirety.

ABS:

<i>FPI Rules</i>	<i>Rules for Building and Classing Floating Production Installations</i>
<i>MOU Rules</i>	<i>Rules for Building and Classing Mobile Offshore Units</i>
<i>Risk Guidance Notes</i>	<i>Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries</i>
<i>RCM Guide</i>	<i>Guide for Surveys Based Reliability Centered Maintenance</i>
<i>UAV Guidance Notes</i>	<i>Guidance Notes on Using Unmanned Aerial Vehicles</i>

American Petroleum Institute:

API 2A-WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design – Twenty-First Edition, 2007
API Bulletin 2INT-EX	Interim Guidance for Assessment of Existing Offshore Structures for Hurricane Conditions, 2007
API RP 2MET	Derivation of Metocean Design and Operating Conditions, 2014
API RP 2FPS	Planning, Designing, and Constructing Floating Production Systems, Second Edition – 2011
API RP 2SIM	Recommended Practice for the Structural Integrity Management of Fixed Offshore Structures, 2014
API RP 2I	In-service Inspection of Mooring Hardware for Floating Structures, 2015
API RP 2FSIM	Recommended Practice for Floating Systems Integrity Management, 2017
API RP 2RIM	Recommended Practice for Risers Integrity Management, 2017
API RP 2MIM	Recommended Practice for Mooring Integrity Management, 2017
API RP 2T	Recommended Practice for Planning, Designing, and Construction Tension Leg Platforms, Third Edition - 2010

International Organization for Standardization:

ISO 19902	Petroleum and natural gas industries – Fixed steel offshore structures, first edition, 2007
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NORSOK Standard:

NORSOK standard N-006	Assessment of structural integrity for existing offshore load-bearing structure, Edition 1, 2009
NORSOK standard U-009	Life extension for subsea systems, Edition 1, 2011

Norwegian Oil and Gas Association:

122 Norwegian Oil and Gas Association recommended guideline for the Assessment and Documentation of Service Life Extension of Facilities, Revision 1, 2012

Oil and Gas UK:

Guidance on the Management of Ageing and Life Extension for UKCS Oil and Gas Installation, Issue 1, 2012

United Kingdom's Health and Safety Executive:

HSE KP4 Ageing and life extension, an interim report by the Offshore Division of HSE's Hazardous Installations Directorate, 2012