

Piping system layout, design and structural analysis

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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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

Annex A and B are informative.

1 Scope

This NORSOK standard covers the basis for layout, design and structural analysis of process, drilling, utility and instrument piping and tubing for offshore oil and/or gas production facilities, upper part of riser, barred Tee and pig trap/launchers. Relevant parts of this NORSOK standard may also be used for control room, laboratory, helideck and other facilities around the platform.

This NORSOK standard does not cover risers, sub-sea pipework, sanitary piping systems, marine systems in hulls of vessels and floating platforms and land based plants.

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

ASME B 31.3,	Process Piping (Main design standard)
ISO 5167,	Measurement of fluid flow
ISO 14692,	Petroleum and natural gas industries – Glass reinforced plastics (GRP)
NORSOK L-001,	Piping and valves
NORSOK L-005,	Compact flanged connections
NORSOK L-CR-003,	Piping details
NORSOK L-CR-004,	Piping fabrication, installation, flushing and testing
NORSOK M-601	Welding and inspection of piping
NORSOK M-622,	Petroleum and natural gas industries – Glass-reinforced plastics (GRP) piping
NORSOK N-001,	Integrity of offshore structures
NORSOK N-004,	Design of steel structures
NORSOK P-001,	Process design
NORSOK R-001,	Mechanical equipment
NORSOK S-001,	Technical safety
NORSOK S-002,	Working environment
NORSOK Z-DP-002,	Coding system
NS 3464,	Execution of steel structures. General rules and rules for buildings
NS 3472,	Steel structures. Design rules
Piping and Valve Material Specification project	
PSA “Framework regulations”	

2.2 Informative references

API RP 2FB	Recommended Practice for the Design of Offshore Facilities Against Fire and Blast Loading - First Edition
ASME B 16.9,	Factory-Made Wrought Buttwelding Fittings
EN 1591,	Flanges and their joints – Design rules for gasketed circular flange connections
EN 13480 – (all parts),	Metallic industrial piping – (all parts)
NORSOK M-501,	Surface preparation and protective coating
NS 3490,	Design of structures. Requirements to reliability
PD 5500,	Unfired fusion welded pressure vessels
DNV-RP-D101,	Structural Analysis of Piping Systems. October 2008
Energy Institute document,	Guidelines for the avoidance of vibration induced fatigue failure in process pipework. Second edition 2008
FABIG Technical Note No 8,	Protection of Piping Systems Subjected to Fires and Explosions
M.W.Kellogg “Piping Design”	
UK-HSE report,	RESEARCH REPORT 285. Protection of piping systems subject to fires and explosions
UKOOA document,	Guidelines for the management, design, installation and maintenance of small bore tubing systems.

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

company

owner or operator of the installation

3.1.3

isolation valve

valve that is used to shut off a piece of equipment or system for maintenance purpose only

3.1.4

may

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

3.1.5

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

3.1.6

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

API	The American Petroleum Institute
ASME	The American Society of Mechanical Engineers
CCR	central control room
3D	three dimensional computer aided design (CAD) model
DNV	Det Norske Veritas
EN	European Standard
FABIG	Fire and Blast Information Group
GRP	glass reinforced plastic
HSE	health and safety executive
ISO	International Organization for Standardization
MOB	man over board
NPS	nominal pipe size
NS	Norsk Standard
OLF	Oljeindustriens Landsforening (The Norwegian Oil Industry Association)
P&ID	piping and instrument diagram
PSA	Petroleum Safety Authority Norway
PSV	pressure safety valve
SN-curve	cyclical stress (S) against the logarithmic scale of cycles to failure (N) curve
UKOOA	UK Offshore Operations Association

4 Layout

4.1 General

The layout shall be developed with the following aims:

- ensure that the arrangement and functionality provided by the layout satisfies all safety, operations and maintenance requirements with minimum impact on space, weight and cost;

- b) the location and spacing of equipment, piping and structures shall take into consideration ventilation aspects in order to avoid accumulation of possible gas and vapour releases and to reduce explosion pressure;
- c) deck elevations in different areas of the installation shall to the extent possible correspond in order to ease material handling and operation;
- d) equipment and systems shall be arranged such that the amount of onshore completion is maximized and offshore work minimized;
- e) all equipment shall to the extent possible be positioned to satisfy both the process flow sequence and gravitational requirements;
- f) all piping and tubing shall be arranged to facilitate supporting, and shall be planned for ease of removal of equipment for inspection and servicing;
- g) space shall be allocated at an early stage for primary and secondary escape routes, access ways, main pipe/cable racks/trunks and main ductwork as well as main penetration areas.

4.2 Miscellaneous requirements

The flare tip shall preferably be located over open sea. Cost implications to be presented before final decision is taken. Heat resistant panels for protection of carry-over shall be installed under the flare-tip.

Provisions for loading and unloading of liquids and dry bulk shall, if possible, be installed on two sides. For small wellhead platforms, where requirements for drilling by separate jack-up rig prevents two loading stations, compensating measures can be to design for increased storage capacity.

Operation and replacement of hoses shall be possible by means of the main cranes. Hose reels shall be used for all loading hoses to provide a safe working environment for the operators.

Deck area with sufficient load capacity shall be allocated for temporary equipment, e.g. pull-in winches, coiled tubing, containers, testing equipment etc.

All workshops (e.g. electrical, instrument, mechanical, welding, insulation, paint) and laboratories, shall be located close to each other, and all unnecessary traffic through any of the rooms shall be avoided.

The location of the CCR shall be subject to due consideration with regard to installation sequence of modules/sections in order to avoid negative impact on the commissioning schedule.

Over pressurized ventilated rooms (e.g. local electrical room) in or close to classified areas shall be avoided.

Coffee-rooms for non-smokers and smokers shall be provided adjacent to the main mechanical workshop, CCR and drilling area.

In cases where two or more process trains are required, both piping symmetry and easy segregation of the equipment and piping shall be aimed at.

4.3 Material handling requirements

4.3.1 General

All material handling aspects which constitute the basis for design and layout of the installation have to be considered. As a minimum the following shall be included:

- a) definition of main material handling equipment (e.g. main cranes, goods lift, mobile lifting beams, forklift truck, etc.), including sizes and capacities;
- b) description of main material handling routes: to and from warehouse, to and from workshops, to and from pipe deck, to and from drill floor, to and from kitchen, to and from supply vessel;
- c) design criteria for all transport routes/roads and parking spaces for mobile cranes, e.g. minimum design load, free width and free height;
- d) lifting restriction charts for the plant, including philosophy for lifting above process areas;
- e) definition of maximum allowable lifting heights, coverage and restrictions for the main cranes;
- f) requirements for lay down and storage areas including function, size and location, also covering lay down/storage areas for and handling of temporary, Company provided and hired equipment;
- g) description including sketches of lifting areas, which are not visible from the crane cabins;
- h) weather constraints (waves and wind);

- i) definition of largest/heaviest item to be handled per area including description of transportation route and type of handling equipment;
- j) description of deck load/ground capacities on all areas in the plant, including loading areas, transport routes and areas between equipment. The deck load/ground capacities shall include allowable evenly distributed load, point loads and forklift truck capacities;
- k) evaluation of concurrent crane operations on pipe deck;
- l) requirements for dropped object and swinging load protection;
- m) description of goods handling to/from helideck;
- n) load categories for monorails, hoists and pad eyes.

Handling of items with weight above 0,25 kN shall be by means of mechanical lifting devices. Items with weight 0,25 kN to 2 kN can be handled by temporary equipment, e.g. elephant cranes, fork lift truck, A-frames, beam clamps etc. For items with weight above 2 kN, permanent arrangements like monorails and/or pad eyes shall be installed. In cases where material handling by means of temporary equipment is specified, sufficient space for access and installation of the lifting equipment shall be allocated to avoid requirement for dismantling/removal of other equipment.

Minimum requirements for material handling of equipment are as follows:

Weight kN	Maintenance interval			
	Several times a year	Yearly	1 year to 4 years	> 4 years
0,25 to 2	A	B	B	B
2 to 30	A	A	B	B
> 30	A	A	A	A
Key A Permanent installed lifting arrangements (e.g. monorails/padeyes). B A documented description (material handling report) for material handling of equipment with use of temporary lifting equipment. The plan shall include documentation of structural capacity of all lifting points of more than 2 kN.				

4.3.2 Main cranes

A crane study based on the principles of the material handling philosophy shall be performed. This shall as a minimum consider the following:

- a) definition of all relevant documents for transmittal to the authorities;
- b) basis for location of main cranes;
- c) visibility to laydown areas, and exceptions, if any;
- d) description of handling with main cranes to and from the supply vessels and internally on the topsides;
- e) listing of the most common lifting operations including frequency of these;
- f) height of crane cabins above the highest elevated crane handling area;
- g) description of maximum allowable lifting heights, coverage and restrictions;
- h) requirements for dropped object and swinging load protection;
- i) description of crane outfitting related to safety, alarms, communication, lighting, etc.;
- j) description of situations where the crane booms have to be brought to the rest position and the frequency of these;
- k) description of weather constraints (waves and wind);
- l) evaluation of concurrent crane operations on pipe deck;
- m) description of crane operations where personnel are transported, e.g. MOB boat, personnel basket, etc.;
- n) heat radiation from flare and exhaust on crane cabin and wire (drying of wire grease);
- o) plot plan showing
 - 1) crane locations,
 - 2) crane operation range with and without jib, minimum radius and radius for heaviest lift,
 - 3) maximum allowable lifting heights,
 - 4) maximum weight capacities for lay down areas and transportation ways,
 - 5) lay down areas, including allowable loads (areas not visible from the crane cabin shall be highlighted),

- 6) hose loading stations,
- 7) tote tank area,
- 8) access and transportation ways, including allowable loads,
- 9) permanent and temporary restriction areas,
- 10) dropped object protection,
- 11) crane maintenance platform(s),
- 12) storage for crane hooks,
- 13) crane boom rests,
- 14) MOB boat.

The main cranes shall be located in positions giving the best combination of crane coverage and free sight from the crane cabins to the handling areas and supply boats. The location shall be optimized such that unnecessary long crane booms are avoided.

The main cranes shall cover the deck area and lay down/storage and handling areas including the entire pipe deck (installations with drilling or work-over facilities only).

On installations with drilling facilities, the main cranes also shall handle tools not handled by the pipe handling system.

The main cranes shall have the necessary reach to avoid off lead in conjunction with loading hose handling to/from supply boats.

The main cranes shall not be used with crane boom or load over non-protected, pressurized process equipment or for direct mounting/dismounting of equipment.

The need for dropped object and swinging load protection shall be evaluated.

The main cranes including the crane hooks shall not be used as hang off point for other material handling equipment.

Crane boom rests shall be provided.

A dedicated area for replacement of crane hooks with an arrangement for storage main load and whip line hook shall be provided. The need for a separate working platform for this purpose to be considered.

A device for load testing of the main cranes shall be installed in the deck structure.

4.3.3 Lay down/storage and other crane handling areas

Lay down and handling areas shall as a main rule be placed in locations visible from the crane cabins. As a minimum, one lay down area per deck level shall be visible from the crane cabin, provided that all items to be handled by the crane within the area can be transported to the actual lay down area. In cases where it is not possible to locate laydown areas in a position visible from the crane cabin, Company shall be notified.

For installations with more than one crane, common lay down areas reachable by two cranes shall be provided.

Lay down areas shall to the largest possible extent be located at the periphery of the installation in order to optimize crane operations.

Lay down areas shall be provided with heavy duty flexible barriers with rubber composite inner lining. The barriers shall have sufficient height to protect equipment and other structures located next to the lay down area.

Lay down areas close to the crane pedestals shall be avoided on floating installations.

Lay down areas on high deck levels shall not overlap laydown areas on lower deck levels.

Lay down areas shall be designed such that the signalman easily can escape to a safe position.

On floating installations, lay down areas shall have provision for sea fastening of equipment during rough weather conditions. These devices shall be recessed if installed in the deck.

Hose loading stations and MOB boat shall be visible from the crane cabins. For MOB boat launching arrangement requirements, reference is made to NORSOK S-001.

A bridge-landing platform shall be provided and shall have easy access to main escape ways. The landing platform shall be located such that emergency release of the bridge is not obstructed by structures in the vicinity of the landing. In cases where the bridge landing is within the reach of the main crane, it shall be designed and equipped for use as a lay down area.

Pipes, ducts, cable racks, lighting fixtures, loudspeakers, detectors etc. shall not be located close to or above lifting areas. If this is inevitable, the actual items shall be mechanically protected.

4.3.4 Transportation ways

Transportation ways shall be sized to allow transportation of the largest/heaviest item to be handled from its position to the actual lay down area. Reference is also made to requirements in NORSOK S-002.

Decks and transportation ways shall, where required, be designed for special transportation remedies such as heavy lifts and/or forklift trucks, air film transporters etc. Transportation ways shall not contain steps or thresholds. If air film transporters shall be used, the use of plated deck shall be evaluated.

The need for protection barriers along transportation routes intended for transportation of large/heavy equipment, and in locations where forklift trucks are used, shall be evaluated. The protection barriers shall not obstruct access to equipment, valves, etc.

4.3.5 Lifts and hatches

For installations with more than one deck on topside, a goods lift shall be installed. The size and capacity shall be adjusted to the size/weight of the largest/heaviest items to be transported by the lift, but the minimum size/capacity shall be 2 m x 3,5 m (width x depth) and 10 kN. The goods lift shall give access to all deck levels, and the access to main workshop/stores shall be emphasized.

Floating installations shall in addition be provided with lifts with sufficient capacity to handle equipment placed in the substructure.

Hatches for material handling purposes shall be avoided on floating installations. However, if use of hatches is inevitable, use of local lifting equipment shall be the first choice. If this is not possible, equipment in the vicinity of the lifting area shall be avoided or suitably protected. Suitable guiding systems shall also be evaluated. Special attention shall be given to installation or maintenance in the wellhead area. Hatches shall be designed or secured in such a way that they cannot fall through the opening.

4.3.6 Material handling report and plan

The material handling report shall identify all equipment above 0,25 kN that requires regular maintenance or replacement during the design life of the installation. This report shall describe the method, equipment and the transport route to be used when lifting out the unit, and transport it to its destiny, and replace it.

The material handling report shall as a minimum contain the following:

- a) description of all material handling equipment, e.g. main cranes, goods lift, fork lift truck, trolleys, air film transporters, elephant cranes, A-frames, mobile cranes etc. including tag numbers (when required), sizes and capacities and requirements for certification, marking and re-certification period;
- b) description of the main material handling philosophy for internal transport on the installation;
- c) description of function, size and location of lay down and storage areas including areas for and handling of temporary, company provided and hired equipment;
- d) description of all items above 0,25 kN to be handled, including tag numbers, location, weight, size, expected maintenance/replacement intervals, type of lifting equipment/ arrangement, lifting/ handling procedure, transport route etc. In cases where the equipment vendor has established thorough handling procedures in the maintenance manual, this can be referred to in the report. The material handling description for such equipment can be reduced to just defining the required lifting/ transportation equipment and transport route;
- e) requirements for transportation ways/roads including width and height in the different areas;
- f) description of goods handling to/from helicopter deck;
- g) description of loading hose handling including hose replacement;

- h) description of areas where special protection of equipment is required, e.g. dropped object protection, truck barriers, swinging load protection etc.;
- i) material handling drawings based on equipment arrangement drawings or 3D plots including piping and valves containing the following:
 - 1) all equipment to be handled including lifting lugs, monorails, access ways etc.;
 - 2) table containing all tags to be handled with corresponding tags for the lifting equipment to be used;
 - 3) load capacities for lay down areas and transportation routes/roads.

4.3.7 Miscellaneous

A forklift truck garage/charging station (approximately 8 m²) shall be located adjacent to the main workshop. A sea fastening arrangement shall be provided on floating installations.

Flush mounted deck lugs for skidding of heavy equipment shall be installed in the main workshop.

4.3.8 Tagging and marking

Material handling equipment which is stored on the installation shall be described in the material handling report by tag number, make, type, storage location and installation method. Material handling equipment not stored on the installation shall be described in the same way, but tag number is not required.

4.4 Safety and work environment

Ergonomic consideration shall be taken in design regarding

- tools, valves and control devices, including emergency controls devices, shall be accessible,
- provision for cleaning, maintenance and repair shall be taken into consideration.

Requirements related to safety and working environment shall conform to NORSOK S-002.

Potential source of hazard (release of hydrocarbons), (e.g. valves and most types of flange joints), shall be located inside hazardous areas as defined in the area classification drawings or specification. However, static seals which are qualified by testing beyond all possible operational scenarios, may be used after Company approval.

Where applicable, provision shall be made to protect piping and equipment from falling objects.

Discharge to sea shall be located such that any hazard to supply vessel personnel is avoided.

5 Piping design

5.1 General

The design of piping and tubing systems shall conform to ASME B 31.3 except where the requirements of this NORSOK standard or Company requirements are more stringent. GRP piping shall be designed in conformance with ISO 14692 and NORSOK M-622.

Company to decide the need for, and eventual extent of independent verification of the piping and tubing design documents with supports and construction work, in order to comply with § 15 in the PSA "Framework Regulation".

Compliance with The Pressure Equipment Directive (PED) does not normally eliminate the need for independent design verification.

The Company decided verification shall be carried out by independent personnel, not involved in design, fabrication, installation or testing. A third party company is normally needed for the verification work in order to obtain sufficient independency. The third party company shall be under direct contract with Company.

NOTE The verification can be performed in conformance with DNV-RP-D101. For pipe supports, also see NS 3490.