

DEP SPECIFICATION

PIPING - GENERAL REQUIREMENTS

DEP 31.38.01.11-Gen.

February 2012

DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for piping systems built in accordance with ASME B31.3. It applies to piping for all types of process fluids (including fluidised solids), and all utility fluids. This DEP specifies additional requirements for specific services in (Appendix 10).

Piping covered under equipment design codes are excluded from the scope of this DEP.

Oil and gas risers, hull piping subjected to Classification Society rules (except for piping associated with topsides process systems), utility piping in living quarters and plant buildings are excluded from the scope of this DEP standard.

Pipelines are excluded from the scope of this DEP.

Pipelines are designed in accordance with codes such as ISO 13623, ASME B31.4, ASME B31.8, NEN 3650 and PD8010 are excluded from the scope of this DEP. Sketches of the interface between pipelines and other equipment are included in ASME B31.8 and ISO 13623. See also DEP 31.40.00.10-Gen.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2011; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
CAD	Computer Aided Drafting
DN	Diameter Nominal. The DN prefix indicates the nominal diameter of a piping system component in millimetres.
EJMA	Standards of the Expansion Joint Manufacturers Association
Fluid	Gas, vapour, liquid or combinations thereof
GTAW	Gas Tungsten Arc Welding
Long-Run Piping	Piping with length more than one pipe support span.
MESC	Materials and Equipment Standards and Code. The MESC codes are contained in the Catalogue Management Tool (CMT) system.
NPS	Nominal Pipe Size
PEFS	Process Engineering Flow Scheme
PFS	Process Flow Scheme
Pipeline	A pipeline is a system of pipes and other components used for the transportation of fluids between (but not within) plants. A pipeline typically extends from pig trap to pig trap (including the pig traps). If no pig trap is fitted, the pipeline extends to the first isolation valve within the plant boundaries.
Piping	Piping is an assembly of straight and bent pipes, fittings, flanges, gaskets, valves and other components (e.g. expansion joints, swivel joints, strainers, devices for mixing, separating, distributing, metering and flow control). It also includes pipe supporting elements and insulation. NOTE: Piping does not include supporting structures (such as frames of buildings, stanchions or foundations) or equipment (e.g. heat exchangers, vessels, columns, pumps) or instrument impulse pipes.
Piping Class	Piping Class is an assembly of piping components, suitable for a defined service and design limits, in a piping system. The piping classes are contained in the following DEP binders: • DEP 31.38.01.12-Gen. Piping classes developed primarily for oil refineries, chemical plants and gas plants; also suitable for onshore exploration and production facilities. • DEP 31.38.01.15-Gen. This binder contains piping classes developed primarily for offshore exploration and production facilities (platform piping). NOTE: For standardization and interchangeability, the Principal may decide to use the E&P piping classes also for onshore facilities, depending on the size of the project.
Pipe Stress Engineer	The engineer(s) approved by the principal to undertake pipe stress analysis for a project. Responsible for obtaining data from disciplines as appropriate, creation, maintenance and issue of the pertinent pipe stress analysis documentation detailed within this standard, analysis and approval of all stress critical lines and the timely dissemination of pipe support/restraint information.
Spec Break	The physical location as a single point dividing one piping class from another

Term	Definition
Very Toxic	See DEP 01.00.01.30-Gen.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (12).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2011. Other than editorial changes, the only change in this revision has been the addition of US Customary units.

Old section	New section	Change
1.1	1.1	Scope has been updated to give more clarity.
1.3.2	1.3.2	Definitions for "EJMA", "GTAW" have been added.
2.2.1	2.2.1	Additional requirement for sizing of liquid piping system has been incorporated.
2.2.4	2.2.5	New section for "Sizing of flare and vent systems" has ben added.
2.2.4	2.2.6	New section for "Two-phase flow" has ben added
2.3	2.3	Requirement for the software and models have been included
2.3.1	2.3.1	Updated this section to include "weight constraints" consideration.
2.3.3.1	2.3.3.1	Updated equivalent length of piping components and valves
2.3.3.2	2.3.3.2	This section has been updated to include equations in dual units.
2.3.3.3	2.3.3.3	Reference to Appendix-6 has been deleted. Incorporated pipe wall roughness into this section.
2.3.3.5	2.3.3.5	Reference to Appendix-4 has been deleted. Incorporated requirements for sizing of steam piping systems.
2.3.4	2.3.4	Entire section has been rewritten to give elaborate screening criteria. New SHALL [PS] requirement has been added in the 3 rd paragraph for surge calculations. "SHALL [PS]" requirement has been changed to "shall" for reporting of results of surge analysis and transient analysis.
2.3.5	2.3.5	Reference to DEP 30.75.10.10-Gen has been incorporated
3.1	3.1	Requirement for piping systems in offshore production platform has been incorporated. Incorporated requirements for demarcation of piping systems built to ASME B31.3 vs. ASME B31.1/ B31.5. Incorporated additional requirements for pipe support span. Mandating of DEM1 DEP piping classes and associated MESC specifications with "SHALL [PS]" requirement has been changed to "shall". "SHALL [PS]" requirement has ben changed to "shall" for Appendix-16, and necessary SHALL [PS] requirements incorporated into Appendix-16.

Old section	New section	Change
3.2	3.2	Incorporated requirements on dissimilar metals welding. Incorporated "Piping systems connected to other systems or equipment with a higher design rating SHALL [PS] have the higher rating for all components up to and including the first block valve in the system of lower rating."
3.3	3.3	Incorporated requirement of piping studies.
3.3.1.1	3.3.1.1	Updated this section to give reference to DEP 30.00.60.20-Gen. and DEP 80.00.10.11-Gen.
3.5.1	3.5.1	As the intent is covered in (3.5.1.2), "SHALL [PS]" requirement has ben changed to "shall" in the 1 st paragraph.
3.5.1.2	3.5.1.2	Incorporated additional requirements for pipe stress analysis of piping systems associated with rotating equipment. Mandating of DEM1 DEP 80.45.10.10-Gen with "SHALL [PS]" requirement has ben changed to "shall".
3.5.1.4	3.5.1.4	Requirements on critical line list has been updated.
3.5.1.5	3.5.1.5	Incorporated additional requirements for analysis.
3.5.2	3.5.2	Incorporated requirement for pipe support span
3.6	3.6	Incorporated requirements for piping through walls in offshore installations. Duplicate mandate of "SHALL [PS]" requirement has ben changed to "shall" for penetrations through walls and floors in the 2 nd paragraph.
3.8	3.8	Updated this section to give reference to DEP 30.00.60.20-Gen.
3.9	3.9	Deleted statement: "All small bore nozzle welding SHALL [PS] be performed by Gas Tungsten Arc Welding (GTAW) in the prefabrication yard or shop." to avoid duplication of statement(in DEP 31.38.01.31-Gen and DEP 31.38.01.11-Gen). Updated design requirements for small bore branch connections. This includes deletion of one of the SHALL [PS] requirement in point no. h). "SHALL [PS]" requirement has ben changed to "shall" in 2 nd paragraph for mandatory size of branch connection to run pipe.
3.10	3.10	Incorporated additional requirements for installation of flanges.
3.12	3.12	Incorporated additional requirements for installation of valves. "SHALL [PS]" requirement has ben changed to "shall" for installation of valves above roads.
3.13.1	3.13.1	Incorporated alternative arrangement for pressure test vent and drain connections.
3.13.2	3.13.2	Incorporated additional requirements for process drain and vent connections. "SHALL [PS]" requirement has been changed to "shall" for mandatory size of branch connection to run pipe.
3.14	3.14	Incorporated additional requirements for manual sampling.

Old section	New section	Change
3.15	3.15	"SHALL [PS]" requirement has been changed to "shall" in third paragraph for non destructive examination of welds.
3.16	3.16	Updated requirement of thermowell connections. "SHALL [PS]" requirement has been changed to "shall" for mandatory size of branch connection to run pipe in first paragraph.
3.19	3.19	Additional requirement for instrument process connections (threaded connections) has been incorporated.
3.23	3.23	Updated this section to incorporate piping system design requirements in vibrating service. New SHALL [PS] requirement has been included in 2 nd and 3 rd paragraphs.
4.1	4.1	Incorporated "The allowable loads and moments on equipment nozzles SHALL [PS] be in accordance with the relevant DEP and their associated standards (e.g. API) for the equipment." Mandating of DEM1 DEP 30.06.10.12-Gen with "SHALL [PS]" requirement has ben changed to "shall". Incorporated reference to DEP 30.00.60.20-Gen.
4.2.1	4.2.1	Deleted statement: "The allowable loads and moments on equipment nozzles SHALL [PS] be in accordance with the relevant DEP and their associated standards (e.g. API) for the equipment." Incorporated reference to DEP 30.00.60.20-Gen.
4.2.2.1	4.2.2.1	Incorporated requirement for vent or drain connection for trapped liquid between the check valve and block valve.
4.2.2.4	4.2.2.4	Incorporated threaded connections requirement.
4.2.2.6	4.2.2.6	Mandating of DEM1 DEP 80.45.10.10-Gen with "SHALL [PS]" requirement has ben changed to "shall".
4.2.3	4.2.3	Incorporated welding/cleanliness requirements for compressor piping. Requirements given in 2 nd paragraph have been incorporated in DEP 31.38.01.31-Gen.
4.2.4	4.2.4	SHALL [PS] requirement of warming up facilities has been changed to "shall" as this is not a process safety concern.
4.3	4.3	Incorporated reference to DEP 30.00.60.20-Gen.
4.5	4.5	Incorporated additional requirements for piping associated with pressure vessels. Updated requirement on vent/drain connections.
4.6	4.6	Mandating of DEM1 DEP 80.45.10.10-Gen with "SHALL [PS]" requirement has ben changed to "shall".
4.7.1	4.7.1	Incorporated additional requirements for level gauges.
4.7.3	4.7.3	Incorporated requirement of level gauge visibility w.r.t. drain valve.
4.8	4.8	Incorporated reference to DEP 30.00.60.20-Gen.

Old section	New section	Change
4.11	4.11	Updated this section to incorporated reference to DEP 31.40.10.12-Gen. for finger type slug catchers design.
4.12	4.12	Incorporated additional requirements for vessel trims.
5.1	5.1	Updated this section to include double barrier concept for relevant piping systems.
5	5.2	Incorporated new section number Mandating of DEM1 DEP 80.47.10.31-Gen with "SHALL [PS]" requirement has ben changed to "shall".
5.2	5.3	Section number has been updated
5.3	5.4	Section number has been updated
5.4	5.5	Section number has been updated. This section has been rewritten to align with DEP 30.75.10.10-Gen.
5.5	5.6	Section number has been updated. This section has been rewritten to align with DEP 30.75.10.10-Gen.
5.6	5.7	Section number has been updated. Mandating of DEM1 DEP piping classes with "SHALL [PS]" requirement has ben changed to "shall". Incorporated requirements for instrument air supply piping.
5.7	5.8	Section number has been updated. Incorporated requirements for tool air piping.
5.8	5.9	Section number has been updated. Also additional requirements for utility station piping systems has been included.
7	7	Updated this section to incorporated reference to DEP 31.06.11.11-Gen. for design piping systems for truck loading facilities.
8.1	8.1	Incorporated additional requirements for piping components.
8.2.2.2	8.2.2.2	Mandating of DEM1 DEP 31.40.10.19-Gen and DEP 31.38.01.12-Gen with "SHALL [PS]" requirement has ben changed to "shall".
8.2.2.2.1	-	Deleted
8.2.2.2.2	-	Deleted
8.2.3	8.2.3	Incorporated requirements for lined piping systems.
8.3.1.1	8.3.1.1	Mandating of DEM1 DEP 31.38.01.31-Gen with "SHALL [PS]" requirement has ben changed to "shall".
8.3.1.2.1	8.3.1.2.1	Updated this section to give more clarity on the usage of socket welded connections.
8.3.1.3	8.3.1.3	Incorporated requirements on insulation joints.
8.3.1.4	8.3.1.4	Incorporated requirements on the usage of plastic tape. Incorporated new SHALL [PS] requirement to avoid the usage of low-grade masking tape.
8.3.1.5	8.3.1.5	Updated this section to give more guidance on the usage of threaded joints .

Old section	New section	Change
8.3.1.6	8.3.1.6	Incorporated additional requirements for application of coated bolts at higher temperatures.
8.4	8.4	Incorporated restrictions on the usage of non-standard fittings. To avoid wrong usage of piping components, new SHALL [PS] requirement for the use of special fittings has been incorporated.
8.5	8.5	Incorporated additional requirements on branch fittings. SHALL [PS] requirement of branch connections on elbows or concentric reducers has been changed to "shall" as this is not a process safety concern.
8.6	8.6	Incorporated "Slip-on flange joints shall not be used in hydrogen service."
8.7.2	8.7.2	Updated this section to give clarity on the usage of blind connections of bleed.
8.7.3.1	8.7.3.1	Updated requirements on the usage of quick acting blinds based on LFI.
8.8.3.6	8.8.3.6	Incorporated requirements for the installation of piston/ball type check valves.
8.8.3.7	8.8.3.7	Updated requirement for process to instrument valves in flashing services.
8.8.6	8.8.6	Updated Tmin. Temperature to -29 deg.c (-20 deg.F). Also the table on non-metallic seat and seal material has been updated.
8.8.7	8.8.7	Updated maximum seat upper design temperature rating for PEEK material.
8.8.8	8.8.8	SHALL [PS] requirement for the mandatory use of MESC SPE 85/203 or MESC SPE 85/204 has been changed to "shall" as this is not a process safety concern.
8.8.10.2	8.8.10.2	Incorporated guidance on the usage of socket welded valves.
8.8.10.9	8.8.10.9	Reference to MESC SPE 77/303 has been incorporated, and also deleted SHALL [PS] requirement for packing of ethylene oxide service valves as this is not a process concern.
9.1.1	9.1.1	Mandating of DEM1 DEP 31.38.01.31-Gen with "SHALL [PS]" requirement has ben changed to "shall".
9.2.1	9.2.1	Mandating of DEM1 DEP 31.38.01.31-Gen with "SHALL [PS]" requirement has ben changed to "shall".
10.1	10.1	Incorporated requirements for insulation of flange joints with spectacle blind , spades or spacers.
Appendix-1	Appendix-1	Deleted
Appendix-2	Appendix-2	Deleted
Appendix-3	Appendix-3	Deleted
Appendix-4	Appendix-4	Deleted
Appendix-5	Appendix-5	Deleted
Appendix-6	Appendix-6	Deleted

Old section	New section	Change
Appendix-7	Appendix-7	Incorporated dual units
Appendix-10, 10.1.2	Appendix-10, 10.1.2	SHALL [PS] requirement for the mandatory use of GTAW method for root pass of piping systems has been changed to "shall" as this is not a process safety concern.
Appendix-10, 10.2.2	Appendix-10, 10.2.2	SHALL [PS] requirement for the mandatory use of GTAW method for root pass of piping systems has been changed to "shall" as this is not a process safety concern.
Appendix-10, 10.3.2	Appendix-10, 10.3.2	SHALL [PS] requirement for the mandatory use of GTAW method for root pass of piping systems has been changed to "shall" as this is not a process safety concern.
Appendix-10, 10.6.1	Appendix-10, 10.6.1	This section has been updated to give clarity on the definitions in upstream and downstream sour services.
Appendix-10, 10.6.3	Appendix-10, 10.6.3	Mandating of DEM1 DEP 30.10.02.17-Gen with "SHALL [PS]" requirement has ben changed to "shall".
Appendix-13	Appendix-13	Incorporated dual units
Appendix-14	Appendix-14	Full vacuum design has been aligned with ASME Section VIII, Division 1.
Appendix 17	Appendix 17	Incorporated requirements for further analysis of piping systems in accordance with new appendix (Appendix 19).
-	Appendix 18	Incorporated new appendix-18 on requirements for drawings.
-	Appendix 19	Incorporated new appendix on "DYNAMIC ANALYSIS DESIGN CONSIDERATIONS FOR PIPING SYSTEMS".

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. PIPE SIZING

2.1 GENERAL

The following pipe sizes shall be used:

DN 15 (NPS 1/2), DN 20 (NPS 3/4), DN 25 (NPS 1), DN 40 (NPS 1 1/2), DN 50 (NPS 2), DN 80 (NPS 3), DN 100 (NPS 4), DN 150 (NPS 6), DN 200 (NPS 8), DN 250 (NPS 10), DN 300 (NPS 12), DN 350 (NPS 14), DN 400 (NPS 16), DN 450 (NPS 18), DN 500 (NPS 20) and DN 600 (NPS 24) in accordance with the following limitations.

- a) Due to their vulnerability to damage and their limited mechanical strength, sizes DN 15 (NPS 1/2) and DN 20 (NPS 3/4) should not be used. Sizes DN 15 (NPS 1/2) and DN 20 (NPS 3/4) shall not be used for long-run piping.
- b) Nominal pipe size in pipe tracks shall not be less than DN 50 (NPS 2);
- c) Nominal pipe size in pipe racks shall not be less than DN 40 (NPS 1 1/2);
- d) Pipe sizes between those given in the piping classes shall not be used.

For requirements of small bore piping, see (3.9).

Unless economically justified otherwise, the range of pipe sizes above DN 600 (NPS 24) shall be restricted to the following, in order to avoid the purchase of many different sizes of pipe and fittings:

- a) DN 750 (NPS 30)
- b) DN 900 (NPS 36)
- c) DN 1050 (NPS 42)
- d) DN 1200 (NPS 48)
- e) DN 1400 (NPS 56)
- f) DN 1600 (NPS 64)
- g) DN 1800 (NPS 72)
- h) DN 2000 (NPS 80).

The identification of piping shall be in accordance with DEP 31.10.03.10-Gen. The identification of piping classes shall be in accordance with DEP 31.38.01.10-Gen.

(Appendix 8) and (Appendix 15) give dimensions and properties of pipe up to and including DN 1200 (NPS 48).

After the basic pipe routes, number of valves, control valves, fittings, etc., have been determined, the anticipated pressure drop for the preliminary pipe sizes shall be checked.

A calculation sheet for pumping data (DEP 31.29.01.85-Gen.) shall be prepared for each pump, showing calculations for suction and discharge conditions, static head, static pressure, vapour pressure at pumping temperature and minimum available NPSH (Net Positive Suction Head), including the calculated pressure drop in equipment, pipes, valves, fittings and control valves.

The Principal shall be consulted for piping systems for which the pressure drop calculations are not covered in (2.3).

The pipe sizes shall be listed on a form which contains as a minimum the data as required in accordance with the requisition datasheet DEP 31.38.01.92-Gen. The format shall be presented using a method acceptable to the Principal.

2.2 PRELIMINARY PIPE SIZING

The process engineer or process designer is responsible for preliminary pipe sizing.

2.2.1 Sizing of liquid piping systems:

The sizing criteria for liquid piping systems will depend on application. The function and application of the piping system will determine the sizing criterion to be selected. Where pressure drop is not a determining parameter, the size should be determined by the velocity constraints as mentioned below:

The velocities shall be kept low enough to prevent problems with erosion, water hammer, pressure surges, noise, and vibration and reaction forces. In some cases, a minimum velocity is required. When determining the velocity of the medium in the lines, account should be taken of the possible generation of static electricity (see Shell Safety Document).

For water and other liquids, velocities in accordance with ISO 13703 may be used for preliminary line pipe sizing (0.5 to 5 m/s (1.6 to 16 ft/s)).

For velocity limitations of steam blowdown, boiler feed water, steam condensate piping systems, see DEP 30.75.10.10-Gen

Preliminary pipe sizing of pump suction piping should be based on a pressure drop of 0.034 to 0.083 bar/100 m (0.15 to 0.37 psi/100 ft) for liquids within 15 °C (27 °F) of their boiling point and 0.15 to 0.4 bar/100 m (0.66 to 1.77 psi/100 ft) for subcooled liquids.

Preliminary pipe sizing of pump discharge piping should be based on a pressure drop of 0.150 to 0.627 bar/100 m (0.66 to 2.77 psi/100 ft).

For piping systems where the process fluids are expected to be contaminated by sand or proppant, the following velocities can be used for preliminary line sizing (in accordance with NORSOK Std. P-001)

Piping systems with carbon steel as material of construction up to 5 m/s (16 ft/s);

Piping systems with stainless steel / duplex stainless steel as material of construction up to 7 m/s (23 ft/s).

For more guidance on maximum velocities for sizing liquid piping systems, see section 6.2, NORSOK Std. P-001.

2.2.2 Sizing of gas and steam piping systems:

The following velocities can be used for preliminary line sizing:

- a) Air and other gases (non-corrosive/non erosive)
 - i. 10 to 20 m/s (33 to 66 ft/s) or
 - ii. $\rho v^2 \leq 20\,000 \text{ kg/ms}^2$ with maximum of 60 m/s (200 ft/s);
- b) Saturated steam (dry) 15 to 30 m/s (50 to 100 ft/s);
- c) Superheated steam 30 to 60 m/s (100 to 200 ft/s);
- d) Vacuum pipes 10 to 100 m/s (30 to 330 ft/s).

For design of piping systems where corrosion inhibition is anticipated, velocity shall be limited in accordance with DEP 39.01.10.11-Gen., Table A4.1 to reduce the effect of stripping the inhibitor film from the pipe wall.

2.2.3 Sizing of amine piping systems:

Following mean linear velocities should be used for sizing of amine piping systems:

- Carbon steel piping: less than 2 m/s (7 ft/s);
- Stainless steel piping: less than 3 m/s (10 ft/s) (recommended) and max 5 m/s (16 ft/s).

2.2.4 Sizing of drilling fluid piping systems:

The minimum flowing velocity of drilling fluid shall not be lower than 0.8 m/s (3 ft/s) in order to prevent the settling of sand in pipes. The maximum velocity in carbon steel should not exceed 4 m/s (13 ft/s) to avoid problems such as cavitation/erosion on bends and damage

to inline equipment and vessel internals. The maximum pressure drop gradient in pump suction and gravity flow pipes (carbon steel) shall be 0.3 bar/100 m (13.3 psi/1000 ft).

The above values are not applicable to sludge, slurry, erosive fluids or two-phase flow. The Principal shall be consulted for those services.

2.2.5 Sizing of flare and vent systems:

For sizing of flare and vent systems and relief valve inlet and discharge piping see DEP 80.45.10.10-Gen.

2.2.6 Two-phase flow:

To determine the flow pattern of two-phase flow see DEP 31.22.05.11-Gen.

2.3 FINAL PIPE SIZING

The process engineer or process designer is responsible for final pipe sizing.

The Principal shall review final pipe sizing where materials of construction are affected by corrosive fluids.

The Principal shall approve the software and models proposed for final sizing of the piping system to ensure optimum economics and integrity of the piping system design is maintained.

2.3.1 Considerations

The following should be considered in determining a suitable pipe size:

- a) The allowable pressure drop.
- b) Whether pressure surges could occur in the piping system.
- c) Whether erosion could occur in the piping system.
- d) Whether the piping system could be subjected to vibration.
- e) Whether solids could settle out from the fluid (e.g. in slurry service).
- f) The type of flow pattern in services where two-phase flow is possible (an intermittent flow pattern shall be avoided).
- g) The allowable temperature drop if the fluid is highly viscous.
- h) The economic pipe diameter, considering the capital expenditure and operating expenditure of the pumps, compressors and the piping system.
- i) Mechanical strength
- j) The required flow demand of the piping system or process (flow constraints)
- k) Weight constraints

The above considerations shall be taken into account both for the design conditions as well as for conditions such as start-up, shut-down and regeneration.

2.3.2 Reynolds number

The Reynolds number indicates whether the product flow is laminar or turbulent. The change from one type of flow to the other occurs at a definite value of the Reynolds number. Laminar flow can be expected in pipes if the Reynolds number is < 2300.

Turbulent flow can be expected when the Reynolds number is > 4000. With Reynolds numbers between 2300 and 4000, the flow can easily switch from one type to the other. This could change the pressure drop by a factor of 3 or more.

Once calculated, the Reynolds number is used in (2.3.3.2) to determine the friction factor for the different types of pipe.

2.3.3 Pressure drop calculations

2.3.3.1 General

The Contractor's in house calculation methodology or software program may be substituted in lieu of the procedures outlined below subject to verification and approval by the Principal of pressure drops, flow regimes and line velocities.

The formulae for pressure drop calculations given in this section are applicable to fluids whose density and viscosity are constant along the length of the whole pipe, which is normally the case for liquids. Pressure drop due to piping components other than straight pipe shall be expressed for calculation purposes as equivalent lengths (L_e) and added to the length of the straight pipe in the system, thus giving the total length (L) to be used in the pressure drop calculations.

For valves and fittings, L_e is given in Table 1 below (in which D = nominal pipe diameter and for reducing fittings D = large end nominal diameter and d = small end nominal diameter):

Table 1			
Type of valve/fitting			L_e *
Valves (fully open)	Ball valve	Reduced bore DN 40 (NPS 1 1/2) and smaller Reduced bore DN 50 (NPS 2) and larger Full bore DN 50 (NPS 2) and larger	65 D 50 D 8 D
	Gate valve	Standard bore Reduced bore DN 40 (NPS 1 1/2) and smaller	13 D 30 D
	Globe valve	Straight pattern Y pattern Angle pattern	135 D 80 D 75 D
	Check valve	Swing type Ball or piston type, DN 40 (NPS 1 1/2) and smaller Dual Plate type	50 D 135 D 75 D
	Plug valve	Regular pattern	60 D
	Butterfly valve	Concentric type Double offset type Triple offset type	25 D 55 D 60 D
Fittings	Tee-equal	Flow straight through Flow through side outlet	20 D 65 D
	Elbow	90°, $R = 1 \frac{1}{2} D$ 45°, $R = 1 \frac{1}{2} D$	20 D 16 D
	Bend	90°, $R = 4 D$ 90°, $R = 5 D$ 180°, $R = 4 D$ 180°, $R = 5 D$	14 D 16 D 25 D 28 D
	Enlargement	Sudden, $d/D = 1/4$ Sudden, $d/D = 1/2$ Sudden, $d/D = 3/4$ Standard reducer, $d/D = 1/2$ Standard reducer, $d/D = 3/4$	73 D 47 D 16 D 35 D 10 D

Table 1			
Type of valve/fitting			L _e *
	Contraction	Sudden, d/D = 1/4	40 D
		Sudden, d/D = 1/2	32 D
		Sudden, d/D = 3/4	20 D
		Standard reducer, d/D = 1/2	16 D
		Standard reducer, d/D = 3/4	5 D
Miscellaneous	Strainer	Pump suction Y-type and bucket type	250 D
	Nozzle	Product outlet nozzle vessel/tank	32 D
		Product inlet nozzle vessel/tank	64 D
* In critical situations, the Manufacturer/Supplier's data shall be obtained.			

The pressure drop across control valves shall be determined in consultation with parties responsible for instrumentation. To obtain a reasonable degree of control, the pressure drop across the control valve (at 80% open position) shall be at least 1 bar (14.5 psi). However, if the pressure drop across the control valve is too high, installation of a piece of small bore pipe in front of the control valve in order to reduce the pressure drop across the valve shall be considered.

The pressure drop of in-line instruments, such as vortex or Coriolis flow meters, shall be determined from the Manufacturer/Supplier's data.

For equipment, the pressure drop shall be taken from the data obtained from the equipment Manufacturer/Supplier.

2.3.3.2 General equation for pressure drop calculation

The pressure drop for a piping system in **metric units** is given by the equation:

$$\Delta P = \lambda \frac{L}{D_i} \times \frac{1}{2} \rho v^2$$

or, to convert pressure drop from N/m² into metres of liquid head loss:

$$\Delta h = \lambda \frac{L}{D_i} \times \frac{v^2}{2g}$$

or, for **circular** cross-section pipe:

$$\Delta P = \frac{8}{\pi^2} \times \lambda \frac{L q_m^2}{\rho D_i^5}$$

where:

$$\lambda = 8 \left\{ \left(\frac{8}{Re} \right)^{12} + (A + B)^{-3/2} \right\}^{1/12}$$

$$Re = \frac{\rho v D_i}{\eta}$$

$$A = \left\{ 2.457 \ln \left(\left[\frac{7}{Re} \right]^{0.9} + 0.27 \frac{\varepsilon}{D_i} \right) \right\}^{16}$$

$$B = \left(\frac{37530}{Re} \right)^{16}$$

in which: ΔP = pressure drop (N/m²)

λ = friction factor (dimensionless)

L = total design length (m)

D_i = inside diameter of pipe (m)

ρ = density (kg/m³)

v = average linear flow velocity (m/s)

Δh = head loss (m)

g = acceleration due to gravity (9.807 m/s²)

q_m = mass flow (kg/s)

η = dynamic viscosity (Pa·s)

ε = internal pipe wall roughness (m)

The pressure drop for a piping system in **USC units** is given by the equation:

$$\Delta P = 0.00259 \times \lambda \frac{L}{D_i} \times \frac{1}{2} \rho v^2$$

or, to convert pressure drop from psi into feet of liquid:

$$\Delta h = 12 \times \lambda \frac{L}{D_i} \times \frac{v^2}{2g}$$

or, for **circular** cross-section pipe:

$$\Delta P = \frac{8}{\pi^2} \times 53.708 \times \lambda \frac{L q_m^2}{\rho D_i^5}$$

where:

$$\lambda = 8 \left\{ \left(\frac{8}{Re} \right)^{12} + (A + B)^{-3/2} \right\}^{1/12}$$

$$Re = 124 \times \frac{\rho v D_i}{\eta}$$

$$A = \left\{ 2.457 \ln \left(\left[\frac{7}{Re} \right]^{0.9} + 0.27 \frac{\varepsilon}{D_i} \right) \right\}^{16}$$

$$B = \left(\frac{37530}{Re} \right)^{16}$$

in which: ΔP = pressure drop (psi)

λ = friction factor (dimensionless)

L = total design length (ft)

D_i = inside diameter of pipe (in)

ρ = density (lbm/ft³)

v = average linear flow velocity (ft/s)

Δh = head loss (ft)

g = acceleration due to gravity (32.174 ft/s²)

q_m = mass flow (lbm/s)

η = dynamic viscosity (cP)

ε = internal pipe wall roughness (in)

2.3.3.3 Pressure drop for liquids

The formulae given in (2.3.3.2) shall be applied. For the internal pipe wall roughness, the following values may be selected:

Piping Material	Absolute Roughness ε	Comments
Carbon Steel (CS) non-corroded:	$50 \cdot 10^{-6}$ m (0.002 in)	Note 2
Carbon Steel (CS) corroded:	$500 \cdot 10^{-6}$ m (0.02 in)	
Carbon Steel (CS) flare lines:	$500 \cdot 10^{-6}$ m (0.02 in)	
Stainless Steel (SS):	$50 \cdot 10^{-6}$ m (0.002 in)	Note 2
Stainless steel (SS) flare lines	$100 \cdot 10^{-6}$ m (0.004 in)	
Titanium and Cu-Ni:	$50 \cdot 10^{-6}$ m (0.002 in)	
Glass fibre Reinforced Pipe (GRP):	$20 \cdot 10^{-6}$ m (0.0008 in)	Without liner
Glass fibre Reinforced Pipe (GRP):	$5 \cdot 10^{-6}$ m (0.0002 in)	With liner
Polyethylene, PVC:	$5 \cdot 10^{-6}$ m (0.0002 in)	
Galvanised Carbon Steel:	$150 \cdot 10^{-6}$ m (0.006 in)	
Drawn Tubing	$1.5 \cdot 10^{-6}$ m (0.00006 in)	
Bitumen-lined pipe	$120 \cdot 10^{-6}$ m (0.005 in)	
Cast iron pipe	$260 \cdot 10^{-6}$ m (0.01 in)	
Cement-lined pipe	$1500 \cdot 10^{-6}$ m (0.06 in)	
Smooth cement-lined pipe $\geq$ DN 400 (NPS 16)	$50 \cdot 10^{-6}$ m (0.002 in)	
Flexible Hose	See Note 1	Consult vendor
NOTE 1: As a rough estimation, $\varepsilon = ID/5 \cdot 10^6$ (m), [ID in (mm)] ($\varepsilon = ID/5 \cdot 10^3$ (in), [ID in (in)]) can be used for steel carcass and $5 \cdot 10^{-6}$ m (0.0002 in) for plastic coating. Note 2: This value should also be used for relief valve <i>inlet</i> pipework sizing.		

2.3.3.4 Pressure drop for gas and vapours

The formulae given in (2.3.3.2) shall not be applied since the density of the fluid will change due to pressure drop and possible temperature changes. To determine accurately the pressure drop in these cases, pressure drop computer programs should be used.

For applications where an accurate determination of the pressure drop is not required the following guidelines may be applied.

- If pressure drop is less than 10 % of the upstream pressure, the formulae given in (2.3.3.2) may be applied with ρ (density) and v (average linear flow velocity) based on either the inlet or outlet conditions.
- If the pressure drop is between 10 % and 40 % of the upstream pressure, the formulae given in (2.3.3.2) may be applied with ρ (density) and v (average linear flow velocity) as averages of inlet and outlet conditions. The calculation becomes an iterative process.

2.3.3.5 Steam pipes

For economic sizing of steam pipes, the following pressure drop in bar/100 m (psi/100 ft) should be used:

- LP and MP steam (up to 22 barg (320 psig):

In **metric** units:

$$0.005 \times (P + 10) \leq \Delta P \leq 0.02 \times (P + 10)$$

P in barg, ΔP in bar/100 m

In **USC** units

$$0.0015 \times (P + 145) \leq \Delta P \leq 0.006 \times (P + 145)$$

P in psig, ΔP in psi/100 ft

- HP steam, between 22 and 68 barg (320 and 985 psig)

In **metric** units:

$$0.001 \times (P + 140) \leq \Delta P \leq 0.001 \times (P + 620)$$

P in barg, ΔP in bar/100 m

In **USC** units

$$0.003 \times (P + 2000) \leq \Delta P \leq 0.003 \times (P + 9200)$$

P in psig, ΔP in psi/100 ft

Off-plot HP steam lines should be designed with a pressure drop of 0.1 bar/100 m (0.44 psi/100 ft)

2.3.4 Pressure surge analysis

Surge is caused by rapid velocity changes of the fluid, e.g. because of rapid valve closure, pump trip or pump start. The steep pressure gradients that may occur under some surge conditions and which cannot be avoided by appropriate means (e.g. non-slam check valves) should be evaluated with regard to the effects on the supports and the design pressure of the system.

Pressure surge calculations are relevant to pipe handling incompressible fluids (liquids). The magnitude of the pressure surge is determined by the velocity of the fluid in the pipe and the rate at which this velocity is changed. As a general rule a sudden velocity change

of 1 m/s (3.3 ft/s) will generate a pressure surge of 10 bar (145 psi). The effect of a sudden velocity change depends on the length of the pipe and of the closing speed of the end valve.

The designer shall ensure that the occurrence of a pressure surge can be tolerated; if in doubt a surge calculation SHALL [PS] be carried out and formally reported, including all scenarios, as specified in this section. As a general rule, pressure surges for piping inside process units may be ignored if the end valve is a manually operated rising stem valve, or a gearbox operated valve. For interconnecting piping, for off-plot piping and for lever-operated quarter turn valves, actuated on-off valves and control valves, pressure surges may generally be ignored if the following conditions are satisfied:

$$P_{operating} + P_{surge} \leq P_{design}$$

And:

$$P_{operating} - P_{surge} \geq P_{vap}$$

The maximum surge pressure develops when the valve closes rapidly relative to the piping length. Using SI units, the maximum surge pressure is:

$$P_{surge} \leq c_{system} \times \rho v_{fluid}$$

In steel piping systems with D/t ~70, the system sonic velocity is roughly 90% of the fluid sonic velocity and for hydrocarbon containing piping a system sonic velocity of 1100 m/s (3600 ft/s) may be taken for the initial assessment.

For shorter pipe sections or slower valve closing speed, using SI units, the minimum pressure surge is:

$$P_{surge} = \frac{2L}{D} \times \rho v_{fluid} \times v_{effective\ valve\ closure}$$

For surge calculation purposes the Effective Valve Closure Time shall be established, being the period within which a given valve reduces the flow from 90 % of its steady state to zero. The effective valve closure time for gate valves, butterfly valves and ball valves represents approximately 5 %, 15 % and 25 %, respectively, of the total valve closure time.

For actuated valves, the valve closure speed is usually 25 mm/s (1 in/s) and under this assumption, for full-bore valves, the Effective Valve Closure Speed is determined as follows:

V_{effective valve closure} :

- Gate valves: 0.5 m/s (1.64 ft/s)
- Butterfly valves: 0.17 m/s (0.55 ft/s)
- Globe and Ball valves: 0.1 m/s (0.33 ft/s)

For reduced-bore valves, the Effective Valve Closure Speed shall be increased with a factor equal to the ratio of pipe size over port size.

In **metric** engineering units, the surge pressure can be represented as follows:

$$P_{surge} = \frac{0.02L}{DN} \times \rho v_{fluid} \times v_{effective\ valve\ closure}$$

while:

$$P_{surge} \leq 10^{-5} \times c_{system} \times \rho v_{fluid}$$

where:

P_{surge}	surge pressure (barg)
L	pipng length between pump and valve (m)
DN	nominal diameter pipe (mm)
v_{fluid}	fluid velocity in pipe (m/s)
$v_{effective\ valve\ closure}$	effective valve closure speed (m/s)
ρ	density of fluid (kg/m ³)
c_{system}	system sonic velocity (m/s)

In **USC** engineering units, the surge pressure can be represented as follows:

$$P_{surge} = \frac{0.0052L}{NPS} \times \rho v_{fluid} \times v_{effective\ valve\ closure}$$

while:

$$P_{surge} \leq 21.6 \bullet 10^{-5} \times c_{system} \times \rho v_{fluid}$$

where:

P_{surge}	surge pressure (psig)
L	pipng length between pump and valve (ft)
NPS	nominal pipe size (in)
v_{fluid}	fluid velocity in pipe (ft/s)
$v_{effective\ valve\ closure}$	effective valve closure speed (ft/s)
ρ	density of fluid (lb/ft ³)
c_{system}	system sonic velocity (ft/s)

Measures should be taken to avoid cavitation since the collapse of a cavity could generate a high pressure surge. Cavities could occur due to a sudden change in flow rate, which can be caused by a shutdown of the supply pump(s) and the closure of the valve at the beginning of the pipe.

The location of the cavity depends on the elevation profile of the pipe and will most likely be directly downstream of the equipment causing the flow reduction (e.g. pump or valve) and at high points in the system.

When a piping system has been checked for surge potential by a full surge analysis and transient analysis, the following shall be reported to the Principal for approval;

- a) selection of surge scenarios and operational conditions;
- b) final surge pressure analysis;
- c) selection of the most severe surge;
- d) selection of representative piping section;
- e) final static and dynamic stress analysis.

The surge scenarios that are evaluated in a full surge analysis SHALL [PS] include:

- a) rapid valve closure with and without pump tripping;
- b) pump tripping;
- c) pump start-up;
- d) pump trip followed by restart.

The study SHALL [PS] cover maximum possible flow rates. Flows in single-pipe operation of multiple pipe systems SHALL [PS] be assessed if pump capacity exceeds the normal pipe capacity.

Surge analysis SHALL [PS] be performed for:

- a) LNG loading and rundown pipes;
- b) LPG loading and rundown pipes;
- c) All hydrocarbon condensate loading pipes;
- d) Natural gas liquid systems;
- e) the main distribution headers for cooling water systems;
- f) the main distribution headers for fire water systems;
- g) piping running to/from tank car, rail car, barge, and ship loading arms and loading facilities.

2.3.5 Two phase flow

Extra precautions shall be taken for two phase flow, particularly if the flow pattern is intermittent (slug or plug flow) and the piping system will be subjected to high excitation forces from fluid momentum. These slug or plug flow regimes shall be avoided whenever possible. These flow regimes can be prevented or reduced by proper location of pressure control valves. The graphs in DEP 31.22.05.11-Gen. should be used to determine what type of two-phase flow pattern will occur, but they are only a rough indication. Furthermore the actual conditions in the plant could largely deviate from the design conditions. This potential deviation shall be taken into account in the design, and when in doubt, the worst case flow pattern shall be assumed (3.5).

Two phase flow regimes in inlet piping to Separators and other pressure vessels should be avoided. For specific requirements, refer to section 4 of DEP 31.22.05.11-Gen.

For two-phase flow in flare pipes, see DEP 80.45.10.10-Gen.

For two-phase flow in steam condensate and blowdown piping systems, see DEP 30.75.10.10-Gen.

2.3.6 Installation requirements for flow instruments

Installation requirements for flow instruments shall be in accordance with DEP 32.31.00.32-Gen.

3. PIPING BASICS

3.1 GENERAL

Piping systems except as mentioned below shall be designed, fabricated, erected, inspected and tested in accordance with ASME B31.3 as supplemented by this DEP and DEP 31.38.01.31-Gen.

Piping systems of “boiler proper piping” as referenced in ASME B31.1, Section 100.1.1 shall be designed, fabricated, erected, inspected and tested in accordance with ASME Section I.

Piping systems of “boiler external piping” (steam, feed water and blow down piping systems) as referenced in ASME B31.1, Section 100.1.1 shall be designed in accordance with ASME B31.1.

Alternatively, piping systems for package refrigeration units may be designed, fabricated, erected, inspected and tested in accordance with ASME B31.5, except that impact test requirements shall be in accordance with DEP 30.10.02.31-Gen.

Piping shall be routed so that the optimum piping layout is achieved in terms of process requirements, ergonomics, commissioning, operation, inspection and maintenance. Having considered these factors, the number of flanges, fittings, valves and welds shall be minimised.

The Principal shall perform design reviews in stages to verify the proposed physical or 3D CAD models to check that the arrangements meet the Principal's requirements. These reviews shall be undertaken in accordance to DEP 30.10.05.11-Gen. Proposed physical or computer piping 3D CAD models shall be accepted by the Principal before proceeding for construction of piping systems.

The selection of piping construction materials is covered in the piping classes, which refer to the MESG system to specify the piping components. The following DEPs and MESGs shall apply:

- a) DEP 31.38.01.10-Gen.
- b) DEP 31.38.01.12-Gen.
- c) DEP 31.38.01.15-Gen.
- d) Standard form DEP 31.38.01.84-Gen.
- e) MESG Group 74 (pipe)
- f) MESG Group 76 (fittings and flanges)
- g) MESG Group 77 (valves)
- h) MESG Group 81 (bolting)
- i) MESG Group 85 (gaskets and packing).

Piping system design development for all piping systems shall be in accordance to (Appendix 16) of this DEP.

Project modifications to piping classes shall be kept to a minimum. When modifications are required, the Principal SHALL [PS] approve. In order to have fixed working documents during a project and reference documents during the lifetime of an installation, a specification for piping systems shall be compiled for each project (see DEP 31.38.01.21-Gen.).

In addition to inspection and testing requirements as specified for piping components and systems in the framework of this DEP, residual concerns may be transferred into the piping component manufacturing, piping fabrication and erection stage. To develop suitable surveillance and inspection plans, the residual concerns from the design process shall be communicated / passed onto the procurement function in form of suitable engineering notes and inputs into the development of the surveillance / inspection plans.

For definition of temperature, pressure and toxicity levels, see DEP 01.00.01.30-Gen.

For the minimum required wall thickness of carbon steel pipes, see (Appendix 14).

Protective steam heating of piping systems shall comply with DEP 31.38.30.11-Gen.

Pipe supports shall be in accordance with DEP 31.38.01.29-Gen.

Spans distances for support of straight pipe shall be in accordance with (Appendix 11). Alternatively, other span distances are allowed when design calculations are provided, and the calculations show the alternate design to be acceptable in terms of the actual stress and deflection for the proposed installation. However, it should be noted that the span distances in Appendix 11 will typically result in a support arrangement classified as "stiff" per the Energy Institute Guidelines for avoidance of vibration induced fatigue in process pipework. As a result, installations with span distances exceeding the limits in Appendix 11 shall be screened for flow-induced piping vibration per the criteria in Appendix 17, with the maximum value of the kinetic energy for the piping system limited to 7000 kg/ms^2 (4700 lbm/fts^2).

Attention should be paid to the recommended practices for design and installation of offshore production platform piping systems as contained in ISO 13703 standard.

3.2 DESIGN CONDITIONS

A piping system SHALL [PS] be designed for the most severe conditions to which it may be subjected. The following may determine the design conditions:

- a) steam-out pressure and temperature
- b) surge pressure, see (2.3.4)
- c) pump shut-off pressure
- d) static pressure
- e) pressure drop
- f) vacuum caused by cooling and possible condensing of trapped medium
- g) steam/nitrogen purge pressure.
- h) Reactor regeneration temperature
- i) Furnace decoking operation temperature
- j) settling pressure of compressor
- k) emergency depressurisation
- l) Killing condition of a well
- m) Possibility of temperature rise due to stagnancy

The (upper) design pressure shall be determined in accordance with DEP 01.00.01.30-Gen. The selected (upper) design pressure subsequently determines the pressure-temperature rating of Piping Class.

With respect to preventing brittle fracture in metallic piping, the so-called reference or determining temperature of a pipe, or a part thereof shall be established in accordance with DEP 30.10.02.31-Gen.

In situations where different design conditions exist in one piping system, different piping classes may be used and shall be divided by a spec break. These "spec. breaks" SHALL [PS] be located so that the more severe design condition can never occur in the part of the system with the lower piping class. Spec. breaks between piping classes of different materials shall be executed as flanged connections. The Principal SHALL [PS] approve all non flanged spec. breaks.

Dissimilar metal weld joints in some fluid services may be prone to premature failure or to significantly reduced useful life. A dissimilar metal weld joint is inherently a "lower integrity

joint", and the use of dissimilar metal welds has to be justified by solid technical and economic considerations.

For dissimilar metal weld joint design requirements, see section 3.4.3 of DEP 31.38.01.31-Gen, and DEP 30.10.60.18-Gen.

Changes in pressure ratings in piping systems should be made at shut-off valves. Spec breaks at mixing or injection points, bypass lines and/ or so called "dead legs" shall receive particular attention. The Principal shall approve dead leg piping layouts where materials of construction are affected by corrosive fluids.

The proposed location of spec breaks in high temperature ($> 400\text{ }^{\circ}\text{C}$ ($> 752^{\circ}\text{F}$)), corrosive, sour or severe hydrogen service (in relation to the Nelson curve) shall be designed to prevent corrosion occurring under normal and marginal/upset conditions. In all such cases, the design shall be approved by the Principal.

Piping systems connected to other systems or equipment with a higher design rating SHALL [PS] have the higher rating for all components up to and including the first block valve in the system of lower rating.

If a system operating above $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$) is connected to a system operating at $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$) or below, the first 50 D (with a maximum of 10 m (33 ft)) SHALL [PS] be designed to the specifications of the lower temperature system. This does not apply to temporary decontamination piping, provided adequate administrative controls are in place.

ASME B31.3 provides allowances for pressure and temperature variations. Selection of a design pressure below the maximum surge pressure on the basis of these allowances SHALL [PS] be subject to the approval of the Principal and shall only be considered in conjunction with a documented risk analysis showing the risk is managed to ALARP and that major cost reductions can be achieved. If an external pressure can only result from structural failure of equipment, failure of safety devices or other unpredictable events, it shall not be taken in consideration when establishing the design pressure of the piping.

Ambient temperature shall neglect the wind chill effect. Due consideration should be given piping subjected to "Shock" (e.g. rapid pressure rise). The effect of blast loads shall be evaluated for piping which is required to maintain the integrity in an explosion event.

For the definition of various pressure and temperature levels, see DEP 01.00.01.30-Gen.

Piping up to and including DN 600 (NPS 24) shall be designed for full vacuum at ambient temperature.

Piping DN 600 (NPS 24) and larger shall designed for full vacuum when containing condensable gasses such as steam and in situations where sub-atmospheric pressure may occur as the result of liquid surge or steam-out. If not subjected to the above, pipes larger than DN 600 (NPS 24) shall be designed for the Lower Design Pressure (LDP) as defined in DEP 01.00.01.30-Gen. Vacuum rings shall not be used.

For additional requirements for specific services, see (Appendix 10).

3.3 PIPING ABOVE GROUND LEVEL

For requirements associated with layout of onshore facilities, see DEP 80.00.10.11-Gen.

For requirements associated with layout of offshore facilities, see DEP 80.00.10.12-Gen.

Except for the services mentioned under (3.4), piping shall be routed above ground level.

Piping Studies shall be carried out to develop the final equipment location and routing of major piping.

Where practical, piping entering and leaving a plot area or a processing unit shall be grouped together.

Where practical, inside-plot piping shall be routed on overhead pipe racks. The distance between the stanchions for these pipe racks is typically around 7 m (23 ft). If there are pipe

sizes that require closer support spacing, intermediate beams shall be installed between main pipe rack stanchions.

If the span between pipe supports is too long for the pipe size selected on the basis of hydraulic sizing criteria, the size of the pipe may be increased rather than providing additional pipe supports. This decision should be justified technically and economically (the technical evaluation shall include the possibility of internal corrosion due to the slower flow causing separation of corrosive liquid from the mixture). This decision is subject to the approval of the Principal.

If a pipe rack forms part of a structure, or is located next to a structure, the stanchions of the pipe rack should be in line with the columns of the structure, to make optimal use of space for incoming and outgoing pipes. Equipment which is a potential source of fire SHALL [PS] not be located under pipe racks. For layout requirements, See DEP 80.00.10.11-Gen. and DEP 80.00.10.12-Gen.

Piping with instrument connections shall be routed so that safe access to these connections is ensured. If necessary, platforms or walkways shall be provided (see DEP 32.31.00.32-Gen.).

The potential for contamination of austenitic stainless steel, duplex stainless steel, nickel alloy or 9% nickel steel components with zinc shall be avoided. If hot work is performed on galvanised items situated in the vicinity of these components, they SHALL [PS] be shielded (e.g. with fire blankets) to avoid contamination. For components which are insulated, the cladding is considered to be sufficient protection.

Piping connected to more than one piece of equipment (e.g. a pump and its spare) shall be designed and supported in accordance with the following:

- so that no excessive loads on equipment may occur when one branch of the pipe is disconnected (e.g. during maintenance operations). Where multiple nozzles are applied (e.g. on air cooler banks) the connecting piping shall be designed so that small dimensional errors in construction can be accommodated.
- The piping itself should be adequately designed to compensate for any thermal expansion due to differential temperatures between operating equipment and spare equipment.

Safety relief valve discharge piping SHALL [PS] be designed to withstand both the dead loads and the reactive or thrust loads. Reactive or thrust design loads SHALL [PS] take into account the most severe case, such as possible flashing conditions and liquid entrainment in vapour flows.

For design requirements of fire water piping, see DEP 80.47.10.30-Gen.

In a pipe rack, piping arrangements shall be implemented in accordance with DEP 80.00.10.11-Gen. In addition, following shall be considered:

- a) The cryogenic pipe should be located at the sides of the pipe rack to provide space for expansion loops and to reduce the moments in the beams caused by the weight and thermal expansion loads from the pipe.
- b) The cryogenic pipes should be grouped separately and located on different pipe rack tiers.
- c) Complicated crossings should be avoided, e.g. by not installing pipe rack spurs opposite each other.

3.3.1 Clearances and access

3.3.1.1 Vertical clearances

The minimum elevation of the bottom of overhead piping shall be in accordance with DEP 80.00.10.11-Gen.

For minimum vertical clearances, see section 5.8 of DEP 30.00.60.20-Gen.

3.3.1.2 Horizontal clearances

There SHALL [PS] be a minimum horizontal clearance of 0.75 m (30 in) for access ways and walkways, and 0.9 m (36 in) for thoroughfares.

Piping shall be kept clear of equipment maintenance drop areas.

Around manholes, a minimum of 760 mm (30 in) on each side of the manhole and a minimum of 1220 mm (48 in) directly in front of the manhole shall be provided clear of obstruction to allow for entry and exit.

3.3.1.3 Platforms

The layout and arrangement of platforms, walkways and means of access thereto must be such that the supervisory rounds can be made at various levels without requiring excessive climbing up or down.

Unless there is a local regulation, platform provision shall be made as per the following:

- Stair or ladders spacing shall be provided in accordance with section 2.4.4, DEP 34.28.00.31-Gen. to provide emergency escape.
- The length of a dead-end platform shall not exceed 7 m (23 ft).

3.3.1.4 Stairs

Stairways are required for access to elevated work platforms, walkways and other elevated work areas where the frequency of use is at least once per shift. Stairways should also be provided for access to Category 1 valves as per DEP 30.00.60.13-Gen.

3.3.1.5 Ladders

Ladders may be provided instead of stairways where ladders are only required for occasional use, or for escape routes.

Single stage ladders shall be no longer than 9 m (30 ft), and multiple stage ladders shall be staggered every 6m (20 ft) with a landing provided.

Ladders serving platforms or landings more than 3 m (10 ft) above grade (or more than 3 m (10 ft) above another platform) shall be fitted with cages.

3.4 PIPING BELOW GROUND LEVEL

3.4.1 Buried piping

Buried piping shall be considered for:

- drainage, storm water, or sewage systems;
- fire water and other water pipes (for protection against heat or frost);
- large-diameter utility pipes (e.g. main cooling water ducts) so as not to impede traffic.

For pressurised hydrocarbon service, buried piping should be avoided.

Buried piping shall be designed and installed in accordance with DEP 34.14.20.31-Gen.

Site preparation and earthwork required for drain installation shall comply with DEP 34.11.00.11-Gen.

Buried piping shall have a minimum cover of soil as shown below:

- | | |
|---|---------------|
| a) fire water pipe (mains) | 0.6 m (24 in) |
| b) in areas inaccessible to heavy traffic | 0.3 m (12 in) |
| a. in areas accessible to heavy traffic and at road crossings, pipes of DN 600 (NPS 24) and smaller | 0.6 m (24 in) |
| b. pipe over DN 600 (NPS 24) | 0.9 m (36 in) |
| c) pipes crossing beneath railways | 1.0 m (40 in) |

- | | |
|--|---------------|
| d) in areas where only night frost can be expected | 0.6 m (24 in) |
| e) in areas where daytime freezing can be expected | 0.7 m (28 in) |

The above soil cover depths depend on the outside temperature and the permeability of the soil. In areas where prolonged freezing temperatures may occur, the suitability of the above soil cover depths shall be confirmed.

The load on pipe crossing railways and roads should be equalised by means of pipe sleeves or a culvert. The pipe shall be centered in the sleeves by use of distance pieces welded to the pipe, or distance pieces fixed to the sheeting if the pipe is insulated for low-temperature service.

Insulated pipe should not be buried. If this is unavoidable, or if it is desired for life-cycle economic reasons, the insulation material shall be able to withstand the stresses caused by the thermal expansion of the pipe. Special attention shall be paid to avoid corrosion under insulation (CUI) and the system shall be designed so that inspection for CUI is possible or not needed.

Soil settlement and thermal expansion of the piping shall be taken into account in the design of underground piping.

For buried pipe operating at a temperature of 60 °C (140 °F) or below, there SHALL [PS] be a clear distance of at least 0.3 m (12 in) between the pipe and any electrical or instrument cables.

For buried pipe operating above 60 °C (140 °F), the pipe shall be insulated to limit the outer surface (cladding) temperature to a maximum of 60 °C (140 °F) and there SHALL [PS] be a clear distance of at least 0.6 m (24 in) between the cladding and any electrical or instrument cables.

Design of cathodic protection of buried pipe shall be in accordance with DEP 30.10.73.10-Gen. For buried pipe with impressed current cathodic protection, there SHALL [PS] be a clear distance of at least 1 m (40 in) between the pipe and any parallel-running cables, to prevent stray-current corrosion of the steel wire armouring of those cables.

Buried piping SHALL [PS] be designed so that the complete system can be flushed and cleaned. (e.g. "dead ends" should be avoided). For vents and drains, see (3.13).

For buried pipe systems where the emission of aromatic hydrocarbons and/or toxic fluids (as defined in DEP 01.00.01.30-Gen.) is a HSE concern (e.g. pollution of ground water), bolted joints shall not be used. Valves in these piping systems shall be installed in pits.

3.4.2 Pipe tracks and pipe trenches

Piping outside process units (e.g. piping between process units and storage facilities) should be supported on sleepers, at ground level in pipe tracks or below ground level in pipe trenches. The choice between pipe tracks or pipe trenches is dictated by technical and economic considerations, e.g. the number of road or rail crossings, the ground water level and the length of the required trench. Pipe racks may be used if space at ground level is limited or if the use of culverts or buried piping is uneconomical.

The distance between sleepers in pipe tracks and in pipe trenches shall be based on the maximum allowed free span of the majority of pipes in accordance with (Appendix 11). Smaller pipe requiring a shorter supporting distance shall be grouped together and be supported on additional supports.

The elevation of the sleepers shall be decided as per the following:

- There shall be a minimum vertical clearance of 0.3 m (12 in) underneath the bottom of safety critical carbon steel pipe in culverts or concrete trenches, to facilitate inspection and coating maintenance.

Access for maintenance and for operation of valves, drains and instrumentation and that pipes and insulation will remain above the highest expected storm water levels. Flanged

connections shall not be installed in trenches, in order to prevent the accumulation of gas and liquid vapours in the trenches. Flanged connections SHALL [PS] not be installed in enclosed trenches, in order to prevent the accumulation of volatile fluids in the enclosed trenches.

Concrete trenches in process units SHALL [PS] be adequately drained into a liquid-sealed drainage system and shall be covered with grating.

3.5 PIPING STRESS ANALYSIS AND PIPE SUPPORTING

3.5.1 Piping stress analysis

Piping systems shall be routed, supported, anchored or guided so that thermal expansion/contraction, weight effects including the pipe contents, insulation and any other superimposed loads, pressure effects, vibration or movements due to earthquakes and storms will not result in stresses in the piping or loads on the connected equipment in excess of those permitted by ASME B31.3 and the equipment design code, in order to prevent:

- failure of piping components due to overstress;
- leakage at joints;
- excessive loads and moments on connected equipment, anchor points, flanged connections, etc.

The Contractor alternate proposal for the stress analysis specification is subject to approval by the Principal.

The following specifications shall be complied with:

- a) Pipe support design based on DEP 31.38.01.29-Gen.
- b) Special requirements of rotating equipment, civil, stationary pressure, storage equipment and heat transfer equipment specialists concerning allowable loads and moments on equipment under their responsibility and are required to be included in the Equipment Manufacturing Data Book.

3.5.1.1 Local regulatory requirements

The Pipe Stress Engineer shall determine whether local regulatory requirements of the country in which the plant will operate, have more stringent requirements than the codes and standards stated within this standard. In these instances, the local regulatory requirement shall govern.

3.5.1.2 Piping stress analysis design basis

Piping systems SHALL [PS] be checked for stresses caused by pressure, weight of pipe, equipment vibration, weight effects of piping components and fluids, external loadings such as wind loads, seismic loads, settlement, frost heave, thermal expansion and contraction, internal/external pressures, stiffness changes, enforced displacements and shock loadings. Generally, most piping movements are due to thermal expansion, but all the above criteria shall be taken into consideration during stress analysis.

Expansion loops and/or offsets shall be provided in piping systems where improved flexibility is required.

Expansion joints or swivel joints may be installed only where loops or offsets cannot be used (e.g. due to limited space) or will not give sufficient flexibility. Expansion joints or swivel joints shall be used only if the fluid fouling properties cannot make them ineffective or leakage. Under special circumstances, an expansion joint may be considered for other services provided that all alternatives without the expansion joint represent a greater safety risk.

The proposal to use expansion joints or swivel joints shall be presented to the Principal for review and approval prior to detailed design development.

Expansion joints shall be provided with guides and anchors to withstand forces generated by the internal pressure. Where an uneven flow is possible, additional supports and/or anchors should be installed to protect the expansion joints. The stresses, forces and movements on expansion joints shall be within the limits stated by the Manufacturer/Supplier. Information about expansion joints and about the location of supports in pipes with expansion joints is given in the EJMA standard. Expansion joints SHALL [PS] not be used in very toxic services or in systems where they would be subjected to torsional loads. Swivel joints SHALL [PS] not be used in very toxic services or in systems where they would be subjected to bending loads.

The upper and lower design temperatures (see DEP 01.00.01.30-Gen.) and differences in temperature between piping and equipment SHALL [PS] be taken into account for all design cases.

Expansion stress range SHALL [PS] be calculated, using a differential temperature of upper and lower design temperature to make sure that this stress range is within the Code allowable. The Project line list shall form the basis of calculation for all these stresses.

If the line is in vapour service, or in liquid service with density less than water, hydrostatic test weight shall also be considered in the analysis.

Cold-spring SHALL [PS] not be used to reduce thrust and moments on flanged joints or equipment nozzles (refer to para. 319.2.4 in ASME B31.3).

The reaction loads resulting from thermal movement shall include the effects of friction of the pipe or pipe shoes on the pipe supports.

Lateral guides shall be provided as necessary to control pipe movements and to prevent buckling.

Flare piping systems shall be designed in accordance to DEP 80.45.10.10-Gen.

For piping connected to rotating equipment, pipe stress analysis SHALL [PS] be based on the following considerations:

- Piping nozzle loads shall be calculated and combined in accordance with NEMA SM 23 or API methods
- A static, pulsation and mechanical analysis shall be conducted on piping systems for reciprocation machinery or machinery subject to pulsating flows.
- Calculation of piping loads shall include the following considerations:
 - a. Weight of the piping system and its contents
 - b. Thermal movement of the pipe and machinery due to process fluid temperature changes, including start-up, shutdown, clean-out, and offdesign operation, as well as the normal operating temperature cases
 - c. Movement of the pipe, machinery, and support systems due to thermal distortion from the sun, weather, radiant heating from nearby equipment, and process flow effects
 - d. Heat tracing
 - e. Differential settlement of foundations and/or frost heaving
 - f. Reactions from restraints such as anchors, pins and ties
 - g. Other attached piping that may exert significant loading
 - h. Adjacent equipment attached to the same header
- When applicable or when specified, the following considerations shall also be included in the analysis:
 - a. Friction forces from piping supports, guides and restrictions
 - b. Unsteady operation, such as two phase flow or vibration

- c. Pulsating flow
- d. Wind loading
- e. Maintenance requirements, including the installation and removal of blinds, startup strainers, etc.
- f. Steam-out conditions
- g. Equipment (such as instruments) supported by the piping
- Actual piping forces and moments shall be qualified without taking the advantage of friction factor at pipe supports.

Suction and discharge nozzle mating pipe flanges shall be designed to maintain the misalignment within tolerances as mentioned in (Appendix12; 3.2(g)). Production flowlines shall be designed for slugging loads. The fundamental natural frequency of flowlines shall be in excess of 4 Hz.

It shall be ensured that flowline movements are kept within a level which will not have detrimental effect on operating and maintenance personnel.

For more guidance, see ISO 13703 section 8.3.

3.5.1.3 Piping stress analysis conditions

3.5.1.3.1 Temperature

Piping stress analysis SHALL [PS] be carried out for the following temperature conditions:

- a) Upper Design Temperature
- b) Lower Design Temperature
- c) Maximum Operating Temperature
- d) Operating Temperature
- e) Transient Temperature conditions possibly caused by, amongst others, the following load cases:
 - i. Start-up and shut-down
 - ii. Steam cleaning (Steam-out) of lines and/or equipment
 - iii. Protective steam heating or electrical heating including winterising
 - iv. Decoking
 - v. Regeneration
 - vi. Compressor recycle
 - vii. Temperature drop by pressure relief, or depressurisation effect

NOTE: If needed, the specific pressure - temperature envelope can be defined as a specific load case to take credit for pressure reduction at low temperatures.

viii. Solar radiation

3.5.1.3.2 Pressure

Piping stress analysis SHALL [PS] be carried out for the following pressure conditions:

- a) Design Pressure
- b) Maximum Operating Pressure
- c) Operating Pressure
- d) Cyclic pressure conditions

3.5.1.3.3 Other conditions

- a) Friction Effects:

The effect of frictional resistance to thermal movement of the pipe for all sizes.

Friction force shall be calculated based on the properties of the sliding surface and contact material.

Table 2 should be used to select the static friction coefficient:

Table 2	
Contact Surface	Friction Coefficient
Stainless Steel on PTFE	0.1
Steel on Steel	0.4
Steel on Concrete	0.6

b) Wind Loads:

Wind loading shall be considered in accordance to the applicable standard. Wind effects shall be analysed by applying wind load in one of four horizontal perpendicular directions which would cause the most severe condition of piping stress.

c) Seismic Loads:

In earthquake prone zones, earthquake loads SHALL [PS] be taken into account.

The frequency of occurrence of earthquakes, and their intensity and duration shall be derived from seismological data and/or accelerograms (i.e. recordings of actual ground accelerations during an earthquake), local codes and standards or as specified by the Principal.

Earthquake loading SHALL [PS] be analysed to ensure structural integrity of pipe support structures. For piping design with seismic loads, see (3.7) of this DEP.

d) Snow Loads:

Snow loads shall be considered, where applicable.

3.5.1.4 Stress analysis critical line list

Pipe Stress Engineer shall identify and produce a formal listing of the critical lines to be analyzed using formal computer analysis for thermal expansion/sustained or dynamic stresses, calculate the nozzle loads on the connected equipment and determine the type of pipe supports required.

The function of critical line list is to identify those piping systems which require investigation by a pipe stress engineer. The critical line-list lines to be computer analyzed SHALL [PS] include the following:

- Pipe size DN 50 to DN 200 (NPS 2 to NPS 8) with design temperature above 230 °C (450 °F).
- Pipe size DN 250 to DN 300 (NPS 10 to NPS 12) with design temperature above 175 °C (350 °F).
- Pipe size DN 350 to DN 450 (NPS 14 to NPS 18) with design temperature above 120 °C (250 °F).
- Pipe size DN 500 (NPS 20) and larger;
- If pipe stress calculations require the approval of national or local authorities they shall be performed by methods approved by those authorities.
- Process pipes DN 80 (NPS 3) and larger if connected to rotating equipment;
- Pipes connected to air-cooled heat exchangers;

- h) Pipes connected to pulsating equipment (reciprocating pumps or reciprocating compressors);
- i) Pipes to and from boilers and heaters;
- j) In cases where external movements, such as differential settlement of equipment and/or supports could cause unacceptable stresses or reaction forces;
- k) Pipes in cyclic service (regeneration / batch process) resulting in a stress range factor $f < 0.7$ per ASME B31.3 Fig. 302.3.5;
- l) Pipes where engineered items are required like spring supports, expansion joints, snubbers etc.;
- m) Pipes subject to slug flow or water hammer;
- n) Pipes for two-phase flow;
- o) Flare pipes DN 100 (NPS 4) and larger;
- p) Pipes subjected to relief loads;
- q) Pipes DN 80 (NPS 3) and larger in very toxic service operating at temperatures above 200 °C (390 °F).
- r) Glass Reinforced Plastic piping
- s) Pipes subject to steam out.
- t) Jacketed piping.
- u) Cryogenic piping systems (below -46 °C (-50 °F))
- v) Pipes connected to Wellheads and X-mas trees;
- w) Piping systems with hub clamp connectors or compact flanges;
- x) Pipes along the derrick and the flare structure;
- y) All piping associated with offshore platform bridges;
- z) All glass-lined pipe or piping connected to glass-lined equipment;

For the following piping systems, as a minimum, a formal analysis (using manual methods) shall be performed:

- Size DN 50 (NPS 2) with design temperatures from 175 °C (350 °F) to 230 °C (450 °F).
- Size DN 80 to DN 200 (NPS 3 to NPS 8) with design temperatures from 93 °C (200 °F) to 200 °C (400 °F).
- Size DN 250 (NPS 10) with design temperatures from 93 °C (200 °F) to 175 °C (350 °F).
- Size DN 300 (NPS 12) with design temperatures from 40 °C (100 °F) to 150 °C (300 °F).
- Size DN 350 to DN 400 (NPS 14 to NPS 16) with design temperatures from 40 °C (100 °F) to 120 °C (250 °F).
- Size DN 450 (NPS 18) with design temperatures from -18 °C (0 °F) to 120 °C (250 °F).

The formal analysis method includes analytical and chart methods that provide an evaluation of the forces, moments and stresses caused by displacement strains.

These lines shall be identified on the project line-list and also highlighted on the PEFS drawings. For all critical piping systems, documentation of the piping stress analysis report shall be in accordance to (3.5.1.7).

The Contractor shall be responsible for ensuring the integrity of "non-critical" lines. Non-critical piping systems shall be adequately flexible and wherever possible this should be achieved by the natural flexibility of the pipe-work configuration.

3.5.1.5 Analysis

Prior to execution, the Contractor shall obtain acceptance from the Principal for the criteria and methods of pipe stress analysis that will be performed for each system.

3.5.1.5.1 The method of analysis shall be determined by the following:

- a) The requirements of the B31.3, para. 319.4.2 shall be met.
- b) Comprehensive methods of analysis shall be used when the service conditions are cyclic, low temperature ($< \text{minus } 45^{\circ}\text{C}$ ($\text{minus } 49^{\circ}\text{F}$)), vibratory when significant external displacements are applied, when the terminal reactions are of concern or when the maximum combined displacement stress range, incorporating appropriate applicable stress intensification factors, estimated by approximate or simplified methods exceeds the allowable stress range.
- c) Buried lines operating at temperatures above 100°C (210°F) SHALL [PS] be checked for upheaval buckling in accordance to DEP 31.40.10.16-Gen.
- d) Stress analysis by manual methods shall be applied only when the conditions of ASME B31.3, para. 319.4.2(b) are met and when the piping is essentially symmetrical in all places, is of simple configuration and is within the scope of published handbook methods. Complex piping systems shall not be reduced to simple configurations by the unnecessary introduction of intermediate anchors or guides.
- e) Piping systems in floating production facilities shall be designed for forces due to motions of the ship.

3.5.1.5.2 All lines subject to vibration due to high velocity flow (where the classification of susceptibility to failure is "high" based on paragraph 17.1), high-pressure drop, water hammer or mechanical excitation (pulsation beyond the criteria specified in paragraph 17.2) shall be analysed by dynamic analysis. Also refer to (3.23) of this DEP for additional advice on piping in vibrating service.

Excitation forces of two-phase flow pipes and flare pipes shall be determined (2.3.5) and a dynamic analysis of the piping system shall be considered. At points where flow conditions change, e.g. where diameter or flow direction change, the possible occurrence of movements shall be analysed and, if necessary, adequate measures shall be taken to hold the pipes in place, without the pipes and the supporting structure being over-stressed by expansion or settlement.

3.5.1.5.3 Flanges and Mechanical Pipe Joints shall be assessed for the applied external forces and moments to ensure that flange and bolt stresses are not excessive and joint leakage will not occur. Particular emphasis shall be placed on those connections in Hydrocarbon and high-pressure systems (600# and above).

Forces and Moments applied to flange joints should be assessed in accordance with ASME BPV Section VIII, Division 1, Appendix 2.

3.5.1.5.4 During the assessment of metallic piping the so-called "Bourdon effect" (pipe elongation due to the axial pipe strain resulting from internal pressure) in general is negligible. Longitudinal pressure strain shall only be taken into account for long runs of pipe for high pressure piping systems (Category K system in accordance with (16.2) of [Appendix16]).

3.5.1.5.5 Careful consideration is required when determining whether the loads/stresses resulting from nozzle/wellhead displacements or relative platform displacements in off-shore applications shall be regarded as primary or secondary. Secondary loads/stresses are compared to secondary allowable values. Secondary allowables are higher than primary

allowables (the secondary stress may even exceed the material yield stress) due to the self-limiting character of secondary loads.

In the case of nozzle/wellhead displacement, it shall be verified whether the displacement induced loads are self-limiting. This is particularly important when a support is unloaded (lifted-off) in the operational load condition,

3.5.1.5.6 For unloaded supports, a more conservative result shall be obtained by the following iterative procedure, which shall be applied whenever a support is lifted-off:

1. Calculate the vertical pipe centreline displacements at the applicable support locations in the operational load case.
2. Re-run all load cases for a new support arrangement where the supports unloaded in the first iteration are now showing a vertical clearance equal to the in the first iteration determined displacements at the applicable locations.

3.5.1.5.7 For support unload, realistic wellhead growth shall be confirmed by regular field measurements. Well head growth shall be applied to piping structural integrity analyses models. Since the well head growth may vary significantly for onshore and offshore installations, they should be determined on a case by case basis and shall be approved by the Principal.

On wellheads, simple provisions shall be made (markers) to regularly measure and check wellhead growth.

3.5.1.6 Allowable loads

Allowable loads and moments on equipment nozzles shall be in accordance with the relevant DEP and their associated standards (e.g. ASME, API, ISO Stds etc.) for the equipment. See (4.1) for requirement on allowable loads and moments on equipment nozzles.

For static equipment, in situations where the relevant DEP standard does not provide allowable nozzle loads, the Contractor shall specify the design nozzle loads for stationary equipment during the early stage of detailed engineering, and the equipment shall be ordered accordingly. In specifying the nozzle loads, the Contractor shall ensure that they are sufficient for reasonably expected piping loads but shall not specify them so high that they require unnecessary nozzle reinforcement. Piping shall be designed such that the specified nozzle loads are not exceeded. Where possible, the Contractor shall provide more flexibility in the piping rather than require additional nozzle reinforcement.

Provided the Manufacturer/Supplier can submit documented design analysis / validation test, that higher loads / moments can be tolerated than those specified in the DEP / industry standard, the Principal may approve such higher allowable loads / moments.

3.5.1.7 Documentation

At the completion of the project, stress reports shall be prepared for each system including the final versions of the Critical Line Lists, the stress sketch(es), and the Stress Analysis reports along with any changes made during construction or start-up. These reports shall become part of the Project documentation. The results of the piping stress analysis shall be documented as a report and shall include:

3.5.1.7.1 Input data to stress analysis and shall include stress isometrics with the following data:

- a) Method used (software revision, handbook ISDN)
- b) Co-ordinates and elevation of at least one reference point to assist in locating on orthographics/electronic model.
- c) Branch points complete with line number.
- d) Critical clearances from piping and equipment.
- e) Design/Upset and operating pressures and temperature.
- f) Dimensions +/- 50 mm (2 in) where possible. Dimensions shall be shown from

support to support, support to branch or fitting to fitting.

- g) Nature of contained fluid (vapour, liquid, 2-phase). Direction of flow and tracing type (if any).
- h) Insulation type and thickness.
- i) Line numbers and Line sizes.
- j) Location and size of reducers.
- k) Location and type of all proposed pipe supports or as a minimum, the location of structural steel for supports.
- l) Location of wall, floor or roof penetrations.
- m) Location of fixed end of horizontal vessels and heat exchangers.
- n) Nozzle number of each vessel or heat exchanger connection. Location of nozzle centre lines relative to fixed points or anchors for horizontal vessels and bottom tangent lines for vertical vessels.
- o) North Arrow.
- p) Piping class and specification breaks.
- q) Input model files

3.5.1.7.2 Output results of stress analysis and shall include the following data:

- a) Displacement report
- b) Restraint summary (Forces and Moments)
- c) Compliance report of actual piping loads on nozzle loads w.r.t. allowable loads.
- d) Stress Compliance report w.r.t. applicable codes and standards
- e) Spring hanger datasheet(s)
- f) Special support drawings (if any)
- g) Bellow type expansion joint data sheet(s)
- h) Flange leakage calculations (if any)

3.5.2 Pipe supports

Pipe supports shall be in accordance with DEP 31.38.01.29-Gen. The Contractor may use his own standards and/or commercially available pipe supports and methods provided they are equivalent with DEP 31.38.01.29-Gen.

The span between horizontal pipe supports shall be selected in accordance with (Appendix 11). Spans longer than those shown in (Appendix 11) are allowed when justified by additional stress and flow induced vibration calculations. The additional calculations shall be approved by the Principal.

Pipes should be supported in groups at a common support elevation.

For pipe supports and a reference to pipe support Standard Drawings, see DEP 31.38.01.29-Gen.

Since civil design is often done earlier than piping support design, special structural provisions for connecting pipe supports, such as inserts poured in concrete beams or supporting structures, should be made during the civil and mechanical engineering phase and should be located at standard locations.

Identification of standard pipe supports and special pipe supports shall be shown in the 3D-CAD model, on piping plan drawings and on piping isometric drawings.

Supports and supporting structures shall be able to sustain the hydrostatic test load. If this is not economical, temporary supports may be applied. Spring supports shall be blocked, or

removed and replaced by temporary supports which are able to sustain the hydrostatic test load.

Weld-on attachments of the pipe supports should be welded to the pipe during prefabrication of the pipe spools. The use of spring supports, snubbers and sway braces should be avoided. If they are unavoidable, they shall be permanently accessible. If this may lead to unacceptable costs, the Principal shall be consulted.

The most commonly applied type of spring assembly is the "variable load" unit. If very low variable loads are essential, such as pipes connected to strain sensitive equipment or for critical systems with large movements, "constant load" type units shall be used.

Guides near expansion loops in these lines should be of the goal post type. Supports shall be located as close as practicable to changes in direction but shall allow adequate flexibility for thermal expansion and settlement of the pipe.

3.6 PIPING THROUGH WALLS, STRUCTURAL DECKS AND CONCRETE FLOORS OF BUILDINGS

3.6.1. General

Sleeves or holes through walls and floors of buildings and through table tops shall have a size permitting the passage of a flange of the relevant pipe size, or the size of the required insulation, whichever is the larger, to allow the installation of prefabricated piping.

Penetrations through walls and floors shall be sealed with a hydrocarbon-resistant filler after piping installation (e.g. a collar shall be fitted around the pipe) to avoid chimney draught in the case of fire. To prevent liquid dripping onto a lower deck, holes SHALL [PS] be provided with concrete curbs, cast-in extended pipes or other means. The fire rating of the wall or floor including the penetration SHALL [PS] be maintained.

Piping shall be routed to avoid penetration of major structural elements supporting decks and walls.

Penetrations through structural decks shall minimize the propagation of corrosion and stress concentrations.

Flange clearance on piping that penetrates the ground or grating on an elevated work platform shall be in accordance with section 5.9 of DEP 30.60.00.20-Gen.

3.6.2 Offshore facilities

For offshore facilities, all penetrations through partitions of any kind shall be rated according to the fire rating of the partition.

All penetrations shall be designed to the same specification for loading, fire rating, etc. as the deck or wall in which they are located. The design shall ensure that there is no loss of strength or stability local to the penetration.

Several types can be distinguished:

- a) Unclassified, open.
 - i. The hole shall allow a flange to pass through.
 - ii. A sleeve with minimal 100 mm (4 in) extension shall be installed.
 - iii. Thermal insulation of the pipe shall not contact the sleeve and can be installed and maintained inside the penetration.
- b) Unclassified, closed and/or watertight.
 - i. The hole shall allow a flange to pass through.
 - ii. A sleeve with minimal 100 mm extension shall be installed on both sides.
 - iii. A watertight sealing device shall be slipped over the sleeve-extension and the pipe (including insulation).
 - iv. To achieve a closed penetration, the installation of a sealing device or

compound between the pipe and the sleeve may be considered.

- v. Attention should be paid to the pipe supporting properties of such a seal.
- c) Classified, fireproof and certified
 - i. The fire resistant seal shall meet at least the classification of the penetrated wall/deck.

The Fire Rated Penetration Seal System shall be specially developed for offshore platform applications.

The seals around penetrations shall be made in such a way that the fire resistance of the boundary or barrier is not reduced. During normal operation the construction is subjected to thermal stresses and vibrations. During a fire these stresses and movements are multiplied at the same time as other forces and threaten to break down its integrity.

Sleeve length: for the Bulkhead or Wall sleeve must be min. 260 mm (10.25 in) long and a Deck sleeve min. 225 mm (8.75 in).

The minimum distances between pipe and sleeve in a single-pipe penetration for all fire ratings, based on the use of suitable silicone material, are:

- Up to and including DN 150 (NPS 6) - 50 mm (2 in)
- > DN 150 - DN 350 (NPS 6 – NPS 14) - 75 mm (3 in)
- > DN 350 (NPS 14) - 100 mm (4 in)

These dimensions allow as a minimum

- Vibrations $\pm 0,1$ mm (4 mil), 100 Hz, 1 hour.
- Axial movements ± 17 mm (0.67 in)
- Radial movements ± 17 mm (0.67 in)

In order to ensure adequate bonding, the insulation should penetrate into the silicone foam of the seal, to a depth of 25 mm (1 in).

3.7 SEISMIC LOADS

If the region is susceptible to earthquakes, the anticipated earthquake loads shall be established.

A piping system in an earthquake region SHALL [PS] have sufficient flexibility to absorb large movements without leading to excessive strain or failure. The following aspects shall be carefully examined and, where necessary, adequate measures shall be taken:

- a) piping shall be provided with sufficient flexibility between two anchor points, taking into account that the two anchor points may respond in different modes during an earthquake;
- b) piping offsets, expansion loops, etc. are normally only provided for absorbing thermal movements. Suitable limit stops shall be provided to restrict this movement in the event of a seismic shock;
- c) supports for branch-off pipes and supports for vital control equipment shall be determined by careful scrutiny;
- d) instrument lead pipes shall have sufficient flexibility to absorb seismic movements of the columns, pipe rack and/or structures to which the instrumentation pipes are attached;
- e) piping going through bund walls, building walls and floors shall be provided with sleeves large enough to allow for the anticipated differential movements due to seismic loads. Dampening and sealing material shall be provided where it is required to maintain a liquid tight connection.

In earthquake regions the following pipe supporting aspects require further scrutiny:

- a) providing additional limit stops for both horizontal and vertical pipes with horizontal

thermal displacements, thus preventing further movement in the event of a seismic shock load;

- b) providing restraints for risers (vertical piping, usually with wind load guides) in the longitudinal pipe direction, thus preventing the pipe jumping in the event of a seismic shock force;
- c) providing additional guides at column resting supports;
- d) providing sway braces or sway struts;
- e) providing snubbers;
- f) providing jump restraining pipe clamps or clips, thus preventing the pipes from jumping off their support member (especially for horizontal pipes running along pipe racks or pipe tracks in places where no branch-off pipes are holding the pipe in place).

3.8 DISTANCE BETWEEN PIPES

The minimum distance between pipes shall be followed in accordance with section 5.8 of DEP 30.00.60.20-Gen. The minimum distance between a flange (with insulation) and a pipe or the insulation of a pipe in pipe tracks and trenches and on pipe racks shall be 30 mm (1.2 in). The minimum distance between a flange (without insulation) and a pipe or the insulation of a pipe in pipe tracks and trenches and on pipe racks shall be 75 mm (3 in) for tools access.

Where required, the distance between pipes shall be increased to allow for movements caused by thermal expansion.

This clearance shall be increased to allow for movements caused by thermal expansion.

Adjacent pipe guides should be staggered, in order to minimise pipe space requirements.

Adjacent flanges should be staggered, in order to minimise pipe space requirements.

Adequate clearance shall be provided for manifold piping and between hand wheels or wrenches of valves.

Valves and flanges shall be staggered whenever possible to ease operation and reduce space.

3.9 SMALL BORE PIPING

Since small bore branches ($\leq$ DN 40 (NPS 1 ½)) to large bore piping are relatively susceptible to failure, the following points shall be incorporated in piping design for avoidance of vibration induced fatigue of small bore piping and branch connections:

- a) Minimise the number of small bore branches to piping.
- b) Small bore piping, including its method of support, shall be shown in full detail, either on the isometric drawings or on a referenced document.
- c) Branches shall not be located in removable spools, unless it is impractical to do otherwise.
- d) Branches shall not be located in high stress areas.
- e) The unsupported length of the branch and associated fittings should be as short as possible.
- f) The mass/weight of the assembly should be as low as possible. Avoid installation of heavy components (e.g. flanged valves) on the end of the connections.
- g) The distribution of the weight along the cantilever branch of the connection should be chosen to minimize reduction of the natural vibration frequency of such assembly.
- h) Unreinforced branch connections SHALL [PS] not be installed immediately in the downstream of high capacity gas pressure reducing systems such as compressor

recycle systems, steam desuperheaters, high-rate depressuring valves and safety relief valves. Also, for flow induced vibration, where the classification of susceptibility to failure is "high" based on paragraph 17.1, special attention shall be paid to the bracing of these branches to the run-pipe (see Standard Drawings S 44.030, S 44.031, S 44.032).

- i) Maximize the diameter of small bore terminal connections. Connections on piping between compressor and pulsation bottles and for all piping directly connected to the compressor should be avoided. If such connections cannot be avoided, their size should be maximized. The preferred size of a nozzles for branches is DN 80 (NPS 3).
- j) The bracing of complex geometries of connections or branches with heavy valve or flange weights shall be checked by a pipe stress engineer or vibration analyst.
- k) In branches with flanged valves, branch fittings with flanged outlets shall be used wherever possible, in order to reduce the number of welds.

Branches (including direct mounted instrument connections) to run pipes shall not be smaller than the sizes as shown below.

Run Size	Branch Size
DN 20 through DN 50 (NPS $\frac{3}{4}$ through NPS 2)	DN 20 (NPS $\frac{3}{4}$)
DN 80 through DN 300 (NPS 3 through NPS 12)	DN 25 (NPS 1)
Greater than DN 300 (Greater than NPS 12)	DN 40 (NPS 1 $\frac{1}{2}$)

Non direct-mounted instrument-connections should be kept as simple as possible. The length of the branch should be minimized (fitting-to-fitting), with isolation valve(s) as per latest piping classes (e.g. with monoflange/slimline (DB&B) valves where design temperature is lower than 150 °C (300 °F)), with only tubing or a pressure gauge to be connected to the isolation valve.

For situations where vibration of piping may be expected, like near compressors, connecting points to the main piping should be located at positions where vibration amplitudes are lower, such as near fixed points at pipe supports. The use of larger piping is preferred over the use of support bracing (attachments) to small bore piping for situations where increased mechanical strength is required.

For critical situations (e.g. where vibration of piping is expected), the mechanical strength of instrument connections can be improved by using reducing nozzles, e.g. weldolet DN40 (NPS 1 $\frac{1}{2}$) – reducer DN 40/15 (NPS 1 $\frac{1}{2}$ / $\frac{1}{2}$) – welding neck flange DN15 (NPS $\frac{1}{2}$).

For piping systems in vibrating service, see (3.23) of this DEP.

Further information on the avoidance of vibration induced fatigue can be found in "Energy institute guidelines for the avoidance of vibration induced fatigue failure in process pipework."

3.10 INSTALLATION OF FLANGES

Flanges in piping systems shall be installed only to facilitate maintenance and inspection and where construction or process conditions dictate.

For flanges in hydrogen service, and flammable liquid services with operating temperatures at or above their auto-ignition temperature, steam shall be used to control fires. The steam has a smothering effect and will limit the overheating of flange bolts. Sufficient steam lances with 15 m (45 ft) long electrically-earthed hoses shall be provided to allow operations to reach the flanges of concern. See standard drawing S 88.005. Steam ring systems (see Standard Drawings S 38.141, S 38.142, S 38.143 and S 38.144) shall be fitted to inaccessible flanges, unless assessed a detailed risk assessment can show that a leak would not present a serious hazard (this being subject to the approval of the Principal).

The risk assessment shall consider the normal operating pressure of the process, compliance with the selected piping class, use of bolt-tensioning equipment, the type of flange connection (end cover, pipe-to-pipe or pipe-to-equipment connection) and the size of the flanges. Steam rings need not be installed on flange connections smaller than DN 150 (NPS 6).

If steam rings are installed, they shall be manually activated. The steam block valves shall be positioned at a safe distance, (i.e., at least 15 m (45 ft) away) from the flange and the related fire hazard. The block valves shall be marked properly to indicate which steam ring they are serving. Steam rings and piping should have 8 mm (0.3 in) diameter drain holes at low points.

Flanges SHALL [PS] not be located above main roads outside unit battery limits.

Piping systems with RTJ flanges shall be designed to allow removal of equipment and pipe sections without the need to remove very long sections of piping system.

For high pressure piping systems (ASME rating class 2500 or higher) connected to vessels, butt welded connections may be considered.

For all welded piping systems in offshore installations, particularly in small pipe sizes, consideration shall be given to installation of sufficient flanges to permit removal and replacement of lines where corrosion, erosion or plugging is expected.

For insulating flanges and isolating joints in cathodically protected piping systems, see DEP 30.10.73.10-Gen. and DEP 30.10.73.31-Gen.

Threaded blind holes shall not be used unless stud bolts cannot be used, especially in high temperature applications. Application of temperature resistant lubricants (anti seize compound) is required in all applications.

For flange alignment and tolerances, see (Appendix 12).

3.10.1 Flange joints in severe operating conditions

Flange Joints in severe operating conditions include high pressure and high temperature services (i.e. above 450 °C (840 °F)), or in batch processes with rapidly fluctuating temperatures.

To reduce joint relaxation in high temperature or cyclic service, spring washers may be installed under the nuts..

As bolt relaxation mainly takes place during the first 1000 hours of operation, retightening may be needed soon after re-start. Care shall be taken not to overstretch the bolts. Flange Joints shall be applied with maximum required torque and/or elongation. Checks e.g. with turn of the nut method, shall be performed.

3.11 BOLT TORQUING AND HYDRAULIC BOLT TENSIONING

For bolt torquing and hydraulic bolt tensioning, see section 3.12 of DEP 31.38.01.31-Gen.

3.12 INSTALLATION OF VALVES

3.12.1 General

The number of different types of valves shall be minimised.

All pipes entering and leaving the process unit SHALL [PS] have block valves and flanges provided to allow for spading (spades or spectacle blinds) at the boundary of the process unit ("battery limit"). The block valves shall be located near each other unless impractical. A drain/vent connection shall be installed as close as possible to the block valves and spades, for draining, venting and testing purposes. Open ended valves in hydrocarbon or sour service shall be equipped with blind flanges or threaded plugs. Valves in horizontal pipes shall be positioned with their stem on or above the horizontal, except as follows:

- Butterfly valves shall be positioned with the stem horizontal in services where fouling substances could collect in the lower shaft bearing;

- Gate valves should be positioned with the stem horizontal in services where fouling substances could collect in the bottom cavity;
- Valves shall be positioned with the stem horizontal in systems where a component failure (e.g. wedge pin) could cause closure of the valve and lead to unsafe situations (e.g. flare systems).

Pipes with wafer and/or lug type valves may require an extra flanged connection for installing a spade flange or removal of a pipe spool.

Main block valves on branch piping systems should be arranged for self-draining on both sides, or provided with drain points at the block valve.

Valves with extended bonnets in low temperature service shall be installed with stem vertical or a maximum stem inclination of 45° from the vertical.

3.12.2 Ergonomic aspects of valves

Valves shall not be installed above roads.

Valves should not be located in overhead pipe racks.

For ergonomic aspects of valves, see DEP 30.00.60.13-Gen.

Valves requiring maintenance during normal operation, e.g. lubrication of plug valves shall be located so as to be easily accessible from deck, platform or permanent ladder.

3.12.3 Selection of gear drives for valves

Gear drives shall be selected in accordance with the applicable valve MESC SPE specifications.

The selection of motorised actuators shall be subject to the approval of the Principal.

3.12.4 Control valve installation

Globe control valves shall be installed with their diaphragm actuator stem in the vertical position, with sufficient clearance above the actuator and under the bottom flange to allow the control valve to be dismantled without removing the valve body from the pipe.

There shall be sufficient clearance to lift and remove the valve. Control valves shall be located so that they are accessible for hoisting equipment where needed. Further requirements for control valves are specified in DEP 32.36.01.17-Gen.

3.12.5 Manifolds for control valves

If required for operational reasons, control valves shall be provided with block valves and a bypass valve, except that a bypass valve shall not be provided in safety shut-off or depressurizing service or in applications where solids suspended in the stream may collect and block the bypass valve.

As the provision of block valves, bypass valves, handwheels, etc. is governed by operational considerations, the PFS and PEFS shall indicate the arrangement required for each application.

The block valves at each side of the control valve shall be of the straight-through type and should be the same size as the control valve, except in the following situations where the block valves should be the same size as the upstream/downstream piping

- if the additional strength of the larger pipe size is required for proper supporting;
- if the size of the upstream/downstream process piping is DN 50 or smaller (NPS 2 or smaller).

For typical arrangements of control valve manifolds, see (Appendix 13).

The bypass valve shall have a nominal capacity factor at least equal to, but not more than twice, the capacity factor of the control valve. Where necessary, the bypass valve shall be capable of proper throttling. For critical applications, the bypass valve shall be of the same type as the control valve, but with handwheel operation only.

In the following services the bypass pipe shall be designed so that there are no vertical dead ends where liquid can collect:

- fouling process conditions;
- steam;
- hydrocarbons containing water.

Provisions shall be made for draining and/or depressurizing the control valve manifold. At least one drain valve shall be provided just upstream or downstream of the control valve, depending of the physical lay-out. Shut-off valves shall have a drain valve on the downstream side so that the shut-off valve can be leak-tested. More extensive provisions may be required in corrosive or very toxic service.

Start-up strainers shall be provided upstream of control valves with labyrinth-type low-noise trims.

3.12.6 Body cavity relief (pressure equalisation) provisions in valves

- a) Cavity pressure relief provision SHALL [PS] be provided for double seated valves (i.e., trunnion mounted ball valves, gate valves and plug valves), in liquid service subject to fluctuating temperature (thermal cycling), where:
 - Design temperature $\geq -50\text{ }^{\circ}\text{C}$ ($-58\text{ }^{\circ}\text{F}$) and $<0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$), for class 150# LPG service, since by design they are relatively weak (oval bonnet on gate valve) for DN 50 (NPS 2) and above,
 - Design temperature $< -50\text{ }^{\circ}\text{C}$ ($-58\text{ }^{\circ}\text{F}$) in all other ASME pressure classes, for all sizes.
- b) In liquid service classed as very toxic services in accordance with DEP 01.00.01.30-Gen. (such as chlorine and EO) for DN 50 (NPS 2) and above,
- c) In steam and condensate systems for DN 50 (NPS 2) and above,
- d) Process block valves around pumps operating at temperatures above $200\text{ }^{\circ}\text{C}$ ($390\text{ }^{\circ}\text{F}$) for DN 50 (NPS 2) and above,

Wherever possible, body cavity relief shall be to the upstream side of the valve.

Depending on the process conditions and service application, for double seated valves in ASME classes $\geq 300\#$, the requirement for body cavity over-pressure relief has to be assessed on a case-by-case basis.

In the following situations, the pressure might act on the downstream side of the downstream valves against the normal flow direction when the valves are in closed position,:

- block valves upstream and downstream of pumps;
- control valve arrangement with block valves upstream and downstream, and with a bypass;
- block valves upstream and downstream of relief valves.

These valves shall incorporate a positive body cavity feature, usually a vent hole drilled through the upstream side of the closure member. This renders the valve as uni-directional; the upstream side of the valve shall therefore be clearly marked High Pressure Side or HP Side. The vent hole shall be a minimum of 3 mm (0.12 in) diameter.

These positions shall be marked as HP on piping isometrics and shown on the PEFS using symbols according to Standard Drawing S.02.002 sheet 2. For an example of the presentation of sealing direction of block valves around a control valve on a PEFS, see Figure 3.12.6.1.

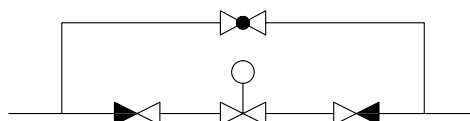


Figure 3.12.6.1

It shall be specified in the purchase order whether the upstream or downstream side of the valve is the high pressure side.

The maintenance manual shall show how the closure member shall be assembled.

There is no need for a external body cavity relief on:

- Double seated valves (i.e., floating ball, gate and plug), used for light hydrocarbon services, operating at around ambient temperature (0 °C/ -29 °C (32 °F/-20 °F)), that might see an operating temperature down to -50 °C (-58 °F) only during emergency depressurizing.
- Trunnion mounted ball valves with single-piston effect seating, because the cavity pressure relief is provided via spring energized seats and they relief to the downstream / low pressure side of the valve. The cavity relief requirement is either specified in the base standard ISO 14313 /API 6D or in the applicable MESC SPE 77/130, amending/supplementing the valve base standard.
- Trunnion mounted ball valves with one single and one double-piston effect seat, where the single piston affect seat on the upstream side will relieve to the upstream side of the valve.

3.12.7 Equalizing of pressure around valves

Quick opening of a large valve holding high pressure may cause a significant shock wave travelling through the pipe at sonic speed. This can cause damage to vessel internals, flanged connections, bellows etc. Since controlled opening (cracking a valve open) is easier with a small valve than with a big valve, large valves should be provide with a small by-pass in order to allow controlled equalization of the high differential pressure. As a guide line, a DN 50 (NPS 2) by pass should be provided when the run pipe is larger than DN 150 (NPS 6) and the pressure difference is larger 15 Bar (218 psi). A bypass is not necessary in cases where a control valve is installed downstream, and the control valve can be opened gradually after opening the upstream block valve. The decision to install an equalizing bypass is a part of the process design.

For equalization of pressure in steam pipes, see (5.5) of this DEP.

3.13 DRAIN AND VENT CONNECTIONS

3.13.1 Pressure Test drain and vent connections

Drain and vent connections shall be installed, without valves, at all low and high points in each piping system to facilitate venting and draining during pressure test after construction or repair of the system. The following minimum branch pipe sizes shall be used for flanged test vent and drain connections:

Run Size	Branch Size
DN 15 (NPS ½)	DN 15 (NPS ½)
DN 20 through DN 50 (NPS ¾ through NPS 2)	DN 20 (NPS ¾)
DN 80 through DN 300 (NPS 3 through NPS 12)	DN 25 (NPS 1)
Greater than DN 300 (Greater than NPS 12)	DN 40 (NPS 1 ½)

Minimum pipe wall thickness for vent / drain connections in carbon steel piping systems shall be maintained as Sch.80.

Test drain and vent arrangements are specified in the piping classes and are shown in DEP 31.38.01.10-Gen. These connections shall not be shown on the PEFS, unless the system is included in a fugitive emissions monitoring program, in which case they shall be shown on the PEFS. All drain and vent points SHALL [PS] be closed with a blind flange or, where these are permitted, a (welded) plug.

Drains shall be located so that there is sufficient free space underneath to install temporary facilities to discharge the drained liquid.

Vents and drains shall be as short as possible. If long connections are required (e.g. due to thick insulation on the main pipe), supports/bracings and/or a larger branch size shall be applied. See Standard Drawing S 44.030.

For pressure test vent and drain connections, see Standard Drawing S 38.154.

As an alternative to flanged pressure test vent and drains, combination socketweld and threaded branch outlet fitting (bosset) may be utilized in services where sockeweld fittings are allowed. When utilizing these fittings, the round plug will initially be inserted using the threaded end, and then after pressure test, the plug can be removed, flipped over, re-inserted, and welded using the socketweld end for permanent installation.

Flanged pressure test vent and drain connections shall be used for all piping systems that require PWHT during fabrication.

3.13.2 Process drain and vent connections

If required for operation/maintenance, valved drain connections shall be installed at low points, and valved vent connections at high points in piping systems. These connections shall be hooked up to a closed drain system and be shown on the PEFS. For drain and vent provisions on equipment, see (4). Valved vents and drains to atmosphere SHALL [PS] satisfy the double barrier concept. In this context, a blind flange on an outlet to atmosphere counts as one barrier. When threaded plugs or caps are allowed per (8.3.1.5), the threaded plug also counts as one barrier.

Where process requirements demand a quick outlet to atmosphere, the double barrier SHALL [PS] be obtained by installing two valves in series. If the effluent will flash and cause sub-zero temperatures, the distance between the two valves shall be at least 0.6 m (24 in) and the downstream (low pressure) valve SHALL [PS] be of the spring loaded, self-closing type. The number of vent and drain connections with valves shall be minimised.

Process drains shall be located and sized to drain pipings systems and vessels systems in a timely manner. The Principal shall be consulted for guidelines.

The size and installation of process drains and vents shall be decided as a part of the process design and depends on required drain time.

For process vent and drain connections, see Standard Drawing S 38.155.

From a mechanical point of view the following minimum branch pipe sizes shall be used for process vent and drain connections:

Run Size	Branch Size
DN 15 (NPS ½)	DN 15 (NPS ½)
DN 20 through DN 50 (NPS ¾ through NPS 2)	DN 20 (NPS ¾)
DN 80 through DN 300 (NPS 3 through NPS 12)	DN 25 (NPS 1)
Greater than DN 300 (Greater than NPS 12)	DN 40 (NPS 1 ½)

The status of vent and drain valves used for instrument maintenance or for decommissioning of plant during turnarounds, as well as those used for operational venting

and draining shall be clearly visible from the operator vantage point at access platforms and walkways.

3.14 CONNECTIONS FOR MANUAL SAMPLING

This section specifies requirements for manual sampling, not for on-line process stream analyser connections (for the latter, see DEP 32.31.50.10-Gen.).

Dedicated connections shall be provided for sample collection.

The sampling point shall be positioned so that the valves are easy to operate and taking the sample will not impair the safety of personnel or plant or cause environmental impact.

The sample shall be maintained in a single phase. The sample take-off shall be at a point where the gas is at least 10 °C (18 °F) above dew point or the liquid is at least 10 °C (18 °F) below the bubble point.

Samples should be taken from a vertical pipe where possible; where this is not possible:

- a) For gaseous products in horizontal pipes, sample take-off connections shall be installed at the top of the pipe.
- b) For liquid products in horizontal pipes, sample take-off connections shall be installed at the side of the pipe.

Sample take-off connections shall not be located at dead ends of piping. The length of the sample piping system shall be kept as short as possible to minimize purging.

For liquid sampling, the sample point should be placed in the 4 o'clock position and shall be positioned no further than the 5 o'clock position.

Sample take-off connections shall be easily accessible and should be at ground level. However, sample pipes shall be as short as possible and not longer than 8 m (26 ft). As far as practicable, sample connections shall be grouped together and provided each with a sample cabinet which can be connected to one common drain facility.

Drain facilities shall be connected to a sample recovery system wherever possible.

Sample points shall have two valves: one at the take-off point from the process pipe and another at the sampling point. The block valve at the take-off point shall have the same size as a standard drain valve. The sampling valve size shall be maximum DN 15 (NPS ½) and shall have good throttling properties. If a short sample take-off pipe cannot be fitted, a closed loop shall be provided. The closed loop shall be a connection to the same process stream, at different pressure. The loop shall be provided with block valves at the connections with the process pipe.

Precautions shall be taken to avoid freezing or plugging of the sample pipe, e.g. for high-pour-point or viscous fluids.

The outlet of a single sample connection, if not connected to a sample cabinet, shall either have a male thread and be closed with a threaded cap, or it shall have a quick-fit coupling which seals when not connected to a sample receiver.

Sample outlets for fluids above their auto-ignition temperature, for LPG and for very toxic products SHALL [PS] have a self-closing downstream valve. If the effluent could flash and create sub-zero temperatures, the distance between the two valves SHALL [PS] be at least 0.6 m (24 in).

Connections for hot samples (i.e. 80 °C or above) shall be provided with a permanently installed sample cooler. The PEFS shall indicate where a cooler is required.

If bleed lines are installed, they shall be led to a safe location.

The following Standard Drawings should be used:

- S 38.007
- S 38.013
- S 38.037

- S 38.038

From mechanical point of view the following minimum branch pipe sizes SHALL [PS] be used for sample connections:

Run Size	Branch Size
DN 15 (NPS ½)	DN 15 (NPS ½)
DN 20 through DN 50 (NPS ¾ through NPS 2)	DN 20 (NPS ¾)
DN 80 through DN 300 (NPS 3 through NPS 12)	DN 25 (NPS 1)
Greater than DN 300 (Greater than NPS 12)	DN 40 (NPS 1 ½)

For ergonomic aspects of piping systems associated sampling systems, see section 5.12 of DEP 30.00.60.20-Gen.

3.15 TEST CONNECTIONS

Connections for pressure testing a piping system shall be provided where required. Drains and vents should be used for this purpose. The location of the connections shall permit the complete removal of the test medium after the test.

The supply connection shall be of a size which will allow the system to be filled within a reasonable time and it shall have a temporary, flanged globe valve which shall also be used for depressurizing.

Test connections SHALL [PS] be closed with a blind flange, or where permitted, a (welded) plug after completion of the test.

Vent flanges for HP and MP steam pipes may be replaced by welded caps after the hydrostatic test. These welds shall be non-destructively examined to the same standards as the other welds in the system and shall be monitored during initial operation at operating pressures.

For test vent and drain connections, see (3.13.1).

3.16 THERMOWELL CONNECTIONS

Flanged thermowells are suitable for run pipe DN 80 (NPS 3) and larger and shall be selected from Table 3:

Table 3			
ASME rating classes	Schedule	Thermowell size	Standard Drawing
150-1500	160 and below	DN 40 (NPS 1 ½)	S 38.113
150-1500	XXS and above	DN 50 (NPS 2)	S 38.114
2500		DN 50 (NPS 2)	S 38.114

NOTE: DN 50 is selected for class 2500 and for class 1500 schedule XXS because the wall thickness does not allow the thermowell to fit in a DN 40 (NPS 1 ½) pipe.

Alternate design of thermowells shall be approved by the Principal.

Alternative designs shall avoid the possibility of inserting thermocouple without thermowell.

Table 4 contains the standardized length of flanged thermowells:

Table 4	
Thermowell length	Used for:
230 mm (9 in)	pipes DN 80 and DN 100 (pipes NPS 3 and NPS 4)
255 mm (10 in)	pipes DN 150 and larger (pipes NPS 6 and larger)
305 mm (12 in), 355 mm (14 in), 405 mm (16 in) and 455 mm (18 in)	equipment (vessels etc)

NOTE: If longer thermowells are required for pipes (e.g. if solidified product on the pipe wall may influence the measurement), longer thermowells from the equipment range may be applied after the mechanical strength of the thermowell has been checked with respect to the flow speed and vibration.

In pipes with turbulent flow, only thermowells with a length of 230 mm (9 in) should be used in order to reduce vibration and forces on the thermowell. In pipes with turbulent flow, the temperature difference between the centre of the pipe and near the pipe wall is negligible so the shorter thermowell should not adversely affect the measurement accuracy.

Thermowells should be avoided in pipes with two-phase flow.

As the vortex shedding frequency (also referred to as the Strouhal Frequency) approaches the thermowell natural frequency, the tip displacement and stresses are greatly magnified and the thermowell can fail due to the large amount of energy it must absorb.

The thermowell supplier shall supply thermowell vibration calculations that demonstrate that the ratio of wake frequency (f_w) to natural frequency (f_n) is less than 0.8 where in line resonance is not a concern. In case "in line resonance" is a concern, the ratio of wake frequency to natural frequency shall be 0.4. If the standard thermowell cannot meet this requirement, the thermowell base diameter shall be increased and/or the thermowell insertion length shall be shortened.

Vibrations induced by a von Karman vortex may occur in pipes with high fluid velocities. Thermowells installed in pipes with liquid velocity greater than 8 m/s (25 ft/s) and with gas velocity greater than 16 m/s (50 ft/s) SHALL [PS] designed in accordance with ASME PTC 19.3 TW to prevent fatigue failure due to vortex induced vibration.

NOTE: In high Reynolds flow regimes, the boundary layer is very thin. Thermowell insertion length can be reduced at no loss of accuracy in order to satisfy ASME PTC 19.3 TW requirements.

Measures to avoid these vibrations are:

- the use of short thermowells ;
- the use of welded thermowells;
- roughening the part of the thermowell exposed to the flow, e.g. by knurling (standard design);
- the use of tapered thermowells (standard design);
- placing the thermowell at a point with lower fluid velocity;
- not installing thermowells downstream of flashing or cavitating valves or other restrictions where the flow is turbulent.

Flanged thermowells shall normally be selected. Welding thermowells according to S 38.112 shall only be installed if, due to high velocity and density of the fluid, the bending loads are too high for flanged thermowells or if they may be subject to vortex induced vibration (see above).