NORSOK STANDARD P-001

Edition 5, Sep. 2006

Process design

Standards Norway
Strandveien 18, P.O. Box 242
N-1326 Lysaker
NORWAY

Telephone: + 47 67 83 86 00
Fax: + 47 67 83 86 01
Email: petroleum@standard.no
Website: www.standard.no/petroleum

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Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

Introduction

This edition replaces edition 4 from 1999.

Significant changes are made in the following clauses:

- Clause 5 regarding use of instrument based systems for secondary protection replaces the HIPPS (high integrity pressure protection system) clause in edition 4. This clause has been simplified and adapted to governing international standards. However, limitations regarding application of such systems are maintained.
- Clause 6, Table 3: Revised numbers regarding flow capacity in near horizontal pipes.
- Clause 7 regarding isolation principles has been restructured.
- Clause 8 regarding insulation and heat tracing has been simplified to avoid duplication of requirements in NORSOK R-004.

In general, references have been updated to reflect development of international standards.

Requirements specific to drilling systems have been deleted from this NORSOK standard.

1 Scope

This NORSOK standard provides requirements for the following aspects of topside process piping and equipment design on offshore production facilities:

- design pressure and temperature;
- safety instrumented secondary pressure protection systems;
- line sizing;
- system and equipment isolation;
- insulation and heat tracing.

These criteria are applicable for all processes, process support and utility systems.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the referenced standards.

2.1 Normative references

API RP 14 C,	Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms
API RP 520,	Sizing, Selection and Installation of Pressure-Relieving Systems in Refineries
API RP 521,	Guide for Pressure-Relieving and Depressuring SystemsBS MA-18, Salt water piping systems in ships
IEC 61508,	Functional safety of electrical/electronic/programmable electronic safety related systems.
IEC 61511,	Functional safety – Safety instrumented systems for the process industry sector
ISO 10418,	Petroleum and Natural Gas Industries – Offshore Production Installations – Basic Surface Process Safety Systems
NORSOK R-004,	Piping and equipment insulation
NORSOK S-001,	Technical safety
NORSOK S-002,	Working environment

2.2 Informative references

API Std 2000,	Venting Atmospheric and Low-Pressure Storage Tanks
ISO 13703	Petroleum and natural gas industries – Design and installation of piping system on offshore production platforms
OLF GL 070,	Recommended guidelines for the application of IEC 61508 and IEC 61511

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.2

design pressure

pressure, together with the design temperature, used to determine the minimum permissible thickness or physical characteristic of each component as determined by the design rules of the pressure design code

NOTE The design pressure is selected by the user to provide a suitable margin above the most severe pressure expected during normal operation at coincident temperature.

3.1.3
maximum operating pressure
maximum pressure including plant operation at unstable conditions

NOTE Unstable conditions include start-up/shutdown, control requirements and process upsets.

3.1.4
maximum operating temperature
maximum temperature including plant operation at unstable conditions

NOTE Unstable conditions include start-up/shutdown, control requirements and process upsets.

3.1.5
may
verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.6
minimum operating temperature
minimum temperature including plant operation at unstable conditions

NOTE Unstable conditions include start-up, shutdown and depressurizing.

3.1.7
operating pressure
pressure during normal operation, including normal variations

3.1.8
operating temperature
temperature during normal operation, including normal variations

3.1.9
settle out pressure
pressure equilibrium after a compressor shutdown

3.1.10
shall
verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.11
should
verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred, but not necessarily required

3.1.12
shut-in pressure
pressure for pumps and compressors determined by the curves for a “no flow” situation, i.e. blocked outlet

3.2 Abbreviations

CS	carbon steel
FB	full bore
GRP	glass fibre reinforced polyester
ID	internal diameter
LO	locked open
NPSH	net positive suction head
PSV	pressure safety valve
SS	stainless steel

4 Design pressure and temperature

4.1 General

Where pressure relief devices are used, set points for these shall be in accordance with the design code applied for the components in the system.

4.2 Design pressure

4.2.1 Maximum design pressure

For systems protected by a PSV, the criteria in Table 1 shall be applied unless the PSV manufacturer guarantees that use of other margins is acceptable. The minimum margin is defined to avoid unintentional PSV opening. The relation between high trip pressure and maximum operating pressure is given in Figure 1.

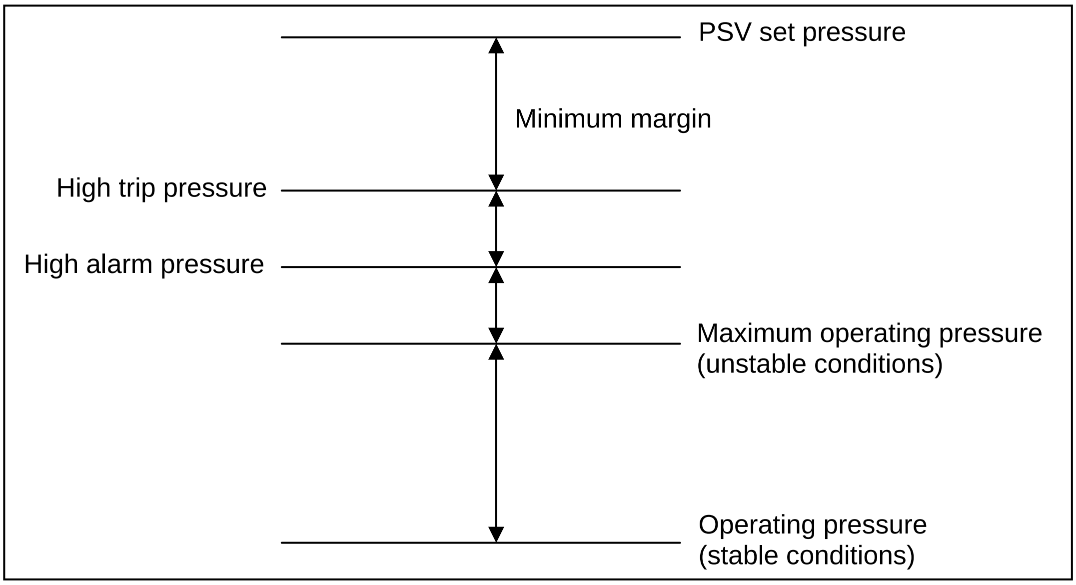


Figure 1 - Pressure relations

Table 1 - Design pressure criteria for pressurised systems

High trip pressure (1),(2) barg	**Minimum margin between high trip pressure (1),(2) and PSV set pressure** bar
0 to 35	3,5
over 35	10 % of PSV set pressure

(1) For systems without a high pressure trip, the minimum margin shall be applied between the maximum operating pressure and the PSV set pressure.
(2) Maximum operating pressure for compressor suction scrubbers and coolers shall be the maximum settle-out pressure, calculated from coincident high trip pressures on both suction and discharge sides of the compressor, and the minimum margin shall be applied between the maximum operating pressure and the PSV set pressure.

When rupture disks are applied, sufficient margin shall be included to

- prevent unintentional disk ruptures, i.e. margin between the disk set pressure and the operating pressure,
- ensure system pressure protection, i.e. margin between the disk set pressure and the maximum accumulated overpressure.

Reference is made to relevant pressure relieving design codes for further guidance.

When accurate information is unavailable, the shut-in pressure for centrifugal compressors should be determined as the maximum operating suction pressure +1,3 times the normal differential pressure developed by the compressor, to include for pressure rise at surge condition and maximum speed. The maximum operating suction pressure for a compressor shall in this case be determined by the high trip pressure from upstream separators or compressors.

When accurate information is unavailable, the maximum operating pressure (shut-in pressure) for centrifugal pumps should be determined as the suction pressure at relieving conditions +1,25 times the normal differential pressure developed by the pump

Care should be taken not to define higher design pressure than required when it affects the selection of material and pressure class rating.

To minimise the requirements for process relief (full flow) the design pressure should be kept identical for systems with almost identical operating pressures.

For piping, occasional variations in the pressure above the design pressure is permissible in some design codes. This shall be subject to due consideration of all aspects in the relevant piping design code. If such variations are permitted by the project owner, the duration and extent of overpressure that the piping is subjected to, shall be logged. Logging is not considered required when it is evident that overpressure will not occur more frequently than allowed by the piping code.

Atmospheric tanks shall as a minimum be designed to be liquid filled to the highest point of the overflow line, and with an overpressure of 0,07 bar. If the overflow line can be blocked or have reversed flow (e.g. during loading) the atmospheric tank shall be designed for a liquid filled vent line up to the goose neck. Reference is made to API Std 2000 for further guidance.

For flare knock out drums, it is acceptable that the design pressure is equal to the maximum operating pressure. A safety margin shall be added to the maximum operating pressure in the design phase to account for increase due to uncertainties in the calculations. When accurate information is unavailable, Table 1 shall be used to set the safety margin.

4.2.2 Minimum design pressure

For equipment where cooling or condensing vapours (e.g. after steam-out of vessels), drainage or pump out may lead to less than atmospheric pressure, the equipment shall be designed for full vacuum or protected by vacuum relief. Reference is made to API RP 521 for further guidance.

4.3 Design temperature

4.3.1 Maximum design temperature

4.3.1.1 General

Where the maximum operating temperature can be determined accurately, this temperature should be used as maximum design temperature, without adding a safety margin. As an example, this can apply to the use of reservoir temperature as maximum design temperature for platform inlet facilities.

Where the maximum operating temperature can not be calculated accurately, the maximum design temperature should be determined by adding 30 °C to the operating temperature. For equipment operating at ambient conditions, the maximum design temperature should be 50 °C for the North Sea.

A high temperature shut down function, in accordance with ISO 10418 or API RP 14C, can limit the maximum operating temperature. A margin should be included to determine the design temperature.

Care should be taken not to define higher design temperature than required when it affects the selection of material and pressure class rating.

Vessels and instruments subject to steam-out shall be designed for temperature during steam-out operation.

4.3.1.2 Sea water systems

For sea water supply systems a maximum design temperature less than 50 °C can be accepted if documented by calculations.

For seawater return systems the maximum operating temperature shall be calculated at the minimum seawater flow. Minimum seawater flow is calculated at lowest seawater supply temperature and heat exchanger without fouling.

4.3.1.3 Compressor systems

The maximum operating temperature on a compressor discharge shall be determined as follows:

- when a compressor curve is not available: as 15 °C above the predicted design point temperature to allow for lower efficiency and higher pressure ratio at compressor surge conditions;
- when compressor curves are available: as the temperature at surge conditions and maximum compressor speed for normal and start up cases.

The following shall be used to determine the maximum design temperature:

- add 15 °C to the maximum operating temperature to allow for margins in the compressor curves, and for wear and tear giving lower efficiency over time;
- add 10 °C as an additional margin.

4.3.1.4 Compressor suction scrubber

Compressor suction scrubber maximum design temperatures shall be the higher of the following:

- maximum operating temperature at the compressor suction in the event of cooling medium failure, the maximum operating temperature can be limited by a high temperature shutdown function on the compressor suction or discharge;
- maximum recycle temperature (maximum discharge (temperature trip) minus temperature drop across anti-surge valve) in the event of cooling medium failure;
- maximum temperature due to settle out conditions;
- operating temperature plus a margin as defined in 4.3.1.1.

4.3.1.5 Heat exchangers

For all heat exchangers, both sides shall have the same maximum design temperature determined by the hottest of the fluids on either side. For upset conditions, overpressure of connected piping at resulting upset temperature may be acceptable if permitted by relevant piping design code, see 4.2.

4.3.2 Minimum design temperature

The minimum design temperature determines the requirements to the low temperature characteristics of the material, and shall be the more stringent of the following:

- minimum operating temperature (obtained during normal operation, start-up, shutdown or process upsets) with a margin of 5 °C;
- minimum ambient temperature, the lowest temperature should be based on available weather data, and safety factors should be selected based on the quality of such weather data;
- minimum temperature occurring during depressurising with a margin of 5 ºC, the temperature calculations shall as a minimum include heat transfer between fluid and vessel, and the most conservative starting conditions for depressurising shall be used including the following considerations as a minimum:
  - cool down to minimum ambient temperature after shut-in at PSV set pressure and corresponding temperature (including reduction in pressure during cool down);
  - conditions during a start-up operation following a depressurisation;
  - minimum operating temperature and maximum operating pressure.

The minimum design temperature may be limited by initiating depressurisation at a higher temperature than the minimum ambient temperature. If implemented, this shall be subject to project owner approval, and be addressed in documentation for operation.

The minimum design temperature may be limited by delaying start-up (to heat the system prior to start-up). If implemented, this shall be subject to project owner approval, and be addressed in documentation for operation.

5 Safety instrumented secondary pressure protection systems

5.1 General

Mechanically based pressure protection systems (e.g. PSV) shall be the preferred solution for secondary pressure protection.

Use of safety instrumented secondary pressure protection systems shall be based on acceptance criteria for overall system integrity, and shall be limited to the following applications:

- as a replacement for PSVs to protect pipelines against overpressure. The pressure specification break shall be downstream the pipeline riser valve. Where leakage or other flow from upstream system through valves in the safety instrumented system may be crucial to the integrity of the downstream system, a PSV shall be installed to prevent overpressure. The valve leakage rate shall be based on relevant experience and consideration of valve damage scenarios;
- to reduce the relief design rate by avoiding simultaneous flaring from parallel equipment/equipment trains. The safety instrumented system is for pressure protection of the flare system only;
- to reduce the relief design rate for process equipment and piping where multiple feeds (each with instrument loops to protect the equipment by shutting off the feed) enter the same equipment. Overpressure protection of the equipment/piping is then dependent of the safety instrumented system.

The relief design rate shall as a minimum be based on instrument loop failure for the largest feed. However, acceptance criteria for overall system integrity may require more failures to be included. This relief rate shall be accommodated within the flare system design pressure. Similarly, flare radiation for this relief rate shall meet the radiation criteria in API RP 521.

Acceptance criteria for frequency of rupture of the protected equipment and piping (i.e. due to pressure exceeding test pressure) as defined in NORSOK S-001 shall be applied.

Safety instrumented secondary pressure protection systems shall be designed in accordance with IEC 61508 and IEC 61511. OLF GL 070 can be used as a guidance in the application of these standards.

Special consideration shall be given to the design of the safety instrumented system due to the potential for erosion problems, hydrate formation, fluid viscosity, wax content etc. Common mode failures (e.g. loss of heat tracing), shall be considered.

The design pressures shall allow for "water hammering" effects caused by valve closure, in particular for liquid service.

5.2 Testing

Safety instrumented secondary pressure protection systems shall be functionally tested to reveal hidden failures to maintain the required safety reliability as defined by IEC 61508 and IEC 61511. The required test frequency shall be established, and the following shall apply:

- a system that requires testing more frequent than every third month to achieve the required reliability, is not considered to be sufficiently robust;
- to ensure that system functionality is maintained, the test frequency shall be equal or higher than once a year.

Where leakage or other flow from upstream system through valves in the safety instrumented system may be crucial to the integrity of the downstream system, the valve leakage rate shall be tested annually.

A high system regularity requirement may dictate the need for parallel systems to enable testing without affecting the plant production.

6 Line sizing criteria

6.1 General

When sizing piping, the following constraints shall be addressed:

- required capacity/available driving pressure;
- flow induced forces;
- noise/vibration;
- pressure surges;
- material degradation - erosion, corrosion, cavitation;
- liquid accumulation/slug flow;
- sand accumulation.

Line sizing criteria in the sub clauses below shall be adhered to for design of new installations. For modification of existing installations, additional considerations shall be given to life cycle cost, and increased velocity and/or pressure drop may be accepted if mechanical integrity can be documented, e.g. ρV^2 > 200 000 kg/ms^2 for a line in the flare system.

In general, sizing of lines should be in accordance with ISO 13703.

Permissible pipe sizes
A minimum size of DN 50 (2 in) should in general be used for all process, process support and utility piping to ensure adequate mechanical integrity. Smaller piping can be used where protection and/or support is provided to withstand human activity.

Minimum size for the sewage and open drain header shall be DN 100 (4 in) and sub-headers DN 80 (3 in). Overflow from atmospheric tanks shall as a minimum be equal to the largest inlet pipe.

Tubing may be used for air, hydraulic oil and other non-combustible/non-hazardous fluids.

Pipe roughness
For all calculations of pressure drop, the following pipe roughness values should be used:

Carbon steel (CS) non-corroded:	0,05 mm
Carbon steel (CS) corroded:	0,5 mm
Stainless steel (SS):	0,05 mm
Titanium and Cu-Ni:	0,05 mm
Glassfiber reinforced polyester (GRP):	0,02 mm
Polyethylene, PVC:	0,005 mm
Flexible hose	vendor to be consulted (see NOTE)

NOTE As a rough estimation, ID/20 mm can be used (ID is the internal diameter in inches) for steel carcass and 0,005 mm for plastic coating.

6.2 Sizing of liquid lines

6.2.1 Velocity limitations

The velocities shall in general be kept low enough to prevent problems with erosion, water-hammer pressure surges, noise, vibration and reaction forces. In some cases a minimum velocity is required.

Table 2 – Recommended maximum velocities for sizing of liquid lines

Fluid	Maximum velocities (m/s)			
	CS	SS/Titanium	CuNi [c]	GRP
Liquids	6	[b]	3	6
Liquids with sand [d]	5	7	NA	6
Liquids with large quantities of mud or silt [d]	4	4	NA	NA
Untreated seawater [a]	3	7	3	6
Deoxygenated seawater	6	[b]	3	6

[a] For pipe less than DN 200 (8 in), see BS MA-18 for maximum velocity limitations.
[b] For stainless steels and titanium the maximum velocity is limited by system design (available pressure drop/reaction forces). 7 m/s may be used as a typical starting value for sizing.
[c] Minimum velocity for CuNi is 1,0 m/s.
[d] Minimum velocity for liquids with sand should be in accordance with ISO 13703.

When the service is intermittent, the velocity can be increased to 10 m/s. For CuNi the maximum velocity is 6 m/s to 10 m/s depending duration and frequency of operation.

6.2.2 Centrifugal pump suction and discharge lines

The suction piping shall be sized based on NPSH requirements. Maximum velocity from Table 2 and the following maximum pressure drops should be used:

Sub-cooled liquids: 0,25 bar/100 m (see NOTE)
Boiling liquids: 0,05 bar/100 m

The fluid temperature shall be at least 15 °C below the fluid boiling point temperature to allow sizing based on the criterion for sub-cooled liquids.

The maximum velocity in the discharge piping is given in Table 2. As a guideline, a pressure drop of up to 0,9 bar/100 m may be used.

6.2.3 Reciprocation pump suction and discharge lines

For reciprocating pumps, the piping shall be sized based on ISO 13703, 5.3.2.

6.2.4 Control valve inlet lines

Control valve inlet lines shall be sized such that single phase liquid is maintained.

6.2.5 Liquid flowing by gravity

Lines flowing by gravity includes tank overflows, drains (sanitary, closed and open drains), and other lines where the liquid flows due to gravity forces instead of pressure difference. Generally, for fixed installations**,** a minimum downward slope of 1:100 shall be used. However, with mud and/or sand, the slope shall be at least 1:50. On floating installations the slopes shall be evaluated according to planned installation trim.

Pipes that are running full, and do not require a minimum downward slope to avoid particle deposition, shall be sized according to the total available static pressure head, and the maximum allowable velocities for liquid lines.

Near horizontal lines

Near horizontal pipes not running full shall be sized based on the maximum flow capacities as given in Table 3.

Table 3 - Flow capacity - Near horizontal pipes

Diameter mm (in)	**Liquid flow capacity (see NOTE)** m^3/h	
	Slope 1:50	Slope 1:100
50 (2)	3,7	2,6
100 (4)	24	17
150 (6)	70	49
200 (8)	150	106
250 (10)	271	192
300 (12)	441	312
350 (14)	665	471
400 (16)	950	672

NOTE According to the Manning formula (see Finnemore and Franzini, "Fluid Mechanics with Engineering Applications", McGraw-Hill, New York, 10. ed. 2002) a pipe "filling degree" of 75 % is assumed.

The liquid in the entrance part of a near horizontal pipe normally need some acceleration distance to reach fully established velocity. To reduce the entrance pressure loss, the inlet section should have increased diameter compared to Table 3. For the first ten pipe diameter length, the next larger pipe diameter in Table 3 should be selected ending with an eccentric reducer.

Vertical lines

Vertical gravity lines with or without submerged outlets (e.g. so-called "dump caissons") shall be designed such that the Froude number is less than 0,3. This is to avoid air entrainment and ensure undisturbed flow without pulsations.

$$\text{Froude number} = \frac{V}{\sqrt{D \times g}} \quad (1)$$

where
V is the velocity assuming full pipe in m/s
D is the pipe inner diameter in m
g is the gravity constant in m/s^2

A vent line shall be included from top of the vertical gravity line to prevent vacuum, flashing or pulsations. The vent line should be designed for an air/vapour volumetric flow-rate equal to the liquid volumetric flow through the vertical line and a pressure loss of maximum 0,005 bar. The vent line for vertical lines/caissons to sea, shall also be designed for the wave motion inside lines/caisson.

The liquid inlet to the "dump caissons" should be tangential and sloped downwards.

Drainage of deluge water from drain boxes through vertical lines shall be sized on basis of 50 % of the available head (assuming the pipe running full of liquid) and not Froude number. The following formulas can be used to determine the capacity:

$$Q = \frac{8855{,}8 \times D^{2,5}}{\sqrt{f}} \quad (2)$$

where
Q is the flow in m^3/h
f is the Moody friction factor
D is the pipe inner diameter in m

The Moody friction factor for fully turbulent flow can be calculated by the Nikuradse formula, given by:

$$f = \frac{1}{\left[2\log(\frac{D}{2k}) + 1.74\right]^2} \quad (3)$$

where the pipe diameter D and pipe roughness k shall be given in the same units.

The flow formula is based on setting 50 % of the available head equal to the piping friction loss i.e.

$$\rho \times g \times 0,5 \times L = \frac{f \times L \times \rho \times V^2}{D \times 2} \quad (4)$$

where
ρ is the density in kg/m^3
L is the pipe length in m
V is the velocity in m/s
g is the gravity constant in m/s^2

6.2.6 Fire water

The line sizing of fire water lines shall be based on available system pressure and allowable flow velocities.

The pressure drop to the large deluge systems shall be calculated on basis of the most unfavourable pipe routing to those systems.

In the ring main pipe-work the flow velocity shall not exceed the velocity as given in Table 2. Upstream the deluge skids, the flow velocities should not exceed 10 m/s. Some areas may require velocities higher than 10 m/s in order to hydraulically balance the systems, which is acceptable provided the reaction force within the system does not cause excessive stress in the pipe work or the supports.

6.2.7 Oily water systems

Where retaining the size of oil droplets in the water is crucial, this can be achieved by providing low flow velocities. Typically the velocity should not exceed 3 m/s. This should also be considered in selection of fittings and instruments in these lines to avoid shearing of oil droplets.

6.3 Sizing of gas lines

6.3.1 General

When sizing gas lines the sizing criteria will be a compromise between the maximum velocity (see 6.3.2) and allowable pressure drop, see 6.3.3.

Piping with gas at the dew-point and/or with some droplets shall be designed as gas lines.

6.3.2 Maximum velocities

In lines where pressure drop is not critical, gas velocity shall not exceed limits which may create noise or vibrations problems. As a rule of thumb the velocity should be kept below:

$$V = 175 \times \left(\frac{1}{\rho}\right)^{0,43} \quad (4)$$

where
V is the maximum velocity of gas to avoid noise in m/s
ρ is the density of gas in kg/m^3

or 60 m/s, whichever is lowest.

In order to avoid excessive dispersion of noise in lines connected to pressure control valves, the valve manufacturer shall be consulted.

For anti-surge lines, the constant 175 in the formula (4) may be replaced with 200 during process upsets, if the noise level is acceptable. However, during normal recycle, the velocity should be limited to the velocity as given by the formula (4).

If solid particles exist, special attention shall be given to particle erosion.

6.3.3 Recommended pressure drop

Where pressure drop is critical (e.g. when it results in unacceptable liquid drop out in suction lines between scrubber and compressor suction, inlet lines to turbo expanders and contactors etc.), the guidelines in Table 4 should be used. The pressure drop should be prorated between the operating pressures given.

Table 4 – Recommended pressure drop for single phase gas process lines

Operating pressure (barg)	**Pressure drop** (bar/100 m)
0 to 35	0,001 to 0,11
35 to 138	0,11 to 0,27
over 138	P/500 [a]
[a] P is operating pressure in bara.	

6.4 Sizing of gas/liquid two-/multiphase lines

Wellhead flow-lines, production manifolds, process headers and other lines made of steel and transporting two-phase or multiphase flow, have a velocity limitation. When determining the maximum allowable velocity, factors such as piping geometry, well-stream composition, sand particle (or proppant) contamination and the material choice for the line shall be considered.

As a guideline, the maximum allowable velocity can be calculated by:

$$V = 183 \times \left(\frac{1}{\rho_{mix}} \right)^{0,5} \quad (5)$$

where
V is the maximum velocity of mixture in m/s
ρ_{mix} is the density of mixture in kg/m^3

When sizing two- or multiphase lines, unstable flow and slugging shall be considered. The number and length of multiphase lines should be kept to a minimum where possible.

Non corrosive service
For non corrosive well-stream and for corrosion resistant pipe materials the velocity should be limited to maximum 25 m/s if the well-stream includes only small amounts of sand or proppants (typical less than 30 mg sand/liter in the mixed flow).

Corrosive service
For carbon steel piping systems the corrosion rate often limits the life time. With increased flow velocity the corrosion rate tend to increase due to increased shear forces and increased mass transfer.
The flow velocity should be restricted to maximum 10 m/s to limit the erosion of the protective layer of corrosion products and reduce the risk for a corrosion inhibitor film break down.

Particle erosion in non corrosive service
For well-stream contaminated with particles the maximum allowable velocity shall be calculated based on sand concentration, piping geometry (bend radius, restrictions) pipe size and added erosion allowance.

For the calculation of maximum velocity and life time specialised computer programmes are available and should be employed.

If the available pressure drop allows, the velocity shall in general be sufficiently high to ensure homogeneous flow. This prevents un-stabilities due to liquid accumulations, and it allows simple pressure drop calculations. If lower velocities are required due to limited available pressure drop or at turndown situations, problems with slugging and/or liquid accumulation in the lines shall be considered.

6.5 Sizing of flare and vent lines

6.5.1 General

In general, all flare lines shall be designed to keep the ρV^2 < 200 000 kg/ms^2 criteria (where ρ is the fluid density or mixed density for two phase conditions in kg/m^3 and V is the velocity in m/s).

Further, the selection of piping specification shall consider the effect of acoustic fatigue, which is affected by factors such as

- relative differential pressure in upstream restriction device,
- temperature in the flowing gas,
- mole weight of flowing gas,
- pipe diameter and wall thickness,
- mass flow rate.

6.5.2 Flare headers and sub-headers

Piping for flare and sub-headers shall be designed for a maximum velocity of Mach 0,6.

6.5.3 Pressure safety valve lines

The upstream and downstream line shall be sized according to requirements in the relevant pressure relieving design code.

Maximum flowing velocity in the lines downstream of the PSVs to the first sub-header, shall in general be less than Mach 0,7. For the PSVs where the outlet velocity is higher, a reducer should be installed as close as possible to the PSV to increase line size and hence limit the velocity to maximum Mach 0,7 downstream of the reducer. Nevertheless, the actual back pressure at the PSV outlet and in the block valve shall be checked to be consistent with back pressure limitations.

6.5.4 Controlled flaring lines

Flaring lines downstream of control valves shall be designed for a maximum velocity of Mach 0,5.

6.5.5 Depressurisation lines

The maximum flowing velocity in the lines downstream the reducer shall be Mach 0,7.

The pressure loss shall not impose any restrictions on the depressurisation objectives.

6.5.6 Relief lines with slug/plug flow

For potential slug/plug flow, line sizing shall be based on slug velocity and slug density. These slug characteristics shall form the basis for stress calculations and design of piping support.

6.5.7 Vent lines

Maximum backpressure shall be 0,07 barg.

7 Detailed requirements for systems and equipment

7.1 System and equipment isolation

7.1.1 General

It shall be possible to isolate equipment, instrumentation, valves and process sections during maintenance work to obtain safe working conditions for the maintenance personnel.

The minimum isolation level required shall be thoroughly considered for all systems where intervention during operation can be required. This consideration shall be based on the risk associated with the intervention operation, including

- requirement for equipment entry during operation,
- fluid category (level of hazard involved, e.g. flammability, toxicity),
- operating pressure and temperature,
- pipe dimension and system volume,
- duration of operation,
- frequency of operation.

Specific criteria for selection of isolation level shall be provided by project owner. The type of valves selected for isolation purposes shall be based on a thorough evaluation of requirements and inherent valve characteristics.

7.1.2 Physical separation

This is the highest standard of isolation and is accomplished through one of the following arrangements to prevent seepage of any fluid:

- spectacle blind;
- spade and spacer;
- spool piece to be removed and blinding off the open pipe end.

It normally requires an initial isolation (see 7.1.3) to be in place in order to install a physical separation.

When sandwich type butterfly valves are used, an additional flange shall be provided between the valve and the spool piece to allow for spool removal without disturbing the butterfly valve.

All vessels that can be entered shall be equipped with physical separation on all nozzles (including PSV nozzles), except for nozzles not permanently connected to any system. Physical separation shall be located as close to the vessel as practical, normally directly on the nozzle. For level instruments, physical separation may be combined and shall then be located on the common closed drain connection.

Spool pieces shall be used when necessary for maintenance purposes. After removal of spool piece, a blind can be installed to achieve physical separation. This requirement applies for pumps, compressors and heat exchangers.

7.1.3 Level of isolation

7.1.3.1 General

The order of the isolation levels listed below reflects the standard of isolation with the highest standard of isolation listed first.

To achieve double block and bleed isolation, a single valve is acceptable only if the force acting on the seal faces is independent of system pressure, and if a bleed connection is provided between the two seal faces (typically a double expanding gate valve). Further, such a valve shall have means to keep the valve in closed position to avoid malfunction or mal-operation.

7.1.3.2 Physical separation with double block and bleed

This is the highest standard of isolation and provides a valved barrier by closing two block valves in series and using a bleed point in between to prove isolation point integrity. The double block and bleed arrangement provides the initial isolation to install the physical separation, see Figure A.1.

During installation or removal of the physical separation it shall be possible to bleed down the trapped pressure by a valve.

7.1.3.3 Physical separation with single block and bleed

A single block isolation provides a valved barrier by closing a single block valve. The single block arrangement provides the initial isolation to install the physical separation. There shall be possibilities for testing the isolation point integrity by bleeding off the pressure and monitoring the pressure at the point to be isolated, see Figure A.2.

7.1.3.4 Double block and bleed

A double block and bleed isolation provides a valved barrier by closing two block valves in series and using a bleed point in between to prove isolation point integrity as shown in Figure A.3.

7.1.3.5 Double block

Double block isolation provides a valved barrier by closing two block valves in series. There shall be possibilities for testing the integrity of the barrier by bleeding off the pressure and monitoring the pressure at the point to be isolated, see Figure A.4.

7.1.3.6 Single block

A single block isolation provides a valved barrier by closing a single block valve. There shall be possibilities for testing the integrity of the barrier by bleeding off the pressure and monitoring the pressure at the point to be isolated, see Figure A.5.

7.1.4 Redundant train/process section

For equipment and valves located within a redundant train/process section that can be isolated, the means for isolation/physical separation for the train/process section can be used.

7.2 Connections to flare, vents and closed drains

7.2.1 Connections to flare

The following requirements apply:

a) Arrangement and location of PSVs and rupture discs shall be in accordance with the relevant pressure relieving design code. and the corresponding mechanical design code. Where a spare PSV is installed, the block valves shall have an interlocking system to ensure availability of PSVs and correct sequence for opening/closing the block valves.
b) The blow down valves shall be located at high points in the piping system.
c) Blow down shall be arranged with one blow down valve and an orifice. Blow down valve shall have isolation towards downstream flare system to allow maintenance and functional testing of blow down valve (i.e. opening of valve) without flaring, see Figure A.6a and Figure A.6b.
d) Manual blow down to flare for maintenance purposes requires throttle valve and block valve, see Figure A.7, alternatively orifice and block valve.
e) For blow down lines, design shall take into account low temperature upstream the orifice resulting from temperature creep-back.
f) For blow down lines, if there is a potential for solidification in upstream or downstream lines, adequate heat tracing or insulation shall be provided.

7.2.2 Connections to vent

The following requirements apply:

a) Atmospheric vents discharging from hazardous sources shall be routed to the atmospheric vent system or another safe location.The hazardous open drain tank(s) should not be connected to the atmospheric vent system. In general, when combining hazardous sources in a common vent system, backflow to open tanks shall be prevented.

b) Atmospheric vents discharging from non-hazardous sources shall be routed to atmosphere and not connected to the atmospheric vent system.
c) For venting to atmosphere during maintenance, a vent valve and blind, alternatively a permanent connection to a common vent system, shall be included. For permanent connections to a common vent system, precautions shall be taken to avoid excess pressure in the system and equipment connected to it, by installing a block valve and an orifice, see Figure A.8. The orifice shall be sized to protect the downstream system in case of accidental opening of the block valve at operating pressure.

7.2.3 Connections to drain

The following requirements apply:

a) Connections to the closed drain system from equipment and piping shall be as shown in Figure A.9.
b) The drain pipe down to the T-piece connection on the header and/or an increase in pipe dimension, should be designed for the same pressure as the system to be drained. Pressure testing of this drain pipe downstream the valve arrangement may be performed in accordance with the pressure testing requirements for the downstream closed drain system.
c) Level instrumentation shall be permanently connected to the drain system where instrument flushing is required. In this case the blind can be left open during normal operation.

7.2.4 Operational drain, vent and flushing requirements

The following requirements apply:

a) All equipment and piping shall be provided with high point vents and low point drains within isolation valves isolating equipment or process sections. All such vents and drains shall be fitted with valve and blind flange. For piping and headers low point drain and high point vent shall in general be provided. However, for systems without free liquid even at standstill or blow down, this is not required. Testing and mechanical completion may require additional drains and vents.
b) Steam-out and utility connections shall be provided and located to ensure efficient flushing and cleaning required for inspection and maintenance.
c) Where provisions shall be made for chemical cleaning of heat exchangers with the tube bundle in place, blind flange connections shall be provided for chemical hose attachments. The connections shall be minimum DN 80 (3 in), but not exceeding line size, and shall be located between the exchanger nozzles and the block valves.

8 Insulation and heat tracing of piping and equipment

8.1 General

Due to corrosion under insulation being a general problem, the philosophy shall be to avoid insulation, where possible. Appropriate coating systems shall be selected to minimise this problem.

The insulation and heat tracing requirements shall be determined with due consideration to safety aspects as well as to process aspects and with the objective to minimise life cycle cost. All operating modes shall be considered.

The insulation classes and detailed requirements for application of insulation are given in NORSOK R-004, NORSOK S-001 and NORSOK S-002, and 8.2.

8.2 Heat conservation and frost protection

Heat tracing shall be applied where there is a potential for hydrate formation or other solidification, for the following functions:

- upstream pressure safety relief devices and blow down valves;
- for process and safety instrumentation, including instrument connections and impulse lines.

The heat tracing shall be specified to maintain temperature above the hydrate formation/solidification temperature with a minimum margin of 5 °C.

Heat tracing shall be applied to prevent unacceptable increase in liquid viscosities.

The need for insulation and heat tracing of "dead legs" shall be based on factors such as operating temperature, distance from main pipe, piping dimension of "dead leg" and ambient conditions.

No winterization is required for water lines (sea water, fresh water, produced water and completion fluid) where continuous flow is assured or the system is self draining when shutdown.

Maintaining the water flows listed in Table 5 is generally sufficient to avoid freezing in lines up to 50 m length for a minimum ambient temperature of -10 °C. The flow-rate should be increased pro rata with the exposed length for lengths over 50 m.

Table 5 - Minimum water flow to avoid freezing

Nominal line size in	**Minimum volumetric flow-rate** m^3/h
below 3	0,02
3 and above	0,10

For equipment and lines where stagnant conditions cannot be avoided, the time to freezing shall be calculated based on local weather conditions. The time to freezing will then determine the need for insulation, heat tracing or system drainage.

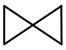
For insulation and heat tracing of sea water lines at ambient temperatures down to –10 °C, Table 6 can be used. For other liquids and ambient conditions, criteria for insulation and heat tracing shall be determined specifically.

Table 6 - Insulation and heat tracing for sea water lines with stagnant conditions

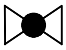
Nominal line size in	**Action**
below 3	Heat trace and insulate
3 to 10	Insulate
above 10	No winterization

Annex A
(Normative)
Figures

Legend:

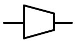
 GENERAL BLOCK VALVE OPEN

 GENERAL BLOCK VALVE CLOSED

 THROTTLE VALVE, NORMALLY CLOSED

 ORIFICE

 PHYSICAL ISOLATION

 REDUCER

SPEC. BREAK = Pressure specification break

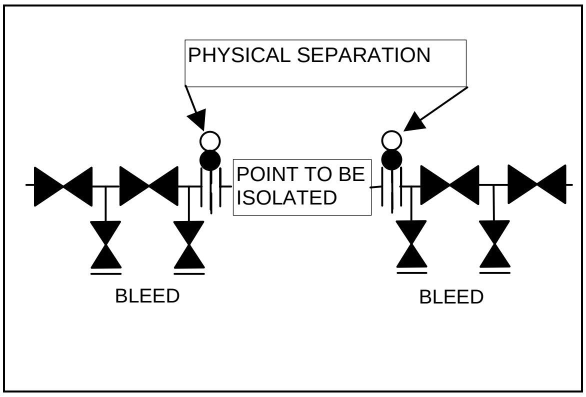


Figure A.1 - Physical separation with double block and bleed

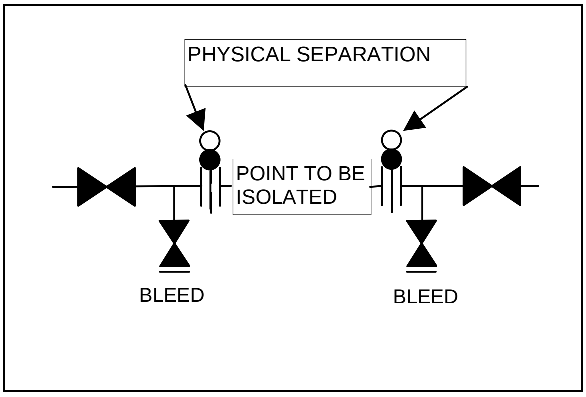


Figure A.2 - Physical separation with single block and bleed

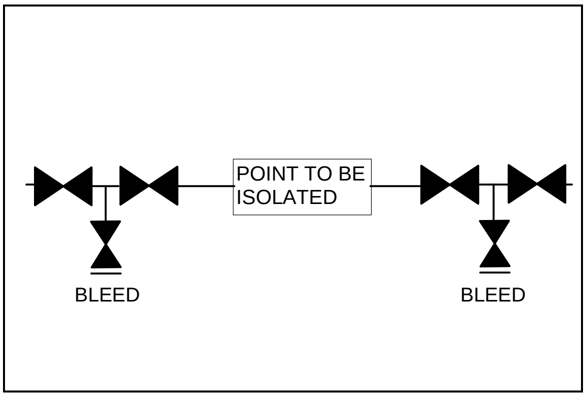


Figure A.3 - Double block and bleed

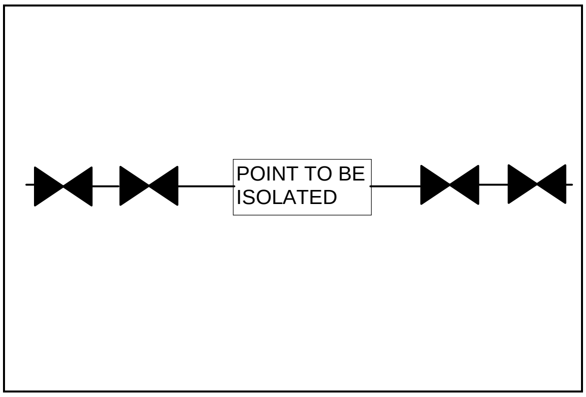


Figure A.4 - Double block

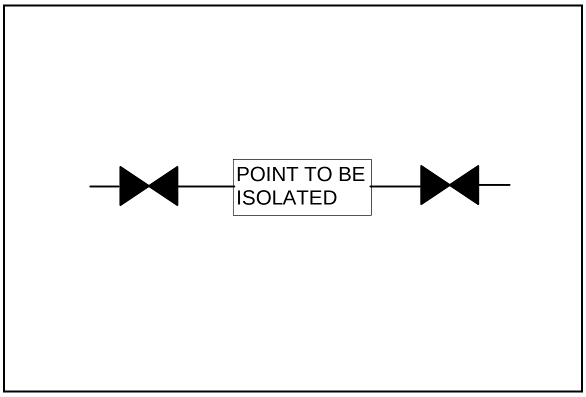


Figure A.5 - Single block

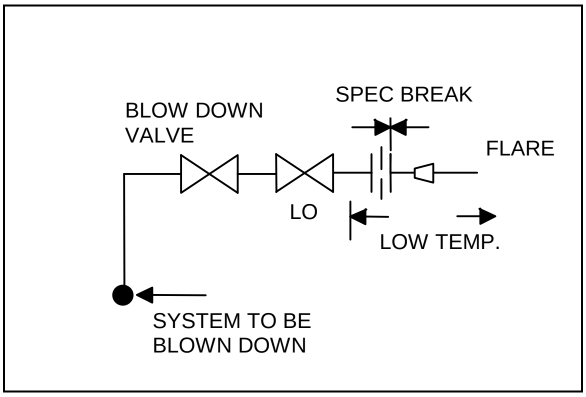


Figure A.6a - Blow down valve arrangement where the orifice can be inspected when the flare is shut down

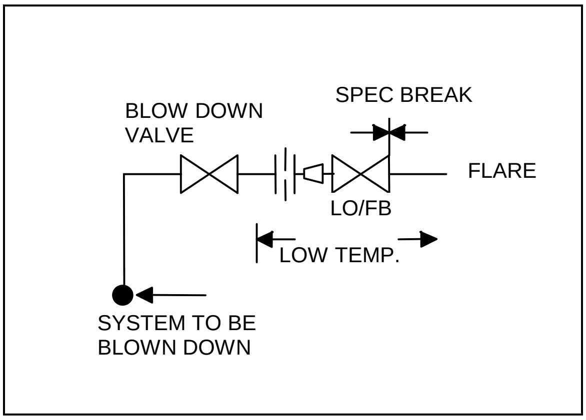


Figure A.6b - Blow down valve arrangement where the orifice can be inspected when the flare is in operation

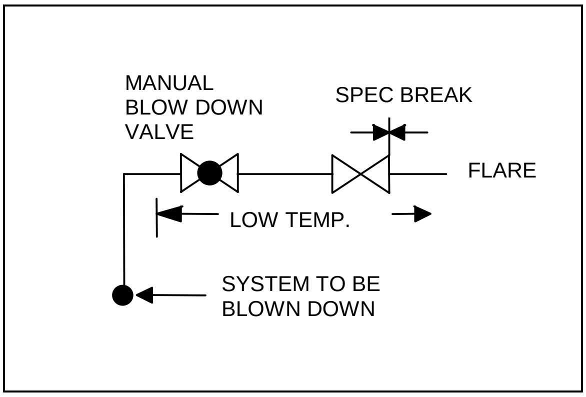


Figure A.7 - Manual blow down for maintenance purposes

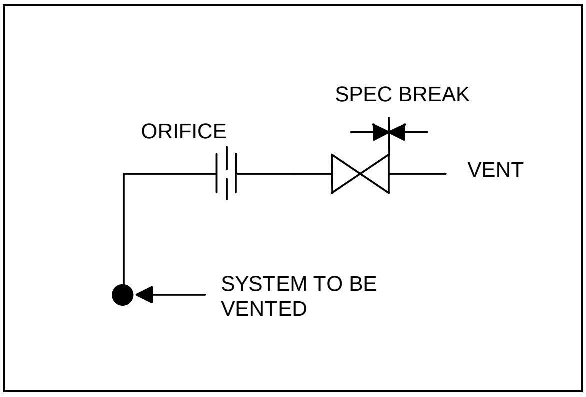


Figure A.8 - Connection to a common vent system

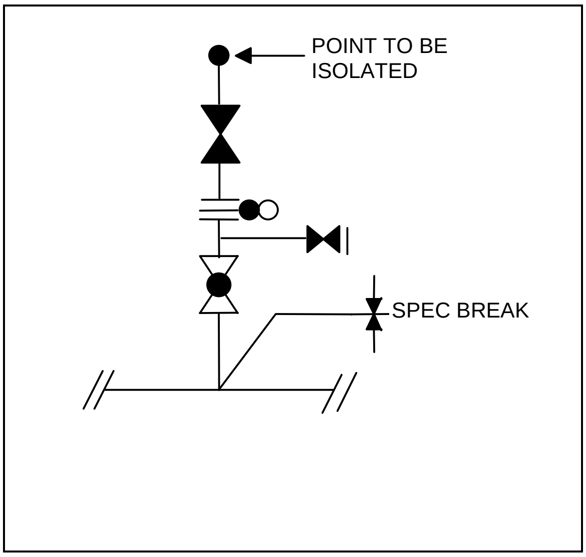


Figure A.9 - Double block for connection to closed drains

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