NORSOK STANDARD

PROCESS DESIGN

P-001
Rev. 3, November 1997

CONTENTS

FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and remove unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and are jointly issued by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered by NTS (Norwegian Technology Standards Institution).

The purpose of this industry standard is to replace the individual oil company specifications for use in existing and future petroleum industry developments, subject to the individual company's review and application.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of this standard will be used to provide input to the international standardization process. Subject to implementation into international standards, this NORSOK standard will be withdrawn.

Annex A is normative.

INTRODUCTION

This standard replaces P-CR-001, rev. 2, September 1996 and includes some revisions marked with a vertical line in the margin.

The following changes has been made in revision 3:
- Chapter 4 and 5 have been renumbered due to relocation of some of the clauses.
- HIPPS have been added to the definition and design pressure section
- Minor revision to the clause 4.2 Design pressure
- Inclusion of LCC for pipe size selection in chapter 5
- Major changes to clause 5.5 Sizing of gas/liquid two or multiphase lines
- Minor changes to clause 5.6 Sizing of gas relief lines
- Clarification and restructuring of isolation requirements in chapter 6

1 SCOPE

The scope of this standard is to provide requirements for the following aspects of topside process piping and equipment design on offshore production facilities:

- Design Pressure and Temperature.
- Line Sizing.
- System and Equipment Isolation.
- Insulation and Heat Tracing.

These criteria are applicable for all process, process support, utility and drilling systems. The design pressure and temperature criterias are mainly based on API RP 521 and line sizing criterias on API RP 14E.

2 REFERENCES

2.1 Normative references

The following standards include provisions which, through reference in this text, constitute provisions 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 standards referenced below.

ANSI/ASME B31.3	Process Piping
API RP 14C	Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms. (New revision of ISO 10418 to be used, when issued in 1999).
API RP 520	Sizing, Selection and Installation of Pressure-Relieving Systems in Refineries
API RP 521	Guide for Pressure-Relieving and Depressuring Systems.
ASME VIII	Boiler and Pressure vessel code
BS 5500	Unfired Fusion Welded Pressure Vessel Code.
BS MA 18	Salt water piping systems in ships
TBK 1-2	Norwegian Pressure Vessel Code.
NORSOK L-CR-001	Piping and valves (will be renumbered L-001)
NORSOK O-CR-001	Life cycle cost for systems and equipment (will be renumbered O-001)
NORSOK R-001	Mechanical equipment
NORSOK R-CR-004	Piping and equipment insulation (will be renumbered R-004)
NORSOK S-DP-001	Technical safety (Will be renumbered S-001)

NORSOK S-DP-002	Working environment (Will be renumbered S-002)
NORSOK S-DP-003	Environmental care (Will be renumbered S-003)

2.2 Informative references

API 2000	Venting Atmospheric and Low-Pressure Storage Tanks
API RP 14 E	Design and Installation of Offshore Production Platform Piping Systems. (Will be covered in the new ISO standard 13703 which is now in preparation. When issued, the ISO standard will replace API RP 14E as a guideline for calculation methods, etc.)
ISO DIS-14313	Petroleum and Natural Gas Industries, Pipeline, Check, Gate and Plug valves

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Can	Can requirements are conditional and indicates a possibility open to the user of the standard.
Design pressure	The maximum internal or external pressure to be used in determining the minimum permissible wall thickness of equipment and piping. Note that the minimum permissible wall thickness may be derived from a lower operating pressure, but higher operating temperature. The first relief valve is normally set to open at design pressure.
Double Block & Bleed	Two barriers with a bleed between the barriers. Typical arrangement is two block valves with a bleed valve in the middle. Double block and bleed as defined in ISO DIS-14313, and adopted by some valve manufacturers, is not according to the definition in this NORSOK standard.
Heat tracing	Use of heat from electrical cables, steam pipes or heating medium for heat conservation or frost protection.
HIPPS	High integrity systems for overpressure protection that shuts down the high pressure source instead of routing it to flare. To be classified as HIPPS system the system shall be independent of other shutdown functions including the process shutdown system. A typical system has shutdown valves, independent shutdown logics and a instrument sensing elements, normally transmitters.
Insulation	Use of a material with a low conductivity applied to equipment and piping in order to prevent energy flow (i.e. heat, noise).

Isolation	Isolation means a physical barrier (blind) or a tested barrier
Maximum design temperature	The material temperature representing the most severe condition of coincident pressure and temperature. The design temperature shall encompass the maximum operating temperature.
Maximum operating pressure	The maximum pressure predicted for deviations from normal operations, like start-up/shutdown, process flexibility, control requirements and process upsets.
Maximum operating temperature	The maximum temperature in the equipment when the plant operate at unstable conditions, like start-up/shutdown, control requirements, process flexibility and process upsets.
May	May indicates a course of action that is permissible within the limits of the standard (a permission).
Minimum design temperature	The minimum temperature which serves as a base for specifying the low temperature characteristics of the material. The design temperature shall encompass the minimum operating temperature.
Minimum operating pressure	The minimum pressure predicted for deviations from normal operations, like process start-up and shutdown.
Minimum operating temperature	The minimum temperature in the equipment when the plant operate at unstable conditions, like start-up, shutdown and depressurizing.
Operating pressure	The pressure in the equipment when the plant operates at steady state condition, subject to normal variation in operating parameters.
Operating temperature	The temperature in the equipment when the plant operates at steady state condition, subject to normal variation in operating parameters.
Shall	Shall is an absolute requirement which shall be followed strictly in order to conform with the standard.
Should	Should is a recommendation. Alternative solutions having the same functionality and quality are acceptable.
Single Block & Bleed	One isolation and a bleed. The point to be isolated can be bled down by the bleeder, but there is only one barrier against the pressure side (e.g. a valve).

Winterization	Use of insulation and heat tracing, or insulation only, for frost protection.

3.2 Abbreviations

FB	Full Bore
HIPPS	High Integrity Pressure Protection System
HP	High Pressure
IPPS	Instrument Pressure Protection System
LC	Locked Closed
LCC	Life Cycle Cost
LO	Locked Open
LP	Low Pressure
OPPS	Over Pressure Protection System
NPSH	Net Positive Suction Head
PSV	Pressure Safety Valve

4 DESIGN PRESSURE AND TEMPERATURE

4.1 General

Normally systems and components shall be protected according to relevant international codes API RP 14C and API RP 520/521. Under special conditions instrument pressure protection systems may be used as an alternative if proved to represent the same safety level (commonly named IPPS, HIPPS, OPPS). Instrument pressure protection systems shall not be used as a secondary pressure protection device for pressure vessels.

4.2 Design Pressure

The design pressure shall be calculated using the following procedures:

For systems protected by a PSV, the criteria in Table 1 shall be applied.

Where rupture discs are applied, the required design pressure of the pressure vessel will depend on the type of disc. As an indication API RP 520 may be consulted.

For piping being protected from overpressure by a PSV, it is allowable to have a PSV setpoint above the design pressure of the piping for some piping design codes. This shall be evaluated for each case, and only applied after examination of the relevant piping design code.

Table 1 - Design pressure criteria for pressurised systems

Maximum operating pressure (barg)	Design pressure (barg)
0-35	Maximum operating pressure +3.5 bar
35-70	Maximum operating pressure +10%
70-200	Maximum operating pressure +8.5% but minimum 7 bar and maximum 10 bar
200 -	Maximum operating pressure + 5%

The limitations given in Table 1 are to ensure proper operation of the PSV.

Mechanical design codes for piping and equipment have different limitations with regard to maximum allowable overpressure. It follows from this that piping and equipment in a system may have different design pressures. For low pressure systems such differences should be avoided, so that the same design pressure is used for the whole system.

For piping occasional variations in the operating pressure above the design pressure is permissible in some design codes. This may be used to limit the design pressure of the piping, but shall be subject to due consideration of all aspects in the piping design code ANSI/ASME B31.3. If such a system is selected, it is a requirement to log the duration and amount of overpressure that the piping is subjected to.

Tanks that are classified as atmospheric tanks shall be designed to be liquid filled and with an overpressure of 0.07 barg.

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

The design pressure at the discharge of positive displacement pumps shall be calculated in accordance with Table 1.

Equipment not protected by PSV or rupture disc and located downstream of a pump or a compressor shall be designed for the shut-in pressure.

For flare knock out drums, it is acceptable that the design pressure is equal to the maximum operating pressure. Normally a safety margin is added to the maximum operating pressure in the design phase to account for increase due to uncertainties in the calculations. Table 1 may be used to set the design margin.

Equipment where condensing vapours (e.g. after steamout of vessels), drainage or pump out may lead to less than atmospheric pressure, shall be designed for full vacuum or protected by vacuum relief, except for vessels where the design requirements for equipment operating below atmospheric pressure shall be used (Table 2).

Table 2 - Design pressure for equipment operating below atmospheric pressure.

Minimum operating pressure	Design pressure
0.35 bara and below	full vacuum
0.35 - 1.00 bara	the minimum operating pressure minus 0.1 bar, but maximum 0.5 bara

Equipment operating below atmospheric pressure shall also withstand an over-pressure of 3.5 bar (3.5 barg).

4.2.1 Maximum operating pressure

Maximum operating pressure for vessels is defined as follows:

- Separators; the highest pressure resulting in a trip.

- Compression suction scrubber and coolers; settle-out pressure.

The maximum operating pressure (shut-in pressure) for centrifugal compressors should, when accurate information is unavailable, 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 minimum flow.

The maximum operating pressure (shut-in pressure) for centrifugal pumps should, when accurate information is unavailable, be determined by choosing the greater of the two following criteria:
- Operating suction pressure +1.25 times the normal differential pressure developed by the pump.
- Maximum suction pressure at relieving conditions plus the normal differential pressure developed by the pump.

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

The maximum operating pressure may be limited by installation of full flow pressure safety valves (PSV's).

4.2.2 Piping

The design pressure of a piping system comprising pipes, fittings, flanges and valves shall in general be according to NORSOK Standard L-CR-001. Pipe classes for design pressures between those pressure class ratings shall be developed when justified by cost savings.

Static head, friction loss and surge pressures shall be taken into consideration.

Occasional variation above design according to ANSI/ASME B31.3 should be evaluated where total cost can be significantly reduced**.**

4.3 Design Temperature

4.3.1 Maximum design temperature

Where the maximum operating temperature can be calculated accurately, this temperature shall be used as maximum design temperature, without adding a safety margin.
Where the maximum operating temperature can not be calculated accurately, the maximum design temperature is normally determined by adding 30°C to the operating temperature. For equipment operating at ambient conditions, the maximum design temperature is 50°C.

For seawater supply systems where the maximum operating temperature is defined by the seawater yearly variations, the maximum operating temperature is defined as 10° above the seawater supply operating temperature chosen for design.

The operating temperature on a compressor discharge, when a compressor curve is not available can roughly be defined as 15°C above the predicted design point temperature to allow for lower efficiency at compressor minimum flow conditions.

When compressor curves are available, the temperature at minimum flow conditions shall be used as the operating temperature.

The following guidelines should be used to determine the upper design temperature:

- Add 15 °C to the 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

Compressor suction scrubber maximum design temperatures are defined as the higher of the following:

- Maximum operating temperature at the compressor suction in the event of cooling medium failure. Maximum operating temperature can be limited by a high temperature shutdown function.
- Maximum recycle temperature (maximum discharge minus Joule Thompson drop across anti-surge valve) in the event of cooling medium failure.
- Maximum temperature due to settle out conditions.
- Operating temperature plus 30°C.

For all heat exchangers, both sides shall have a maximum design temperature determined by the hottest fluid.

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

4.3.2 Minimum design temperature

The minimum design temperature shall be the more stringent of the following:

- Operating temperature (obtained during normal operation, start-up, shutdown or process upsets) with a margin of 5°C.
- Minimum ambient temperature. Lowest temperature should be based on available weather data. Safety factors should be selected based on the quality of such weather data.
- Minimum temperature occurring during depressurizing from settle-out pressure and subsequent cooling to ambient temperature. Pressure reduction due to cooling before depressurisation shall be included.
  The minimum temperatures to be expected in a process plant after depressurisation will occur at low pressures. Designing the process plant for lower design temperature at full design pressure often will result in a conservative design and should be avoided if possible.
  If calculations results in unacceptable values, operational procedures may be included for only partial depressurisation of equipments or start of depressurisation at higher temperature.

- Minimum temperature occurring during depressurising from settle-out pressure and temperature with a margin of 5ºC.

The depressurisation calculations shall as a minimum include heat transfer between fluid and vessel.

5 LINE SIZING CRITERIA

5.1 General

When sizing lines the sizing criteria shall be minimum life cycle cost, this may include evaluation of functional requirements, cost of piping, weight, CO_2-tax, energy costs, mechanical and process limitations, expected lifetime of piping, maintenance cost etc.

When sizing piping, the following contraints shall be addressed:

1. Required capacity/available driving pressure
2. Flow induced forces
3. Noise/vibration
4. Pressure surges
5. Material degradation - erosion, corrosion, cavitation
6. Liquid accumulation/slug flow
7. Sand accumulation

In some cases the contraints will govern the pipe size selection, not the life cycle cost evaluation.

5.2 Design Basis

5.2.1 Permissable pipe sizes

A minimum size of DN50 (2") should in general be used for all process, process support and utility piping to ensure adequate mechanical integrity. Piping of diameter DN25 (1") can be used, where protection and/or support is provided for the following services:

- Instrument air.
- Chemical injection.
- Auxiliary services such as pump cooling.
- Services where a minimum velocity is required.
- Internal piping on equipment skids.
- Sample connections.
- Instrument connections (3/4" is allowed according to NORSOK standard L-CR-003).
- Purge/vent

Minimum size for the sewage and open drain header shall be DN100 (4") and sub-headers DN80 (3"). 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.

5.2.2 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 Pipe (GRP): 0.02 mm
Polyethylene, PVC: 0.005 mm

Flexible hose: Vendor to be consulted. (As a rough estimation, ID/20 mm can be used (ID in inch) for steel carcass and 0.005 mm for plastic coating.)

5.3 Sizing of Liquid Lines

5.3.1 Velocity limitations

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

A compromise between line size and pump power has to be taken.

Table 3 - Maximum velocities for sizing of liquid lines.

Fluid	Maximum velocities (m/s)			
	CS	SS	CuNi 4)	GRP
Liquids 2)	6	7	3	6
Liquids with sand 3)	5	7	N.A.	6
Liquids with large quantities of mud or silt 3)	4	4	N.A.	N.A.
Untreated Seawater 1)	3	7	3	6
Deoxyginated Seawater 2)	6	7	3	6

Notes:
1) For pipe less than DN200 (8"), see BS MA-18 for maximum velocity limitations.
2) For Stainless Steels and Titanium the maximum velocities is limited by system design (available pressure drop/reaction forces).
3) Minimum velocity shall normally be 0.8 m/s
4) Minimum velocity for CuNi is 1.0 m/s.

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

With corrosion inhibited fluids in carbon steel piping, the velocity shall be limited by a wall shear stress of 40 N/m^2 to maintain the corrosion inhibiting film at the pipe wall, with the corresponding maximum velocity:

$$V_{max} = \sqrt{\frac{80}{f\rho}} \text{ (m/s)}$$

f = Fanning's friction factor = ¼ of Darcy’s friction factor (Moody diagram)
ρ = fluid density (kg/m^3)

5.3.2 Centrifugal pump suction and discharge lines

The suction piping shall be sized based on NPSH requirements. Maximum velocity from Table 3 and the following maximum pressure drops shall in general be used:

Subcooled liquids: 0.25 bar/100 m
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 subcooled liquids.

The maximum velocity in the discharge piping is given in Table 3. As a guideline, a pressure drop of up to 0.9 bar/100 meter may be assumed.

5.3.3 Reciprocation pump suction and discharge lines

For reciprocating pumps, the suction piping shall be sized based on NPSH requirements.

Table 4 - Recommended maximum velocity in reciprocating pump piping.

Speed (RPM)	Maximum velocity (m/s)	
	Suction	Discharge
< 250	0.6	1.8
250-300	0.5	1.4
> 300	0.3	0.9

The limits are for a single plunger pump and the velocity is the average during several strokes. The discharge velocities can be increased if the number of plungers are increased, and/or if dampers are installed (ref. API RP 14E).

5.3.4 Control valve suction lines

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

5.3.5 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 must 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 pipes not running full shall be sized based on the maximum flow as given in Table 5.

Table 5 - Flow Capacity - near horizontal pipes.

Diameter (mm (inch))	Liquid flow capacity		
	Entrance to pipe (m^3/h)	Slope 1:50 (m^3/h)	Slope 1:100 (m^3/h)
50 (2)	1.8	3.0	2.5
100 (4)	8	20	15
150 (6)	20	60	35
200 (8)	50	240	170
250 (10)	80	440	310
300 (12)	130	620	440
350 (14)	200	710	500
400 (16)	280	890	630

Vertical gravity lines (such as liquids from sea water returns and produced water discharge) shall be designed such that the Froude number is less than 0.3 to avoid air entrainment and ensure undisturbed flow without pulsations.

$$\text{Froude number} = \frac{V}{\sqrt{Dg}}$$

V = Velocity assuming full pipe (m/s)
D = pipe inner diameter (m)
g = gravity constant (m/s^2)

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.

For sea water and produced water discharge lines to sea, a vent line is normally included from top of the vertical gravity line from platform topside to sea. The vent line should be designed for an air volumetric flowrate equal to the liquid volumetric flow through the vertical line and a pressure loss of maximum 0.02 bar/100 m.

5.3.6 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 pipework the flow velocity shall in general not exceed the velocity as given in Table 3. Upstream the deluge skids, the flow velocities shall normally 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.

5.3.7 Oily water systems

The lines for oily water to water treatment facilities, shall be sized in order to retain the size of oil droplets in the water. 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.

5.3.8 Drilling fluid systems

The minimum flowing velocity of drilling fluid shall not be lower than 0.8 m/s in order to avoid sand settling in pipes.

The maximum velocity in carbon steel should not exceed 4 m/s to avoid problems such as cavitation/erosion on bends and damage to inline equipment/vessels internals.

Line sizing criteria for drilling fluids are summarised in Table 6.

Table 6 - Allowable pressure drop and velocity in drilling fluid systems.

Line Service	Max pressure drop [bar/100 m]	Velocity limits [m/s]	
		Min	Max
Pump Suction (and Gravity) flow (Carbon Steel pipes)	0.3	0.8	4.0

5.4 Sizing of Gas Lines

5.4.1 General

Gas lines shall generally be sized in order to not exceed the acceptable noise level at the platform.

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

5.4.2 Maximum velocities

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

$$V = 175 \left(\frac{1}{\rho}\right)^{0.43} \quad \text{or} \quad 60 \text{ m/s, whichever is lowest}$$

where : V = max. velocity of gas to avoid noise (m/s)
ρ = density of gas (kg/m^3)

The requirement set by this formula can be omitted by doing more detailed noise calculations of individual pipes. Where high noise levels are not considered as a problem, the maximum velocity can be calculated as for gas relief lines.

For sizing and arrangement connected to and adjacent to pressure control valves in order to avoid excessive dispersion of noise, the valve manufacturer shall be considered.

For antisurge lines the constant 175 in the formula may be replaced with 200 during process upsets, if the noise level is acceptable. However, during normal recycle, the velocity shall be limited to the velocity as given by the equation above.

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

5.4.3 Recommended pressure drops

Sizing of piping shall be based on LCC. Where this becomes impractical due to small size or low cost, the guidelines in Table 7 should be used. The pressure drop should be prorated between the operating pressures given.

Table 7 - Pressure drop for single phase gas process lines

Operating pressure (Barg)	Pressure drop (Bar/100 m)
0 - 35	0.001 - 0.11
35 - 138	0.11 - 0.27
Over 138	P/500 [1)]

Note 1: P is operating pressure in bara.

Sizing of Gas/Liquid Two-or Multi-Phase Lines

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

As a guideline, the maximum allowable velocity shall not exceed the lowest of

$V=183/(\rho_{mix})^{1/2}$ and maximum velocity for single gas flow

(ρ_{mix} = mixture density in kg/m^3).

When sizing two- or multiphase lines slugging must also be considered.
The number and length of multiphase lines should be reduced where possible.

Non corrosive service

For non corrosive wellstream and for corrosion resistant pipe materials the velocity shall be limited to maximum 25 m/s if the wellstream 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 shall 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 wellstream contaminated with particles the maximum 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 unstabilities due to liquid accumulations, and it allows simple pressure drop calculations. If lower velocities are required due to limited available pressure drop, problems with slugging and/or liquid accumulation in the lines shall be considered.

5.5 Sizing of Gas Relief Lines

5.5.1 General

In general, all flare lines shall be designed to keep the ρV^2 <200 000 kg/ms^2 criteria (ρ is the fluid density kg/m^3).

Where the ρV^2 criteria will not be met, additional calculations will be required to document that the selected pipe size is still acceptable. This involves evaluating acoustic fatigue, piping stress levels, supporting, noise etc.

Further, the selection of piping specification must consider the effect of acoustic fatigue, which are affected by factors such as:

- relative differential pressure in upstream orifice
- temperature in the flowing gas
- moleweight of flowing gas
- pipe diameter and wallthickness

5.5.2 Flare headers and subheaders

The maximum velocity for flare headers and subheaders shall not exceed 0.6 Mach.

5.5.3 Pressure safety valve lines

The upstream and downstream line shall be sized based on the rated capacity of the PSV. The upstream line shall be sized so that the pressure loss is below 3% of valve set pressure to avoid valve chattering. Pilot operated valves can tolerate a higher inlet-pipe pressure losses when the pilot senses the system’s pressure at a point that is not affected by inlet-pipe pressure drop. In any case the upstream line size should be at least equal to the PSV inlet nozzle size.

The maximum back pressure on PSV's should be determined by consulting API 520/521. Normally the maximum back pressure on a spring loaded PSV is 10% of set point. The backpressure on a bellows type conventional PSV may be limited by the bellows design pressure. If the backpressure on a PSV goes above 30-50% of set pressure the flow in the PSV may become subsonic. This is normally not advisable, as the flow through the PSV becomes unstable. For special applications it may be acceptable, but then after due consideration of all aspects.

Maximum flowing velocity in the lines downstream of the PSVs shall in general be less than 0.7 Mach. For the PSVs where the outlet velocity is higher, a reducer shall be installed adjacent to the PSV to increase line size and hence limit the velocity to max 0.7 Mach 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.

5.5.4 Controlled flaring lines

Flaring lines downstream of control valves shall be designed for a maximum velocity of 0.5 Mach.

5.5.5 Depressurisation lines

In the lines, upstream or downstream of the blowdown valve, the value of ρV^2 should not exceed 200 000 kg/ms^2. The maximum flowing velocity in the lines downstream the reducer shall be 0.7 Mach.

The pressure loss shall be so as to not impose any restrictions on the depressurisation objectives.

5.5.6 Two/multiphase relief lines

Two/multi phase relief lines shall be sized based on the following criteria:

Potential slug/plug flow: $V < 50$ m/s (branch lines only)

Homogenous flow: $\rho V^2 < 200\ 000\ kg/ms^2$

5.5.7 Vent lines

Maximum backpressure shall be 0.07 barg .

5.6 Maximum allowable velocities due to reaction forces

If $\rho V^2 > 200\ 000$ the piping discipline shall be consulted in order to consider reaction forces. (ρ is fluid density in kg/m^3 and V is velocity in m/s)

This applies to all fluid services (gas, liquid, two-phase).

6 SYSTEM AND EQUIPMENT ISOLATION

6.1 System and Equipment Isolation

6.1.1 General

It shall be possible to isolate equipment or process sections during maintenance work to obtain safe working conditions for the maintenance personnel. Process sections will also be isolated for leak testing before commissioning, after a maintenance operation, and for pressure testing.

In general single block and bleed shall be used on all systems.

Double block and bleed should only be used on hydrocarbon systems after considering the following:

- special safety considerations
- the system is critical for the overall regularity
- the equipment is maintained when the rest of the process system is in operation

Based on regularity, typical locations for double block and bleed are:

- pig launchers and receivers
- process compressors
- crude oil export pumps

Illustrations of different isolation arrangements are given in Annex A Figure A.1 and A.2.

6.1.2 Isolation of pressure vessels

All vessel that can be entered shall be equipped with spectacle blinds or blinds/spacers on all nozzles, except for instrument nozzles.

Vessel isolation shall be located as close to the vessel as practical, normally directly on the nozzle. Purge and steam valves shall be provided with blind flanges.

Connections to vent/drain systems from instruments shall be isolated on the instrument.

6.1.3 Isolation of Equipment being Removed for Maintenance

Spool pieces shall be used when necessary for maintenance purposes. This type of isolation requirement is generally used for pumps, compressors and heat exchangers.

6.1.4 Isolation of control valves and PSV's

Control valves shall be equipped with single isolation and bleed valves. See Annex A, Figure A.4.

On non essential systems, single control valve without isolation is acceptable. See Annex A Figure A.6.

If tight shut-off is required, an isolation valve shall be installed upstream the bypass throttling valve. See Annex A, Figure A.5.

For PSV's single isolation valve is sufficient when the valve will be replaced with a blinding when being removed.

6.1.5 Isolation of pressure and level instruments, chemical injection and sample points

Generally, the same requirements applies to instruments as to system and equipment isolation.

All pressure instruments shall have a flanged isolation valve at the point where pressure is tapped off on a process line, vessel, etc.

In addition, chemical injection points shall have a check valve.

6.1.6 Isolation devices

Provisions necessary to facilitate isolation are:

- Shut off valves or manual block valves on all connections to equipment or the process section to be isolated.
- Vent/drain (bleed) between isolation valves, or between a valve and a blind.
- Flange pair with blind at the point of isolation.

The actual blinding is accomplished through one of the following arrangements:
- Spectacle blind.
- Spade and spacer.
- Spool piece and blind flange.

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

The location of line blinds and insulation spools shall be shown on the P&ID's.

A single valve is acceptable as double block and bleed 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.

6.2 Connections to Vents and Drains

6.2.1 General

The philosophy for connections to flare, vents and drains is described in this section:

1. Closed drain system
   Intended for draining of liquid after depressurisation from vessels, piping and other equipment due to maintenance work etc. All pressure drain connections shall be equipped with a blind to avoid accidental draining of pressurised liquids/gas.

2. Flare system
   Process relief system. Also used to blow down equipment to flare header pressure.

3. Vent system
   System for venting of hydrocarbon gas to an atmospheric vent at a safe location. Used during maintenance before equipment is opened and normally done after blowdown of equipment to flare system. If a vent system is not present, alternatively a blinded nozzle is acceptable for connections of high pressure hoses to a safe location.

6.2.2 Detailed requirements

a) All equipment and piping shall be provided with highpoint vents and lowpoint drains.

b) All pressure vessels shall be provided with a vent valve and blind, venting to atmosphere during maintenance.

c) To allow for inspection, flushing and cleanout of vessels and piping, steamout and utility connections shall be provided. For piping diameters above DN 150 (6"), the connections for flushing shall be DN 150 (6"), to give access for rotating hoses.

d) All vessel or tower drains discharging into the oily water drain system shall have permanent piping arranged with visual observation of flow. Drains used only during major shut-down shall be fitted with blanks or plugs.

e) Vent and drain connections shall be fitted with block valves for all heat exchangers. On stacked exchangers operating in series, drain valves with plugs shall be installed on the lower exchanger only.

f) Where provisions shall be made for chemical cleaning with the tube bundle in place, blind flange connections shall be provided for chemical hose attachments. The connections shall preferably be 3" NPS, but not exceeding line size, and shall be located between the exchanger nozzles and the block valves.

g) All pump casing vents and drains not permanently connected to the flare/drain system shall be blinded off downstream of the valves.

h) Connections to the closed drain system from equipment and piping shall have two valves, one block and one throttling valve, and single blinded bleed valve arrangement. A spectacle blind shall be located between the upstream block valve and the bleed valve. See Annex A, Figure A.7.

i) The drain pipe down to the T-piece connection on the header**,** should be designed for the same pressure as the system to be drained. The last drain valve should be a slow opening valve or alternatively an orifice to prevent too high pressure ratio/flow.

j) A single block valve with blind flange/plug shall be used for level transmitters and level gauges for connections to closed drain and flare systems. If permanently connected to the flare or closed drain system, the blind is not necessary.

k) Connections to the atmospheric vent system from pressurised vessels require single isolation, valve and blind. Connections to the atmospheric vent system from atmospheric vessels require a blind

l) Atmospheric vents discharging from hazardous sources including tanks shall be routed to the atmospheric vent system. However, tanks vents from non-hazardous tanks may be routed individually to atmosphere.

m) Single relief valve discharging to flare shall be equipped with a single block valve downstream. See Annex A, Figure A.8.

n) Relief valves or rupture discs with spare shall be equipped with single selector valves or mechanically interlocked block valves upstream and downstream and a single blinded bleed valve, upstream of each relief valve. See Annex A, Figure A.9.

o) The pressure relief valves shall be located at high points in the piping system. Piping to pressure relief valve inlet shall be as short as possible. All branch connections on relief and blowdown system will enter the header at 90° unless otherwise highlighted on the P&ID's.

p) Blow down shall be arranged with one blow down valve, orifice and a locked open, full bore, block valve. See Annex A, Figure A.10.

q) The P&ID's shall show all process drains, vents and sample points required for flushing, testing, commissioning and operation. Vents and drains exclusively used for hydrostatic pressure testing will be added by piping layout and design.

7 INSULATION AND HEAT TRACING OF PIPING AND EQUIPMENT

7.1 Insulation and Heat Tracing Requirements

7.1.1 General

Due to corrosion under insulation being a general problem on insulated equipment, the philosophy shall be to avoid insulation where possible. Appropriate coating systems shall be selected to minimise the above problem when insulation is required.

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.

Insulation and heat tracing shall be avoided on spectacle blinds and flanges.

The insulation classes are designated as follows:

Code	Description	Abbreviation
0.	No Insulation	NI
1.	Heat Conservation	HC
2.	Cold Medium Conservation	CC
3.	Personnel Protection	PP
4.	Frost Proofing	FP
5.	Fire Proofing (Insulation)	FI
6.	Acoustic 10 dB	AI
7.	Acoustic 20 dB	AI
8.	Acoustic 30 dB	AI
9.	External Condensation and Icing Protection	EP

Design requirements and criteria for the respective insulation classes are specified in the following sections. (Detailed requirements for application of insulation is given in NORSOK standard R-CR-004 Piping and equipment insulation.)

7.1.2 Heat conservation

Insulation/Heat tracing for this purpose shall be used where heat losses from the piping and equipment to the surroundings are to be minimised for the following reasons:

- Maintain a proper heat balance for optimum operation of the process and utility systems.
- Limit heat losses in heat exchangers and heater systems to minimise required heat input and thereby reduce equipment size and weight.
- To avoid internal condensation in gas systems (e.g. fuel gas system).
- To maintain sufficient liquid temperature and avoid increased liquid viscosities.

If sufficient (waste) heat is available, consideration shall be given to possibly avoid insulation.

7.1.3 Cold medium conservation

This insulation type shall be used for piping and equipment including valves and instruments which normally operate below ambient temperature and where heat transfer from the surroundings shall be minimised for the following reason:

- Maintain a proper heat balance and low temperature in the process system.
- Limit heat input to piping, and thereby reduce equipment size and weight.

7.1.4 Personnel protection

Shields are the preferred option for personnel protection against hot and cold surfaces, unless insulation is required for other purposes.

Where shields are not a practical solution, insulation for personnel protection shall be considered on surfaces that can be reached from workareas, walkways, ladders, stairs or other passageways and where the surface temperature exceeds 70°C or is below -10°C (see NORSOK S-DP-002 and NORSOK R-CR-004).

7.1.5 Frost protection

Insulation/heat tracing for external low temperature protection shall only be used for safety reasons or where a positive effect on regularity can be demonstrated.

Equipment and piping should be protected for purposes such as:

- Prevention of hydrate formation. Heat tracing specified to maintain minimum fluid temperature required.
- Protection of standby pumps in unheated areas to avoid the pumping medium to freeze or become too viscous to pump.
- Heat tracing to maintain operating temperature may be required for operational reasons, e.g. instrument connections and impulse lines. In this service, thermostat controlled heat tracing is preferred.
- Frost protection of equipment, piping and instrumentation in systems carrying fluids which in a stagnant flow and low ambient temperature condition may be subject to solidification. This may be applicable to liquid-filled small bore lines carrying fresh water, sea water or pure glycol. Heat tracing shall be specified to maintain minimum temperature above 5°C, however, for pure glycol, the temperature shall be maintained above 20°C to reduce viscosity.

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.

The piping shall be arranged to minimise the part of the system containing stagnant or slow moving fluids. Stagnant conditions shall be avoided by design, but where this cannot be done, provisions must be made to drain or flush out the system (i.e. winterization bleeds). Adequate protection may sometimes be obtained by increasing the velocity in a line.

Maintaining the flows listed below is generally sufficient to avoid freezing in lines up to 50m length. The flowrate should be increased pro rata with the exposed length for lengths over 50m. The table below can be used for sea water and, if applicable, fresh water.

Line Size	Minimum Volumetric Flowrate
below 3"	0.02 m^3/h
3" and above	0.10 m^3/h

Where such provisions can not be made, heat tracing and/or insulation shall only be applied based on a critical evaluation of:

- Location/Environmental conditions.
- Ambient conditions.
- System criticality.

For lines where intermittent flow and stagnant conditions cannot be avoided, the following guidelines shall apply (the table is based on -10°C as minimum ambient temperature):

Line size	Action
< 3"	Heat trace and insulate
3"-10"	Insulate
>10"	No winterization

For tanks containing stagnant water, the same guidelines should be applied.

7.1.6 Fire proofing

Fireproofing insulation shall be applied on equipment and piping where passive protection against a hydrocarbon fire is required, and on equipment which is required to be operable during a fire.

The philosophy and criteria for application of passive fire protection are detailed in NORSOK S-DP-001.

7.1.7 Acoustic insulation

Acoustic insulation comprise Insulation Classes 6, 7 and 8. The respective requirements for these classes are 10, 20 and 30 dB linear average attenuation between 500 and 2000 Hz.

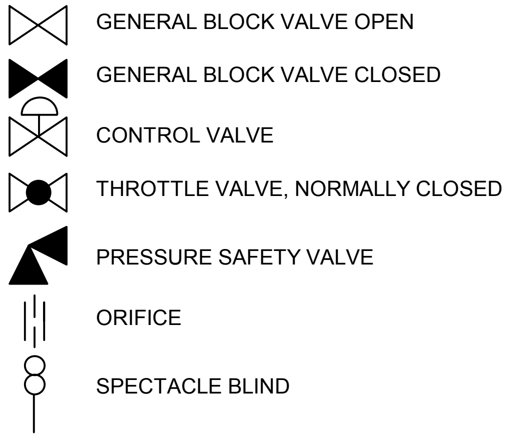
The philosophy and criteria for application of such insulation are detailed in NORSOK Standard S-DP-002.

7.1.8 External condensation and icing protection

This type of insulation shall be used to prevent external condensation and icing on piping and equipment in order to protect personnel and equipment. Normally, insulation for external condensation and icing protection shall not be installed.

ANNEX A: FIGURES (NORMATIVE)

Legend:



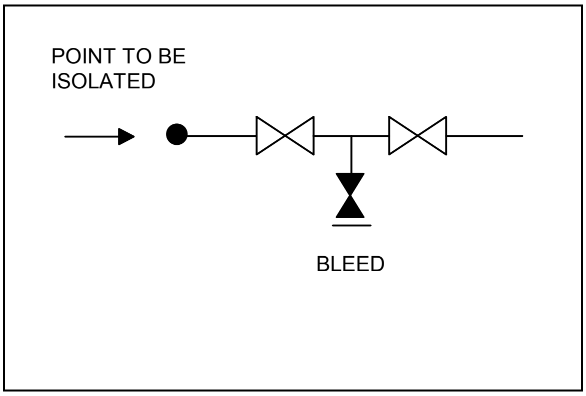


Figure A.1: Double block and bleed for process systems

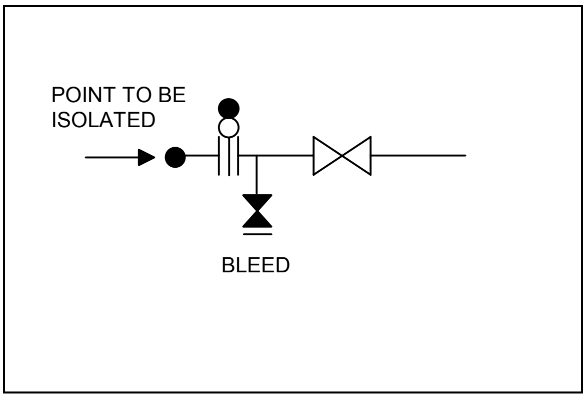


Figure A.2: Single block and bleed for process systems

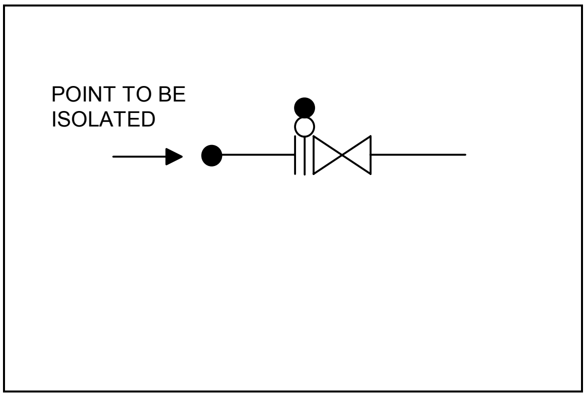


Figure A.3: Single block for pressure vessel isolation.

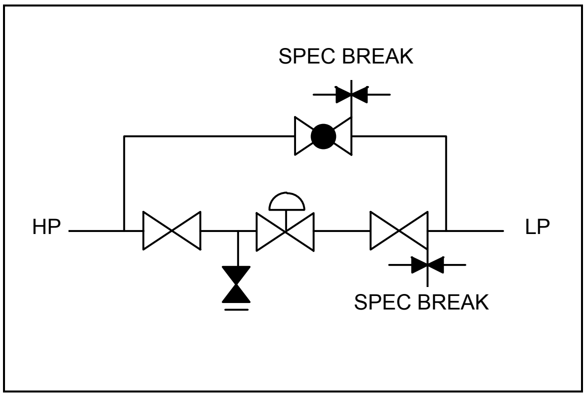


Figure A.4: Isolation of control valve having bypass.

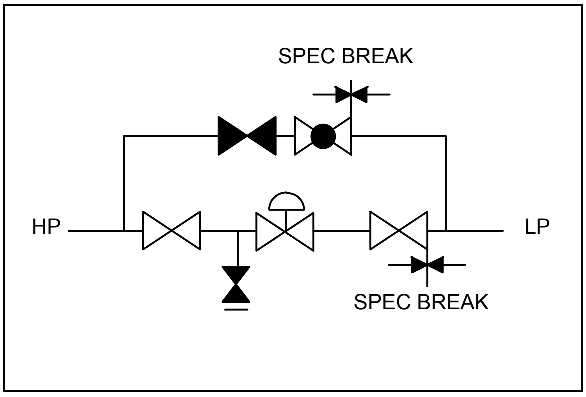


Figure A.5: Isolation of control valve having bypass where tight shut off of bypass is required.

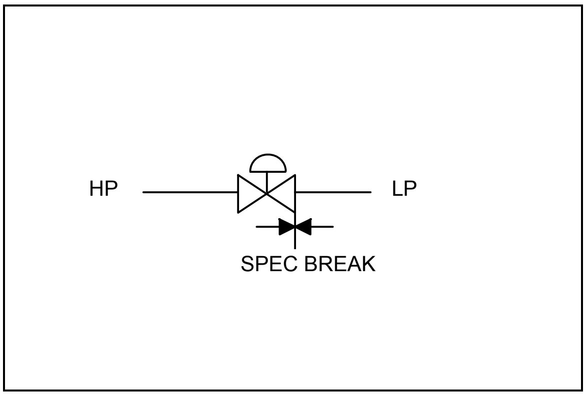


Figure A.6: Single control valve on non essential systems (no isolation).

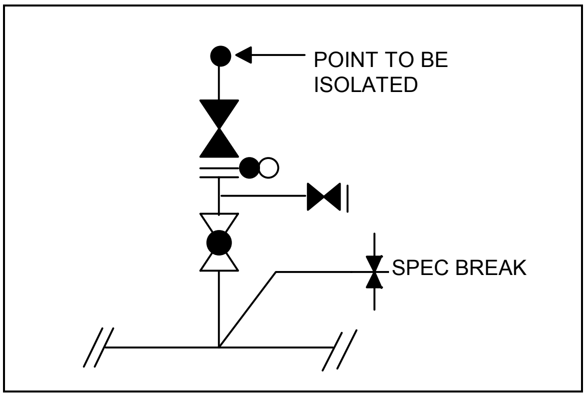


Figure A.7: Double block for connection to closed drains.

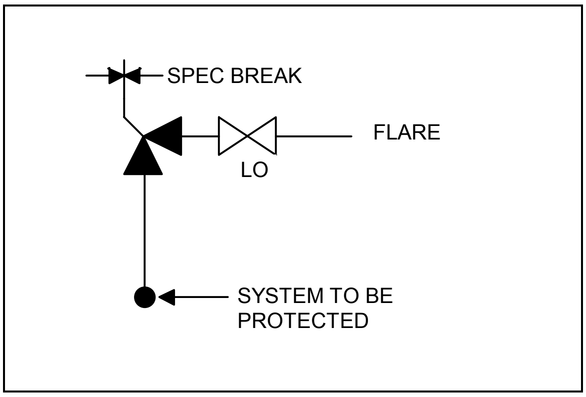


Figure A.8: Arrangement for single relief valve (PSV).

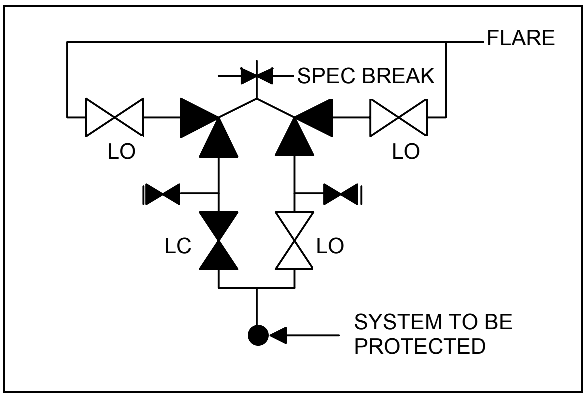


Figure A.9: Arrangement for interlocked relief valves (PSV's).

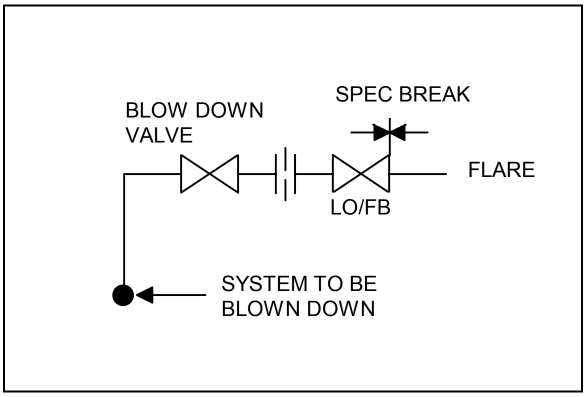


Figure A.10: Blow down valve.