



Exploration & Production

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.

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.

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. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

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 analysed 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.

Standards

Reference	Title
API STD 520	Sizing Selection and installation of Pressure relieving devices in refineries
API STD 610	Centrifugal Pumps for General Refinery Service
API STD 617	Centrifugal Compressors for General Refinery Service
API STD 661	Air-Cooled Heat Exchangers for General Refinery Service
API STD 662	Plate Heat Exchangers for General Refinery Service
ASME B16.5	Pipe Flanges and Flanged Fittings (NPS ½ through NPS 24)
ASME B16.47	Large Diameter Steel Flanges NPS 26 through NPS 60



Professional Documents

Reference	Title
CONCAWE Report n° 87/59	The prediction of noise radiated from pipe systems - An engineering procedure for plant design
EJMA	Standards of the Expansion Joint Manufacturers Association
NEMA SM 23	Steam Turbines for Mechanical Drive Service
WRC 107	Welding Research Council Bulletin 107 - Local Stresses in Spherical and Cylindrical Shells due to External Loadings
WRC 297	Welding Research Council Bulletin 297 - Local Stresses in Cylindrical Shells due to External Loadings on Nozzles - Supplement to WRC Bulletin 107

Regulations

If the country of installation has its own regulation, it must be applied wherever more stringent than the Basic Code.

Reference	Title
Not applicable	

Codes

Reference	Title
API RP 2A-WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design
API TR 6AF	Technical Report on Capabilities of API Flanges Under Combinations of Load - Third Edition
ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME III Div. 1 Subsection NB	Rules for Construction of Nuclear Facility Components Class 1 Components
ASME VIII Div. 1	Rules for Construction of Pressure Vessels
BS 7159	Design and Construction of Glass-Reinforced Plastics (GRP) Piping Systems for Individual Plants or Sites
BSI PD 5500	Specification for Unfired Fusion Welded Pressure Vessels
UKOOA	Specifications and Recommended practice for the Use of Glass Fibre Reinforced Plastic Piping Offshore



Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
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 149	Spring hangers and supports
GS EP PVV 178	Design and erection of Glass Reinforced Plastic (GRP) piping system
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 joints
- 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.

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.

The purpose of this General Specification is to:

- Categorise piping systems into Critical stress levels
- Define criteria and coefficients so that loading conditions may be applied
- State allowable stress 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.)
- 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 analysed by the individual consideration of each line affected by restraints (temperature, imposed displacements, etc.) to determine the reactions produced at anchors and 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 actual values of forces and moments acting on supports are requested for a level 1 analysis.

3.3.2 Level 2: Simplified analysis

This method includes the use of charts, nomographs and simplified formulae which may only be accepted 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.

The result of a level 2 analysis may be shown only 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 § 12).



The accuracy 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

A stress calculation needs not to be performed 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 are revised without significant changes of successfully operating operations
- Piping systems which can be readily judged adequate by comparison with previously analyzed systems.

4. Critical Line List

All lines of accuracy 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).

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.

4.1 Critical Line List for Basic Engineering

Basic engineering studies shall normally establish required 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 the Basic Engineering stage, a special care shall be taken to design the piping routing in a proper way to allow a good flexibility and to avoid any major changes during the detailed engineering when the piping stress analysis is finalised.

Lines of level 3 to be calculated at Basic Engineering shall be identified in 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
- 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
- All lines connecting to compressors and high pressure pumps linked to gas/water reservoir injection or hydrocarbon export.

4.2 Critical Line List for Detailed Engineering

At the Detailed Engineering stage, the flexibility of all the piping systems shall be checked in the different conditions expected during their lifetime. The piping systems shall be able to withstand applied loads without permanent deformations at any time of the fabrication (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 level:

- Lines having substantial concentrated loads such as valves, fittings, unsupported vertical risers and branches
- 3" and larger closed pressure relief system piping, where design temperature exceeds 93°C (200°F) or is less than -73°C (-100°F)
- Lines having local reduction in strength due to installation of special fittings (i.e. oblique connections)
- 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 vent piping, but not atmospheric vent piping
- Piping with pressure surge, slug and two phases flow
- Normally dry firewater piping and normally water-filled firewater ring main piping
- Piping subject to short term variations such as steam-out or purge piping
- Pig receiver and launcher lines up to and including off-shore riser support
- Relief valve or rupture disc piping reaction forces
- Expansion bellows
- Lines affected by deck deflection, platform settlement, wellhead movement or any other significant displacement
- Lines subject to vacuum conditions
- Cryogenic lines:
 - It is considered as cryogenic service all applications below -46°C.

- 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 subjected to severe cyclic temperature conditions
- GRP lines larger than a diameter to be defined for each project
- Lines with special design requirements
- In addition, the effect on piping of other conditions such as temperature gradients that could cause thermal bowing or where piping is connected to equipment with significant thermal growth
- Lines design to B31.3 chapter IX
- All piping with $t > OD/6$ or $P/S_E > 0.385$
- 4" and larger with $t > 10\% OD$
- Lines with $OD/t > 120$

Where:

OD is the piping Outside Diameter

t is the piping thickness

P is the Design Pressure

S_E is the Allowable Stress as per defined in the [ASME B31.3](#) code for the thickness calculation.

5. Piping Stress Analysis

5.1 List of calculation reports

A list of the calculations reports shall be issued and regularly updated. The lines which are subject to approximate or comprehensive analysis methods (levels 2 and 3) shall be registered on this list which shall include the following information:

- Line number, including revision and date
- Calculation number
- Type of analysis
- Revision and date of issue.

5.2 Screening or hand calculations

All level 1 and level 2 lines shall be checked by piping and/or supporting engineers. 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.

Differential displacements shall be considered.

All piping stress calculation notes of level 2 lines shall be submitted to COMPANY for review.



5.3 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, 4.50 or 5.0 version, developed by COADE Inc. (Houston - Texas USA).

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	FPSO unit
X = North direction	X = Horizontal axis parallel to the FPSO longitudinal axis (forward)
Y = Transversal axis (toward West)	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.

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

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

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,

depressurisation and other special conditions shall also be considered. This temperature shall be taken from the process and utilities list and shall be specified on 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 lines list.

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 operating temperature may be applied for the calculation of the loads on the supports.

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 (i.e. 60°C for exposed pipes in Africa).

6.2.3 Dry out and steam out

Dry out and steam out temperatures (if any) shall be taken from the process and utilities 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.

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

6.2.4 "Dead branch"

For the lines which do not have 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.

6.2.5 Plant temperature

The plant temperature is defined by considering the Project environmental conditions:

- For cold piping stress, the installation temperature is the maximum air temperature
- For hot piping stress, the installation temperature is the minimum air temperature.