

Piping system layout, design and structural analysis

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Foreword	4
1 Scope	5
2 Normative and informative references	5
2.1 Normative references	5
2.2 Informative references	5
3 Terms, definitions and abbreviations	6
3.1 Terms and definitions	6
3.2 Abbreviations	6
4 Layout	6
4.1 General	6
4.2 Miscellaneous requirements	7
4.3 Material handling requirements	7
4.4 Safety and work environment	11
5 Piping design	11
5.1 General	11
5.2 Numbering systems	12
5.3 Arrangement	12
5.4 Clearance and accessibility	13
5.5 Provisions for easy maintenance, testing and cleaning operations	13
5.6 Valves	14
5.7 Vents, drains and sample connections	15
5.8 Equipment piping	16
5.9 Additional requirements related to piping systems	20
5.10 Fittings	22
5.11 Hook-up piping	23
5.12 Hoses and flexible pipes	23
5.13 Instrumentation	23
5.14 Welding	25
6 Structural analysis of piping systems	25
6.1 General	25
6.2 Analysis	25
6.3 Selection criteria	25
6.4 Calculation models	26
6.5 Design temperature	26
6.6 Environmental temperature	26
6.7 Pressures	26
6.8 Explosion loads	26
6.9 Fire, heat and noise insulation	27
6.10 Vessel/deck deflections	27
6.11 Vessel accelerations	27
6.12 Dynamic loads	28
6.13 Other loads	28
6.14 Fatigue	28
6.15 Loads from piping systems on equipment	28
6.16 Flanges	29
6.17 Pipe supports	29
Annex A (Informative) Acoustic fatigue in piping systems	31
Annex B (Informative) Acoustic resonance with flexible riser as initiating source	34

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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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

- a) 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.

5.2 Numbering systems

Numbering systems for piping, piping items, valves and tubing shall be in accordance with NORSOK Z-DP-002 or the project codification manual.

5.3 Arrangement

All piping shall be routed so as to provide a simple, neat and economical layout, allowing for easy support and adequate flexibility.

Piping should be arranged on horizontal racks at specific elevations. Care shall be taken to avoid pockets.

No piping shall be located inside instrument, electrical or telecommunication control/switchgear rooms, except fire fighting and cooling medium piping serving these rooms. Piping for liquid flow shall be all welded and contain no valves inside such rooms. Exceptions are subject to Company approval. Pipe connections to equipment located in these rooms (e.g. coolers for transformers etc.), shall be provided with protection covers to avoid damaging leakages.

Bridge piping shall be designed with expansion loops capable of handling relative movement of platforms in design storm conditions.

All hydrocarbon gas piping including bypasses (e.g. equalizing lines), shall be arranged to prevent the possibility of trapping or collecting liquid.

Dead ends shall to the extent possible be avoided for all piping and tubing systems.

Reducers in conjunction with control and pressure release valves shall be located directly upstream/downstream the valve.

Routing of piping in areas which are not accessible for inspection and maintenance without extensive use of scaffolding (e.g. below cellar deck, outside columns etc.), shall be avoided. However, if this is inevitable, special attention shall be paid to material selection in order to minimize the need for maintenance.

Effects of wave slamming and wave run-up along columns on piping and supports, as well as possible negative effects on the integrity of the unit, shall be investigated. This is normally not relevant for jackets.

Piping connected to noisy equipment (e.g. main generators, sea water disposal caissons, or piping which create noise due to e.g. restriction orifices or control valves), shall not be routed through manned areas such as workshops, offices etc.

When allocating space for future installation of piping, possible extra space requirement in conjunction with offshore installation shall be evaluated to facilitate the installation work and avoid inappropriate short pipe spools (and a large number of field welds).

In cases where the project scope of work includes study/routing of future piping, this shall also include design of pipe supports/pipe racks, either as standalone supports or as extensions of "basic scope of work" supports/pipe racks. All known future lines shall be included in the 3D-model, but shall neither be prefabricated nor installed. Pipe supports for the same lines shall be designed and included in the 3D model, but shall neither be prefabricated nor installed. Starter bars/reinforcement plates only shall be installed. The deliverables of "future scope of work" shall include documentation of the pipe routing, stress calculations and support design, i.e. that design drawings for both piping and pipe supports shall be issued for all known future lines.

Minimum distance between extremities of piping/valves and/or insulation in operating conditions shall be 25 mm. Greater distance might be required to achieve access for installation of e.g. insulation.

In cases where Company has permitted use of tubing as a substitute for piping, reference is made to the project piping and valve material specification, the following applies:

- a) tubing shall not be used inside walls or other enclosed compartments without access;
- b) tube fittings and flanges shall not be used in enclosed areas for nitrogen service due to the risk potential in case of leakage;
- c) if tubing is used for drainage of instrument equipment in hydrocarbon service, the piping block valve shall be easily accessible from floor or platform;

- d) use of tubing shall be kept to a minimum.

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

5.4 Clearance and accessibility

All piping shall be arranged to provide specified headroom and clearances for technical safety, easy operation, inspection, maintenance and dismantling as stated in NORSOK S-002.

Particular attention shall be addressed to clearances required for the removal of pump, compressor and turbine casings and shafts, pump and fan drivers, exchanger bundles, compressor and engine pistons. Piping shall be kept clear of manholes, access openings, inspection points, hatches, davits, overhead cranes, runway beams, clearance areas for instrument removal, tower dropout areas, access ways and emergency escape routes.

A vertical clearance of 40 mm is recommended between bottom of skid and deck/floor to facilitate cleaning/maintenance.

Pipe, fittings, valve controls, access panels or other equipment shall not extend into escape areas.

Acoustic enclosures shall not cause hindrance to operations or maintenance activities. The enclosures shall be provided with hatches/doors, which readily can be opened or removed. The enclosures shall be equipped with all necessary safety equipment and devices to ensure safety of personnel.

Storage tanks integrated in the platform structure shall have internal ladders, e.g. fixed tanks for diesel, water, mud etc.

Insulated piping systems shall be designed with sufficient space around inline equipment, flanges, supports etc. to allow for installation of insulation boxes. Straight length of pipes should be provided between fittings and flanges.

Pipe supports shall be designed such that proper access for painting of the support, guides, line stops and the pipe at the support point is ensured. Bolted (shoe) supports, guides and line stops should be evaluated to fulfil this requirement. Where bolted solutions are not practicable, the use of stainless steel materials should be evaluated.

Access for performing non-destructive examination internally and externally, and painting of the pipe shall be ensured by the layout of the pipe supports.

Pipe supports shall be designed such that the support will not act as a corrosion trap.

Piping penetrations through deck or wall shall be equipped with sleeves that give a minimum clearance of 100 mm between pipe and sleeve.

For further requirements, see NORSOK S-001 and NORSOK S-002.

5.5 Provisions for easy maintenance, testing and cleaning operations

5.5.1 General

In addition to requirements in NORSOK P-001, the following requirements shall apply:

- a) piping systems shall be designed to provide effective flushing (usually with water) for removal of all kind of debris and particles. This includes that
 - 1) blind legs should be avoided. Where this is impossible, use blind flange instead of cap,
 - 2) if the system will require cleaning during operation, the design shall incorporate provisions (e.g. cleaning and drain nozzles), for this purpose. The design, including size and orientation of nozzles, shall reflect the foreseen cleaning operations with due consideration to the relevant flow medium. This applies both for pipes, vessels and equipment,

NOTE Nozzles for flushing shall normally be 152,4 mm (6 in) size for flushing of lines 152,4 mm (6 in) and above in order to provide access for a rotating hose system. Access for a rotating nozzle shall normally be provided for lines between 50,8 mm (2 in) and 152,4 mm (6 in).

The final selection of locations and sizes of nozzles to be agreed by Company,

- 3) nozzles for flushing are required at high points in the system.

Drain points pointing downwards shall be minimum 300 mm from deck levels to provide access for connection to a hose.

5.5.2 Grouping and location

Cold and hot piping should be grouped separately with hot, non-insulated, lines at a higher elevation than cold lines. Un-insulated lines with possibility for ice build-up, shall not be run above walk ways.

When expansion loops are required, lines should be grouped together and located on the outside of the rack.

Small pipes should be grouped together to simplify support design.

Locating small pipes between large pipes shall be avoided especially when the large lines are hot. Heaviest lines should be located furthest from centre of the rack.

5.5.3 Sloping pipes

Sloping pipes (e.g. flare headers and drain lines), should be located together and the routing established at an early stage in the design period to prevent difficulties which may occur if other process and utility lines are routed first.

5.5.4 Utility headers

Utility headers for water, steam, air, etc. shall be arranged on the top of multi-tiered pipe racks, if practical feasible.

5.6 Valves

5.6.1 Accessibility and installation

All actuated valves and all manually operated valves requiring operation during normal or emergency conditions shall be accessible from a deck or a permanent platform.

Manually operated isolation valves shall as main rule be accessible from deck or a permanent platform.

Permanent access to valves that are likely to be operated only rarely (less than once per year) may be omitted upon Company consent. Contractor shall in such cases demonstrate that the actual valves are positioned such that access from temporary facilities can be obtained in a safe and proper way. The temporary facilities shall be included as volumes in the 3D computer assisted design model to ensure space reservation.

Fire water ring main isolation valves shall always be accessible from deck or platform.

Pressure relief devices (e.g. relief valves, rupture discs) shall be accessible and installed for easy removal from deck or permanent platform. Relief valves and actuated valves including control valves, and valves with welded ends and top entries for maintenance in situ, shall be installed with the stem in the vertical position. Welded top entry ball valve shall preferably be installed in horizontal lines to avoid use of special tools for maintenance work.

Other flange end valves may be tilted, as long as the stem is above horizontal position. Valve stem orientation shall be shown on both piping plans and piping isometrics.

Butterfly valves of 304,8 mm (12 in) nominal bore and greater shall be installed with the stem horizontal, where possible. Turbulence/vibration problems may overrule this criterion, e.g. close to a vertical bend valve stem to be vertical.

Valves in vertical lines intended for in situ maintenance, shall be supplied with tailor made equipment for the safe handling of internal trim materials, if this is recommended by the valve supplier. If the vertically installed valve is actuated, it shall then be possible to remove and reinstall the actuator without disconnection of the valve from the line.

When emergency shut down valves are installed as isolation valves, they shall be located as close as possible to the fire/blast partition.

Sufficient flexibility in the piping system shall be assured for removal of valves and other inline items. Particular attention shall be paid to items with seal rings, e.g. ring type joint flanges, compact flanges or clamp connectors. Items that protrude axially into the pipe (e.g. conical strainers) will normally require break out spools.

Chain operated valves shall not be used without Company approval.

For further evaluation of accessibility for operation and maintenance, see NORSOK S-002.

5.6.2 Check valves

Check valves may be installed in vertical lines providing the flow is upwards, with the exception of some type of lift checks. Draining of the downstream side shall be provided.

5.6.3 Control valves

Control valves shall be located as near as possible to the relevant equipment to which they apply, and where possible, along stanchions, columns, bulk heads or tower skirts. Suitable areas where control valves may also be located are alongside walkways, working areas and other aisles providing no obstructions such as valve stems extended into the walkways occurs.

Control valves operated by a local controller shall be located within the visual range of the controller to enable the operation of the valve to be observed while adjustments are made on the controller.

Spools or reducers between flanged block and control valves shall be made long enough to permit bolt removal.

Where high pressure drop conditions exist across control valves, sonic harmonics together with extreme noise levels can be expected. Piping subjected to these conditions shall be carefully evaluated and designed to ensure that its size and configuration downstream of the valve prevents transmission of excessive vibration and noise.

5.7 Vents, drains and sample connections

5.7.1 General

Vents and drains exclusively used for hydrostatic pressure testing shall be provided if those showed on the P&IDs are not sufficient/suitable.

5.7.2 Vents and drains for operational use

Operational vents and drains shall be designed according to NORSOK L-CR-003.

Sloped drain lines shall be run to the nearest deck drain, avoiding walking areas. Open drains shall be provided with valve(s) and located such that discharge may be observed. Open pipe ends shall extend well into tundishes to avoid spillage.

5.7.3 Vents and drains for hydrostatic pressure testing

High point vents and low point drains shall be designed according to NORSOK L-CR-003.

5.7.4 Sample points

All sample connections shall be designed in accordance with NORSOK L-CR-003 with capability to flush through test lines and containers before samples are taken.

Sample points for gas shall be connected to the flare system to ensure satisfactory flushing in advance of samples being taken. The sample connection shall be located as close as possible to the separator/scrubber outlet, and preferably directly after the first elbow on vertical line.

Points for oil and gas samples shall be located on vertical part of pipe. Locations subject to vibrations shall be avoided. Sample stations shall be designed such that spillage is minimized.

Sample points for heli-fuel shall be located inside a dry room adjacent to the helideck.

Sample points, where sample bottles are used, shall be located in easily accessible areas. Ladder access is not acceptable.

5.7.5 Injection points

Injection points for chemicals shall be provided as indicated on the project P&IDs, see NORSOK L-CR-003 for details for injection points. The design shall be approved by Company.

It shall be evaluated to use corrosion resistant alloy for the spool down-stream the injection point.

5.7.6 Modular valves

Use of "modular" valves shall be evaluated instead of use of double block and single blinded bleed valve arrangement. The modular valves shall be in conformance with the relevant pipe class sheet for the piping system.

5.8 Equipment piping

5.8.1 General

Piping connected to equipment shall be designed so that loads do not exceed the limits specified by NORSOK R-001 or the equipment manufacturer. When new piping is to be connected to existing equipment, the maximum allowable dead and operating loads as specified in NORSOK R-001 do not automatically apply. The Contractor shall perform a verification of the actual load limits.

For accidental loads the load and deflection limits to be agreed with Company.

The design of structural steel shall be done to minimize any loads exerted to the equipment nozzles from the pipe work due to deflections of steelwork caused by live loads, environmental loads and explosion loads. Special attention shall be made for floating production units to areas where compressor and other strain sensitive equipment are located.

In order to obtain a piping design less affected by deflections of surrounding structural steel, the pipe work should be designed to facilitate supporting from the same deck structure as the equipment is resting on, or to secondary steelwork fixed to this.

Piping configurations at equipment shall be designed and supported so that equipment can be dismantled or removed without adding temporary supports or dismantling valves and piping other than removing spool pieces or reducers adjacent to equipment. Clearances shall permit installing blind flanges or reversible spades on block valves on hazardous fluids or high pressure lines. Break out spools shall be as short as possible.

In the design of piping for rotating equipment, provision shall be made for sufficient flexibility without the use of flexible couplings and expansion bellows. Cold springing of piping at rotating equipment shall not be used.

Where deck level pipe supports are required at pumps, compressors or turbines, they shall be supported on integral extensions of the equipment support structure, and not be anchored to the equipment base plate. This requirement shall apply to resilient as well as fixed supports, guides and anchors.

Provision shall be made for the isolation of equipment with blinds or the removal of spool pieces for pressure testing and maintenance.

Suitable supports and anchors shall be provided so that excessive weight and thermal stresses are not imposed on the casing of rotating equipment.

5.8.2 Pumps

Suction lines shall be as short as possible and designed without pockets where vapour or gas can collect. Where possible, the piping shall be self-venting to the suction source. The suction line shall be checked to ensure that the net positive suction head fulfils relevant pump requirements.

Eccentric reducers shall be used in horizontal runs. If there is a possibility for air or gas pockets, the flat side shall be mounted up. If this is not the case, the flat side shall be mounted down, in order to avoid debris and to simplify drainage.

To minimise the unbalancing effect of liquid flow entering double suction centrifugal pumps, vertical elbows are preferred adjacent to suction flanges. If this requirement can not be met, the elbows in piping shall be at least five pipe diameters upstream of the pump suction flanges with the following qualifications:

- where no reducer is employed between the pump flange and the elbow, a straight run of at least five pipe diameters long shall be provided;
- where a reducer is located between the pump flange and the elbow, a straight run of at least two pipe diameters long, based on the larger pipe diameter, shall be provided. A reducer next to the pump flange is considered to be equivalent to three large diameters.

Valves in pump discharge lines shall be located as close to the pump nozzles as possible.

All valves adjacent to pumps shall be accessible for hand operation without the use of chains or extension stems. Hand-wheels and stems shall not interfere with the operational passageways or the removal of pumps.

Suction piping shall be designed to enable strainers to be easily installed or removed without springing the pipe.

5.8.3 Compressors

5.8.3.1 Gas compressors

In order to get a neat layout, top and bottom entry compressors should be evaluated.

All gas compressors suction piping between the knockout vessel and the compressor shall be arranged to prevent the possibility of trapping or collecting liquid.

Piping shall slope continuously downwards from the suction cooler to the knockout vessel connection. Piping shall be routed so that any condensate drains back from the compressor suction to the knockout vessel.

All compressors shall be provided with a temporary strainer in the suction line unless a permanent strainer is indicated on the P&IDs. The strainer shall be located as close to the compressor as possible, unless the P&IDs indicate otherwise. The opening of the strainer shall be located in the horizontal direction to prevent condensate accumulation in the tee piece.

Compressor discharge lines shall be equipped with check valves installed as close as possible to the compressor discharge nozzle. The compressor discharge line shall be routed without pockets from the compressor to the cooler.

5.8.3.2 Air compressors

For parallel compressor trains, with a parallel layout within the same area, utility pipe nozzles for two trains may be mirror imaged in order to get easy access to common maintenance areas.

Suction line silencers, where required, shall be located as close to the compressor suction connection as possible according to the compressor manufacturer's instructions.

When two or more compressors are installed in parallel, the discharge piping shall enter the header from the top to avoid condensate to enter the standby compressor.

5.8.4 Turbines

Fuel gas lines in non-hazardous area shall be all-welded and without potential leakage points, e.g. flanges, valves, high point vents, low point drains etc. Valves and turbine connections may be flanged inside turbine

enclosure. In the non-hazardous areas, fuel gas piping shall be routed without pockets in order to avoid trapping of liquid after pressure testing or during operation. Turbine fuel control and fuel filters shall be easy accessible.

All inlet and exhaust piping/ducting for turbines shall be adequately supported to the approval of the equipment manufacturer. Exhausts shall be routed into a non-hazardous area and shall not prove hazardous to personnel or foul air inlet.

The design of the exhaust system from gas turbines shall satisfy requirements for classified area. Exhaust ducts with overpressure-ventilated casings shall be considered to avoid surfaces with a temperature above the permissible.

5.8.5 Diesel engines

Pipe work shall not be run directly over diesel engines, exhaust piping or any position where leaking fuel oil can impinge onto hot parts.

The fuel oil header shall not be "dead ended", to simplify cleaning/purging.

Where a positive static head is required from the day tank, the minimum operating level shall be 300 mm above inlet of the fuel injection pump.

The drain line from the day tank shall be positioned so that the drain line outlet into the main drain is visible from the drain valve position.

5.8.6 Vessels and towers

Where possible, blinds, spacers and block valves shall be located directly on the vessel nozzles.

Check valves shall be installed on the block valve at the vessel nozzle where not in conflict with 5.6.2.

To reduce the risk of overstressing vessel nozzles, pipe size should be equal or less than nozzle size.

Manway hinges/davits shall be oriented such that the cover opens away from ladders/stairs and instrument access.

5.8.7 Heat transfer equipment

Valves shall not be located directly on top of channel nozzles, to avoid obstructing the removal of channel ends. Spool pieces shall be provided to facilitate the tube pulling and maintenance.

Piping shall be arranged to permit cooling fluid to remain in all units on loss of cooling fluid supply. Where this is not possible, an evaluation of the use of check valves shall be performed.

Thermo-wells for inlet and outlet temperatures for each fluid service shall be provided, and shall be located in adjacent piping when the exchanger nozzles will not permit a 90 mm immersion for the thermo well.

Gas coolers with U-shaped tube design, and gas on the tube side, shall not be located vertically in order to avoid accumulation of condensate in the U-shaped tubes. In such cases, straight through, single pass coolers shall be selected.

5.8.8 Launcher and receiver traps

Consideration shall be given to mechanical handling facilities for pigs and line logging devices. The facilities should include the following:

- a) overhead hoists or access for forklift truck;
- b) winching points for logging device withdrawal;
- c) storage and inflation facilities for pigs and logging devices,
- d) cradle for inserting the pig.

The pig receiver opening closure shall face the sea. Vertical launchers shall be placed on the outside area on the platform and shall be open to air. Provision shall be made within the closure for hydraulic connections to allow the operation of hydraulic equipment, e.g. maintenance pigs and hydro plugs.

Elevation of traps shall be kept to a minimum. Where a sight glass is specified on the drain line, sufficient space shall be provided for observation of flow.

The traps shall have a pressure indicator positioned so that it will be visible to personnel operating the trap closures.

Piping upstream receivers and downstream launchers shall have a minimum bend radius of three times the nominal diameter. Bend internal dimensions shall meet the requirements set by the pig supplier(s).

The junction between the production line and the inlet/outlet to the launcher/receiver shall be designed to prevent pigs from entering the production line.

Specially designed sphere or barred tee suitable for the logging device to be used.

The launcher/receiver shall be sloped towards the trap closure, and a spillage retention tray provided with drain, shall be installed. The retention tray for the receiver shall be sized according to the length and volume of the receiver. The retention tray shall be located at an elevation directly underneath the end closure and shall be provided with grating.

Receivers to include internal rail system, which provides clearance between tool underside and trap, to improve drainage of the trap before closure is opened.

The trap design details (e.g. barrels bores, barrels lengths, bore tolerances, closure type, nozzles positions and sizes) shall be approved by Company.

Valves in pipeline risers shall be located in a horizontal or vertical part of the riser.

A minimum of 2 m straight run should be arranged between the sphere or bar tee and the pipeline emergency shut down valve in order to accommodate for installation of an inflatable welding sphere. This is to provide double isolation against the pipeline if repair of the isolation valves to the pig trap or isolation valves to the process area should be necessary. This is applicable to piping where non flexible risers are used.

Pipeline valves installed in a vertical part of a riser shall be equipped with tools and supporting arrangement for easy and safe on-site replacement of valve drive train, i.e. actuator and valve trim materials.

5.8.9 Flowlines and manifolds

The distance between the well slots on a fixed offshore installations shall be minimum 2,5 m. On floating units, a greater minimum distance may be required to avoid interference between the risers.

In the design of piping manifolds, preference shall be given to the use of hot isostatic process or standard tees.

The manifolds shall be designed with flanges or clamp connectors at each end for cleaning and future expansion purposes.

The manifold and flowline piping shall be supported to minimize vibration and whip, but at the same time ensure that sufficient flexibility is provided to take up variations in movement and settlement between topside wellheads or flowline risers and manifold piping.

Production manifolds shall be designed for solid (scale) removal where this may be a problem.

The manifold piping arrangement shall provide easy access to all valves and instruments for operational and maintenance purposes. Special attention shall be given to requirements for removal of components for maintenance.

Consideration shall be given to any changes of direction in the flowlines where the product contains particles at high velocities which will erode the fittings. Target tees or long radius (3 x pipe diameter, or more) bends should be specified in order to reduce erosion and simplify inspection.

Flow lines and gas lift lines should be such designed that the stiffness of the system is approximately the same regardless of which direction the X-mas tree is moving.

An erosion pipe spool, of length approximately 10 times the line size, shall be considered for installation at the location of highest turbulence downstream of each choke for corrosion/erosion monitoring. If the spool length between the choke valve and the shut off valve on the manifold is sufficiently short, it can be considered as an erosion spool unless higher turbulence may occur in a downstream manifold or header.

Space shall be provided in the wellhead area for a cabinet containing lubricant for the X-mas trees. Approximately size is 800 mm x 1 200 mm x 2 100 mm (width x depth x height). The cabinet shall be equipped with an air-powered pump for lubricant, and a hose on reel which can reach all well slots and electrical heating.

5.9 Additional requirements related to piping systems

5.9.1 Air piping

Air piping shall have self draining provision at all low points for the collection of condensate. Air traps shall be provided with isolation valves, balance lines and drains to local collection points.

Instrument air headers and manifolds shall not be dead ended, but supplied with blind flanges for cleaning and maintenance. Sufficient number of take-off connections, to ensure adequate supplies to air operated instruments and equipment shall be provided.

All branches and take-offs shall be from the top of the headers.

5.9.2 Steam piping

Steam piping shall be run to prevent pockets. Condensate shall be collected at low points by using a standard steam trapping system.

Drain points shall be from the bottom of the header and steam take-offs from the top. Steam traps shall be accessible from deck or platform.

The high operating temperature of this type of piping may require special considerations related to

- expansion,
- temperature gradients with and without thermal insulation in flanges, gaskets and bolts,
- bolt pretension loads in flanges.

5.9.3 Utility stations

Utility stations shall be provided as required for air, water, steam/hot water and nitrogen. Each station shall be numbered and located in the general working areas at deck level. Freshwater, seawater and plant air systems shall be equipped with hose reels. Nitrogen stations shall not be located inside enclosed areas.

Nitrogen hoses shall be installed, if required. For reference, see NORSOK L-CR-003. Different types of couplings shall be used for air and nitrogen.

5.9.4 Pressure relief piping

Piping to pressure relief valve inlet shall be as short as possible.

When relief valves discharge to atmosphere, the elevation at the top of the discharge line shall typically be 3 000 mm above all adjacent equipment. This is to keep adjacent equipment or operating platform outside gas exposed area. Discharge tail pipes shall have a drain hole at the low point of the line. Location of discharge points shall be as specified by the safety discipline.

Relief valves discharging to a flare system shall be installed so as to prevent liquid being trapped on the outlet side of the valve. All relief lines and headers shall be designed to eliminate pockets, but if a relief valve must be located at a lower elevation than the header, an automatically operated drain valve shall be installed at the valve outlet and piped to a collecting vessel or closed drain.

Relief valve headers shall slope towards the knock-out drum, taking into account anticipated deck deflection and platform tilt during operation. Pockets are to be avoided, but where a pocket is unavoidable, some approved means of continuous draining for the header shall be incorporated.

Unless specifically noted on the P&IDs, all branch connections on relief and blowdown systems shall be at 90° to the pipe run. Should there be a special requirement for a particular branch to enter a header 45°, this shall be highlighted on the P&IDs.

5.9.5 Open drain systems

Drains shall have slope as specified on the P&IDs. Open drain branch connections shall all be 45°. Roding points shall preferably be through drain boxes and change of direction shall be evaluated against flushing requirements, where the total change of direction is greater than 135°.

Where rod out through drain boxes is impossible, or not sufficient for full coverage, separate rod out points shall be provided. For drain systems with a great probability of clogging, including drilling drain and sewage systems, the rod out points shall be accessible without the use of scaffolding.

Drain boxes shall be covered with an easily removable mesh plate or grating, which shall be flush with the deck surface. The outlet from the drain boxes shall be provided with an easily removable strainer. The design of the drain boxes in a deck area shall ensure sufficient capacity to drain the area with the strainers 50 % filled of waste. This requirement shall also include drainage of deluge water from the actual area, if not separate overflow lines are provided.

Where pipe-in-pipe systems are used, the system shall be provided with visible drain points in order to detect leakages.

5.9.6 Pneumatic conveying

Pneumatic conveying piping shall be designed according to and approved by the pneumatic conveying system manufacturer. Purge connections shall be easy accessible to avoid waste of time when plugs occur.

5.9.7 Fire/explosion protection

All project accidental load requirements shall be met, see NORSOK S-001.

5.9.8 Firewater distribution system

The layout of the firewater distribution system shall be carefully designed with respect to hydraulic pressure drop. Firewater systems may be subject to surge and dynamic phenomena due to rapid start-up and stop of firewater pumps. The forces introduced by such phenomena shall be evaluated in order to ensure that these are within acceptable limits, and to ensure that sufficient support arrangement is provided for the distribution system.

Deluge nozzles branch off in carbon steel piping systems shall be located away from the bottom of the header to avoid plugging of nozzles. All low points in piping downstream deluge and monitor skids shall be equipped with weep holes or other type of arrangement to prevent pockets of water to be entrained. Adequate venting facilities with valves shall be provided for wet pipe sprinklers.

Location of nozzles shall be as specified by the safety discipline. Necessary deviations to avoid obstructions etc. shall be approved by the safety discipline.

Dead end headers shall be avoided.

5.9.9 Lube, seal and hydraulic oil systems

Lube, seal and hydraulic oil systems shall have flanges and blind flanges on header ends for pickling and hot oil flushing. Components and flanges to be used shall be easy to clean. Ring type flanges to be avoided since gap between flanges is difficult to clean without complete dismantling.

5.9.10 Blow down

Reference is made to NORSOK P-001 for blow down arrangements.

The need for increased pipe wall thickness of the first part of the piping downstream the flow orifice shall be evaluated.

5.9.11 Nitrogen purging

Connections for purging with nitrogen shall be provided for gas freeing at each item of process equipment.

5.9.12 Break out spool

Break out spools to be provided for all equipment that may be removed unless easy removal of the equipment is achieved without spool.

5.10 Fittings

5.10.1 General

All piping fittings shall conform to the relevant code or standards listed in NORSOK L-001 or in the project piping and valve specification.

Short radius elbows, reducing elbows, expansion bellows and flexible couplings shall not be used without written approval by Company.

5.10.2 Line blinds

Location of line blinds are indicated on the project P&IDs.

The provision for blinding shall consist of a pair of flanges, one of which may be a flanged valve (except wafer type valves) or equipment nozzle.

Spectacle blinds, blinds and spacers shall be used in accordance with the project "Piping and Valve Material Specification".

Provision shall be made for using mechanical means of lifting either by davits or block and tackle lifting points, where the weight exceeds tabulated. Wherever possible, blind/spacer shall be located in horizontal runs. Values are given in NORSOK S-002.

Where line blinds are installed, the piping shall be designed to allow enough flexibility to spring the line by means of either jack screws or other jacking arrangements. On ring joint, compact flanges and hubs the flexibility allowance shall be sufficient to allow for the removal of the ring without overstressing the piping.

If required, a break out spool shall be provided for dismantling.

When the weight of blinds and spacers exceeds 0,25 kN, provision shall be made for using mechanical means of lifting either by davits or block and tackle.

All stainless steel spade and spacers shall be stored adjacent to their insertion point. Carbon steel spade and spacers shall be stored in a heated, ventilated and air conditioned controlled area with easy access for transportation. The spade and spacers shall be stored in racks or on hooks fitted for the different sizes and types and secured with respect to platform movements. All sealing surfaces shall be preserved and protected against mechanical damage. Spade and spacers above 0,25 kN shall be located such that handling by permanent or temporary lifting equipment is possible without dismantling of other equipment.

All spectacle blinds and spade/spacers shall be accessible from deck level or permanent platform.

5.10.3 Insulation spools

In piping systems where risk of internal, galvanic corrosion between dissimilar materials exist (e.g. seawater, produced water etc.), the need of mitigating measures shall be evaluated.

Examples of dissimilar metal flanged interfaces that can be used to mitigate the galvanic corrosion threat in corrosive service are as follows:

- a) install a distance spool between the dissimilar metals so that they will be separated by at least 10 pipe diameters from each other. The distance spool may be either of a solid electrically non-conducting material (e.g. GRP) or of a metal (might be the less noble metal) that is coated internally with a robust electrically non-conducting material, e.g. rubber, polyethylene or fusion bonded epoxy. The need for performing holiday detection of the coating to be evaluated;
- b) apply a non-conducting thin film coating on the most noble of the dissimilar metals. The coating shall extend at least 10 pipe diameters into the most noble pipe material;
- c) apply a corrosion allowance on the less noble metal of a sacrificial thick-walled carbon steel spool, which is designed for replacement at scheduled intervals;

- d) install internal sacrificial anodes through access fittings near the interface, e.g. resistor controlled cathodic protection.

Eventual insulation spools shall be shown on the P&IDs. Technical details/spool dimensions shall be specified in special item data sheets.

See NORSOK P-001 for more design guidance, and NORSOK M-501 for information regarding surface treatment.

5.10.4 Strainers

The P&IDs will indicate whether a permanent or a temporary strainer shall be used to protect equipment.

Easy removal and cleaning of filters shall be possible. The mesh size of the strainer shall be determined and approved by the equipment manufacturer of the equipment to be protected. The physical strength shall allow for a pressure drop during maximum flow rate at test/start-up/operation of at least 10 times the pressure drop across the strainer in the clean condition.

The strainer housing shall conform to the appropriate material classification for the service in which it is installed. The housing of permanent strainers shall have either flanged ends or butt-weld ends. Butt-weld ends are preferred due to weight saving, especially for the larger sizes.

The installation of permanent strainers shall permit cleaning without dismantling the strainer housing or piping.

Break out spool to be installed in conjunction with temporary strainers installed between flanges.

5.10.5 Piping in non-hazardous areas

In non-hazardous areas all piping containing hydrocarbons shall be all-welded and without potential leaking points, e.g. flanges, valves, high point vents, low point vents etc.

However, Company can decide that components (e.g. flanges) can be accepted for piping containing hydrocarbons in non-hazardous areas provided the sealing capacity of the flanges are load tested before start-up to a level which will exceed all operating conditions. The recommended type of flange is specified in NORSOK L-005.

5.10.6 Use of flanges or welds for offshore modification projects

When modification of existing operating offshore facilities shall be planned it should be evaluated to use flanges instead of welding to join pipe spools. The recommended type of flange to be used for this type of projects is the compact flange, see NORSOK L-005. Selection of type of flange(s) shall be agreed with Company.

5.11 Hook-up piping

Offshore hook-up piping shall be kept to a minimum.

5.12 Hoses and flexible pipes

If hoses are used, it shall be documented that they are suitable for the medium and the required pressure and temperature. Hoses with associated couplings shall be marked in accordance with applicable standards. Components should be designed so as to avoid them being wrongly connected. Hoses should be protected against damage from crushing/compression, if their design will not withstand such loads.

Flexible pipes shall be designed in accordance with recognised standards.

5.13 Instrumentation

5.13.1 Materials and rating

Materials and rating for instrument connections shall conform to the relevant material and pressure rating classification of the parent line.

5.13.2 Accessibility, location and orientation

Special attention shall be given, with respect to accessibility, location and orientation of valves, vents and drains as well as block and by pass valves.

Control cabinets (accumulator packages) shall be located as close as practically possible to the respective valves.

Location of flow orifices shall be in accordance with ISO 5167. For liquid services, flow orifices shall not be put on vertical pipe runs. Tapping points shall be in accordance with NORSOK L-CR-003.

For instrument items considerations shall be made during design for operator access requirements, see Table 1.

The installation of flow meters shall be in accordance with manufacturer's recommendations. Special attention shall be given to ultrasonic, coriolis and magnetic flow meters.

Table 1 – Location and access for instrument items

Type of instrument	Access required for operations	Access via fixed ladder	Access via fixed platform
Thermocouples	No		
Test thermowells	Yes	Yes	Acc.
Local temperature indicator	No ^a	No	No
Pressure gauge	No ^a	No	No
Level gauges	Yes	Yes	Acc.
Temperature transmitter and switches (indicating)	Yes	Yes	Acc.
Temperature transmitter and switches (blind)	Yes	Yes	Acc.
Other transmitters and switches (blind)	Yes	Yes	Acc.
Other transmitters and switches (indicating)	Yes	Yes	Acc.
Recorders and controllers	Yes	No	Yes
Control valves and other final control elements, PSVs	Yes	No	Yes
All flow primary elements (orifice plates, ventures pitot tubes)	Yes	No	Yes
Key			
Yes :Required minimum			
Acc. :Acceptable, but not mandatory			
^a Shall be able to read from platform or fixed ladder.			

5.13.3 Tubing

Process and instrument tubing shall be designed and installed in conformance with ASME B 31.3.

Tubing shall be supported to field trays or cable ladders for tubing sizes less than 16 mm outside diameter. Cable tray, ladder or equal to be used for larger sizes when mechanical protection is required. Trays are not required for internal tubing on components if tubing is sufficiently protected.

Tubing to be fastened to self drained tubing clamps with span maximum every 60 x tubing diameter. Tubing sizes above 25 mm outside diameter shall as a minimum have support every 1,5 m. Tubing clamps shall be made of non-corrosive material, stainless steel AISI 316 and/or flame retardant plastic.

Galvanic corrosion between tubing and tubing support system shall be avoided. The tubing clamp shall, when installed, not allow for water/sea water to be accumulated between tubing and tubing clamp on wall, this is to avoid crevice corrosion.

Parallel runs of tubing on the same support shall be arranged such that it is possible to have access to every connection point.

Installation into or through panels shall be by use of bulkhead unions or multi cable transits. Tubing and cables may be installed on the same field tray for shorter distances (approximately 5 m).

All tubing and/or tube fittings, which are not connected, shall be sealed by use of end-plug/cap of same material as the tubing and/or tube fittings.

Vent, drain and manifold valves shall be available outside insulation for test connections. Tubing shall be installed to reach outside insulation for test connections.

All compression tube fittings shall be of the same make.

NOTE Additional information can be found in the UKOOA document.

5.14 Welding

For requirements for welding and construction, see NORSOK L-CR-004, NORSOK M-601 and Company procedures and technical requirements.

6 Structural analysis of piping systems

6.1 General

Pipe stress and flexibility (structural) analysis shall be performed in conformance to ASME B 31.3, if not otherwise specified by Company.

6.2 Analysis

If computerized methods are used, the structural calculation program shall be accepted by Company.

The an-isotropic properties of composite materials (e.g. GRP), shall be considered in the flexibility analysis.

6.3 Selection criteria

As a general guidance, a line shall be subject to comprehensive stress analysis if it falls into any of the following categories:

- a) all lines at design temperature above 180 °C;
- b) 4 in NPS and larger at design temperature above 130 °C;
- c) 16 in NPS and larger at design temperature above 105 °C;
- d) all lines which have a design temperature below -30 °C provided that the difference between the maximum and minimum design temperature is above
 - 190 °C for all piping,
 - 140 °C for piping 4 in NPS and larger,
 - 115 °C for piping 16 in NPS and larger.

NOTE These temperatures above are based on a design temperature 30 °C above maximum operating temperature. Where this is not the case, 30 °C must be subtracted from values above.

- e) lines 3 in NPS and larger with wall thickness in excess of 10 % of outside diameter. Thin walled piping of 20 in NPS and larger with wall thickness less than 1 % of the outside diameter;
- f) all lines 3 in NPS and larger connected to sensitive equipment, e.g. rotating equipment. However, lubrication oil lines, cooling medium lines etc. for such equipment shall not be selected due to this item;
- g) all piping expected to be subjected to vibration due to internal and external loads (e.g. pressure transients, slugging, flow pulsation, external mechanical forces, vortex shedding induced oscillations, high gas velocities) and herby acoustic vibration of the pipe wall;

- h) the ring-main and distribution firewater lines. Pressure surges (water hammer) and blast to be considered for the entire system;
- i) all hydrocarbon lines containing oil and gas which shall be de-pressurized after a design blast/explosion event (see the design accidental load report for selection of lines);
- j) all relief lines connected to pressure relief valves and rupture discs;
- k) all blowdown lines 2 in NPS and larger excluding drains;
- l) all piping along the derrick and the flare tower;
- m) lines affected by external movements from structural deflections, connecting equipment, bridge movements, platform settlements, X-mas tree/wellhead, vessel hogging/sagging etc.;
- n) GRP piping 3 in NPS and larger;
- o) all lines 3 in NPS and larger subject to steam out;
- p) long straight lines (typical 20 m);
- q) all production and injection manifolds with connecting piping;
- r) other lines as requested by the project "stress" engineer or Company;
- s) lines falling into Category III according to the Pressure Equipment Directive (PED).

Manual calculations may be used in cases of simple configurations and low stresses.

6.4 Calculation models

The calculation models used to analyse the piping system shall contain sufficient connected piping to ensure properly defined boundary conditions. Special attention shall be given to boundary conditions with movements. In cases where the boundary is an equipment nozzle, even relatively small movements may cause excessive forces and moments, it is important to implement the boundary movements in the calculation model.

6.5 Design temperature

The design temperature for the selection of lines subject to stress analysis shall be as stated on the P&IDs/line lists.

Calculation of expansion stress shall be based on the algebraic difference between the minimum and maximum design temperature. The maximum design temperature shall not be lower than the maximum ambient temperature.

Reaction forces on supports and connected equipment may be based on the maximum algebraic difference between the installation temperature and the maximum or minimum design temperature.

For un-insulated lines subject to heat from sun radiation, 60 °C shall be used in the calculations, where this is higher than the relevant maximum design temperature.

In cases where it is possible to have different temperatures in different parts of the system, all relevant combinations of hot/cold have to be considered.

6.6 Environmental temperature

The minimum/maximum environmental temperature shall be as specified by the project. Unless otherwise specified, the following environmental temperatures shall apply for the North Sea:

- a) installation temperature: 4 °C
- b) minimum ambient temperature: -7 °C
- c) maximum ambient temperature: 22 °C

6.7 Pressures

The design pressure for the piping system shall be as stated on the P&IDs/line lists. Where internal pressure below atmospheric pressure can exist, full vacuum shall be assumed for stress calculations.

6.8 Explosion loads

The effect of blast loads shall be evaluated for piping which is required to maintain the installation integrity in an explosion event. Normal working conditions with respect to temperature and pressure may be used for the blast calculations.

Drag load from explosion shall be calculated from equation (1):

$$F = p \times A \times CD \times DAF \quad (1)$$

where

p is the drag pressure from the blast in Pa
 A is the projected area in m²
 CD is the coefficient of drag (to be determined for the actual pipe or equipment)
 DAF is the dynamic amplification factor (minimum 1,5, if not evaluated in detail)

NOTE For selection of drag factor reference is made to API RP 2FB and FABIG Technical note No 8.

A simplified approach may be used in lack of accurate data. The static overpressure used for structural dimensioning may be used as basis, and an estimated drag pressure calculated as 1/3 x static overpressure may be used.

Maximum allowable stress in blast case shall be the minimum of 2,4 x S or 1,5 x S_y, where S is the ASME B 31.3 allowable stress limit and S_y is the pipe material yield stress.

The standard stress intensification factor values can be multiplied with a factor of 0,75 for the explosion design case. However, the stress intensification factor values shall not be less than 1,0.

The potential effects of deck and wall deflections due to blast loads (movement of equipment and pipe supports) shall be evaluated.

NOTE For design advice, see the UK-HSE report.

It shall be documented that the mechanical joints (e.g. flanges, hubs, couplings, etc.) on piping systems selected for blast calculations are leak free after the explosion event. However, it is acceptable that the mechanical joints leaks during the explosion event.

NOTE EN 1591 may be used for documenting the tightness requirement for the critical mechanical joints.

6.9 Fire, heat and noise insulation

The use of insulation on piping, flanges and valves shall be kept to a minimum.

If fire insulation is required, it shall be evaluated to use

- a higher pressure class,
- high strength steel for the relevant lines,
- higher pressure class for flanges than required by the selected pipe class sheet for the pipe,

in order to full fill the fire protection requirements without use of fire insulation.

It is recommended to install additional pipe supports with fire insulation (if needed) if that can eliminate the need for fire insulation on piping, flanges and valves.

If insulation is needed in order to meet heat or noise requirements, the recommendations above are not relevant.

6.10 Vessel/deck deflections

If the piping system is installed on a vessel, the hogging/sagging effect of the vessel shall be included in the calculations. When piping is run between individual modules on a vessel, the relative movement between modules due to hogging/sagging shall be included in the calculations.

On fixed installations deck deflections may have a significant effect on the calculations and this has to be evaluated as a part of the analysis.

6.11 Vessel accelerations

For piping installed on vessels (e.g. floating production, storage and offloading vessels), vessel accelerations due to waves shall be included in the calculations.

6.12 Dynamic loads

A piping system may be subject to dynamic loads such as, but not limited to

- a) PSV reaction forces,
- b) slug loads,
- c) dynamic loads from density variations in two-phase flow,
- d) water hammer,
- e) earth quake.

These loads may be taken into account by either estimating an equivalent static load combined with a conservative dynamic amplification factor or by performing more elaborate dynamic analysis.

The effects of vibration imposed on piping systems shall be evaluated and vibration sources which can be realistically determined shall be accounted for. This also includes acoustic induced vibration.

6.13 Other loads

Other loads that shall be considered are, but not limited to

- a) wind,
- b) snow/ice,
- c) X-mas tree movements,
- d) lifting and transportation,
- e) current, vortex shedding,
- f) pressure testing,
- g) acoustics, see Annex A and Annex B.

6.14 Fatigue

The provisions covering analysis of fatigue loads in ASME B 31.3 are quite rudimentary. There are examples of piping applications exposed to severe cyclic loadings where the need for a more comprehensive fatigue assessment is evident, for instance piping exposed to wave loads such as wellhead piping on jacket platforms and expansion loops on bridges.

In such applications, a fatigue assessment method outlined in PD 5500, Annex C, may be utilised. This method is based on the theory of cumulative fatigue damage (Miner Palmgren) using SN-curves to evaluate fatigue lifetime expectancies.

Flowlines may be subject to dynamic loading caused by variation in density of the fluid as well as wave induced movement of the X-mas tree. In order to reduce the potential for dynamic movements, the lowest eigenfrequency of the flowline should preferably be above 4 Hz. A too stiff supporting may on the other hand lead to unacceptable load and stress levels. The need for fatigue calculations shall be considered.

6.15 Loads from piping systems on equipment

When analysing piping connected to parallel located equipment, the relevant worst temperature combination case shall be used.

Calculation of thermal nozzle loads shall be based on the maximum or minimum design temperature.

Piping connected to compressor and pump suction and discharge nozzles shall be fully force balanced through its supports in the operating condition, and shall exert only minimal loads on the nozzles in order to minimise equipment misalignment caused by external loads.

Allowable loads on equipment shall be calculated in accordance with vendor drawings. For guidance, see NORSOK R-001.

When calculating loads on compressor nozzles, the point for resolvment of forces and moments shall be agreed with the compressor vendor.

6.16 Flanges

In order to minimise the risk of leakage at valves, flanges and mechanical joints, the bending moments on these shall be evaluated. Special attention shall be made to bolt tensioning values to ensure that sufficient gasket surface pressure is maintained at all conditions. For additional information, see NORSOK L-CR-004.

NOTE Flange and bolt pretension load calculations can be done in conformance with EN 1591.

Flanged joints designed and made up according to requirements in NORSOK L-005 need no further evaluation regarding leak tightness, since these joints are always considered to remain tight within acceptable stress levels in the piping system. Mechanical integrity shall be considered in accordance with NORSOK L-005.

6.17 Pipe supports

6.17.1 General

Pipe supports shall be designed in conformance with recognised design standards, e.g. EN 13480-(all parts) and NS 3472. For construction requirements, see NS 3464.

Design standards and extent of documentation for the pipe supports for the actual project to be agreed with Company.

NOTE All supports on pipes subject to comprehensive analysis should be treated as support class 3, see EN 13480 – (all parts).

For the blast load case allowable stress, the minimum of $2,4 \times S$ or $1,5 \times S_y$, where S is the ASME B 31.3 allowable stress limit and S_y is the pipe material yield stress, can be used as allowable stress for welded attachment to the pipe.

If a pipe support structure is bolted to the structural steel, the ultimate capacity of the bolted connection shall be minimum 150 % of the ultimate structural capacity of the pipe support, i.e. the bolted connection shall not be a weak link.

When pipe supports are designed, possible loads from the piping construction, erection, installation, testing and demolition shall be included in the design. It may not be sufficient to use only the design loads from the piping stress report.

The stiffness of the pipe supports shall be as assumed in the pipe stress report. It may be necessary to use deflection requirement rather than allowable stress as the design limit.

Supporting of small-bore piping tie-ins shall ensure that movement of the main pipe or equipment will not cause overload or fatigue damage in the connection. All small-bore piping such as by pass lines and short drain lines shall normally be supported from the main pipe.

Where thermal and pressure expansion will cause movement of any branch points on headers, the branch line shall be stress evaluated up to the first point of support restricting movement in the header movement direction.

Piping shall not be forced to fit with support locations in such a manner that additional stress is introduced.

Pipes shall not normally be supported by other pipes, i.e. individual supporting is required.

If bolted supports are used, which rely on friction for staying in place or fulfil the design function, the design shall ensure that the bolt pretension loads do not diminish during the design life time of the support.

Line stops shall normally be designed with welded attachments to the pipe.

Where increased flexibility is required within the pipe system, but can not be obtained by normal pipe route changes, standard pipe support restraint gaps may be increased in increments of 5 mm. Restraint gaps below 5 mm shall not be considered for flexibility purposes, and allowance should be made for any installation tolerances within the analysis. All restraint gaps greater than the agreed project standard shall be clearly noted on the pipe support drawings.

Supports for piping systems consisting of flexible hoses, instead of hard piping, shall be documented to the same level as a conventional hard piping system.

Pipe supports shall be in accordance with the relevant pipe support detail drawings developed for the project.

6.17.2 Bracing of branch connections

Piping branch connections in services that give potential for piping vibration, shall be designed with bracing. Unsupported branch connections with a mass concentration (e.g. vent/drain valves), attached shall be braced against the parent pipe for the following services:

- a) process rotary piping;
- b) reciprocating pumps- and compressors piping;
- c) piping subject to slugging or flow induced vibrations;
- d) gas piping;
Velocities larger than $V = 175 \times (1/\rho)^{0.43}$, where V is the velocity in m/s and ρ is the density at operating condition in kg/m^3 , shall have special attention.
- e) other services that typically can excite pipe vibration.

An alternative solution may be to reinforce the parent pipe in order to prevent fatigue failure due to shell vibration in parent pipe.

Branches having only minor weights attached do not require bracing, provided the branch is short enough to ensure adequate integral stiffness. Normally branches shall be provided with bracings in two directions. Bracings shall preferably be made from L-profiles.

Bracing can be omitted if it can be demonstrated that the branch connections are not likely to be exposed to structural overload or vibration.

NOTE For design advices, see the Energy Institute document.

6.17.3 Spring supports

In general, the use of spring supports shall be kept to a minimum by careful consideration of support location and alternative pipe routing. All spring support shall be fitted with durable nameplates.

6.17.4 Welded attachments

Stresses introduced in pipe due to loads from welded attachments (i.e. trunnion supports), shall be examined.

Stresses in the trunnion/pipe interface and in the trunnion proper shall be evaluated by a qualified pipe stress engineer, see ASME B 31.3, para 301.1.

NOTE It is recommended to use method described in M.W. Kellogg "Piping Design" taking into consideration the prevailing cross-sectional forces and moments, also those not originating from trunnion reactions. The stresses shall in operating conditions be limited to $1,5 \times f$ for straight pipe and $1,0 \times S$ for elbows (S = ASME B 31.3 allowable stress limit, see 6.17.1), while in blast scenario, the stress limit should be the same as the blast stress limit for the pipe itself, see 6.8.

Stresses in the trunnion proper shall be analysed using methods outlined in NS 3472 with allowable stresses accordingly (von Mises criteria). In operating cases, NORSOK ultimate limit state load factors and NS material factors shall apply. In the blast scenario, load factors and material factors shall be set to 1,0 and the stress limit should be the same as the blast stress limit for the pipe itself.

Stresses in the weld between trunnion and process pipe (or between trunnion and reinforcement pad) shall be evaluated using methods outlined in NS 3472. Flat plate approximation of the weld cross-section may be done. In case of no reinforcement pad, the effects of pressure strain in the weld shall be included. In the operating cases, NORSOK N-001, Section 6, ultimate limit state partial action factors (load factors) and NORSOK N-004, Section 6.1, material factors shall apply. In the blast scenario, partial action factors shall be set to 1,0.

Annex A (Informative) Acoustic fatigue in piping systems

A.1 Excitation from pressure reduction sources

High pressure drop across valves or other restrictions in gas piping may cause fatigue in the piping system if the pipe wall thickness is relatively small compared to the pipe diameter. The noise energy caused by the pressure reduction propagates inside the pipe and may be large enough to excite the pipe shell, resulting in shell to vibrate at its natural frequency. This may lead to fatigue in the pipe. Abrupt change in stiffness of the pipe shell suppresses the free vibration mode of the shell which may lead to high bending stress in the shell at the suppressed location. Branch connection is an example of design where stiffness changes abruptly.

Smooth transitions from the header to branch will reduce the risk of fatigue. Flare systems are typically a system which should be evaluated for acoustic fatigue. This is due to the high pressure drop in the process letdown valves such as PSVs or blow down valves.

Not many methods exist to calculate the risk for acoustic fatigue realistically. The method in A.2 may be used if no better method is available

A.2 Method for evaluating acoustic fatigue

Reference for equation (A.1) and (A.2) is:

ASME publication PVP-Vol. 328, Flow induced vibration, ASME 1996, by Eisinger.

Sound power level from the pressure reduction source (typically a valve or orifice) is calculated according to equation (A.1). In some cases the pressure drop in a branch junction may be large enough to contribute as source and should then be added with any other source.

$$PWL = 10 \times \log \left[\left(\frac{P_1 - P_2}{P_1} \right)^{3.6} \times \left(\frac{W}{3600} \right)^2 \times \left(\frac{T_1 + 273}{M} \right)^{1.2} \right] + 126,1 \quad (\text{A.1})$$

where

PWL is the sound power level in dB

P_1 is the upstream pressure of pressure letdown source in bar

P_2 is the downstream pressure of pressure letdown source in bar

T_1 is the upstream temperature of pressure letdown source in °C

W is the gas flow in kg/h

M is the molecular weight

NOTE For valves equipped with low noise trim, equation (A.1) should not be used. See the acceptance level below under subheading, "Acceptance level". PWL for low noise trim valves should be obtained from the valve manufacturer, if required.

Attenuation along the pipe downstream the source can be calculated by equation

$$PWL_{At} = 0,06 \times \left(\frac{L}{D_i} \right) \quad (\text{A.2})$$

where

PWL_{At} is the sound power attenuation along the pipe in dB

L is the distance from source along the pipe in mm

D_i is the inside diameter of pipe in mm

Bend, tee junctions, reducers etc. in the piping give also attenuation of the noise along the pipe. Methods for calculation of attenuation through such fittings may be proposed by Contractor.

The sound power level at the L distance along pipe from the source is:

$$PWL_L = PWL - PWL_{At} \quad (A.3)$$

NOTE The fatigue evaluation need only extend down to entrance of any vessel, unless new noise sources are located in downstream piping from the vessel.

If more than one source generates noise, the noise shall be added at the pipe junctions where the piping from the sources meets:

$$\sum PWL_L = 10 \times \log \left[10^{(PWL_1/10)} + 10^{(PWL_2/10)} + \dots + 10^{(PWL_n/10)} \right] \quad (A.4)$$

where

$PWL_{1, 2 \text{ etc.}}$ is the power level PWL_L for each source at location L in the downstream piping.

A.3 Acceptance level

The acceptance level can be calculated from

$$PWL_A = 173,6 - 0,125 \times \left[\frac{D_i}{t} \right] \quad (A.5)$$

where

t is the pipe wall thickness in mm

D_i is the inside diameter of pipe in mm

If the source is a PSV the acceptance level can be increased by 5 dB under the condition that design improvements are applied. Design improvements are required downstream the PSV as described in A.5 for a distance corresponding to the calculated sound power above the acceptance level in equation (A.5) and the calculated attenuation along the pipe in equation (A.2).

If the source is a low noise trim valve designed for maximum 110 dBA sound pressure level at an outside distance of 1 m from the valve, then the pipe inside noise power level is regarded as being too small to create acoustic fatigue and further calculations is thus not required.

A.4 Additional evaluation to further increase the acceptance level

Further increase of acceptance level should be considered instead of specifying larger wall thickness or design improvement. Parameters that will contribute to increased acceptance level, are e.g.:

pressure letdown scenario;
piping configuration;
pipe attachments;
nozzles and branches.

The evaluation to increase acceptance level should be done in cooperation with Company.

A.5 Design improvements

The following design improvements shall be considered to reduce the risk of acoustic fatigue:

- "Olets" larger than 50,8 mm (2 in) should be substituted by Welded-in contour inserts or Tee (e.g. ASME B 16.9 Tee, not fabricated Tee);
- any reinforcement plate or attachment plate should envelope the full circumference of the pipe.

A.6 Remedial action to reduce noise from the source

If the acceptance level above can not be met, then the noise generating source should be considered as follows:

- a) select valves with low-noise trim;
- b) evaluate to use more valves in parallel which will reduce the noise;
- c) reduce pressure in steps.

However, if it is more economical to increase the wall thickness of the piping resulting in increased acceptance level of noise, then this should be the solution.

Annex B

(Informative)

Acoustic resonance with flexible riser as initiating source

B.1 Acoustic resonance with flexible riser as initiating source

Flexible riser with corrugated carcass for transportation of gas may initiate acoustic resonance in the topside piping system. Note that the responsibility for flexible risers and seabed piping is not covered in this NORSOK standard. However, for the flexible riser, an increased "carcass spacing" and helix angle of the carcass should reduce the problem and is thus important for the topside piping. Note also that the seabed piping in nature, relative to the flexible riser, is the same as for the topside piping, but it is normally less complex or close to infinity in length, and may thus not be of concern. However, complex seabed piping should be of concern, and may have an effect also on the topside piping if common resonance length exist. The flexible riser and seabed piping are not further discussed in this NORSOK standard.

B.2 Topside riser with branch piping

The geometry of topside riser, the piping from the termination of the flexible riser to the pig trap on the platform, is important. The following shall be considered:

- a) based on the carcass spacing, speed of sound and the flexible riser length, the "frequency menu" from the flexible riser can be determined. When reaching a threshold velocity, the topside riser will determine a fixed frequency interval (stepping frequency) that will give a large acoustic resonance amplitude at each interval step above the threshold velocity;
- b) topside riser distance from riser hang off to block valve for the pig trap (normally closed), or termination flange of the topside riser, shall be as short as possible. That will reduce the number of frequency steps proportional to the topside riser length;
- c) the process piping branch to the topside riser should be located to avoid acoustic pressure anti node at the branch. That may be best done by locating it close to the block valve (or terminating flange) for the pig trap. However, it will be more difficult to achieve a solution if a large velocity range is to be considered. Sound attenuation device in the branch, or other means to suppress the acoustic resonance may be a solution;
- d) more complex piping in the topside riser makes it more complicated or more difficult to predict.

Contractor shall evaluate the solution in cooperation with Company and it requires Company acceptance.

B.3 Acoustic absorber

If it can not be determined that the selected riser and the layout of the topside riser is sufficient to reduce the acoustic resonance to an acceptable level, then other means shall be considered to suppress the acoustic source. This may be an acoustic absorber in the topside riser that has to be designed for the system. An absorber or suppression device shall be located as close to the flexible riser as possible. Contractor shall evaluate the solution in cooperation with Company and it requires Company acceptance.

B.4 Gusset plates and other means to reduce potential vibration

If it can not be determined that the acoustic resonance is sufficiently suppressed, then piping nozzles shall be made resistant to vibration. Also branches shall be evaluated for resistance to vibration. Acoustic resonance will typically be high frequency source. In that case, the following design shall be implemented:

- a) flanged nozzles attached to header by o-lets, fitting to fitting, to be stiffened by gusset plates. Any valves mounted on the flange should be selected with small mass/cantilever solution;

- b) for branches that contain valves, the valves should be located away from the header to include a reasonable flexibility in order not to imposing high frequency excitation with significant amplitude at the valve.

However, if the valve is normally closed, potential for “ $\frac{1}{4}$ resonance” in the dead leg should be evaluated.

Contractor shall evaluate the solution in cooperation with Company and it requires Company acceptance.

