

GENERAL SPECIFICATION

PIPING VALVES VESSELS

GS EP PVV 107

Piping Stress Analysis

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1. Scope

This document sets the rules for the piping stress analysis of the process and utilities piping systems of onshore and offshore petroleum installations excluding Subsea applications.

For the lines within equipment packages that are not ruled out by the managing entity named on the front page of the document, the application of this general specification shall be decided by the entity in charge on a case-by-case basis.

Its scope is essentially the same as that of [ASME B31.3](#).

The following are specifically excluded: onshore and offshore pipelines, furnaces and boilers piping, building heating and ventilation piping etc.

However particular cases can be considered when the [ASME B31.3](#) piping system is connected to a system designed under another code (i.e. [ASME B31.1](#), [ASME B31.8](#)...). In such cases, the rules of this specification remain applicable with specific amendments, such as the acceptance criteria of the relevant code, shall be defined in the Project Piping Stress Design Basis.

The outcome of the studies shall be used to assess the quality and integrity of the construction of piping systems.

This document does not include the structural attachment between piping supports and the main structure.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

Process and utilities piping shall comply with the requirements of [ASME B31.3](#).

This document clarifies or complements some requirements of [ASME B31.3](#) when deemed necessary considering Company experience.

Piping systems covered by this specification shall be designed and analyzed in accordance with this Code and with the documents listed hereafter.

Any divergence between any of the Reference Documents, or between this specification and any Reference Document, shall be reported to the Company for decision. In such a case, and unless otherwise agreed or decided by the Company, it is understood that the more stringent requirement shall apply.

Exceptions to, or deviations from this specification are not permitted unless previously accepted in writing by the Company. For this purpose, requests for substitutions or changes of any kind shall be completed with all pertinent information required for the Company assessment.

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External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published at the effective date of this document.

Reference	Title
API RP 2A-WSD	Planning, Designing, and Constructing Fixed Offshore Platforms-Working Stress Design
API STD 520 PT II	Sizing, Selection, and Installation of Pressure-relieving Devices - Part II-Installation
API STD 610	Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries
API STD 617	Axial and Centrifugal Compressors and Expander-compressors
API STD 650	Welded Steel Tanks for Oil Storage
API STD 661	Petroleum, Petrochemical, and Natural Gas Industries - Air-cooled Heat Exchangers
API STD 662 Part 1	Plate Heat Exchangers for General Refinery Services - Part 1: Plate-and-Frame Heat Exchangers
API RP 2FB	Recommended Practice for the Design of Offshore Facilities Against Fire and Blast Loading
ASCE 7	Minimum Design Loads for Buildings and Other Structures
ASME B16.47	Large Diameter Steel Flanges: NPS 26 through NPS 60 Metric/Inch Standard
ASME B16.5	Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard
ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME B31.8	Gas Transmission and Distribution Piping Systems
ASME BPVC Section III Div 1	ASME Boiler & Pressure Vessel Code - Section 3 Division 1 Addenda A: Rules for Construction of Nuclear Facility Components
ASME BPVC Section VIII Div 1	ASME Boiler & Pressure Vessel Code - Section 8: Rules for Construction of Pressure Vessels - Division 1: Pressure Vessels
PD 5500	Specification for unfired fusion welded pressure vessels
BS 7159	Code of practice for design and construction of glass-reinforced plastics (GRP) piping systems for individual plants or sites
DNV-RP-C203	Fatigue Design of Offshore Steel Structures
DNV-RP-D101	Structural Analysis of Piping Systems

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Reference	Title
Energy Institute Guideline 2008	Guidelines for the avoidance of vibration induced fatigue failure in process pipework
ISO 14692-3	Petroleum and natural gas industries - Glass-reinforced plastics (GRP) piping - Part 3: System design
UKOOA	Specifications and Recommended Practice for the Use of GRP Piping Offshore

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published.

Reference	Title
GS EP ECP 103	Process design criteria
GS EP MEC 300	Noise and Vibration of Rotating Machine Packages
GS EP PVV 111	Piping design specification
GS EP PVV 112	Piping material classes
GS EP PVV 119	Design and fabrication of metallic piping supports - Standard for piping supports
GS EP PVV 171	Steel piping fabrication
GS EP PVV 211	Design and fabrication of pressure vessels according to ASME VIII
GS EP PVV 212	Design and fabrication of pressure vessels according to BSI PD 5500

3. Design basis

3.1 General

Piping systems shall have sufficient flexibility to prevent thermal expansion or contraction from causing:

- Failure of piping or supports from overstress or fatigue
- Leakage at mechanical or welded connections
- Detrimental stresses or distortion in piping and valves or in connected equipment.

Piping systems shall be designed in accordance with the requirements of the [ASME B31.3](#) Code and the present specification. They shall take into account all the different conditions expected during their lifetime: operating conditions, environmental conditions, occasional and accidental conditions.

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All piping shall be adequately supported (anchors, guides, limit stop, etc.) to prevent excessive stresses from the different expected conditions.

Pipe stress analysis shall be carried out at pressure and temperature conditions as stated in the Critical Line List.

Pipe supports with huge loads, i.e. loads far in excess of good engineering practice and at least close to what may be acceptable by the underneath supporting structure, shall have appropriate contact point with piping and well justified to avoid punching effect that may damage the external surface of piping.

The purpose of this General Specification is to:

- Categorize piping systems into Critical stress levels
- Define criteria and coefficients so that loading conditions may be applied
- Define methodologies and rules for the piping stress calculation activity
- State allowable stress, displacements, loadings and first natural frequency levels to ensure safe plant operations.

3.2 Design Data

The main design data of each line shall be taken from the following documents:

- Line list: Operating and design pressures, operating and design temperatures, type and thickness of insulation (if any), type of hot tracing (if any), test conditions (pressure, fluid, etc.). This document is established and issued by Process group.
- Piping material classes: Material, diameter, wall thickness, type of fittings, flanges and valves.
- Project Specification: Site data e.g. the minimum/maximum ambient temperature, the maximum solar temperature, the wind data such as wind speed for each grade level, the earthquake data, etc.

3.3 Method of Analysis

The piping layout shall be analyzed by the individual consideration of each line affected by restraints (temperature, imposed displacements, etc.) to determine the reactions produced at anchors, terminal points and the stresses in the piping. The methods of analysis are classified into three Stress Analysis Levels.

The levels of requirements and the corresponding methods of analysis are defined as follows:

3.3.1 Level 1: Visual inspection (or by analogy)

It is an approximate, visual inspection method. It shall be restricted to lines that are similar to other calculated lines, or lines having a clear and adequate flexibility.

If not, these lines shall be classified as level 2 or 3.

No formal report and actual values of forces and moments acting on supports are requested for a level 1 analysis.

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3.3.2 Level 2: Simplified analysis

This method includes the use of charts, nomographs, simplified formulae or simplified CAESAR II model. It may be considered if they are used in the range of configuration for which their accuracy is acceptable.

In case of doubt, the line shall be classified as level 3.

In the discretion of the Company, the result of a level 2 analysis shall be shown either on the calculation isometric, or in a simplified report including isometric and a computer calculations output restrain summary.

3.3.3 Level 3: Comprehensive analysis

It is a comprehensive method by computer calculations exclusively that shall meet the requirements of the piping code.

A complete calculation report shall be issued (refer to the paragraph 12) for Company approval.

The stress analysis level selection shall be indicated in a document called "Critical Line List". This document shall include all the lines to be reviewed by the stress analyst and shall be submitted to the Company for approval.

3.3.4 Exemptions

No stress calculation is required on the piping systems that meet one of the following requirements according to [ASME B31.3](#), paragraph 319.4.1:

- Piping systems which are duplicated or revised without significant changes, operated system with a successful service record
- Piping systems which can be readily judged adequate by comparison with previously analyzed systems.

4. Critical Line List

All lines of stress analysis levels 2 and 3 shall be reported in the Critical Line List. These lines must be classified in accordance with the criteria shown on Appendix 1 (General Chart and Specific Cases), and the other specific criteria defined in the paragraphs 4.1 and 4.2 below.

This requirement applies also to lines included in packages. To facilitate tie-ins and assign responsibilities, vendors will be responsible for the pipework design within their package and an anchor support must be provided at the limit of all packages. This anchor point shall be sufficient to accept the loads from interconnecting piping arrangement and the package internal piping systems.

The Critical Line List shall be a separated document from the Line List and shall be issued by the group in charge of the Piping Stress Studies.

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As minimum, the critical line list shall contain the following, in addition to the information in the Process Line list:

- Stress analysis level for each line
- Calculation number and stress isometric number
- Originator of the calculation, checker
- Revision and date of issues.

All lines that are subject to slug flow, surge, acoustic induced vibration, flow induced vibration, shall be clearly identified in the Critical Line List.

4.1 Critical Line List for FEED or Basic Engineering level

The established FEED or Basic Engineering 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.

At FEED or Basic Engineering 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 when the piping stress analysis is finalized. This shall be conducted in conjunction with the development of the 3D Model.

If piping stress calculations are performed during FEED or Basic Engineering, lines of level 3 shall be identified in the Critical Line List.

This Critical Line List shall be updated during the Detailed Engineering in accordance with the possible modifications or Project up-dating.

Unless otherwise required by the project, diameter 18" and above lines which are submitted to differential displacements (platforms or pipe racks differential displacements due to earthquake or to special operating cases) shall be checked as per level 3 lines.

Piping stress analysis level 3 shall also include:

- Lines submitted to wellhead displacement with growth higher than 50 mm
- Lines affected by deck deflection, platform settlement inducing significant displacement: i.e. 5 mm relative displacement and more
- Lines with oblique connections
- Lines with expansion bellows
- Carbon Steel and Low Temperature Carbon Steel lines used at a temperature lower than the minimum shown on the Piping Class
- GRP lines larger than a diameter to be defined for each project (NP6" and above by default)
- All lines connecting to compressors and high pressure pumps linked to gas/water reservoir injection or hydrocarbon export

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- Lines subject to slug flow
- Lines subject to dynamic pressure (pv^2) exceeding the criteria specified in **GS EP ECP 103** or as identified by Process Discipline
- Lines subject to the calculation of dynamic pressure (pv^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.

4.2 Critical Line List for Detailed Engineering

At Detailed Engineering stage, the flexibility of all piping systems shall be checked in different conditions expected during their lifetime. The piping systems shall be able to withstand applied loads without permanent deformations at any time of the operation and of the fabrication too (i.e. load-out, transportation, lifting, partial hydrostatic test, etc.).

Lines of levels 2 and 3 to be calculated at Detailed Engineering shall be identified in the Critical Line List. This Critical Line List shall be regularly updated in accordance with the possible modifications.

In addition to the Appendix 1 (General Chart and Specific Cases), the following criteria shall be considered in order to finalize the checking of critical level 3 lines:

- Lines having substantial concentrated loads such as valves, fittings, unsupported vertical risers and branches.
- 3" and larger closed pressure relief system piping (typically rupture disc, safety valves), where design temperature exceeds 93°C (200°F) or is less than -46°C (-50.8°F)
- Lines having local reduction in strength due to installation of special fittings (e.g. oblique connections)
- All Lines with hub connectors in hydrocarbon service and water injection
- Piping 3" and larger connected to:
 - Rotating equipment such as pumps, blowers and compressors
 - Air cooler
 - Plate and frame heat exchanger
 - Gas turbine.
- Blowdown and flare header or cold vent piping (but not atmospheric vent piping) with design temperature below -48°C
- Piping with pressure surge, slug and two phases flow
- Normally dry firewater piping and normally water-filled firewater ring main piping subject to dynamic load more than 1 KN and the pipe material is either Cu-Ni or non metallic (i.e. GRP)
- Piping subject to short term variations such as steam-out or purge piping
- Pig receiver and launcher lines up to and including offshore riser support
- Lines with Expansion bellows

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- Lines affected by deck deflection, platform settlement, wellhead movement or any other significant displacement i.e. 5 mm relative displacement and more
- Lines subject to vacuum conditions
- Cryogenic lines:
 - It is considered as cryogenic service all applications below -46°C
 - Piping stress shall respect the allowable load figures provided by cryogenic equipment manufacturer
 - Surge may be expected as a result of rapid valve closure, pump start-up, pump stop (i.e. loss of power), emergency shutdown, etc.
 - Accurate calculation of surge effects must be obtained for vibration and unbalanced forces generated by surges in the system
 - Surge analysis at the jetty head and LNG Storage Tank shall be performed accordingly
 - All low temperature carbon steel lines that shall be justified at temperature below -46°C according to clause 323.2.2 of [ASME B31.3](#).
- Lines which may create large forces or moments on structure or skid base
- Unbalanced piping configuration such as a long run of pipe with a short branch connected to anchor
- Piping subject to severe cyclic temperature conditions
- GRP lines of diameters to be defined for each project (NPS3" and above by default)
- Pipework subject to other conditions such as temperature gradients that could cause thermal bowing or where piping is connected to equipment with significant thermal growth 50 mm and more
- Lines design to [ASME B31.3](#) chapter IX
- All piping with $t > OD/6$ or $P/SE > 0.385$
- 4" and larger with $t > 10\% \text{ OD}$
- Lines with $OD/t > 120$
- Lines subject to vibration due to internal and external loads (e.g. pressure transient, slugging, flow pulsations, external mechanical forces, vortex induced vibration, high gas velocity, and acoustic vibration of the pipe wall)
- Piping systems subject to extreme environmental condition such as wind, arctic environment, i.e. -40°C or below outside temperature, earthquake and any combination of those conditions as required by the Design Code
- Whatever the acceptance level status of the flexibility analysis reports, lines further incorporating closure welds for construction purposes shall be subject to one additional verification, with a SIF factor of 1.2 applied to nodes located at the closure weld positions.

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Where:

OD is the piping Outside Diameter

t is the piping thickness

P is the Design Pressure

SE is the product of allowable Stress and quality factor as per defined in the [ASME B31.3](#) code for the thickness calculation.

5. Piping Stress Analysis

5.1 Screening or hand calculations

Screening or hand calculations shall be used to verify that enough inherent flexibility exists in the piping system to prevent excessive thrusts, stresses and distortion. Screening and hand calculations shall be supported with sufficient references and data to allow Company to carry out check.

Spreadsheets using "Excel" and other program such as "Mathcad" may be used to support the calculations of level 2 and level 3 lines provided that the validation of the routine is available for Company to carry out check.

5.2 Computerized analysis

Comprehensive computer analysis shall be performed for critical lines level 3 (or assimilated level 3).

The calculation program used shall be CAESAR II, not less than 5.1, developed by COADE Inc. (Houston - Texas USA). Version shall be defined at the beginning of project with Company agreement on the basis of the last version positively experienced by Company.

The lines shall be calculated, including branch lines up to the first anchor or acceptable boundary condition when branch diameter $\geq$ half header diameter.

When small size lines (branch) connected to main lines (header) are to be calculated separately (when branch diameter $<$ half header diameter) the linear and angular movements of the junction point shall be calculated or estimated for proper analysis of the branch line.

Axis for piping stress analysis shall be the same as for the structure calculation, normally:

Onshore site or offshore platform	Floating facilities unit
X = East direction	X = Horizontal axis parallel to the floating facilities longitudinal axis (forward)
Y = North axis	Y = Horizontal axis perpendicular to X (toward portside)
Z = Vertical axis (upward)	Z = Vertical axis (upward)

All piping stress calculation notes of level 3 (or assimilated) shall be submitted to Company specialist for acceptance once the Contractor has approved them.

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In particular case, preliminary calculation notes should be submitted to Company specialist in order to obtain early comments.

Input data for all Piping Stress Calculation Notes (in electronic files) shall be transmitted to Company for check.

The computer outputs shall be submitted to the Company for review.

5.3 Use of Finite Element (FE) Analysis

Shell based Finite Element method shall be used for local stress calculation when:

- D/T is larger than 100
- Piping system having unlisted piping components outside those listed standard components in [ASME B31.3](#) Table 326.1
- Area of high local stress like Trunnion attachments/Pipe shoe which are showing unacceptable result using spreadsheet formula
- Piping components subjected to a complex loading having a geometric nonlinearity and material nonlinearity.

5.4 Units

Unless otherwise specified by the Project requirements, the unit system shall be the metric system.

6. Design Conditions

The following paragraphs detail the design conditions, the Caesar model, the load cases and the acceptance criteria to be considered.

6.1 Design Pressure

The design pressure of each component in the piping system shall be equal to the most severe design conditions expected, indicated in the Critical Line List.

In particular cases, the design pressure specified in the Critical Line List may be replaced by the maximum operating pressure upon Company approval.

6.2 Calculation Temperature

The basic temperature for the flexibility analysis shall be the Design temperature. The temperature for the occasional conditions such as start-up, cool-down, shutdown, regeneration, depressurization, fire case scenario, steam-out condition and other special conditions shall also be considered. This temperature shall be taken from the Process and Utilities Line List and shall be specified in the Critical Line List.

The following rules shall be taken into account:

6.2.1 Nozzles and supports

The maximum operating temperature shall be considered for nozzle loads on rotating equipment and air coolers. This temperature is taken from the Process and Utilities Line List.

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The thermal displacement of the equipment nozzles shall be calculated using the relevant line temperature. The temperature homogeneity shall be met between piping and equipment.

The design temperature shall be considered on piping and structure design. In the particular case, maximum operating temperature may be applied on loads calculation of the supports with huge loads. It shall be defined in the Piping Stress Design Basis of each project.

The use of hold-down on standard supports shall be reserved to stabilize lines under dynamic effects only (i.e.: blast, surge, acceleration, sway, etc.). It shall not be used in the thermal case that causes piping lift.

The applied load on PTFE or other non metallic or composite sliding components shall be identified in piping stress report with a table to allow verification of the thickness calculation of and bearing pressure exerted on the sliding components.

6.2.2 Solar heating temperature

The solar heating temperature shall be used for the design of the exposed un-insulated lines when the operating temperature is lower than the solar heating temperature. The value of the solar heating temperature to be considered shall be specified in the Project environmental conditions.

6.2.3 Dry out and steam out

Dry out and steam out temperatures (if any) shall be taken from the Process and Utilities Line List. 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.

6.2.4 Jacketed lines

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

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

6.2.5 "Dead branch"

For the lines which have no permanent flow, such as piping connected to the spare pumps, by-pass, etc., the following value shall be considered:

- Insulated line: 50% of the operating temperature in the dead branch
- Non-insulated line: plant temperature in the dead branch
- Steam traced line: 70% of the operating temperature of the steam line in the dead branch
- Warm-up by-pass of the spare pumps: 70% of the operating temperature of the line.

Note: Dead branch shall be considered for its full length between the two ending connections.