

Process systems

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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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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

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
GPSA: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.

5.3 Heat exchanger design

5.3.1 General

5.3.1.1 Definitions

Primary side: Main process fluid or main utility fluid
Secondary side: Utility fluid

The requirements given in 5.3.1.2 to 5.3.4 are formulated for process heaters and coolers, and some requirements may therefore not be applicable for process/process exchangers.

If not otherwise specified, the term “design temperature” as used in 5.3, is the temperature used to design the heat exchanger area.

5.3.1.2 Design of heat exchanger area

Primary side design case

Normally the maximum continuous duty will determine the heat exchanger area, but for heat exchangers in a compressor train, the heat exchanger area shall be designed for all continuous operating cases including

- all realistic flow rates and temperatures determined by the compressor curves;
- recycle flow rate and temperature along the whole anti-surge control line of the compressor.

Temperature drop over anti-surge valve should be included. For a heat exchanger in an oil train the heat exchanger shall be designed for all realistic flow rates and temperatures.

Design margin

Fouling or extra heat exchanger area should be added as a design margin. Recommendations and requirements are given in TEMA. Beware that such design margins easily can bring the wall temperature to fouling conditions (e.g. hydrate, wax, scale, decomposed glycol/degenerated glycol, coking) during turndown.

Primary side margin

In the design of the heat exchanger area, the primary side temperatures should have the following design margins:

- a heat exchanger which has its feed from gas compressors should have its inlet gas temperature increased by 10 °C;
- a heat exchanger which has its feed from production separators should have its inlet fluid temperature increased (coolers) /decreased (heaters) by 5 °C;
- a heat exchanger which has its feed from both gas compressors and production separators, should have its inlet fluid temperature increased based on +10 °C from the compressor and +5 °C from the separator.

An alternative is to increase the secondary side design flow rate to handle the same temperature margins without increasing the heat exchanger area.

Secondary side margin

The heat exchanger area should be determined based on the following considerations for the secondary side:

- highest normal supply temperature of cooling fluid;
- lowest normal supply temperature of heating fluid;
- capacity limitations for secondary fluid.

5.3.1.3 Cleaning requirements

Nozzles for chemical flushing should be located on the heat exchanger or on the piping close to the heat exchanger to minimise chemical consumption (volume to be flushed). Nozzles for chemical cleaning and vent/drain can be combined.

5.3.1.4 Bulk outlet temperature requirements

The bulk outlet temperature of the primary fluid shall under no circumstances, neither intermittent nor continuous, be below the wax or hydrate formation temperature. Beware that a multi-pass heat exchanger

with its first pass as counter-current flow may have internal temperatures which are below the bulk outlet temperature at turndown conditions.

A requirement for minimum temperature change of secondary fluid should be established to reduce the required flow.

5.3.1.5 Skin temperature

The skin temperature is the temperature outside the fouling layer or the metal surface temperature for a clean heat exchanger.

Primary side of shell and tube heat exchangers and plate heat exchangers

The skin temperature shall be kept above the hydrate formation temperature or wax appearance point and below any temperature that will cause other fouling, e.g. coking. Temporary deposit may be acceptable if these deposits will disappear when the heat exchanger is brought back to normal operation.

Secondary side of shell and tube heat exchangers and plate heat exchangers

Skin temperature for sea water shall be kept below 60 °C to avoid scale deposition on the heat exchanger wall. Exception can be taken if parallel 100 % equipment is installed so that regeneration or cleaning of the standby unit can be done during operation. For a clean heat exchanger, seawater skin temperature above 60 °C is acceptable. When the exchanger has reached its design fouling condition, skin temperature on the seawater side above 60 °C is not acceptable.

For an exchanger, which is designed with “extra heat exchanger area” as design margin, the following apply:

- skin temperatures above 60 °C shall not occur in the area of the exchanger which is equal in size to the area before extra design margin was added;
- skin temperatures above 60 °C can be accepted, but should be avoided, in the area of the exchanger which is equal in size to the extra design margin added to the heat exchanger.

Skin temperature for coolant with anti-freeze (e.g. glycol mixtures) shall be kept below the decomposition temperature of the anti-freeze.

The maximum/minimum skin temperature is normally calculated from one of the operating cases listed in Table 2 and Table 3. The heat exchanger skin temperature shall as a minimum be simulated for these operating cases (performance simulation with total heat exchanger area, i.e. for an exchanger designed with “extra heat exchanger area” as design margin, the extra area shall be included).

Table 2 – Off-design cases to be checked for skin temperatures where its primary side flow rate is determined by a compressor

Conditions to be used in the performance simulation (see key)	1	2	3	4
Clean and fouled heat exchanger/minimum flow	X		X	X
Clean and fouled heat exchanger/maximum flow		X	X	X
Key 1. Gas flow rate defined by the compressor in the same recycle loop as the cooler operating at surge flow and minimum speed. 2. Gas flow rate defined by the compressor in the same recycle loop as the cooler operating at surge flow and maximum speed. 3. Gas temperature defined by the heat exchanger feed equipment(s) with a margin on the gas temperature from compressor(s) of +10 °C or 10 % in °C, whichever is the larger, due to compressor wear and tear (and variation in compressor inlet temperature). 4. Minimum operating temperature of the cooling medium (cooler) or maximum operating temperature of the heating medium (heater).				

Table 3 – Off-design cases to be checked for skin temperatures for a liquid heat exchanger where its primary side flow rate is determined by a separator control system (pump or valve)

Conditions to be used in the performance simulation (see key)	1	2	3
Clean heat exchanger (no fouling)	X	X	X
Fouled heat exchanger (at design fouling conditions)	X	X	X
Key 1. Minimum operating temperature of the cooling medium (cooler) or maximum operating temperature of the heating medium (heater). 2. Minimum normal operating flow of the primary fluid. 3. Cooler: Maximum normal operating primary side temperature plus a margin of +5 °C due to uncertainties in well fluid temperature. Heater: Minimum normal operating primary side temperature with a margin of minus 5 °C due to uncertainties in well fluid temperature.			

Skin temperatures along the heat transfer area shall be reported for both the hot and cold side.

5.3.1.6 Heat exchanger failure and contamination of low pressure side

In order to limit contamination of the low pressure utility side through back flow in the event of internal leakage or tube rupture, a check valve or shut down valve may be installed in the upstream piping connected to a shell and tube heat exchanger. The use of shut down valves in the utility piping may further limit the contamination of the system.

5.3.2 Shell and tube heat exchangers

Shell and tube heat exchangers shall be designed such that the flow of the shell-side fluid will not cause severe tube vibration which can damage the tube bundle or tube sheet. The main flow-induced tube vibration phenomena are vortex shedding, turbulent buffeting, fluid elastic instability and acoustic vibration. Special attention shall be given to high velocities of the fluid leaving the impingement device. The analysis shall cover all relevant shell-side flow scenarios with corresponding span in temperature, pressure and gas-liquid ratio, including upset conditions. Fully open temperature control valve and high operating pressure on the secondary side shall be considered.

5.3.3 Compact heat exchangers/printed circuit heat exchangers

Printed circuit heat exchangers can be used for clean service. Special attention shall be given to the following:

- particles: A permanent strainer shall be fitted on the inlet of both sides of a PCHE according to manufacturer's recommendation. Typically 300 microns is used;
- the temperature control shall be designed to limit thermal cycling to avoid fatigue. A travel stop for 20 % minimum flow through the control valve is recommended.

Pressure drop over strainers and heat exchanger core shall be monitored. PCHEs are not recommended when sea water is used as coolant.

Wall temperatures along the heat transfer area shall be calculated and documented for both the hot and cold side for the two outer channels of the plate and the mid channel of the plate.

5.3.4 Plate heat exchanger

Plate heat exchangers shall be designed such that a stable overpressure on one side is maintained. Varying pressure difference may cause mechanical fatigue of the plates.

5.4 Pig launcher/receiver design

Pig launcher and pig receiver shall be equipped with a system ensuring that the launcher door is not opened when the equipment is pressurised and that isolation valves around the launcher will not be opened when the launcher door is open.

Local pressure monitoring shall be provided for pig launchers and pig receivers. When frequent pigging is necessary, pressure monitoring and pig detector alarm may also be required. Pig receivers/launchers shall

be connected to flare, vent and drain system with hard piping. Pig receivers and launchers shall be provided with nozzle/valve to allow purging and to verify that the system is completely depressurised prior to opening the door.

5.5 Filters

A correct design of filters may require a thorough evaluation of the degree of contamination of the flow into the filter. The filters shall be designed so that maintenance work on the filter (i.e. cleaning/exchange of filtration units) can be performed with an acceptable frequency.

The collapse pressure of a dirty filter shall be identified and evaluated as part of system design.

6 Topside flow lines and manifolds (system 13)

6.1 General

The topside flow lines and manifolds system shall gather and transfer well stream from individual wells to downstream systems.

6.2 System design

Erosion, particularly in bends, from well clean-up and backflow operations should be considered when determining required wall thickness.

Where scale formation is expected, provision for removal of scale shall be installed.

Individual well flowlines should be accessible for maintenance and hook-up without shut-down of manifolds.

Drainage of flowlines and manifolds to the closed drain system shall be provided.

6.3 Monitoring

Pressure and temperature transmitters should be included upstream and downstream of the choke valve. The choke valve should have position feedback. The chokes should be remotely operated from the CCR with local manual override.

6.4 Safety

Choke valve failure and valve maloperation may result in flow rates that are higher than the maximum flow given by the production profiles. For detailed description of such scenarios and associated relief rates, see 16.2.

7 Separation and stabilisation (system 20)

7.1 General

The separation and stabilisation system shall separate and stabilise the hydrocarbon liquid.

7.2 Pressure and level control

Pressure control shall be designed to avoid shut-down of the oil separation train(s) as a result of gas compression shut-down. Installation of a full-flow bypass (with valve suitable for regulation) across all level control valves should be considered.

7.3 Test separator

The size shall as a minimum cater for the maximum production from any well.

The test separator should have monitoring of pressure, temperature(s) and outlet flows. Slug flow may require additional control.

Sampling of oil and water from the test separator shall be possible. The sampling stations shall be permanently piped to flare/vent and drain.

7.4 Layout

The following layout recommendations and requirements apply:

- level control valves should be located to avoid flashing upstream the valves, and to minimise slugging in the lines downstream such valves. Pressure variations and corresponding effect on boiling point should be considered;
- the layout should allow for gravity draining of the separators (without pockets in the drain lines) to the closed drain system;
- jet water disposal lines should have no pockets to avoid sand accumulation and blockage;
- for plate heat exchangers used for oil cooling, the layout should be such that flashing will not occur in the cooler.

7.5 Injection of chemicals

Injection points for production chemicals should be installed upstream all separator inlets. Locating the injection points upstream the production choke should be considered to improve efficiency. When two or more chemicals are injected into the same stream, it should be checked whether a minimum distance is required between the injection points.

8 Crude handling (system 21)

8.1 General

The crude handling and metering system shall meter the oil flow and provide the oil export pressure as required for export. The system may include facilities for pigging.

8.2 Design requirements

If the wax appearance temperature (cloud point) is less than the cold medium inlet temperature, a counter-current heat exchanger is recommended. Further information on heat exchanger design is given in 5.3.

Export cooler spare unit should be considered when de-waxing operations are required. The selection of fixed speed vs. variable speed should be based on operating energy and utility consumption and the power considerations during start up and tail end production. Normally, booster pumps are supplied with fixed speed, while the export pumps are supplied with variable speed drive.

If pump motors cannot tolerate free flow, a control valve to establish back pressure or other means of controlling pump motor load shall be included.

8.3 Safety

An emergency shutdown valve shall be installed downstream export pump and as close to riser or offloading hose (for shuttle tanker) as possible.

Before and after shuttle tanker loading, the hose shall be purged with inert gas. Permanent connection should be provided.

Systems and components between oil export/off-loading and storage facilities are often characterized by different areas of responsibility, various pressure ratings and design codes. The set pressure of the devices for overpressure protection shall be determined by the pressure rating required overpressure protection for all components in the downstream system. The setting of the functions for overpressure protection may be determined by downstream components (e.g. hoses, piping and valves at the receiving end), unless these are adequately protected by dedicated relief devices in the low-pressure system.

Pressure effect of unexpected "slam-shut" of valves shall be considered. For further information, see 4.2.4.

Further requirements are given in FOR 1994-02-10 nr 123, § 35, and DNV-OS-E201, chapter 2, section 4.

9 Gas compression (system 23 and 27)

9.1 General

The gas compression systems shall collect the gas from the different stages of separation, cool it, remove condensed liquids and compress the gas to a pressure suitable for export and or re-injection.

9.2 System design

To optimise compressor system design, the intermediate operating pressure(s) and drive selection shall be based on an energy optimisation study and compressor vendor recommendations. The system shall be capable of handling the variations in capacity and gas compositions resulting from operations over the lifetime of the field at the required delivery pressure. Re-bundling of compressors may be required to achieve this, and shall be evaluated.

Where a significant reduction in molecular weight can occur during start-up or recycling, a line to flare shall be provided to allow light gas to be discharged to enable the compressor to produce sufficient discharge pressure to establish forward flow.

Where two compression trains are running in parallel, the transient conditions when one compressor trips, shall be considered. The coolers and scrubbers should be able to withstand the maximum flow that the running compressor can handle at minimum discharge pressure without incurring mechanical damage.

The conditions downstream the liquid control valve shall be checked for hydrate formation, and suitable precautions taken.

Pump system design and location shall ensure that sufficient NPSH is maintained during fast pressure transients which may cause liquid flashing.

Bypass valves or control valves shall be installed to enable pressurization of the system during start-up.

If compact heat exchangers are used, temporary spools bypassing the exchangers should be provided to allow full flow flushing of the cold side piping. Temporary inlet strainers/filters shall be installed upstream compact heat exchangers on both sides. Filters should be located as close to the heat exchangers as possible. Vendor shall be consulted to determine required filtration grade.

9.3 Compressors

Temporary strainers shall be installed upstream each compressor.

If dry gas seals are used, the hydrocarbon seal gas shall be dehydrated, dew point controlled or superheated to prevent condensation or hydrate formation. For start-up purpose, use of nitrogen should be evaluated as a mean to avoid liquid drop out.

Arrangement for direct filtering and filling of seal oil, plus drainage of seal and lube oil to closed drain should be installed.

9.4 Pressure relief and depressuring

When determining required relief capacity downstream the compressor, the following shall be taken into consideration:

- maximum power available;
- maximum speed;
- maximum pressure on suction side (no credit for response in PSD system shall be taken in determining the maximum suction pressure);
- higher than normal molecular weight, if applicable;
- low suction temperature.

Overpressure protection of the scrubber shall take into account leakage from a centrifugal compressor discharge side if the discharge check valve fails to close on compressor shutdown. If, in case of check valve failure, the common settle out pressure exceeds the design pressure of the suction side, two check valves shall be installed in series.

Further guidance for determination of the relief rate is given in ISO 23251.

Automatic depressurisation due to seal oil/seal gas failure shall be included. Maximum depressurisation rate (dP/dt) shall be specified by compressor vendor to ensure seal integrity.

9.5 Layout

Coolers and compressors should be elevated above scrubbers. Lines shall slope towards scrubber. Anti-surge line shall be sloped with the anti-surge valve at the highest point. When hydrate inhibitor injection is required upstream the cooler, the piping shall slope from injection point towards the cooler.

To reduce the settle out pressure, the discharge side volume of centrifugal compressors shall be minimised, e.g. pre-cooling is preferable as opposed to discharge cooling. The check valve(s) should be located as close to the compressor as possible, but downstream of the anti-surge recycle line and any discharge PSV.

10 Gas treatment (system 24)

10.1 General

The dehydration system shall remove water vapour from the gas to a level suitable for transport, injection and/or further processing.

10.2 Glycol contactors

The movements on floating installations shall be taken into account when designing the glycol distributor, packing, chimney tray and glycol circulation rate.

The volume of the bottom section of the glycol contactor shall be designed to handle liquid draining from the packing/trays without initiating high level.

Packing/internals

Structured packing should be used rather than trays. Packing selection should emphasise capacity and low pressure drop in preference to high efficiency and low glycol circulation rate.

A distribution device shall be installed to provide an even distribution across the packing. Some types of distribution devices are susceptible to blocking from sludge, scale, or corrosion products accumulating in the glycol. To prevent this, a filter may be installed upstream the contactor.

The contactor internals shall be able to withstand the maximum gas velocity that may occur under any operating condition, including backflow, without sustaining mechanical damage.

To minimise glycol losses, a demisting device shall be located at the gas outlet of the vessel. Sufficient height should be allowed above the demister to assure that gas coning will not occur.

The chimney tray hats shall be designed to avoid liquid entrainment from hats.

The differential pressure across the glycol contactor should be monitored.

Condensation

A scrubber shall be provided upstream the contactor, either as a separate vessel, or integrated in the same vessel as the contacting section. Care should be taken to prevent condensation due to pressure or temperature drop in the line between the upstream scrubber and the glycol contactor. Alternatively superheating of gas might be required to avoid condensation in the contactor.

Facilities for skimming of condensate from the glycol should be provided. The skimming line shall be fitted with a valve to close on PSD and high level in the contactor to avoid loss of glycol during shutdowns.

The glycol inlet temperature shall be maintained 5 °C above the feed gas temperature to prevent condensation where the glycol enters the contactor.

10.3 Regeneration unit and storage

A bypass line around the glycol contactor shall be provided to allow circulation and heating of the glycol in periods where the contactor is not operating. In this mode the glycol will not contain any gas, and fuel gas may be required to provide sufficient pressure in the regeneration system.

Isolation shall be provided to allow maintenance on all parts of the regeneration system without having to depressurise the contactor column.

A flow meter shall be installed in the glycol line upstream the contactor. The differential pressure across the glycol filters should be monitored. Local indication of glycol flow to the stripping column should be provided.

For gas stripping regeneration towers, structured packing is recommended.

Where recirculation of a stripping gas or stripping agent is selected, the system shall be designed to avoid build up of CO₂, H₂S and methanol. Note that methanol lowers the boiling point of the glycol.

Glycol drainage

Drainage of all equipment shall be collected in a dedicated glycol sump. Both the sump and storage tank shall be blanketed by inert gas to prevent oxidation of the glycol. The vent shall be routed to a safe location. The oxygen level in the inert gas shall be sufficiently low to prevent oxidation. To establish acceptable oxygen levels the glycol supplier should be contacted.

Chemicals

Provision shall be made to inject antifoam, although this should only be used as a last resort as it can cause some fouling in the contactor tower. Provision shall be made to inject antifoam, although this should only be used as a last resort as it can cause some fouling in the contactor tower. The need for further injection points shall be considered.

Re-boiler

When electric heating elements are used for re-boiling, it shall be possible to remove individual elements without draining the unit. The heater skin temperature shall not cause thermal decomposition of the glycol during normal operation and fluctuations. The re-boiler shall be designed for full vacuum.

Glycol flash tank

Condensate removal facilities shall be installed.

Glycol filtration

Glycol filters shall be provided to remove particulate degradation and corrosion products from the lean glycol. If differential pressure is used as an indicator for filter replacement on a slip stream filter, a flow meter shall be installed.

Still column

Dissolved hydrocarbons, mainly aromatics, may be present in the feed to the glycol re-boiler. These will be vaporised in the reboiler and may cause flooding in the still column. This shall be evaluated in the design of the still column, notably the increased vapour flow rate and the extra duty in the re-boiler.

Structured packing is recommended in the still column. The upper section of the still column will have low liquid load, while the lower section will have a higher load. This shall be reflected in the selection of packing material.

To minimise glycol losses while maintaining sufficient glycol purity, the temperature in the top of the still column shall be monitored.

There may be potential for CO₂ corrosion in the upper section of the still column, and this shall be considered in the material selection.

10.4 Wet gas inlet coolers

The inlet gas to the dehydration unit should be cooled to limit the water load. The system shall be designed to avoid hydrate formation caused by low skin temperatures in the cooler.

10.5 Pressure relief

Selection of pressure rating and the need for overpressure protection shall take into consideration the potential for clogging of the glycol line downstream of the glycol contactor.

10.6 Layout

It is recommended to locate the contactor in a location not exposed to weather and wind to avoid insulating the vessel due to condensation.

The distance from the scrubber to the contactor should be minimized to avoid condensation.

The temperature transmitter controlling the glycol feed temperature to the contactor shall be located close to the contactor. This will ensure correct glycol temperature independent of ambient temperature and wind chilling.

Outlet piping from glycol re-boiler should be designed to minimise backpressure on the re-boiler.

10.7 Environmental requirements

The atmospheric discharge of stripping gas and aromatics shall be minimized or preferably avoided. For further environmental requirements and recommendations, reference is made to NORSOK S-003. Electric heating of glycol re-boilers has a low thermal efficiency. It should therefore be evaluated to use heating medium, preferably from waste heat recovery for this purpose. This will reduce CO₂ emissions.

It shall be possible to regulate the glycol circulation rate to the contactor to match the gas production rate. This will also reduce overall energy consumption.

Direct fired reboiler shall only be considered after a rigorous evaluation of all relevant safety and environmental aspects.

11 Gas conditioning (system 25)

11.1 General

The objective of the gas conditioning system is to process the feed gas stream to meet the downstream requirement and/or optimise the economic value of the products.

The gas conditioning system shall lower the hydrocarbon dew point to a level suitable for transport, injection or sales gas requirements.

The system shall be capable of handling the variations in capacity and gas compositions during the lifetime of the field.

11.2 Heat exchangers and scrubbers

It shall be possible to bypass the cold stream(s) to allow melting of any hydrates and/or ice and for temperature control.

Differential pressure protection of the heat exchanger shall be considered if the heat exchanger is installed inside a pressure vessel (e.g. scrubber) and the heat exchanger design pressure is based on elevated surrounding pressure.

The liquid removal efficiency of the scrubber shall match the requirements of the turboexpander to protect the downstream equipment and maintain product specifications.

Where two trains are running in parallel, the transient conditions when one train trips, shall be considered. The coolers and scrubbers shall be able to withstand the maximum flow through the expander at minimum discharge pressure without incurring mechanical damage.

The heat exchanger should have temperature monitoring on both hot and cold side stream(s).

11.3 Turbo expander and recompressor unit

Hydrate inhibitor injection points shall be provided at the expander for start-up purposes. The liquid fraction in the turbo expander outlet stream should typically be limited to 20 % to 30 % by mass. This limitation may require two turbo expanders with inter-stage liquid separation.

A Joule-Thomson (JT) valve system should be installed in parallel with the turbo expander. The Joule-Thomson (JT) valve is used during start-up to ensure a smooth start-up of the turbo expander and as back-up when the turbo expander is out of service.

Vendor shall verify the requirements for start-up, turndown and anti surge control.

Consideration shall be given to the formation of solids in the gas stream, e.g. freezing of CO₂.

Temporary strainers should be installed upstream the expander and the re-compressor.

If dry compressor seals are used, the seal gas should be dehydrated and dew point controlled or superheated to prevent condensation and hydrate formation.

Lubrication oil and seal oil drain and filling from tote tanks shall be hard-piped.

The expander is normally equipped with guide vanes. Capacity control should not only rely on guide vanes throttling since leak rate through "closed" guide vanes can be very high. To ensure soft shut down and sufficient turn down capability a control valve upstream the expander may be required.

11.4 Design pressure and temperature

The design pressure shall be equal through the whole system. Pressure increase and/or temperature drop caused by liquid boil-off during shutdown and depressurisation of isolated system shall be considered. Use of nitrogen purging for gas freeing prior to maintenance operations may further increase the boil-off rate.

11.5 Layout

The feed line to the expander and the compressor shall be sloped to ensure that liquid condensed in the piping is drained back to the inlet scrubber/separator.

The anti-surge line should be sloped with the anti-surge valve at the highest point.

12 Water injection (system 29)

12.1 General

The water injection system shall deliver water at high pressure to maintain reservoir pressure or for disposal.

Some of the requirements in this clause may not be valid for a particular project due to reservoir conditions and/or material selection. Such requirements can be omitted. Typical examples are filtration, disinfection and de-oxygenation.

Sampling points shall be provided for monitoring of water quality and process performance.

12.2 Filtration

Filters or other means for particle removal should be installed on the suction side of the injection pumps to protect the pumps and reservoir from sand and other residues. The maximum particle size shall be verified for each project based on reservoir and pump.

12.3 Disinfection

Disinfection, if required, shall be achieved with a minimum use of chemicals. Seawater supply shall be chlorinated, unless already chlorinated at the seawater intake. Disinfection can be achieved by use of ultra violet sterilising units as an alternative to injection of organic biocides.

12.4 Deoxygenation

If carbon steel piping and vessels are used, the seawater shall be deoxygenated.

Deoxygenating should be achieved without the use of chemicals.

For vacuum de-aeration tower(s) the following apply:

- vacuum pumps should be oversized by 20 % due to possible leakage in gaskets;
- deoxygenated water should flow into a buffer tank (normally part of the deaerator). Upstream of the buffer tank, provision shall be made for injection of chemicals for oxygen removal in case of operational problems. The buffer tank should be sized based on necessary time for the chemical to react and to ensure stable system conditions in case of fluctuations in seawater supply.

Other processes for oxygen removal may also be used, e.g. stripping gas.

12.5 Pumps

Start up return/dump line shall be installed downstream the booster pump.

The injection pumps should be of variable speed type. Adequate buffer volume shall be provided upstream the injection pumps to ensure safe run-down in shutdown scenarios.

12.6 Chemical injection

The interaction of different chemicals and location of injection points shall be considered as some chemicals react with each other.

The use of ferric chloride or equivalent coagulants to enhance filtration efficiency should be avoided due to negative experience with iron oxide precipitation in seawater injection systems.

12.7 Monitoring

The differential pressure across the filters, the oxygen concentration downstream the deoxygenation unit, pressure in the buffer tank, the discharge of the booster and injection pumps, and system flow should be monitored.

13 Cooling medium (system 40)

13.1 General

The cooling medium system shall remove heat from process and utility systems where direct seawater cooling and air cooling is not applicable.

If the cooling medium has a freezing point above minimum ambient conditions, measures shall be implemented to prevent freezing.

Injection of corrosion inhibitor/pH stabiliser upstream of pumps should be provided for carbon steel systems.

Connection to emergency or essential power should be considered.

The system shall be sized for the sum of all normal continuous operating loads plus an appropriate margin.

A permanent filling line shall be installed. Facilities shall be available for drainage by gravity to tank or boat.

13.2 Filtration

If the piping in the cooling medium system is made of carbon steel, a slip stream filter shall be installed. This filter is typically designed to remove particles larger than 80 microns. The slip stream rate should be approximately 10 % of the total flow rate. For cooling medium systems with PCHEs, the heat exchanger vendor shall be consulted regarding filtration grade.

13.3 System operating pressure

Cooling medium should be maintained at a higher pressure than the seawater in the cooling medium cooler to prevent seawater (chloride) migration into the cooling medium. Also the pressure in the cooling medium

system should be sufficiently high to avoid boiling during turndown or stagnant conditions. The required pressure shall be calculated at the maximum operating hot side temperature in the heat exchanger.

13.4 Expansion tank

An expansion tank shall be included in the system. The tank should be blanketed with inert gas with spill off to flare to prevent oxidation and degradation.

In determining the design pressure of the expansion tank, the back pressure during flaring (typically during heat exchanger rupture conditions) shall be considered. Thus, the effect of the flow from the point of rupture, through the tank to the flare shall be designed for.

The tank should typically be sized to cater for the volumetric expansion of the cooling medium within the 25 % and 75 % of the total tank volume (for temperatures between minimum ambient and maximum operating).

The expansion tank should have pressure and level monitoring. The tank shall also be equipped with a hydrocarbon detector to detect hydrocarbon leakages into the cooling medium system where the consumers contain hydrocarbons.

13.5 Layout

The following recommendations and requirements apply:

- cooling medium coolers should be located at low elevation to reduce seawater pump head;
- expansion tank shall be located at the highest point in the circulation loop;
- pipes and headers shall be arranged to reduce number of high points, to ease system priming and prevent local accumulation of gas;
- pipes and headers should be arranged to ease drainage, especially for systems subject to freezing.

14 Heating medium (system 41)

14.1 General

The heating medium systems shall provide heat to process and utility equipment. The heat may be supplied through a waste heat recovery system or other heat sources.

The need for a separate heating medium drain system shall be considered. The volume of heating medium storage should, as a minimum, be equal to the volume of the largest equipment.

The system shall be sized for the sum of all normal continuous operating loads plus an appropriate margin. Filling and drain lines should be hard-piped.

For severe hazards related to water entering a hot oil system, reference is made to ISO 23251.

14.2 Pumps

Pumps and motor should be sized for maximum viscosity of heating medium for start up at reduced rate. To ensure sufficient available NPSH it shall be assumed that the heating medium is at boiling point in the expansion tank.

14.3 Waste heat recovery units

It shall be possible to bypass the waste heat recovery tube bundle on the exhaust gas side to avoid boiling or decomposition of heating medium within the heating coil.

Minimum operating temperature for the exhaust gas should be sufficiently high to avoid condensation of water. A minimum temperature of 120 °C is commonly used. A sufficient minimum flow through heating coils in standby units should be secured to maintain system temperature, thereby allowing quick start and avoiding condensation on the heating tubes.

14.4 Filter

If the piping in the system is made of carbon steel, a slip stream filter shall be installed around the pumps to filtrate the flow with 80 microns filtration grade. The slip stream rate should be approximately 10 % of the total flow rate. For systems with PCHes, the heat exchanger vendor shall be consulted regarding filtration grade.

14.5 Expansion tank

An expansion tank shall be included in the system. The tank should be blanketed with inert gas with spill off to flare to prevent oxidation and degradation. The degradation rate as result of elevated temperature in the expansion tank shall be considered.

In determining the design pressure of the expansion tank, the back pressure during flaring (typically during heat exchanger rupture conditions) shall be considered. Thus, the effect of the flow from the point of rupture, through the tank to the flare shall be designed for.

The tank should typically be sized to cater for the volumetric expansion of the heating medium within the 25 % and 75 % of the total tank volume (for temperatures between minimum ambient and maximum operating).

The expansion tank should have pressure and level monitoring. The tank shall also be equipped with a hydrocarbon detector to detect hydrocarbon leakages into the heating medium system where the consumers contain hydrocarbons. If the heating medium is hot oil, the detector shall be capable of distinguishing between light hydrocarbons and hot oil vapours.

Low liquid level in the expansion tank shall open the bypass of the exhaust gas around the waste heat recovery unit tube bundle and stop the pump.

14.6 Layout

The heating medium expansion tank shall be located at the highest point in the heating medium system.

The system shall be designed such that accumulation of gas from leakages in local high points is minimised and the gas flows to the expansion tank

Low point drains should be installed to ensure easy drainage of the system,

Connections to route the hot oil through the expansion tank to dewater the system at start up should be considered.

15 Chemical injection (system 42)

15.1 General

The chemical injection system shall store, distribute and inject chemicals into the process and utility systems.

This system does not cover injection of hypochlorite or methanol as these are covered by system 46 (methanol injection) and 47 (chlorination).

Facilities for chemical injection shall have fixed arrangements for storage tanks and piping.

Each chemical shall have separate piping from tote tank laydown area to storage tank. If there are chemicals that can react with each other, these chemicals shall have unique identification on the fill hoses to avoid mixing.

System capacity shall be calculated as design load of continuous consumers plus peak load from intermittent consumers.

15.2 Storage tanks

Storage capacity should be based on supply frequency and required design margin.

Tote tanks should be located above storage tanks to ensure drainage of transfer lines/hoses and avoid the need for transfer pumps.

The storage tank should as a minimum have capacity corresponding to the volume of one tote tank.

Vent pipes from storage tanks shall be routed to a safe location.

The level in the storage tank should be monitored. For system where loss of injection is critical, the flow should also be monitored.

15.3 Drip trays and drainage

All chemical storage tanks, injection pumps and loading stations shall have drip trays to collect spillage.

The liquid overflow system and drip tray drains from the various tanks may be routed to a common manifold. The system shall have continuous slope, no dead legs and sufficient capacity to prevent back flow through the overflow line. The loading location shall be designed to handle the leakage of one tote tank without spillage to the open drain system or sea.

Chemicals that react with other fluids may require separate drain facilities. For environmental reasons, a dedicated drain tank for chemical polluted drain shall be evaluated. Drag reducers may react with water or hydrocarbons to form sticky slurry. Drain from such systems should be routed to a separate drain transport tank.

15.4 Injection points

Facilities shall be provided for calibration of flow to each consumer and proper mixing of chemical into the fluid.

A check valve and shut off valve shall be fitted as close to the injection point as possible.

Antifoam should be injected to prevent foaming in the deoxygenator. Scale inhibitor may be required to prevent scaling in the reservoir. Polyelectrolyte may be injected to enhance filtration efficiency in fine filters.

Filtration of chemicals for use upstream of topside and subsea valves may be necessary and the valve vendor should be consulted for detailed requirements. Strainer on fill line to storage tank and pump suction is recommended.

15.5 Safety

Shutdown of the chemical injection system shall be considered when the system it injects into shuts down, unless injection is required in a shutdown situation.

15.6 Maintenance

The system shall be designed such that normal maintenance work can be performed on the injection system for one chemical without interfering with the operation of the injection system for other chemicals.

16 Flare (system 43)

16.1 General

The flare system shall provide safe disposal of fluids from pressure relief, depressurisation and control valves. This clause also covers common vent systems.

The capacity, relief loads and system design shall be in accordance with the principles of ISO 23251. Mechanical details and utility systems, shall be in accordance with requirements in ISO 25457

Caution should be exercised to avoid mixing of water with other sources if there is a potential for solids formation in the flare system. For more detail requirements for design of disposal systems, see ISO 23251, clause 6.

16.2 Inlet overpressure protection

16.2.1 Valve mal-operation

In some cases there may be a substantial difference between the maximum pressure that can occur in a pipeline or a production well and the normal operating pressure, as the pressure upstream a closed valve may reach the maximum shut-in pressure of the source after a shutdown. The relieving capacity shall be sufficient to prevent overpressure in case of valve mal-operation. In determining the required relieving rate, the following shall be included:

- opening of flow line isolation valves with 100 % open choke valve (highest realistic GOR in import flow line riser shall be used in design);
- the shut-in pressure of the source shall be used, unless the potential pressure buildup is thoroughly analysed and an automated shutdown system is implemented to reduce the normal upstream pressure after a shutdown. A risk based approach may be used to determine the normal initial condition prior to valve mal-operation.

The topside chokes shall be confirmed in closed position to allow opening of shutdown valves. The consequences and resulting overpressure caused by the valve mal operation shall be considered when designing and implement the measures to prevent mal operation.

16.2.2 Choke valve collapse

Experience has shown that production chokes may be subject to a sudden and complete failure of the valve trim, leading to a dramatic increase in the valve's flow capacity. Such a failure may lead to a sustained flow that is substantially larger than normal flow.

Among the possible causes are

- impact by solids from the formation, e.g. during a well cleanup,
- impact by fragments of tools/devices from the well,
- erosion/corrosion,
- mechanical fatigue,
- brittle fracture due to temperatures below minimum design temperature, e.g. chilling during vapour depressurization.

The relieving rate and the resulting pressure build-up in case of choke collapse shall be determined. The relieving capacity shall be sufficient to prevent overpressure. In determining the required relieving rate, the highest realistic GOR and pressure in flow-line/riser shall be used. A dynamic analysis may be required to determine these effects.

Measures to consider for mitigating the consequences of a choke failure should include the following:

- replacing a large valve with multiple smaller valves, as it is necessary to consider only one choke valve failure at a time;
- the user may define choke failure as not credible based on selection of high integrity choke designs. Such a conclusion should be substantiated by a careful analysis of the nature and characteristics of mechanical loads and/or a program for testing and qualification;
- use of dedicated choke valves or change of choke trim for special operations in which solids are expected, e.g. well cleanup;
- means for limiting the maximum mechanical load caused by impacts, e.g. perforated plate.

A program for regular inspection and maintenance for the choke valves shall be established.

16.3 Knock-out drum

Sizing of flare knock out drums for liquid hold-up shall be performed in accordance with ISO 23251; in particular the time required for operator response shall be determined, see 5.4. Unless the instrumented protection systems are documented to be of sufficient quality to allow for a reduction in relief load (see 7.1.4.3), the maximum liquid inflow shall be assumed to last for the full operator response time.

Production shutdown shall be initiated by two independent LAHH trip transmitters linked to the PSD and ESD system respectively. The quality of these two trip functions shall be documented to allow for a reduction in relief load as mentioned above.

The effective response time of the instrumented function shall not be considered to be less than 90 s.

The liquid level in the drum just prior to relief, shall be assumed to be PSD LAHH.

The liquid accumulation will reduce the volume available for vapour/liquid disengagement. The flare tip manufacturer shall be consulted regarding the maximum allowable droplet size. For further information, see ISO 23251. If sizing of the drum is based on an assumption of evenly distributed flow across the vapour space, inlet internals may be required.

The liquid volume between control level and PSD trip level should be sufficient to accommodate the maximum liquid condensation rate during spill-off or pipeline/flow line depressurization for a typical period of 20 min. The liquid return system from knock out drums shall as a minimum have sufficient capacity to allow continuous production flaring without build up of liquids in the drums.

No internals shall be installed near the gas outlet nozzle of the knock-out drum due to the risk of blocking the outlet. Any internals at the inlet of the drum shall be designed to withstand all forces during normal operation and upset conditions, including relevant slug flow cases. See further detailed requirements in 5.1.3.2 and 5.2.6.1.

The knockout drum liquid outlet piping may be subject to freezing at no-flow and/or cold ambient conditions, and requirement for winterisation/heat tracing shall be evaluated. If a heater is installed in the flare knock-out drum, a low level trip shall ensure that the element is completely immersed during operation. Electrical heaters shall be equipped with protection against overheating.

16.4 Thermal radiation

Recommended maximum levels for thermal radiation towards personnel are given in ISO 23251.

Recommended maximum levels for radiation towards buildings, equipment, etc. are given in EN 1473.

16.5 Flare gas recovery systems

Flare gas recovery systems shall be designed such that the integrity of the flare system is not jeopardised and in accordance with ISO 23251.

16.6 Relief devices

Location of relief devices and design of inlet and outlet piping shall be in accordance with ISO 23251, API Std 520 and ISO 4126.

Pilot operated relief valves shall not be used in dirty service (typically well-stream and hydrate forming fluids) due to the risk of clogging impulse lines and/or the pilot.

17 Oily water treatment (system 44)

17.1 General

The system shall collect and treat produced water from the production separators and coalescer, such that the water can be discharged to sea or re-injected into the reservoir, and the oil can be recovered and returned to the production system.

Produced water shall not be mixed with seawater before discharged to sea, as a mixture of seawater and produced water may cause scaling problems in piping and equipment, dependent on composition of the produced water.

Reclaimed oil sump is described in clause 24.

17.2 Produced water treatment

The required produced water quality may be achieved by application of different technologies, such as hydrocyclones, flotation units, etc.

A mixing unit for flocculation chemicals, or other coalescing means upstream of the treatment system, should be considered.

Pumps and valves upstream of the treatment system should be of low shear type to avoid shearing and break-up of oil droplets.

The treatment system shall be designed to give a flexible system with respect to turndown rate, future capacity and maintenance requirements.

Produced water should not be recycled into the separation train, as this may impair oil/water separation.

If there is a potential for scaling, scale inhibitor injection points shall be provided. Flanged pipe connections or rod out points should be considered.

17.3 Flash drum

The flash drum shall be designed with a retention time of minimum 60 s for degassing of the water.

Provisions shall be made for automatic oil skimming.

The flash drum should be designed with a system for disposal of solid particles. If jet water is required for the flash drum, produced water should be used.

17.4 Layout

All equipment shall be located in hazardous areas. Jet water disposal lines should have no pockets to avoid sand accumulation and blockage.

18 Fuel gas (system 45)

18.1 General

The fuel gas system shall provide superheated fuel gas to the consumers.

Dry and dew-point controlled hydrocarbon gas should preferably be used to prevent hydrate formation or condensation. If fuel gas supply is wet gas, injection of hydrate inhibitor at start-up should be provided.

18.2 System design

The fuel gas system shall have sufficient volume to enable a smooth changeover to an alternative fuel source.

Filtration requirements for the fuel gas supply should be specified by turbine vendor.

Block valves and flare connection should be provided for fuel gas line to each turbine, to enable depressurisation prior to maintenance.

System should be designed or facilities provided (e.g. heat tracing) such that liquid accumulation in piping and the gas turbine(s) is prevented after a shutdown.

18.3 Fuel gas heating

Actual superheating requirements will be determined by turbine vendor, and are typically

- 20 °C to 30 °C above its water dew-point,
- 25 °C to 35 °C above its hydrocarbon dew-point.

For purge and flare pilot gas, the temperature should be 10 °C above the water or hydrocarbon dew-point.

"Warm-up" lines routing the fuel gas at start-up to flare, should be provided upstream each of the gas turbines. When continuous heating is covered by a heating medium, an electric heater should be installed in parallel for start-up purpose.

A sampling point downstream the fuel gas heater should be provided. Heat tracing of supply lines to critical consumers (e.g. gas turbines) should be included.

19 Methanol injection (system 46)

19.1 General

The methanol system shall receive, store and inject methanol. Injection shall prevent and dissolve hydrates, when required.

19.2 System design

The system shall be located in classified area.

The piping for the supply of methanol to the storage tank shall be self draining.

Loading hoses from supply boats shall be equipped with unique identification, and couplings shall be electrically earthed.

Drainage facilities shall be designed such that human exposure to methanol is minimized during maintenance. All equipment shall be provided with permanent connection to closed drain and valves should be provided at low points in the piping system.

19.3 Storage tank

For intermittently used systems the storage tank shall have sufficient capacity for the operation with the largest volumetric requirement plus the volume required during one shutdown.

For continuously operated systems, the storage tank shall be sized based on the maximum average daily demand, delivery frequency plus the volume required during one shutdown.

The storage tank shall be provided with purging or blanketing. Inert gas is preferred, but fuel gas can alternatively be used for this purpose.

For systems with recycle flow back to the storage tank, the methanol temperature in the storage tank may increase. The system design shall ensure that the temperature rise does not lead to excessive vapour losses or unacceptable reduction in net pressure suction head available.

The level in the storage tank should be monitored.

19.4 Injection

Injection pumps shall be sized based on the peak injection demand.

The methanol injection rate shall be adjustable at all injection points. For continuous consumers flow should also be monitored. For intermittent consumers total flow shall be monitored.

A check valve and shut off valve shall be fitted as close to the injection point as possible.

20 Chlorination (system 47)

20.1 General

The chlorination system shall generate or receive, store and inject hypochlorite into systems containing seawater. The concentrations specified below shall be used to prevent fouling of equipment and piping:

- continuous design dosing concentration (equivalent free chlorine): 2,0 mg/l;
- continuous residual concentration in distribution system (equivalent free chlorine): 0,2 mg/l to 0,5 mg/l.

In addition, capacity shall be provided for batch treatment with higher dosage for shorter periods.

Feed to the hypochlorite generator shall be from downstream of the seawater filters. The system shall operate continuously and produce hypochlorite at a stable rate at the required concentration.

The hypochlorite injection point should be as close as possible to the seawater intake.

The use of a combined hypochlorite-copper ion system may be considered to reduce the total consumption of hypochlorite.

20.2 System design

The system capacity should be determined by the continuous seawater consumption of the facility. Facilities shall be provided to manually adjust the flow of concentrated hypochlorite to each consumer.

The system shall be controlled via a local panel with CCR interface, shutdown input signals and supplier package common alarm.

The flow from the electrolysis cell should be monitored. In addition, local flow monitoring at the injection points shall be provided.

The air blower shall be powered from either the essential power or the emergency power system. A spare blower shall be installed. Loss of the blower shall lead to shutdown of the power supply to the cells. Upon a shutdown the blower shall continue to operate for a period to ensure a hydrogen free system.

The hydrogen generated in the cells shall be diluted by means of the air blower to a maximum of 25 % of the lower explosive limit (LEL), in air (LEL=4 % vol/vol). The diluted hydrogen stream shall be vented to a safe location.

If the system is equipped with a hypochlorite head tank, the tank overflow shall contain a liquid seal to prevent hydrogen leakage.

Facilities shall be provided to enable maintenance of parts of or entire system while the seawater system is in operation. Facilities to drain the electrolysis cells shall be provided.

Isolation facilities shall be installed around each electrolysis cell. It shall be possible to isolate all consumers individually.

Spool pieces for electrical isolation shall be provided to prevent galvanic corrosion around the electrolysis cells.

The hypochlorite storage tank, if any, should be located at a higher elevation than sea level to enable gravity flow to the lift pump suction.

20.3 Electrolysis cells

The seawater flow rate to the electrolysis cells shall be at a sufficient rate to remove the generated heat at an adequate rate. The cells shall be designed such that deposition of solids on the electrodes is prevented.

The electrolysis cells transformer/rectifier shall have the facility to manually adjust the current in order to adjust the hypochlorite concentration.

Provision for sampling from the electrolysis cell inlet and outlet lines shall be installed.

21 Sea water (system 50)

21.1 General

The system shall lift and filter seawater for distribution to the various users.

System capacity shall be based on the simultaneous design load of continuous consumers plus the load from the largest intermittent consumer.

The seawater system shall be designed to prevent or control the effects of water hammer. See description of water hammer in 4.2.4.

21.2 Pumps

Fixed speed pumps shall have minimum flow protection. The minimum flow should be controlled on flow, and not on pressure.

The discharge pipe from the pump minimum flow valve should be arranged such that backpressure is provided to prevent cavitation.

Vacuum breaker /air release system shall be provided to prevent vacuum in the riser during shutdown and prevent pressure surge during start-up. The air release valve will then ensure a slow filling of the riser and release of the compressed air.

Standby pump shall start automatically upon trip of duty pump.

21.3 Filters

A coarse filter shall be located downstream of the pumps. Typical filtration requirement is 2 mm. The filters should be equipped with an automatic backwash facility.

A strainer should be located upstream of the pump to prevent pump damage.

21.4 Prevention of marine growth

The potential for marine growth in the seawater system should be minimised by locating the seawater intake at an adequate water depth.

Injection points for chlorine shall be provided. The concentrated chlorine injection shall be stopped when the pump is stopped.

21.5 Layout

Where seawater is used for process cooling it is recommended to dump seawater to a caisson at a higher elevation than the high point in the seawater system. By applying this solution the use of a dump valve is avoided and the potential for vacuum is reduced. For design of caissons, see NORSOK P-001. The caisson termination depth shall consider safety and environmental aspects.

22 Fresh water (system 53)

22.1 General

The system shall produce and/or receive, store and distribute fresh water to all users on the facility.

Requirements and references for system design and potable water quality are given in Water Report No.111.

The system shall be designed to eliminate the risk of contamination. Facilities shall be provided at each user to prevent backflow to the distribution system.

22.2 Fresh water treatment

The hypochlorite dosing unit and palatability unit, if any, shall be sized for the maximum fresh water production rate. The palatability unit shall be specified for six months continuous operation.

22.3 Maintenance

It shall be possible to carry out maintenance on fresh water production equipment without affecting storage and distribution.

It shall be possible to completely drain all equipment and sections of piping. All piping shall be designed such that there are no dead legs or stagnant sections.

Facilities shall be provided to enable all equipment and piping in the potable water system to be cleaned and sterilised by flushing.

23 Open drain (system 56)

23.1 General

The open drain system shall handle rainwater, firewater, wash down water including spillage of liquids containing solids from deck areas, equipment drip trays and bounded areas. For floating installations seawater drainage may need consideration.

The open drain system is a safety system and shall prevent spreading of flammable liquids and maintain the separation of fire areas. The system shall not be modified in a way that reduces system capacity.

Hydrocarbon liquid spill shall be recovered, and only clean water shall be dumped to sea.

Drains from non-polluted areas should be routed directly to sea. Compatibility of the various fluids shall be considered to prevent chemical reaction and solidification in the open drain system.

The system shall be designed in accordance with ISO 13702, clause 8, and B.4.

23.2 System capacity

The deluge water should be routed to sea either via overflow lines from the drain boxes or from fire-seal overflow lines. The overflow lines shall be designed for the full deluge capacity in each area. Provision shall be made to prevent flow of hydrocarbons from one fire area to another. The treatment system capacity shall be adequate for the maximum wash-down of one deck or peak rainfall on weather decks.

For drip tray capacity and design, see DNV-OS-E201, chapter 2, section 2H.

23.3 Drain tanks

The hazardous open drain tank shall be continuously purged with inert gas to prevent ingress of oxygen in the tank.

The hazardous and non-hazardous open drain tanks shall be designed for easy disposal of solid particles. The tanks should have sloped tank bottom to ease the tank cleaning. Strategy for handling solids built up in the drain tank shall be implemented in the design.

Connection for biocide injection shall be provided for batch dosing.

23.4 Drilling drain

There shall be no connection between the drilling and production open drain systems. The quantities and type of solids from drilling activities may cause clogging of the production open drain system and damage to pumps and valves.

23.5 Maintenance

The fire seal pots shall be included in the maintenance program and should be accessible for maintenance without scaffolding.

Preferred location for pumps is outside the tanks. Where the location of the tanks makes this impractical, provision shall be made for safe withdrawal of a pump from the hazardous open drain tank during operation.

23.6 Layout

The hazardous open drain tank, pump and the treatment unit shall be located in hazardous area.

The collection tanks shall be located such that gravity draining is possible from all sources.

Piping system shall be designed with rod-out/flushing facilities. Minimum header size shall be 76,3 mm (3 in). Drain headers should be located above high levels in collection tanks.

23.7 Safety

The inlet lines to the collection tanks shall be submerged below liquid low level to prevent back flow of hydrocarbon gas.

Drains from hazardous areas shall be provided with a fire-seal for every fire area. The fire-seal shall prevent gas migration from one fire area to another.

Tundishes and gullies shall be designed for easy plugging to prevent hydrocarbon gas migration during hot work.

24 Closed drain (system 57)

24.1 General

The closed drain system shall collect hydrocarbon liquid drains from equipment and piping, and safely dispose and degas the liquid.

24.2 Closed drain flash drum

The closed drain flash drum shall be designed for a liquid retention time of minimum 1 min to achieve proper degassing.

The low pressure flare knock-out drum may be used as a closed drain flash drum. The reclaimed oil sump may also be used for drainage of small oil volumes from levels below closed drain flash drum inlet level.

The design flow to the closed drain flash drum shall be based on credible coincident flows.

The maximum flow rate from manual draining of vessels should cater for drainage from low alarm level of the largest vessel inventory in 1 h.

24.3 Design temperature

The system shall be designed to handle the temperatures of the fluids entering the system. If the system is designed for temperatures different than the source, operational procedures shall be in place to prevent drainage of fluids with temperatures below or above the design temperatures.

Depressurisation of sources may result in temperatures below minimum operational temperature for the source. Unless operational procedures are established, the closed drain system shall have the same minimum design temperature as the source. If the closed drain system is combined with a flare system, the minimum design temperature may be determined by the flare sources.

24.4 Reclaimed oil sump

The volume of the sump should as a minimum be sufficient to collect the liquid inventory of any one of the production separators from low liquid level. The reclaimed oil sump shall be located to ensure gravity draining from the sources.

The sump shall be designed with continuous purging, and be provided with chemical injection points for batch dosing of biocide. Inert gas is preferred for purging, but fuel gas can alternatively be used for this purpose.

24.5 Reclaimed oil sump pump

The pump should be of low shear type to avoid shearing of water droplets. Sparing of the reclaimed oil sump pump is required.

The pump system should be designed to avoid unstable conditions in the downstream system.

24.6 Safety

The non-continuous sources shall be provided with a closed spectacle blind during normal operation. Before manual draining to the closed drain system, the sources shall be depressurised. Opening to closed drain from small volumes (e.g. level glass drainage, cavity drain) without prior depressurisation may be acceptable.

The relief devices on the closed drain system shall be sized for the maximum incoming flow, including flow from continuous sources, if any.

LAHH on the closed drain vessel should shut down liquid flow from continuous sources.

Piping from open drain and closed drain may be terminated in the reclaimed oil sump, and these pipes shall be submerged to prevent gas from migrating into the open drain system.

Piping and equipment shall be located in hazardous area.

25 Diesel oil (system 62)

25.1 General

The diesel system shall provide storage and treatment of raw diesel and supply diesel to users.

Facilities to remove particles and water in treated diesel shall be based on specific consumer requirements, e.g. diesel engines, turbines etc.

25.2 Storage tanks

Total storage tank capacity should be for minimum 4 days normal consumption. Sparing of raw diesel tanks should be 2 x 50 % or 3 x 33 %. Each storage tank shall include a low point for gathering and drainage of water.

25.3 Hose loading stations

Hose loading stations shall be provided on two sides of the facility. Sampling points shall be installed. Hook-up points for biocide treatment shall be installed.

Hose loading stations shall as a minimum have one check valve and one block valve. The hoses shall be of anti-static type.

25.4 Day tanks

Automatic refilling shall be provided on large consumers. Overflow from day tanks should normally be routed to raw diesel storage. To prevent overfilling the day tank, it shall be fitted with an automatic operated shut-off valve. A mechanical device is acceptable.

25.5 Maintenance

Drip trays shall be installed under equipment where leakages may occur.

If the system is required to operate during a maintenance shutdown of the facility, it shall be possible to maintain the system during normal operation. Adequate provision of equipment bypass shall be made to enable such activities.

26 Compressed air (system 63)

26.1 General

The compressed air system shall provide compressed air at a defined quality and pressure to instrument air consumers and to plant air consumers.

Topping up compressor and black-start compressor may be required. The topping up compressor shall maintain the pressure in the start air vessels/bottles during normal operation. The black start air compressor shall charge the start air vessel/bottles for the emergency generators and fire water pumps.

26.2 Dehydration

The air should be cooled as much as possible to minimise requirement for dehydration. In design it shall be assumed air with 100 % humidity at maximum ambient temperature. Air should be treated to a dew point to either -25 °C or to 15 °C below minimum ambient temperature, whichever is lower, at maximum operating pressure.

26.3 Filtration

Filters should be installed between dryer and receiver if required by consumers. If oil lubricated compressors are used, facilities to remove oil impurities should be installed upstream dryers.

26.4 Air receiver

There shall be sufficient capacity in the air receivers to supply the instrument air system for 5 min with no supply from the air compressors. This pressure depletion period shall be from the time all non-critical consumers are shut off until the minimum operating pressure for critical consumers has been reached. This is to ensure smooth facility shutdown.

A by-pass line should be installed to route the instrument and plant air directly to the instrument air header and the plant air header during maintenance of air receiver(s).

26.5 Sparing

Two air compressors are sufficient on the condition that each compressor can provide the total instrument air requirement and both together cover the total compressed air requirement.

Minimum two air compressors for supply of instrument air should be connected to emergency power. When determining the emergency generator capacity, only load from one air compressor should be included.

Bleed air from gas turbines should be considered as additional supply source, if needed.

The dehydration facilities shall as a minimum be 2 x 100 % for instrument air.

26.6 Safety

In case of low system pressure, low priority users (e.g. plant air) shall shut down first. This will give priority to high priority users, e.g. instrument air.

On loss of air pressure, an automated production shutdown should be initiated, to ensure a controlled plant shutdown before the pressure is too low for operation of critical components.

Gas detection shall be provided on air intake unless air is supplied from an area that already has gas detection.

26.7 Layout

The discharge dump line from compressor control valve should be routed away from areas where personnel will require frequent access.

Low point drains should be provided to remove any moisture accumulating in the distribution headers and air receivers.

Inlet air should be taken from safe location.

Connection for extra plant air shall be supplied.

Valves shall be installed on distribution system to enable modifications/extensions to the system during operation.

27 Inert gas (system 64)

27.1 General

The following requirements are valid for nitrogen gas system for general topside use. Special requirements may apply for exhaust gas.

The inert gas generator shall deliver inert gas with low oxygen content at a specified pressure and temperature.

Typical continuous inert gas users are atmospheric tank purging, see 4.1.3 for capacities.

Peak loads during maintenance periods may be supplied by liquid nitrogen. The distribution system shall allow connection from vaporiser package.

27.2 System design

The inert gas content shall be 97 % volum at normal operation and 95 % volum at peak load. Water dew point should be lower than -20 °C at maximum operating pressure. For some consumers, stricter quality requirements may be required.

Where a feed air heater is required a by-pass line should be installed to allow maintenance without plant shutdown.

The inert gas plant should, because of the risk of a non-breathable/suffocating atmosphere, be located in a naturally ventilated area. Oxygen rich gas shall be ventilated to a location where personnel have no access.

Nitrogen storage/back-up shall be located in the utility area.

27.3 Sparing

Critical consumers (e.g. compressor gas seals) should have separate back-up and prioritised supply.

The nitrogen generator module should be configured such that full capacity can be maintained with one unit isolated for maintenance. Isolation valves shall be located upstream and downstream each membrane unit.

Requirement for a nitrogen receiver should be evaluated as a buffer in order to dampen nitrogen pressure and purity variations and as a storage device in case of limited supply of nitrogen after nitrogen generator shut-down.

27.4 Operational requirements

Low priority users shall, in case of low system pressure, automatically be shut off favouring high priority users.

The oxygen content shall be monitored and high oxygen concentration shall initiate opening of a dump valve and route product to location where personnel have no access.

28 Hydraulic power (system 65)

28.1 General

The hydraulic power package shall provide hydraulic power to all topside users at specified pressures and cleanliness levels.

For subsea hydraulic power packages, requirements can be found in ISO 13628-6.

The system shall have a back-up facility in case the main power source fails.

28.2 Reservoir

The hydraulic reservoir shall be sized such that when all actuators are driven, the tank shall not be less than 25 % full, and when total actuator capacity is returned, the level shall not be greater than 75 %.

The system shall be designed to avoid the accumulation of water/solids and shall be provided with the following means for their removal:

- a filter shall be installed on the filling line to the hydraulic reservoir;
- the oil in the reservoir should be circulated through a filter to maintain the cleanliness level;
- return from down-hole safety valves should be returned to closed drain or to a separate drain pot.

The hydraulic reservoir vent should be designed to prevent ingress of moisture and particles. The reservoir shall be designed for easy draining of particles collected at tank bottom.

It shall be possible to drain the hydraulic oil into the closed drain system or transportation pod.

28.3 Pumps

The pumps shall be sized, allowing for simultaneous use of standby pumps, to have sufficient capacity to move all valves and equipment away from their shutdown positions within a period of 10 min and all accumulators empty.

The pumps shall have an auto start and stop function initiated by the system header pressure transmitters.

28.4 Filters

The hydraulic oil shall have a cleanliness level according to the hydraulic components requirements.

Particles larger than typically 5 microns shall be removed by filters.

28.5 Accumulator capacity

The hydraulic system shall be equipped with central accumulator capacity to activate connected valves minimum once. For ESD valve accumulator capacity, further requirements can be found in NORSOK S-001. Valves with local accumulator should not be included in this calculation. This requirement is included to give the system operational flexibility when operating many valves without tripping the hydraulic system on low pressure.

Provision for expansion of central accumulator capacity should be included.

28.6 Safety

The return header shall not impose any restrictions on safety-related valves and equipment returning to their fail positions within their specified stroke times.

If there is a possibility of process hydrocarbons being returned to the reservoir with the hydraulic fluid, the system shall be classified as hazardous. This will typically be the case for the return from the downhole safety valve.

The vent from the reservoir shall be routed to a safe location.

28.7 Maintenance

Oil sample points shall be included on the reservoir, supply and return lines.

Maintenance of any part of the hydraulic power package, with the exception of the reservoir, shall be possible during operation. The hydraulic unit shall have a drip tray for collection of hydraulic oil spills during maintenance.

29 Sewage (system 66)

29.1 General

This specification covers design of sewage system outside the living quarter.

Requirements and recommendations for design of the collection system inside the living quarter are given in NORSOK H-CR-002.

The sewage system should not have any piping interfaces towards any systems on the installation.

29.2 System capacity

The sewage collection headers/caissons shall as a minimum be designed for maximum simultaneous drainage rates calculated by the living quarter contractor based on rules given in "Normalreglementet for sanitæranlegg". Alternatively peak flow from the potable water supply to the living quarter can be used as a more conservative figure. Additional liquid load should be added if other drainage sources are tied-in into the sewage lines.

The slope and sizing of the sewage collection headers and caissons shall be as stated in NORSOK P-001 for liquids flowing by gravity unless the requirements in "Normalreglementet for sanitæranlegg" are more stringent.

If a vent line is installed at the top of the sewage caisson, then the vent line capacity calculations should take into account the effect of wave motions inside the caissons.

29.3 Operating temperature

The maximum operating temperature shall be based on maximum liquid temperature from the living quarter, including periodic drainage of hot water from the hot water system, washing machines etc.

29.4 Layout

Number of caissons should be evaluated/selected based on practical interfaces towards the living quarter and required system capacity.

The system shall be provided with sufficient number of rodding points and flushing for maintenance purposes of the system.

Sewage caissons outlets shall be terminated sufficiently below mean sea level (MSL) and far from the main seawater intake. The effect of ocean currents should also be taken into consideration.

The top of the sewage caisson(s) should be made fully open ended to avoid possible discharge of sewage through undersized vent lines at extreme wave motions. The top of the sewage caissons or the vent line shall be terminated in safe location.

