

DEP SPECIFICATION

PIPING – PROCESS DESIGN REQUIREMENTS

DEP 31.38.01.25-Gen.

February 2019

DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the process design aspects that impact on the response of piping hardware and equipment to fluid flow, that address the inherent unreliability of valves, that optimise commercial and market availability of standardized sizes and components, that influence fluid flow energy losses, and that affect maintenance aspects of piping systems built in accordance with ASME B31.3 and pipeline facilities (pump stations, compressor stations, valve stations, pig stations) built in accordance with pipeline codes such as ISO 13623, ASME B31.4, ASME B31.8, NEN 3650 and PD 8010. It applies to piping for all types of process fluids (including fluidised solids), and all utility fluids.

Piping covered under equipment design codes is 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), subsea piping systems, utility piping in living quarters and plant buildings are excluded from the scope of this DEP.

Cross-country sections of pipelines - with the exception of pipeline facilities - designed in accordance with codes such as ISO 13623, ASME B31.4, ASME B31.8, NEN 3650 and PD 8010 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.

Piping fabrication requirements are covered in DEP 31.38.01.31-Gen.

Piping systems of "boiler proper piping" as referenced in ASME B31.1, Section 100.1.1 are covered by 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 are covered by ASME B31.1.

Piping systems for package refrigeration units are covered by ASME B31.5, except that impact test requirements are covered by DEP 30.10.02.31-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 new the DEP that has been developed in the course of splitting the content of DEP 31.38.01.11-Gen.; see (1.5) regarding the change.

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.

The word **may** indicates a permitted option.

1.3.2 Specific definitions – General

Term	Definition
Cryogenic fluid service	A fluid service in which the piping metal temperature has a lower design temperature (LDT) < minus 50 °C (minus 58 °F)
Deadleg	Components of a piping system that normally have no significant flow. Some examples include blanked branches, lines with normally closed block valves, lines with one end blanked, pressurized dummy support legs, stagnant control valve bypass piping, spare pump piping, level bridles, relief valve inlet and outlet header piping, pump trim bypass lines, high-point vents, sample points, drains, bleeders, and instrument connections.
Dry chlorine	Chlorine containing less than 150 ppmw of water
flashing fluid	Fluids listed in Energy Institute IP 15 as Class 0, I, II (2) and III (2). Where warm/hot surfaces are within the distances defined in API RP 505:2018, section 14.3, fluids listed as Class II (1) and III (1) also are included.
Flowline	Piping which carries well fluid from wellhead to manifold or first process vessel
fluid	gas, vapour, liquid or combinations thereof
HP steam	Typically steam between 40 barg and 100 barg (580 psig and 1450 psig)
hydrogen service (H2 service)	Service in which the hydrogen partial pressure is greater than 700 kPa absolute (100 psia) at any temperature. See also API RP 941:2016, Figure 1.
MP steam	Typically steam between 12 barg and 18 barg (175 psig and 260 psig)
Oxygen service	Any gas mixture with an oxygen content of 35 vol% for metallic material selection, 21 vol% for non-metallic material selection, and requiring cleanliness of oxygen service products (in accordance with NFPA 53).

Term	Definition
pipe track	Piping route typically consisting of multiple pipes, where pipes are routed at grade level using concrete sleepers as pipe supports
Pipeline	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	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. 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. Instrument specifications apply downstream the last joint of the last process to instrument valve or valve assembly, defined for the instrument connection in the mechanical piping class. This can include the 5 mm restriction nipple where applicable.
Piping class	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 31.38.01.14-Gen. - Piping classes DEP 31.38.01.23-Gen. - Piping classes developed primarily for use in the oil, multi-phase, water and gas pipeline systems from a wellhead to a plant facility administered primarily to the CSA Z662 standard.
Small bore	Piping components of size DN 50 (NPS 2) and below
spec break	Physical location as a single point dividing one piping class from another.
Superheated steam	Steam with a temperature of 25 °C (75 °F) or more above saturation temperature at steam pressure.
Very Toxic	Includes very toxic – acute / very toxic – chronic / very toxic – environment. For details, see DEP 01.00.01.30-Gen.

1.3.3 Specific definitions – Valves

Term	Definition
bellows	Flexible, thin-walled, circumferentially corrugated cylinder. It can have integral ends and can expand or contract axially under changing pressure.
closure member	Moving part of the valve which closes off the seat, e.g., ball, disc, gate.

Term	Definition
double block and bleed	Arrangement of valves, which includes two valves in series and has a bleed valve between. Total isolation of the pipework is achieved when both valves are closed and the bleed is open. Special integral DBB units are available to reduce weight and to give minimal joints. The valve ends can be flanged, hub type or butt weld.
fouling/ scaling service	Liquids or slurries, carrying suspended particles that can form a deposit on surfaces or build up in pockets within a valve. These can seriously impair the performance of valves unless the correct type is selected.
full bore	Valve in which the bore (port) is equal to the bore of the connecting pipe.
linear motion valve	Valve that has a sliding stem that pushes the obturator closed or pulls it open. They are capable of being adapted to bellows sealed. See also rising stem.
non-return valve	Valve that allows fluid flow in only one direction. Also known as check valve.
obturator	Valve closure member (e.g., ball, gate, globe, disc)
on-off valve	Basic operation of a valve to start or stop the flow of a fluid, also referred to as isolating or stop valves.
positive body cavity relief	Dedicated feature within a double seated valve which gives an actual connection of the close valve cavity with either the high pressure or low pressure side of the valve.
quarter turn valve	Valve (such as ball, plug, butterfly) which requires a 90-degree operation of the stem to move from the fully open to the fully closed position. They will readily accept any type of actuation (pneumatic, hydraulic, electric).
reduced bore	Valve in which the bore (port) is smaller than the bore of the connecting pipe.
rising stem	Non-rotating, linear motion stem, where the threads are outside the valve body and not subjected to possible negative effects of the process fluid.
safety/relief valve	Pressure relief valve that is designed to relieve excessive pressure.
seat	Part of a valve against which a closure member effects a tight shut-off, or a rate of shut-off, the material can be soft (polymeric/ elastomeric) or metallic, or a combination of both.
throttling	Intentional restriction of flow by partially closing or opening a valve.

1.3.4 Abbreviations

Term	Definition
ASL	Atmospheric safe location

Term	Definition
DN	Diameter Nominal. The DN prefix indicates the nominal diameter of a piping system component in millimetres.
LCO	Light Cycle Oil
NPS	Nominal Pipe Size. The NPS prefix indicates the nominal diameter of a piping system component in inches
PEFS	Process Engineering Flow Scheme
PFS	Process Flow Scheme
TSO	Tight Shut-Off
VGO	Vacuum Gas Oil

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (11).

1.5 SUMMARY OF MAIN CHANGES

DEP 31.38.01.11-Gen., "Piping – General Requirements" has been divided into three separate DEPs:

DEP 31.38.01.24-Gen.: Piping – Engineering and Layout Requirements

DEP 31.38.01.25-Gen.: Piping – Process Design Requirements

DEP 31.38.01.26-Gen.: Piping – Pipe Stress Analysis Requirements

Section/Clause	Change
2.2.7, Item 5	New SHALL [PS] statement added. This statement was not present in the former DEP 31.38.01.11-Gen.
2.3.4	Merged SHALL [PS] statements regarding surge analyses from the same section in the former DEP 31.38.01.11-Gen.
3.4.1, Item 3	Modified the SHALL [PS] statement. In the former DEP 31.38.01.11-Gen., this clause was 3.13.3, Item 3.
3.10, Item 2	Rephrased the SHALL [PS] statement. In the former DEP 31.38.01.11-Gen., this clause was 3.25, Item 2.
4.1.2.1, Item 3	Rephrased the SHALL [PS] statement. In the former DEP 31.38.01.11-Gen., this clause was 4.2.2.1, Item 3.
4.1.2.1, Item 5	Rephrased the SHALL [PS] statement. In the former DEP 31.38.01.11-Gen., this clause was 4.2.2.1, Item 5.
4.1.2.4, Item 3	Changed from SHALL [PS] to 'shall'. In the former DEP 31.38.01.11-Gen., this clause was 4.2.2.4, Item 4.
4.1.2.4, Item 4	Changed from SHALL [PS] to 'shall'. In the former DEP 31.38.01.11-Gen., this clause was 4.2.2.4, Item 5.
4.1.3, Item 4	Rephrased the SHALL [PS] statement. In the former DEP 31.38.01.11-Gen., this clause was 4.2.3, Item 6.

Section/Clause	Change
5.4	The SHALL [PS] statement from (5.4, Item 6) of the former DEP 31.38.01.11-Gen. has been deleted.
5.5	The SHALL [PS] statement from (5.5, Item 2) of the former DEP 31.38.01.11-Gen. has been deleted.
6.2, Item 1	Rephrased the SHALL [PS] statement. In the former DEP 31.38.01.11-Gen., this clause was 6.2, Item 3.
8.2	Rewrote SHALL [PS] statements and updated figures regarding isolation. This section was Section 8.7 in the former DEP 31.38.01.11-Gen.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

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.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. PIPE SIZING

2.1 GENERAL

1. Up to and including size DN 600 (NPS 24), the pipe sizes in Table 1 shall be used with the following limitations:
 - a. due to their vulnerability to damage and their limited mechanical strength, sizes DN 15 (NPS ½) and DN 20 (NPS ¾) should not be used except for short branch connections;
 - 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 1½).

Table 1 Pipe sizes

DN 15 (NPS 1/2)	DN 200 (NPS 8)
DN 20 (NPS 3/4)	DN 250 (NPS 10)
DN 25 (NPS 1)	DN 300 (NPS 12)
DN 40 (NPS 1-½)	DN 350 (NPS 14)
DN 50 (NPS 2)	DN 400 (NPS 16)
DN 80 (NPS 3)	DN 450 (NPS 18)
DN 100 (NPS 4)	DN 500 (NPS 20)
DN 150 (NPS 6)	DN 600 (NPS 24)

2. For small bore piping, refer to DEP 31.38.01.26-Gen.
3. Unless economically justified otherwise, the range of pipe sizes above DN 600 (NPS 24) shall be restricted to those in Table 2, to avoid the purchase of many different sizes of pipe and fittings:

Table 2 Pipe sizes above DN 600 (NPS 24)

DN 750 (NPS 30)	DN 1400 (NPS 56)
DN 900 (NPS 36)	DN 1600 (NPS 64)
DN 1050 (NPS 42)	DN 1800 (NPS 72)
DN 1200 (NPS 48)	DN 2000 (NPS 80)

4. For Greenfield projects, refer to DEP 01.00.09.10-Gen. for the identification of piping.
DEP 01.00.09.10-Gen. excludes Brownfield projects and projects at existing sites from its scope. Brownfield projects and existing site projects will use the existing site conventions.
5. Refer to DEP 31.38.01.10-Gen. for the requirements for the identification of piping classes.
6. After the basic pipe routes, number of valves, control valves, fittings, strainers and nozzles, have been determined, the anticipated pressure drop for the preliminary pipe sizes shall be checked.
7. A calculation sheet for pumping data 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.

8. 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.

2.2 PRELIMINARY PIPE SIZING

2.2.1 General

1. Where inline instruments such as flowmeters are to be installed into the line being sized, further velocity restrictions might apply and such restrictions shall be determined based on the requirements of the inline instrument.

2.2.2 Sizing of liquid piping systems

1. Where pressure drop is not a determining parameter, the size should be determined by the velocity constraints.
2. The velocities shall be kept low enough to prevent problems with erosion, water hammer, pressure surges, noise, and vibration and reaction forces.
 - a. Final velocities shall be kept above the minimum process velocity that is determined by the Contractor's process engineer, subject to approval by the Principal's process engineer.
 - b. When determining the velocity of the medium in the lines, the design should be able to withstand the potential generation of static electricity (refer to DEP 80.64.10.11-Gen.).
3. For liquids other than water, velocities in accordance with ISO 13703 should be used for preliminary line pipe sizing (0.5 m/s to 5 m/s (1.6 ft/s to 16 ft/s)).
4. For water other than steam blowdown, boiler feed water, and steam condensate, preliminary line pipe sizing should be based on Table 3.

Table 3 Preliminary line pipe sizing

Type of water	Minimum velocity	Maximum velocity			
		Carbon steel	Stainless steel / Titanium	Cu-Ni	GRP
Fresh water / potable water	1.5 m/s (5 ft/s)	4 m/s (13 ft/s)	5 m/s (16 ft/s)	3 m/s (10 ft/s)	6 m/s (20 ft/s)
Brackish / sea water		3 m/s (10 ft/s)	5 m/s (16 ft/s)	3 m/s (10 ft/s)	6 m/s (20 ft/s)

5. For velocity limitations of steam blowdown, boiler feed water, steam condensate piping systems, refer to DEP 30.75.10.10-Gen.
6. Preliminary pipe sizing of pump suction piping should be based on a pressure drop of:
 - a. 0.034 bar/100 m to 0.083 bar/100 m (0.15 psi/100 ft to 0.37 psi/100 ft) for liquids within 15 °C (27 °F) of their boiling point.
 - b. 0.15 bar/100 m to 0.4 bar/100 m (0.66 psi/100 ft to 1.77 psi/100 ft) for subcooled liquids.
7. Preliminary pipe sizing of pump discharge piping should be based on a pressure drop of 0.15 bar/100 m to 0.627 bar/100 m (0.66 psi/100 ft to 2.77 psi/100 ft).

8. For piping systems where the process fluids are expected to be contaminated by sand or proppant, the following maximum velocities should be used for preliminary line sizing (in accordance with NORSOK Std. P-002):
 - a. up to 5 m/s (16 ft/s) for carbon steel;
 - b. up to 7 m/s (23 ft/s) for stainless steel/duplex stainless steel.

For situations not covered in (2.2.2, Items 1 through 8), the Principal will consult with the Contractor to provide further guidance.

9. In cases of intermittent flow, a higher design velocity might be considered as the cumulative effect of the higher velocities might not be an issue.

Screening for flow induced vibration in accordance with DEP 31.38.01.26-Gen. remains a requirement.

10. For the sizing of liquid lines, Equation 1 or Equation 2 from ISO 13703/API RP 14E may be used.

$$V = \frac{353.7Q}{di^2} \quad \text{Eqn 1}$$

Where:

V = liquid velocity to be selected from the range specified in the DEP, m/s

Q = liquid flowrate, m³/h

di = pipe internal diameter, mm

$$V = \frac{0.012Q}{di^2} \quad \text{Eqn 2}$$

Where:

V = average liquid flow velocity, feet/second

Q = liquid flow rate, barrel/day.

di = pipe inside diameter, inches.

2.2.3 Sizing of gas and steam piping systems

1. The velocities in Table 4 may be used for preliminary line sizing:

Table 4 Velocities for line sizing

Air and other gases (non-corrosive/non erosive)	10 to 20 m/s (33 to 66 ft/s)
	maximum 60 m/s (200 ft/s) where $\rho v^2 \leq 50\,000 \text{ kg/ms}^2$ is maintained
Saturated steam (dry)	15 to 30 m/s (50 to 100 ft/s)
Superheated steam	30 to 60 m/s (100 to 200 ft/s)
Vacuum pipes	10 to 100 m/s (30 to 330 ft/s)

2. For design of piping systems for Upstream applications where corrosion inhibition is anticipated, refer to Table A.4 of DEP 39.01.10.11-Gen. for velocity limitations to reduce the effect of stripping the inhibitor film from the pipe wall.

3. For the sizing of gas lines, Equation 3 or Equation 4 from ISO 13703/ API RP 14E may be used.

$$V = \frac{131 ZQT}{P d_i^2} \quad \text{Eqn 3}$$

Where:

V = gas velocity specified from the range 10-20m/s

d_i = internal diameter, mm

Q = gas flowrate, m³/h (at 1.01325 bara and temperature of 0 °C)

T = temperature, °K

P = operating pressure, kPa (abs)

Z = compressibility factor

$$V = \frac{60 ZQT}{P d_i^2} \quad \text{Eqn 4}$$

Where:

V = gas-velocity, feet/second

d_i = pipe inside diameter, inches

Q = gas flow rate, million cubic feet/day (at 14.7 psia and temperature of 32 °F).

T = operating temperature, °R

P = operating pressure, psia

2.2.4 Sizing of amine piping systems

1. The mean linear velocities in Table 5 should be used for sizing of amine piping systems:

Table 5 Velocities for sizing amine piping systems

Carbon steel piping	less than 2.2 m/s (7.3 ft/s)
Stainless steel piping	less than 3 m/s (10 ft/s) maximum 4.5 m/s (14.5 ft/s)

Rationale: With the velocity limits mentioned in Table 5, the pv^2 is kept below 5 000 kg/(ms²) for carbon steel and below 20 000 kg/(ms²) for stainless steel.

2.2.5 Sizing of drilling fluid piping systems

The values in (2.2.5, Items 1 through 3) are not applicable to sludge, slurry, erosive fluids or two-phase flow, and the Principal will consult further with the Contractor regarding these services.

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

2.2.6 Sizing of flare and vent systems

1. For sizing of flare and vent systems and relief valve inlet and discharge piping, see DEP 80.45.10.10-Gen.
2. The opening through all pipe and fittings between a pressure vessel and its pressure-relief valve shall have the area of the pressure-relief device inlet.
3. The minimum flow area in the isolation valve shall be equal to or greater than the inlet area of the pressure-relief valve.
4. The design of relief valve inlet and discharge piping and valves shall be implemented such that the requirement in (2.2.6, Item 3) can be met.
5. Flare or vent piping system shall be designed to maintain $pv^2 < 200,000 \text{ kg/ms}^2$.

2.2.7 Two-phase flow

1. The length of piping subject to two-phase flow should be minimised e.g., by locating the control valve close to the downstream equipment.
 - a. Refer to DEP 31.22.05.12-Gen. for distance requirements for piping in separator systems.
2. In cases where two-phase flow cannot be avoided, the flow pattern should be stable i.e., stratified smooth/wavy, annular dispersed, dispersed bubble or mist flow.
3. To determine the two-phase flow pattern, the following steps shall be followed:
 - a. gas Froude number:

$$Fr_G = v_G \sqrt{\rho_G / \{(\rho_L - \rho_G)gd_{fp}\}} \quad \text{Eqn 5}$$

- b. liquid Froude number:

$$Fr_L = v_L \sqrt{\rho_L / \{(\rho_L - \rho_G)gd_{fp}\}} \quad \text{Eqn 6}$$

In the above formulae v_G and v_L are the superficial gas and liquid velocity respectively in the feed pipe and d_{fp} is the inner diameter of the feed pipe.

$$v_G = Q_G / (\pi(d_{fp})^2 / 4) \quad (\text{m/s}) \text{ (ft/s)}$$

$$v_L = Q_L / (\pi(d_{fp})^2 / 4) \quad (\text{m/s}) \text{ (ft/s)}$$

and the averaged liquid density ρ_L is defined as

$$\rho_L = M_L / Q_L \quad (\text{kg/m}^3) \text{ (lb/ft}^3\text{)}$$

For SI units ρ in kg/m^3 , v in m/s , d in m and gravity constant $g=9.81 \text{ m/s}^2$

For US units ρ in lb/ft^3 , v in ft/s , d in ft and gravity constant $g=32.19 \text{ ft/s}^2$.

- c. Refer to Figures A.1 and A.2 (Appendix A) for the flow maps for two-phase flow regimes in a horizontal pipe and vertical pipe (upflow), respectively.

Strictly, the flow maps are only applicable to very long pipes with equilibrium two-phase flow. However, if the feed pipe is longer than ten pipe diameters, the flow maps still give a fair indication of the prevailing flow regime for a given set of conditions.

4. Velocities of 5 m/s (16 ft/s) for horizontal pipe sections and 10 m/s (33 ft/s) for vertical pipe sections should be used for preliminary line sizing.

This implies the use of reducers for transitioning to and from vertical sections. For further guidance, see Section 7.4 of NORSOK Std. P-002.

5. Where two-phase flow is anticipated and the Gas Froude number $Fr_G < 1$ then at least one of the following actions SHALL [PS] be implemented for maximum design flow, normal operating flow, minimum turndown flow and transient (upset) conditions:
 - a. alter the process design conditions such that Gas Froude number $Fr_G \geq 1$;
 - b. design the piping support system to accommodate the reaction forces that result from the two-phase flow.

2.2.8 Wellhead flowlines

1. Flowlines shall be sized in accordance with ISO 13703.

2.3 FINAL PIPE SIZING

2.3.1 General

1. Final pipe sizing calculations shall be documented and subject to review and approval by the Principal.
2. The software and models proposed for final sizing of the piping system shall be subject to the approval of the Principal.

2.3.2 Considerations

1. The following should be considered in determining a suitable pipe size:
 - a. the allowable pressure drop;
 - b. whether pressure surge 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 and unstable flow pattern should 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;
 - l. any additional capacity margin required, as determined by the Design Class.
2. The pipe sizing shall be designed to withstand the design conditions for normal operation and for turndown, transient/peak conditions such as start-up, shut-down and regeneration as appropriate.

2.3.3 Pressure drop calculations

2.3.3.1 General

1. 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.
2. For valves and fittings, refer to Table 6 for values of L_e . Where D = nominal pipe diameter.
 - a. For reducing fittings D = large end nominal diameter and d = small end nominal diameter.

- b. Manufacturer/Supplier's data may be used where more accurate pressure drop calculations are required.
3. Refer to DEP 32.36.01.17-Gen. for the requirements to determine the pressure drop across control valves.
4. The pressure drop of in-line instruments, such as vortex or Coriolis flow meters, shall be determined from the Manufacturer/Supplier's data.
5. For piping components not covered in Table 6, the pressure drop shall be taken from the data obtained from the equipment Manufacturer/Supplier.

Table 6 Valve and fitting equivalent length

Type of valve/fitting			L _e
Valves (fully open)	Ball valve	Reduced bore DN 40 (NPS 1 ½) and smaller	65 D
		Reduced bore DN 50 (NPS 2) and larger	50 D
		Full bore DN 50 (NPS 2) and larger	8 D
	Gate valve	Standard bore	13 D
		Reduced bore DN 40 (NPS 1 ½) and smaller	30 D
	Globe valve	Straight pattern	135 D
		Y pattern	80 D
		Angle pattern	75 D
Fittings	Check valve	Swing type	50 D
		Ball or piston type, DN 40 (NPS 1 ½) and smaller	135 D
	Dual Plate type		75 D
	Plug valve	Regular pattern	60 D
	Butterfly valve	Concentric type	25 D
		Double offset type	55 D
		Triple offset type	60 D
	Tee-equal	Flow straight through	20 D
		Flow through side outlet	65 D
Fittings	Elbow	90°, R = 1 ½ D	20 D
		45°, R = 1 ½ D	16 D
	Bend	90°, R = 4 D	14 D
		90°, R = 5 D	16 D
		180°, R = 4 D	25 D
		180°, R = 5 D	28 D
	Enlargement	Sudden, d/D = 1/4	73 D
		Sudden, d/D = 1/2	47 D
		Sudden, d/D = 3/4	16 D
		Standard reducer, d/D = 1/2	35 D
		Standard reducer, d/D = 3/4	10 D
Fittings	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
	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

2.3.3.2 General equation for pressure drop calculation

The pressure drop for a piping system in metric units is given by Equation 7 or Equation 9:

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

Eqn 7

To convert pressure drop from N/m² into metres of liquid head loss, use Equation 8:

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

Eqn 8

For circular cross-section pipe, use Equation 9:

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

Eqn 9

where:

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

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

$$A = \left\{ 2.457 \ln \left(\frac{1}{\left[\frac{7}{Re} \right]^{0.9} + \frac{0.27\varepsilon}{D_i}} \right) \right\}^{16}$$

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

- 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 Equation 10 or Equation 12: