

Process systems

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Foreword	6
Introduction	6
1 Scope	7
2 Normative and informative references	7
2.1 Normative references	7
2.2 Informative references	7
3 Terms, definitions and abbreviations	7
3.1 Terms and definitions	8
3.2 Abbreviations	8
4 General requirements	8
4.1 General system design	8
4.2 Safety requirements	9
4.3 Maintenance and isolation	10
5 General process equipment design	10
5.1 Horizontal separator design	10
5.2 Scrubber design	12
5.3 Heat exchanger design	14
5.4 Pig launcher/receiver design	16
5.5 Filters	17
6 Topside flow lines and manifolds (system 13)	17
6.1 General	17
6.2 System design	17
6.3 Monitoring	17
6.4 Safety	17
7 Separation and stabilisation (system 20)	17
7.1 General	17
7.2 Pressure and level control	17
7.3 Test separator	17
7.4 Layout	18
7.5 Injection of chemicals	18
8 Crude handling (system 21)	18
8.1 General	18
8.2 Design requirements	18
8.3 Safety	18
9 Gas compression (system 23 and 27)	19
9.1 General	19
9.2 System design	19
9.3 Compressors	19
9.4 Pressure relief and depressuring	19
9.5 Layout	20
10 Gas treatment (system 24)	20
10.1 General	20
10.2 Glycol contactors	20
10.3 Regeneration unit and storage	21
10.4 Wet gas inlet coolers	21
10.5 Pressure relief	22
10.6 Layout	22
10.7 Environmental requirements	22
11 Gas conditioning (system 25)	22
11.1 General	22
11.2 Heat exchangers and scrubbers	22
11.3 Turbo expander and recompressor unit	23
11.4 Design pressure and temperature	23
11.5 Layout	23
12 Water injection (system 29)	23

12.1	General	23
12.2	Filtration	23
12.3	Disinfection	23
12.4	Deoxygenation	23
12.5	Pumps	24
12.6	Chemical injection	24
12.7	Monitoring	24
13	Cooling medium (system 40)	24
13.1	General	24
13.2	Filtration	24
13.3	System operating pressure	24
13.4	Expansion tank	25
13.5	Layout	25
14	Heating medium (system 41)	25
14.1	General	25
14.2	Pumps	25
14.3	Waste heat recovery units	25
14.4	Filter	26
14.5	Expansion tank	26
14.6	Layout	26
15	Chemical injection (system 42)	26
15.1	General	26
15.2	Storage tanks	26
15.3	Drip trays and drainage	27
15.4	Injection points	27
15.5	Safety	27
15.6	Maintenance	27
16	Flare (system 43)	27
16.1	General	27
16.2	Inlet overpressure protection	28
16.3	Knock-out drum	28
16.4	Thermal radiation	29
16.5	Flare gas recovery systems	29
16.6	Relief devices	29
17	Oily water treatment (system 44)	29
17.1	General	29
17.2	Produced water treatment	29
17.3	Flash drum	30
17.4	Layout	30
18	Fuel gas (system 45)	30
18.1	General	30
18.2	System design	30
18.3	Fuel gas heating	30
19	Methanol injection (system 46)	31
19.1	General	31
19.2	System design	31
19.3	Storage tank	31
19.4	Injection	31
20	Chlorination (system 47)	31
20.1	General	31
20.2	System design	32
20.3	Electrolysis cells	32
21	Sea water (system 50)	32
21.1	General	32
21.2	Pumps	33
21.3	Filters	33
21.4	Prevention of marine growth	33

21.5	Layout	33
22	Fresh water (system 53)	33
22.1	General	33
22.2	Fresh water treatment	33
22.3	Maintenance	33
23	Open drain (system 56)	34
23.1	General	34
23.2	System capacity	34
23.3	Drain tanks	34
23.4	Drilling drain	34
23.5	Maintenance	34
23.6	Layout	34
23.7	Safety	34
24	Closed drain (system 57)	35
24.1	General	35
24.2	Closed drain flash drum	35
24.3	Design temperature	35
24.4	Reclaimed oil sump	35
24.5	Reclaimed oil sump pump	35
24.6	Safety	35
25	Diesel oil (system 62)	36
25.1	General	36
25.2	Storage tanks	36
25.3	Hose loading stations	36
25.4	Day tanks	36
25.5	Maintenance	36
26	Compressed air (system 63)	36
26.1	General	36
26.2	Dehydration	36
26.3	Filtration	36
26.4	Air receiver	37
26.5	Sparing	37
26.6	Safety	37
26.7	Layout	37
27	Inert gas (system 64)	37
27.1	General	37
27.2	System design	38
27.3	Sparing	38
27.4	Operational requirements	38
28	Hydraulic power (system 65)	38
28.1	General	38
28.2	Reservoir	38
28.3	Pumps	39
28.4	Filters	39
28.5	Accumulator capacity	39
28.6	Safety	39
28.7	Maintenance	39
29	Sewage (system 66)	39
29.1	General	39
29.2	System capacity	39
29.3	Operating temperature	40
29.4	Layout	40

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

The development of this NORSOK standard is primarily based on proven technology, but it does not preclude the use of new technology.

The following changes have been made to edition 3 of this NORSOK standard:

- content has been simplified and some superfluous text has been deleted;
- the document has been updated to reflect current industry practice and relevant international standards. In many cases, text has been replaced with references to such standards;
- a new clause covering sewage outside living quarter has been introduced;
- the sub-clause regarding HAZOP studies has been expanded to emphasize the importance and to approach international methodology;
- clause 4 has been expanded to include several requirements previously found in the system clauses;
- in clause 16, the sizing of knock out drum with respect to liquid accumulation, has been made more consistent with international standards. The use of instrumented protection functions to allow for reduced liquid accumulation capacity requires more stringent documentation.

The system numbers used in this NORSOK standard are those defined in NORSOK Z-DP-002.

1 Scope

This NORSOK standard defines the minimum functional requirements for process systems on an offshore installation. In addition the standard includes a number of recommendations to give additional guidance for the system design.

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 the requirements of the referenced standards.

2.1 Normative references

API Std 520,	Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries
API RP 14C,	Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms
DNV-OS-E201:2005,	Oil and Gas Processing Systems
EN 1473,	Installation and Equipment for Liquefied Natural Gas – Design of Onshore Installations
FOR 1994-02-10 nr 123,	Norwegian Maritime Directorate (NMD) : Forskrift for flyttbare innretninger med produksjonstekniske installasjoner og utstyr
IEC 61882:2001,	Hazard and operability studies (HAZOP studies) – Application guide
ISO 4126,	Safety devices for protection against excessive pressure
ISO 10418,	Petroleum and natural gas industries – Offshore production installations – Basic surface process safety systems
ISO 13702:1999,	Petroleum and Natural Gas Industries – Control and Mitigation of Fires and Explosions on Offshore Production Installations – Requirements and Guidelines.
ISO 23251:2007,	Petroleum, petrochemical and natural gas industries – Pressure-relieving and depressuring systems
ISO 25457,	NOTE This standard is identical to API Std. 521. Petroleum, petrochemical and natural gas industries – Flare details for general refinery and petrochemical service
ISO 28300,	NOTE This standard is identical to API Std. 537. Petroleum, petrochemical and natural gas industries - Venting of atmospheric and low-pressure storage tanks
NORSOK H-CR-002,	NOTE This standard is identical to API Std. 2000. Piping and plumbing
NORSOK P-001,	Process design
NORSOK S-003,	Environmental care
NORSOK Z-DP-002,	Coding System
TEMA ,	Standards of Tubular Exchanger Manufacturers Association
Water Report No.111,	PSA Regulations with references ("Sufficient, Safe and Good Potable Water Offshore"; Water Report No.111)

2.2 Informative references

API RP 576,	Inspection of Pressure-Relieving Devices
API Publ. 2210,	Flame Arrestors for Vents of Tanks Storing Petroleum Products
GPISA:1998,	Engineering Data Book, Gas Processors Association
ISO 13628-6,	Petroleum and natural gas industries – Design and operations of subsea production systems – Part 6: Subsea production control systems
NORSOK S-001,	Technical Safety

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

may

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

3.1.3

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

3.1.4

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

3.2 Abbreviations

CCR	central control room
ESD	emergency shutdown
GOR	gas oil ratio
HAZOP	hazard and operability
LAHH	level alarm high high (trip level)
LALL	level alarm low low (trip level)
NPSH	net pressure suction head
PCHE	printed circuit heat exchanger
PSD	process shutdown
PSV	pressure safety valve

4 General requirements

4.1 General system design

4.1.1 Design for minimum impact of facility movement

Design criteria for floating installations shall take into account movements and accelerations under which the process facility is required to operate. Any limitations shall be specified in the engineering documentation.

4.1.2 Relief devices

All relief devices shall be tagged and included in a maintenance program.

For pumps with internal pressure relief capability, a dedicated external relief device shall be installed if the internal relief device is not designed and located such that maintenance and testing is possible.

4.1.3 Atmospheric tanks

For atmospheric tanks containing flammable liquids, the purge/blanketing gas flow rate shall be at least 5 % higher than maximum pumping capacity. The design of the vent and purge shall be according to ISO 28300.

In some cases flame arrestors are recommended for use on atmospheric tanks containing petroleum products. Reference is made to ISO 28300 for more specific requirements and guidance. The use of a flame arrestor within the tank's relief path introduces the risk of overpressure due to the flame arrestor clogging/fouling. Flame arrestors shall be located for easy access and included in a rigorous maintenance program. Continuous monitoring of differential pressure across the flame arrestor is advised if the process fluid is known to contain particulates or substances which may block the flame arrestor. The materials in the vent pipe should be non corrosive to reduce the risk of plugging the flame arrestor. Further recommendations for inspections and maintenance are given in API RP 576 and API Publ. 2210.

4.1.4 Material selection

All chemical components and their concentrations in the fluid in all services shall be specified to ensure correct material selection. Certain chemicals (e.g. methanol) are aggressive against gasket materials and titanium and require special considerations.

4.2 Safety requirements

4.2.1 Safety analysis

The following systems shall be designed in accordance with API RP 14C/ISO 10418:

- all hydrocarbon containing systems in wellhead and main process (system 13, 20 to 39, except 29 and 34);
- flare (system 43);
- oily water treatment (system 44) including injection (system 29) of produced water;
- fuel gas (system 45);
- methanol injection (system 46);
- hazardous open drain (system 56);
- closed drain (system 57);
- jet fuel (system 61);
- diesel oil (system 62).

Design in accordance with API RP 14C/ISO 10418 shall also be considered for other systems that involves hazards due to

- flammability/flash point,
- temperature,
- pressure,
- volatility,
- toxicity,
- fluid content/volume.

4.2.2 Hazard and operability (HAZOP)

HAZOP studies shall be carried out in accordance with IEC 61882.

HAZOP shall as a minimum include the systems covered by API RP 14C/ISO 10418 as defined in 4.2.1 including equipment packages and non hazardous open drain (system 56). Additional systems and equipment packages may require a HAZOP analysis.

The team shall be as small as possible consistent with the relevant technical and operating skills and experience being available. The number of participants shall be limited to ensure an efficient HAZOP process. For description of roles and responsibilities, including the requirement for an independent study leader, see IEC 61882, 6.3.

The documentation shall be in accordance with requirement in IEC 61882, 6.6, and the full recording method as described in 6.6.2 should be applied.

4.2.3 Overpressure protection

Overpressure protection shall be in accordance with the recommendations in API RP 14C/ISO 10418 and NORSOK P-001, clause 5, for systems as defined in 4.2.2. All scenarios as described in ISO 23251 shall be covered. A risk based design approach shall not be used to eliminate any of these standard scenarios. The existence of other credible scenarios shall be evaluated.

The low pressure side of a shell and tube heat exchanger shall be protected against overpressure in case of a sudden tube rupture. For further guidance, see ISO 23251.

Pressure protection of expansion tanks may require careful consideration, as all relief scenarios for the serviced system may also be relevant for the expansion tank. This includes scenarios such as heat exchanger internal failure, tube rupture with subsequent liquid displacement and gas blow-by. These potential causes of overpressure shall be taken into account when determining the design pressure of the expansion tank and when sizing the relief devices or vessel vent.

4.2.4 Water hammer

The potential for water hammer in liquid lines shall be evaluated, and application of sound engineering practice will typically be required to prevent this phenomenon.

Water hammer can typically not be controlled by use of pressure relief devices due to the fast dynamics of the pressure fluctuations. Water hammer is often avoided by ensuring that block valves in the liquid line has a closure time that is sufficiently long. A detailed analysis may be required to determine an acceptable closure time. Such valves shall be included in the preventive maintenance program and be tested regularly, including testing of the criterion for required closure time to prevent water hammer. The system should be designed such that the pressure relief devices, including rupture discs, are not activated as a result of pressure fluctuations.

Joints in glass fiber reinforced plastic piping systems are typically susceptible to the effects of water hammer and the design of such systems may require careful consideration.

4.2.5 Check valves

When two check valves are installed in series to prevent overpressure by reverse flow, leakage shall be tested, e.g. by monitoring of the intermediate pressure. Upstream PSV shall be designed for leakage through the check valves. The leakage area is typically 1 % opening of the cross sectional area of the largest pipe, unless available information from the valve manufacturer dictates the use of a more stringent criterion. For more guidance, see ISO 23251.

If credit is taken for check valves in determining required relief flow, the check valves shall be tagged, defined as safety critical and included in a maintenance program.

4.2.6 Piping

Hydrocarbon lines through non-hazardous area should be avoided; if not, the pipes shall be welded.

4.3 Maintenance and isolation

Equipment that requires removal for maintenance shall be provided with pipe spools.

It shall be possible to remove pumps and clean the suction strainer without draining upstream tank/vessels. Provision shall be made for withdrawal of sump pumps during operation of the system without loss of blanket or purge gas and minimizing liquid flashing to atmosphere, e.g. by use of a well inside the tank.

Bypass piping should be considered installed across heaters, coolers, filters and coalescers.

Nozzles on pressure vessels and atmospheric tanks shall be provided with spectacle blinds. For general isolation requirements, reference is made to NORSOK P-001.

Utility stations shall be located to enable flushing of all drip trays and mechanical equipment.

5 General process equipment design

5.1 Horizontal separator design

5.1.1 General

Separator inlet and outlet process nozzles (gas, oil, water) should be sized a minimum of one standard dimension larger than the connected piping, to give possibility for future capacity increase.

Gas nozzles with connection to flare shall be located at top of tank to avoid liquid carry-over. The instrument nozzles shall be located to minimize potential for blockage.

5.1.2 Separator sizing

5.1.2.1 Gas velocity

For calculation of gas velocity, guidance can be found in GPSA, chapter 7. The calculation shall be based on a liquid level corresponding to LAHH.

5.1.2.2 Liquid residence time

The residence time shall be calculated from normal levels in the separator. The effective separation volume, from where the residence time shall be calculated, is from the flow straightening plate (if installed) to the weir plate.

5.1.2.3 Liquid levels

The residence time between normal operating and alarm level and between alarm level and trip level shall not be less than 30 s. However, the distance between each of these levels shall not be less than 100 mm. For floating installations, additional margins may be required to account for motion effects.

The maximum slug volume shall be accounted for between normal and alarm liquid level.

5.1.3 Separator internals

5.1.3.1 General

For certain types of separator internals (e.g. inlet cyclones and gas demisters), the turndown of the equipment is important for its performance. In such cases, both minimum and maximum liquid, crude oil, water and gas rates shall be considered.

Increased internal pressure drop caused by fouling shall be considered for all relevant scenarios, including pressure drop in drain pipes (from gas outlet internals).

On floating installations motion/wave-dampening internals shall be installed.

The separator design shall ensure that undesired channelling, non-plug flow or short circuit flows do not occur in liquid or gas phase.

5.1.3.2 Inlet internals

The inlet internals shall prevent generation of foam and emulsion and small droplets.

The internals shall be designed to withstand all forces during normal operation and upset conditions, including relevant slug flow cases. Reactions on the vessel and nozzles shall be included. These forces shall be included in the vessel specifications. Determination of forces caused by slug flow may require detailed engineering analysis. For guidance, reference is made to GPSA, section 17.

Flow induced vibration and fatigue, including fluttering or resonance, shall be considered. However, due to the complexity of these phenomena, a detailed analysis may not be possible. Simple conservative assumptions for robust design will typically be more appropriate.

A flow straightening device should be located downstream the inlet device and should cover the full cross-sectional area. Care should be taken to avoid plugging due to fouling, e.g. scale, solids, asphaltenes, etc.

5.1.3.3 Gas phase internals

Gas outlet nozzles shall be provided with demister internals. The liquid collected by the gas outlet device shall be drained by a drain pipe to the bottom of the separator. The pipe shall be submerged below the LALL.

Sufficient drainage head shall be assured, so that liquid carry-over through the drain pipe does not occur. The total differential pressure over the demisting section, measured in liquid height, shall not be more than 50 % of the available drainage height related to LAHH. The drainage is normally internal, into the vessel bottom, but should be routed externally in case of insufficient drainage height.

5.1.3.4 Liquid phase internals

The use of internals in the liquid phase should be minimised due to potential clogging. Internals for improved efficiency of liquid/liquid separation shall be applied based on knowledge about emulsifying and separability characteristics and fouling mechanisms, e.g. scaling, sand accumulation and deposits of heavy hydrocarbons.

Liquid outlet nozzles shall be provided with vortex breakers.

5.1.3.5 Solids removal

All production separators shall have nozzles for sand removal.

When solid production is expected, all production separators shall have facilities for sand removal. The system shall provide efficient sand removal along the entire length of the separator.

5.2 Scrubber design

5.2.1 General

Vertical scrubbers are used for separation of liquid from streams with high gas-to-liquid ratios to protect downstream equipment from liquid carry-over. For elimination of very fine mist (droplet size < 3 microns) filter separators are required. Filter separators are not covered in this NORSOK standard.

5.2.2 Definitions

K-value	= $V_s [(\rho_g / (\rho_l - \rho_g))]^{0.5}$ (m/s), design factor for demisting internals
V_s	= flow rate/available cross-sectional area, superficial gas velocity (m/s)
ρ_g	= gas density (kg/m^3)
ρ_l	= liquid density (kg/m^3)
ρ_b	= bulk fluid density (kg/m^3)

5.2.3 Nozzles and sampling

Sampling points should be provided to monitor the scrubber performance.

Instrument nozzles in the gas phase shall be protected against liquid and high velocity gas flow to avoid erroneous readings.

5.2.4 Design rates and vessel sizing

For compressor suction scrubbers, the entire compressor operating envelope, including turndown, shall be checked when specifying scrubber design rates. A minimum margin of 10 % shall be added to the maximum operating flow rates, to allow for fluctuations due to process control. The specification for maximum allowable liquid entrainment from the scrubber, shall be set in agreement with the downstream equipment vendor.

The residence time between normal operating and alarm level and between alarm level and trip level shall not be less than 30 s. However, the distance between each of these levels should not be less than 100 mm. The motion of floating installations shall be considered and may increase the required distance between levels.

Typical minimum distance between scrubber elements

Adequate distance between scrubber elements shall be provided to ensure an even gas distribution and to avoid re-entrainment from the liquid surface. The following minimum values may be used as guidance, although adequate distance depends on scrubber type and configuration of internals:

- | | | |
|--|---|--|
| • inlet internals to LAHH | : | largest of 300 mm and inlet nozzle diameter; |
| • inlet internals to only mesh for demisting | : | 900 mm; |
| • inlet internals to vane with horizontal gas flow | : | 500 mm; |
| • inlet internals to mesh as agglomerator | : | 750 mm; |
| • mesh to outlet cyclones | : | 750 mm. |

5.2.5 Level instrumentation

The instrumentation shall be designed so that

- offset due to variations in liquid and gas densities is minimized,
- level instruments are not connected to the liquid outlet,
- the level glass covers the total range from LALL to LAHH,
- insulation and heat tracing on the level instrumentation on scrubbers/contactors shall be provided to prevent condensation and hydrate formation. Facilities for condensate drainage of level glasses and transmitters shall be provided through a separate drain connection (level glasses and transmitters with three nozzles).

5.2.6 Scrubber internals

5.2.6.1 Inlet internals

Flow regime correlations should be used when determining the fraction of mist versus bulk liquid in the inlet pipe. The upstream piping shall be designed without pockets that can lead to slug flow into the scrubber.

An inlet device shall be installed. The inlet device shall reduce the inlet momentum, separate bulk liquid with minimum creation or break-up of droplets, and create good vapour distribution. The operating envelope is limited for some types of inlet devices, and the full operating envelope shall be considered in the selection.

For inlet vane the maximum inlet momentum should typically be limited to 6 000 kg/ms². The scrubber inlet piping should be designed with pipe diameter corresponding to this inlet momentum for sufficient length to ensure homogenous flow at inlet nozzle.

When designing the inlet device, conservative liquid carry-over from upstream equipment (e.g. separators) shall be assumed. In addition, condensation +10 % margin from upstream coolers should be used.

5.2.6.2 Mesh pad

The K-value for a mesh pad as demister should be below 0,10 m/s. At K-values above 0,10 m/s the mesh may be flooded.

At elevated pressures and in critical service, the K-value shall be multiplied by an adjustment factor. The adjustment factor is typically in the range 0,75 to 1,00 and decreasing with increasing pressure. Further guidance is given in GPSA, section 7, fig. 7-9.

5.2.6.3 Demisting vanes

The sizing factors given in Table 1 should be applied for demisting vane elements.

Table 1 – Sizing factors for demisting vanes

	Vertical gas flow	Horizontal gas flow
ρV_s^2 (kg/ms ²)	20 to 30	30 to 45
K-value (m/s)	0,12 to 0,15	0,20 to 0,25

The liquid collected by the vanes shall be collected and drained by a drain pipe to the sump of the scrubber. The pipe outlet shall be submerged below the LALL. Sufficient drainage head shall be assured, so that liquid carry-over through the drain pipe is avoided, see 5.1.3.3.

5.2.6.4 Demisting cyclones

For axial cyclones, typical minimum droplet removal size is 5 microns to 10 microns, depending on swirl velocity. The typical pressure drop is 20 mbar to 100 mbar. The total differential pressure over the demisting section, measured in liquid height, shall not be more than 50 % of the available drainage height related to LAHH. The cyclone deck shall be equipped with drainage to avoid liquid accumulation. The drainage is normally internal, into the vessel bottom, but should be routed externally in case of insufficient drainage height.

A cyclone based scrubber should have a mesh upstream the cyclones. The mesh will act as a demister at low gas rates, and as an agglomerator at high gas rates. The performance curves of the mesh and cyclones shall overlap to assure good demisting in the whole operating range.

Scrubbers with cyclones have been successfully implemented in both high and low pressure applications. Scrubber with inlet vane and mesh and cyclones should typically be sized for a maximum vessel K-factor of 0,15 m/s.