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ADNOC

ADNOC GROUP PROJECTS AND ENGINEERING

SPECIFICATION FOR PIPING SYSTEM STRESS & FLEXIBILITY ANALYSIS

Specification

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EFFECTIVE DATE:

AGES-SP-09-004

GROUP PROJECTS & ENGINEERING / PT&CS DIRECTORATE

CUSTODIAN	Group Projects & Engineering / PT&CS
ADNOC	Specification applicable to ADNOC & ADNOC Group Companies

REVISION HISTORY

DATE	REV. NO	PREPARED BY (Designation / Initial)	REVIEWED BY (Designation / Initial)	ENDORSED BY (Designation / Initial)	ENDORSED BY (Designation / Initial)
10-Feb-2021	1	Arun Kumar Mehta Sr. SPLT Piping Arun Kumar Mehta Digitally signed by: Arun Kumar Mehta DN: CN = Arun Kumar Mehta C = AE O = ADNOC Onshore OU = SSE Piping, TC Eng Date: 2021.03.17 15:06:08 +05'00'	Ashwani Kumar Kataria / A/MIHE,TC-Eng Digitally signed by Ashwani Kumar Kataria DN: cn=Ashwani Kumar Kataria, o=ADNOC Onshore, ou=ADNOC Onshore, email=akataria@adnoc.ae, c=AE Date: 2021.03.31 13:42:53 +04'00' Reuben Yagambaram / SPM GPE Reuben Yagambaram Digitally signed by Reuben Yagambaram Date: 2021.04.13 14:53:39 +04'00'	Abdulla Al Shaiba/ VP-GPE 21/04/2021	Zaher Salem/ SVP-GPE 22/04/2021

Group Projects & Engineering is the owner of this Specification and responsible for its custody, maintenance and periodic update.

In addition, Group Projects & Engineering is responsible for communication and distribution of any changes to this Specification and its version control.

This specification will be reviewed and updated in case of any changes affecting the activities described in this specification.

INTER-RELATIONSHIPS AND STAKEHOLDERS

a. The following are inter-relationships for implementation of this Specification:

   i. ADNOC Upstream and ADNOC Downstream Directorates; and

   ii. ADNOC Onshore, ADNOC Offshore, ADNOC Sour Gas, ADNOC Gas Processing. ADNOC LNG, ADNOC Refining, ADNOC Fertil, Borouge, Al Dhafra Petroleum, Al Yasat

b. The following are stakeholders for the purpose of this Specification:

   i. ADNOC PT&CS Directorate

c. This Specification has been approved by the ADNOC PT&CS is to be implemented by each ADNOC Group COMPANY included above subject to and in accordance with their Delegation of Authority and other governance-related processes in order to ensure compliance.

d. Each ADNOC Group COMPANY must establish / nominate a Technical Authority responsible for compliance with this Specification.

DEFINITIONS

"**ADNOC**" means Abu Dhabi National Oil Company.

"**ADNOC Group**" means ADNOC together with each company in which ADNOC, directly or indirectly, controls fifty percent (50%) or more of the share capital.

"**Approving Authority**" means the decision-making body or employee with the required authority to approve Policies & Procedures or any changes to it.

"**Business Line Directorates**" or "**BLD**" means a directorate of ADNOC which is responsible for one or more Group Companies reporting to, or operating within the same line of business as, such directorate.

"**Business Support Directorates and Functions**" or "**Non- BLD**" means all the ADNOC functions and the remaining directorates, which are not ADNOC Business Line Directorates.

"**CEO**" means chief executive officer.

"**Group COMPANY**" means any 'COMPANY' within the ADNOC Group other than ADNOC.

"Specification" means this Specification for Piping System Stress & Flexibility Analysis.

"FEED" means Basic engineering or Define stage of project

"EPC" means Execute stage of project

"CONTRACTOR" means the party(s) which carries out all or part of the design, engineering, procurement, construction, commissioning or management of the PROJECT.

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1 GENERAL

1.1 Introduction

The objective of this Document is to identify COMPANY minimum requirements for piping stress analysis of the process and utilities piping systems of onshore and offshore facilities.

1.2 Purpose

1.2.1 This Document is intended to provide and highlight the minimum basic Piping Stress Analysis requirements for COMPANY projects and shall not relieve the CONTRACTOR of his contractual obligations. Any deviation from this Specification shall be identified by CONTRACTOR and shall require written approval from COMPANY.

1.2.2 The scope of this specification covers the process and utilities piping system stress analysis for onshore and offshore facilities within COMPANY.

1.2.3 The requirements specified in this document shall be followed in all Greenfield and Brownfield projects for COMPANY.

1.2.4 The contents of this specification shall be followed and used as a guide to engineering. Subjects which are not covered by this document which are specific to individual projects shall be developed by CONTRACTOR/CONSULTANT and included within specific project Stress and Flexibility Analysis Specifications.

1.2.5 This Document covers stress analysis requirements for above ground, underground onshore piping, topside offshore piping and piping within the package equipment / unit in accordance with ASME B 31.3, ASME B31.1 (as applicable) and GRP piping in accordance with BS EN ISO 14692.

1.2.6 This Document excludes the stress analysis requirement of onshore pipeline, subsea pipeline, furnace and boiler package piping, HVAC duct and tubing as well as instrumentation tubing.

1.3 Definitions and Abbreviations

1.3.1 Definitions

The following defined terms are used throughout this specification:

'**[PSR]**' indicates a mandatory Process Safety Requirement

"**COMPANY**" means ADNOC, ADNOC Group or an ADNOC Group COMPANY, and includes any agent or consultant authorized to act for, and on behalf of the COMPANY.

"**CONTRACTOR**" means the parties that carry out all or part of the design, engineering, procurement, construction, commissioning or management for ADNOC projects. CONTRACTOR includes its approved MANUFACTURER(s), SUPPLIER(s), SUB-SUPPLIER(s) and SUB-CONTRACTOR(s).

"**MANUFACTURER**" means the Original Equipment MANUFACTURER (OEM) or MANUFACTURER of one or more of the component(s) which make up a sub-assembly or item of equipment assembled by the main SUPPLIER or his nominated SUB-SUPPLIER.

‘may’ means a permitted option

‘shall’ indicates mandatory requirements

‘should’ means a recommendation

“**SUB-CONTRACTOR**” means any party engaged by the CONTRACTOR to undertake any assigned work on their behalf. COMPANY maintains the right to review all proposed SUB-CONTRACTORs; this right does not relieve the CONTRACTOR of their obligations under the Contract, nor does it create any contractual relationship between COMPANY and the SUB-CONTRACTOR.

“SUPPLIER” means the party entering into a Contract with COMPANY to provide the materials, equipment, supporting technical documents and / or drawings, guarantees, warranties and / or agreed services in accordance with the requirements of the purchase order and relevant specification(s). The term SUPPLIER includes any legally appointed successors and / or nominated representatives of the SUPPLIER.

“**SUB-SUPPLIER**” means the sub-contracted SUPPLIER of equipment sub-components software and / or support services relating to the equipment / package, or part thereof, to be provided by the SUPPLIER. COMPANY maintains the right to review all proposed SUB-SUPPLIERS, but this right does not relieve the SUPPLIER of their obligations under the Contract, nor does it create any contractual relationship between COMPANY and any individual SUB-SUPPLIER.

1.3.2 Abbreviations

The abbreviations used throughout this Specification are shown in Table 1.1.

Table 1.1 List of Abbreviations

Abbreviations	
AIV	Acoustic Induced Vibration
ALS	Accidental Limit State
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
BS EN	European Standard adopted by British Standard Institution
BDV	Blowdown Valve
BEDD	Basic Engineering Design Data
AASHTO	American Association of State Highway and Transportation Officials
BOD	Basis of Design
CLL	Critical Line List
CoE	Coefficient of Expansion

Abbreviations	
CS	Carbon Steel
Cu-Ni	Copper-Nickel Alloy
DEP	Design Engineering Practices (Shell)
DLF	Dynamic Load Factor
DN	Nominal Size
DR	Dimension Ratio
DSS	Duplex Stainless Steel
EPC	Engineering, Procurement, Construction
ESD	Emergency Shutdown
EXP	Expansion Load (CAESAR II®)
FCV	Flow Control Valve
FEA	Finite Element Analysis
FFD	Full Fields Development
FRP	Fibre Reinforced Plastic
FIV	Flow Induced Vibration
FLS	Fatigue Limit State
GRP	Glass Reinforced Plastic
IFC	Issued for Construction
H	Hanger Load (CAESAR II®)
HDPE	High Density Polyethylene
LOF	Likelihood of Failure
LRFD	Load and Resistance Factor Design
MMT	Maximum Metal Temperature
MAWP	Maximum Allowable Working Pressure
NACE	National Association of Corrosion Engineers
NEMA	National Electrical MANUFACTURER's Association
NFPA	National Fire Protection Association
NPS	Nominal Pipe Size
OCC	Occasional Load (CAESAR II®)
OPE	Operational Load (CAESAR II®)
P	Pressure Load (CAESAR II®)
PE	Polyethylene
P&ID	Piping & Instrumentation Diagram
PMC	Piping Material Class
PN	Nominal Pressure rating

Abbreviations	
PO	Purchase Order
PRV	Pressure Control Valve
PTFE	Poly Tetra Fluro Ethylene
PWL	(Sound) Power Level
QMS	Quality Management System
RFC	Released for Construction
RPM	Revolutions per Minute
RV	Relief Valve
SDR	Standard Dimension Ratio (outer diameter to thickness ratio for PE piping)
SIF	Stress Intensification Factor
SS	Stainless Steel
SUS	Sustained Load (CAESAR II®)
T	Thermal Load (CAESAR II®)
TOS	Top of Steel
TPA	Third Party Agreement
U	Seismic Load (CAESAR II®)
UBC	Uniform Building Code
ULS	Ultimate Limit State
W	Weight Load (CAESAR II®)
WIN	Wind Load (CAESAR II®)
WNC	Weight No Content (CAESAR II®)
WRC	Welding Research Council

1.4 Units

SI Units shall be used in CAESAR II for stress calculation and documentation.

Table 1.2 Units of Measure

System of Units		
Description	**SI Units**	**FPS Units**
Force	N	lb.
Moment	Nm	lb.ft.
Stress	MPa	psi
Pressure	barg	psig
Temperature	°C	°F
Movement	mm	Inch
Nominal Pipe Size, NPS	mm	inch
Length	mm	inch
Density	kg / m^3	Ib / in^3

SECTION A - GENERAL

2 REFERENCE DOCUMENTS

2.1 International Codes and Standards

The following Codes and Standards shall form a part of this specification. When an edition date is not indicated for a Code or Standard, the latest edition in force at the time of the contract award shall apply.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.1	Unified Inch Screw Threads (UN, UNR, and UNJ Thread Forms)
ASME B16.5	Pipe Flanges and Flanged Fittings NPS 1 / 2 through NPS 24
ASME B16.47	Large Diameter Steel Flanges (NPS 26 through NPS 60)
ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME B31.4	Pipeline Transmission Systems for Liquid Hydrocarbons and Other Liquids
ASME B31.8	Gas Transmission and Distribution Piping Systems
ASME B31J	Stress Intensification Factors (i-Factors), Flexibility Factors (k-Factors), and Their Determination for Metallic Piping Components
ASME B36.10M	Welded and Seamless Wrought Steel Pipe
ASME B36.19	Stainless Steel Pipe
ASME BPVC SECTION IIA	BPVC Section II-Materials-Part A-Ferrous Materials Specifications (2 Volumes)
ASME BPVC SECTION VIII	BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1 and Division 2
ASME-OM	Standards and Guides for Operation and Maintenance of Nuclear Power Plants- Part 3.

AMERICAN PETROLEUM INSTITUTE (API)

API 6A	Specification for Wellhead and Christmas Tree Equipment
API STD 560	Fired Heaters for General Refinery Service
API STD 610	Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries (ISO13709)
API STD 611	General Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services

API STD 612	Petroleum, Petrochemical and Natural Gas Industries - Steam Turbines - Special-Purpose Applications
API STD 616	Gas Turbines for Petroleum, Chemical, and Gas Industry Services
API STD 617	Axial and Centrifugal Compressors and Expander-compressors
API STD 618	Reciprocating Compressors for Petroleum, Chemical and Gas Industry Services
API STD 619	Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical and Natural Gas Industries
API STD 650	Welded Tanks for Oil Storage
API STD 660	Shell-and-Tube Heat Exchangers
API STD 661	Petroleum, Petrochemical, and Natural Gas Industries-Air-cooled Heat Exchangers
API STD 662	Plate Type Heat Exchangers for General Refinery Service
API STD 674	Positive Displacement Pumps - Reciprocating
API STD 675	Positive Displacement Pumps - Controlled Volume for Petroleum, Chemical, and Gas Industry Services
API STD 676	Rotary Positive Displacement Pumps
API RP 520	Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries; Part 1 - Sizing and Selection
	Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries; Part 2 – Installation
API RP 686	Recommended Practice for machinery installation and installation design
API TR 6AF	Technical Report on Capabilities of API Flanges Under Combinations of Load

ASTM (AMERICAN SOCIETY FOR THE TESTING OF MATERIALS

ASTM D2321	Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
ASTM D2774	Standard Practice for Underground Installation of Thermoplastic Pressure Piping

BRITISH STANDARDS INSTITUTION (BSI)

BS 7159	Code of practice for Design and construction of glass reinforced plastics (GRP) piping systems for individual plants or sites
BS PD 5500	Specification for Unfired fusion welded pressure vessels

INTERNATIONAL STANDARDS ORGANIZATION (ISO)

BS EN ISO 9001	Quality Management Systems - Requirements.
BS EN ISO 9004	Managing for the sustained success of an organization - A quality management approach
BS EN ISO 9080	Plastics piping and ducting systems. Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation
BS EN ISO 14692	Petroleum and natural gas industries Glass-reinforced plastics (GRP) Piping Part 1 to 4
	Part 1 - Vocabulary, symbols, applications and materials
	Part 2 - Qualification and manufacture
	Part 3 - System design
	Part 4 - Fabrication, installation and operation
BS ISO 4427	BS ISO 4427-1 Plastics piping systems for water supply and for drainage and for sewerage under pressure – Polyethylene (PE) General
	BS ISO 4427-2 Plastics piping systems for water supply and for drainage and for sewerage under pressure – Polyethylene (PE) Pipes
	BS ISO 4427-3 Plastics piping systems for water supply and for drainage and for sewerage under pressure – Polyethylene (PE) Fittings
	BS ISO 4427-5 Plastics piping systems for water supply and for drainage and for sewerage under pressure – Polyethylene (PE) Fitness for Purpose of the System
BS ISO 13761	Plastics pipes and fittings. Pressure reduction factors for polyethylene pipeline systems for use at temperatures above 20°C

OTHER STANDARDS AND SPECIFICATIONS

ADMA SP-1160	Abu Dhabi Marine Operating Company Specification for Glass Reinforces Plastics (GRP) Piping Systems
ASCE 7	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
AWWA M45	Fiberglass Pipe Design Manual
AWWA M55	PE Pipe Design and Installation Manual
DNVGL-RP-C203	Fatigue design of Offshore steel structures
NEMA SM24	Steam Turbines for Mechanical Drive Service
PPI TN-38	Plastic Pipe Institute Technical Note 38 Bolt Torque for Polyethylene Flanged Joints
WRC 297	Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles.

WRC 537	Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells Due to External Loadings for Implementation of WRC Bulletin 107
EI	EI Guidelines for the Avoidance of Vibration Induced Fatigue in Process Pipework
EJMA	The EJMA Standards for design, installation and use of expansion bellows
PPI	PPI handbook of polyethylene pipe
Roark	Roark Formulas for Stress and Strain

2.2 ADNOC Specifications

AGES-GL-08-001	Process Design Criteria
AGES-GL-08-003	Flow Assurance Guidelines
AGES-SP-01-003	Structural Design Basis - On Shore Specification
AGES-SP-05-001	Centrifugal Pumps (API 610) Specification
AGES-SP-05-002	Centrifugal Compressors (API 617) Specification
AGES-SP-05-003	Reciprocating Compressors (API 618 and ISO 13631) Specification
AGES-SP-05-004	General and Special Steam Turbines (API 611 and 612) Specification
AGES-SP-05-005	Gas Turbines (API 616) Specification
AGES-SP-05-006	Rotating equipment minimum general requirements and system integration specification
AGES-SP-05-008	Centrifugal pumps for general (utility) & fire water service specification
AGES-SP-05-010	Rotary-type positive displacement compressors & pumps (API 619 and API 681) specification
AGES-SP-06-001	Design Criteria for Static Equipment
AGES-SP-06-002	Pressure Vessel Specification
AGES-SP-06-003	Shell and Tube Heat Exchanger Specification
AGES-SP-06-004	Air cooled heat exchangers specification
AGES-SP-06-005	Above ground vertical storage tanks specification
AGES-SP-07-004	Painting and Coating Specification

AGES-SP-09-001	Piping Basis of Design
AGES-SP-09-002	Piping Material Specification Index
AGES-SP-09-003	Piping & Pipeline Valves Specification
AGES-SP-11-001	Offshore Steel Structures Specification

3 DOCUMENT PRECEDENCE

The specifications and codes referred to in this Specification shall, unless stated otherwise, be the latest approved issue at the time of contract award.

It shall be the CONTRACTOR's responsibility to be, or to become, knowledgeable of the requirements of the referenced Codes and Standards.

The CONTRACTOR SHALL notify the COMPANY of any apparent conflict between this specification, the related data sheets, the Codes and Standards and any other specifications noted herein.

Resolution and / or interpretation precedence shall be obtained from the COMPANY in writing before proceeding with the design / manufacture.

In case of conflict, the order of document precedence shall be:

a. UAE Statutory requirements

b. ADNOC HSE Standards

c. Equipment datasheets and drawings

d. Project Specifications and standard drawings

e. This Specification

f. National / International Standards

4 SPECIFICATION DEVIATION / CONCESSION CONTROL

None at present

SECTION B – TECHNICAL REQUIREMENTS

5 PIPE STRESS ANALYSIS PHILOSOPHY

5.1 General Requirements

5.1.1 The required purpose of piping stress analysis that shall be carried out by the CONTRACTOR is to produce a piping system whose stresses, reactions and displacements are within acceptable limits in accordance with the applicable codes, conditions and stipulations of this specification.

5.1.2 CAESAR II® software shall be used for Piping Stress Analysis unless otherwise defined in an individual Project specification or approved by COMPANY.

5.1.3 The use of CAESAR II® does not relieve the CONTRACTOR from his ultimate responsibility of ensuring the integrity of the entire piping system. This responsibility includes piping assessed either visually or by simplified methods.

5.1.4 It is the responsibility of Stress Engineering to assign levels of criticality to all piping and ensure compliance with the requirements of this document.

5.1.5 It is the responsibility of the CONTRACTOR to ensure stress analysis is carried out, checked and approved by appropriately qualified and experience engineers.

5.1.6 The CONTRACTOR shall be responsible for the production of an economic, flexible, mechanically sound and practical layout. The overall aim should be to achieve an economic, safe, operable, maintainable, optimal design for both piping and structures.

5.2 Allowable Stresses

5.2.1 The stress ratio of actual stress to allowable stress should not exceed the following unless approved with COMPANY:

a. 90% for expansion load case

b. 70% for sustained load cases).

5.2.2 At FEED engineering stage, the displacement stress range shall be limited to 80% of the allowable stress in order to provide adequate margin for any routing modification during detailed engineering stage.

5.3 Allowable Displacements

5.3.1 For non-rack piping within units, any computed displacements in lateral direction should be limited to ± 20mm. Displacements greater than 20mm shall be examined to avoid clashes with existing and / or new piping and / or structures.

5.3.2 For piping running within racks or in tracks, any computed displacements in axial directions should be limited to 100mm within unit pipe racks and offsite areas. In case this is not avoidable the shoe length shall be designed accordingly. Any lateral displacements greater than 20mm shall be examined to avoid clashes with existing and / or new piping and / or structures.

5.3.3 In the sustained case, the maximum deflection or sagging is governed by the support spans. Sustained sagging shall be below 10 mm for process lines and below 3 mm for steam, two phase and flare lines. For slope lines, sagging shall be avoided and shall not exceed 3 mm.

5.3.4 During the computer stress analysis, an intermediate node should be created at the midpoint between the two supports having maximum span to get the value of maximum deflection.

5.3.5 Significant thermal movement at longer pipe run or where shoe extended is required, shall be indicated in the relevant stress isometric. The maximum displacement expected to occur during operation of the system on sliding pipe supports shall be provided in each calculation report.

5.4 Displacement checks

5.4.1 The following shall be checked for displacement at each point:

a. Is the value safe enough at each point's displacement for pipe shoe falling?

b. Displacement at each point is not interfering adjacent piping or equipment.

c. Displacement does not make the slope of free drain line upside down.

d. The point with Y restraint is not lift off.

e. Deflection due to dead load is within the allowable value.

5.5 Support Forces

5.5.1 Displacement and load at the point of support and support adequacy shall be checked.

5.5.2 Spring hanger or spring support, displacement load and spring stiffness shall be checked in compliance with manufacturer's specification.

5.6 Restraint Reaction

5.6.1 The calculated forces and moments at nozzle shall be in compliance with codes and standards /vendor allowable (refer Appendix -A3)

5.7 Code Compliance

5.7.1 Code compliance for stress shall [PSR] be evaluated in line with applicable codes & standard.

5.8 Overall Stress Requirements

5.8.1 Detailed stress analysis carried out by the CONTRACTOR shall consider the following:

a. Pressure
b. Weight effects of piping components and fluids
c. Equipment and other sources of vibration
d. Thermal expansion and contraction
e. Stiffness variations and changes
f. Imposed Displacements
g. Shock loadings

5.8.2 External loadings on piping from applicable environmental conditions as follows, shall be included:

a. Wind loads
b. Seismic loads
c. Settlement
d. Frost heave
e. Snow loads

5.9 Detailed Stress Requirements

5.9.1 Forces and moments imposed by piping on equipment nozzles to which each pipe is connected are within the maximum allowable forces and moments as listed in .APPENDIX A3.

5.9.2 The imposed loadings at welded or mechanical connections, especially flanged joints, which would result in leakage shall be evaluated.

5.9.3 The piping stresses developed due to Primary, Secondary and Occasional load cases shall be within the allowable values defined in ASME B31.3 and applicable code.

5.9.4 The load cases analysed shall consider all viable and reasonable operating and design variations which may occur during the operational life of the plant and are required by project scope.

5.9.5 Stress analysis shall be carried out on all critical piping systems as identified in Section 7.

5.9.6 Distortion in piping and valves or in connected equipment (for example, pump, compressors, turbines, etc.) resulting from thrusts or piping displacements shall be evaluated against allowable..

5.9.7 Stress analysis shall represent practical solutions, which avoid piping arrangements be sensitive to pipe support positions, precise dimensions, pipe support functional requirements or small / limited field tolerances.

5.9.8 Piping and supporting arrangements shall be designed to avoid failure due to overstress or fatigue.

5.9.9 Piping and support arrangements with low natural frequencies (below 3 Hz) or which provide excessive piping flexibility with susceptibility to 'in service' vibrations shall be avoided. Also refer Section 11.3 for required piping system natural frequency for specific services.

5.9.10 Resonances due to machinery vibration or fluid induced vibration are avoided.

5.9.11 For existing plant modifications, the stress analysis shall also consider the following:

a. Mechanical modifications, for example, re-routing and / or extension to an existing piping system, including changes in weight due to reconfigured valve or flange arrangements.

b. Temperature variations

c. Modifications to piping stiffness resulting from pipe wall thickness or material changes.

d. Material changes in connecting equipments (like columns, vessels etc.)

e. Process modifications (i.e. changes from original design conditions, including pressure, temperatures and flow rate, or any transient conditions which may not have been considered in the original design.

5.10 Pipe Support Considerations

5.10.1 The requirements for pipe support, given in COMPANY Pipe Support Specification(s), shall be followed.

5.10.2 Stress analysis shall ensure pipe support arrangements avoid the following:

a. Pipe support arrangements shall ensure mid span and overhang sag is within allowable limits and maintains slopes defined on P&IDs or drainage requirements.

b. Long runs of piping without axial stops or guides.

c. Excessive loads at supports, restraining elements or supporting structures.

d. Destructive vibration due to any flow, acoustic or other reason.

e. Disengagement of piping from its supports.

f. Clashes between adjacent lines due to thermal expansion or contraction of the piping system.

g. Special supports requiring complex design details or impractical construction tolerances.

6 PROCESS AND ENVIRONMENTAL CONDITIONS AND BASIC DATA

6.1 Design Life

6.1.1 Piping system shall be designed for 30 years unless stated otherwise in the project contract or basis of design Specification.

6.2 Environmental Design Conditions

6.2.1 Detailed site-specific design conditions shall be in accordance with Project Environmental Design Basis. However, relevant analysis parameters shown below shall be considered as minimum.

6.3 Process Design Conditions

6.3.1 The Process line list contains all design, operating and upset / transient temperatures, pressures and density data. This information shall be included in the Critical Line List (CLL) and incorporated into piping stress analyses to determine the most severe conditions on piping and loadings on equipment.

6.3.2 If not available from the Process line list, information relating to flow conditions which produce forces requiring stress analysis and / or specific pipe support requirements shall also be obtained from the project Process team. These include the following:

a. Slug flow
b. 2 phase flow / Multiphase flow
c. Surge
d. Acoustic Induced Vibration (AIV)
e. Flow induced Vibration (FIV)

6.3.3 A list of lines which will be subjected to more than one cycle of operation per day or greater than 7000 cycles total during the life of the plant, shall be obtained from Process.

6.3.4 For the list of lines described in 6.3.3, coincident temperatures and pressures including the expected number of full and partial cycles, including upset and transient conditions, during operation shall be obtained from Process.

6.4 Temperature

6.4.1 In accordance with ASME design codes the primary temperature for stress analysis shall [PSR] be based on design temperature. Maximum and minimum design temperature shall be obtained from the Process line list and shall be reflected in Critical line list.

6.4.2 The operating temperature is determined by process engineering and shall be taken from the process line list. Process shall also provide values for maximum and minimum operating temperatures. These represent temperature variations which could occur throughout plant operations and lifecycle.

6.4.3 Stress analysis shall be performed for the temperature range which is the algebraic difference between maximum design temperature and minimum design temperature.

6.4.4 The temperature for the occasional conditions for example, start-up, cool-down, shutdown, regeneration, depressurization, fire case scenario, steam-out condition, decoking, compressor recycle, temperature drop resulting from pressure relief / depressurisation and other special conditions shall also be considered. This temperature shall be taken from the Process Line List and shall be specified in the Critical Line List.

6.4.5 For design temperature of heat traced, refractory (lined) and jacketed piping refer to section 10.16, 10.17 and 10.18.

6.4.6 Maximum and minimum design temperatures shall be used to determine maximum pipe support loads.

6.4.7 The thermal displacement of equipment nozzles shall be calculated using the relevant design temperature.

6.4.8 For lines operating above 0°C, an installation temperature of 21ºC for all COMPANY facilities shall be used. For lines operating below 0°C, an installation temperature of 40°C shall be used.

6.4.9 For above-ground uninsulated metallic pipe, the solar radiation temperature for all ADNOC Group of COMPANY facilities shall be taken as 85°C.

6.4.10 For underground lines, the max operating temperature or the maximum soil temperature whichever is higher shall be considered

6.5 Pressure

6.5.1 Stress analysis shall calculate stresses in each component considering the most severe design pressure conditions expected, as indicated in the process line list and CLL.

6.5.2 Test pressure and weight of testing fluid shall be included in stress analysis load cases. The design of pipe supports shall consider the weight of the pressure testing fluid if greater than the service fluid.

6.5.3 External pressure shall apply to piping where the internal pressure is below atmospheric pressure due to process conditions, as noted on the Process line list as “vacuum”. In this case full vacuum shall be assumed.

6.5.4 Where external pressure in excess of full vacuum may exists, for example, in jacketed piping systems, all loading conditions including test pressure shall be considered.

6.6 Piping Material Class / Specification

6.6.1 Piping Stress analysis shall incorporate piping information from the Piping Material Specification AGES-SP-09-003 and Project Piping Material Specifications as applicable. This information will also be used by and conform with, piping design, be a part of every line number and listed in the Process Line List and Critical line list.

6.6.2 Piping stress analysis shall be based upon the following:

a. Piping material Specification / Pipe class

b. Nominal Pipe Wall thickness

c. Corrosion allowance

d. Branch connection details taken from individual Piping Material Classes.

Note 1: Branch connection types listed in the PMC are determined based primarily on area replacement.

Note 2: Branch connection types may be changed to reduce SIF values if required.

6.7 Weights and Dimensions

6.7.1 It is critical for the weights and dimensions of piping components to be modelled accurately and included in pipe stress calculations.

6.7.2 ASME pipes, fittings and flanges - The weight and dimensions of piping components shall be taken from the relevant ASME standard or CAESAR II® library. Wall thicknesses shall be obtained from appropriate PMC details.

6.7.3 Non ASME flanges - For API, compact and non-standard flanges as well as hub connectors, weight and dimensions shall be taken from Vendor drawings where available. Until such data is available, preliminary calculations or VENDOR catalogue should be used.

6.7.4 Valves - Until actual VENDOR drawing dimensions and weights are available, this information shall be taken from the CAESAR II® library or Vendor catalogue. Weight of the gear box or actuator shall be included. For the instrument tagged items, the weights shall also be supplied by Vendor. The final stress analysis report shall incorporate actual valve data including actuator weight.

6.7.5 Non-standard items - The weights of all non-standard items incorporated with individual analyses shall be listed on the associated stress sketch.

6.7.6 Insulation- The weight of all insulation shall be included in piping stress analysis. The weight of insulation shall be determined accurately using confirmed layer thickness and densities including the weight of internal and external metallic layers and cladding. The analysis of piping with cold preservation insulation shall include the weight of contraction joints and valve boxes which are not independently supported.

6.7.7 Pipe supports - The weight of pipe support components if acting as an additive load on the piping system, shall be included in the pipe stress analysis and in restraint load values.

7 STRESS CRITICALITY SELECTION

7.1 General

7.1.1 All piping shall be considered as stress critical. However, due to mechanical and process reasons, not all the piping has the same criticality. Stress criticality shall be assigned to each pipe in the Critical Line List (CLL) see 7.2. The criticality level listed below, shall be based on the criteria given in 7.3, 7.4, 7.5 and 7.6.

a. L1 - Stress Critical Line (Comprehensive Analysis Required)

b. L2 - Stress Critical Line (Simplified Analysis Required)

c. L3 – Non-Critical Line (Visual Inspection)

7.1.2 The stress analysis of lines designated with a criticality of L1 shall be included in a comprehensive stress report. All piping stress calculation notes, source of the equations and / or charts used in the evaluation of lines designated with a criticality of L2 and L3 shall also be submitted for review.

7.2 The Critical Line List

7.2.1 A CLL is expected to be a key deliverable developed during the FEED phase and updated during EPC phase.

Note: The CLL is an evolving document and should be updated at all stages of the project. This will ensure correct and up to date data is being used to carry out the required levels of stress analysis.

7.2.2 The critical line list shall include and consist of the combination of Process, Piping and Stress information given in Appendix A1 based on its applicability to the project. The combinations shall be agreed with COMPANY during the initial stage of the project.

7.2.3 The critical line list should be created using any suitable method which is efficient and reliable and shall be in Excel format.

7.2.4 Any site modifications, changes in final VENDOR data for L1 lines shall be reassessed for comprehensive stress analysis and the stress analysis reports shall be resubmitted for COMPANY review.

7.3 L1 Lines - Comprehensive Analysis Methods

7.3.1 A comprehensive computer analysis shall be performed for L1 stress critical lines.

7.3.2 The latest version of CAESAR II® computer software, at the time of contract award, shall be utilized.

7.3.3 Complete calculation reports with contents listed per Section 8 of this specification shall, as a minimum requirement, be prepared and submitted to COMPANY for review and approval.

7.3.4 The piping system shall be subjected to comprehensive stress analysis (L1), if it falls under any of the following categories.

a. All lines according to Table 7-1 in conjunction with below requirements
b. All Lines in Toxic service, Lethal service , Category “M” fluid service (per ASME B313) and lines designed to Chapter IX of ASME B31.3
c. All NPS 4 and larger lines with ASME class 900 or higher
d. All NPS 2 and larger lines connected to either rotating or reciprocating machinery or fired heaters
e. All lines NPS 3 and above likely to be affected by movement of connecting equipment or by structural deflection, for example, lines subject to differential settlement or structural sway
f. All lines NPS 3 and larger connected to pressure relief valves and rupture discs
g. All lines NPS 3 and larger subject to steam out

h. All lines NPS 3 and larger where engineered items are required for example, spring supports, expansion joints, bellows, snubbers

i. All lines NPS 2 and larger connected to Reactors, Process heaters, Air coolers and strain sensitive nozzles

j. All lines NPS 6 and larger, to and from static equipment.

k. Boiler feed water, steam lines to and from boilers and steam generators.

l. Lines with operating temperature below 5 Deg C with cold insulation or where engineered pipe support for cold insulated pipe are required.

m. All lines 3” and above in steam, steam condensate and flare service.

n. All main Fire water network lines and connected lines.

o. All lines subjected to potential vibration due to mechanical, flow, acoustic or any other reason for example, pressure surges, slug flow or water hammer, as listed in the EI Guidelines

p. All lines NPS 2 and above subject to two-Phase Flow or Multiphase flow or blowdown conditions excluding open drains

q. All lines subject to wind loads as per this specification

r. All jacketed lines.

s. All FRP (GRE, GRP, etc) and other non-metallic lines pressurised line excluding sanitary & irrigation lines

t. All lines routed on inter-platform bridges

u. All production / test and injection manifolds with connecting lines

v. All pressurised metallic underground lines networks NPS 6 and above (including closed drain lines).

w. Lines of any size in cyclic service (regeneration / batch process) resulting in a stress range factor f<1 per ASME B313 Fig 302.3.5;(i.e. greater than 7,000 cycles)

x. Flow lines connected to X-mas trees including headers and / or manifolds up to nearest anchor or equipment.

y. All small bore lines connected with / to stress critical lines up to minimum two supports.

z. Lines reassigned by stress engineer from L2 and L3 categories

aa. Other lines as requested by the COMPANY stress engineer

7.4 L2 Lines – Simplified Analysis Methods

7.4.1 Stress approval by simplified methods, includes the use of charts, nomographs and simplified formulae.

7.4.2 The results of the analysis using charts, nomographs or simplified formulae should be shown on the stress sketch or isometric.

7.4.3 A simplified CAESAR II® analysis and report may be used in lieu of charts, nomographs or simplified formulae. If this is used, the results shall be included in a simplified report with CAESAR native file including the stress sketch or isometric and a computer output stress result and restraint summary.

7.4.4 All piping stress calculation notes of L2 lines shall be submitted to COMPANY for review along with the source of the equations and / or charts used in the evaluation. For L2 category refer Table 7.1 below.

7.5 L3 Lines – Visual Inspection Analysis Methods

7.5.1 Stress approval by visual inspection should be applied to lines having adequate flexibility or by comparison with piping having a similar configuration that have been analysed using L1 or L2 methods. L3 stress approvals are typically applied to utility piping with the exception of lines in steam and hydrocarbon utility service.

7.5.2 A formal analysis for criticality L3 piping is not required for the piping system that meets one of the following requirements:

a. Piping system which can be readily judged as being adequate by comparison with previously analysed systems.

b. Piping, which is of uniform size, have no more than two points of fixation, no intermediate restraints and falls within the limitations of the following empirical equation from ASME B31.3:

$$\frac{D \cdot y}{(L-U)^2} \leq K_1$$

Where:

D = Outside diameter of pipe (mm)

y = Resultant of total displacement to be absorbed by the piping system (mm)

L = Developed length of piping between anchors (m)

U = Distance between anchors, straight line between anchors (m)

K_1 = 208000 S_A / E_a. (mm / m²)

S_A = Allowable displacement stress range (MPa)

E_a = Reference modulus of elasticity at 21°C

7.5.3 This empirical equation represents no more than a rule of thumb. This accomplishes only a preliminary check for simple basic layouts and shall not be applied in complex three-dimensional configurations with multiple restraints and anchors or piping connected to sensitive equipment. Engineering judgment must still be exercised.

7.5.4 All systems not meeting the above criteria, or if cannot be assessed confidently, shall be analysed by either simplified or Comprehensive methods. If CAESAR II® is used it is expected that a 'thermal only' analysis will be sufficient for such piping.

7.6 Piping Criticality Diagram

7.6.1 Table 7.1 shall be used to determine the Level of Stress Analysis required for all lines based on the relationship between Pipe Size and Temperature.

Table 7.1 Criteria for Flexibility Analysis of Piping

Size	Design Temperature (ºC) Less than or equal to													
NPS (in)	-30 and below	30	50	65	85	120	150	170	205	230	260	290	315	345
1	L1	L3	L3	L3	L3	L2	L2	L2	L2	L2	L1	L1	L1	L1
2	L1	L3	L3	L3	L3	L2	L2	L2	L2	L1	L1	L1	L1	L1
3	L1	L3	L3	L3	L2	L2	L2	L2	L2	L1	L1	L1	L1	L1
4	L1	L3	L3	L3	L2	L2	L2	L2	L1	L1	L1	L1	L1	L1
6	L1	L2	L2	L2	L2	L2	L2	L1	L1	L1	L1	L1	L1	L1
8	L1	L2	L2	L2	L2	L2	L2	L1	L1	L1	L1	L1	L1	L1
10	L1	L2	L2	L2	L2	L2	L1	L1	L1	L1	L1	L1	L1	L1
12	L1	L2	L2	L2	L2	L2	L1	L1	L1	L1	L1	L1	L1	L1
14	L1	L2	L2	L2	L2	L1	L1	L1	L1	L1	L1	L1	L1	L1
16	L1	L2	L2	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1
18	L1	L2	L2	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1
20	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1
≥24	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1	L1
L3	- Neither manual nor computer analysis is generally required. A visual review of the piping drawing or sketch should be made to ensure that the piping system has flexibility.													
L2	- A simplified or approximate analysis method should be used.													
L1	- A comprehensive computer stress analysis and stress report is required.													

Note:
1) Criticality of piping connected to equipment is not included in the above table.
2) For offshore application due to space constraints, the above table shall be aligned with respective Group company project specification

7.7 Performance Requirements for Critical Lines

7.7.1 Critical line design adequacy should be demonstrated during start up stage or during performance test as per ASME OM code for the below lines. The list of such lines should be identified in the FEED stage of project and further developed or shall be developed during detailed engineering stage. These lines shall be identified / annotated in Stress Critical line list

7.7.2 Typical lines to be considered shall include:

a. 2-phase flow lines with thermal flexibility requirements example Amine vertical piping to regenerators column, Gas with powder, etc.

b. Gas line with considerable pressure drop example PCV, BDV, etc.

c. Brownfield piping subject to FIV where flow capacity is increased by 10% or more

d. Any other critical lines identified like lines subjected to FIV and AIV, etc.

8 COMPUTER MODELLING

8.1 General Requirements for Computer Software

8.1.1 The software used shall be the CAESAR II® Version applying the contractually agreed revision of ASME B31.1 and / or ASME B31.3, and other codes / standards as applicable.

8.2 CAESAR II® Set-up file

8.2.1 At the start of each project standardised CAESAR II® config and units' files shall be set up, approved with COMPANY. These files shall be used for all stress analysis files on that project and must not be modified unless approved by the COMPANY.

8.2.2 Confirmation the standard 'config' file was used shall be included in the stress checking of each analysis with confirmation included in the overall stress report.

8.2.3 Refer to APPENDIX A2 for a sample of Standard CAESAR II® Config file based on 2019 version for reference

8.3 Standard Load cases

8.3.1 Load cases shall be defined so as to show all possible combinations of operating, sustained, thermal and occasional load cases. It is the CONTRACTOR's responsibility that these load cases reflect all possible scenarios of operation. These load cases shall be proposed by the CONTRACTOR, according to conditions of each individual case, and submitted to COMPANY for discussion, review and approval. Stresses, loads on supports and displacements shall be reviewed in their relevant load cases so to be within permissible limits.

8.3.2 The basic load cases are described in APPENDIX A5.

8.4 Stress Modelling Considerations

8.4.1 Stress models shall be kept to a minimum size which accurately represents the connectivity and pipe support arrangement of the piping system to be analysed whilst maximising the efficiency of the overall system analysis.

8.4.2 The set of line numbers in the model, together with representative to and from nodes, shall be identified on the title page of Stress File.

8.4.3 The extent of the modelling shall include the following considerations, the system under consideration together with accurate representations of piping or equipment connectivity outside of the system under analysis. Terminations of stress analysis models shall ensure the behaviour, deflections and effect of restraints on the piping shall be correctly defined, realistic and practical. The objective is to ensure the stresses and restraint loadings calculated are accurate.

8.4.4 Stress models shall be terminated with an anchor or the next guide after a guided axial stop (with no gap in the axial direction) in order to accurately represent the system analysed.

8.4.5 For a stress critical piping system of NPS 6 and above, the branch connections from 1 / 3 of the header NPS up to the header NPS, shall be included in the stress analysis. The branch shall be terminated at the first anchor and / or guided axial stop. If the branch size is less than 1 / 3 of the header NPS, then stress critical lines criteria shall prevail. However, as a minimum, associated small-bore lines shall be modelled up to the second support.

8.4.6 Where ASME B31.3 piping interfaces with ASME B31.4 / ASME B31.8 pipeline other applicable codes, model boundary conditions shall be based on pipeline system loads and deflections at the interface.

8.4.7 If a piping system is partially buried or connected to the underground piping, the effect of buried pipeline over the above ground piping shall be considered. The underground piping shall be included in the analysis up to the nearest thrust anchor block point. In the absence of a thrust anchor, the buried model shall be extended up to 2 changes of direction or a virtual anchor position.

8.4.8 All concrete wall penetrations with puddle flanges shall be considered as anchors. In the case of sleeves i.e. without puddle flange the point of vertical or lateral support shall be considered to be a sliding restraint. The extent of the system modelled shall continue up to the next anchor or guided axial stop location.

8.4.9 Directly buried piping under plant road crossing (without sleeve / culvert) should be considered as an anchor point.

8.5 Pipe Supports Consideration

8.5.1 The supporting of the piping system shall be evaluated during the establishment of the piping layouts.

8.5.2 The piping system shall be balanced, i.e. supported frequently in such a manner that ensures avoiding high load concentrations and large pipe deflections.

8.5.3 Except the case of the spring supports or special supports, piping supports shall be included in the piping stress analysis by considering them as rigid elements in the stress model.

8.5.4 In case of pipe "lift-off", an additional piping model shall be created by removing the supports of the pipework and follow-up by rechecking the results (i.e.: stresses, loads on equipment and forces balance on the entire supports Alternatively, follow the method suggested in the Appendix S of B31.3.

8.5.5 Stress analysis shall provide the maximum pipe support loads for design, from all load cases including hydrostatic test.

8.5.6 Pipe support shall be provided in such a way that it shall take the load in all operation and shutdown conditions.

8.5.7 Where possible, pipe supports shall be located on straight sections pipe. Pipe supports welded to pipe bends or fittings shall be avoided wherever possible.

Note: Fittings have higher stress concentrations compared to straight pipe and the addition of supports has an undefined effect on the SIF value.

8.5.8 Where welding of trunnions on elbows cannot be avoided, the minimum wall thickness for elbows with trunnions shall be Schedule 40. If less than schedule 40, reinforcement pad shall be provided in line with Support standards.

8.5.9 Stress analysis shall include the stiffening effects of attachments welded to elbows.

8.5.10 Calculations shall be provided where welded or reinforced welded attachments are incorporated. These calculations shall accurately represent the detailed configuration.

8.5.11 Trunnion support shall be modelled with the size and length matching the design, according to any of the three methods of simulation shown in CAESAR II® Applications Guide manual.

8.5.12 Up to NPS 24 pipe size support shall be modelled at the centre of pipe i.e. radial expansion of pipe shall be neglected and support shall be assumed to be acting at the centre of pipe and for larger pipes 24" and above model rigid element from the centre of the pipe to the bottom of the pipe up to the supporting point considering the pipe radial expansion.

8.5.13 Valves supports provided for transportation shall not be used as pipe supports. Wherever due to space consideration & for large valves, designed valve support should be installed if required. These supports shall be designed by valve manufacturer based on the calculated loads from stress analysis.

8.5.14 The requirement for bracing of small-bore branch connection piping NPS 2 and below, shall be determined using the E.I. guidelines.

8.5.15 If the piping has removable spool, stress analysis shall ensure that the remaining part is independently and adequately supported.

8.5.16 Large diameter and / or thin wall piping (D/t >96) shall be analysed to determine crushing loads at supports and ensure suitable reinforcement pads/ wear pad are incorporated as required.

8.5.17 Pipe supports located on platform decks shall be locally reinforced and structurally supported.

8.5.18 Special attention shall be given to supporting piping made from FRP. VENDOR / MANUFACTURER recommended spans and practices shall be used in determining the types of pipe supports required.

8.5.19 Allowable vertical and horizontal deflection limits specified in Structural specifications AGES-SP-01-003 and AGES-SP-11-001 shall be considered in piping design/stress analysis.

8.5.20 Pipe supports which will be subject to vibration, shall be discussed with the civil / structural group, at the initial stage of detailed design, to determine and agree the structural frequency limit and ensure resonance is avoided.

8.6 Pipe Spans

8.6.1 Piping spans should consider the following criteria:

a. Maximum bending stress of 50% of the longitudinal stress (ASME B31.3: Sh)

b. Indentation stress at support locations

c. Allowable loads at support location

d. Lowest fundamental frequency of 4 Hz or greater.

8.6.2 The maximum mid-span deflection shall be limited as specified in 5.3.3

8.7 Friction

8.7.1 Friction coefficient shall be considered in the stress calculation at all pipe supports, in accordance with Table 8.1 and the requirements of Structural Design Basis AGES-SP-01-003.

Table 8.1 Friction Coefficient

Material	Friction Coefficient
Proprietary low friction sliding surfaces or coating (e.g. Teflon)	According to VENDOR data but not less than 0.1
Carbon steel on carbon steel	0.4
Steel on concrete	0.6
Stainless steel on carbon steel	0.3

8.7.2 Stress analysis shall minimise the requirement for low friction sliding surfaces. These items shall be avoided at locations where inspection / maintenance and replacement is impractical. If a low friction sliding surface is incorporated, the coefficient of friction value for aged-sliding surfaces shall be obtained from the VENDOR and used in the design

Note: Low friction sliding surfaces deteriorate over time and lose its original function and low friction characteristics.

8.7.3 Code stress checks and actual piping forces and moments for equipment nozzles qualified with and without friction factor at pipe supports.

8.7.4 Axial and lateral restraint loads transferred to structures and used for structural design shall not consider any advantage of proprietary low friction pads (like Teflon).

8.7.5 For all pipe supports affecting sensitive equipment, friction shall be considered to act on all active faces of each pipe support.

8.7.6 Stress analysis shall identify positions on stress sketches, where calculations require low friction slide plates.

8.8 Pipe Support Gaps and Hold Downs

8.8.1 Stress analysis shall assume standard pipe support gaps of 3mm.

8.8.2 Unless specified otherwise, on issued isometrics and pipe support details, stress analysis of brownfield piping shall be modelled to incorporate standard 3mm gaps.

8.8.3 The use of non-standard pipe support gaps and gaps that differ between faces shall be avoided. However, if required for analysis, the gaps shall be shown on the stress sketch.

8.8.4 Where hold-down supports are required, stress analysis shall identify the positions on stress sketches.

Note: Hold down supports are used to stabilize piping subjected to dynamic effects including FIV, 2 phase flow, pulsating flow and transportation.

8.9 Spring Support

8.9.1 Lines incorporating spring supports shall be assigned as criticality level L1.

8.9.2 Stress analysis shall minimise the use of spring supports by careful consideration of support location and alternative pipe routing.

8.9.3 Normal operating temperature shall be used to determine spring support set position however the load range shall be selected to accommodate maximum and minimum operating temperature

8.9.4 Variable type springs shall be selected to ensure the maximum load variation for all conditions does not exceed 25%. Where that limit cannot be achieved, due to support displacements, "constant load" type units shall be used. Maximum load variation for Constant spring shall be 5%.

8.9.5 Variable load type springs effecting sensitive equipment like for example compressors, turbine, etc. shall have a maximum load variation of 10%. Where this value is be exceeded, "constant load" type units shall be used.

8.9.6 Stress analysis shall ensure spring travel range includes potential contributing structural displacements.

8.9.7 The automatic spring selection option within CAESAR II® shouldl be used wherever possible. Spring support details may be manually selected where specific spring characteristics are required such as those local to compressors, expanders and turbines.

8.9.8 Where manually selected spring selection is used, the reference VENDOR spring data shall be included in the stress report.

8.9.9 Stress analysis of liquid filled piping connected to equipment and tanks and supported by spring supports, shall include the WNC (Weight No Contents) load case and ensure nozzle loads are within allowable limits for normal operating and WNC cases.

8.9.10 As a part of the work to determine the imposed piping loads a WNC (Weight No Contents) analysis shall be carried out for each pipe where springs are positioned at rotating equipment's like Pumps, compressors, etc.) nozzles, a separate nozzle load check is required to cover the short-term spring active condition where the line is empty (WNC) i.e. weight only' analysis.

8.9.11 Where spring supports are located close to nozzles, the spring load shall also be determined with the pipe released from the nozzle in all directions. This analysis will determine the 'as-installed' spring support load settings and optimum support locations. When finalised, this analysis will be used to demonstrates free flange alignments with the 'as installed' spring support settings is inherently achievable and within API RP 686 allowable limits. This 'weight only' analysis will incorporate no connection between the piping and compressor and model only the restraining effects and directionality of the permanent pipe supports..

8.9.12 The maximum allowable angular movement of hanging springs (including any extension rods) shall be limited to ±4 degrees between pivot points. Similarly pedestal type springs support should avoid large spring bending by frictional force and displacement.

8.9.13 The CONTRACTOR shall develop and issue a spring support index / schedule with the required information for design, installation, and adjustment procedure. This is essential for further performance monitoring of spring supports.

8.10 Struts and Dampers

8.10.1 Lines requiring rigid struts and damper pipe support solutions shall be classified as L1 criticality.

8.10.2 The use of dampers shall be used with approval by COMPANY for the following applications:

a. To absorb dynamic loads, including vibration and to absorb two-phase flow forces, for example, column piping in amine service, when pipe routing and other pipe support solutions are not viable.

   Note: Selection shall include consideration maintenance requirements.

b. To provide a frictionless zero gap solution to provide lateral or axial restraints (or combinations), which is easy and accurate to adjust.

c. Used at support locations to enable an easy form of adjustment for piping alignment including around compressors, expanders and turbines.

8.10.3 The selected load / size rating of rigid strut units shall be a minimum of two times the calculated maximum restraint loads.

8.10.4 Where rigid strut units are selected for use around sensitive equipment, the stiffness and angulation shall be included in the stress analysis.

8.10.5 When a damper unit is selected, a ‘dead band’ of 3mm shall be incorporated into the stress analysis.

Note: This value represents the typical minimum displacement which will occur before a damper starts to function.

8.10.6 Stress analysis shall specify the end connection details for rigid struts or dampers.

Note: These are selected to provide long term functional restraint against vibration of repeated load applications.

8.11 Temporary Pipe Supports

8.11.1 Stress analysis shall identify positions where temporary pipe supports for transportation are required. The use of such supports shall be minimised and be clearly identified on the stress sketches.

8.12 Modelling of Equipment

8.12.1 The calculation of equipment nozzle and pipe support displacements shall consider potentially different coefficients of thermal expansion of the equipment material and connected piping.

8.12.2 For a piping system connected to static equipment (for example, vessels, exchangers) the effect of shell expansion or contraction shall be considered in all direction. Shell expansion or contraction shall be calculated separately, or the equipment included in the stress model as rigid element in all direction.

8.12.3 For a piping system connecting with a pump, the effect of casing expansion or contraction shall be considered by introducing the displacement in the stress model. The displacement at nozzle face due to casing expansion or contraction shall be calculated separately or modelled as rigid element up to the fixed point.

8.12.4 The nozzle displacements due to thermal conditions for large rotating equipment including compressors and turbines, shall be taken from final VENDOR drawings.

8.13 Stress Analysis Check List

8.13.1 Refer to APPENDIX A6 for typical stress analysis checklist to be used.

8.14 Stress Analysis Report – Format and Contents

8.14.1 The Stress input file, in its native format, shall be submitted electronically to COMPANY for review and approval.

8.14.2 The following should be included in Stress analysis report, as applicable, but not limited to:

a. Introduction

b. System description / limits in terms of boundary conditions / methodology used for stress analysis specifying the software version, line numbers involved etc.

c. Design Input parameters including specific process information like velocity, density of 2 Phase flow, etc.

d. Load Cases including narrative description of all foreseen load cases and modes of operation

e. Assumptions & boundary conditions

f. Reference document number for Piping loads communicated to Structural / Civil

g. Summary of Calculations (with relevant node numbers) as applicable including:

   - Trunnion check
   - Slug force / surge force and vector calculations
   - API tank settlement vectors
   - PSV reaction force calculations

h. Special support reference details

i. Result summary

   - Stress summary including Maximum Code stress vs. Allowable stress for all applicable load cases
   - Maximum equipment nozzle loads vs. Allowable loads
   - Maximum restraint forces & moments
   - Maximum displacement summary
   - Modal analysis results if any
   - Spring hanger reports
   - Results of Flange leakage Calculation
   - Any other Calculation like WRC 107, etc. including those listed in 'g' above

j. Recommendations & Conclusion

k. Appendix should contain the following

   - Marked up P&ID & Line list (extracted)
   - CAESAR II Plot showing Nodes & Restraints
   - Stress isometrics mark-up
   - Detailed CAESAR II reports including Input & Output Listing
   - Other relevant vendor details & reference calculations like equipment drawings, Valve details spring details, Expansion bellow details, Non-standard flanges, hub connector, etc.

8.14.3 Stress Isometrics shall be included in the stress report and include the following details as applicable, but not limited to:

a. Node numbers
b. Line numbers
c. Line size / thickness
d. Dimensions
e. Temperature and Pressure conditions
f. Material
g. Piping class
h. Support types (at all support location, in case of guide support or axial stop gap should be mention if varying from standard gap)
i. Plant north
j. Global axis
k. Support function
l. Spring support details
m. Expansion bellows details
n. Special component details and weights
o. Nozzle thermal displacements
p. External / calculated loads and applied nodes
q. Special notes (if any)

9 STRESS ANALYSIS TO ASME B31.3 CODE REQUIREMENTS

9.1 General

9.1.1 The stress analysis cases shall meet the code requirements of ASME B31.3. These consist of Thermal Expansion, Sustained and Occasional cases as described in this specification and applicable code.

a. ASME B31.3 Code requirements are updated regularly. Greenfield projects shall use and meet the version of the code applicable at the time of contract signing.
b. For brownfield applications, the applicability of the version of code shall be agreed with COMPANY.

9.1.2 ASME B31.3 Para. 302.3.5.d Eq 1(b) liberal stress shall not be used without COMPANY approval

9.1.3 Stress analysis for occasional loadings, for example, wind or seismic and reaction loads from slugs, relief valves and rupture discs, shall be carried out in accordance with the requirements of ASME B31.3 and applicable code.

9.1.4 Wind and earthquake conditions need not be considered as concurrent.

9.2 Stress Intensification Factors (SIFs)

9.2.1 Stress analysis of piping systems shall include stress intensification factors to ensure that the system is safe, fit for purpose and that all stresses are within the ASME B31.3 code allowable values.

9.2.2 SIFs for standard components are available in ASME B31.3 Appendix-D and ASME B31J and the same shall be used. .

9.2.3 User defined SIFs shall be used when determined by FEA or obtained from previously reliable information which satisfies ASME B31.3 requirements for components not available in ASME B31.3 Chapter D or ASME B31J

9.2.4 Where fabricated lateral tees are used in process piping systems, accurate and representative SIF values shall be determined by FEA and satisfy ASME B 31.3 Appendix D and ASME B31J requirements.

9.2.5 The flexibility factor and SIFs for branches and tees for lines that have a D / t ratio >100 shall be determined by FEA or other alternative methods and shall be approved by COMPANY. Such calculations shall be included in the stress report.

9.2.6 SIF correction values for large diameter thin-wall bends, shall be accounted for in the analysis in accordance with ASME B31.3 Appendix D, Table D300 or ASME B31J

9.3 Wind Case Analysis

9.3.1 Wind loads shall be applied at maximum operating temperature.

9.3.2 Wind Loads etc shall be determined in accordance with Structural Design Basis - Onshore AGES-SP-01-003

9.3.3 Wind loading shall be applied to piping 10m above site grade or wave datum for offshore applications.

9.3.4 A wind shape factor of 0.7 shall be considered in wind analysis of piping for pipes where the outside diameter (including any insulation) > NPS 8 (200mm).

9.3.5 The effects of shielding by the structure and piping should be considered as applicable.

9.3.6 The prevailing wind shall be considered as acting North-South and East-West, and independently, not simultaneously. Wind profile (velocity / pressure versus elevation) shall be in accordance with Structural Design basis and shall be used for calculating the wind effect in applicable piping systems

9.3.7 The maximum occasional loads shall be considered as operational (OPE in CAESAR II®) and shall include the combined effects of weight + pressure + thermal + wind (W + P + T + wind). Stress analysis shall include structural movements and accelerations caused by wind where applicable.

9.4 Seismic Case Analysis

9.4.1 When calculating the seismic loads, the full operating content of piping shall be included.

9.4.2 Stress analysis shall include `g' forces aligned with the respective site location based on geographically applicable seismic parameters in accordance with Structural design basis, AGES-SP-01-003

9.4.3 Stress analysis of seismic conditions shall normally be carried out using statically applied g forces. The use of response spectrum data shall be restricted to arrangements for which the static method cannot achieve reliable or acceptable results.

9.4.4 Seismic loads shall be considered as acting in the Horizontal orthogonal axes and not acting simultaneously. Vertical seismic component as per ASCE 7 should be applied as applicable. In such case, the load cases provided in Appendix A4 shall be adjusted to suit the vertical seismic component.

9.4.5 The largest pipe restraint loading cases may result from seismic conditions and these calculated loadings shall be provided to structures to ensure full compliance with structural design.

9.4.6 The maximum operating temperature shall be used when determining maximum seismic plus operating loadings.

9.5 Hydro test Analysis

9.5.1 Pressure testing shall be considered in the stress analysis. Pressure and additional loads from testing with water shall be evaluated for pipe supports.

9.5.2 A hydro test load case with the piping full of water is required for all Liquid, Gas and Vapour lines where the test medium is water.

9.6 Transportation

9.6.1 A separate stress analysis shall be carried out to assess the effect of all forms of transportation and determine any additional pipe support requirements in piping and at nozzle disconnections

9.6.2 During detailed engineering phase the differential displacement due to transportation of module / deck shall be considered in transportation analysis. The values shall be defined by the structure studies. The maximum displacement stress range shall be checked according to ASME B31.3 requirements. CONTRACTOR shall provide a method explaining the differential displacements considered with the justification of their value.

9.6.3 The stress analysis will determine if additional pipe supports are required to control and locate piping which is unconnected to sections in other modules. These additional supports are termed “transportation supports”. Such supports forms rigid vertical and lateral restraints and will usually incorporate ‘Hold-Down’ features.

9.6.4 Transportation supports shall be part of the permanent design where possible. The objective is to minimise complexity of onsite support removals once the module(s) / skids has been installed.

9.6.5 If pipe supports are required specifically for transportation, they shall be clearly identified on the Stress Isometrics as transportation supports .The final design should consider easy identification (like separate colour) with a specific tag number for removal prior to Mechanical completion. Final as-built isometrics drawings shall be without any transportation support. .Piping restraint loadings may vary significantly and be in positions which occur during operation. The allowable structural stress for transportation is also different from operational loadings. Accordingly, transportation loads at all piping support positions shall be evaluated and transmitted to the structural group.

10 OTHER STRESS ANALYSIS CONSIDERATIONS

10.1 General

10.1.1 The piping flexibility and associated allowable expansion stress shall include consideration of the resulting natural frequency of the pipework. Hence piping flexibility for thermal analysis should target between 50% and 80% of the allowable stress.

10.2 Flange Leakage

10.2.1 All flanges (stress criticality L1) shall be checked for high bending moments that would tend to open the flange and cause leakage. Calculation shall be performed where necessary to show moments are acceptable. This should be carried out using CAESAR II® built in flange leakage evaluation module.

10.2.2 Forces and moments applied to flange joints should be assessed in accordance with ASME BPVC Section VIII, Division 1, Appendix 2 by considering the equivalent pressure method or by using ASME Section VIII Division 2 part 4.16 or ASME Section III, NC-3658.

10.2.3 Flange leakage criteria for API 6A flanges shall be in accordance with API 6AF.

10.2.4 Allowable loads at hub connectors and compact flanges shall be in accordance with ASME BPVC Section VIII Div 1 Appendix 2 or VENDOR’s proven calculations considering external loads and deflections from piping stress analysis and the stress shall not exceed 90% of the allowable.

10.3 Fatigue Analysis

10.3.1 The methodologies and standards proposed to be used for fatigue analysis shall be approved by COMPANY prior to commencing work.

10.3.2 Fatigue analysis of complex geometric arrangements or sections, including flanges and fittings, and items subjected to complex behaviour, for example, those occurring during cyclic loading conditions, shall be carried out as per code.

10.3.3 When the total number of significant stress cycles due to all causes exceeds 100 000, fatigue assessment rules in ASME B31.3 Appendix W shall be carried out.

10.3.4 In addition following fatigue analysis methods as applicable can be used as applicable with prior approval:

a. The general recommended design procedure for fatigue analysis of piping systems is described in the British Pressure Vessel Code PD5500 “Specification for Unfired Fusion Welded Pressure Vessels’ Annex C which defines the S-N curves and contains methodology for including all fatigue loadings (imposed movements, pressure transients, thermal gradients, etc.) based on the Palmgren- Miner- rule fatigue damage calculation method.

b. For investigation of the fatigue effect from wave loading alone, the methodology listed in DNV RP-C203 “Fatigue strength analysis of offshore steel structure”.

c. The Institute of Gas Engineers Code, IGE / TD / 12, “Pipework Stress Analysis for Gas Industry Plant” for evaluation of high frequency fatigue caused by high gas and steam velocities (acoustic fatigue).

10.4 Finite Element Analysis (FEA)

10.4.1 When Stress analysis will not provide a reliable stress solution or to carry out designs accurately without conservative considerations, it shall be necessary to perform a finite element analysis (FEA) with prior approval of COMPANY.

10.4.2 FEA for the part / components shall be carried out according to ASME B31.3 para. 304.7.2.

Note: In ASME B31.3 para. 304.7.2, reference is given to the ASME BPVC Section VIII, Division 2, Part 5.

10.4.3 The contents of a Comprehensive FE Analysis report shall contain the contents listed below, as applicable.

a. Executive summary which briefly describes the scope of the FE Analysis and the main conclusions.

b. A description of the component explaining its intended use and functionality.

c. References to governing design specifications including relevant standards and applicable pressure design codes.

d. References to project design premises, design requirements and a summary of applicable loadings.

e. A detailed description of the analysed component geometry with references to associated detail drawings.

f. A detailed description of any geometrical simplifications incorporated into the FEA model with discussion of those effects on the accuracy of the analysis. This should include how fabrication methods, tolerances and corrosion allowances are accounted for in the design of the component.

g. Material descriptions including designations details and applicable reference standard or specifications. Details shall include material properties within the specified design temperature range of the component.

h. A detailed description of the FE model discretisation, element types and sizes shall be discussed with respect to the resulting accuracy, tolerance or limitations of the calculated stresses.

i. A description of load application and boundary conditions and associated colour plots.

j. A clear presentation of results in the form of coloured plots showing stresses and strains together with plots of linearized stresses.

k. Code compliance check and clear conclusion of stresses and strains for the limit states, ULS, ALS and FLS.

l. Relevant functionality checks in the applicable limit state.

m. Conclusions from FE model verification and load application including the check of reaction forces.

n. For sample FEA Check list refer Appendix- A7 and shall be filled and attached with FEA report.

10.5 High Pressure Piping Requirements

10.5.1 High pressure piping shall meet the requirements of ASME B 31.3, Chapter IX where specified on the respective piping classes.

10.5.2 Allowable stress as per ASME B 31.3 Table K-1 shall be used in stress analysis

10.5.3 ASME B31.3 Chapter IX Fatigue Analysis - A fatigue analysis shall be performed on each piping system, including all components, joints therein, and considering the stresses resulting from attachments, to determine its suitability for the cyclic operating conditions specified in the critical line list. The cyclic conditions shall include pressure variations as well as thermal variations or displacement stresses.

10.5.4 ASME B31.3 Chapter IX Fatigue Analysis shall be in accordance with ASME BPVC, Section VIII, Division 2 or 3.

10.6 Pressure Relief

10.6.1 Safety relief valve discharge piping, for both open and closed systems, shall be designed to withstand both the dead loads and the reactive or thrust loads with a dynamic load factor (DLF) = 2. This shall consider the most severe case, for example, possible flashing conditions and liquid entrainment in vapour flows.

10.6.2 Suitable supports shall be designed / installed in line with the good engineering practice to absorb PSV discharge reaction forces (in order to prevent overloading and over stressing of the piping system). In addition the calculated restraint loads shall be transferred to Structural group.

10.6.3 Relief valve reaction forces shall be considered as an occasional load in accordance to code. The forces shall be determined using values taken from the instrument data sheet or VENDOR data. Where this information is not available, relief valve discharge forces shall be calculated in accordance with API RP 520 Part II.

10.6.4 Reaction force values from PSV discharges shall be included on the stress sketch and within the stress report.

10.7 Standby and Operating

10.7.1 For the lines which have no permanent flow (dead branch), for example, piping connected to the spare pumps, by-pass, etc., the following values are applicable:

a. Insulated line: 50% of the maximum operating temperature

b. Non-insulated line: Plant ambient temperature

c. Steam traced line: Maximum Operating temperature of the traced line or 70% of the steam whichever is the greater

d. Warm-up by-pass of the spare pumps: 70% of the maximum operating temperature of the line

10.8 Start up, Shutdown and Regeneration

10.8.1 Piping Stress analysis shall consider differential temperatures / conditions resulting from start-up, shutdown and regeneration operations.

10.8.2 Imposed loadings on equipment nozzles occurring during start-up, shutdown and regeneration operations shall be evaluated.

10.8.3 Start-up, shutdown and regeneration conditions shall be confirmed in consultation with the process engineer.

10.9 Cold Spring

10.9.1 Cold springing of piping shall [PSR] not be permitted under any condition.

10.10 Thermal Bowing

10.10.1 Thermal gradients (bowing effect), shall be considered for the following cases that causing a temperature difference between opposite sides of the pipe (normally top and bottom) ≥ 50°C:

a. Lines subject to uneven radiation

b. Lines with stratified flow due to stagnation

c. Lines with low flowrate and partially filled with hot / cold liquid

d. Steam / condensate systems as applicable

e. Cryogenic systems including rundown and loading services

f. Introduction of a fluid at or near its boiling temperature

g. Cold flare lines

10.10.2 Lines shall be subject to Thermal bowing conditions and associated temperatures shall be confirmed in consultation with the process engineer.

10.10.3 Flanged joints shall be avoided in sections of piping which will be subject to thermal bowing as these will be subject to significant bending but if located shall be subjected to flange leakage checks.

10.10.4 Thermal bowing effect is included in CAESAR II® within the set-up file where a specific differential temperature is selected.

10.10.5 Stress analysis shall be carried out on all lines subject to thermal bowing.

10.10.6 Stress analysis should stipulate regular ‘hold down’ supports for all lines subject to thermal bowing.

10.11 Steam Out

10.11.1 The steam out requirement, steam out temperature and the corresponding pressure is determined by Process and this shall be taken from process line list.

10.11.2 In the case of the steam out procedure allowing steam to escape at an open end of the pipe, causing jet force at the point, the piping shall be securely restrained at the steam exit point to ensure that the loadings on the pipe and restraint system meet design limits.

10.11.3 Steam out temperature, where greater than process design temperature, shall be used in the stress calculations to determine the expansion stress range and nozzle loads. The analysis shall also consider whether the equipment and the piping are steamed out together or separately.

10.12 Bourdon Effect

10.12.1 The Bourdon effect results due to the difference between the pressures inside the pipe in relation to the pressure outside the pipe. If the inside pressure is greater than the outside pressure the pipe will expand. The bourdon effect causes straight pipe to elongate, and bends to open-up in a translational direction along a line connecting the curvature end points.

10.12.2 Usually bourdon effect is neglected in case of steel pipes except in case of long runs (60m long and above, irrespective of size or pressure) or in high pressure (40 barg and above), large diameter (NPS 30 and above), bends adjacent to sensitive equipment. Bourdon effect shall always be considered in case of FRP / GRP pipe systems.

10.12.3 The Bourdon effect shall be included in the stress analysis by activating “Activate Bourdon Effects” of each CAESAR II® input file. Two options are available as follows:

a. Translation only

This option will be used for in-plant piping where applicable, as for in plant piping generally forged / wrought or welded fittings are used which can reasonably be assumed to have circular cross section, and therefore bends doesn’t tend to ‘open up’.

b. Translation and Rotation

This option will not be used for in-plant piping. This will be used only in pipelines, where cold or hot bends are used, as in this case the slight residual ovality of the bend cross section causes bends to straighten out when pressurized.

10.13 Differential Vertical Settlement

10.13.1 Differential settlement is the difference in vertical deformation between two points at the foundation structure interface.

10.13.2 Differential settlement originates from one or more of the following causes:

a. Non-homogeneous geometry or compressibility of soil deposit.

b. Non-uniform distribution of load applied to the foundation.

c. Uniform stresses acting over a limited area of the soil stratum.

10.14 Sway

10.14.1 The sway deflection of structures for piping analysis shall be considered in accordance with the allowable limits in specification, AGES-SP-01-003.

10.14.2 Methodology for the stress analysis of sway effects shall be carried out as detailed in APPENDIX A4.

10.15 Vessel Skirt Temperature

10.15.1 Vessel skirt temperature and movements shall be considered in stress analysis.

10.15.2 The vertical movement of the lower vessel tangent line due to the skirt thermal expansion should be calculated by using the average temperature of the skirt and the skirt height.

10.16 Heat Tracing Elements

10.16.1 Where piping is heat traced and subject to a ‘process flow off / heat tracing on’, the process piping metal temperature shall be considered 100% of the trace element design temperature.

10.16.2 In case of steam traced lines, the operating temperature of the traced line or 70% of the steam temperature, whichever is greater shall be considered.

10.17 Refractory (Lined) Piping

10.17.1 The increased weight and stiffness of a piping system caused by a refractory lining shall be considered when determining reaction loads.

10.17.2 To protect a piping system against collapse due to creep, the increased stiffness due to a refractory lining shall not be included in the span calculations, any sustained load analysis, and flexibility analysis.

10.17.3 Fracture limits of the refractory lining shall be considered as these can often be less than the bending stress limits of the metallic piping.

10.18 Jacketed Piping

10.18.1 The stress analysis of jacketed pipe shall incorporate special considerations due to differential temperatures between the core pipe and outer jacket.

10.18.2 All possible conditions shall be taken into account from construction phase to full operating situation including shut-down situation

10.18.3 For jacketed lines, the design temperature of heated line or steam temperature whichever is greater shall be considered

10.18.4 The thermal effect due to differences in expansion characteristics, of piping in jacketed pipe shall be taken into account in the calculation of stresses and loads in the system.

10.18.5 Deflection for the jacket shall be calculated to ensure that it does not create obstruction to the flow of the hot medium in the jacket. The allowed deflection of the jacket shall be limited to T / 2, where T is the thickness of the jacket.

10.18.6 Stress analysis of jacketed piping shall model core and jacket piping, internal and external pipe supports. Suitable SIFs shall be established for any special fittings, such as a cross.

10.18.7 Based on inputs from stress analysis, interference checks and weld strength calculations shall be performed manually and included in the stress analysis report.

a. The forces at the junction points between the core and jacket pipe shall be calculated. These shall be compared, manually, with the allowable Buckling Loads calculated using the Euler's equation for column buckling.

b. The forces at the junction points between the core and jacket pipe shall be calculated in CAESAR II® (P calculated) and compared to the allowable load at the weld point, using the formula:

P allowed = area of weld x 80% of hot allowable stress of material

11 DYNAMIC EFFECTS

11.1 General

11.1.1 The CONTRACTOR shall ensure that all piping subject to dynamic forces are evaluated using the E.I. Guidance for Avoidance Piping Vibration and included in stress analysis scope.

11.1.2 Dynamic loads on piping systems can be categorised as follows:

a. Mechanically induced dynamic loads

- These are often related to rotating equipment.
- These are characterized by periodic excitation forces or displacements of moderate amplitude but of long duration. (Of the order of minutes - days).
- For the mechanically induced excitation type, mitigation attention is focused on keeping the natural frequency of the pipe away from the source frequency or isolating the piping system from vibrating equipment. Important mitigation contributors are support stiffness and mode shape.

b. Fluid mechanical excitation dynamic loads;

- Fluid mechanical excitations dynamic loads are distributed over the piping system. Fluid mechanical forces consist of two components, a friction component tangential to the pipe wall and a pressure component normal to the pipe wall. In general, the friction component is small compared to the pressure contribution. Since pressure forces act normal to the pipe wall they are generally balanced by the circumferential pipe stress

c. Transient dynamic loads

- Transient dynamic loads are characterized by relatively large forces of relatively short duration (fractions of a second).
- Typical examples of transient dynamic loads are:
    - Slug loads;
    - Relief loads;
    - Surge (water hammer) loads;
    - Earthquake.
- For the transient excitation the attention is focused on control of support location, type span and support stiffness.

11.1.3 Dynamic analysis of piping systems shall be carried out using the following methods as appropriate:

a. Modal analysis

Modal Analysis is a simplified method of dynamic analysis which may be carried out within CAESAR II® in order to find the natural frequencies and the associated mode shapes of piping systems.

b. Harmonic analysis

Harmonic analysis is used to determine the steady-state response of a piping system to loads that vary sinusoidal with time. Imposed loads are modelled in stress model as displacements (or concentrated forces) separated by phase angle timing to provide the maximum dynamic loads, stresses and deflections (amplitudes).

c. Response spectrum analysis

Response spectrum analysis based on project “Design Basis” information shall be used to account for exceptional loads for example, earthquake. The response spectrum method of dynamic analysis requires additional work over modal analysis but usually provides significantly lower loads and hence reduced structure requirements.

d. Time history analysis

Time History Analysis should be used to study the effects on a piping system resulting from time-dependent loads including the following: ESD and pump actuation, surge, PSV, seismic or blast events. Modal responses are combined to obtain an estimate of the maximum piping system response.

11.1.4 Systems requiring detailed dynamic analysis shall be performed during detailed design stage, when detailed information is available from the VENDOR and Process.

11.2 Natural Frequency Considerations

11.2.1 For piping subject to mechanically induced vibration, the allowable piping natural frequency range shall be determined by the excitation frequencies.

11.2.2 For mechanically induced vibration, piping natural frequencies and excitation frequencies shall be separated by more than 20%.

11.3 Vibration Analysis

11.3.1 The CONTRACTOR shall produce an overall Piping Vibration report which includes all Likelihood of Failure (LOF) piping vibration assessments and supporting calculations in accordance with E.I. Guidelines.

11.3.2 The lowest fundamental natural frequency of piping shall meet the following minimum values:

a. Lines subject to hydraulic transients including water hammer and pressure surges - 6 Hz

b. Lines connected to reciprocating pumps and reciprocating compressors - 6 Hz

c. Lines subject to slug, mixed or two-phase flow - 5 Hz

d. All stress critical lines - 4 Hz

11.3.3 CAESAR II® setup parameters shall use a stiffness factor of friction of 1.0, to avoid low frequency vibration, thus ensuring a reasonable level of rigidity to the piping system.

11.4 Flow Induced Vibration (FIV)

11.4.1 All piping shall be evaluated for FIV sources and conditions by Process. FIV screening shall be carried out for all lines during the detailed engineering stage and also during FEED projects for lines within Brownfield Tie-in scope.

11.4.2 The preliminary FIV identification is recommended to be done at the FEED stage in order to avoid late changes, however the same shall be verified during the detailed engineering stage

11.4.3 Lines subject to FIV shall be assessed by piping stress to be fully in compliance with E.I. Guidelines by comparing values of ρv2 against an E.I. Guidelines criteria.

11.4.4 Piping containing high velocity compressible fluid flowing inside a pipe in a turbulent manner may induced piping vibrations and shall be investigated by pipe stress.

11.4.5 Piping subject to two-phase flow shall be investigated by piping stress especially where changes of process / operations will result indifferent levels of frequency and increase possibility of resonance.

11.4.6 The assessment of Likelihood of Failure (LOF) following the Energy Institute Guideline shall be performed for the main lines and small bore connections as follows:

- All main lines subject to flow induced turbulence shall be design with support arrangement criteria based on Energy Institute Guideline Table 2.1 ("flexible" support arrangement criteria being excluded).

- If main line LOF < 0.3: no need further assessment.

- If 0.3 ≤ main line < 0.5: Small Bore Connection (SBC) LOF shall be assessed as follow:

    - If 0.4 < SBC LOF < 0.7: Contractor shall specify the appropriate assessments and corrective actions to be performed.

    - If SBC LOF > 0.7: SBC corrective actions as given in Energy Institute Guideline Module T11 shall be applied.

- If support arrangement criteria based on Energy Institute Guideline table T2.1 ("flexible" support arrangement criteria being excluded) can't be satisfied, then assessment based on Energy Institute Guideline module T2.2.4 shall be performed.

- In case the result of main line LOF assessment using module T2.2.4 is 0.5 or above (LOF ≥ 0.5), a more detailed vibration and dynamic analysis shall be performed (i.e. using Finite Element Analysis Method) by including the piping system, the supports and the structures. This analysis shall determine the level of dynamic stress and the fatigue life of the system. This may require expertise of third party specialist

11.5 Acoustic Induced Vibration (AIV)

11.5.1 The piping subject to AIV shall be identified by Process and is normally associated with large pressure reductions systems local to the following such as:

a. Blowdown valves & restriction orifices

b. Relief valves

c. Pressure reducing valves

d. Compressor Anti surge valves

e. Orifice Flow Elements

11.5.2 Preliminary analysis of AIV screening should be carried out during FEED, for all applicable lines, irrespective of pipe size, pressure ratio and sonic velocity. Further assessment, evaluation, analysis and incorporation of the recommendations shall be carried out during detailed design. These lines shall be specified in the Critical Line List

11.5.3 Mitigation measures to reduce, limit or remove the effects of AIV, shall be developed in consultation with Process and Instrument departments. The use of special control valves or restriction orifices to reduce the energy at the acoustic energy source and addition of in line silencers to attenuate the energy in the piping shall be considered.

11.5.4 Piping Stress analysis of lines subject to AIV shall ensure the following:

a. The analysis considers the correct wall thickness is included for the associated sound power level of each pipe section and this extends to the correct distance from energy source(s).

b. The stress analysis includes the pipe branch connections and pipe support details which comply with specific design requirements like brace supports etc.

11.5.5 Special Pipe classes for AIV services should be developed (if required) which shall have increased wall thickness or special branch connection like sweepolet, etc

11.5.6 The CONTRACTOR shall assess the possibility of induced vibration shall be checked in accordance with the guidelines stated in the 'Energy Institute' Publication: 'Avoidance of Vibration Induced Fatigue Failure in Process Pipe work' and the recommendations from published papers 'Acoustically Induced Piping Vibration in High Capacity Pressure Reducing Systems' by V.A. Carucci & R.T. Mueller and 'Designing Piping Systems Against Acoustically Induced Structural Fatigue' by F. L. Eisenger. An alternative method shall only be used with the prior agreement of COMPANY.

11.5.7 Piping systems with sound power levels (PWL) > 155 dB shall be further assessed and designed in accordance to "Quantitative" methods given in section T-2 of the E.I. Guidelines.

11.5.8 For each project the CONTRACTOR shall produce and submit a detailed AIV assessment report. The objective of this document shall be to define how AIV will be determined, coordinated, engineered and managed.

11.6 Slug Flow

11.6.1 Lines which will be subject to slugging shall be identified on the line list and noted on P&ID's.

11.6.2 For all lines that will be subject to slugging, Process shall provide, velocity, density data and slug type assessments for the determination of slug forces.

11.6.3 Lines subject to slugging shall be identified in the critical line list and classified as L1 criticality level.

11.6.4 Slug forces shall be applied at changes of direction (not simultaneously to ensure the unbalanced force effect) for the calculation of stresses and pipe support loads.

11.6.5 In the absence of accurate data during FEED stage , calculations of slug loads on 90 degree elbows shall be based on the following simplified calculation which assumes equal inlet and outlet velocities and zero difference in pressure between those points:

$$F_1 = \rho \cdot v_2 \cdot A \cdot (1-\cos(\theta)) \cdot DLF\ [N]$$
$$F_2 = \rho \cdot v_2 \cdot A \cdot \sin(\theta) \cdot DLF\ [N]$$

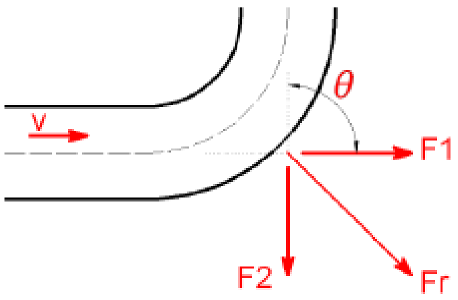
Where:

DLF = 2.

v = mixed phase speed [m/s].

ρ = liquid phase density [kg/m3].v = slug velocity (1.2 x the average mixture velocity)

θ = the bend / elbow angle



11.6.6 Calculated unbalanced slug forces shall be included in the stress analysis for both metallic and non-metallic piping.

11.6.7 Piping stress analysis shall incorporate axial restraints to absorb ‘slugging’ forces, preferably in all changes of direction, to avoid unacceptable bending stresses.

11.6.8 The piping geometry of lines subject to slugging shall be routed with minimal changes of direction which are not required to meet thermal expansion stress limits.

11.6.9 Particular attention shall be made to pipe supports and structures shall be designed to withstand slugging loads and the combinations with those resulting from thermal effects.

11.7 Mechanical Excitation

11.7.1 Mechanical Excitation shall be considered to occur in piping systems connected to all types of compressors, turbines, pumps, etc.

Note. In these machines, the dynamic forces directly load the pipework connected to the machine or cause vibration of the support structure which in turn results in excitation of the pipework supported from the structure.

11.7.2 Three cases shall be considered:

a. Pipework which is directly attached to machinery (for example, suction and discharge lines of a pump, compressor and turbine).

b. Pipework which does not form part of the piping system associated with a machine as above but routed close to a machine and therefore may be subjected to mechanical excitation by transmission through the supporting structure.

c. Pipework which shares common supports (for example, the same pipe rack) with another line which itself displays high vibration levels.

11.8 Pulsation

11.8.1 Pulsation forces shall be determined from information obtained from Process. Pulsation forces in a piping system depend on the following:

a. Pipe diameter (Cross sectional area)

b. Process parameters

c. Molecular weight

d. Fluid density

e. Fluid properties

11.8.2 The predominant sources of low frequency pressure pulsation are:

a. Reciprocating / Positive displacement pumps and compressors generating oscillating pressure fluctuations in the process fluid simply by virtue of the way in which they operate.

b. Centrifugal compressors generating the pressure pulsations at low flow conditions.

11.8.3 Pulsation events associated with rotating equipment shall consider the pipework upstream and downstream to the first major vessel or volume.

11.8.4 The characteristics of pulsation events and associated acoustic modes respond to changes of pressure, temperatures and molecular weight or fluid density and hence all operations scenarios (for example, recycling, change in speed, running trains in parallel, change overs etc.).

Note: The full range of operating conditions should be obtained from Process and considered as part of the assessment and included in consultations with equipment MANUFACTURER.

11.9 Vortex Shedding

11.9.1 Vortex shedding around piping resulting from wind, shall be avoided by positioning of pipe supports and guides.

Note. In the case of wind loads on piping, the fluid is flowing past a right-circular cylinder causing vortex shedding. This flow frequently produces vortices that are referred to as Karman vortices, and shed in a regular pattern over a wide range of Reynolds numbers.

11.9.2 Vortex Shedding shall be assessed where components are introduced into piping which effect flow changes which could causes vortices to be shed at specific frequencies. This is likely for flows past the end of a dead leg branch, past components inserted in the fluid stream (such as thermowell probes) or geometries which produce non-symmetrical flow at vessel outlets. In such cases the natural frequencies of piping elements and structures shall be checked to ensure that they do not coincide with vortex shedding frequency.

11.10 Surge / Momentum Changes Due to Valve Operation

11.10.1 Surge loads shall be based on process data which will provide transient data relating the simulated force / time history of the surge. Data obtained from a process simulation model which can predict valve Cv as a function of time shall be used as input to the stress model.

Note. Surge (or water hammer) resulting from pressure waves caused by the kinetic energy of a fluid in motion when it is forced to stop or change direction suddenly. If the pipe is suddenly closed at the outlet (downstream) a pressure wave is generated which travels back upstream at the speed of sound in the liquid. This can give rise to high levels of transient pressure and associated forces acting on the pipework.

11.10.2 The CONTRACTOR should be required to ensure the results and values obtained from early stage surge analysis are re-confirmed using final data. This is especially relevant for pump curves and impellor inertia and control valve actuation control / times

11.10.3 The lines submitted to the surge effects shall be identified in the Critical Line List.

11.10.4 The peak surge pressure in a pipe should determine pipe wall thickness and flange rating.

11.10.5 The forces generated by surge are proportional to the distance between changes of direction and increase with length.

11.10.6 Lines subject to impact forces due to rapid valve closures / opening, pump start up, etc. shall be designed to avoid vibration.

11.10.7 Excitation due to surge and momentum changes shall be considered for fast acting valves actuated valves as follows: which excludes all manually operated valves. Typical automatic valves to be considered in the assessment include:

a. Blowdown Valves (BDV)

b. Emergency Shut Down Valves (ESD)

c. Flow Control Valves (FCV)

d. Pressure Relief Valve (PRV)

e. Relief Valves (RV)

11.10.8 An equivalent static stress analysis shall be performed where the force due to the pressure surge is applied at appropriate locations (changes of direction). The forces shall be modelled acting on straight part of pipe (at the inlet node of the elbows for example).

11.10.9 A force spectrum dynamic analysis shall be performed when high surge pressure fluctuations and high stress level (or high loads on supports) are obtained from the static stress analysis.

11.10.10 In the absence of accurate data during FEED stage, surge load can be determined by a simplified method as follows:

$$FR = (\pi D^2 P)\ \mathrm{DLF} / 4$$

Where:

FR is the estimated Surge Force

D is Pipe Internal Diameter

P is Design Pressure x 1.33

DLF Dynamic Load Factor = 2

11.10.11 Stress analysis of piping systems subject to surge may incorporate axial restraints acting in line with surge forces to prevent excessive bending stresses at changes of direction.

11.10.12 Stress analysis shall ensure restraint loadings and pipe support designs are designed to withstand surge loads and the combinations with those resulting from thermal effects.

11.11 Cavitation

11.11.1 Potential causes of cavitation shall be avoided as piping vibration will occur in such case. The dynamic process which causes this, is due to the creation of vapour bubbles which rapidly form and collapse where there is a localized pressure drop within the process fluid (for example, at centrifugal pumps, valves, orifice plates). This process creates very high localized pressures which results in noise, damage to components, vibrations, and a loss of efficiency. Process design shall ensure avoidance of cavitation in piping system.

11.12 Flashing / Sudden Cooling

11.12.1 Stress analysis of piping subject to flashing or sudden cooling shall ensure pipe supports are positioned to limit potential vibration. Pipe support loadings and designs shall ensure pipe deflections and stresses will not cause fatigue failures. Process design shall avoid such issues and they shall clearly identify all such lines in the P&ID notes and Line list / critical line list.

Note. Flashing happens when the pressure within the pipe becomes less than the vapour pressure of the fluid, the fluid can suddenly change from liquid into vapour state. Sudden cooling of hot vapours can release huge amounts of energy. The hot vapours when contacted with sub cooled liquid results in violent condensation causing high levels of piping vibration which must be avoided.

11.12.2 Flashing typically occurs where:

a. There is localized pressure drop within the process fluid (for example, at centrifugal pumps, downstream of control valves, orifice plates).

b. Where two-phase flow or mixing of the fluids (for example, chemical injection, merging of process streams or steam condensate at different pressures).

11.12.3 Stress analysis shall consider the localised effects on piping components subjected to differential cooling / heating especially where these are regular cyclic events resulting from process / operations.

11.12.4 CONTRACTOR process team shall study the possible design solutions as recommendations and submit to COMPANY for approval.

12 EQUIPMENT CONSIDERATIONS

12.1 Nozzle Loads

12.1.1 The temperatures of equipment (obtained from equipment data sheets) and the resulting effects of imposed displacements on connected piping shall be included in piping stress calculations.

12.1.2 All the nozzle loads shall be qualified with design temperature and not normal operating temperature. Where this may lead to an over-conservative design, the Process department shall be consulted or if Process has defined the max / min operating temperature in the line list then the same can be used to qualify the nozzle loads with COMPANY approval. In such cases the stress sketch and stress critical line list shall be suitably annotated.

12.1.3 Wherever the maximum operating temperature cannot be provided by process, then the design temperature shall be used to determine the nozzle loads.

12.1.4 The allowable nozzle loads for equipment, pumps, pressure vessels, heat exchangers, fired heaters; atmospheric tanks, skid mounted packages shall be in accordance with the Appendix A3 of this specification or allowable loads provided by Vendor.

12.1.5 The CONTRACTOR shall ensure that the Vendor drawing show the allowable loads for all 6 degrees of freedom (3 forces and 3 moments).

12.1.6 Thermal movement of the equipment nozzle shall be obtained from the MANUFACTURER or if not available, calculated using process and equipment data.

12.1.7 Wherever the nozzle loads exceeds the allowable values, (after exhausting options of pipe rerouting, rearranged supports, etc.), written approval of respective MANUFACTURER shall be submitted with respect to acceptability of higher loads imposed by external piping that can be absorbed without jeopardizing integrity of the equipment / system as well as adequacy of connecting flange joint based on flange leakage analysis. Such vendor concession shall be documented in the stress analysis report.

12.1.8 When the loads due to earthquake / wind acting on equipment nozzles exceed the allowable then approval can be obtained from the MANUFACTURER for the occasional loads. In all such cases, revised stress analysis reports along with MANUFACTURER approved nozzle loading shall be submitted for COMPANY approval. Wind and seismic effects upon nozzle loads shall not be combined, but independently added to loads resulting from operating conditions.

12.1.9 All calculated imposed loadings on all equipment shall be tabulated on stress summary sheets which shall be included within the stress analysis report.

12.1.10 Nozzle loads on equipment bridle nozzles shall be analysed if the vessel operating temperature is above 260°C. It shall be assumed that the level gauge is at ambient temperature. The effects of weight shall be included in the analysis.

12.2 Nozzle Flexibility

12.2.1 The nozzle to shell intersection at a Pressure Vessel shall be considered as rigid.

12.2.2 In general, nozzle flexibility shall not be incorporated within the stress analysis.

12.2.3 Nozzle flexibility may be used in limited specific cases, for example, in cases where the application of very high temperatures results in high imposed piping loads on nozzles. The application of nozzle flexibility requires the prior approval and written confirmation from COMPANY (both Piping and Mechanical) and the equipment MANUFACTURER and shall be included in the stress report and summarised on the associated stress sketch.

12.2.4 Where nozzle flexibility is included in the stress analysis, the stress engineer should ensure the region of shell considered flexible accurately and shall be modelled accordingly considering all internal features, components, stiffness etc.

12.3 Centrifugal Pumps

12.3.1 The allowable Nozzle loads for Centrifugal pumps shall be as per stated in Appendix A3

12.3.2 First support shall be independent of the pump foundation and of adjustable type for Side / End Nozzle Pumps to assist flange alignment.

12.3.3 Systems with multiple pumps in operating + standby arrangements shall be analysed with combination of load cases which shall satisfy all possible operational scenarios. An average of analysis and installation temperature or temperature obtained from heat transfer calculations shall be considered for pipe to and from the stand-by pump, if check valve is fitted with a by-pass to facilitate a 'warm up'.

12.3.4 If a by-pass is not provided, the temperature of dead leg for the stand-by pump from the tee to the block valve, for both suction and discharge lines, shall be considered as the average of the analysis temperature and the installation temperature. The temperature of the piping from the block valve to the pump shall meet the requirements of Section 10.7.

12.3.5 During stress analysis, misalignment check between the pump nozzle & the piping free end flange in the weight case (W) shall ensure that it follow the stipulations dictated by API RP 686**.** This will ensure a relatively easy alignment of piping with rotating equipment's nozzle and as well as very low imposed loads will act on the pump during installation. This is also applicable for all rotary equipment like turbines, compressors etc

12.4 Non-API Pumps

12.4.1 When Non-API pumps are procured, VENDOR allowable nozzle loads shall be used in analysis.

12.5 Positive Displacement Pumps

12.5.1 Positive displacement pumps shall be either Reciprocating type to API 674 or controlled volume type to API 675.

12.5.2 Pulsation analysis shall be required on piping connected to a reciprocating type pump.

12.5.3 The maximum piping forces and moments acting on the nozzle of a reciprocating positive displacement pump shall not exceed the allowable forces and moments stated in Appendix A3. Pulsation control devices shall be incorporated in the system design to limit the out of balance forces imposed on the piping system in consultation with the pump VENDOR.

12.5.4 The pipe supports on suction and discharge piping connected to positive displacements reciprocating type pumps shall incorporate hold down restraints to minimise the potential effects of pulsation loads on the equipment.

12.6 Centrifugal Compressors, Expanders and Steam / Gas Turbines

12.6.1 The stress analysis of new piping arrangements or modification of existing piping connected to compressors, expanders or turbine equipment shall incorporate the resolution points, fixed and casing displacements (axial, lateral & vertical direction) of nozzles relative to the fixed end position based on Vendor drawings and Appendix A3.

12.6.2 The calculated individual forces, moments and associated resolved values determined for all operating case including such as recycle, depressurisation, etc. acting on the compressor nozzles shall not exceed the allowable force and moment limits specified by the Vendor (3 forces and 3 moments) and Appendix A3.

12.6.3 During stress analysis, misalignment check between the compressor nozzle & the piping free end flange in the weight case (W) shall ensure that it follow the stipulations dictated by API RP 686. This will ensure a relatively easy alignment of piping with rotating equipment's nozzle and as well as very low imposed loads will act on the pump during installation. This is also applicable for all rotary equipment like turbines, pumps, etc.

12.6.4 If Variable springs are selected, then the load variations shall be within ± 10%

12.6.5 Pipe support designs shall be provided local to anti-surge or recycle valves to adequately restrain the resulting forces from valve action and potential vibrations resulting from gas turbulence.

12.6.6 In offshore installations or those within modules, the location of compressors (and other large rotating equipment) shall consider the surrounding structural displacements with the objective to minimise the effect of imposed supporting and overhead deck displacements.

12.7 Reciprocating Compressors

12.7.1 The compression stroke of the piston within the reciprocating compressor causes pressure pulses that induce vibration in the suction and discharge piping system. These pressure pulse variations are limited by the inclusion of a pulsation damper which shall be sized and specified in accordance with AGES-SP-05-003 and API-618.

12.7.2 Pipe support restraints shall be designed to limit the stresses resulting from the applied forces where cyclic displacements occur.

12.7.3 The pipe support used in reciprocating service piping is recommended to be supported directly from grade.

12.7.4 Pipe Support span in long runs of piping shall be varied to prevent adjacent spans having identical frequencies and to ensure the lowest natural frequency of the piping is greater than the critical frequency of equipment. The critical frequency shall be agreed with the compressor VENDOR

12.7.5 Hold down restraints shall be incorporated into the pipe support designs to avoid disengagement of piping and to minimise the potential imposed loadings on compressor and connected equipment nozzles.

12.7.6 The maximum piping forces and moments acting on reciprocating compressors nozzle shall not exceed the allowable forces and moments provided by the VENDOR (3 forces and 3 moments) and Appendix A3.

12.7.7 The following steps shall be considered for Dynamic Analysis (Analog / Pulsation study) for Reciprocating Compressors Piping as defined in API 618 and AGES-SP-05-003:

a. An initially static thermal and sustained stress analysis or the intended piping and support design shall be carried out by the CONTRACTOR. This analysis shall include nozzle displacements and allowable loadings provided by the VENDOR.

b. Modal analysis shall be used as a basic confirmation of the piping natural frequencies. (thermal and dead weight)

c. The initial details of the compressor suction and discharge piping, including pipe support details, locations and restraints directions shall be submitted to Compressor Vendor for considerations in the Analog / Pulsation study. This study will include the piping between the compressor machine and compressor suction and discharge KO drums and air coolers and agreed battery limits.

d. The CONTRACTOR and compressor VENDOR shall work closely to implement the Analog / Pulsation study recommendations into detail engineering design. All the recommendations of the Analog / Pulsation study shall be implemented by the CONTRACTOR.

e. The initial static analysis carried out by the CONTRACTOR shall be revised/updated taking into considerations the Analog / Pulsation study supporting recommendations.

12.7.8 The results and requirements from the Analog / Pulsation study shall be implemented into the design and stiffness of steel structures (including pipe racks) pipe supports and all related structures to ensure adequacy for the various vibration modes and imposed loadings. Coordination between piping and structural group is required to implement this requirements.

12.8 Positive Displacement Rotary Pumps

12.8.1 Piping connected to rotary positive displacement pumps with horizontal suction and discharge nozzles, is considered to be in non-pulsating service.

12.8.2 Allowable forces and moments on Positive Displacement Rotary Pump nozzles (normally horizontal orientation for both suction and discharge nozzles) shall be in accordance with API-676 and APPENDIX A3 of this document.

12.8.3 The construction of the pumps usually permits the use of adjustable base supports for the piping close to the pump nozzles.

12.9 Fired Heaters

12.9.1 Stress analysis of fired heater piping shall focus on early provision of the following information for review and approval by the equipment VENDOR:

a. The nozzle and shell displacements

b. The manifolds support arrangement around the equipment.

c. Guides and anchors on manifolds.

d. Pipe support loads on platforms and the heater structure.

12.9.2 If the fired heater piping analysis incorporates the heater coil connections in the stress model, the calculated displacements at interface points shall be submitted to the equipment VENDOR for review and approval.

12.9.3 The maximum piping forces and moments for the fired heaters shall not exceed the allowable force and moment limits specified in Appendix A3. The calculated values shall be provided to the equipment VENDOR for review and approval.

12.10 Air Coolers

12.10.1 Piping stress analysis shall include all operating conditions based on discussions with Process to determine worst case nozzle loads. Isolation valve operation where one bundle is at stand-by and the others operating shall also be considered.

12.10.2 Piping stress analysis shall determine the individual nozzle loadings and resolve the combined loadings on equipment framework in accordance with API 661. Allowable nozzle loads for air cooler shall be in accordance with the requirements of the standards listed in APPENDIX A3 of this specification

12.10.3 The effect and limitations of tube expansion / displacements shall be included in the stress analysis model, based on VENDOR drawings.

12.11 Storage Tanks

12.11.1 Allowable Nozzle loads for storage tank shall be in accordance with APPENDIX A3 of this specification.

12.11.2 The allowable nozzle loads for storage tanks designed to codes other than those listed in Appendix A3 shall be discussed and agreed with the tank MANUFACTURER and COMPANY.

12.11.3 Piping stress analysis of lines connected to storage tanks shall incorporate all variations of the radial and vertical expansion / contraction of the tank.

a. Nozzle rotation which occurs due to bowing of the tank wall resulting from variations in the level of the tank contents.

b. Position of the nozzle relative to tank base and top ring stiffness.

c. Tank design parameters.

d. Tank settlement.

12.11.4 Nozzle displacements and rotations shall be calculated in accordance with API 650 (where appropriate) and modelled within stress model.

12.11.5 Differential settlement of storage tanks is particularly important to the stress analysis of lines connecting to a tank. The data shall be obtained from civil group, prior to design the piping and it shall include the following

a. Amount of settlement and recovery that will occur following construction and hydro test.

b. Amount of settlement after hydro test and over the period of time which it will occur.

12.11.6 Tank settlement may damage piping connection due to differential settlement between the tank shell and piping connection. This can be avoided by using proper pipe supporting philosophies. Equipment foundation settlement shall also be considered. Supporting the piping adjacent to equipment experiencing settlement shall account for possible misalignment during installation and major overhauls

12.11.7 Piping connected to storage tanks shall incorporate a horizontal 90 degree change of direction as close as practical to the nozzle..

12.11.8 The use of spring supports close to storage tank nozzles should be avoided where possible. Where spring supports are used, the effects on nozzle loadings as a consequence of variations in tank fill levels and the weight of pipe contents shall be considered. In such case additional WNC (Weight No Contents) analysis shall be carried out.

12.12 Tower and Vertical Vessels

12.12.1 The stress analysis of all piping and pipe support locations shall include the vertical and radial displacements which occur due to all of the temperature profiles of the equipment and include consideration of thermal growth and sway.

12.12.2 The contribution of skirt growth shall be included in the temperature profiles.

12.12.3 While analysing reactor bottom / column bottom nozzle, the spacer gap in skirt opening shall be taken into consideration in the analysis.

12.12.4 Nozzle loadings and pipe stresses shall consider all operating and maintenance conditions and differential temperature effects for example, those occurring during start up, steam-out and shutdown.

12.12.5 Piping connected to and routed down the side of towers and vertical vessels shall incorporate a load taking support as close as possible to each nozzle.

Note: Additional spring supports attached to the equipment may be used to redistribute weight loadings for lines other than two phase flows.

12.12.6 Vertically acting supports shall be designed (with dampers) adequately for piping subject to two phase flow with relative thermal displacement (including occasional jerks), in order to control and distribute nozzle and pipe support loadings, limit displacements and stresses and avoid pipe support disconnections.

12.12.7 In addition to the vertical support, additional guides shall be positioned to control nozzle loads, distribute occasional loads and avoid vortex shedding frequencies.

12.12.8 The piping included in the scope for transported 'dressed vessels' shall be subject to pipe stress analysis in the transported and lifting orientations. Pipe supports shall be provided to ensure nozzle loads, pipe stresses and pipe support designs are acceptable for these conditions.

12.13 Packaged Equipment

12.13.1 The VENDOR shall be responsible for determining the extent and execution of stress analysis for piping on standard skid mounted units / packages, for example, lube oil skids, seal gas conditioning skids, seal gas skids, pneumatic conveying system, etc.

12.13.2 Pipe stress analysis of VENDOR package piping shall consider all appropriate load cases and service conditions and meet the requirements of applicable code and standards.

12.13.3 When stress analysis is performed for packaged units, the VENDOR shall provide stress reports and native files of all stress analysis to COMPANY as part of the package documentation.

12.13.4 The allowable loads at the fixed points which is at, or near the tie-in point (Package / Skid battery limit) shall be agreed with the VENDOR.

12.13.5 The analysis of piping connected to vendor package equipment shall comply with VENDOR allowable nozzle loads as tabulated in APPENDIX A3. Otherwise, this shall be discussed and agreed between the package VENDOR and the CONTRACTOR.

12.14 Pressure Vessels and Shell and Tube Heat Exchangers

12.14.1 The stress analysis of piping to pressure vessels and shell and tube exchangers shall include all possible operating cases and combinations, including start-up, shutdown and steam-out.

12.14.2 The fixed end position of horizontal equipment, for example, exchangers and vessels, shall be determined by the stress engineer. The selection of the fixed end position shall consider minimising relative expansion and relative forces and moments between piping and the equipment nozzles.

12.14.3 Allowable Nozzle loads shall be in accordance with Appendix A3 of this specification.

12.15 Christmas Tree Equipment

12.15.1 Wellhead piping shall be subject to a formal piping stress analysis and satisfy the requirements of ASME B31.3.

12.15.2 Wellhead piping shall be designed for slug loads anticipated during the lifetime of the well.

12.15.3 The fundamental natural frequency, determined by modal analysis of wellhead flow lines, shall be greater of 4 Hz.

12.15.4 Wellhead piping shall be sufficiently flexible to absorb all of the following:

a. Vertical movement of the Christmas tree relative to the platform, the settlement of wells, and the settlement of the platform.

b. Horizontal movements of the Christmas tree relative to the platform, due to the conductor to guide clearance and conductor to wellhead clearance.

12.15.5 The effect of lift-off of the first support downstream of the wellhead / Christmas tree, due to thermal growth / contraction of the well piping, shall be included in the determination of loads and stresses.

12.15.6 First pipe support should be typically adjustable type (i.e. adjustable support) , to ensure that the wellhead piping is supported during operation and shutdown periods and that no lift-off occurs.

12.15.7 Christmas tree vertical growth shall be considered as follows unless otherwise specified by the project specifications.

a. Onshore Oil / Gas Producer wells: 50mm

b. All Offshore wells (Producers & Injectors): 75mm

c. Onshore Injection wells like Water Injector, Gas Injector and Water supply and Disposal wells: 25mm

12.15.8 Allowable nozzle loads for Christmas tree connections shall be in accordance with API TR 6AF and API TR AF2 or per Christmas tree VENDOR as applicable.

12.16 Articulated Joint

12.16.1 Any proposal to use any type of articulated joints, for example, expansion bellows or swivel joints, shall be presented to the COMPANY for review and approval prior to detailed design development as this is a non-preferred solution.

12.16.2 Piping flexibility shall be obtained through pipe routing or expansion loops unless process conditions, limitations of space dictate the use of flexible connectors. The use of articulated joints like expansion joint (bellows), swivel joints, etc. shall be minimized and if unavoidable, COMPANY approval is required

12.16.3 The arrangement of metallic expansion joints shall ensure that it is not possible for the convolutions to experience squirm or torsion.

12.16.4 The stress engineer shall discuss and agree with the VENDOR the selection, arrangement and suitability of metallic expansion joints and all applicable data shall be included in the design datasheet.

12.16.5 Piping with expansion joints shall be provided with guides and anchors to withstand forces generated by the internal pressure.

12.16.6 Where unbalanced forces may arise, due to uneven flow, expansion joints shall be installed with liners or internal sleeves, and with additional supports or anchors to protect the expansion joints.

12.16.7 The stress analysis shall comprehensively model the characteristics of the articulated joint assembly, including friction, in accordance with the issued datasheet.

12.16.8 Location of adjacent supports shall follow the recommendations in the EJMA standard.

12.17 Special Items

12.17.1 Stress engineer attention is required for Piping Speciality (SP) Items. Vendor details shall be incorporated to include specific features of these SP items into the stress model / calculations. These items may include project specific items and or the following:

a. Special valves
b. Flame arrestors
c. Filters / Strainers
d. Traps
e. Silencers
f. Level gauges
g. Ejector

12.17.2 The criticality of each SP item shall be the same as the criticality of the line in which it is installed.

13 SYSTEM CONSIDERATIONS

13.1 Stress Analysis of Flare and Relief System

13.1.1 Flare lines are often subject to AIV therefore require higher wall thickness, which shall be considered during analysis based on AIV studies and EI Guidelines.

13.1.2 Piping exposed to flare radiation: stress analysis accounts for the increase in temperature of the piping system due to flare radiation.

13.1.3 The pipe support arrangement for flare system piping, shall consider the presence of liquid in accordance with Table 13.1. However if these are hydro tested then the additional requirements stated in Section 9.5 shall be followed.

Note: The requirements in Table 13.1 are intended to calculate pipe support loads for structural design and to verify acceptability of the mid-span longitudinal stress.

Table 13.1 Presence of Liquid in Flare Lines

Header Dia.	Liquid
Up to NPS 10	Full
NPS 12 – NPS 16	half full
NPS 18 – NPS 36	1 / 3 full
NPS 38 and above	1 / 4 full

13.1.4 For weld testing, pneumatic and hydrostatic requirements, reference shall be made to the relevant project specific requirements.

13.2 Stress Analysis of Firewater Systems

13.2.1 Surge effects shall be considered on all firewater piping. Surge loads shall be specified by the Process and HSE groups.

Note: Surge forces occur in firewater systems principally at start up when sudden pump start-up, shutdown or rapid valve closure may cause pressure / flow unsteady condition.

13.2.2 A surge analysis shall be performed by process to determine surge pressure and to determine associated differential / unbalanced forces in piping which shall be included in the piping stress analysis.

13.2.3 A dynamic load factor DLF = 2 shall be applied to the unbalanced forces provided by the surge simulation from Process.

13.2.4 Maximum surge pressure shall meet the following criteria:

a. For FRP (GRE, GRP, etc.) Piping systems, surge pressure shall not exceed the design pressure and flange rating of fire water piping.

b. The joints of FRP piping including coupling joints if any shall be analysed for surge

13.2.5 Aboveground firewater systems shall be frequently supported with hold down supports and guides and with line stops to accommodate the unbalanced forces.

13.2.6 The pipe supports for dry deluge systems shall be designed to accommodate the forces resulting from pressurisation and liquid filling upon opening of the deluge valves and any consequent pressure surges.

13.3 Stress Analysis of Buried Piping

13.3.1 All buried pressurised metallic piping (6” and above) shall be subject to stress analysis which shall consider soil parameters as well as process maximum operating and design conditions.

13.3.2 For Buried piping, soil properties, depth of sand bed / soil over the pipes shall be agreed as part of stress analysis basis, prior to carrying out analysis.

13.3.3 Large cooling water pipes shall be assessed to prevent subsidence.

13.4 Stress Analysis of FRP Piping

13.4.1 The FRP (GRE GRP, etc.) piping VENDOR shall endorse or perform the design and stress analysis calculations for above and underground non-metallic piping systems in accordance with BS EN ISO 14692 Pt 3 and applicable COMPANY FRP specification

13.4.2 FRP Vendor/ Manufacturer or his qualified and experienced engineering service provider shall carry out the Stress Analysis of new GRE System by Caesar II software in line with ISO 14692-3, using the GRE mechanical properties supplied by manufacturer to ensure all forces, loads, moments and stresses are within allowable stress limits.

13.4.3 The flexibility and stress intensity factors for FRP pipe and fittings shall be as per ISO 14692 Part 3 Annex B.

13.4.4 The stress analysis shall use the allowable stress envelope for non-metallic pipe and fittings together with pipe span considerations based on FRP Manufacturer data.

13.4.5 Finite element analysis (using a recognized FE package approved by the COMPANY) of non-standard shapes or critical components as defined by the COMPANY shall be performed to demonstrate fitness for purpose as requested by the COMPANY

13.4.6 The stress analysis at interfaces between non-metallic / metallic piping materials shall include the metallic piping system up to the nearest anchor block, limit stop or other fixed points. The minimum forces and moments shall be maintained at the interface of FRP and Metallic pipes not to have any adverse effect on FRP part of piping.

13.4.7 FRP piping design and calculation documents shall be submitted for COMPANY review and approval prior to fabrication and subsequent activities. Refer Appendix A8 for Documents & Information required for FRP stress analysis

13.4.8 The surge loads and details like location etc. should be provided to the FRP VENDOR by the CONTRACTOR.

13.4.9 The FRP pipe system shall be evaluated and analysed for adequate flexibility and stress level in accordance with the following;

1. Prevention of thermal expansion or contraction which may cause;

   a. Failure of the pipe system or supports from over-stress or fatigue
   b. Excessive loads on connected equipment
   c. Leakage at joints
   d. Excessive stresses or distortion of pipes or valves
   e. Disengagement of pipe system from its supports.

2. The following applied loads shall be considered (if applicable);

   a. Design conditions, pressure, temperature
   b. Loads induced from connected equipment, supports, anchors, guides
   c. Dead loads due to pipe weight, valves, service fluid, insulation or other permanent loads
   d. Soil and traffic loads on buried pipe systems
   e. Hydrostatic test loads
   f. Thermal loads
   g. Frictional loads
   h. Environmental conditions, e.g. wind, seismic
   i. Vibrational loads
   j. Differential settlement
   k. Spring forces due to bellows
   l. Pressure relief valve reaction forces
   m. Water hammer or pressure surge forces Installation loads, e.g. transportation, erection etc.

3. All stress analysis calculations shall be based on the structural wall thickness only

4. Consideration shall be taken of startup, emergency shut down and any other dynamic loading situations

5. Consideration shall be taken of the interface with existing plant or lines and the relevant boundary conditions

6. Consideration shall be taken of the required project design lifetime

7. If the analysis determines that the flexibility of the FRP pipe system is insufficient

   a. Optimize/modify anchors, line stops or guides
   b. Change in pipe routing
   c. Expansion joints shall not be used and if used in utility system with prior approval with COMPANY after exhausting all options.

13.4.10 In addition to the above requirements, the following shall be considered in the analysis

a. For buried pipe the axial stress analysis shall include (according to AWWA M 45) thermal expansion/contraction, Poisson's effect, etc. If coupling joints (i.e. joints that do not transmit axial loads) are used then the axial loads from frictional resistance should be included
b. For above ground pipe the hoop stress analysis shall include internal pressure, hoop bending due to hoop deflection and pipe interactions with pipe supports
c. For above ground pipe the axial stress analysis shall include axial bending due to gravity, environmental loads, thermal loads, Poisson effect due to internal pressure and internal pressure induced effects at fittings
d. The axial pipe stress between anchors associated with axial forces due to Poisson effect due to internal pressure, thermal expansion/contraction loads. Also the interaction between the pipe and supports shall also be considered

13.5 Stress Analysis of HDPE Piping

13.5.1 The stress analysis of HDPE piping shall comply with the requirements of BS ISO 4427 and in line with AGES-SP-10-009 (High Density Polyethylene (HDPE) for Pipeline and Piping Systems

13.5.2 MANUFACTURER should submit a pipe stress analysis based on data belonging to the project specific operating conditions and to the actual HDPE material used. Also, the MANUFACTURER should submit the results of analyses e.g. finite element, confirming the adequacy of the design of components/fittings under dynamic (e.g. surge) loadings.

14 BROWNFIELD WORKS & TIE-INS

14.1 General

14.1.1 Piping stress analysis shall account for the stresses, displacements and pipe support locations of existing lines and determine how flexibility can be provided for new piping.

14.2 Tie-ins

14.2.1 The stress engineer shall participate in design discussions to determine the location of tie-ins to existing lines.

14.2.2 Tie-in locations close to equipment nozzles shall be avoided.

14.2.3 Wherever feasible, a tie-in to an existing header shall be located close to an existing axial stop to minimise the displacements imposed on the new pipe.

14.2.4 The extent and scope of modelling of existing piping integrated with new pipe system shall be up to the nearest stress isolation boundary like axial stop / anchor and the same shall be agreed with COMPANY.

14.2.5 The CONTRACTOR shall ensure, stress analysis of tie-in or modified existing piping complies with all ASME B31.3 code requirements and that load, deflection and other criteria meet the requirements of this specification.

14.2.6 The stress analysis of the existing sections of the tie-in arrangement shall take into consideration the version of ASME B31.3 applicable at the time of the original design. Any non-compliance issue with respect to existing and new system shall be discussed and agreed with the COMPANY

14.2.7 The stress analysis of tie-in piping shall consider the existing pipe stress analysis and associated stress sketch information, where available. This shall include the following:

a. Piping geometry
b. Pipe support functions and gaps
c. Operational functionality according to assumptions in the stress analysis (for example, no uncontrolled lift off).
d. Whether the loads and spring rates of existing spring supports require modification.
e. Existing and new springs and other purchased item tag numbers shall be recorded on the new stress sketch.
f. Tie-in numbers should be identified in the stress model as a "Node name".
g. If a tie-in location and / or associated piping is included within two different models, stress reports shall be cross referenced.

14.2.8 Where existing piping or stress analysis details are unavailable the CONTRACTOR shall create a new CAESAR II analysis file. The new analysis shall accurately model the existing system and support functionality and suitability for the addition of new lines and the tie-in piping. This will require site surveys and obtaining of existing wall thicknesses by inspection if not available. The CONTRACTOR shall ensure all the relevant data on existing lines including any site information related to the stress analysis of tie-in's or modifications to existing piping are included in the related stress analysis report.

15 OFFSHORE PIPING

15.1 General

15.1.1 The stress analysis of piping for offshore installations requires additional considerations additional to those for onshore facilities.

15.1.2 The piping stress analysis for offshore installations in addition to static thermal, sustained and occasional cases shall include the effects of wave induced accelerations, build and transportation and differential structural displacements.

15.1.3 Piping systems shall be designed based on criticality listed in accordance with section 7.

15.1.4 Stress sketches for offshore installations shall specifically note the maximum calculated movements at all platform and deck penetrations.

15.2 Fixed Structure Production Facilities

15.2.1 Transit from the production yard shall consider the following:

a. During lifting and load out operations the structural deflections of a module are likely to differ from the displacements which will occur during operation. The stress analysis of piping shall assess the effect of these differences. These differential structural deflections are different to the effects which may occur due to live load variations.

b. The piping within skid and modules which are mounted to fixed platform topsides shall be designed for the effects of the horizontal and vertical, wave induced accelerations resulting from barge motions during all transit stages.

c. The relevant operating conditions during transit of piping within skids, modules and topsides shall be included within the stress analyses.

15.2.2 Temporary pipe supports required for transit stages shall be identified and included on associated stress sketches. Particular attention shall be made to lines which are partially disconnected which therefore may not be fully stable without additional transit supporting.

15.3 Deck Deflection Effects

15.3.1 Pipe support locations relative to equipment shall consider deck deflection at pipe support locations. Deck deflections will vary, depending on the loads and the stiffness of the individual structure's platform / module and shall be provided by the Structural group. Particular attention shall be paid to relative structural deflections and included in the piping design, stress analysis and pipe supporting arrangement.

15.3.2 Pipe supports may be located in two different locations relative to the equipment as follows.

a. Preferred solution - Pipe supported from same deck as equipment (simplest arrangement which minimises the effects of differential structural movements).

b. Non-preferred solution - Pipe supported from different deck as equipment (more complex piping design, pipe stress and pipe support arrangements).

For pipe supported from the same deck as equipment (as shown in

15.3.3), structural deflections of pipe support attachments due to the following shall be evaluated and included in the analysis where applicable.

a. Live Loads

b. Wave induced loads acting on substructure

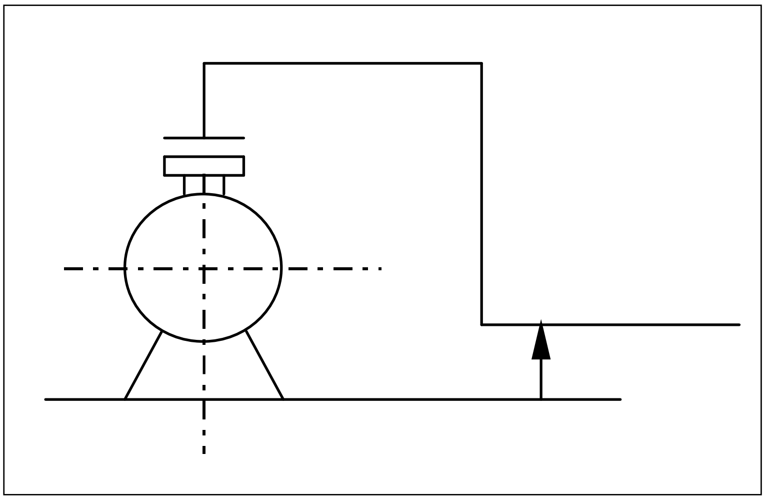


Figure 15.1 Pipe supports from same deck as Equipment

15.3.4 For pipe supported from different deck to equipment (as shown in **Figure 15.2**), the live load deck deflections will vary at the different elevations and the difference in the deflections shall be considered.

Note: Piping flexibility will be required to compensate for the relative deflections.

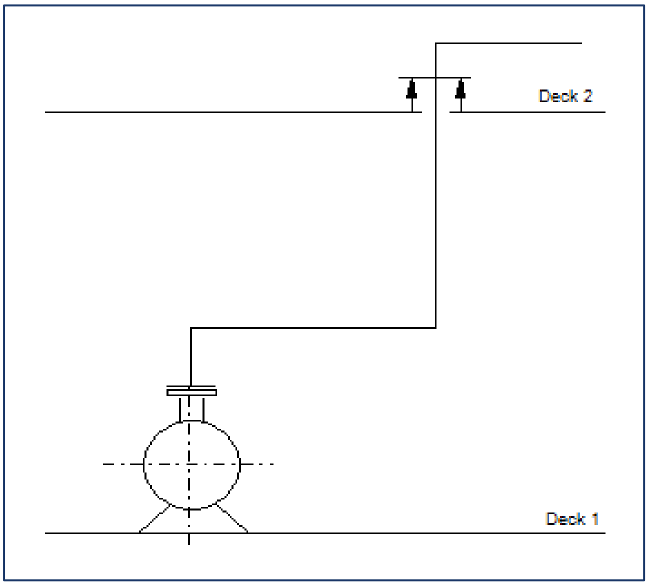


Figure 15.2 Pipe supports from different Deck to Equipment

15.4 Penetration and Pipe Movements

15.4.1 Generally, the pipe movement in penetration seals shall be kept within the following limits:

a. ±20 mm lateral.

b. ±35 mm axial.

15.4.2 If the above requirements cannot be met and where sealing is required, a more flexible seal shall be used. Global position of this special penetration including the actual movement of pipe shall then be issued to the structure department for wall and deck penetrations.

15.5 Offshore Flare

15.5.1 It is common practice to support the weight of the off-shore flare tip and flare line within boom tower close to the base of the flare structure, allowing thermal effects in the piping to displace the flare tip axially. This may not be possible in the case of a combined high and low pressure flare tip with two independent inlet lines. The interaction of both on the flare tip and supports must then be considered. It may be necessary to anchor both lines immediately below the combined flare tip and provide flexibility in the piping below.

15.5.2 The following conditions shall be considered for the piping located in the flare tower.

a. Structural deflections in the flare tower - The Flare tower deflections must be obtained from the Structural group. Differential deflections between support points to be considered. Wind and ice formation (if applicable) shall be considered.

b. Jet-thrust from the flare tip – The jet reaction force created by the flare tip must be obtained from the flare tip VENDOR.

15.5.3 Where significant thermal movement of the flare tip is likely, connected igniter, pilot lines etc. must be designed accordingly. Small-bore lines must be checked for susceptibility to vortex shedding induced vibration.

15.6 Riser Analysis

15.6.1 The topsides piping stress section shall model riser piping from interface flange at code break between ASME B31.3 / ASME B31.8 or ASME B31.3 / ASME B31.4 or ASME B31.3 / DNVGL-ST-F101 as applicable. An anchor shall be provided local to the interface flange in ASME B31.3 scope of piping.

15.6.2 There will normally be an overlap in analysis by the topside sections and Pipelines group of risers, associated piping and receivers or launchers.

15.6.3 The topsides piping stress analysis model shall include ASME B31.8 / B31.4 / or DNVGL-ST-F101 (Typical) scope of pipe to riser dead weight support. Although the responsibility of the B31.8 piping is pipeline scope for realistic analysis boundary conditions line shall be modelled to riser dead weight support. This dead weight support should be modelled as a full anchor for ASME B31.3 topside stress analysis. The Pipelines group shall include piping up to the launcher or receiver in their model.

15.6.4 In reality the dead weight support is a rest together with a two-direction guide with additional all round guides on the subsea section of the line. The responsibility for analysis of this line is both subsea and pipelines group hence simplified approach for topside piping anchored at dead weight support.

15.6.5 The piping stress section shall issue to the Pipelines Department a stress isometric indicating location and type of restraints required for the topsides portion of the riser.

15.6.6 For confirmation, the pipelines group shall provide a copy of their isometric indicating similar locations prior to analysis.

15.6.7 Subsequent to their analysis the Pipelines Department shall issue to the piping stress section their approved stress isometric of the riser plus topsides piping together with a summary stress report for all load cases considered. This report must contain at least the following:

a. Maximum calculated stresses with corresponding Design Code compliance allowable stresses

a. Forces and moments at topsides supports (restraint loads)

b. Forces and moments at flange connections and butt weld valves (data points located at butt welds)

c. A statement of acceptance of data supplied by the Piping Stress group.

15.7 Offshore Bridge Piping Analysis

15.7.1 On projects where two platforms are connected by a bridge, the two substructures will move independently due to exposure to wave, current and wind loadings. The two substructures will be independently exposed to wave, current and wind loadings. The routing of piping along the bridge shall be analysed to include sufficient flexibility for process conditions, imposed occasional loads and for repeated differential structural movements.

15.7.2 The structural solution by which the relative movements between the platforms are accommodated, shall be discussed and agree with the Structural group.

15.7.3 The bridge structural solution will normally be achieved in two ways each of which have different piping solutions as follows:

a. The bridge piping may be anchored on the sliding end of the bridge as shown in Figure **15.3**. The thermal expansion will then be absorbed on the fixed end side.

b. The bridge piping may be fixed at both ends with expansion loops on the bridge to absorb the thermal expansion as shown in Figure **15.4**.

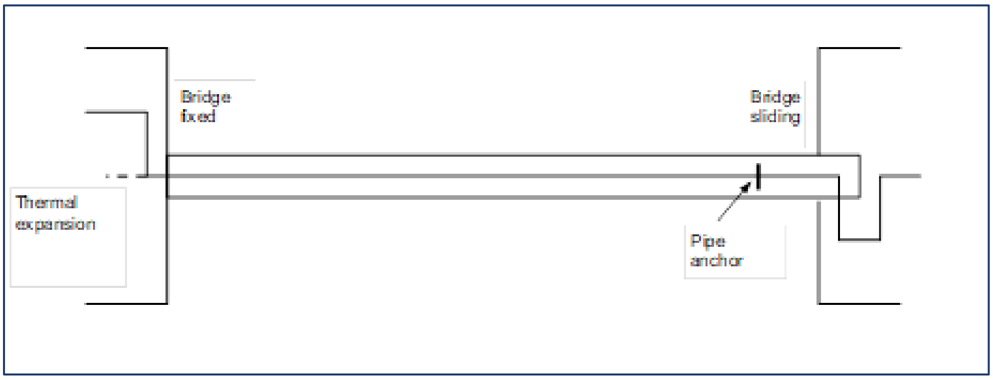


Figure 15.3 Piping anchored on the sliding end

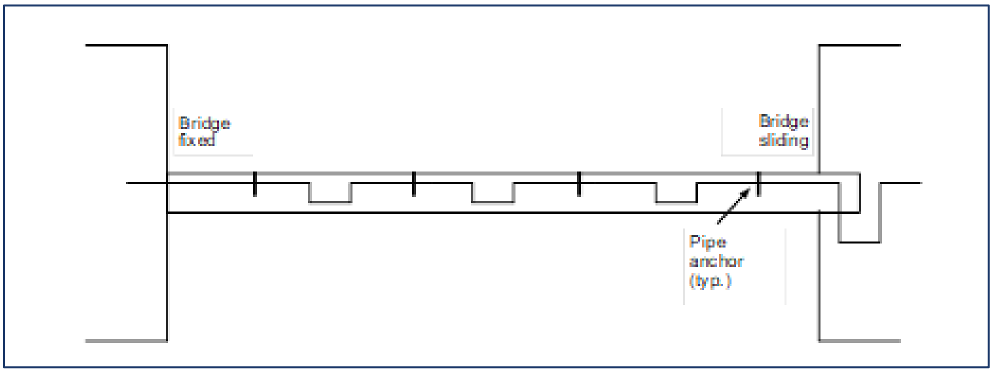


Figure 15.4 Piping anchored at both ends

15.8 Offshore Bridge Fatigue Analysis

15.8.1 A fatigue analysis shall be performed to determine the effects on piping routed across a bridge. The fatigue analysis shall consider all the factors which will contribute to the life of all bridge piping.

15.8.2 Friction at pipe supports shall be included especially when considering relatively piping of small diameter small deflections resulting from smaller wave heights and smaller diameter pipes. It may be the case that the force imposed at the bridge end is insufficient to cause the entire loop to move, effectively reducing the loop size. This has the effect of introducing non-linearity and increasing stress local to the bridge.

15.8.3 The fatigue assessment shall be determined with consideration of waves over a one-year period. This will then be translated to the number of designated years or life for the facility.

15.8.4 A fatigue analysis shall be performed to determine the effects on piping routed across a bridge. The fatigue analysis shall consider all the factors which will contribute to the life of all bridge piping.

15.8.5 The CONTRACTOR shall provide a detailed method of bridge piping fatigue assessments to COMPANY for approval before commencing work.

15.8.6 The fatigue assessment shall be determined with consideration of effect of waves and effects of all other contributions of pipe stresses over the life of the facility.

15.8.7 Piping wall thickness values after the corrosion allowance has been deducted shall be used when evaluating fatigue stresses.

15.9 Green Water Loadings

15.9.1 In lower levels of offshore installations, loads on piping may occur where subjected to submerging in water and subject to wave impact. This force may be significant and greater than blast loadings. The forces on the pipe resulting from drag, inertia and slamming shall be determined by the CONTRACTOR for individual lines and the variables associated for each project.

16 FEED PROJECT STRESS ANALYSIS - MINIMUM REQUIREMENTS

16.1 General

16.1.1 The details provided in this section shall be used to define the piping stress activities carried out in FEED (or basic engineering project stage) unless otherwise required and defined by the project scope of work.

16.1.2 The piping stress work is envisaged to be carried out during FEED stage will not be to a detailed engineering level due to the absence of key information, including vendor details.

16.1.3 The established FEED studies shall normally require piping materials, pipe routing, and pipe support arrangements in conjunction with structural design studies, process function, and mechanical agreements/specifications in order to demonstrate multi-disciplinary feasibility of the layout consistent with the achievement of equipment nozzle loadings agreed with potential equipment Vendors.

16.1.4 At FEED stage, a particular attention shall be given to design the most critical piping routing in a proper way to allow good flexibility using preliminary stress analysis as necessary and to avoid any major changes during the detailed engineering stage

16.2 Stress Analysis

16.2.1 The stress analysis shall include the following:

a. Development of the critical line list to identify the lines for which stress calculations are carried out during FEED and finalised when issued process information becomes available during the Engineering phase.

b. Stress analysis calculations and assessments of piping which are critical to the development of the overall plant layout (see below).

c. Stress analysis of all piping within tie-in scope to the level of detail required by the scope of work.

d. Definition of anchor points on pipe racks and the positions and number of expansion loops required.

Note: This work will be in conjunction with piping and civil / structural groups to develop major structures.

16.2.2 Unless otherwise required by the project scope, the following lines shall be analysed:

a. All lines connected to compressors, turbines and high pressure pumps

b. Lines NPS 18 and larger

c. Piping in AIV service

d. All Flare headers

e. Lines affected by wellhead displacement growth (50mm or more)

f. Lines which will be affected by significant deck or platform deflections and / or settlement

g. Lines with oblique connections

h. Lines with expansion bellows

i. Piping which will require to have a fundamental Natural Frequency equal and greater than 6 Hz

j. FRP lines larger than a NPS 6 unless specified otherwise for a project

k. All critical tie-in related lines larger than NPS 6

l. Lines assessed to be likely subject to slug flow.

m. Lines subject to dynamic pressure (ρv^2) exceeding the criteria specified in EI guidelines

n. Lines subject to the calculation of dynamic pressure (ρv^2) for which the stiff or medium stiff requirement for the support arrangement as defined by the process study cannot be implemented due to space constraint or due to the need of flexibility

SECTION C – OTHER REQUIREMENTS

17 QUALITY ASSURANCE

17.1 General

17.1.1 All activities and services associated with the scope of this Document shall be performed by CONTRACTOR / Consultant approved by COMPANY.

17.1.2 The CONTRACTOR / Consultant shall have an established Quality Management Systems (QMS) within his / her organization, which ensures that the requirements of this Document are fully achieved.

17.1.3 The CONTRACTOR / Consultant Quality Management System shall be based on COMPANY Specifications and the latest issue of ISO 9001 Series that is accredited by an international certifying agency.

17.1.4 The CONTRACTOR / Consultant's Quality Manual shall provide details for the preparation of a Quality Plan, which shall include provisions for the QA / QC of services activities.

17.1.5 Where an approved CONTRACTOR / Consultant revises their Quality Management System that affect the COMPANY approved Quality, then the revised Quality Plan shall be submitted for COMPANY approval before initiating any service activities.

17.1.6 The effectiveness of the CONTRACTOR / Consultant's Quality Management System may be subject to monitoring by COMPANY or its representative and may be audited following an agreed period of notice.

17.1.7 The CONTRACTOR / Consultant shall make regular QA audits on all their Sub- CONTRACTORs / SUPPLIERs / Vendors in compliance with ISO-9001. Details of these audits shall be made available to COMPANY when requested.

17.1.8 The CONTRACTOR / Consultant shall maintain sufficient Inspection and Quality Assurance staff, independent of the service provider management, to ensure that the QMS is correctly implemented and that all related documentation is available.

17.1.9 Using Sub-CONTRACTORs is not allowed for services / functions carried out by a CONTRACTOR / Consultant without prior approval from COMPANY.

17.2 Quality Plan

17.2.1 The CONTRACTOR's Quality Manual shall provide details for the preparation of a Quality Plan, which shall include provisions for the QA / QC of services activities. The Quality Plan shall be submitted to COMPANY for approval. Moreover, in case of any revision in the Quality Plan due to change in Quality Management System, then the revised QP shall be submitted for COMPANY approval before initiating any service activities.

17.2.2 The level of detail required in the Quality Plan shall be commensurate with the scope of services provided.

17.2.3 The quality of works is an essential factor in carrying out all services and activities covered by this Document.

17.2.4 During services / activities, Quality Assurance / Quality Control issues are the responsibility of the CONTRACTOR and shall be approved and certified by the Third Party Agency (TPA).

17.2.5 All Conflicts among CONTRACTOR, MANUFACTURER and TPA shall be reported in writing to COMPANY for resolution.

17.3 Inspection and Certification Requirements

17.3.1 Inspection and certification requirements for material shall be based on COMPANY Standards and BS EN 10204.

17.4 Piping Stress Technical Assurance Audits

17.4.1 Technical Assurance Audits shall be carried out to confirm the work process, accuracy of technical data and quality of piping stress work / calculations is in adherence to project scope requirements, deliverables and associated CONTRACTOR's procedures.

17.4.2 Audits shall be carried out throughout each project execution to suit the nature, complexity and duration of each project. However, the audit schedule, content, and timing shall be discussed and agreed with COMPANY.

17.4.3 Technical audits shall be prepared under the direction of senior members of the CONTRACTOR's engineering team.

17.4.4 Technical audits shall include the work carried out on a project by all contributing offices and locations.

17.4.5 The technical auditor shall be assigned by CONTRACTOR's Piping department management and shall not be someone who has worked on the project.

17.4.6 Technical audits are separate from the Project Quality Audits performed by the Project Quality Manager.

17.4.7 The report shall identify the extent of the review while highlighting items audited, general comments, and corrective actions. The audit report shall be approved by the CONTRACTOR's Piping department manager.

17.4.8 The project piping and stress engineering technical leads on the project shall be responsible for implementing the required corrective actions as required by the audit report findings.

17.4.9 A copy of the audit report clarifying that all corrective issues have been closed out shall be issued to the Piping department manager, Project Quality manager and Engineering manager.

17.4.10 Project related corrections shall be completed under the direction of the project piping lead. This person shall resolve any findings very quickly to minimize the effect that any shortcomings would have on work in progress.

SECTION D – STANDARD DRAWINGS AND DATASHEETS

‘Not applicable.

SECTION E - APPENDICES

APPENDIX A1. CRITICAL LINE LIST (CLL) - REQUIRED CONTENTS

The Critical Line list shall be created using a combination of information contained in the Process Line List and the reasons for stress criticality described in Section 7 of this Specification. Therefore, the critical line list shall be formed using both information in an Excel file. Intelligent conditional formatting may be used to cross relate information to automatically derive the criticality level and highlight the reasons which justify that conclusion. The below requirement is considered as comprehensive and optimisation may be acceptable on project specific requirements and shall be agreed with COMPANY

LOCATION AND TYPE INFORMATION

UNIT

AREA

PIPE SIZE

LINE NUMBER

FROM

TO

PIPE CLASS

SERVICE

P&ID NUMBER

PROCESS CONDITIONS

1. DESIGN TEMP (°C)
   a. Max
   b. Min
2. OPERATING TEMP (°C)
   a. Max
   b. Upset
   c. Min
3. DESIGN PRESS (barg)
   a. Max
   b. Min
4. OPERATING PRESS (barg)
   a. Max
   b. Min
5. OTHER CONDITIONS
   a. Steam Out
   b. Fluid Phase (single or two phase)

6. DENSITY

PIPE CONDITIONS

1. DESIGN CODE
2. FLUID CATEGORY
3. PIPE WALL
4. PWHT
5. INSUL TYPE
6. INSUL THK. (mm)
7. FULL VACUUM
8. TEST CONDITION
    a. PRESS (barg)
    b. MEDIUM

CALCULATION REGISTER

1. ANALYSIS FILE NAME
2. REVISION
3. ORIGNATOR
4. CHECKED
5. APPROVED
6. REMARKS

OVERALL CRTICALITY RATING

1. LEVEL 1: COMPREHENSIVE ANALYSIS
2. LEVEL 2: SIMPLIFIED ANALYSIS
3. LEVEL 3: VISUAL ANALYSIS

ANALYSIS CARRIED OUT

1. STATIC CODE
2. OCCASIONAL
3. BLOW DOWN
4. DYNAMIC Type
5. SURGE / SLUGGING

6. FLANGE LEAKAGE
7. FATIGUE
8. FEA

PIPE CRITERIA

1. SEE Table 7.1 Criteria for Flexibility Analysis of Piping.
2. NPS >=4 AND PRESSURE RATING >= 900#
3. DESIGN TEMP. < MINUS 30°C AND OPERATING TEMP < 5°C
4. EXOTIC MATERIALS
5. NON-METALLIC
6. TEMP > 427°C
7. D / T > 100

SERVICE CRITERIA

1. PUMPS
2. COMPRESSORS
3. TURBINES
4. BLOWERS
5. LINES TO AND FROM REACTORS AND PROCESSHHEATERS
6. 4" >= CONNECTED TO AIR COOLERS PLATED HEAT EXCHANGERS and SHELL AND TUBE)
7. OTHER SENSITIVE EQUIPMENT (VESSELS / TANKS)
8. CONNECTED TO EQUIPMENT AND SUBJECT TO STEAM OUT
9. BOILER FEED WATER AND STEAM LINES TO AND FROM BOILERS AND STEAM GENERATORS
10. WELLHEAD / XMAS TREE

OTHER CRITERIA

1. 2 PHASE FLOW, SURGE, BLOW DOWN LINES
2. SUPERHEATED STEAM
3. VACUUM LINES
4. RELIEF SYSTEMS
5. JACKETED LINES
6. EXPOSED TO FLARE RADIATION

7. TOXIC CATEGORY 'M' SERVICE
8. SEVERE CYCLIC SERVICE
9. SUBJECT TO FATIGUE
10. AIV SERVICE (IN EPC)
11. THERMAL BOWING

Note : Brace / Gussets support requirement for small bore lines in critical service (as defined in Piping Design Basis AGES-SP-09-001 Appendix A4) shall be indicated in the Critical line list

APPENDIX A2. STANDARD CAESAR II SETUP FILE TEMPLATES

Listed below are examples of CAESAR II® 'CONFIG' file and 'SPECIAL EXECUTION' settings. These should be carefully reviewed in each project.

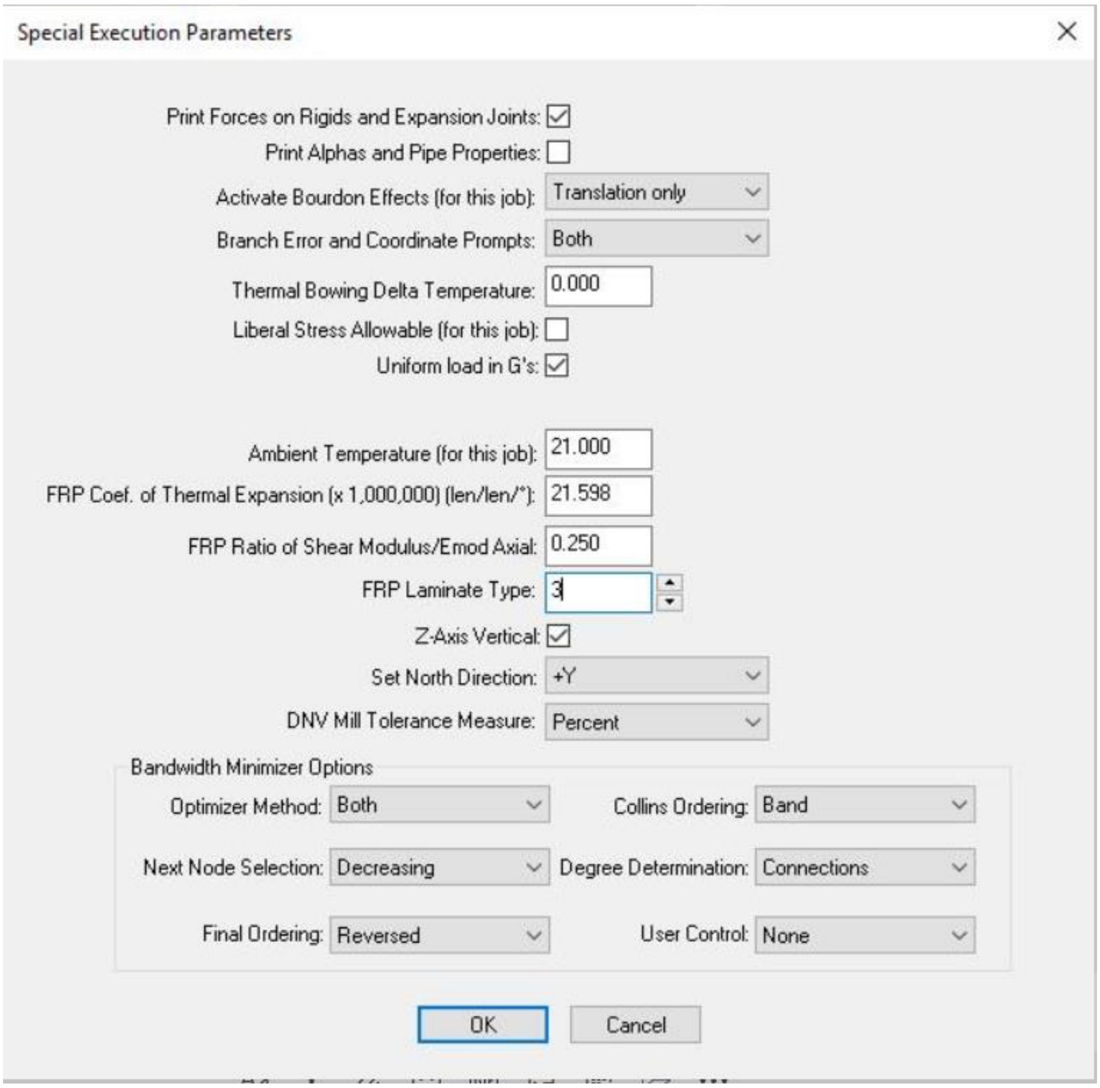
CAESAR II® SAMPLE 'CONFIG' FILE Based on Version 11			
EGAMEMORY =	128K	10	
CONNECT_GEOMETRY_THRU_CNODES =	YES	34	1.
MIN_ALLOWED_BEND_ANGLE =	0.5000000E+01	36	
MAX_ALLOWED_BEND_ANGLE =	0.9500000E+02	37	
BEND_LENGTH_ATTACHMENT_PERCENT =	0.1000000E+01	38	
MIN_ANGLE_TO_ADJACENT_BEND_PT =	0.5000000E+01	39	
LOOP_CLOSURE_TOLERANCE =	0.1000000E+01	42	
THERMAL_BOWING_HORZ_TOLERANCE =	0.1000000E-03	92	
AUTO_NODE_NUMBER_INCREMENT=	0.1000000E+02	109	
Z_AXIS_UP=	NO	129	1.
USE_PRESSURE_STIFFENING =	DEFAULT	65	2.
ALPHA_TOLERANCE =	0.5000000E-01	33	
RESLD-FORCE =	NO	44	0.
HGR_DEF_RESWGT_STIF =	0.1000000E+13	49	
DECOMP_SNG_TOL =	0.1000000E+11	50	
BEND_AXIAL_SHAPE =	YES	51	1.
FRICT_STIF =	0.1000000E+07	45	
FRICT_NORM_FORCE_VAR =	0.1500000E+00	47	

FRICT_ANGLE_VAR =	0.1500000E+02	48	
FRICT_SLIDE_MULT =	0.1000000E+01	46	
ROD_TOLERANCE =	0.1000000E+01	59	
ROD_INC =	0.2000000E+01	58	
INCORE_NUMERICAL_CHECK =	NO	60	0.
OUTCORE_NUMERICAL_CHECK =	NO	61	0.
DEFAULT_TRANS_RESTRAINT_STIFF=	0.1000000E+13	98	
DEFAULT_ROT_RESTRAINT_STIFF=	0.1000000E+13	99	
IGNORE_SPRING_HANGER_STIFFNESS =	NO	100	0.
MISSING_MASS_ZPA =	EXTRACTED	101	1.
MIN_WALL_MILL_TOLERANCE =	0.1250000E+02	107	
WRC-107_VERSION =	MAR_79_1B1 / 2B1	119	3.
WRC-107_INTERPOLATION =	LAST_VALUE	120	1.
DEFAULT_AMBIENT_TEMPERATURE=	0.7000000E+02	135	
BOURDON_PRESSURE=	NONE	136	1.
COEFFICIENT_OF_FRICTION_(MU) =	0.3000000E+00	140	
INCLUDE_SPRG_STIF_IN_HGR_OPE =	NO	141	0.
INCLUDE_INSULATION_IN_HYDROTEST =	NO	147	0.
REDUCED_INTERSECTION =	B31.1(POST1980)	32	1.
USE_WRC329	NO	62	0.
NO_REDUCED_SIF_FOR_RFT_AND_WLT	NO	53	0.
B31.1_REDUCED_Z_FIX =	YES	54	1.

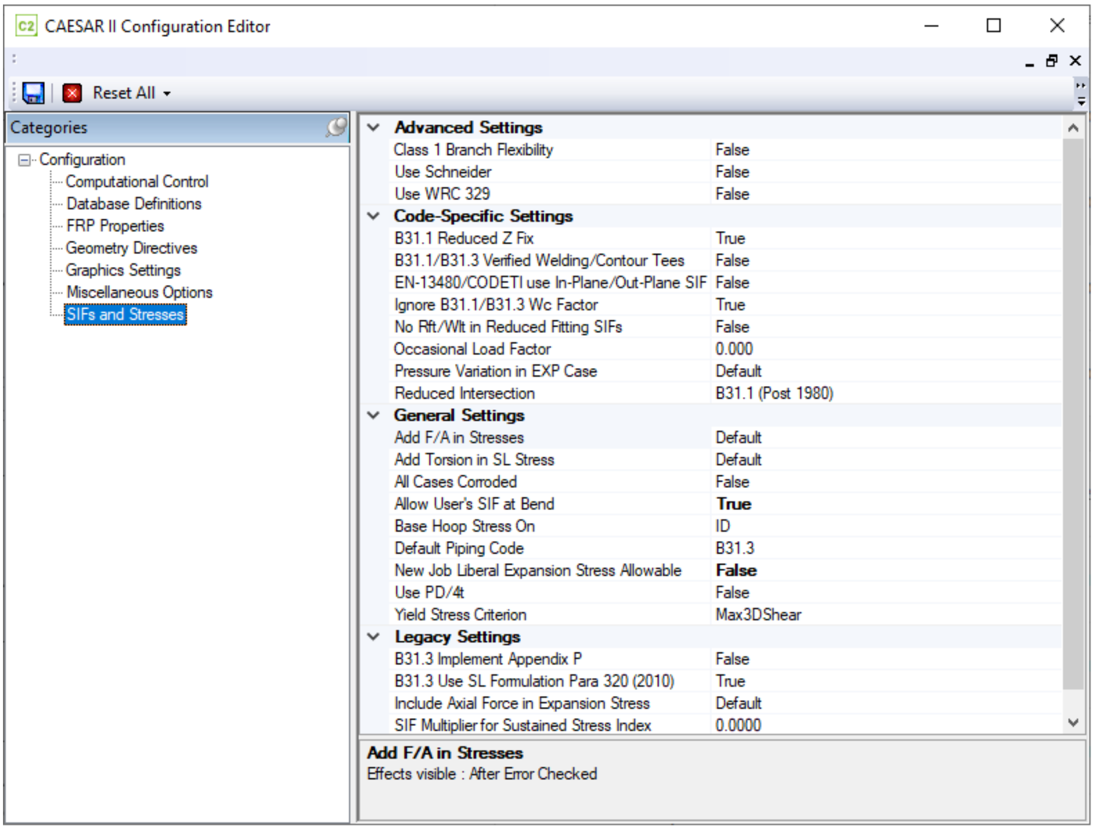
CLASS_1_BRANCH_FLEX	NO	55	0.
ALL_STRESS_CASES_CORRODED =	NO	35	0.
ADD_TORSION_IN_SL_STRESS =	DEFAULT	66	2.
ADD_F / A_IN_STRESS =	DEFAULT	67	2.
OCCASIONAL_LOAD_FACTOR =	0.0000000E+00	41	
DEFAULT_CODE =	B31.3	43	3.
B31.3_SUS_CASE_SIF_FACTOR =	0.0000000E+00	40	
ALLOW_USERS_BEND_SIF =	NO	52	1.
USE_SCHNEIDER	NO	63	0.
YIELD_CRITERION_STRESS =	MAX_3D_SHEAR	108	0.
USE_PD / 4T	NO	64	0.
BASE_HOOP_STRESS_ON_? =	ID	57	0.
EN13480_USE_IN_OUTPLANE_SIFS=	NO	133	0.
LIBERAL_EXPANSION_ALLOWABLE=	NO	137	0.
B31.3_SEC_319.2.3C_SAXIAL=	Default	146	3.
B31.3_WELDING / CONTOUR_TEE_ISB16.9	FALSE	139	0.
PRESSURE_VARIATION_IN_EXP_CASE=	DEFAULT	143	2.
IMPLEMENT_B313_APP-P	NO	144	0.
IMPLEMENT_B313_CODE_CASE_178	YES	145	1.
IGNORE_B31.1 / B31.3_Wc_FACTOR=	YES	148	1.
USE_FRP_SIF =	YES	110	1.
USE_FRP_FLEX =	YES	111	1.

BS_7159_Pressure_Stiffening=	Design_Strain	121	1.
FRP_Property_Data_File=	CAESAR.FRP	122	1.
FRP_Emod_(axial) =	0.3200000E+07	113	
FRP_Ratio_Gmod / Emod_(axial) =	0.2500000E+00	114	
FRP_Ea / Eh*Vh / a =	0.1527300E+00	115	
FRP_Laminate_Type =	THREE	116	3.
FRP_Alpha =	0.1200000E+02	117	
FRP_Density =	0.6000000E-01	118	
EXCLUDE_f2_FROM_UKOOA_BENDING =	NO	134	0.
INTRO_EXIT_SCREENS	ON	85	1.
YES / NO / ARE_YOU_SURE_PROMPTS	ON	86	1.
OUTPUT_REPORTS_BY_LOAD_CASE	YES	87	1.
DISPLACEMENT_NODAL_SORTING	YES	89	1.
DYNAMIC_INPUT_EXAMPLE_TEXT	MAX	94	0.
TIME_HIST_ANIMATE	YES	104	1.
OUTPUT_TABLE_OF_CONTENTS	ON	105	1.
INPUT_FUNCTION_KEYS_DISPLAYED	YES	106	1.
ENABLE_AUTOSAVE	YES	130	1.
AUTOSAVE_TIME_INTERVAL	0.3000000E+02	131	
PROMPTED_AUTOSAVE	YES	132	1.
DISABLE_UNDO / REDO	NO	128	0.
STRCT_DBASE=	AISC89.BIN	70	1.

VALVE_and_FLANGE=	CADWORX.VHD	90	1.
EXPANSION_JT_DBASE=	FLEXPATH.JHD	91	1.
PIPING_SIZE_SPECIFICATION	ANSI	88	1.
DEFAULT_SPRING_HANGER_TABLE=	0.1600000E+02	112	
SYSTEM_DIRECTORY_NAME=	SYSTEM	123	1.
UNITS_FILE_NAME=	USER.FIL	124	0.
ENABLE_ODBC_OUTPUT=	NO	125	0.
APPEND_RERUNS=	NO	126	0.
LOADCASE_TEMPLATE=	LOAD.TPL	142	1.
Valve / Flange_Dbase_File_Location=	CAESARII / CWX	149	2.
User_Material_File_Name=	UMAT1.UMD	150	1.
ODBC_DATABASE_NAME=	<none>	127	0.



Special Execution Parameters
Print Forces on Rigids and Expansion Joints:
Print Alphas and Pipe Properties:
Activate Bourdon Effects (for this job):
Translation only
Branch Error and Coordinate Prompts:
Both
Thermal Bowing Delta Temperature:
0.000
Liberal Stress Allowable (for this job):
Uniform load in G's:
Ambient Temperature (for this job):
21.000
FRP Coef. of Thermal Expansion (x 1,000,000) (len/len/°):
21.598
FRP Ratio of Shear Modulus/Emod Axial:
0.250
FRP Laminate Type:
3
Z-Axis Vertical:
Set North Direction:
+Y
DNV Mill Tolerance Measure:
Percent
Bandwidth Minimizer Options
Optimizer Method:
Both
Collins Ordering:
Band
Next Node Selection:
Decreasing
Degree Determination:
Connections
Final Ordering:
Reversed
User Control:
None
OK
Cancel



CAESAR II Configuration Editor
Reset All
Categories
Configuration
Computational Control
Database Definitions
FRP Properties
Geometry Directives
Graphics Settings
Miscellaneous Options
SIFs and Stresses
Advanced Settings
Class 1 Branch Flexibility False
Use Schneider False
Use WRC 329 False
Code-Specific Settings
B31.1 Reduced Z Fix True
B31.1/B31.3 Verified Welding/Contour Tees False
EN-13480/CODETI use In-Plane/Out-Plane SIF False
Ignore B31.1/B31.3 Wc Factor True
No Rft/Wlt in Reduced Fitting SIFs False
Occasional Load Factor 0.000
Pressure Variation in EXP Case Default
Reduced Intersection B31.1 (Post 1980)
General Settings
Add F/A in Stresses Default
Add Torsion in SL Stress Default
All Cases Corroded False
Allow User's SIF at Bend True
Base Hoop Stress On ID
Default Piping Code B31.3
New Job Liberal Expansion Stress Allowable False
Use PD/4t False
Yield Stress Criterion Max3DShear
Legacy Settings
B31.3 Implement Appendix P False
B31.3 Use SL Formulation Para 320 (2010) True
Include Axial Force in Expansion Stress Default
SIF Multiplier for Sustained Stress Index 0.0000
Add F/A in Stresses
Effects visible : After Error Checked

APPENDIX A3. EQUIPMENT ALLOWABLE LOAD TABLES

Unless the Manufacturer / Supplier can submit documented design analysis or validation test that higher loads / moments can be tolerated, allowable loads and moments on equipment nozzles shall [PSR] be in accordance with the relevant section of the associated standards for the equipment listed below.

The initial pipe stress analysis shall be carried out using the standard allowable loads / moments from the applicable standards. Subsequent verification for the final analysis shall be done in consultation with the Manufacturer / Supplier.

For equipment not listed below, allowable loads and moments shall [PSR] be followed in accordance with vendor specified values.

STATIC EQUIPMENT AND PACKAGES				
Equipment	**Applicable Standards**	**AGES Specification**	**Allowable Load**	**Remarks**
Pressure Vessels		AGES-SP-06-001 & AGES-SP-06-002	• Refer to AGES-SP-06-001 Appendix 2 • ≤ 24” use Table A2-2 • > 24” to be agreed with VENDOR	
Shell and Tube Heat Exchangers	API 660	AGES-SP-06-001 & AGES-SP-06-003	• Refer to AGES-SP-06-001 Appendix 3 • ≤ 24” use API 660 Table 2 • >24” To be agreed with Vendor	
Air-Cooled Heat Exchangers	API 661	AGES-SP-06-001 & AGES-SP-06-004	• Refer to AGES-SP-06-001 Appendix 5 • 2 times values in API 661 Table 4	
Plate Frame Heat Exchangers	API 662	AGES-SP-06-001 & AGES-SP-06-012	• Refer to AGES-SP-06-001 Appendix 4 • Standard service use API 662 table 1 • Offshore applications and pre-assembled modules and severe service use API 662 table 2	
Fired Heaters for General Refinery Service	API 560	AGES-SP-06-001 & AGES-SP-06-007	• Tubes: API 560 Figure 4 and 2 x values in Table 6 and 7 • Manifolds: API 560 Figure 5 and 2 x values in Table 8 and 9	
Welded Storage Tank (API 650)	API 560	AGES-SP -06-005	• API 650 Annex P.	
Pressurized and refrigerated storage tanks	-	-	• To be agreed with VENDOR	
Rectangular tanks	-	-	• To be agreed with VENDOR	

ROTATING EQUIPMENT				
Equipment	**Applicable Standards**	**AGES Specification**	**Allowable Load**	**Remarks**
Centrifugal Pumps	API 610	AGES-SP-05-001	• 2 x values in API 610 Table 5	API 610 clause 6.5
Rotary Positive Displacement Pumps	API 676	-	• 1 x values in API 676 Table 2	API 676 clause 6.7
Reciprocating Positive Displacement Pumps	API 674	-	• 1 x values in API 674 Tables 6A and 6B • VENDOR allowable at Package/skid battery limit	API 674 clause 6.6
Reciprocating Positive Displacement Controlled Volume Pumps	API 675	-	• VENDOR allowable at pump nozzle • VENDOR allowable at Package / skid battery limit	
Axial and Centrifugal Compressors and Expander Compressors for Petroleum, Chemical and Gas Industry Service	API 617	AGES-SP-05-002	• ~2.7 x API 617 loads (~5 x NEMA SM 24)	
Reciprocating Compressors	API 618	AGES-SP-05-003	• VENDOR allowable at Compressor nozzle • VENDOR allowable at Package / skid battery limit	.
Steam turbines	API 611 & API 612	AGES-SP-05-004	• 1 x NEMA SM24 unless Vendor allowable provided	
Gas turbines	API 616	AGES-SP-05-005	• VENDOR allowable at Package / skid battery limit	
General purpose Pumps, Firewater, Electro submersibles, Vertical Pumps	ASME ISO NPFA	AGES-SP-05-008	• VENDOR allowable	See respective standard 1 x allowable values
Packaged, Integrally Geared Centrifugal Air Compressors	API 672	AGES-SP-05-009	• VENDOR allowable at Compressor nozzle • VENDOR allowable at Package / skid battery limit	API 672 clause 6.4 and Annex I
Liquid Ring Vacuum Pumps and Compressors	API 681	AGES-SP-05-010	• 1 x NEMA SM24 unless Vendor allowable provided	API 681 clause 2.4

ROTATING EQUIPMENT				
Equipment	**Applicable Standards**	**AGES Specification**	**Allowable Load**	**Remarks**
Rotary-Type Positive Displacement Compressors	API 619	AGES-SP-05-010	• 1 x API 619 tables C1 and C2 • VENDOR allowable at Package / skid battery limit	API 619 Annex C
Other rotating and package items	-	-	• VENDOR allowable at battery limit	

Note : NEMA SM 23 and NEMA SM 24 Nozzle loads and moments are identical for various sizes and ratings.

APPENDIX A4. SWAY ANALYSIS METHODOLOGY FOR STRUCTURES AND EQUIPMENT

A4.1. Scope

This Appendix defines the design methodology to be followed for including the effect of wind induced sway on equipment / structures, on connected piping systems.

The main effects of wind on piping are summarised below:

a. Primary stress

b. Secondary stress due to wind induced sway on pipe rack / equipment

A4.2. Primary stress calculation

Primary stresses due to wind loading shall be calculated in accordance with ASME B31.3

A4.3. Secondary stress calculation

Sway check shall be performed for the following stress critical lines.

- Flare headers (Branches to flare header in accordance with the following criteria)
- Stress critical lines NPS 8 (including insulation) and above on pipe racks

Equipment deflection shall be considered for tall vertical equipment's like process columns. For horizontal equipment and vertical equipment with large diameter to height ratio, like tank / others, equipment deflection due to wind will not be significant and can be ignored.

For pipe racks, in a particular segment, deflection in transverse direction only needs to be considered as deflection in longitudinal direction is generally insignificant for piping and may be ignored.

A4.4. Acceptance criteria

Acceptance criteria shall be in accordance with ASME Section III, Division I, NC-3653.2b

The stress due to the resultant moment from a time independent, single non-repetitive anchor movement (for example, predicted building settlement, sway) is to be limited to 3 times of Sc (Basic allowable stress at room temperature).

SIF (Stress Intensification Factor) may be ignored (i.e. considered as 1.0) if required for this occasional loading in line with ASME B31.3.

Sway deflection shall be considered in two principal directions north-south and east-west in two separate stress checks, for example, when sway deflection is imposed on a pipe routed in north south direction, the wind effect and sway deflection shall not be imposed on pipe routed in east west direction.

APPENDIX A5. TYPICAL LOAD CASES

A5.1. Definition of Terms

T1 → Maximum design temperature for the pipe.

T2 → Operating temperature for the pipe.

T3 → Minimum design temperature for the pipe.

P1 → Design pressure for the pipe.

W → Pipe dead weight, including operating fluid weight and insulation weight, if applicable.

WW → Pipe dead weight, including full of water and insulation weight, if applicable.

WIN1 → Wind load in North-South direction.

WIN2 → Wind load in East-West direction.

U1 → Seismic load in North-South direction.

U2 → Seismic load in North-South direction.

D → Displacement vector for the corresponding direction

Note :

1) Additional Maximum Operating Temperature (T4) may be introduced to qualify equipment nozzle loads, etc. in line with this specification if applicable. Load cases shall be updated accordingly

2) Whenever spring supports are used for liquid lines at equipment nozzles (Tanks pumps etc) additional WNC (weight with No liquid) has to be run.

A5.2. Typical Load Case Combinations for CAESAR-II Stress Analysis

The below are minimum Load cases required, the CONTRACTOR shall establish the additional required load cases based on the Process / Operation scenario

L1 = T1 + W + P1 (OPE at max design temp)

L2 = T2 + W + P1 (OPE at oper temp)

L3 = T3 + W + P1 (OPE at min design temp)

L4 = W + P1 (SUS at design press)

Stress Comparison of Load Case L4 ≤ Sh (Sh in accordance with ASME B 31.3)

L5 = WW + Hydro Test Pressure (Hydro Test case)

L6 = T2 + W + P1 + WIN1 (OPE: wind in +X at oper temp & Des pr)

L7 = T2 + W + P1 – WIN1 (OPE: wind in –X at oper temp & Des pr)

L8 = T2 + W + P1 + WIN2 (OPE: wind in +Z at oper temp & Des pr)

L9 = T2 + W + P1 – WIN2 (OPE: wind in –Z at oper temp & Des pr)

L10 = T2 + W + P1 + U1 (OPE: seismic in +X at oper temp & Des pr with friction multiplier zero)

L11 = T2 + W + P1 - U1 (OPE: seismic in -X at oper temp & Des pr with friction multiplier zero)

L12= T2 + W + P1 + U2	(OPE: seismic in +Z at oper temp & Des pr with friction multiplier zero)
L13= T2 + W + P1 - U2	(OPE: seismic in -Z at oper temp & Des pr with friction multiplier zero)
L14 = T2 + W + P1 + D	(OPE: oper temp & Des pr, with +X sway)
L15 = T2 + W + P1 – D	(OPE: oper temp & Des pr, with –X sway)
L16 = T2 + W + P1 + D	(OPE: oper temp & Des pr, with +Z sway)
L17 = T2 + W + P1 – D	(OPE: oper temp & Des pr, with –Z sway)
L18 = L6 – L2	(OCC: +X wind only, algebraic combination method)
L19 = L7 – L2	(OCC: –X wind only, algebraic combination method)
L20 = L8 – L2	(OCC: +Z wind only, algebraic combination method)
L21 = L9 – L2	(OCC: –Z wind only, algebraic combination method)
L22 = L10 – L2	(OCC: +X seismic only, algebraic combination method)
L23 = L11 – L2	(OCC: –X seismic only, algebraic combination method)
L24 = L12 – L2	(OCC: +Z seismic only, algebraic combination method)
L25 = L13 – L2	(OCC: –Z seismic only, algebraic combination method)
L26 = L18 + L4	(OCC: +X wind with Weight & Des press for Primary code stress check, scalar combination method)
L27 = L19 + L4	(OCC: –X wind with Weight & Des press for Primary code stress check, scalar combination method)
L28 = L20 + L4	(OCC: +Z wind with Weight & Des press for Primary code stress check, scalar combination method)
L29 = L21 + L4	(OCC: –Z wind with Weight & Des press for Primary code stress check, scalar combination method)
L30 = L22 + L4	(OCC: +X seismic with Weight & Des press for Primary code stress check, scalar combination method)
L31 = L23 + L4	(OCC: –X seismic with Weight & Des press for Primary code stress check, scalar combination method)
L32 = L24 + L4	(OCC: +Z seismic with Weight & Des press for Primary code stress check, scalar combination method)
L33 = L25 + L4	(OCC: –Z seismic with Weight & Des press for Primary code stress check, scalar combination method)

Stress Comparison of Load Case L26, L27, L28, L29, L30, L31, L32, L33 ≤ 1.33 Sh (Sh in accordance with ASME B 31.3)

L34 = L1 – L4	(EXP: Stress range between max design Temp & install Temp; algebraic combination method)
L35 = L2 – L4	(EXP: Stress range between oper Temp & install Temp; algebraic combination method)

L36 = L3 – L4	(EXP: Stress range between min design Temp & install Temp; algebraic combination method)
L37 = L1 – L3	(EXP: stress range between max design temp & min design Temp; algebraic combination method; for secondary thermal stress range check.)

Stress Comparison of Load Case L34, L35, L36, L37 ≤ f [(1.25 Sc+0.25Sh)]

(f, Sc, Sh, SL in accordance with ASME B 31.3)

L38 = L14 – L2	(OCC: +X sway for Secondary stress check, algebraic combination method)
L39 = L15 – L2	(OCC: –X sway for Secondary stress check, algebraic combination method)
L40 = L16 – L2	(OCC: +Z sway for Secondary stress check, algebraic combination method)
L41 = L17 – L2	(OCC: –Z sway for Secondary stress check, algebraic combination method)

Stress Comparison of Load Case L38, L39, L40, L41 ≤ 3 Sc

When using ASCE 7-16 for seismic load calculations, the related load combinations shall be suitably updated in accordance with the respective code provisions to include Vertical seismic loads

A5.3. Support Loads:

Support Loads shall be based on CAESAR-II load cases as below:

A5.3.1 OPE Load Cases

L1 = T1 + W + P1	(OPE at max design temp)
L3 = T3 + W + P1	(OPE at min design temp)
L4 = W + P1 (	SUS at design press)
L5 = WW + Hydro Test Pressure	(Hydro Test case)

A5.3.2 OCC Load Cases

L6 = T2 + W + P1 + WIN1	(OPE: wind in +X at oper temp & Des pr)
L7 = T2 + W + P1 – WIN1	(OPE: wind in –X at oper temp & Des pr)
L8 = T2 + W + P1 + WIN2	(OPE: wind in +Z at oper temp & Des pr)
L9 = T2 + W + P1 – WIN2	(OPE: wind in –Z at oper temp & Des pr)
L10 = T2 + W + P1 + U1	(OPE: seismic in +X at oper temp & Des pr with friction multiplier zero)
L11 = T2 + W + P1 - U1	(OPE: seismic in -X at oper temp & Des pr with friction multiplier zero)
L12 = T2 + W + P1 + U2	(OPE: seismic in +Z at oper temp & Des pr with friction multiplier zero)
L13 = T2 + W + P1 - U2	(OPE: seismic in -Z at oper temp & Des pr with friction multiplier zero)

A5.3.3 Sway Load Cases

L14 = T2 + W + P1 + D	(OPE: oper temp & Des pr, with +X sway)
L15 = T2 + W + P1 – D	(OPE: oper temp & Des pr, with –X sway)

L16 = T2 + W + P1 + D	(OPE: oper temp & Des pr, with +Z sway)
L17 = T2 + W + P1 – D	(OPE: oper temp & Des pr, with –Z sway)

APPENDIX A6. STRESS ANALYSIS CHECKLIST

The following typical checklist should be used, however, additional items shall be added /modified where included to suit individual project specific stress analyses.

Project Name:			**Calculation #:**			
Sr. No.		**Item**	**Y**	**N**	**N / A**	**Remarks**
Basic Stress Input Data						
1	1	Design Temperature(s) implemented?				
2	2	Installation Temperature (21ºC or as applicable) implemented?				
3	3	Solar Radiation Temperature(s) (85ºC) implemented?				
4	4	Design Pressure(s) implemented?				
5	5	Operating Pressure(s) implemented?				
6	6	Hydrostatic Pressure(s) implemented?				
7	7	Piping Code (B31.3) implemented?				
8	8	Pipe material(s) implemented?				
9	9	Pipe size(s) checked?				
10	10	Pipe wall thickness(es) checked?				
11	11	Corrosion Allowance(s) checked?				
12	12	Fluid Density checked?				
13	13	Insulation thickness(es) checked?				
14	14	Insulation Density(ies) checked?				
15	15	Wind / Wave checked?				
16	16	Displacements checked?				
17	17	Pipe Supports checked?				
Stress Analysis Criteria (Brownfield)						
18	1	Mechanical modifications: Re-routing, pipe extension, change in weight due to addition of flange, valve or insulation?				
19	2	Process modifications: Change in temperature, pressure, flow rate or any transient?				
20	3	Piping system experiencing excessive vibration?				
21	4	Equipment-related problems: Distorted vessels, tank connections, and pump or compressor alignment?				

Project Name:			Calculation #:			
Sr. No.		**Item**	**Y**	**N**	**N / A**	**Remarks**
22	5	Installation alignment problem?				
Stress Analysis Criteria (Greenfield)						
23	1	Line falls under category L1 of Table 7.1?				
24	2	Line falls under category L2 of Table 7.1?				
25	3	Line is NPS 4 and larger with ASME class 900 or higher?				
26	4	Line is NPS 2 and larger connected to either rotating or reciprocating machinery or Fired heaters?				
27	5	Line is subjected to any kind of vibration due to either flow or acoustic reasons?				
28	6	Line is connected to pressure relief valves and rupture discs?				
29	7	Blow-down line NPS 2 and larger (excluding open drains)?				
30	8	Line considered as flare piping?				
31	9	Line NPS 3 affected by movement of connecting equipment or by structural deflection?				
32	10	Line is NPS 3 and larger subject to steam out?				
33	11	Line crossing inter platform bridges?				
34	12	Production / test and injection manifolds with connecting piping?				
35	13	Two-Phase Flow Piping such as blow down, steam condensate and flare piping?				
36	14	Process lines to and from centrifugal compressors and blowers?				
37	15	Boiler feed water, steam lines to and from boilers and steam generators?				
38	16	Line is either to or from static equipment?				
39	17	A process line in toxic service?				
40	18	Pipes subject to wind load as per this specification?				
41	19	Line is either to or from gas or steam turbine?				
42	20	Underground piping networks (such as fire water piping)?				
43	21	Line is subject to external pressure due to vacuum or jacketing?				

Project Name:			Calculation #:			
Sr. No.		**Item**	**Y**	**N**	**N / A**	**Remarks**
44	22	Line is designated as category “M” according to ASME B31.3?				
45	23	Flow line is connected to Christmas trees including headers / manifolds up to nearest anchor or equipment nozzle?				
46	24	Line is made of FRP(GRE, GRP, etc.)?				
47	25	Long vertical lines (typical 10 meters and higher)?				
48	26	Line is requested by the COMPANY?				
Stress Analysis Special Conditions						
49	1	Line experiencing steam out conditions?				
50	2	If **YES**, was the steam out temperature used in the calculation?				
51	3	Line experiencing standby and operating conditions?				
52	4	If **YES**, was the solar temperature considered for the standby portion?				
53	5	Line experiencing start-up and shut down conditions?				
54	6	Is cold spring applied?				
55	7	Does thermal bowing condition apply?				
56	8	Does bourdon effect condition apply?				
57	a	If **YES**, is pipe length ≥ 60 m? **OR**				
58	b	Pressure ≥ 40 Bars and Size ≥ NPS 30?				
59	c	Alternatively, is the pipe made of FRP / GRP?				
60	9	Any differential settlement conditions apply?				
Stress Model Boundary Conditions						
61	1	Is the piping model terminated at an anchor or a guided axial stop (with no gap in the axial direction)?				
62	2	If **YES**, does the model, unless it’s terminated by an anchor, show the piping up to the next guide?				
63	3	Is the piping system partially buried or connected to a buried pipeline?				
64	4	If **YES**, does the model include the buried portion up to the nearest thrust block?				
65	5	Is the piping system connected to any static equipment?				

Project Name:			Calculation #:			
Sr. No.		**Item**	**Y**	**N**	**N / A**	**Remarks**
66	6	If **YES**, were the calculated displacements of the equipment nozzles included in the model?				
67	7	Is the piping system connected to any rotary or reciprocating equipment?				
68	8	If **YES**, were the calculated displacements of the equipment nozzles included in the model?				
69	9	Does the model contain any pipe size ≥ NPS 6 having branch size ≥ one third header sizes?				
70	10	If **YES**, are these branches included in the model?				
71	11	If **YES**, are these branched terminated by an anchor or a guided axial stop (with no gap in the axial direction)?				
72	12	Does the model contain pipe size ≥ NPS 6 having branch size < one third header sizes?				
73	13	If **YES**, do these branches fall under any of the criteria stated in the “GREENFIELDS” section above and therefore included in the model?				
74	14	Package line: Are all the tie-ins anchored and / or have allowable loads and / or displacements?				
75	15	Is the CAESAR II® model showing the entire model to be physically interconnected?				
76	16	Does the “Title Page” contain all the line numbers included in the model?				
Dynamic Behaviour of Piping System						
77	1	Is the piping system subject to slug flow?				
78	2	If **YES**, was the spectrum analysis performed?				
79	3	Is the piping system subject to fluid hammer?				
80	4	If **YES**, was the spectrum analysis performed?				
81	5	Is the piping system subject to pressure surge?				
82	6	If **YES**, was the surge analysis approved by COMPANY Process?				
83	7	Were the surge pressures included in the analysis?				
84	8	Is the piping system subjected to cyclic loading?				
85	9	If **YES**, was a fatigue evaluation carried out?				

Project Name:			Calculation #:			
Sr. No.		**Item**	**Y**	**N**	**N / A**	**Remarks**
86	10	Does the piping system contain any relief valves or rupture discs?				
87	11	If **YES**, was a spectrum analysis carried out?				
88	12	Were the natural frequencies for the piping system determined?				
89	13	If **YES**, how much is the lowest of these frequencies?				
90	14	Does the piping natural frequencies and excitation frequencies separated by more than 20%?				
91	15	Were brace supports added to branches ≤ NPS 2 in ASME class ≥ 300?				
92	16	Were the recommendations of the AIV and / or FIV study incorporated?				
Piping System Supports						
93	1	Do any of the pipe guides have a special gap (> or < 3 mm)?				
94	2	If YES, is this gap value shown in the stress isometric?				
95	3	Are trunnion supports properly simulated?				
96	4	Are friction coefficients properly selected?				
97	5	Is there a spring within 4 pipe diameters after the equipment nozzle?				
98	6	If **YES**, were the restraints at that nozzle released?				
99	7	How much is the spring vertical movement (mm)?				
100	8	How much is the maximum load variation (%)?				
101	9	Are there any expansion joints in the model?				
102	10	Was the use of such expansion joint approved by COMPANY?				
103	11	Was that expansion joint modelled automatically by CAESAR II®?				
104	12	Was the piping arrangement involving that expansion joint reviewed by the joint Manufacturer?				
Special Design Considerations						
105	1	Is any part of the piping system subjected to either platform or deck deflections?				

Project Name:						Calculation #:
Sr. No.		**Item**	**Y**	**N**	**N / A**	**Remarks**
106	2	If, **YES**, were the proper magnitude and direction of platform or deck deflections considered in the model?				
107	3	Were the calculated nozzle loads verified against the appropriate standard shown in Appendix A3?				
108	4	If YES, was that check performed via CAESAR II®?				
109	5	If NO, were the calculated nozzle loads verified against Vendor data?				
110	6	Was the misalignment check carried out for the equipment nozzle?				
111	7	If **YES**, was it found to be within the acceptable limits?				
112	8	Was the flare header analysed considering the appropriate liquid content?				
Miscellaneous						
113	1	Was the stress analysis for the GRE / GRP carried out by Manufacturer and endorsed by contractor?				
114	2	Do the tie-in numbers appearing on the P&ID's appear in the stress model as "Node Name"?				
115	3	Do the displacements of the tie-in point(s) in this model need to be transferred to another model?				
116	4	If **YES**, which tie-in point? And to which model?				
117	5	Were the displacements of the tie-in point(s) in this model extracted from another model?				
118	6	If **YES**, which tie-in point? And from which model?				
119	7	Are the requirements of Small bore piping as per Appendix A1 of AGES-SP-09-001 fulfilled?				
CAESAR II® Requirements and Results Evaluation						
120	1	Is the utilized version of CAESAR II®, at the time of contract awarding, applying the contractually agreed revision of ASME B31.3?				
121	2	Does the Contractor certify that the proposed load cases reflect ALL possible scenarios of operation?				
122	3	Were the "SIF's and Stresses" configuration parameters found to be in compliance with COMPANY requirement?				
123	4	Is there any Stress Ratio exceeding 90% of the allowable stress?				

Project Name:			Calculation #:			
Sr. No.		Item	Y	N	N / A	Remarks
124	5	Are the horizontal and vertical displacement values within acceptable levels?				
125	6	If **NO**, specify value and node number.				
126	7	Is the vertical load variation between the sustained and the operating cases exceeding 150%?				
127	8	Were **ALL** the applicable flanges assessed for flange leakage?				
128	9	If **YES**, was this assessment carried out using CAESAR II® flange leakage module?				
Stress Analysis Report						
129	1	Was the preliminary stress native input files submitted?				
130	2	Were the relevant data sheets and / or Vendor drawings submitted?				
131	3	If YES, were the nozzle allowable loads (3 forces and 3 moments) shown in the drawing?				
132	4	Was the final report, containing all the relevant data, submitted along with the final stress files?				

APPENDIX A7. FEA CHECKLIST

FE-ANALYSIS CHECK LIST FOR PIPING COMPONENTS				
PROJECT:			Revision:	
ITEM DESCRIPTION:				
ID	REFERENCE	DESCRIPTION	Used	Chk'd
PROJECT SPECIFICATIONS				
International regulations		Are international regulations complied with?		
National regulations		Are National regulations complied with?		
Class Society		Are Class Society rules complied with (ABS, DNV, Lloyds, etc.)?		
Piping Code		Are the correct piping code and corresponding pressure vessel code used for the design of this component e.g. ASME B31.3 & ASME VIII Div 2 part 5?		
Drawings, materials, design basis		Are all component drawings, material data, project design basis, etc. received and complied with?		
FE- ANALYSIS AND HAND CALCULATIONS				
3D-Model		Is the geometric 3D model of the piping component in accordance with project specifications? Does it have sufficient level of details? If used, are symmetry planes selected correctly? Is the centre of gravity and weight correct? Does the model contain unwanted gaps? (A third party may need access to the original or a universal (neutral) file-format of the 3D CAD file in order to be able to verify the model against drawings).		
Material properties		Are the material properties at the operating and design temperatures correct?		
Type of Analysis		Is the chosen FE-analysis appropriate for the loading conditions (linear static analysis, nonlinear static analysis, contacts analysis, etc.)?		
Restraints, loads and other boundary conditions		Have the restraining loads, pre-described displacements, contact surfaces and boundary conditions in general been applied correctly? Have colour plots clearly showing these topics been included in the report?		

FE-ANALYSIS CHECK LIST FOR PIPING COMPONENTS			
PROJECT:		Revision:	
ITEM DESCRIPTION:			
ID / REFERENCE	DESCRIPTION	Used	Chk'd
Element type	Is the element type (beam, truss, shell, solid, etc.) used for the FE analysis appropriate for the part(s) being analysed? If solid elements are used, is the chosen element suitable for the part under analysis?		
Meshing	Is the mesh density (element size) confirmed accurately by sensitivity analysis or other suitable method? Are stress precision values and / or mesh convergence studies OK? Has the mesh been checked and found OK in critical areas?		
Results	Are the stresses, strains, rotations, deflections, etc. within the design code allowed or project specifications? Is penetration of contact surfaces avoided? Has the methodology outlined in the governing Pressure vessel code (e.g. ASME VIII, Div2, part 4 or 5) been complied with? Has applicable code compliance check and clear conclusion of stresses and strains for the limit states, ULS, ALS and FLS complied with?		
Hand calculations	Have some basic hand calculations been performed to roughly estimate and validate the FE results? E.g. are the reaction forces from the FE-analysis checked against applied loads?		
Independent Analysis (Third party verification)	Has any third-party FE- analysis been performed to validate the FE-analysis of the component?		
DOCUMENTATION AND QA			
Qualifications, CV	Is the person responsible for this FE analysis considered competent in his field and does the person have sufficient analytical skills, experience or back-up to make a safe design in accordance with project specifications? Problems?		
FEA Report	Does the FEA report as a minimum contain the information listed in Section 10.4.		
Electronic 3D CAD files	Has the original or some electronic universal (neutral) file-format for the 3D CAD or FE model been made available to the project for third party review?		
Filing	Has the report, analysis and checklist been properly filed?		
Use of Checklist:	Y=Yes, N=No, OK=OK NA= Not Applicable, NC= Not Checked		
Checked by / Third party review by:		Date:	

APPENDIX A8. DOCUMENTS / INFORMATION REQUIRED FOR FRP STRESS ANALYSIS

Sl No	Description	Mandatory Requirement (Y/N)	To be provided by
1	P&IDs	Y	COMPANY / CONTRACTOR
2	General arrangement drawings	Y	COMPANY / CONTRACTOR
3	Piping design basis	Y	COMPANY / CONTRACTOR
4	Project specification for pipe stress analysis	Y	COMPANY / CONTRACTOR
5	Piping isometrics	Y	COMPANY / CONTRACTOR / GRE Manufacturer
6	Piping isometrics for overlap piping (piping connected to the fiberglass piping)	Y	COMPANY / CONTRACTOR
7	Product dimensional drawings (these drawings should show dimensions of pipes and fittings and wall thickness)	Y	GRE Manufacturer
8	Pipe material properties including pipe thickness values	Y	GRE Manufacturer
9	Material properties and Stress envelop shall be re-verified again before installation.	Y	GRE Manufacturer
10	Weight and dimensions of inline elements such as valves	Y	COMPANY / CONTRACTOR
11	Design conditions: - Design pressure - Hydro test pressure - Maximum design temperature - Minimum design temperature - Installation temperature - Seismic loading (if applicable) - Wind loading (if applicable) - Soil properties (for buried lines) - Fluid density	Y	COMPANY / CONTRACTOR / GRE Manufacturer
12	Allowable loads for equipment nozzles (if applicable)	Y	COMPANY / CONTRACTOR
13	General arrangement drawings for equipment (if applicable)	Y	COMPANY / CONTRACTOR
14	Stress Analysis report	Y	CONTRACTOR / GRE Manufacturer
15	Hydraulic Analysis Report	Y	CONTRACTOR / GRE Manufacturer
16	Surge Analysis Report	Y	CONTRACTOR / GRE Manufacturer

Note :

1. COMPANY / CONTRACTOR are applied based on the Project. For EPC project "COMPANY / CONTRACTOR" shall be replaced with CONTRACTOR
2. For item 15 & 16, relevant disciplines like HSE / Process Safety / Process shall review the documents with due considerations to the impact of velocity/pressure surge etc. on FRP piping design.