REVISION INDEX

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ISSUE
A	General Revision.

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DATE	NOV/03/22	DEC/16/22							
DESIGN	EEA	EEA							
EXECUTION	CJV5	CJV5							
VERIFICATION	CXDI	CXDI							
APPROVAL	U32N	U32N							

Summary

1 PURPOSE

The purpose of this document is to define the minimum requirements to be employed in the piping flexibility and stress analysis for the project.

This specification describe BUYER´s minimum requirements for offshore piping systems, including the line selection and classification criteria to be used during detailed engineering and construction stage for flexibility and stress analysis. This specification shall be applied for piping on hull and modules (Topside). However, it is SELLER´s responsibility the fully design the piping systems in compliance with the applicable codes and best engineering practices, and also to select and perform additional analysis where deemed necessary based on the available input data.

This specification does not dispense the SELLER with the compliance with any reference specification, code, law, regulatory or classification society requirements herein informed or elsewhere in the contract.

For this technical specification, BUYER is Petrobras, PNBV or other, as indicated on the contract.

2 SCOPE OF THE PIPING STRESS ANALYSIS

It is intended from the SELLER to achieve, as minimum, the following objectives with the piping flexibility and stress analysis:

- To obtain a safe and economical layout.
- To prevent failure of piping or supports from overstress or fatigue.
- To ensure that all loading conditions that may be experienced by a piping system are considered and suitable for design life.
- To ensure that all pipe stress analysis comply with Minimum Requirements for Piping Mechanical Design and Layout (I-ET-3010.00-1200-200-P4X-001) and materials specifications, piping engineering codes, standards, and piping specification referenced within this document and all applicable regulatory codes.
- To assure that all calculations are performed in accordance with uniform analysis procedures and methods.
- To select and position suitable piping restraints, and other special pipe support item as required.
- To ensure that the stress analysis problems are properly reviewed for Code and specification compliance.
- To avoid detrimental stress or deformation to the functioning of the system, which has the potential for clash, distortion and overstrain of piping, valves, supports and connecting equipment.
- To avoid unintentional disengagement of piping from its supports.
- To prevent buckling collapse due to vacuum.
- To confirm that flanges are not prone to leakage or overstressing.

- To confirm that piping loads acting at equipment nozzle and supports are within corresponding acceptable limits.
- To provide the restraint loads from the flexibility and stress analysis calculations to the structure team to enable the design of the supporting structures.
- To confirm the adequate operation of expansion joints or other couplings.
- To provide adequate design to mitigate the failure risk due to vibration and dynamic transient loads.
- To provide the necessary communication so that the information (e.g., pipe stress isometrics, support loads and module limit anchor) is efficiently transmitted among SELLERs/ Module suppliers, equipment vendors and BUYER´s.

3 REFERENCES

The following referenced documents shall be used as reference for flexibility and stress analysis, besides the Rules of Classification Society. For undated references, the latest edition of the referenced document applies.

3.1 CODES AND STANDARDS

3.1.1 ASME B16.5 - PIPE FLANGES AND FLANGED FITTINGS NPS ½ THROUGH NPS 24.

3.1.2 ASME B16.47 - LARGE DIAMETER STEEL FLANGES NPS 26 THROUGH NPS 60.

3.1.3 ASME B31.3 - PROCESS PIPING.

3.1.4 ASME B31.4 - PIPELINE TRANSPORTATION FOR LIQUID AND SLURRIES.

3.1.5 ASME B31.8 - GAS TRANSMISSION AND DISTRIBUTION PIPING SYSTEMS.

3.1.6 ASME B31J - STRESS INTENSIFICATION FACTORS (I-FACTORS), FLEXIBILITY FACTORS (K-FACTORS), AND THEIR DETERMINATION FOR METALLIC PIPING COMPONENTS.

3.1.7 ASME SECTION VIII – BOILER AND PRESSURE VESSEL CODE.

3.1.8 API BULL 6AF - CAPABILITIES ON API FLANGES UNDER COMBINATIONS OF LOAD.

3.1.9 API 610 - CENTRIFUGAL PUMPS FOR PETROLEUM, PETROCHEMICAL AND NATURAL GAS INDUSTRIES.

3.1.10 API 617 - AXIAL AND CENTRIFUGAL COMPRESSORS AND EXPANDER.

3.1.11 API 618 – RECIPROCATING COMPRESSORS FOR PETROLEUM, CHEMICAL, AND GAS INDUSTRY SERVICES.

3.1.12 API 619 – ROTARY-TYPE POSITIVE-DISPLACEMENT COMPRESSORS FOR PETROLEUM, PETROCHEMICAL AND NATURAL GAS INDUSTRIES.

3.1.13 API 650 – WELDED TANKS FOR OIL STORAGE.

3.1.14 API 661 – PETROLEUM, PETROCHEMICAL, AND NATURAL GAS INDUSTRIES-AIR-COOLED EXCHANGERS.

3.1.15 API 674 - POSITIVE DISPLACEMENT PUMPS – RECIPROCATING.

3.1.16 API 675 – POSITIVE DISPLACEMENT PUMPS – CONTROLLED VOLUME FOR PETROLEUM, CHEMICAL AND GAS INDUSTRY SERVICES.

3.1.17 API 676 - POSITIVE DISPLACEMENT PUMPS – ROTARY.

3.1.18 API RP 520 - RECOMMENDED PRACTICE FOR THE DESIGN AND CONSTRUCTION OF PRESSURE-RELIEVING SYSTEMS IN REFINERIES

3.1.19 API RP 686 - RECOMMENDED PRACTICE FOR MACHINERY INSTALLATION AND INSTALLATION DESIGN.

3.1.20 DNV-RP-D101 - STRUCTURAL ANALYSIS OF PIPING SYSTEMS.

3.1.21 DNVGL-RP-C203 – FATIGUE DESIGN OF OFFSHORE STEEL STRUCTURES

3.1.22 EJMA - STANDARDS OF THE EXPANSION JOINTS MANUFACTURERS ASSOCIATION.

3.1.23 ENERGY INSTITUTE – GUIDELINES FOR THE AVOIDANCE OF VIBRATION INDUCED FATIGUE FAILURE IN PROCESS PIPEWORK.

3.1.24 ISO 13703 – PETROLEUM AND NATURAL GAS INSDUSTRIES – DESIGN AND INSTALLATION OF PIPING SYSTEMS ON OFFSHORE PRODUCTION PLATFORM.

3.1.25 ISO 14692 – GLASS-REINFORCED PLASTICS (GRP) PIPING.

3.1.26 ISO 27509 – COMPACT FLANGED CONNECTION WITH IX SEAL RING.

3.1.27 ISO/DIS 24200 – PETROLEUM, PETROCHEMICAL AND NATURAL GAS INDUSTRIES – BULK MATERIAL FOR OFFSHORE PROJECTS – PIPE SUPPORT

3.1.28 NEMA SM 23 – STEAM TURBINE FOR MECHANICAL DRIVE SERVICE.

3.1.29 NORSOK L-002 - PIPING SYSTEM LAYOUTS, DESIGN AND STRUCTURAL ANALYSIS.

3.1.30 NORSOK L-CR-003 – PIPING DETAILS.

3.1.31 PD 5500 – SPECIFICATION FOR INFIRED FUSION WELDED PRESSURE VESSEL.

3.1.32 WRC107/ 297/ 537 - LOCAL STRESSES IN SPHERICAL AND CYLINDRICAL SHELLS DUE TO EXTERNAL LOADING.

3.1.33 WRC-198 - SECONDARY STRESS INDICES FOR INTEGRAL STRUCTURAL ATTACHMENTS TO STRAIGHT PIPE.

3.1.34 WRC-329 - ACCURACY OF STRESS INTENSIFICATION FACTORS FOR BRANCH CONNECTIONS

3.2 REFERENCE DOCUMENTS

The following specifications shall be used. Specification or requirements presented in contract not listed herein shall also be followed. For undated references, the latest edition of the referenced document applies.

3.2.1 Metocean Data.

3.2.2 Acceleration at Hull and Riser Supports.

3.2.3 Acceleration at Topside.

3.2.4 NOT APPLICABLE.

3.2.5 Hull deflection.

3.2.6 Piping Material Specification.

3.2.7 Detailed Engineering Explosion Analysis.

3.2.8 I-ET-3010.2E-1200-200-P4X-004 - Requirements for Piping Support.

3.2.9 I-ET-3010.2E-1200-200-P4X-005 – Minimum Requirements for Piping Mechanical Design and Layout.

3.2.10 I-ET-3010.2D-1200-200-P4X-010 – Technical Specification for Hard Pipe.

3.2.11 I-ET-3010.00-1200-310-P4X-002 – Positive Displacement Pumps Specification.

3.2.12 I-ET-3010.00-1225-323-P4X-001 – Vapor Recovery Unit.

3.2.13 I-ET-3010.2E-1351-140-P4X-001 - Hull Structural Requirements.

4 TECHNICAL REQUIREMENTS

The engineering design of piping systems shall comply with the requirements of the applicable design code (e.g., ASME B31.3, B31.4, B31.8, ISO 14692) approved by BUYER. It shall also meet Classification Society requirements and any additional requirements included in this specification and best engineering practices.

4.1 Piping system arrangement shall have sufficient flexibility (change in directions and supports) to ensure that the stresses are within the recommendations and limits allowed by applicable code and comply with this technical specification.

4.2 Piping system shall be designed to achieve, as minimum, the objectives indicated at item 2.

4.3 All piping systems shall be analyzed and evaluated for adequate flexibility, stress level, fatigue life and natural frequency in accordance with applicable codes referenced standards and this technical specification.

4.4 The piping flexibility analysis shall be performed using software previously approved by the BUYER, as its version.

4.5 All digital files required to verify and rerun the analysis shall be issued complete to BUYER. The database (or input files) shall also be issued to BUYER.

4.6 Each flexibility and stress analysis report (see ATTACHMENT A) shall be accompanied by respective electronics files (.c2 or similar, if necessary, a compressed extension may be used).

4.7 The axis orientation on flexibility and stress analysis model on software shall be according to the axis orientation used on 3D model for the project.

4.8 Finite element analysis may be applied as complementary analysis and whenever a local analysis is necessary or required (e.g., overstress in trunnion or reinforcement pad, ratio diameter to thickness larger than 100). The finite element software shall be previously approved by BUYER. Finite element analysis electronics files (.c2 or similar, if necessary, a compressed extension may be used) and information about the analysis shall be included on the flexibility and stress analysis report.

4.9 Any communication with SUB-SELLERS and Vendors is SELLER responsibility.

4.10 After pipe stress analysis is done, any comments, configuration and layout changes, support details or locations changes shall be transmitted to the piping design group for implementation on the design.

4.10.1 The acceptability of fabrication isometrics shall be made based on the approved stress analysis.

4.10.2 Any revision on piping systems layout or supports shall be re-submitted for stress analysis review and issued for BUYER's approval.

5 PIPING FLEXIBILITY AND STRESS ANALYSIS CLASSIFICATION CRITERIA

All LINES shall be analyzed and classified according to the criteria listed on this section. When a formal stress analysis is required (Category 2 and 3) a simplified, approximate, or a comprehensive method of analysis shall be done, according to ASME B31.3 code, or similar. The classification of type of analysis shall be indicated for each piping. A formal stress analysis may not be required for some lines (Category 1).

5.1 The classification of lines requires an experienced judgment of the process plant, hull systems and the environment in which the lines are inserted. All category 2 and 3 (critical lines) shall be reviewed and approved for design.

5.2 The classification shall be done for each line present in the design. The Category definitions are as followed:

5.2.1 Category 1 - These lines are considered noncritical lines and stress calculation needs not be performed on the piping systems which meet one of the following requirements:

5.2.1.1 Piping systems which are duplicates, or replaces without significant change, a system operating with a successful service record (ASME B31.3, Paragraph 319.4.1(a)).

5.2.1.2 Piping systems which can be readily judged adequate by comparison with previously analyzed systems (ASME B31.3, Paragraph, 319.4.1(b)).

5.2.1.3 Is of uniform size, has no more than two points of fixation, no intermediate restraints, and falls within the limitations of empirical equation 16 of ASME B31.3, paragraph 319.4.1(c).

5.2.2 Category 2 - These lines are reviewed and supported by stress analysis using simplified or approximate method, guided cantilever method, graphical method or method as outlined in paragraph 319.4 of ASME B31.3; or, a comprehensive stress analysis shall be done for the analysis. A combined collective stress report, for the system or module, shall be issued for this category (see Attachment A). If a line under review fails the criteria, then this line shall be classified to Category 3 type.

5.2.3 Category 3 - These are critical lines. A computational comprehensive stress analysis shall be done. Stress reports shall be issued for this category (see item A.6).

5.3 The operation temperature and the minimum temperature (design, operational or eventual) shall be used for the stress analysis selection criteria. However, the temperature used for flexibility and stress analysis shall be according to item 7.5.

5.4 Manual calculations may be used in cases of simple configurations, low responsibility, and low stresses.

5.5 The classification in Categories for each line shall be done and send to BUYER for approval. As a general guidance, a line shall be subject to a comprehensive stress analysis (Category 3) for the systems/lines indicated in Table 1 (area highlighted in grey).

5.6 Lines that meet one or more different categories shall always be classified and analyzed by the most restrictive one.

5.7 Lines classified in a lower category may always be analyzed as a higher category as defined by the project stress analyst or Company, while the opposite is not allowed.

5.8 As a rule, all branches with diameter relation branch-header (pipe run) of 1/3 or higher shall be considered in the analysis obeying the selection of their header. As minimum NPS 3 and larger shall be considered in the analysis obeying the selection of their header.

5.9 For small bore piping less than NPS 3 a comprehensive analysis in Category 3 may be not mandatory but these lines shall be carefully analyzed, considering a shorter length layout and the actual weight and size of accessories, valves and instruments.

5.10 BUYER, classification society, or piping stress analyst may request that one or more lines or a system be classified and analyzed as Category 3.

5.11 A Flexibility and Stress Analysis Datasheet shall be produced according to ATTACHMENT A.

Table 1 – Systems or lines that shall be submitted to a comprehensive analysis

Systems	Temperature (°C)	Max T - Min T (°C) Note 1	NPS <= 1 1/2	2	3	4	6	8	10	12	14	16	18	>= 20
Geral (metallic lines)	> 150	-												
	> 100	-												
	> 75	-												
	< 0	> 151												
		> 101												
		> 76												
FRP Lines	All	-												
Lines subject to "steam out"	All	-												
Lines with $t/D_{ext} > 0,1$ (thick lines)	All	-												
Lines with $t/D_{ext} < 0,01$ (thin lines)	All	-							STRESS ANALYSIS CATEGORY 1 or 2 Note 7					
sensitive equipment (ex.: turbine, compressors) Note 2	All	-												
Piping expected to be subject to vibration/ surge due to internal and external loads Note 3	All	-												
Main ring fire water line and distribution firewater lines Note 4	All	-												
Hydrocarbon lines containing oil and gas which shall be de-pressurized after a design blast/explosion event Note 5	All	-								STRESS ANALYSIS CATEGORY 3				
Relief lines connected to prssure relief valves and rupture disc	All	-												
Blowdown lines Note 6	All	-												
Lines along the derrick and the flare tower	All	-												
Lines affected by external movements from structural deflections (e.g. platform settlement, Sagging/Hogging)	All	-												
All production and injection manifolds with connecting	All	-												
Lines with expansion joints (bellow or dresser type)														
lines subject to wave loads/green water														
Static equipment (non-fragile equipment)	> 75	-												
Static equipment (non-fragile equipment)	< 0	-												
Static equipment (non-fragile equipment)	All	-												
Lines with Pressure Class 600 and 900	All													
Lines with Pressure Class 1500 and up	All													
Lines design ASME B31.4/31.8														
Lines that do not meet any other requirement	All	-												

NOTES:
1 - The difference between the maximum operation and minimum (operational, design or eventual) temperature is above following values.
2 - Lubrication oil lines , cooling medium lines etc. for such equipment shall not be selected due to this item.
3 - Piping expected to be subjected to vibration due to internal and external loads (e.g. pressure transients, slugging, flow pulsation, external mechanical forces, vortex shedding induced oscillations, high gas velocities) and herby acoustical vibration of the pipe wall.
4 - Pressure surges (water hammer) and blast (if applicable) to be considered for the entire system;
5 - See the design accidental load report for selection lines.
6 - Excluding drains.
7 - Categorization shall be done according Item 5, applicable design codes and Classification Society requirements.

6 DESIGN GUIDELINES

6.1 All design life considerations shall be in accordance with a project lifetime of 30 years.

6.2 The loads components to be considered by the pipe stress analyst in the assessment of piping systems are at least, but not limited to: design pressure, static dead weight, thermal expansion, live loads, hydrostatic test, equipment nozzle displacement, wind loads, structural deflections, deck box deflection, environmental loads, inertial accelerations due to platform motions, slug effect , water hammer effect, relief valve thrust loads, green sea (green water) loads, damage loads, blast loads, transit loads and any combination among them to compose operational loads, or any other loads from structure, naval, classification society requirements or not mentioned above that the stress analyst decide that shall be considered.

6.3 Dead Weight

6.3.1 The deadweight load is the sum of weights from pipe, content, insulation, flanges, bolts, tees, bends, valves and valve actuators etc.

6.4 Internal Pressure

6.4.1 This is the static end-cap pressure load caused by the internal pressure exposed to the cross-sectional area of the pipe internal diameter or for expansion joints the pipe outer diameter or mean-bellow diameter.

6.5 Sustained loads

6.5.1 Sustained loads are the sum of dead weight loads, axial loads caused by internal pressure and other applied axial loads that are not caused by displacement strains. For ASME B31.3 the allowable sustained stress is listed in section 302.3.5.

6.6 Occasional loads

6.6.1 Occasional loads are loads such as wind, earthquake, breaking waves or green sea impact loads and dynamic loads such as pressure relief, fluid hammer or surge loads. The ASME B31.3 code has specific requirements to the accumulated hours of occurrence of such loads. For ASME B31.3, the allowable occasional stress limit is listed in section 302.3.6.

6.7 Environmental loads

6.7.1 Environmental loads are loads caused by, waves, wind. Environmental loads are treated as either sustained or occasional in nature and hence should meet the stress limits for sustained or occasional stresses.

6.8 Thermal expansion and contraction loads

6.8.1 Thermal expansion and contraction loads may be detrimental for the pipe itself, flanges and bolts, branch connections, pipe-supports and connected equipment such as pumps and compressors. Hot-cold system combinations of manifold piping and by-pass piping are typical examples where thermal loads have a major influence on the total stress levels. Sufficient pipe flexibility is necessary to prevent such detrimental loads.

6.9 Structure Deflection (Structural displacement and deck-box deflections)

6.9.1 The vertical and horizontals deflections of the platform have effects on the piping. Design of this piping system should be as such that the impact of deflection to the piping must produce stress levels that are within the allowable limits according to design code.

6.9.2 Differential module movement due to hogging/ sagging during loading and off-loading, and deflection due to vessel inertial acceleration, shall be considered for both maximum displacement stress range criteria, fatigue criteria, and piping reaction loads on support structures and equipment for piping interfacing modules. The effects on piping systems of relative movements in modules, between the FPSO modules, rack/module/deck deflection, and other imposed deflections shall be considered where appropriate. For each project a study about this subject can be developed and a special consideration may be applied.

6.9.3 Structure deflection shall be adjusted considering the distance from neutral line to the piping elevation.

6.10 Inertial Acceleration

6.10.1 The effect of the wave loading on piping depends on the wave induced hull and structural deflection and shall be considered on the piping stress analysis.

6.10.2 Inertial accelerations due to sea wave shall be considered for maximum sustained stress criteria, fatigue criteria, piping reaction loads on structure and equipment.

6.10.3 Piping shall be designed for induced horizontal accelerations caused by the pitch and roll of the platform, and induced vertical accelerations caused by heave. The extra loads caused by these movements shall also be considered on the design and strength integrity check of the supports and equipment connections.

6.10.4 Accelerations values from motion analysis are to be used on analysis for each module and concerning zone within the module. DEC, DOC and transit have to be considered.

6.11 Fatigue Assessment

6.11.1 Design life shall be according to project.

6.11.2 A fatigue assessment due to low cycle fatigue shall be performed based on ASME B31.3 or PD 5500.

6.11.3 A fatigue assessment due to wave motion shall be performed based on DNV-RP-C203. It is not allowed to use ASME B31.3 Appendix W.

6.11.3.1 The fatigue curve used shall be F3 for DNV or F2 for PD-5500 approach. Selection different from that shall be technically justified, discussed with BUYER and submitted for approval.

6.11.3.2 Alternatively, for fatigue assessment of carbon steel piping and stainless steel piping the see DNV RP C203 “Guidance to when a detailed fatigue analysis can be omitted” (section 2.12 of DNV RP C203 2020 edition) may be used to achieve a design life specified by project. Fatigue curve as per item 6.11.2 from this technical specification shall be used.

6.11.4 Fatigue due to cyclic loadings shall be considered in the piping design.

6.11.4.1 Fatigue assessment in piping flexibility and stress analysis shall include structure deflection and inertial acceleration due to sea wave, structure deflection due to production loading/unloadings, process thermal expansion, slug loads and any other cyclic loads.

6.11.1 Low and high cycle fatigue assessment shall be considered. DNV have a particular consideration for elements that are subjected to both conditions. The superposition of cycles from various sources of loading which produce a total stress range greater than the stress ranges resulting from individual sources. Low and high cycle for fatigue shall be evaluated together. See DNV-RP-C203 app F and Norsok N-006 requirements.

6.11.2 SELLERs/Module suppliers shall establish sufficient load cases in piping flexibility and stress analysis to calculate maximum cyclic stress range ($\Delta\sigma_{max}$) due to both hogging/sagging, inertial acceleration and others fatigue loads presented.

6.11.3 Fatigue analysis from structure deflection may be done with alternating displacement from wave induced bending moment. Displacement caused by still water bending moment structure deflection shall be considered as the loading/unloading cycles.

6.11.4 Fatigue analysis shall be performed using stress amplitude or stress range.

6.11.4.1 This information shall be indicated on the flexibility and stress analysis report.

6.11.4.2 Analysis shall be consistent with amplitude or range choose. The fatigue analysis shall reflect this condition, attention for the chosen fatigue curve.

6.11.4.3 The SELLER shall assess the "full range" condition in the case of temperature displacement strains stress calculation when there is any temperature below ambient.

6.11.5 The stress range reduction factor (f) of ANSI B31.3 shall not be used to calculate the allowable displacement stress range (S_A) for other than thermal displacement.

6.11.6 The fatigue cycles and the fatigue method shall be discussed and submitted for BUYER approval.

6.11.6.1 For both high cycle and low cycle fatigue, damage calculations shall consider the number of cycles correspondent to the design life indicated on item 6.1.

6.11.7 Fatigue from temperature displacement loads shall consider the range from maximum and minimum expected temperature, according to item 7.5. The number of cycles shall be as minimum of 7.000 cycles or according to piping design operational requirements.

6.11.7.1 Low frequency cyclic effects due to cargo tanks loading/unloading shall be considered assuming number of cycles according to Hull Structural Requirements (I-ET-3010.2E-1351-140-P4X-001).

6.11.7.2 High frequency cyclic effects due to slug cycles shall consider an average frequency of 5Hz and no damage on fatigue life.

6.11.7.3 For hydro test shall be considered 1 cycle.

6.11.7.4 High frequency cyclic effects due to vessel displacements and acceleration fatigue and number of cycles shall be discussed with BUYER and shall have BUYER approval.

6.11.8 For any additional/complementary program used for fatigue calculation the pdf and native file shall be send with calculation report for BUYER evaluation, e.g. spread sheet (.xlms).

6.11.9 Any necessary adjustment for elastic modulus and thickness shall be applied on fatigue assessment.

6.11.9.1 A design fatigue factor (DFF) minimum of 1 shall be applied.

6.11.10 Transit condition shall also be considered on fatigue assessment.

6.12 Wind Load

6.12.1 Wind effects may be considered as occasional, as per ASME B31.3.

6.12.2 The wind speed may be obtained from Metocean data report.

6.12.3 The wind velocity or pressure versus elevation may be considered.

6.12.4 Wind speed shall be considered for pipes of 150mm (6”) and above and all pipes along flare booms.

6.12.5 Wind shape factor (C) shall be considered as 0.7.

6.12.6 Lines in sheltered or protected from wind do not require the consideration of wind load in the analysis. Lines on those condition shall be discussed with BUYER.

6.12.6.1 Alternatively, a wind shape factor may be calculated as per DNV RP C205. This calculus shall be submitted for BUYER approval and clearly described in the piping flexibility and stress analysis report.

6.12.6.2 The wind shape factor from API RP-2A is not applicable.

6.12.7 Wind loads shall be considered as acting along the horizontal axes, that is, along North, South, East and West directions), but not acting simultaneously.

6.13 Blast Loading Analysis

6.13.1 Piping systems required to hold integrity during a blast occurrence will be identified based on project requirements or Classification Society requirements by SELLERs/Module suppliers and reviewed by BUYER. The lines that are subjected to blast loading analysis shall be defined on detail engineering phase and be analyzed based on Explosion Analysis study.

6.13.2 If no specific information is available, blast drag loads shall be considered to occur from all main directions, also downwards.

6.13.3 It is not required to analyze two independent blast events happening at the same time.

6.13.4 Blast load on piping systems will be modelled as a “drag force” proportional to the density of the vapor cloud ignited, velocity of the shock front during ignition, the projected area/drag coefficient of the piping system and the dynamic load effect.

6.13.5 Blast drag load may be calculated as per DNV RP D101 item 3.11.2.2 (2017 edition). Other form shall be sent for BUYER´s approval.

6.13.6 Blast minimum diameter and piping service (fluid) assessment shall be defined by classification society, safety and piping team during the detail design.

6.13.7 Otherwise determined by classification society and safety teams, blast exceedance for overpressure and drag pressure to be used is 2,5E-4 with no scalation occurrence.

6.13.8 While doing the Blast loading stress analysis, the following points need to be considered:

i. Allowable stress can be “1.8 x Basic allowable stress at that temperature” as per EN-13480. Other allowable stress and analysis methodology will be acceptable if approved by classification society. The methodology shall be issued for BUYER describing all calculation instructions, methods and references. The report analysis shall include the classification society approval.

ii. Blast equivalent wind shape factor (Cd) shall be 1.0.

iii. If no dynamic analysis is carried out, then a conservative DLF of 2 shall be used to account for the dynamic effect of a blast.

iv. A dynamic analysis may be performed. Even so, the DLF shall never be less than 1 (one).

v. The allowable pipe design stress and young’s modulus for the blast condition may be adjusted to reflect the design temperature for the analysis.

vi. Blast analysis shall be carried out in combination with the total deadweight of the piping and the internal design pressure. Other considerations shall be sent for BUYER´s approval.

vii. Thermal expansion stresses may be ignored in blast analysis.

6.13.9 Pipe support shall be designed as per Blast loading analysis, exceptions shall be discussed with BUYER and submit for approval.

6.13.10 Pipe support necessary only for blast condition shall be indicated on piping documents, including isometrics.

6.14 Analysis ambient temperature shall be the minimum air temperature from Metocean data.

6.15 Green Sea (green water)

6.15.1 The impact loads from breaking waves or green sea (green water) entering over the shipside of the FPSO shall be considered in piping design, if and where applicable.

6.15.2 The lines that are subjected to green water shall be defined on detail engineering phase using Motion Analysis study or wave model evaluation, as well the basic necessary data and information.

6.15.3 All parameters necessary for the green water piping flexibility and stress analysis shall be presented by SELLER for BUYER approval. This may be presented on each Flexibility and Stress Analysis Report or in the Piping Flexibility and Stress Analysis Technical Specification.

6.16 Pressure Surge

6.16.1 Normal piping system operating procedures e.g. pump start-up, sudden shutdown, and rapid valve closure may produce unsteady pressure-flow conditions (sudden increase in pressure and high dynamic loads) in the piping and equipment.

6.16.2 Surge analysis for the FPSO firewater ring main system, water lift pump systems and water injection pump system shall be conducted. For other systems, the piping stress analyst shall clarify with process, safety and mechanical group which are the system/lines concerned by surge and their basic data. This lines shall be include on the scope of analysis.

6.16.3 Surge pressure data shall be incorporated and applied in the pipe stress analysis.

6.16.4 It is the piping stress analyst´s responsibility to choose a static or a dynamic assessment that will be applied.

6.16.4.1 For an equivalent static stress analysis to be performed the force due to pressure surge shall be applied at appropriate locations (changes of direction) to determine the stress and support loads.

6.16.4.2 In case of static assessment, a DLF (Dynamic Load Factor) equal to 2 (two) shall be considered regarding load application.

6.16.4.3 A dynamic analysis may be performed. The considerations shall be submitted to BUYER for approval. All detailed information shall be registered in the flexibility and stress analysis report. Even so, the DLF shall never be less than 1 (one).

6.17 Slug Flow

6.17.1 It is the piping stress analyst´s responsibility to clarify with process and safety group which lines may be affected by slugging. These lines shall be included on the scope of analysis.

6.17.2 Slug properties shall be obtained from Process group.

6.17.3 The slug force calculus that will be used on the model shall be presented on flexibility and stress analysis report.

6.17.4 Piping flexibility and stress analysis shall be performed considering slug flow-induced forces. This shall be clearly indicated on the flexibility and stress analysis report.

6.17.5 Slug flow-induced force shall be applied on changes of direction to determine stress and pipe support loads.

6.17.6 The slug force shall be inputted in 2 directions on piping changes of direction.

6.17.7 The resultant slug force Fs acting on a bend may be defined according to Equation 1.

$$F_S = \rho * V^2 * A[2 * (1 - \cos\theta)]^{1/2} * DLF \qquad \text{Eq. 1}$$

ρ – Liquid density;
V – Gas velocity or slug velocity at the moment it hits the bend;
A –internal pipe cross section area;
θ – bend angle;
DLF – Dynamic load factor.

6.17.8 For a static assessment a DLF (Dynamic Load Factor) of 2 (two) shall be considered regarding load application.

6.17.9 For straight tees, load shall be calculated the same as for 90 degree bend.

6.17.10 For a static assessment, BUYER may request additional analysis to guarantee the adequate response of the model.

6.17.11 A dynamic analysis may be performed. The considerations shall be submitted to BUYER for approval. All detailed information shall be registered in the flexibility and stress analysis report. Even so, the DLF shall never be less than 1 (one).

6.17.12 Change in direction shall be kept as minimum as necessary on lines subjected to slug.

6.18 Pressure relief devices (e.g., rupture disc, pressure relief valve - PSV and blow down valve - BDV) and Valve Piping Systems.

6.18.1 The discharge force (relief reaction) of relief devices shall be considered in the piping stress analysis.

6.18.1.1 Relief reaction may be considered as an occasional load.

6.18.1.2 The discharge force shall be considered on the discharge line until its next discharge point or until reaction force influence is no more significant for the system.

6.18.2 Relief devices discharge force (relief reaction) and the vendor document reference shall be presented on the flexibility and stress analysis report.

6.18.2.1 The Vendor document used as reference shall be attached in the piping flexibility and stress analysis report.

6.18.2.2 The discharge force calculus with references shall be clearly described in the piping flexibility and stress analysis report, if the force is not obtained from vendor documents.

6.18.3 The discharge force shall be applied at relief devices discharge lines on flexibility and stress analysis to obtain the pipe stress and support loads.

6.18.4 For a static assessment, a Dynamic Load Factor (DLF) equal to 2 (two) shall be applied on the valve reaction force value.

6.18.5 A dynamic analysis may be performed. The considerations shall be submitted to BUYER for approval. All detailed information shall be registered in the flexibility and stress analysis report. Even so, the DLF shall never be less than 1 (one).

6.18.6 A typical support configuration shall be used on PSV/BDV discharge line, open and closed end, as per Requirements for Piping Support (I-ET-3010.00-1200-200-P4X-004), unless otherwise noted by piping flexibility and stress analysis.

6.19 Vortex induced vibration shall be verified, analyzed and mitigation shall be proposed whenever necessary.

6.20 Sloshing

6.20.1 For piping inside the vessel tanks the sloshing analysis shall be considered in the piping stress analysis.

6.20.2 Sloshing data used and analysis shall be discussed with BUYER and shall have BUYER approval.

6.21 Equipment Nozzle Loading

6.21.1 Piping loads on equipment nozzle shall comply with allowable loads provided by equipment Vendor.

6.21.2 Certified Vendor documents with the allowable loads used shall be included as reference documentation and a copy attached in the flexibility and stress analysis report.

6.21.3 The allowable loads and a percentage used ratio shall be clearly informed on the flexibility and stress analysis report, indicating the load case and nozzle nodes number.

6.21.4 Piping loads on equipment nozzle that do not comply with allowable loads on Vendor documents and are verified in accordance with the WRC 107 and WRC 297, BS 5500 (annex G) codes requirement or any FEA program shall have the VENDOR agreement. This verification, its premises and references and agreement shall be clearly presented on the flexibility and stress analysis report.

6.21.4.1 For both analyses, the pressure thrust shall be considered.

6.21.4.2 All contact to equipment vendor is responsibility of the SELLER.

6.21.5 Designer shall perform the piping flexibility and stress analysis for DAMAGE condition to verify integrity of piping and supports during this event. The piping lines and supports are kept in place during this most severe condition (under calculation parameters foreseen in the detail design). In case the applied loads are over the maximum allowable loads in equipment nozzle, this information shall be clearly informed on the piping stress report, so that after an event special care can be taken by the unit operator.

6.22 Sensitive Equipment Nozzle Loading

6.22.1 Piping loads on sensitive equipment nozzle, such as rotating equipment, shall comply with allowable loads provided by equipment Vendors.

6.22.2 Certified vendor documents with allowable loads used shall be included as reference documentation and a copy attached in the flexibility and stress analysis report.

6.22.3 For load evaluation on equipment nozzle, a simulation shall be done considering the friction coefficient as zero between pipe and supports complementing the analysis with the friction´s coefficient informed on item 8.7.8.2. The most critical case between those indicated above shall be considered for the load’s evaluation on equipment nozzle.

6.22.4 Regarding non API 610 pumps, Vendors shall be consulted to inform/approve allowable nozzle loads values for a safer operation.

6.22.5 The calculated nozzle loads on centrifugal/axial compressors shall satisfy the allowable load criteria of the applicable standard.

Flexibility analysis program shall be used to calculate nozzle load summary for rotating equipment.

6.22.6 The allowable loads and a percentage used ratio shall be clearly informed on the flexibility and stress analysis report, indicating the load case and nozzle nodes.

6.22.7 Multiple operating conditions shall be considered where a common header connects two or more rotating equipment.

6.22.8 SELLER shall perform the piping flexibility and stress analysis for DAMAGE condition to verify integrity of piping and supports during this event. The piping lines and supports shall be kept in place during this most severe condition (under calculation parameters foreseen in the detail design). In case the applied loads are over the maximum allowable loads in equipment nozzle, this information shall be clearly indicated on the piping stress report, so that after an event special care can be taken by the unit operator.

6.23 Stress Analysis Brake-Point

6.23.1 As stress analysis brake-point is understood to be a division of a piping or piping system in a stress analysis.

6.23.2 The scope of piping flexibility and stress analysis shall be until an anchor point (or 3-way) - stress analysis brake-point. If the stress analysis brake-point is not an anchor (or 3-way), the stress analysis shall be extended over its particular scope until next anchor point (or 3-way).

6.23.2.1 It is not allowed to consider an anchor (or 3-way) where there is not an anchor (or 3-way) in the design.

6.23.2.2 This action shall be done for both sides of the analysis.

6.23.3 Alternatively, for stress analysis brake-point, it is acceptable in place of an anchor (or 3-way) type support a sequence of one stopper and one guide or one guide and one stopper.

6.23.4 Piping deflection due to differential module movement and thermal expansion shall be considered, as applicable.

6.23.5 Whenever there is a line that extends to another stress analysis model, this line extension shall be clearly identified on the flexibility and stress analysis report, as well as the report number to which this line originally belongs/continue.

6.24 Interface SELLERs

6.24.1 If there is any SUB-SELLERS, the MAIN SELLER is responsible for coordination, interface and integration of the scope of flexibility analysis among SUB-SELLERS.

6.24.2 The SUB-SELLER shall comply with this technical specification, its references specification and requirements.

6.24.3 BUYER shall receive all technical documentation produced by SUBSELLER according to this technical specification.

6.24.4 It is MAIN SELLER´s responsibility to comment and also send to BUYER all technical documentation produced by SUBSELLER according to this technical specification for comments and approval. It is MAIN SELLER responsibility sent to BUYER the SUBSELLER final versions documents.

6.24.5 The definition of stress analysis brake-point and anchor location (or 3-way) shall be verified and approved by the MAIN SELLER.

6.24.6 The SELLER is responsible for ensuring the fulfillment of the requirements described in this technical specification with the piping project being handed over to the BUYER at his sole responsibility.

6.24.7 Module Limit

6.24.7.1.1 A module limit anchor (or 3-way) or support module limit brake point in stress analysis have to be acceptable for both analysis sides, it should be located as close to the module limit as possible, within the modules.

6.24.7.1.2 Module limit Anchors (or 3-way) or support module limit brake point in stress analysis shall be able to take piping loads from both sides of stress analysis. Those supports shall be designed for both side loads of stress analysis.

6.24.7.2 Communication between SELLERS and SUBSELLERs shall be established during early design stage to decide and define the location of the stress analysis break point (module limit) that is acceptable for the piping systems interface, especially between modules and piping rack or marine systems.

6.25 Loads on flanges and mechanical connections

6.25.1 To minimize the risk of leakage at flanges, valves and mechanical connections, all relevant loads on these elements shall be considered.

6.25.2 For mechanical connections the combined external bending moments and axial forces shall be compared and kept within the allowable given by the Vendor.

6.25.3 For flanges the combined external bending moments and axial forces shall be evaluated according to item 6.26.

6.25.4 Supports on flanges shall be avoided. If used shall be approved by stress analyses. The loads from supports on flanges shall be considered on flange leakage check.

6.26 Flange Leakage Check

6.26.1 Flange integrity and leakage check shall be assessed for Category 3 lines and for any line requested by Classification Society. This assessment with input data, references and analysis file or calculus shall be included on the flexibility and stress analysis report.

6.26.2 The paragraph UG-44 ASME VIII div.1 method shall be applied to “ASME flange” integrity and leakage check assessment.

6.26.2.1 An allowable pressure limits table shall be produced and send for BUYER approval (UG-44 ASME VIII div.1 method).

6.26.3 Alternatively, ASME flange leakage and stress check assessment may be performed in accordance with ASME Section III NC-3658.3 or ASME Section VIII Div. 1 Appendix 2.

6.26.4 Flange leakage shall be checked with the maximum operational (OPE) load case. This load case must assess the design conditions, acceleration and vessel deflection.

6.26.5 For API flanges, external combined bending moment and axial force (together with internal pressure) shall be compared and kept within the allowable given by API 6AF.

6.26.6 For all compact flanges, the leakage verification shall be done according to ISO 27509 Annex A, or any reliable method approved by BUYER.

6.26.7 For others non-ASME flanges, the stress analysis has to ensure the integrity of flanges against leakage based on applicable codes and standards. The verification shall be described, analyzed and presented on flexibility and stress analysis report.

6.27 Transportation and Transit

6.27.1 Piping flexibility and stress analysis and support configuration for the modules shall be arranged and designed for transit condition from fabrication yard to field location and any other intermediate location (indicated on project).

6.27.2 Transit acceleration values and other applicable data shall be used on piping Stress Analysis.

6.27.3 Piping loads on Equipment nozzle, static and sensitive (such as rotating equipment), shall be within allowable as indicated in Vendor data sheets/ Drawings.

6.28 Module Lift

6.28.1 Piping flexibility and stress analysis and support configuration for the modules shall be arranged and designed for module lift condition.

7 PIPING FLEXIBILITY AND STRESS ANALYSIS REQUIREMENTS

7.1 SELLERs/Module suppliers shall issue a Piping Flexibility and Stress Analysis Technical Specification document to fulfil and complement the requirements herein specified.

7.1.1 The Piping Flexibility and Stress Analysis Requirements Technical Specification complement this document (I-ET-3010.00-1200-200-P4X-002) and shall have all information that describe and define the overall premises, assumptions, references, criteria, among other definitions and information currently applicable for all the stress analysis that are going to be done, clearly indicating each definition made with the respective reference and calculus, if applicable (see ATTACHMENT A).

7.1.2 Piping Flexibility and Stress Analysis Technical Specification is not intended to be a copy of this document (Requirements for Piping Stress Analysis).

7.2 The Piping Flexibility and Stress Analysis Technical Specification shall be reviewed and approved by BUYER before starting piping flexibility and stress analysis by SELLERs/ Module suppliers.

7.3 All piping in the project shall be analyzed and classified according to piping flexibility and stress analysis classification criteria. A Piping Flexibility and Stress Analysis Datasheet with all lines, respective classification and others information according to documentation minimum requirements presented in ATTACHMENT A shall be prepared by SELLERs/Module suppliers.

7.3.1 The project shall have a unique Piping Flexibility and Stress Analysis Datasheet for HULL and other unique for Topside.

7.4 The ASME B31.3 code shall be used to determine the allowable displacement stress range (S_A). It is not allowed to use equation 1b paragraph 302.3.5 from ASME B31.3 code, unless previously approved by BUYER.

7.5 Piping temperature used for flexibility and stress analyses shall consider all the three listed conditions:

7.5.1 The operation temperature.

7.5.2 The worst temperature condition among those described below, shall be used:

a) Maximum operating temperature of piping and/or minimum operating temperature (for cold lines). The maximum operating temperature is not the normal operating temperature and shall be indicated in piping line list data-sheet by process team, otherwise the design temperature shall be used.

b) Temperature of heating steam, in the case of piping with steam tracing.

c) 60 ºC: for all non-insulated piping exposed to insolation.

d) 45 ºC: for all non-insulated piping in the machinery space.

7.5.3 Eventual temperatures such as alternative design temperature, alternative operational or design temperature that is below the ambient temperature, operational abnormalities, emergency, steam-out, shall also be considered.

7.6 Exception may be accepted from the provision in item 7.5 for rotating equipment admitting the use of the operating temperature to evaluate nozzle loads.

7.7 The SELLER shall assess the "full range" condition in the case of temperature displacement strains stress calculation when there is any temperature below ambient.

7.8 Design pressure shall be considered in the piping stress analysis.

7.9 Test condition with the corresponding pressure test and test conditions shall be evaluated in the stress analysis.

7.10 Line properties, valves, material and other stress analysis input and output data pertaining to each stress analysis shall be documented in a unique stress analysis package.

7.11 Stress Intensification Factor (SIF)

7.11.1 SIF for piping branch connections shall be in accordance with ASME B31J.

7.11.2 CANCELLED.

7.11.3 SIF and Flexibility factor for D/t>100 shall be defined using finite element method (FEM).

7.11.4 Oblique / Lateral tees have SIF higher than those for straight tees due to the angle of connection between branch and the header. SIF shall be doubling the default SIF for unreinforced fabricated tees in the pipe stress analysis unless an analysis (FEA) determines otherwise.

7.11.5 For elbows with welded trunnion/dummy support, reduced piping flexibility shall be considered. In flexibility program, modeling trunnion/dummy support at mid-point of elbow with “Double Flange” Bend option is required. These modeling techniques will eliminate the flexibility of the bend.

7.11.6 Those calculus shall be previously sent to BUYER for review and approval.

7.11.6.1 The calculus and used data shall be clearly presented on the flexibility and stress analysis report or a particular report shall be issued with input / output files, premises, and a conclusion.

7.11.6.2 The flexibility and stress analysis report shall indicate the type (SIF and flexibility factors), the value and the node number used with a calculated SIF with FEM.

7.11.7 Other condition that leads to a SIF that is not covered by the design code shall be discussed and submitted for BUYER approval.

7.12 For actuated valves, and manual valve class 1500 and higher, data and weights may be taken from one of the potential valve suppliers but shall be verified once the final valve supplier has been selected.

7.12.1 The preliminary data shall be indicated on the flexibility and stress analysis report as “preliminary”.

7.12.2 Once the final valve supplier has been selected the stress analysis shall be updated and the report shall be revised indicating the final valve data and weights and its vendor reference. The vendor document shall be attached in the flexibility and stress analysis report.

7.12.3 The valve actuator weight and bend moment due to misalignment from piping axis shall be taken into consideration on piping stress analysis.

7.13 The vertical displacement (sag) of a line in sustained load shall be limited to 6 mm.

7.13.1 For lines with slop requirements the 6 mm limitation shall be restricted.

7.14 Piping maximum operational displacement shall be evaluated to check, identify, avoid and solve interferences.

7.15 Cold spring of piping lines shall not be used, unless previously approved by BUYER and shall be described its use, its benefits, the risks and the object of its mitigation on flexibility and stress analysis report.

7.16 SELLER shall assure proper support and analysis of piping, where analysis shows support lift-off.

7.16.1 For an intentional lift-off support, this shall be clearly indicated on the stress analysis isometric.

7.17 All rotating equipment analysis shall be evaluated with support friction and frictionless.

7.17.1 Both conditions shall be analyzed and the results shall be presented.

7.17.2 Frictional effects shall not be considered to reduce nozzle loads or piping stresses.

7.18 All lines category 3 shall have the attribute which indicates the status of the stress analysis report on 3D model as “released” or the agreement of the piping flexibility and stress analysis group for isometric document emission for fabrication.

7.19 Sufficient load cases and their combination for stress analysis software shall be established to obtain stress and loads for code stress check, equipment nozzle load check and piping reaction loads on pipe support structures.

7.19.1 If necessary, more than one file for the same group of lines may be done.

7.19.2 The stress analysis shall provide loads for non-structural pipe support steel frames as required. These calculations are to be numbered and filed for future reference.

7.20 The ‘minimum’ required load cases for calculations shall be:

7.20.1 All Functional Loads (including pressure, weight, temperature, inertial acceleration – DEC and DOC, displacements due to hog/sag and inertial structural deflection, thermal displacement, slug load and wind load etc.).

7.20.1.1 Inertial acceleration shall be considered in all directions (positive and negative).

7.20.2 Primary Sustained loads only (include maximum inertia due to wave variations).

7.20.3 Displacement strain loads.

7.20.4 Code compliance cases for sustained and displacement stresses.

7.20.5 Occasional load cases.

7.20.6 Hydro-test, if appropriate. Pneumatic test is not allowed to be considered on stress analysis even if it will be performed on design.

7.20.7 Fatigue life evaluation cases due to cyclic hog/sag, cyclic inertial acceleration, cyclic inertial structure deflection, loading/unloading, slug and cyclic thermal stress etc.

7.20.7.1 CANCELLED.

7.20.7.2 Shall be considered 1 cycle for hydro test case.

7.20.7.3 CANCELLED.

7.21 Nozzle evaluation shall be done considering DEC.

7.21.1 Sustained and operation cases with acceleration (DEC), displacement and wind shall be used to assessing the maximum static equipment nozzle load.

7.21.2 Sustained and operation cases with acceleration (DOC) and displacement may be used instead of DEC to assessing the maximum sensitive equipment nozzle load, such as rotating equipment.

7.21.2.1 Piping loads on sensitive equipment nozzle load, such as rotating equipment, shall comply with allowable loads approved or provided by equipment vendors.

7.21.2.2 Certified vendor documents with the allowable loads used in the stress analysis shall be included as reference documentation and a copy attached in the flexibility and stress analysis report.

7.21.2.3 In absence of Vendor information or designer reference, as a suggestion for initial analysis, allowable loads for sensitive equipment may be used as follows:

Equipment Type (standard):	Permissible Limits:
Centrifugal Pumps (API STD 610)	In accordance with API STD 610 formulas
Centrifugal Pumps (ANSI B73.1, ANSI B73.2)	75% of the value calculated by API STD 610 formulas
Reciprocating Pumps (API STD 674)	In accordance with API STD 674 formulas
Gas Turbines (API STD 616)	In accordance with API STD 616 formulas
Centrifugal Compressors (API STD 617)	In accordance with NEMA SM 23 with constants in the formulas increased by a factor of 1.85
Reciprocating Compressors (API STD 618)	In accordance with API STD 618 formulas.
Steam Turbines (NEMA SM 23, API STD 611, API STD 612)	In accordance with NEMA SM 23 formulas

7.22 Hydrostatic test, sustained and operation cases with acceleration (DEC), displacement and wind shall be used to assess the maximum support load. Particular cases may be discussed.

7.23 A base for the load cases definition by the SELLER is stated in Attachment B. The indicated examples are not exhaustive and it is responsibility of SELLERS to adapt and add the load cases to adequate them to actual piping layouts, service, equipment, location, type of loadings and other requirements. The SELLER load cases shall have BUYER approval.

7.23.1 It may be necessary to develop some specific load cases to meet the demands for piping loads information according to Structural Group requirements.

7.23.2 SELLERS are allowed to add/ modify some load cases based on project or Class requirement, however those modification shall have BUYER approval.

7.24 Thin wall pipes

7.24.1 Piping with Dext / t >100 are considered thin wall.

7.24.2 Support shall be placed to avoid local buckling on piping.

7.24.3 Local buckling shall be checked, even for hydrostatic test.

7.24.4 Finite element analysis may be used to analyze and prove this condition.

7.25 Regard concerning small bore branches, NPS 2 and below, such as vents, drains and instrument connections, see Minimum Requirements for Piping Mechanical Design and Layout (I-ET-3010.00-1200-200-P4X-001).

7.26 Overboard lines shall be assessed and analyzed as multiphase flow, as per the presence of vacuum breaker valve.

7.27 Overboardlines near vessel limits may be subjected to wave loads and near main deck may be sujected to greenwater. Both conditions shall be verified and evaluated, when the loads are present.

7.28 Piping Natural Frequency

7.28.1 All lines subjected to vibration, pulsation, surge, slug, vortex, multiphase flow, relief valve and relief devices loads (e.g. PSV, SDV and rupture disc), condensate lines, overboard lines and lines with cavitation or anti-cavitation valves shall be designed with natural frequency higher than 5 Hz.

7.28.2 For other lines than those on item 7.26, according DNV RP D101 the piping system's natural frequency should be kept above 4Hz. However, it is not acceptable the following:

7.28.2.1 Flare lines natural frequency bellow 3 Hz;

7.28.2.2 Natural frequency bellow 2 Hz for all other lines.

7.28.3 Typical arrangement for lines not modelled on stress analysis shall be used to guarantee the achievement of minimum natural frequency.

7.29 Piping supports shall not be located on pressure vessels for lines susceptible to vibration, including on multiphase flow. Analyst is responsible to check the piping vibration condition, especially if the flow is turbulent or multi-phase, before support a piping on a pressure vessel.

7.30 Piping systems subject to vibration or pulsation shall have anti-vibration solutions.

7.30.1 The type and the location of the anti-vibration solution shall be previously discussed and submitted for BUYER approval.

7.30.2 The flexibility and stress analysis report shall contain the type, location, basic information and data (at least manufacturer and catalog) about anti-vibration solution.

7.31 The line from Free Water Separator Level Control Valve to the pre-oil dehydrator degasser (V-TO-122301) and the line from Pre-Oil Dehydrator Level Control Valve to oil dehydrator degasser (V-TO-122302) shall have dampers (viscoelastic) to reduce dynamic effects due to multiphase flow. The quantity, type and size shall be defined according to the mass, the piping natural frequency and a vibration range around 15 Hz.

7.31.1 The damper (viscoelastic) shall be considered on the stress analysis.

7.31.2 The modal analysis shall be performed including the damper presence.

7.31.3 Other systems may need dampers, snubber or others anti-vibration solutions. This necessity shall be evaluated.

8 STRESS ANALYSIS MODELLING REQUIREMENTS

8.1 Global coordinates shall be included on the piping flexibility and stress analysis model´s first node.

8.2 The axis orientation on piping flexibility and stress analysis model shall be according to the axis orientation used on the project 3D model.

8.3 The project system units shall be used. If different from the default values in Caesar program, a unit file shall be created with a unique assigned file name.

8.4 The piping flexibility and stress analysis shall consider the design data and also the different conditions that may occur during operation, as: steam out, start-up, shut-down, dry-out, depressurizing, cold branch for spare equipment, tracing and other process conditions specified.

8.5 The piping line tag number (line number) according to P&ID shall be indicated on the stress analysis model.

8.6 The valve tag number according to P&ID shall be indicated on the stress analysis model.

8.7 Supports Modelling

8.7.1 The use of gap in stress analysis model is not allowed, unless previously discussed and with BUYER approval. Exception made for rest support. This condition does not necessary modify the construction gap as informed on item 8.7.2.

8.7.2 On installed supports, the typical (construction) gaps on either side of guides will be 2.0 mm, as per Requirements for Piping Support (I-ET-3010.00-1200-200-P4X-004). Flexibility and stress analysis report shall inform whenever these gaps shall be reduced (e.g. lines subject to vibration may require no gap).

8.7.3 The stress analysis shall verify the compliance of the support analysis loads with the allowable loads indicated on each piping support component and indicate, if necessary, a special support.

8.7.3.1 Supports with prescribed gaps from stress and flexibility analysis shall be special supports. It is not allowed to use standards supports indicating modifications.

8.7.4 Supports shall have the 3D model support TAG indicated on the flexibility and stress analysis model. It shall be updated in all document revision including as-built revision project phase.

8.7.5 Regarding Hull Lines, all supports aligned with structural frames shall be identified with the corresponding frame number on the flexibility and stress analysis model.

8.7.6 Spring supports and other support types (e.g., damper) shall have the 3D model support TAG indicated on the flexibility and stress analysis model. It shall be updated in all document revision including as-built revision project phase.

8.7.7 According to item 9.3 the actual support stiffness may be inputted on the piping flexibility stress analysis model.

8.7.8 Friction supports effects shall be applied at all supports.

8.7.8.1 As per Requirements for Piping Support (I-ET-3010.00-1200-200-P4X-004), metal to metal contact shall be avoided, exception made when it is prescribed from stress analysis, this condition shall be previously discussed and approved by BUYER.

8.7.8.2 Friction supports effects shall be calculated based on the following friction coefficient:

i. 0.30 - for steel to steel (attention to item 8.7.8.1);

ii. 0.10 - for polished steel to PTFE;

iii. 0.15 - for metal to FRP/GRP.

iv. Any other friction reducer shall be previously approved by BUYER.

8.7.8.3 Frictionless support modelling may be generally employed for guides and line stops only. However, friction effects on guides and stops shall be applied at all supports close (last 3 supports as minimum) to rotating/sensitive equipment for nozzle loading qualifications.

8.7.8.4 Supports, as rigid strut and roller, maybe applied. Care shall be taken about maximum and operational angle and movement.

8.7.8.5 For load evaluation on equipment nozzle, a friction and a frictionless (coefficient as zero between pipe and supports) analysis shall be done. The most critical case between them shall be considered for the loads evaluation on equipment nozzle. Maximum load for both conditions (friction and a frictionless) shall be indicated on the flexibility and stress analysis report.

8.7.9 Unless otherwise noted by the piping stress analysis, all control valve station shall have a typical support configuration: anchor (or 3-way) support at one end and guided at the other. Typically, the anchor (or 3-way) would be on the upstream side of the control valve.

8.7.10 Pipe supports attached to flange connections shall be avoided. Nevertheless, if used, these type of support shall be clearly indicated on the flexibility and stress analysis report and the flange leakage check shall be performed on this flange, regardless it class or type.

8.7.11 All guides for lines up to 6” shall have hold down support type provided, unless otherwise noted by piping flexibility and stress analysis.

8.7.12 Unless otherwise specified by piping stress analysis, lines NPS 1½” and below shall be guided on every rest support, and 2” and larger guided on every second rest support.

8.7.13 Unless otherwise noted by piping stress analysis, the maximum support distance shall be determined according to maximum pipe support span (see I-ET-3010.00-1200-200-P4X-004).

8.7.14 Supporting lines on other pipelines shall be avoided. Exceptions shall be analyzed and approved by flexibility and stress analysis.

8.7.14.1 Nonmetallic piping shall not be used to support other piping.

8.7.14.2 When a small bore line or branch is supported by a parent pipe of small diameter (i.e. typically less than 6”) the effect of the added mass (supported mass) may affect the parent pipe, this presence shall be clearly evaluated on the flexibility and stress analysis.

8.7.15 All firefighting equipment type water or foam nozzle with thrust forces on operation shall be supported with an anchor at its base to resist the forces and moments according to manufacturer brochure.

8.8 Support location and type shall allow piping assembly and dis-assembly of maintenance component (e.g. flanged valves, strainers) without the necessity of temporary support.

8.9 Support location and type shall allow sensitive nozzle alignment. In view the difficulties from alignment and maintenance with spring supports, flexibility and stress analysis shall evaluate the presence of a rest support near the nozzle, even in a condition of lift-off in operation.

8.10 All piping support loads above 30 kN shall be indicated on the flexibility and stress analysis report. The Structure Group approval/compliance statement or the structural analysis report number shall be presented on this report.

8.11 Regarding modal/dynamic analysis, the maximum distance between nodes shall be evaluated for a proper model response. Hence, mass space program (Coade/Hexagon) or another similar tool may be used.

8.11.1 As minimum, an intermediate node shall be modeled in the middle of all pipe spam to permit verification of the vertical displacement and perform modal analysis.

8.12 Expansion joints and other coupling shall have the 3D model support TAG indicated on the stress analysis model.

8.13 Piping clad thickness shall not be considered to enlarge piping thickness on stress analysis or pressure thickness. Clad thickness shall be used as input data on stress and flexibility model.

9 PIPE SUPPORTS

9.1 Pipe supports shall fully comply with ASME B31.3 and Requirements for Piping Support (I-ET-3010.00-1200-200-P4X-004).

9.2 Pipe supports shall be considered on stress analysis for operation, design and transportation, and any other conditions herein informed.

9.2.1 Temporary supports that need to be removed after transport, including sea fasteners, shall be indicated in piping isometric and flexibility isometrics: “This support must be removed after transportation”.

9.3 The actual support stiffness may be used. The actual support should be used on the stress analysis close to sensitive equipment, e.g., near compressor and water injection pump machines process nozzle. DNV RP D101 Section Item 3.16.2 (2017 edition) may be used as orientation.

9.3.1 The support stiffness value used shall be indicated on the flexibility and stress analysis report and its origin´s reference.

9.3.2 For compressor systems the support stiffness shall comply with API 618 requirements.

9.4 Attention shall be taken to the support stiffness of lines subjected to service with potential vibration risk (e.g., sensitive equipment, multiphase flow, slug and surge).

9.5 Anchor supports shall be avoided.

9.5.1 A 3-way restraint support with no gaps shall be preferred used in place of welded or bolted anchorage.

9.6 For lines with displacements greater than half of the total pad or shoe length, a movement check shall be done and displacements specified to ensure that support pipe shoe sizes are correct defined to avoid line disengagement. Evidence of this check shall be clearly presented on flexibility and stress analysis report.

9.7 A Pipe Load Diagram Report shall be produced.

9.7.1 The report shall have as minimum the information listed in ATTACHMENT A.

9.7.2 For horizontal force due to frictional force of many pipes standing on the same support, consider a simultaneity factor in relation to the number of pipes, as indicated in Requirements for Piping Support (I-ET-3010.00-1200-200-P4X-004).

9.7.3 See Requirements for Piping Support (I-ET-3010.00-1200-200-P4X-004) as reference for a recommended procedure to calculate the simultaneous action of these reactions.

9.7.3.1 The loads for non-structural pipe support steel frames shall be provided as required. These calculations shall be numbered and filed for future reference.

9.8 SPRING SUPPORTS CONSIDERATIONS

9.8.1 The use of spring hanger is allowed but shall be avoided as much as possible.

9.8.2 An accurate weight balance calculation shall be made to determine the required supporting force at each hanger location.

9.8.2.1 It is important that the correct weight for each valve is input to the analysis of critical piping systems, such as lines to/from gas compressors, steam turbine and pumps, and any piping system that requires spring hangers.

9.8.3 Spring hanger in multiphase flow piping shall not be used, unless previously approved by BUYER and described the use, its benefits, the risks and its mitigation on flexibility and stress analysis report.

9.8.4 Spring shall be verified for both condition, operation and design, to guarantee that systems is on allowable limits on operation condition, as per item 7.6, and spring support is adequate for both conditions not exceeding its limits.

9.8.5 The spring hanger supporting force variation between hot and cold conditions shall be less than or equal to 20% of the hot condition supporting force.

9.8.6 Whenever possible, spring support shall be selected for hot load centered and for a free restraint at nozzles.

9.8.7 A spring support list shall be properly produced containing all spring supports in the project and at least the information presented in ATTACHMENT A.

10 EXPANSION JOINTS (METALLIC AND RIGID – DRESSER TYPE)

10.1 The use of expansion joints metallic or rigid (dresser type) shall be avoided. The expansion joint shall be used strictly when it is not feasible to give enough flexibility to the piping system.

10.1.1 NOT APPLICABLE.

10.1.2 For hull systems the use of rigid expansion joints is allowed if indicated on the P&ID, but the location and quantity shall be previously discussed and approved by OWNER. For other systems or lines, the use of rigid expansion joints shall be previously approved by OWNER.

10.2 Metallic expansion joints shall be designed according to ASME B31.3, EJMA and any additional requirements from classification society.

10.3 Rigid expansion joints shall comply with requirements presented on I-ET-3010.2E-1200-253-P4X-001.

10.4 It is piping stress analyst´s responsibility to use the correct data about expansion joints, e.g. spring rate, weight, effective area, geometrical data, rated movements on piping flexibility and stress model and analysis.

10.5 It is the stress analyst responsibility to observe and comply with manufacture installation instructions and EJMA for the metallic expansion joints, and to meet the requirements established by the manufacturer regarding the support arrangement, e.g., maximum spans and support.

10.6 The flexibility and stress analysis shall be updated and rechecked if the expansion joints data used do not comply with the supplier data.

10.7 Certified Vendor documents with at least spring rate, weight, effective area, geometrical data, rated movements, material, design cycles, spare parts and calculus datasheet shall be included as reference documentation and a copy attached in the flexibility and stress analysis report.

10.8 The design fatigue life of each expansion joint shall comply with the project life and cycles number. The design life cycles for these components shall be clearly indicated on documents.

10.9 The flexibility analysis with expansion joints subject to hull movements shall contemplate a verification of all hull movement: vertical and longitudinal displacement and rotation, according to Hull deflection document.

10.10 Expansion joints shall be flanged end, unless otherwise specified on the project. The proper weight shall be used on flexibility and stress analysis.

10.11 Rigid expansion joints shall be located between two anchor (or 3-way) supports and adequate supported to avoid bending or torsion, or according to manufacturer recommendation.

Guide minimum distance shall be according to manufacturer recommendation or in absence according to EJMA recommendations.

10.12 Metallic expansion joints shall have anchor (or 3-way) supports and guides located according EJMA recommendations.

10.12.1 Intermediate Anchor in systems with shut-off valve (e.g., isolations valve, SDV, control valve) shall be designed for expansion joints thrust loads as Main Anchor according to lay-out. The loads informed in each support shall properly consider this condition.

10.12.2 All Intermediate Anchors shall be designed for expansion joints thrust loads, considering partial operation and/or maintenance of piping systems (e.g., TC, TR system, firewater ring), to guarantee the structure integrity. The loads informed for each support shall properly consider this condition.

10.13 An expansion joint list or other coupling list shall be properly generated containing all expansion joint in the project and at least the information presented in ATTACHMENT A.

10.14 All requirements from classification society for expansion joints shall be followed, including tests and any imposed limitation or restriction. The details and tests of the expansion joints are to be submitted by the manufacturer for Classification Society approval during the review of the detail design phase.

11 FLEXIBILITY AND STRESS ANALYSIS FOR GRP PIPING

11.1 It is GRP Vendor responsibility the piping components design, type of restraints and its location, piping layout acceptance, calculations, and dynamic analysis. Any other consideration foreseen by Vendor for a safe GRP system shall be presented and included in piping design. It is Vendor responsibility to present and include in piping design.

11.2 GRP piping flexibility and stress analysis report shall be issued with the correspondent electronic file according to this Technical Specification.

11.2.1 The GRP piping flexibility and stress analysis shall have the approval of the GRP Vendor.

11.3 The piping flexibility and stress analysis report shall contain a GRP piping stress isometric detailing all supports and the correspondent loads. The content of this document shall at least comply with ATTACHMENT A, DNV RP D101 Section 3.17.4 (2017 edition) may be used as a reference.

11.4 System layout shall prevent overstrain. Pipe displacement shall be controlled by routing and expansion loops permitting angular, rotational and/or axial movements. Expansion joints shall not be used unless when previously approved by BUYER.

11.5 Flexibility and stress analysis shall follow at least the requirements given in the ISO 14692–3.

11.6 Material properties, flexibility factors and stress intensification factors shall be based on vendor data. The properties required for ISO 14692-3 analysis shall be informed by the manufacturer and included on the flexibility and stress analysis report, including the following information:

- Mechanical properties of the material

  - Elastic Modulus/axial - Axial Modulus of Elasticity at room temperature;
  - Elastic Modulus (H1) to (H9) - Axial Moduli of Elasticity at design temperatures;
  - vh/a - Poisson's ratio of the strain in the hoop direction resulting from a stress in the axial direction;
  - Eh/Ea Ratio of the hoop modulus to the axial modulus of elasticity;
- Failure envelope
  - al(0:1) - Long term envelope axial stress for a pure axial loading condition at xx °C
  - al(2:1) - Long term envelope axial stress for an unrestrained, hydraulic (2:1) condition at xx °C
  - a_R - Long term envelope axial stress for an unrestrained, hydraulic (Rtest) condition at xx °C
  - hl(2:1) - Long term envelope hoop stress for an unrestrained, hydraulic (2:1) condition at xx °C
  - h_R - Long term envelope hoop stress for an unrestrained, hydraulic (Rtest) condition at xx °C
  - f_2 - Part factor for sustained loading (System Design Factor)
  - A_0 - Partial factor for design life
  - A_2 - Partial factor for chemical resistance
  - A_3 - Partial factor for cyclic service
- Stress Intensification Factors

11.7 Supports in all cases shall have sufficient width to comply with piping flexibility and stress analysis foreseen movement, to support the piping without causing damage and shall have a pad.

11.8 GRP piping shall be supported according to the pipe vendors engineering guidelines, but at least shall comply with the recommendation from ISO 14692. Support design shall allow for expansion, contraction and deflection resulting from pressurization, temperature variations, slugging (water hammer) and weight of the pipe content. Special attention shall be given to proper supporting of metal valves, filters and others mechanical equipment installed in the system.

11.9 Any item of this specification even though related to metal piping shall be verified for GRP and included on the report. (Modal analysis, flange leak verification, fatigue, loads on nozzle equipment, blast, damage, transport, etc.).

11.10 For the GRP flange leak verification the bondage flange x pipe through the loads, moments and cyclic loadings shall be verified. This verification shall be presented on the flexibility and stress analysis report.

12 FLEXIBILITY AND STRESS ANALYSIS FOR PVC/CPVC PIPING

12.1 Thermal expansion shall be considered in the design of nonmetallic (CPVC) piping systems. The design expansion rate shall be 1/2" per 10°F change in temperature per 100' of length.

12.2 PVC/CPVC piping shall be supported according to the pipe vendors engineering guidelines.

12.3 PVC/CPVC piping shall be supported according to the pipe vendors engineering guidelines. Those requirements shall be presented on the design documentation.

12.4 Supports in all cases shall have sufficient width to comply with piping foreseen movement, to support the piping without causing damage and shall have a pad.

13 MODAL ANALYSIS

13.1 Modal analysis shall be done for all lines considering the operational condition, for linearization.

13.2 The natural frequency minimum cut-off to be displayed on the flexibility and stress analysis report for general systems shall be 50Hz.

13.2.1 For screw and reciprocating compressor systems, the natural frequency minimum cut-off to be displayed on the flexibility and stress analysis report shall be over the 3rd mode imposed by the machine.

13.2.2 Depending on the dynamic phenomenon involved and depending on the calculations performed, it may be necessary to increase the cut-off limit to be displayed on the flexibility and stress analysis report to properly assess the risk of vibration in each case.

13.3 For modal analysis, real values of weight piping components should be considered, preferably from the supplier's documentation, with special attention to the weight of components, fluid weight in the operating condition, thermal insulation weight, among other components.

13.4 It shall be adopted the valve weight reported by the valve manufacturer, including the actuator, without safety factors. If necessary, the modal analysis shall be updated with the final data from valve and actuators.

13.5 Under BUYER´s request the support structures and pipe supports shall have their stiffness properly considered in the simulation (either by including stiffness in the support points or by coupling the structural model and pipe) given their influence mainly for the calculation of natural vibration modes and frequencies.

13.6 For harmonic loads, natural frequencies should be away from excitation frequencies around 20% more or less. The flexibility and stress analysis report shall have an attention indication whenever this condition is not met.

13.6.1 Machine vendor requirements shall be followed. It is analyst´s responsibility to apply on piping design those requirements.

13.6.2 Special attention for reciprocating systems and its requirements according machine design codes.

13.7 When a small bore line or branch is supported by a parent pipe of small diameter (i.e. typically less than 6”) the effect of the added mass (supported mass) could affect the parent pipe, this presence shall also be evaluated on modal analysis.

14 VIBRATION ANALYSIS

14.1 All vibration analysis shall be sent to BUYER for approval.

14.2 Vibration analyses are not limited to lines classified as Category 3.

14.3 "Guidelines for the avoidance of vibration induced fatigue failure in process pipework" from Energy Institute shall be used as main reference. Other references may be used under BUYER approval.

14.4 Special care shall be taken regarding vibration. Refer to "Guidelines for the avoidance of vibration induced fatigue failure in process pipework" from Energy Institute for sources, assessment and actions.

14.5 Small bore connections, mainly drain, vents and instrument branches may not be analyzed on flexibility and stress model but shall be evaluated and SELLER shall guarantee it comply with this technical specification and references, design codes and "Guidelines for the avoidance of vibration induced fatigue failure in process pipework" from Energy Institute, for static and dynamic conditions.

14.6 Piping shall be evaluated for flow induced turbulence. Piping with $Rho*V^2 > 5.000$ shall need attention is piping supports and natural frequency requirements. This assessment shall be done on Vibration report to identify those piping.

14.7 No flow branches (dead leg), permanent or temporary, in gas service shall be verified for pulsation.

14.7.1 As good practice, the branch block valve or device shall be located as close as possible from its header.

14.8 For lines with fast actuation valves a surge/momentum analysis shall be performed. Supports shall also be evaluated for this maximum force condition.

14.9 Cavitation and flashing shall be evaluated mainly on large pressure drop and overboard lines.

14.9.1 Attention for piping with anti-cavitation valve.

14.10 A high frequency acoustic excitation analysis shall be performed for piping flow velocity higher than 0.5*Mach.

14.11 A high frequency acoustic excitation analysis shall be performed for piping with D/t > 90 in depressurization systems.

14.12 Systems with mechanical excitation shall be evaluated for vibration and pulsation.

14.12.1 Machine vendor requirements shall be followed. It is analyst´s responsibility to apply on piping design those requirements.

14.12.2 Special attention for reciprocating systems and its requirements according machine design codes.

14.12.3 The Positive Displacement Pumps Specification technical specification (I-ET-3010.00-1200-310-P4X-002) requirements for piping shall be attended.

14.12.4 The Vapor Recovery Unit technical specification (I-ET-3010.XX-1225-323-P4X-001) requirements for piping shall be attended.

14.12.5 The piping layout, supports information (e.g. type, position and stiffness) and any other requested piping information shall be supplied to machine PACKAGER/MANUFACTURER as many times as necessary.

14.12.6 SELLER shall follow the instructions/ recommendations from machine PACKAGER/MANUFACTURER regarding piping design and perform the flexibility and stress analysis for piping as many times as necessary until both pulsation and vibration analysis and flexibility and stress analysis converge to a common piping run design.

14.12.7 SELLER shall provide piping information feedback as many times as necessary to machine PACKAGER/MANUFACTURER after piping design and flexibility and stress analysis is performed with provided instructions.

14.13 Production lines from wells (start at shut down valve - SDV, to the Dehydrator Degasser -V-TO), which have multiphase flow, shall be properly assessed taking into consideration the risk of slug flow and flow induced turbulence.

14.14 Condensate lines which have the potential for the occurrence of slug-flow shall be properly assessed according to this phenomenon, e. g production lines, condensate lines from the safety vessel, main compression unit scrubber vessels, and vapor recovery unit scrubber vessels.

14.15 The supports for small bore branches (NPS 2 and lower) on Vapour Recovery Unit main process lines may require a FEM analysis to define the support geometry, verify the necessity of adding masses and ratify the use of welded type support or proposes the use of clamp.

14.16 A report with vibration assessment shall be issued. The Vibration Report shall be used as reference for the stress analysis, it shall be considered at least for piping route, support type and positioning definition and natural frequency modes evaluation.

ATTACHMENT A – DOCUMENTATION OF PIPING STRESS ANALYSIS

DOCUMENTATION FOR PIPING FLEXIBILITY AND STRESS ANALYSIS

A.1. For each project shall be produced at least these documents:

- i. Piping Flexibility and stress analysis Technical Specification (item A.2).
- ii. Piping Flexibility and stress Analysis Datasheet;(item A.4).
- iii. Piping Flexibility and stress Analysis Reports – Category 2 (item A.5).
- iv. Piping Flexibility and stress Analysis Reports with stress isometric – Category 3 (item A.6).
- v. Piping load diagram on pipe-rack (item A.7).
- vi. Piping expansion joint list (item A.8).
- vii. Piping spring supports list (item A.9).
- viii. Piping support list.
- ix. Vibration Report (item A.11).

A.2. A hold list shall be included on each document with the information / item that do not have information or have a preliminary information.

A.3. Piping Flexibility and stress Analysis Technical Specification shall contain all the chosen options and details that are used on the flexibility and stress analysis for each stress analysis type (category 1 to 3). All flexibility and stress analysis performed shall comply with the information proposed on this document.

A.3.1. Typical layout configuration and requirements for small bore connection shall be according to piping Minimum Requirements for Piping Mechanical Design and Layout (I-ET-3010.00-1200-200-P4X-001).

A.3.2. For category 1, as minimum, a statement shall be presented saying that the pipe size, material, layout, supporting a pressure, temperatures, imposed deflections environmental and accidental loads are similar to the visually approved system and the reference piping system that has been analyzed by comprehensive methods. Information about the reference piping systems shall be given according to section “Requirement to documentation of visually approved piping” from DNV RP D101 (section 3.15.4 2017 edition).

A.3.3. For category 2, as minimum, the range of configurations that are applied shall be presented, showing a demonstrated adequacy, which method will be applied for analytical methods and also the references and charts that are used on the assessment. If a computational method is used, as minimum, the basic description of the analysis shall be presented.

A.3.4. For category 3, as minimum, the basic description of the analysis and all general data that are used on the flexibility and stress analysis shall be presented, e.g. typical load cases, acceleration data, wind data, friction considerations, and fatigue analysis basis.

A.4. Piping flexibility and stress Analysis Datasheet shall cover all project lines, with an independent document list for the Hull, and another independent document list for the Topside. Lines is scope of SUBSELLERS shall also be included.

A.4.1. Piping Flexibility and stress analysis datasheet shall contain for each line of the project at least the following information:

a) Line identification (diameter, service piping specification, sequential, area);

b) Thermal insulation thickness;

c) P&ID of the corresponding line;

d) Fluid characteristics (design temperature, design pressure, test pressure, operation temperature and eventual temperature if applicable);

e) Flexibility and stress report tittle (Equipment associated or system);

f) CANCELLED

g) Analysis category (1 to 3) according to item 5 of this document;

h) The selection criteria (item) which lead to the analysis category, according to Table 1 or any complementary classification issued;

i) The corresponding flexibility and stress analysis report code number (document tag);

j) Type of performed analysis (e.g. static, blast, green water, slug, surge, dynamic). Shall be informed all the performed analysis;

k) Revision;

l) And notes, if necessary.

A.5. Piping Flexibility and stress Analysis Report for category 2 shall contain at least the following information:

a) Scope of analysis, purpose;

b) The computer program used and its version, if applicable; in this case each flexibility and stress analysis report shall be accompanied by its respective electronic files (.c2 or similar, if necessary, a compressed extension may be used).

c) Line identification (diameter, service piping specification, sequential, area) that is analyzed on this report;

d) P&ID of the corresponding line;

e) A technical positive position or conclusion of the analysis, regarding the suitability of the lines evaluated.

A.5.1. Each report shall be fully comprehensive and be identified by one document number.

A.5.2. At least one report per module or system shall be produced.

A.5.3. If a non-computational analysis is performed the report shall also inform the lines that are reviewed and supported by stress engineer using guided cantilever method, graphical method or other. The considerations for the use of this methods shall also be described.

A.6. Piping Flexibility and stress Analysis Report for Category 3 shall contain at least the following information.

A.6.1. Each report shall be fully comprehensive and be identified by one document number.

A.6.2. The input of the analysis shall be shown on a calculation report, which shall include, at least but not limited to:

a) Scope of analysis, purpose;

b) The computer program used and its version;

c) Reference documentation (e.g. P&ID, equipment drawings, piping data sheet, valve drawing).

d) Reference documents from design shall be included/attached on the stress analysis report;

e) Premises (design code, acceleration, wind, fatigue);

f) Indication of which analysis will be performed on report (e.g. static, transit, blast, green water, fatigue, modal);

g) Design data: line identification, diameters, piping spec, material, thickness, corrosion allowance, piping class, basic allowable stress for cold and hot condition, thermal expansion factor, operational and design temperature, operational, design and hydro test pressure, fluid density, insulation thickness). This information can be presented as colored images (windows from flexibility analysis program may also be used with clear information).

h) Static and dynamic load cases analyzed, according to the basic codes and project specification (load case, stress type, load cycles if applicable and description);

i) Legend with information about which symbol used on the load cases, e.g. T1 – operating temperature, D1 – SAG.

j) A summary of each load case used with definition (sustained, thermal, displacement);

k) Displacement input of supports, structure or nozzle equipment with the considerations about material, thermal expansion, temperature and dimensions involved.

l) Any calculus performed as input, including equipment thermal expansion, PSV reaction force.

m) Explanation of each load acronym used on load cases.

n) P&ID mark-up with lines pertaining to the analysis scope.

o) A print layout of the model issued.

A.6.3. All results of the flexibility and stress analysis shall be presented on the calculation report.

A.6.4. The results of the analysis shall be shown on a calculation report, which shall include, at least but not limited to:

a) Stress table for each analyzed condition, indicating the load case and node number most requested, the calculated and allowable stress, the stress percentage relation.

b) It shall also contain a summary of reactions on equipment nozzles and supports for each load case combined which are being considered and its computer output reports. The allowable nozzle loads, the percentage relation and the nozzle node.

c) Maximum displacement in each direction, indicating the load case and the nodes number associated.

d) Maximum cumulative fatigue, indicate de the line tag, node and the usage ratio.

e) Spring table data with spring node number position, cold load, spring rate, cold to hot movement and quantity.

f) Equipment nozzle loads checking - summary of loads on equipment nozzles, indicating the nozzle node, the maximum and the allowable loads, and the percentage ratio;

g) Modal analysis results.

h) Additional requirements, such as reinforcing pad, etc.

i) The correspondent load on each support shall also be informed on the Report. Loads over the maximum informed on supports standard and special book shall have indication of the structure analysis compliance or the report number analysis. For supports loads over 30 kN the Structure Group approval/compliance or the report number analysis shall be presented on this report.

j) A flange check leak report with all input data described.

k) Extra analyses that were performed, e.g. FEA, stiffness calculation, WRC verifications, with corresponding native files and report.

l) For any additional/complementary program used the pdf and native file shall be attached, e. g. support verification or fatigue calculation.

m) Annex with expansion joints or other coupling supplier drawings, valves supplier drawings, spring support supplier drawings, equipment or skid supplier drawings.

A.6.5. Each flexibility and stress analysis report shall have all input and output report data from flexibility and stress analysis program.

A.6.6. Each flexibility and stress analysis report shall be accompanied by respective electronics files (.c2 or similar, if necessary a compressed extension may be used).

A.6.7. The stress analysis file shall contain beyond all the basic necessary information for the analysis, the line identification number. And the initial node shall have the global coordinates associated to the 3D model.

A.6.8. The report shall contain a flexibility isometric with all lines of the analysis and detailing all supports function, position, and nodes number necessary for the calculation. Lift-off and transport supports shall be indicated. A computational generation flexibility isometric is preferable.

A.6.9. DNV RP D101 Section 3.17.4 may be used as other reference.

A.6.10. Reference to Vibration Report, that shall be used as reference for piping stress analysis, e.g. for piping route, support type and positioning and natural frequency modes evaluation.

A.7. The design shall have a Piping Load Diagram on pipe-rack, one for each pipe-rack, and this document shall contain at least the following information:

a) Schematic division of pipe-rack modules;

b) Pipe-rack schematic drawing with line identification;

c) Premisses;

d) Used load case from each stress analysis report shall be indicated.

e) Load table for DEC, DOC and test conditions. Each one shall contain:

i. Line identification;

ii. TAG;

iii. System;

iv. Nominal diameter;

v. Load (X, Y, Z) from each line for each frame. All lines shall be presented for every frame on table, if a line do not have a load in a particular frame, a dashed line may be used.

vi. Stopper loads shall be highlighted.

vii. Terminal stopper loads from expansion joints thrust, shall also be highlighted.

f) Any preliminary information as thrust loads due to expansion joints and weight of pipe filled with water considering pipe shall be demonstrated and informed on this document.

g) This document shall reflect the loads from piping flexibility and stress analysis.

h) Stress analysis report number that supply information for those loads shall be on reference documentation including revision.

i) Reference documents, including piping stress analyses report, and notes if necessary.

A.8. Piping expansion joint or other coupling list shall contain at least the following information:

a) Expansion joint identification TAG (according to 3D Model);

b) Indication if it is a metallic expansion joint with type (e.g. axial, gimbal, hinged) or a dresser coupling with style (e.g. traditional, harnesses);

c) Line identification;

d) System;

e) P&ID;

f) Module/block;

g) Expansion joint coordinate (X, Y, Z);

h) Diameter of expansion joint;

i) Overall length;

j) Spring rate on flexibility and stress analysis;

k) Maximum rated movements of expansion joint as per flexibility and stress analysis (axial, lateral and angular).

l) Expansion joint node number on stress analysis;

m) Expansion joint supplier drawing number associated;

n) Piping flexibility and stress analysis report number associated;

o) Indication whether fire test resistance certificate is necessary according design requirements;

p) Reference documents and notes if necessary.

A.9. A Piping spring support list shall contain at least the following information:

a) All spring support shall be identified according to 3D Model.

b) Line identification;

c) P&ID;

d) Module;

e) Type of spring support;

f) Size of spring support;

g) Travel (vertical movement);

h) Cold/ Installation load;

i) Hot/ Operation load;

j) Spring rate;

k) Flexibility and stress analysis report number associated;

l) Node number on flexibility and stress analysis;

m) Quantity (number required) at the same position;

n) Supplier;

o) Reference documents and notes if necessary.

A.10. A Piping snubber and damper support list shall contain at least the following information:

a) All snubber and damper support shall be identified according to 3D Model.

b) Line identification;

c) P&ID;

d) Module;

e) Type of support (snubber or damper);

f) Size/model/type of support;

g) Travel (allowable movement);

h) Allowable loads and damping resistance;

i) Flexibility and stress analysis report number associated;

j) Node number on flexibility and stress analysis;

k) Quantity (number required) at the same position;

l) Supplier;

m) Reference documents and notes if necessary.

A.11. A Piping Vibration Report

A.11.1. Each piping or piping system shall have an assessment considering the piping susceptibility and the vibration mechanism presented.

A.11.2. Shall be issued at least one report for the design or one per module. This assessment shall not be presented on the stress and flexibility report, shall be used as reference for piping route, support type and positioning.

A.11.3. "Guidelines for the avoidance of vibration induced fatigue failure in process pipework" from Energy Institute shall be used as main reference. Other references may be used under BUYER approval.

A.11.4. Item 14 shall be used as basic vibration mechanism issues. It is SELLER / VENDOR scope to define the vibration mechanisms that occurs in each piping and piping system. It is SELLER / VENDOR scope to analyses and mitigate vibration issues.

A.11.5. The contain at least the following information:

a) Line identification.

b) P&ID.

c) Module.

d) Vibration mechanism evolved (could be more than one).

e) Data for vibration analysis.

f) Vibration analysis performed (could be more than one).

g) Proposed solution / mitigation.

h) References.

ATTACHMENT B – LOAD CASES COMBINATIONS

The purpose of the load cases herein showed is to guide the stress analyst. It is a reference and cannot be used to waive any condition not included, as green water, damage, etc. For fatigue cases the cycle number shall be assessed according to each project and shall also be discussed and have BUYER approval.

The load cases here described assume that all calculated cases are linear (i.e. no nonlinear restraints, gaps or friction).

The load case examples here presented are not exhaustive and it is the responsibility of each stress analyst to adapt the load cases according to piping layouts, service, equipment, location, type of loadings and other requirements stated on this specification or design codes and rules; and compose the final load cases for each line and analysis.

Case No.	Load Case Combination Design Runs	Description	Stress Category	Combined Method	Output
1	WW+HP	Hydro Test pressure	(HYD)	-	Disp/ Force/Stress
2	W+P1	Wt.+ Design Press.	(SUS)	-	Disp/ Force/Stress
3	W+D1+T1+P1	Max. Design Conditions1	(OPE)	-	Disp/ Force
4	W+D1+D10+T1+P1	Max. Design Conditions1+ Still water	(OPE)	-	Disp/ Force
5	W+D1+D10+D3+T1+P1	Max. Design Conditions1+ SAG	(OPE)	-	Disp/ Force
6	W+D1+D10+D3+T1+P1+-U1+-U2+-U3	Max. Design Conditions1+ Acceleration combination	(OPE)	-	Disp/ Force
7	W+D1+D10+D3+T1+P1+WIN	Max. Design Conditions1+ WIND	(OPE)	-	Disp/ Force
8	W+D1+D10+D3+T1+P1+-U1+-U2+-U3+WIN	Max. Design Conditions1+ Acceleration combination+ WIND	(OPE)	-	Disp/ Force
9	L3-L2	Thermal 1+ Disp. 1 (Max. Design)	(EXP)	-	Disp/ Force/Stress
10	L4-L2	Thermal 1+ Disp. 1 +Still Water (Max. Design)	(EXP)	-	Disp/ Force/Stress
11	L5-L2	Thermal 1+ Disp. 1 + SAG (Max. Design)	(EXP)	-	Disp/ Force/Stress
12	L5-L3	SAG	(EXP)	-	Disp/ Force/Stress

Case No.	Load Case Combination Design Runs	Description	Stress Category	Combined Method	Output
13	L4-L3	SAG (still water)	(EXP)	-	Disp/ Force/Stress
14	L5-L4	SAG (wave induced)	(EXP)	-	Disp/ Force/Stress
15	L6-L5	Acceleration vector (Only)	(SUS)	-	Disp/ Force/Stress
16	L7-L5	Wind (Only)	(OCC)	-	Disp/ Force/Stress
17	L2+L15	Sustained+ Accelerations	(SUS)	-	Disp/ Force/Stress
18	L16+L17	Sustained+ Accelerations +WIND	(OCC)	-	Disp/ Force/Stress
19	L1	1 cycle	(FAT)	-	Disp/ Force
20	L9	Operational cycle – 7.000 Cycles	(FAT)	-	Disp/ Force
21	L13+L15	1 cycle	(FAT)	-	Disp/ Force
22	L14+L15	Cycles to define	(FAT)	-	Disp/ Force
23	L2,L3,L4,L5,L6,L7,L8	Operating Loads+ Acceleration+ WIND	(OPE)	(MAX)	Force
24	L2,L17	Máxima SUS tensão	(SUS)	(MAX)	Stress
25	L9,L10,L11,L12,L13,L14	Máxima EXP Tensão	(EXP)	(MAX)	Stress
26	L18	Max. Stress (Sustained +Occasional)	(OCC)	(MAX)	Disp/ Force/Stress
27	L1,L2,L3,L4,L5,L6,L7,L8	Max. Support Load (Design)	(OPE)	(MAX)	Force
28	L2,L3,L4,L5,L6	Operating Loads (dynamic equipment)+ Acceleration (DEC)	(OPE)	(MAX)	Force

Where:

Load	Description	CAESAR II Load Identifier
T1	Maximum Temperature	Temp1
T2	Minimum Temperature	Temp2
T3	Operating/ Normal Temperature	Temp3
D1	Design displacement	Disp1
D10	Still water bending moment displacement	Disp2
D3	Wave induced bending moment displacement	Disp3
U1	Acc.1 – Acceleration from wave motion (Pitch)	Uniform G Load Vector 1
U2	Acc.2 – Acceleration from wave motion (Heave)	Uniform G Load Vector 2
U3	Acc.3 – Acceleration from wave motion (Roll)	Uniform G Load Vector 3
W	Normal operating weight with contents	Dead Weight with Contents
P1	Design Pressure	Pressure 1
WIN 1	Maximum Wind in “Y” direction (Longitudinal)	Wind Load 1
WIN 2	Maximum Wind in “X” direction (Lateral)	Wind Load 2
WW	Weight with water content	Weight of water

NOTE:

1. Load cases need to be discussed and agreed with BUYER at the beginning of the project.