OFFSHORE STANDARD

DNV-OS-H205

Lifting Operations
(VMO Standard - Part 2-5)

APRIL 2014

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DET NORSKE VERITAS AS

FOREWORD

DNV is a global provider of knowledge for managing risk. Today, safe and responsible business conduct is both a license to operate and a competitive advantage. Our core competence is to identify, assess, and advise on risk management. From our leading position in certification, classification, verification, and training, we develop and apply standards and best practices. This helps our customers safely and responsibly improve their business performance. DNV is an independent organisation with dedicated risk professionals in more than 100 countries, with the purpose of safeguarding life, property and the environment.

DNV service documents consist of among others the following types of documents:

— *Service Specifications.* Procedural requirements.
— *Standards.* Technical requirements.
— *Recommended Practices.* Guidance.

The Standards and Recommended Practices are offered within the following areas:

A) Qualification, Quality and Safety Methodology
B) Materials Technology
C) Structures
D) Systems
E) Special Facilities
F) Pipelines and Risers
G) Asset Operation
H) Marine Operations
J) Cleaner Energy
O) Subsea Systems
U) Unconventional Oil & Gas

Any comments may be sent by e-mail to *rules@dnv.com*

CHANGES – CURRENT

General

This document supersedes DNV Rules for Planning and Execution of Marine Operations, (1996/2000) Pt.2 Ch.5.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Det Norske Veritas AS, company registration number 945 748 931, has on 27th November 2013 changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to "Det Norske Veritas AS" or "DNV" shall therefore also be a reference to "DNV GL AS".

This is a new document in a series of documents replacing the DNV "Rules for Planning and Execution of Marine Operations" (1996/2000). Extensive revisions and/or amendments have been made, with the following main changes:

- Section 2 "General Requirements" is new, combining new content with some original text from Section 5 of the previous Rules.
- Lifting of objects weighing less than 50 t has been included, with factors/text updated accordingly.

Editorial corrections

In addition to the above stated main changes, editorial corrections may have been made.

CONTENTS

SECTION 1 INTRODUCTION

1.1 Application

1.1.1 General

1.1.1.1 This standard provides specific guidance and recommendations for Engineered onshore, inshore and offshore lifting operations, conducted both in air and sub-sea, see [1.1.2.2].

Guidance note:

'Engineered' refers to lifts that are planned, designed and performed according to requirements in DNV-OS-H101, i.e. specially prepared and documented.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

1.1.1.2 Weight limitations (upper or lower bound) are not specified herein, however, requirements in other standards and local/international regulations may be relevant and governing, for objects with lower weights (typically less than 50 tonnes) and for operations involving routine lifts.

Guidance note:

'Routine' lifts are considered 'everyday' lifts, without specific supporting documentation; e.g. lifts associated with general cargo carrying or portable units from/to supply vessels, minor erection lifts on construction yards, etc. For such lifts higher safety factors may be applicable to compensate the lack of detailed engineering. However, routine lifts are not covered in this standard.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

1.1.2 Complementary standards

1.1.2.1 DNV offshore standards covering marine operations, i.e. DNV-OS-H101, DNV-OS-H102 and DNV-OS-H201 to DNV-OS-H206, are collectively referred to as the VMO Standard.

Guidance note:

The VMO Standard supersedes and replaces "DNV - Rules for Planning and Execution of Marine Operations". See also Table 1-2.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

1.1.2.2 For sub-sea lifting relevant parts of DNV-OS-H206 shall be considered.

1.1.2.3 The sea transportation phase for lifted objects and lifting equipment is covered in DNV-OS-H202.

1.1.2.4 General recommendations for planning, loads and design of marine operations are given in DNV-OS-H101 and DNV-OS-H102.

1.1.3 Objectives and conditions

1.1.3.1 The objectives of this Standard are stated in DNV-OS-H101, Sec.1A.

1.1.3.2 The general conditions for use of this Standard are stated in DNV-OS-H101, Sec. 1 B200.

1.2 References

1.2.1 Numbering and cross references

1.2.1.1 Table 1-1 defines the numbering system used throughout this standard, in comparison with that adopted in some of the DNV-H series of offshore standards, published to date. See Table 1-1.

1.2.1.2 The text in this standard includes references to documents listed in Table 1-2. Where referred to, the referenced text shall be considered part of this standard.

Table 1-1 Numbering

Level	*Numbering*	*Numbering in some published DNV-H standards*
Sections	1	Sec. 1, 2, 3…
Sub-Sections	1.1	A., B., C.….
Paragraphs	1.1.1	A 100, A 200, A 300…
Items	1.1.1.1	101, 102.., 201, 202.., 301, 302…

1.2.1.3 Requirements herein are based on the document revisions listed in Table 1-2; however the latest revision shall normally be applicable, unless otherwise agreed.

Guidance note:
Agreement should be made between involved parties (normally through contracts) as Company, Contractors and MWS.

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Table 1-2 References including requirements

Reference	*Revision*	*Title*
DNV-OS-H101	Oct. 2011	Marine Operations, General
DNV-OS-H102	Jan. 2012	Marine Operations, Design & Fabrication
DNV-OS-H201	Apr. 2012	Load Transfer Operations
DNV-OS-H202	See note	Sea Transport (VMO Standard Part 2-3)
DNV-OS-H203	Feb. 2012	Transit and Positioning of Offshore Units
DNV-OS-H204	Nov. 2013	Offshore Installation Operations (VMO Standard Part 2-4)
DNV-OS-H206	See note	Sub Sea Operations (VMO Standard Part 2-6)
DNV-OS-E303	Dec. 2012	Offshore Fibre Ropes
IMCA M 179	Aug 2005	Guidance on the use of cable laid slings and grommets
DNV 2.22	Oct. 2011	DNV Standard for Certification No. 2.22, Lifting appliances

Note: The DNV-OS H-series is planned issued during the period October 2011 - October 2014. Each OS will enter into force on the date of publication. Until the OS is published the relevant requirements in “DNV - Rules for Planning and Execution of Marine Operations” shall be considered governing.

1.2.1.4 The documents listed in Table 1-3 include information that through references in this text, clarify and indicate acceptable methods of fulfilling the requirements given in this standard.

1.2.1.5 The latest revision of the informative references should normally be used.

Table 1-3 Informative References

Reference	*Title*
DNV-RP-H101	Risk Management in Marine and Subsea Operations
DNV-RP-H102	Marine Operations during Removal of Offshore Installations
DNV-RP-H103	Modelling and Analysis of Marine Operations
DNV 2.7-1	DNV Standard for Certification No 2.7-1 – Offshore Containers
DNV 2.7-3	DNV Standard for Certification No 2.7-3 – Portable Offshore Units
ISO 2408	Steel wire ropes for general purposes – Minimum requirements
ISO 3108	Steel wire ropes for general purposes – Determination of actual breaking load
ISO 4309	Cranes — Wire ropes — Care and maintenance, inspection and discard
EN 818	Short link chain for lifting purposes - Part 1 to Part 7
ISO 19901-6	Petroleum and natural gas industries - Specific requirements for offshore structures - Part 6: Marine operations.
EN 10204	Metallic products - Types of inspection documents
EN 10164	Steel products with improved deformation properties perpendicular to the surface of the product
EN 12385-4	Steel wire ropes; Safety; Part 4: Stranded ropes for general lifting applications
EN 13414-1	Steel wire rope slings - Safety - Part 1: Slings for general lifting service
EN 13414-3	Steel wire rope slings - Safety - Part 3: Grommets and cable-laid slings
EN 13411-2	Terminations for steel wire ropes - Safety - Part 2: Splicing of eyes for wire rope slings
EN 13411-3	Terminations for steel wire ropes - Safety - Part 3: Ferrules and ferrule-securing
EN 13411-4	Terminations for steel wire ropes - Safety - Part 4: Metal and resin socketing
NORSOK N-004	Design of steel structures
NORSOK R-003	Safe use of lifting equipment

1.3 Terminology and definitions

1.3.1 Terminology

1.3.1.1 Terminology of special importance and used throughout this standard is defined below.

1.3.1.2 *Shall:* verbal form used to indicate requirements strictly to be followed in order to conform to the document.

1.3.1.3 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.

1.3.1.4 May: verbal form used to indicate a course of action permissible within the limits of the document.

1.3.2 Definitions

1.3.2.1 Definitions are included in DNV-OS-H101; terms of special importance for this standard are defined below.

Bobbin: Sheaves applied to increase the bending diameter of double slings around a pin. May also be used to centralise the load, then normally referred to as load centralising bobbin.

Cable laid grommet: Steel ropes arranged into a stranded construction, cabled together, right or left lay, and spliced such that there is no end.

Cable laid sling: Steel ropes arranged into a stranded construction, cabled together, right or left lay, with a hand spliced eye in each end.

Design factor: Factors to be applied for design of structural elements which include relevant load factors, consequence factors, and local dynamics.

Dynamic amplification factor: A factor accounting for the global dynamic effects normally experienced during lifting. The dynamic amplification factor is defined as (Dynamic Load + Static Load)/Static Load.

Fibre sling: Slings made of high performance man-made fibres.

Grommet: Endless sling.

Lifting: The activities necessary to lift or assist a structure by crane(s).

Lifting equipment/gear: Temporary installed equipment such as slings, shackles, sheaves, spreader beams or frames, necessary to perform the lift.

Lifted object: A structure or parts thereof subjected to lifting.

Lift points: The attachment points for slings on the lifted object. Lift point are normally designed as padeyes or trunnions/padears.

Padear: Type lift point on a structure, normally consisting of a tubular member and an end-plate, to ensure sling retention. The sling/grommet may be laid around the tubular member such that a shackle is not needed.

Padeye: Lift point on a structure consisting of a steel main plate with a matched machined or drilled hole for the shackle pin. The hole may be reinforced by a plate (cheek plate) on each side.

Plate shackle: A shackle where the bow is replaced by two steel plates and an extra pin.

Rigging arrangement: The complete system, as applicable, of slings, shackles and, spreader beams or frames.

Shackle: A structural component composed by a bow and a pin linking e.g. a sling/grommet to a padeye.

Single laid sling: Preformed steel wire rope, with hand splices, swaged splices, pressed sockets or resin sockets to form eye terminations at each end.

Skew load factor: A factor accounting for the extra loading on slings caused by the effect of inaccurate sling lengths and other uncertainties with respect to force distribution in the rigging arrangement.

Sling: A strap used between lift point and crane hook during lifting. The term sling is also used for a steel rope with an eye at each end.

Spreader beam/frame – loose gear and part of the rigging used to:

— minimise/eliminate compressive forces imparted into the lifted object
— reduce the effect of inaccurate sling lengths or
— to avoid clashes between slings and the lifted object.

Trunnion: Another name for padear type lift points. It may also be a type of double padear, i.e. a pin (tubular) supported in the centre with slings/grommets on both sides.

1.3.3 Symbols and abbreviations

1.3.3.1 The list below defines symbols used in this chapter

A:	Nominal cross sectional area of all 4 slings.
CGBL:	Calculated Grommet Breaking Load
CoG:	Centre of gravity.
CSBL:	Calculated Sling Breaking Load
D:	Bending diameter of slings.

DAF:	Dynamic amplification factor.
DHL:	Dynamic hook load.
DHL_i :	Dynamic hook load for hook no. i.
d:	Diameter of sling.
DF:	“Design Factor” introduced to ensure that slings/grommets are not too oversized (stiff) to apply the tabulated STF_{sl}.
E:	Young's modulus.
F_{ds}:	Lift point design load in the sling direction.
F_{sling} :	Maximum dynamic sling load.
F(SPL):	Additional hook load due to SPL.
$F(SPL)_i$:	Additional hook load due to SPL for crane no. i.
GN:	Guidance Note
HMPE:	High-Modulus Polyethylene
IACS:	International Association of Classification Societies
MBL:	Minimum breaking load.
MWS	Marine Warranty Surveyor/Survey
P:	Nominal dynamic sling load.
SHL:	Static Hook Load
SKL:	Skew load factor.
SKL_e:	Skew load factor due to elongation of slings.
SKL_{sl}:	Global skew load factor, see [3.3.2].
SKL_t :	Skew load factor due to tilt.
SKL_y :	Skew load factor due to yaw.
SPL:	Special loads, see [3.1.3].
SSCV:	Semi-submersible crane vessel.
SWL:	Safe working load.
Tz:	Zero upcrossing wave period
UT:	Ultrasonic Testing
W:	Object weight.
WLL:	Working Load Limit = SWL
W_{rig} :	Weight of rigging/lifting equipment.
$W_{rig,i}$:	Weight of rigging/lifting arrangement no. i.
WSD:	Working Stress Design also known as Permissible Stress Method
α_{CoG} :	Maximum theoretical part of total load at hook no. i with CoG in extreme position.
ε :	Average strain in the slings caused by P.
ε_0 :	Sum of sling and padeye fabrication tolerance divided by sling length.
ε_1 :	Average strain in the slings diagonal 1.
ε_2 :	Average strain in the slings diagonal 2.
γ_b.:	Reduction factor due to bending.
γ_c :	Consequence factor.
γ_{design} :	Design factor for lift points, equipment and supporting structures.
γ_f :	Load factor.
γ_m :	Material factor.
γ_r :	Resulting reduction factor due to splicing or bending.
γ_s :	Reduction factor due to splicing.
γ_{sf} :	Nominal safety factor for slings.
γ_w :	Wear factor.
γ_{tw} :	Twist reduction factor
θ :	Average sling angle from a horizontal plane.

SECTION 2 GENERAL REQUIREMENTS

2.1 Planning and documentation

2.1.1 General

2.1.1.1 Planning, including the design process, documentation and risk management, for lifting operations shall comply with requirements and philosophies given in DNV-OS-H101, Section 2.

Guidance note:

The documentation associated with the above shall be commensurate with operational complexity and the experience of those parties involved in any given operation.

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2.1.2 Documentation

2.1.2.1 The general requirements to documentation are given in DNV-OS-H101, Section 2B.

2.1.2.2 The lifting operation should be clearly described by drawings, calculations and procedures.

2.1.2.3 All applicable input data should be documented.

2.1.2.4 A manual covering all relevant aspects of the lifting operation should be prepared, see also DNV-OS-H101, Sec.4G 200.

2.1.2.5 All relevant certificates, test reports, release notes and classification documents for equipment, cranes and vessels involved should be available for review.

2.2 Crane and crane vessel

2.2.1 General

2.2.1.1 The crane, crane vessel and all associated equipment should be in good condition, properly manned and fit for performing the intended operations.

2.2.1.2 The crane should be equipped with a reliable load monitoring system with an accuracy normally not exceeding 5% of the maximum crane capacity, or 10% of the weight of the lifted object.

2.2.2 Positioning

2.2.2.1 The crane vessel should be positioned, moored and/or operated on DP according to relevant requirements stated or referred to in DNV-OS-H203.

Guidance note:

For inshore and weather restricted mooring systems the requirements in DNV-OS-H101, Sec. 6B normally apply.

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2.2.3 Crane vessel certificates

2.2.3.1 The crane vessel shall comply with the requirements in DNV-OS-H101, Sec. 6D.

2.2.3.2 Hydrostatic stability data should be available on-board.

2.2.3.3 The following vessel certificates should normally be presented in valid condition:

- certificate of registry
- certificate of classification
- safety construction certificate
- certificate of international load line
- safety equipment certificate.

2.2.4 Crane documentation

2.2.4.1 The crane lift capacity for the required lift radius and height shall be properly documented, considering all operational limitations and clearance requirements.

2.2.4.2 The following crane certificates should normally be presented:

- Certificate of classification or maker’s certificate.
- Crane test report issued by a recognised authority.

- Latest annual survey report.
- Lift record for preceding operations.
- Load-radius curves for static and dynamic lifting conditions. Limiting condition, see [2.2.4.4], for each load-radius curve shall be clearly indicated.

2.2.4.3 Safe handling instructions for the crane operation shall be available, in particular alarm settings and handling of alarms shall be properly documented.

2.2.4.4 Clearly defined operating parameters shall be presented for the applied load-radius curve(s), to ensure that the crane is suitable, given the design assumptions made.

Guidance note:

The limiting crane operational condition could normally be expressed by relevant combinations of the following (maximum) parameters:

a) DAF
b) wind speed
c) hoist line angle tolerances relative to crane (both in-line and sideways)
d) static heel and trim of crane vessel
e) crane tip motions/accelerations due to waves
f) motions/accelerations of the vessel where the cargo is lifted from
g) wave conditions, e.g. expressed by Hs, Tz and relative wave/vessel direction(s).

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2.2.4.5 For lifts by two (2) or more hooks on the same crane boom, total lift capacity of the crane (boom) structure shall be documented. The most unfavourable load distribution between the hooks shall be applied.

Guidance note:

Requirements to hook load distribution assessments are included in [3.3.5.1]. Note that the DAF indicted in [3.2.2.4] are based on the load in each hook.

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2.3 Operational aspects

2.3.1 General

2.3.1.1 General requirements for operational aspects are given in DNV-OS-H101, Section 4.

2.3.1.2 The operation shall be carried out with due consideration of identified risks and prescribed risk mitigations.

2.3.2 Control of lift

2.3.2.1 The lifted object shall be adequately controlled in order to avoid any significant and undesirable yawing and/or pendulum motions. See also the requirements for bumpers and guides in [5.1.7].

Guidance note:

Control should be ensured by applying an adequate combination of:

- a detailed step by step lift and handling procedure
- monitoring and evaluating relative crane tip and hook positions before lift-off
- tugger lines
- tag lines
- bumpers and guides.

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2.3.2.2 Maximum expected (relative) vertical motions of the crane and lifted object should be properly accounted for - see [2.3.3.3] and [5.1.7].

2.3.2.3 Rotation (yaw motion) of the lifted object should normally be controllable in both directions during all phases of the lift. See also [2.3.4.7].

2.3.2.4 The use of tugger lines should be properly planned and designed; design documentation should normally include:

- layout sketches/drawings
- attachment point detailing
- required tension in tugger lines due to vessel motions (to avoid slack and snap loads) and how to maintain it

— tugger line(s) to crane hook and/or spreader bars if applicable
— capacity checks of all associated components.

Guidance note:

In general all components associated with the tugger line arrangement (e.g. wires, winches, winch foundations, sheaves and blocks) should have adequate ultimate structural strength (MBL) to withstand the maximum loads which can be imposed on them by the tugger lines. See also [3.4.2.7].

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2.3.3 Clearances

2.3.3.1 All relevant clearances should be determined and thoroughly assessed for all stages of the lift.

2.3.3.2 Clearances required during crane vessel operations should be determined on the basis of the expected duration of the operation, the operational procedure (see [2.3.2]), crane functionality, environmental conditions, positioning and fendering systems, back-up systems, configuration lay out, possible tilt of object, etc.

Guidance note:

Minimum clearances should consider maximum motions of the crane vessel and transport vessel/barge, associated with the environmental design conditions and DP capability/mooring system. Required clearance depends on a number of factors such as size and weight of the lifted object, ability to control the lift (see [2.3.2]), vessel motions, weather conditions, consequence of impact loads etc. The following clearances could be used as guidance for objects lifted offshore:

a) The minimum clearance between the lifted object or lifting equipment and the crane boom should normally not be less than 3.0 m.
b) For objects to be lifted over, around or between other objects a minimum clearance of 3.0 m is recommended.
c) Minimum 5.0 m between lifted object and other structures on the same transport barge, unless specific bumpers/guides/tugger lines are used for lift off.

Clearances for lifts by floating crane vessels onto floating structures (e.g. spars, FPSO's) will need special consideration. It is expected that the clearances for this case will need to be larger than those stated above. The design clearances should be defined with due attention to the maximum expected relative motions of the floating structure and the lifting vessel.

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2.3.3.3 Clearances between the underside of the lifted object and grillage or seafastening structures on the transport vessel/barge should be evaluated, with due consideration given to relative vertical and possible horizontal motions after lift-off. If these clearances are small, particular attention should be given to avoid damages in case of subsequent impacts.

Guidance note:

The probability of the barge/vessel impacting with the lifted object after lift-off could be estimated using the methods described in DNV-RP-H103 Section 9.5.

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2.3.3.4 The minimum clearances indicated in DNV-OS-H203, Table 4-2 for moored vessels in weather restricted operations and if applicable, Table 4-3 for mooring lines should be considered.

Guidance note:

The indicated minimum clearance in ULS/ALS is for possible contact with critical structures/elements such as the crane boom, single critical structural elements, under water buoyant compartments and/or sensitive equipment. Clearances to other elements should normally not be less than 3.0 m in ULS.

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2.3.3.5 Minimum clearances for DP vessels should be defined according to DNV-OS-H203, Sec.5 C200.

Guidance note 1:

For short time lifting operations close to fixed platforms, a smaller minimum distance than recommended in DNV-OS-H203 may be considered, given that most of the below listed items are giving favourable effect:

a) Records of favourable (small) vessel footprints during similar operations are presented.
b) Maximum expected yaw motions of the vessel have been considered in the clearance calculation.
c) The operational weather conditions are well within the limiting DP capacity in DP 3 (or 2).
d) The crane vessel is operating on the leeward side of the installation.
e) Possible motions of the installation are considered.

If the first contact in case of lost position will be with critical elements, see [2.3.3.4] GN, the minimum recommended distance is 10.0 m; for contact with non-critical elements this may be reduced to 5.0 m. Adequate (contingency) fendering could be used to further reduce the recommended minimum distance.

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Guidance note 2:

Clearances around the crane vessel (either moored or dynamically positioned) and any floating platform, FPSO, drilling rig or submersible, shall be determined as special cases based on the station keeping analysis of the floating structure and the lifting vessel. Positioning equipment and procedures shall be defined to maintain the minimum clearances required for each specific operation. The procedures should minimise the durations for which these are required.

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2.3.3.6 Circumstances that could reduce the available lift height according to load-radius curves shall be thoroughly evaluated.

Guidance note:

In addition to the clearances mentioned in [2.3.3.2], such considerations could include:

a) Varying tide levels, with due consideration given to combinations of floating and/or bottom fixed units/cranes.
b) Recommended (3.0 m in ISO 19901-6) minimum distance between travelling block and fixed block not properly included in the crane charts.
c) Hoist line angle restrictions for multi hook lifts applying fixed (no slewing) crane booms.

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2.3.3.7 Sufficient bottom clearance between the crane vessel and the sea bed should be documented for lifting operations in shallow waters.

Guidance note:

There should be a minimum underkeel clearance of 3 m between crane vessel (including thrusters) and seabed, for an offshore lift after taking account of tidal conditions, vessel motions, increased draft and changes in heel or trim during the lift. Lesser clearance for operations in sheltered waters may be applicable depending on the seabed and environmental conditions, but should not be less than 1 m.

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2.3.4 Lifting

2.3.4.1 Operational criteria such as, wind speed, wave conditions, relative motions, etc., should be established prior to starting the lifting operation. These criteria should be included in the operation manual.

Guidance note 1:

For vessel to vessel lifts relative vertical motion between crane hook and object should be carefully evaluated before commencement of the lift. Relative motions exceeding 2.0 m is not recommended. See also [3.2.2.4].

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Guidance note 2:

Considerations should be given to the effect of wind loading to ensure that such loads will not jeopardise the operation. It is recommended that a limiting wind criterion is clearly expressed.

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2.3.4.2 General crane operational procedures and limitations, see [2.2.4.4], shall be considered.

2.3.4.3 Connection (and disconnection) of the lifting rigging between object and crane hook shall be planned in detail.

Guidance note:

The planning should/may include items such as, but not limited to:

— Safe handling during installation/connection of heavy lifting equipment, e.g. shackles, lift tools and spreader bars/frames.
— Easy access and appropriate working environment for riggers.
— Colour coding of slings/lift points to be connected together in order to avoid mix up.
— Securing (during sea transportation) for rigging equipment that is pre-connected to the object. See [5.1.8].
— Back loading of heavy lifting equipment.
— Lift point detailed design, see e.g. [5.1.4.6]
— Practical use requirements, see [4.1.6] and [4.2.2].

— For subsea disconnection, see DNV-OS-H206.

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2.3.4.4 The crane hook should be positioned accurately over the centre of gravity of the lifted object prior to commencement of the lift.

Guidance note:

When lifting from another vessel/barge or from shore by crane vessels, possible restraint loads between crane vessel and lifted object should be relieved by slackening mooring lines as much as possible and restricted use of thrusters.

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2.3.4.5 Ballasting of transportation vessel/barge prior to or during lifting in order to obtain simultaneous lift off at all support points should be considered.

2.3.4.6 If counterweights are to be used to adjust the centre of gravity during lifting, such weights should be securely fastened to the lifted object.

2.3.4.7 Eccentric and/or none symmetric hook loading should be within acceptable limits.

Guidance note:

E.g. objects with a CoG distant from the central axis of lift (single hook lifts) will lead to considerable differences in sling angles and eccentric hook loading. It should be documented that the subsequent moment will not overload the hook or blocks, or make rotation of the hook impossible.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

2.3.4.8 Where shimming arrangements between support structure/grillage and the object are used, shims should be adequately secured to one of the surfaces.

Guidance note:

Securing to grillage is preferable. If securing has not been properly done a check-point and procedure for removal of shimming plates (that may be stuck under the object) should be included. Removal of shims should preferably be performed immediately after lift-off.

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2.3.5 Monitoring of lifting operations

2.3.5.1 The following parameters should normally be monitored manually/visually or by monitoring systems if needed to obtain sufficient accuracy and/or to ensure adequate response time:

— hook load(s)
— crane radius
— crane slew angle
— crane boom angle
— crane block elevation
— environmental conditions
— tilt of lifted object, especially for multi-hook lifts
— relative motions of lifted object
— position and orientation
— clearances
— hoisting velocity.

2.3.6 Cutting of seafastening

2.3.6.1 The cutting procedure should be such that no vertical restraint will be present during lift off.

Guidance note:

Vertical cutting of seafastening with a flame cutter may, due to the coarse cut, result in restraining effects. It is recommended that the cut is performed at an angle of 10 - 15 degrees minimum (to the vertical) or that each piece is removed using two parallel cuts.

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2.3.6.2 Rotational restraint, at single support points, e.g. module footings, shall be avoided.

2.3.6.3 It should be thoroughly verified (by dedicated personnel) that the cutting is complete before the final ‘go-ahead’ for lifting is given.

Guidance note:

It should also be ensured that the crane operator obtain up-to-date load information to be able to stop lift during lift-off phase, in case seafastening not completely cut off.

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2.3.6.4 Cutlines should be marked on the seafastening in advance.

Guidance note 1:

Cut lines to be decided with due consideration to avoid damage to the structure and its surface protection.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 2:

To avoid damaging the barge deck and provide for safe and easy handling, considerations should be made to avoid large pieces of loose seafastening debris. Seafastening of large loose seafastening or grillage debris after lift-off should be considered.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

SECTION 3 LOADS

3.1 Basic loads

3.1.1 Weight and centre of gravity

3.1.1.1 The object weight (W) as lifted should be the characteristic weight defined in DNV-OS-H102, Sec. 3C 100.

3.1.1.2 Inaccuracies in CoG position should be considered according to the principles in DNV-OS-H102, Sec. 3C 200.

Guidance note 1:

Geometry changes due to CoG uncertainties may for unconventional rigging arrangements (e.g. for two- or one sling riggings) influence the design loads (e.g. out-of-plane loads on lift points). The effect of geometry changes shall in these cases also be considered.

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Guidance note 2:

To simplify the design and procurement of lifting equipment, lifting points etc. a sling load inaccuracy factor, based on the weight inaccuracy and CoG envelope study are often used; the assumptions used to derive this factor must be confirmed.

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3.1.2 Weight of rigging

3.1.2.1 The weight of rigging (W_{rig}) is the total weight of the rigging arrangement, i.e. equipment such as shackles, slings, spreader bars or frames, etc.

3.1.2.2 Hook, block and hoist line weights do not need to be considered as a part of W_{rig}.

Guidance note:

This is most relevant for cranes with several possible rigging configurations typically for onshore crawler cranes.

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3.1.2.3 W_{rig} should be included in the applied crane load, but does not need to be considered for elements below each part of the rigging.

3.1.3 Special loads

3.1.3.1 When appropriate, allowances for special loads (SPL) should be made. Special loads may include tugger line loads, guide loads, wind loads, hydrodynamic and hydrostatic loads, etc.

3.2 Dynamic loads

3.2.1 Dynamic effects

3.2.1.1 All lifts are exposed to dynamic effects due to variation in hoisting speeds, crane and vessel motions, cargo barge movements, object movements etc.

3.2.1.2 The effect of global dynamics will be significantly influenced by parameters such as:

- environmental conditions
- rigging arrangement
- type of crane vessel
- stiffness of crane-boom and lifting appliances
- type of cargo vessel
- weight of lifted object
- lifting procedure
- whether the lift takes place in air, in water or through both.

Global dynamic loads should be calculated with due consideration given to these and other parameters, where identified and as applicable. See also [3.2.2].

3.2.1.3 Dynamic effects during lifting onto a floating offshore structure or vessel should be specially considered. See DNV-RP-H102, Section 3.3.4 for guidelines.

3.2.1.4 For lifts through water special investigations should be made in each case, taking proper account of the hydrostatic and hydrodynamic effects, during all critical phases of the lift, see DNV-OS-H206 and DNV-RP-H103.

Guidance note:

For lifting in water, additional local dynamic effects may govern the design of lifting equipment elements. Such effect could be local sling dynamics due to motion of the object initiated by waves.

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3.2.2 Dynamic amplification factor

3.2.2.1 The global dynamic load effects may be accounted for by using a dynamic amplification factor (DAF).

3.2.2.2 The DAF should for major offshore lifts be established on the basis of a dynamic analysis, considering the effects in [3.2.1].

3.2.2.3 Environmental design conditions applied in the dynamic analysis should be duly reflected in the operations manual, see also DNV-OS-H101, Section 4B.

3.2.2.4 In lieu of more refined analyses, the values for DAF given in Table 3-1 may be considered as minimum factors for lifts in air, provided the lifting operation will not take place under adverse conditions.

Guidance note 1:

The dynamic amplification factors in Table 3-1 are indicated for the following lift types:

a) Onshore = Quay and yard crane lifts from/to barge/ship moored along quay.
b) Inshore = Lift with crane vessel from/to barge/ship in sheltered waters.
c) Offshore = Lift with crane vessel or platform crane from barge/ship (supply vessel) to a fixed platform. See [3.2.1.3] for lift to a barge/ship.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 2:

The definition of adverse conditions depends on the lift configuration and should normally be defined on the basis of analysis - see [3.2.2.2]. For offshore lifts with SHL ≥ 100 tonnes, the following could be used as general rough guidance:

a) Significant swell (i.e. swell with a period and height creating significant crane vessel motions, see e.g. [2.3.4.1] GN1).
b) For lifts not involving ballasting of crane vessels during lift-off, waves with (Hs) > 2-2.5m.
c) For lifts involving ballasting of crane vessels during lift-off, waves with (Hs) > 1-1.5m

For offshore lifts with SHL < 100 tonnes the following could be used as general guidance:

a) Waves with Hs > 2.5-3.5m (highest value for small SHL).
b) Swell/waves that are creating significant motions of the crane vessel.

For lifts from small vessels, say with length less than 80m, lesser wave limits should be considered.

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Guidance note 3:

For offshore lifting from deck of SSCV’s to a fixed platform, the DAF for inshore lifts in Table 3-1 may normally be used. Also for lifts from own deck with mono hull crane vessels (e.g. for the lifting in air phase of subsea lifts) the inshore factors may be considered applicable for offshore lifts. Note that the DAF should not be taken less than (1.5a + g)/g, where “a” is the maximum expected/calculated crane tip acceleration due to crane vessel motions in the limiting wave conditions for the lift. Normally a rough estimate of “a” based on maximum crane tip vertical movement and associated period will suffice to document this requirement.

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Table 3-1 Dynamic Amplification Factors[1)]

SHL (Static Hook Load)	*DAF Onshore*	*DAF Inshore*	*DAF Offshore*
3[2)] – 100 t	1.10	$1.07 + 0.05\sqrt{100/SHL}$	$1 + 0.25\sqrt{100/SHL}$
100 - 300 t	1.05	1.12	1.25
300 - 1000 t	1.05	1.10	1.20
1000 - 2500 t	1.03	1.08	1.15
> 2500 t	1.03	1.05	1.10

1) See Guidance Notes in [3.2.2.4].

2) For objects weighing less than 3 tonnes it is recommended to assume an object weight of 3 tonnes and use this throughout the calculations.

3) See [6.2.3.2] for recommendations to moving cranes onshore.

3.3 Skew loads

3.3.1 General

3.3.1.1 Skew loads are additional loading caused by equipment / fabrication tolerances and other uncertainties with respect to asymmetry and associated force distribution in the rigging arrangement.

Guidance note:

Effects that may cause skew loads are:

— sling length inaccuracies
— fabrication tolerances of lift points
— deflections of lifted object
— crane hook geometry
— multi hook lifting
— doubled slings
— difference in sling elongations.

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3.3.1.2 The lifting procedure shall be carefully evaluated for the potential occurrence of skew load effects, other than those mentioned in [3.3.1.1] GN.

3.3.1.3 For rigging configurations involving slings from more than 4 lift points converging on a single hook, skew load effects shall be calculated on a case by case basis.

3.3.1.4 Skew load effects shall be considered as outlined in the sub-sections below.

3.3.2 Sling tolerance effects

3.3.2.1 The effects of sling length tolerances are dependent on the fabrication tolerance of slings and lift points, the rigging geometry, sling characteristics and the utilisation of the slings. The effects may be accounted for by a factor SKL_{sl}.

Guidance note:

In general SKL_{sl} should be calculated for each lift rigging, however for some typical rigging configurations, the standard SKL_{sl} indicated in [3.3.2.3], [3.2.2.4], [3.3.2.5] or [3.3.2.6] may be applied. Note that the indicated assumptions should be fulfilled. SKL_{sl} for 4 point symmetric lift riggings may also be calculated in accordance with App.A. App.A includes also some background for the SKL_{sl} factors in this sub-section.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

3.3.2.2 The SKL_{sl} should always be calculated in the following cases:

— The slings or lift points have excessive fabrication tolerances.
— The rigging has an unusual geometry, e.g. small sling opening angles, more than 4 slings and/or no symmetry. See also 3.3.2.3 GN.
— Not any of the standard SKLsl indicated in [3.3.2.3], [3.2.2.4], [3.3.2.5] or [3.3.2.6] are applicable.

3.3.2.3 For statically determinate rigging arrangements (with or without spreader bar) with typical geometry and sling lengths within tolerances of ±0.5% of their nominal length, a SKL_{sl} of 1.0 may be applied. The effect of tolerances on rigging geometry and sling load distribution should otherwise be considered.

Guidance note:

By typical geometry, it is meant that all slings (i.e. 2 or 3 for statically determinate configurations) carry a significant part of the load and that the angle(s) between any slings is (are) more than 30 degrees. For 3 and 4 sling arrangements, it is normally assumed that the sling angles are between 45 and 70 degrees with the horizontal.

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3.3.2.4 For four points lifting with 'floating' spreader bars a SKL_{sl} of 1.1 is acceptable, on the assumption that the following conditions are fulfilled:

a) An approximately symmetric rigging geometry is utilised.

b) The sling lengths are within ± 0.5% of their nominal length.

c) The calculated axial load in the spreader bar is at least 15% of the sling load.

Guidance note 1:

'Floating' spreader bars, as defined in this standard, are used between two slings in a conventional 4 sling rigging. The 'floating' spreader bars are connected to only two slings in each end. The four slings (two each end) and the spreader bar will form one plane.

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Guidance note 2:

If the stated conditions are not met the SKL_{sl} should normally be found by calculation. However, generally if the length tolerance is stricter than stated the minimum axial load requirement in the spreader bars could be relaxed.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

3.3.2.5 For statically indeterminate 4 point lifts using cable laid slings or grommets, a SKL_{sl} of 1.25 is normally acceptable, subject to the following conditions:

a) The total deviation in length between both diagonals is maximum 0.5% of the nominal length. Note that the manufacturing tolerance needed to satisfy this requirement is quite strict, see [4.1.7] for guidance. See also [3.3.2.6] GN.

b) Sling/grommet elastic modulus E ≤ 20 000MPa, see also [4.1.7.5] and App.A.

c) The applied slings/grommets have no significant deviations in characteristics (construction, dimension and condition/age/earlier use).

d) An approximately symmetric rigging geometry is applied and the slings angles (θ) are maximum 60 degrees with the horizontal.

e) The sling/grommet DF is ≤ 5.0. DF = MBL / (DHL /4/sinθ), For MBL see [4.1.3] and for DHL see [3.4.2].

Guidance note:

If the stated conditions are not met the SKL_{sl} should normally be found by calculation. However, if the length tolerance is stricter than stated, the maximum safety factor and sling angle requirements could be relaxed.

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3.3.2.6 For statically indeterminate 4 points lifts using wire rope slings or grommets, the SKL_{sl} could be selected according to Table 3-2.

Table 3-2 SKL_{sl} for Wire Rope Slings & Grommets

SKL	*Associated diagonal load Distribution*	*Assumptions as defined in [3.3.2.5] valid (Yes) or modified as indicated below.*				
		a)	b)	c)	d)	e)
1.25	5/8 – 3/8	Max. 0.3%	E ≤ 70 000MPa	Yes	Yes (60 deg.)	DF ≤ 4.0
1.33	2/3 – 1/3	Max. 0.3%			Ang. ≤ 70 deg.	DF ≤ 5.0
1.5	3/4 – 1/4	Yes (0.5%)			Yes (60 deg.)	DF ≤ 5.2
1.6	4/5 – 1/5	Yes (0.5%)			Ang. ≤ 70 deg.	DF ≤ 5.6

Guidance note:

In order to ensure maximum 0.3% deviation on the diagonals the sling length tolerance needs to be set to +/- 0.15% for slings that are not interchangeable and the lift point fabrication tolerances have to be insignificant. Hence, symmetric (preferably double symmetric) interchangeable rigging is recommended.

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3.3.3 Deflections of object

3.3.3.1 It is normally acceptable to assume that the lifted object has infinite stiffness for the purpose of calculating nominal sling loads and skew load effects; this in most cases will be conservative. However, see [3.3.3.2].

Guidance note:

Deflections of the lifted object could also reduce the SKL_{sl} effects significantly and could be considered whenever found relevant. Note also that the SKL factors in [3.3.2.5] and [3.3.2.6] have been calculated considering some object deflection. See also App.A.

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3.3.3.2 For some lifts with a statically indeterminate rigging system, object deflections could influence the sling load distribution considerably. In these cases it is normally required to carry out structural calculations, with due consideration given to the stiffness of both rigging and lifted object.

Guidance note:

Typical examples include:

— Slender objects e.g. spool pieces.
— Asymmetrically loaded objects with limited torsional stiffness, e.g. non-clad frames or modules and flat skid-type ‘pancakes’.
— Lifts involving more than 4 lift points.

All possible combinations of maximum and minimum sling lengths should be included in the model, e.g. by applying temperature elements, in order to find the skew load effects.

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3.3.4 Crane hook geometry

3.3.4.1 The crane hook geometry will influence the theoretical sling angles, lengths and loads. This should be considered.

3.3.4.2 The minimum hook prong radius in way of the slings should be included in the hook technical documentation.

3.3.4.3 Two (2) prong or asymmetric four (4) prong hooks may reduce the skew load in four (4) sling lifts as the hook may rotate. This may be considered in skew load calculations.

Guidance note:

A rotation of these hooks will in a horizontal projection reduce the length of one diagonal by that the sling-hook-sling projected line is getting more close to a straight line. The angles in the other sling-hook-sling projected line get greater and this line length hence increase.

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3.3.5 Skew loads for two-hook lifts

3.3.5.1 Skew load effects associated with the use of multi-hook lifts shall be considered, in addition to skew load effects for rigging at each hook.

Guidance note:

The effect of any CoG position within the defined envelope and the effect of tilt and yaw shall be considered for multi hook lifts. The yaw and tilt effects may result from deviations of the hooks from their ideal, relative positions. The magnitude of this deviation will depend on whether the two cranes are on the same or separate vessels, the vessel's motion response, and the lifting procedure.

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3.3.5.2 The yaw effect factor SKL_y, accounts for increased sling loading due to rotation of the object about a vertical axis; a yaw effect factor of 1.05 is normally sufficient. For lifts with small sling opening angles at the hooks and/or significant wind/tugger line loads a greater yaw effect factor may be applicable.

3.3.5.3 A tilt effect factor SKL_t, shall be calculated to account for the increased sling loading caused by rotation of the object about a horizontal axis and the effect of out-of-plumb hoist lines. The tilt effect factor should be based on possible tilt caused by maximum hook height tolerances and hoist line deviations from the vertical.

Guidance note:

For lifting with crane vessels the tilt effect factor may normally be calculated for a tilt of 3° when the hooks (cranes) are on the same vessel and for a tilt of 5° when the cranes are on separate vessels (hoist line out-of-plumb included). Alternatively a maximum possible deviation in hook heights could be defined/documented/controlled and SKL_t

calculated accordingly. Normally maximum +/- 1.0m hook height difference needs to be used for multi-hook lifting with the cranes on the same vessel.

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3.3.6 Skew loads for multi-hook lifts

3.3.6.1 For lifts involving more than two hooks, the maximum variation in load distribution between the hooks shall be specially considered.

Guidance note 1:

For statically determinate configurations the variation could be found as indicated in [3.3.5.3]. Tilt of object in two directions may be applicable.

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Guidance note 2:

For statically indeterminate configurations the variation will depend on the following two main factors:

— Control of relative hook heights (and hook load).
— Stiffness of the system, i.e. object, rigging and cranes (relative stiffness between hooks).

Subject to the below listed conditions a factor of 1.1 (+/- 10% variation in hook loads) is normally acceptable:

— A proper operational procedure describing how to control the hook loads throughout the lifting operation.
— Onshore or inshore lifting.
— Hook elevations can be shown to be accurately individually controlled from one location.
— All crane hook loads are continuously monitored from one location.
— Limited (i.e. < 2 deg.) tilt of object in any direction will not significantly influence the hook loads.
— The cranes are fairly highly utilized (i.e. normally object weight/crane capacity > 50%).

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3.3.7 Double slings

3.3.7.1 For doubled slings, e.g. both eyes connected to same lifting point, uneven loading on each part can occur and should be considered in the design.

Guidance note:

Equal loading on each part can be considered valid for single hook lifts where the slings are allowed to adjust during a “slow” tensioning phase and do not involve upending/tilting (i.e. no rotation of the slings over a fixed trunnion or similar after the slings are loaded will occur). It is assumed that each part has the same axial stiffness. For lifts with rapid tensioning of the slings a 45:55% distribution should be assumed.

For lifts that do involve upending/tilting or different axial stiffness of each part, the effect of uneven distribution between the sling parts should be considered, assuming a maximum possible sling friction coefficient at the hook, trunnion, shackle etc. Friction coefficient values less than 0.13 for well-greased steel slings should be documented. For slings with a dry surface higher friction coefficient values should be considered. For a 180 degree contact area and a friction coefficient of 0.13, the load distribution will theoretically be 40:60%.

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3.3.7.2 When using doubled-doubled slings/grommets in terms of a defined distribution (e.g. 45:55), this effect shall be doubled (i.e. 0.55×0.55 if a 45:55 distribution is defined), when determining the highest sling load.

3.3.7.3 If the doubled sling consists of two parallel slings, the load distribution should be calculated considering the maximum sling length difference and maximum sling modulus (E).

3.3.8 Tilt of lifted object – single hook lift

3.3.8.1 Object tilt (due to CoG position and/or imposed horizontal loads) will influence the sling load distribution for most rigging configurations. The effect of tilt should be considered in the load calculations where relevant.

Guidance note:

Where calculated maximum tilt is less than 2°, it is normally not necessary to consider related effects in the sling load calculations.

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3.3.8.2 If the object’s lift points are at different elevations it shall be ensured that this has been properly taken into account in the tilt (and sling force) calculations.

3.3.8.3 Variable sling elongation, sling length and lift point fabrication tolerances could increase object tilt.

Where lifting points are located below the vertical CoG of the object, forces in the most utilised slings will tend to increase due to sling elongation; in this case a factor SKL_e, should be estimated.

3.4 Loadcases and analysis of forces

3.4.1 General

3.4.1.1 Lifts shall be analysed for all relevant loadcases, in order to define the maximum characteristic loads on the crane, rigging and the lifted object.

Guidance note:

Lifting operations cannot be represented by a single well defined loadcase, but rather a sequence of different/critical ones. Uncertainties with respect to for example internal force distribution, skew loads, dynamic effects, possible accidental loads, etc. introduce further complexities. The entire lifting operation should be considered sequentially and the most critical loadcase for each specific member/element should be identified. For most conventional lifts however, the entire sequence is adequately covered by the basic loadcases described in [3.4.2] and the additional loadcases described in [3.4.3].

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3.4.1.2 For lifting operations involving pivoting and/or upending manoeuvres, an adequate number of steps shall be analysed to ensure that the critical loadcase/s for all members are identified.

Guidance note:

For some stages of the upending consideration of only a few degrees between each step may be necessary; a maximum of 15 degrees between each step should normally be adopted

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3.4.1.3 Special considerations will be necessary for lifting operations in water, guidelines for which are given in DNV-OS-H206.

3.4.2 Basic loadcase and force distribution

3.4.2.1 For single hook lifts, the dynamic hook load is normally expressed as:

$$DHL = DAF\ (W + W_{rig}) + F(SPL)$$

where:

DHL = Dynamic hook load.
DAF = Dynamic amplification factor, see [3.2.2].
W = Object weight, see [3.1.1.1].
W_{rig} = Rigging weight, see [3.1.2].
SPL = Special loads, see [3.1.3].
F(SPL) = Additional hook load due to SPL.

3.4.2.2 For two hook lifts, the dynamic hook load for each hook (DHL_i) is normally expressed as:

$$DHL_i = DAF\ ((\alpha_{CoG} \times SKL_t \times W) + W_{rig,i}) + F(SPL)_i$$

where:

α_{CoG} = Maximum theoretical part of total load at hook “i” with CoG in extreme position.
SKL_t = Factor expressing the increase in hook load “i” due to tilting of the object.

3.4.2.3 The basic loadcase for a given lift could normally be calculated as a (quasi) static loadcase by applying DHL at the hook position, and distributing weight and any special loads to each element; however, see [3.3.3].

3.4.2.4 In order to find maximum dynamic forces in each element (e.g. sling, lift points, supporting structure), the sling forces found in the basic loadcase (according to [3.4.2.3]) should be adjusted considering all relevant skew load effects as described in [3.3].

Guidance note:

Skew load effects will tend to increase forces in some slings, whilst reducing forces in others. It may be necessary to define various loadcases in order to address all possible combinations of sling loads.

For a conventional four sling lift, the following two (skew) load cases should normally be considered:

1) The force distribution calculated according to [3.4.2.3], modified by multiplying the forces in two diagonally opposite slings with the skew load factor. The forces in the remaining two slings should be determined by (quasi) static equilibrium.
2) As 1 above but with the skew load applied on the other pair of slings.

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3.4.2.5 Maximum dynamic forces calculated according to [3.4.2.4] are the design forces for slings/grommets and shackles. This force is for each sling defined as F_{sling}.

3.4.2.6 For structural components, the maximum dynamic design force should be calculated using the characteristic forces calculated according to [3.4.2.4] with appropriate design factors defined in [5.1].

3.4.2.7 If tugger lines are attached to the lifted object, attachment points should normally have a documented ultimate structural strength (minimum breaking load) that is minimum 1.3 times the maximum load which can be imposed by the tugger lines.

Guidance note:

Tugger lines should where possible be equipped with a load limiting device or be arranged in a way preventing overloading the tugger line arrangement.

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3.4.3 Additional loadcases

3.4.3.1 Members which may be exposed to loads not adequately addressed in [3.4.2] should be identified; relevant design loads should be established accordingly.

3.4.3.2 Loads due to rotation of an object in slings when lifted shall be considered in loadcases for lifting points and lifting equipment. See [3.3.5].

3.4.3.3 If slings/grommets could be (are) transferring load at additional locations other than the lift points, e.g. due to tilt of the object, the corresponding forces should be considered in the design.

3.4.3.4 Local lateral forces and moments shall be considered for the purposes of designing lift points and lifting equipment, with due consideration given to relative sling/lift point positions and angles, maximum fabrication tolerances and object tilt.

Guidance note:

In the absence of a detailed study and assuming minimum anticipated relative deviations, it is normally adequate to consider a lateral load, acting simultaneously with the in-plane load, of 3.0% of the maximum sling force. The lateral load should be applied at the point of action, e.g. at the shackle bow (see sketch in App.B) or at the trunnion stopper plate, etc.

If the out-of-plane load has been calculated based on actual tolerances/measurements it is normally not required to add the 3% load. Further guidance regarding out-of-plane load calculations can be found in DNV 2.7-3, Sec.3.5.5.

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SECTION 4 LIFTING EQUIPMENT

4.1 Slings and grommets

4.1.1 General

4.1.1.1 This section covers slings and grommets manufactured according to a recognised code/method.

4.1.1.2 For deep water installation lifts and abandonment and recovery (A&R) operations using traction winches and very long ropes, reference is made to DNV-OS-H206.

4.1.2 Materials and construction

4.1.2.1 Lifting slings and grommets can be manufactured using steel, polyester, high-modulus polyethylene (HMPE), aramid or other synthetic fibre materials. The quality and performance characteristics of all materials used shall be adequate and documented.

4.1.2.2 Since the failure modes for different sling / grommet materials vary, different safety factors should be applied.

4.1.2.3 The construction of slings and grommets shall be adequate for the designated use.

Guidance note:

Guidance can be found in various codes from IMCA, ISO and EN. Steel slings or grommets may be constructed from a single wire rope, or multiple wire ropes (cable laid). See e.g. IMCA M 179, ISO 2408 and EN 12385-4 for further information.

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4.1.3 Minimum breaking load of steel wire rope

4.1.3.1 The minimum breaking load (MBL) of steel wire-rope slings and grommets shall be documented (and certified) in accordance with a recognized standard. Documentation should clearly indicate how the stated MBL has been determined.

Guidance note 1:

Ideally, the MBL for wire rope should be determined by pulling a complete rope to destruction. If adequate facilities are not available for such testing, the rope MBL should be established in accordance with a recognised standard. For grommets, strength of the core element should not be included when calculating the MBL. When fabricating steel slings from several individual ropes, the total MBL should normally be taken as the sum of the unit rope MBL's, divided by a sling spinning loss factor of 1.18.

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Guidance note 2:

It is assumed that the MBL for steel slings/grommets is specified without possible reductions due to end connections, see [4.1.5.5].

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4.1.4 Minimum breaking load of fibre rope

4.1.4.1 MBL for fibre slings and grommets should be established on the basis of destructive tests, using complete rope specimens.

Guidance note 1:

It is normally acceptable to define the MBL as the lowest value of three tests (see also DNV-OS-E303), however defining the MBL based on the 5^{th} percentile of results is recommended. See DNV-OS-H101, Sec. 5 A500.

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Guidance note 2:

For large slings where destructive testing of whole specimens is not possible, an alternative method of establishing the MBL may be deemed acceptable in the certification process.

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Guidance note 3:

Fibre slings may be subjected to a bedding in procedure of 10 cycles to 30% MBL before testing to destruction.

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4.1.4.2 For the purposes of testing, the eye of the sling shall be bent around the minimum permissible eye bending diameter during normal use; the minimum eye bend diameter should be marked on the ID tag.

Guidance note:

The minimum bending diameter could be specified on the certificate/data book only, but in this case the ID tag should include a reference to restrictions/limitations on the certificate/data book.

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4.1.4.3 If any parts of a fibre sling, other than the eyes, will be bent during normal use, such bending should be included during MBL testing.

4.1.4.4 For the purposes of testing, grommets shall be bent around the minimum permissible bending diameter during normal use; the minimum bend diameter should be marked on the ID tag.

4.1.4.5 For fibre slings and grommets the maximum and minimum operating temperature shall be defined and clearly specified.

4.1.4.6 All relevant possible failure modes such as creep, stress rupture, overloading or abrasion, shall be identified, and the avoidance of these failure modes shall be ensured by defining the requirements to condition management and discard.

Guidance note:

The condition management includes procedures for handling and storage. Discard criteria should be established considering the worst possible combination of temperature (see [4.1.4.5]) and loading. It should normally be indicated on the ID tag. The slings and grommets should be verified (surveyed) according to the discard criteria prior to each lift. Slings not meeting the criteria should be discarded and it is recommended that these slings are physically marked (e.g. cut in two) to avoid any possibility of re-use.

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4.1.4.7 Fibre slings should normally be proof load tested before being used for the first time. The proof load for fibre slings should be1.3 × SWL, with SWL = $MBL_{sling} / \gamma_{sf}$. For γ_{sf} see [4.1.5.1].

Guidance note:

For products that are certified according to the principles in DNV-OS-E303 it may be agreed to disregard the proof loading requirement.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.5 Nominal safety factor

4.1.5.1 The nominal safety factor for slings and grommets γ_{sf}, should be taken as the greatest of the following products of partial factors:

$\gamma_{sf} = \gamma_f \gamma_c \gamma_r \gamma_w \gamma_m \gamma_{tw}$

$\gamma_{sf} = 2.3\ \gamma_r \gamma_w \gamma_{tw}$

See [4.1.5.3] through [4.1.5.13] for definitions of the partial safety factors.

4.1.5.2 Calculated maximum dynamic sling load F_{sling}, see [3.4.2.5], should fulfil the equation below.

$$F_{sling} < \frac{MBL_{sling}}{\gamma_{sf}}$$

4.1.5.3 γ_f : Load factor = 1.3

Guidance note:

A reduced factor may be found applicable in some cases, e.g.:

— For lifts with load factor 1.2, see [5.1.2.3] (GN) and where all (skew) load effects have been accurately calculated γ_f = 1.2 may be used.

— If accurate calculations in accordance with the alternative method in [5.1.3] are undertaken, the factor may be taken as the greater of (%P and Q-Loads × 1.3 + %E-loads × 0.7) and (%P and Q-Loads × 1.0 + %E-loads × 1.3).

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.5.4 γ_c : Consequence factor = 1.3

Guidance note:

If single sling failure does not result in total loss, or the consequences of sling failure may be regarded as negligible, a lower factor may be applied. See also DNV-OS-H206 for subsea applications.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.5.5 Reduction factor γ_s due to the end termination of slings and wire ropes shall be documented.

Guidance note:

The following minimum factors should normally be adopted (note that EN 13411 formally covers sling diameters up to 60 mm only):

— Hand spliced according to EN 13411-2: $\gamma_s = 1.25$
— Ferrules and ferrule-securing according to EN 13411-3: $\gamma_s = 1.12$
— Metal and resin socketing according to EN 13411-4: $\gamma_s = 1.0$ (note - normally not recommended for lifting slings)
— Cable laid slings spliced as described in IMCA M 179, see [4.1.7.1]: $\gamma_s = 1.33$
— Fibre slings shall be tested with the actual termination, hence $\gamma_s = 1.0$.

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4.1.5.6 Reduction factor γ_b due to bending, for steel wire slings and grommets should be taken as:

$$\gamma_b = 1/(1\text{-}0.5/(D/d)^{0.5})$$

where:

D = diameter of bend (if D is varying, the minimum diameter should be used, see e.g. [3.3.4.2])

d = nominal diameter of sling or single part cable laid grommet.

4.1.5.7 Reduction factor γ_b for fibre slings may be taken as 1.0. The bend diameter for fibre slings shall not be less than minimum bend diameter specified by the fabricator and as used in the testing for sling MBL.

Guidance note:

See [4.1.4.2] GN. A bend diameter less than specified may be considered acceptable if a conservative γ_b factor is applied and documented. In no case should D/d < 1.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.5.8 Resulting reduction factor γ_r due to end termination or bending should be taken equal to the greatest of γ_s and γ_b.

4.1.5.9 Wear and application factor $\gamma_w = 1.0$ for steel slings, with material factor according to [4.1.5.10] and inspection requirements according to [4.1.9]. For frequently used slings without thorough inspection before each lift $\gamma_w \geq 1.10$ is normally required.

Guidance note:

For jacketed fibre slings this factor can be taken as 1.0, unless the jacket is damaged in such way that the load bearing fibres may have been affected or could be affected when the sling is used, in which cases the sling should be discarded. For unjacketed fibre slings the appropriate wear factor needs to be evaluated on a case by case basis.

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4.1.5.10 The material factor (γ_m) should be taken as minimum 1.5 for steel wire rope slings certified according to [4.1.8.1].

Guidance note:

For as-new slings with adequate 3rd party certification, see [4.1.8.1] - the material factor (γm) may be reduced to 1.35.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.5.11 For lifting with fibre slings the material factor (γ_m) will depend on the material type and relevant failure mode. The following minimum factors are given in DNV-OS-H102:

Polyester	:	$\gamma_m = 1.65$
HMPE and Aramid	:	$\gamma_m = 2.0$
Other fibre materials	:	$\gamma_m = 2.5$

Guidance note:

For fibre slings subject to a robust certification process, other material factors may be considered acceptable; however, γ_m should not be less than 1.65.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.5.12 Discard criteria shall be established and clearly stated on the sling label and certificate - see also [4.1.4.6].

Guidance note:

The discard criteria could be specified on the certificate/data book only, but in this case the ID tag should include a clear reference to the discard criteria on the certificate/data book.

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4.1.5.13 If there is any risk of twisting a fibre lifting, see e.g. [4.1.6.6], a twist reduction factor γ_{tw} shall be applied.

4.1.6 Practical use

4.1.6.1 It shall be ensured that slings/grommets are properly handled and installed to allow for a safe hook-on and tensioning. See also [2.3.4.3] and [5.1.8].

Guidance note:

Slings should be handled in the fabrication yard in strict accordance with agreed procedures, in order to prevent sling damage during handling of slings.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.6.2 The eye of a single part steel wire-rope sling should not be bent around a diameter less than the nominal diameter of the cable laid rope from which it is formed.

Guidance note:

In order to maintain the sling eye in good condition it is recommended not to bend the sling eye around a diameter less than two times the sling diameter. If the sling eye for some reason is bent around a diameter less than the nominal diameter a reduction in the sling capacity, see [4.1.5.6], needs to be considered. As the eye has two legs only bending reduction greater than 50% according to the equation in [4.1.5.6] actually reduces the sling capacity.

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4.1.6.3 In order to maintain steel wire-rope slings and grommets in good condition no other parts should be bent around a diameter less than 4 times the nominal diameter of the cable laid rope. A reduction of the capacity due to bending should nevertheless be considered, see [4.1.5.1].

4.1.6.4 Bending in way of splices should be avoided unless otherwise specified by the sling manufacturer.

Guidance note:

Several suppliers of braided fibre rope grommets recommend placing the splice on the hook or shackle, to ensure even load distribution.

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4.1.6.5 Bending in way of grommet butt and tuck locations shall be avoided. Both locations shall be marked.

4.1.6.6 Sling lay-down arrangements should be carefully considered to avoid the possibility of twisting during rigging and tensioning. The slings should be clearly marked, preferably with longitudinal paint markings.

4.1.6.7 If there is a possibility that the fibre sling may twist in use, an appropriate and approved twist factor must be applied. The twist reduction factor γ_{tw} shall be determined by testing and the corresponding permissible number of turns established.

4.1.6.8 Due considerations to avoid connecting right and left hand laid ropes shall be made when several slings are connected together. Torque neutral slings including braided may be connected together, but not with right or left hand laid ropes.

4.1.6.9 If lifting with a single sling located between the lifted object and crane hook, possible rotations of either hook (due to swivel arrangements in hook) or object shall be restrained.

4.1.6.10 For lifting with fibre slings, rigging design and lift procedure shall thoroughly consider and prevent the possibilities for mechanical damages (e.g. cutting or abrasion) and sliding of the sling relative to the lifted object. The possibility for abrasion or damage due to elongation of the sling during loading shall be considered. Avoid folding, bunching and pinching when connecting fibre slings to shackles or other rigging components.

4.1.7 Manufacturing and tolerances

4.1.7.1 The manufacturing of slings and grommets should be performed by a recognised manufacturer. The rope construction should be well suited for the intended use and comply with recognised codes or standards.

Guidance note:

Examples of recognised codes are DNV 2.22, ISO 2408 and EN 13414-1. For heavy cable laid ropes IMCA M 179 applies.

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4.1.7.2 Sling eye length should be no shorter than specified by the manufacturer or less than 10 times the rope diameter.

Guidance note:

The above requirement to 10 times rope diameter is based on a bolt/hook diameter of maximum 3 times the rope diameter. If minimum eye sling length is defined by the manufacturer he also needs to specify the corresponding maximum bolt/hook diameter.

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4.1.7.3 Lengths and tolerances of cable laid steel slings, grommets or fibre slings should be adequately specified in order to fulfil the assumptions for the applied SKL_{sl}, see [3.3.2].

Guidance note:

The standard length tolerances for slings and grommets specified in recognized codes may differ from the assumptions in [3.3.2]. It should also be noted that it is the actual differences in sling length under lift load that are important for the SKL_{sl}. The stiffness (E) will influence the under lift load sling lengths, see App.A.

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4.1.7.4 The length of slings and grommets should be documented by adequate measurements.

Guidance note:

During measuring, slings or grommets should be fully supported and adequately tensioned. The tension should be agreed with the manufacturer and normally be minimum in the range of 2.5 - 5.0 per cent of MBL for steel slings. Matching slings should be measured with the same tensile load and under similar conditions. The tension and the bending diameter during length measurements should be specified on the test certificate. If needed, see [4.1.7.5] GN, the lengths should be measured at adequate tensions to establish the elastic modulus (E).

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4.1.7.5 The modulus of elasticity (E) of slings and grommets used in an indeterminate lift rigging configuration should be indicated.

Guidance note:

E should at least be specified for sling/grommet loading close to SWL. The indicated E could be based on standard values if these are considered reliable/conservative. For sling/grommet types where no reliable standard values are available, E should be based on measurements. E.g. by including length measurements, see [4.1.7.4] GN, with tensions around the SWL. The required documentation of the indicated E should reflect the criticality of the applied SKL_{sl}.

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4.1.8 Certification of slings

4.1.8.1 For wire rope used for slings and grommets a Manufacturers Certificate corresponding to the requirements in EN 10204, type 3.1 (or type 3.2) should be provided. For slings or grommets made of steel wire ropes and used with a material factor of less than 1.5 (see [4.1.5.10]), a 3.2 certificate (as defined in EN 10204, issued/endorsed by a recognised Certifying Body) is required.

Guidance note:

Where 9-part slings are proposed for use in a lifting system, certification shall be given special consideration.

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4.1.8.2 Safety factors and other restrictions or limitations imposed by other relevant directives/standards in a Declaration of Conformity (if accepted as adequate certification) shall be adhered to. However, the level of safety shall not be less than stated in this standard.

Guidance note:

European Economic Area (EEA) Statutory Declaration of Conformity (Samsvarserklæring) from the manufacturers and Certificate of Application (Bruksattest/ILO form) from a Competent Person may be acceptable as the only sling certification where applicable.

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4.1.8.3 All Directives referred to in a Declaration of Conformity, together with the standards used, shall be clearly stated in the Declaration of Conformity. Fibre rope certification should follow the principles indicated in DNV-OS-E303.

4.1.8.4 The sling/grommet certificate should indicate as a minimum:

- unique identification number/s
- name of manufacturer
- date of manufacture
- clearly defined MBL (or CSBL/CGBL)
- diameter and length (nominal and actual/measured)

— type of construction
— modulus of elasticity (E), if applicable – See [4.1.7.5].

4.1.8.5 Additional information for cable laid slings or grommets include:

— certificate number/s for unit rope (certificate/s to be enclosed)
— MBL of rope
— MBL (or CSBL/CGBL) of sling or grommet.

4.1.8.6 For fibre slings, the following are also relevant:

— minimum bend diameter
— reject criteria
— maximum working temperature and
— applied proof load (if applicable).

4.1.8.7 Each sling or grommet should be clearly identified with reference to the corresponding certificate.

4.1.9 Inspection

4.1.9.1 All lifting equipment shall be in good condition and thoroughly inspected before each lift or series of lifts.

4.1.9.2 Slings and grommets shall be regularly inspected (normally at least every 12 months) by a competent person. Special attention should be given to the condition of splices and terminations.

Guidance note:

According to NORSOK R-003, Annex H3, the re-certification/periodic control should be performed annually: Lifting appliances and lifting gear shall be controlled periodically by enterprise of competence. As a general rule, periodic control shall be carried out every twelve months, but no later than in the same month one year after the previous control.

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4.1.9.3 Slings and grommets with:

— apparent damage or deterioration
— indications of previous overloading
— unknown internal condition
— unreliable handling or storage history
— or certification older than 5 years

shall be discarded, or subject for revalidation/re-certification according to [4.1.10].

4.1.9.4 De-rating slings is normally not accepted.

Guidance note:

For steel slings and grommets reject criteria and testing requirements should comply with the following Standards:

— ISO 3108
— ISO 4309
— DNV 2.22.

For fibre slings and grommets suitable reject criteria should be applied, see [4.1.4.7] and [4.1.5.8] GN.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.1.10 Revalidation of slings and grommets

4.1.10.1 Slings and grommets subject to revalidation shall be thoroughly inspected and evaluated by a competent person. Destructive testing and issuance of new certificates shall when required, be done by a recognised sling manufacturer and/or Certifying Body.

4.1.10.2 Revalidation/re-certification procedures should be according to a recognised code and normally include the elements indicated in the below GN.

Guidance note:

Slings and grommets subject for revalidation should be properly cleaned. Random opening should be carried out to check for internal condition and corrosion. The number of openings is subject to the length of the sling, but as a minimum the sling should be opened in at least three different locations.

A rope, or unit ropes of one sling (if cable laid) in a series of used slings should be subject to destructive testing, if there are uncertainties with respect to capacity or internal conditions of the series.

The nominal length of slings as specified in their original certificates should be verified or re-determined by measuring under tension, prior to issuance of new certificate. See [4.1.7.3] GN for recommended tension.

For heavy slings (normally MBL > 500t) the data/log book for each sling should contain (as a minimum) the following information;

— all relevant certificates
— handling and storage/conservation procedure
— survey reports, and
— storage history.

Cable laid slings and grommets subject for revalidation shall be thoroughly inspected and evaluated by a competent person from a recognised sling manufacturer and/or Certifying Body.

In addition, the data/log book for each cable laid sling should contain:

— records of previous lifts
— lift weights and preferable loading in each sling
— minimum bend radii.

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4.1.10.3 When cable laid slings are being handled, the owner or an appointed representative should witness the operations; any incidents shall be recorded in the data/log book for that sling. Special attention should be given to incidents resulting in compression loads in splices.

4.2 Shackles

4.2.1 Safe working load

4.2.1.1 The safe working load is generally used as reference for the strength of shackles. SWL is normally determined by the Manufacturer or a Certifying Body.

4.2.1.2 The shackle allowable dynamic load shall not be taken greater than the minimum of:

a) SWL×DAF

b) MBL/3.0

c) Documented “Proof Loading”, see [4.2.3.3].

The acceptance criterion defined in DNV-OS-H102, Section 5 A400, is fulfilled when the dynamic shackle load does not exceed the allowable load as defined above.

4.2.1.3 The shackle MBL, normally defined by specifying a minimum safety factor on SWL, shall be documented.

4.2.2 Design considerations and practical use

4.2.2.1 Shackles are designed and rated to withstand loading in-line with the plane of the bow, perpendicular to the pin; other load conditions should normally be avoided.

Guidance note:

Eccentric loading may be acceptable if the shackle capacity is de-rated according to original Manufacturer guidelines and/or calculations. The total pad eye thickness at the hole shall not be less than 75% of the internal jaw-width of the shackle.

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4.2.2.2 Shackles shall be loaded according to the manufacturer’s recommendations.

Guidance note:

If no recommendations are available conservative assumptions should be made. E.g. the following will normally not be acceptable:

— Multiple slings carried by a single shackle pin.
— Point loading of the shackle pin (without de-rating the shackle capacity).

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.2.2.3 Shackle dimensions should be selected with due regard to bending radii of slings and grommets, see [4.1.6.2] and [4.1.6.3].

4.2.2.4 Shackles should not normally be connected together, however shackles connected bow-to-bow is normally considered acceptable for most shackles without de-rating of the capacity.

Guidance note 1:

Wide body shackles should not be connected bow-to-bow unless specifically allowed by the manufacturer.

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Guidance note 2:

Pin-to-pin connections shall be avoided. Pin-to-bow connections may be accepted, if de-rating is considered appropriately. It shall be ensured (by use of for example spacer-plates) that the shackles are correctly loaded, see [4.2.2.1].

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.2.2.5 Shackles shall be prevented from accidental opening during all stages of the handling and lifting operations.

Guidance note:

Shackles should as a minimum have one adequate safety mechanism (e.g. nut), itself protected against accidental release, e.g. split pin/cotter pin; no interaction between these mechanisms should exist.

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4.2.3 Manufacturing and testing

4.2.3.1 Manufacturing and testing of shackles used for lifting should be carried out in accordance with sound practice and a recognised code or standard - for plate shackles see [5.1.5].

4.2.3.2 Material requirements for new shackles should be in accordance with the requirements summarised in DNV 2.22 Ch.2 Sec.1 Table 1-2.

Guidance note:

Shackles not complying with these material requirements may be acceptable, if produced by a recognised shackle manufacturer. Old shackles may be considered acceptable on the basis of a review of available information/ certification and the results from the non- destructive examination, see also [4.2.4] and [4.2.5.3].

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.2.3.3 Every shackle should be proof load-tested after fabrication. The proof load should not be less than indicated in DNV 2.22:

— $2 \times$ SWL for SWL ≤ 25 tonnes
— $1.22 \times$ SWL + 20 tonnes for SWL > 25 tonnes.

Appropriate post-test inspection shall be carried out.

Guidance note:

See DNV 2.22 Ch.2 Sec.12.2 for applicable test procedure requirements including to inspection after testing.

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4.2.3.4 A shackle shall not be used if the inspection after the proof loading reveals any geometrical deformations, cracks, or other defects.

4.2.4 Inspection

4.2.4.1 Every shackle should be visually inspected before each lift for indications of abnormal loading, overloading, damages or cracks, etc.

4.2.4.2 Shackles that do not fulfil all requirements in [4.2.5] and/or with indications of abnormal loading, damages, cracks etc. shall be subject to thorough visual inspection, magnetic particle inspection, and ultrasonic testing before use.

4.2.5 Certification of shackles

4.2.5.1 A manufacturer's certificate and proof load certificate signed by a recognised Certifying Body should be provided for each shackle.

4.2.5.2 A shackle certificate should normally contain the following minimum information:

— certificate identification code
— shackle identification code
— MBL
— proof load
— safe working load
— name of manufacturer

— date of manufacture
— material type
— manufacturing method
— reference code, standard or specification
— date of certification.

4.2.5.3 For shackles accepted without documented material properties complying with [4.2.3.2], the proof load certificate should not be older than 2 years.

4.2.5.4 Each shackle should be clearly identified with reference to the corresponding certificate. The safe working load as specified in the certificate should be clearly marked on the shackle.

4.3 Other lifting equipment

4.3.1 General

4.3.1.1 Other lifting equipment is in this standard defined as all elements transferring loads between the hook and the object lift points; e.g. chains, rings, hooks, links, swivels, sheave blocks, lifting beams/frames, specially fabricated equipment and heave compensators.

Guidance note:
Dedicated lifting equipment may be defined as “structures”, see [5.1.5].

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.1.2 Lifting equipment shall be designed, manufactured and tested according to a recognized code for such equipment.

Guidance note:
For chain slings EN 818 normally applies.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.1.3 Proof loading of each component should be included in the testing. See DNV 2.22 Ch.2 Sec.12.2 for applicable test loads and other test requirements.

Guidance note:
For lifting equipment defined as “structures”, see [5.1.5], test loading may be omitted.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.1.4 Lifting equipment shall be delivered with adequate certification.

Guidance note:
The indicated certificate requirements for slings, shackles or structures (as found relevant for the type of lifting equipment) could be used as basis to define the adequate certification according to this standard. See also DNV 2.22.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.1.5 All standard lifting equipment including chain slings shall have a proof load certificate.

4.3.2 Safe working load (SWL)

4.3.2.1 SWL should normally be defined in accordance with the applicable design code. However, the achieved safety factor (i.e. documented breaking load/SWL) shall not be less than specified in this standard.

Guidance note:
The indicated design factors for slings, shackles or structures (as found relevant for the actual type of lifting equipment) could be used as basis to define the required minimum safety factor according to this standard.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.3 External and internal lifting tools

4.3.3.1 Where lifting tools are used as part of a lifting arrangement, the maximum loads imposed on such tools shall not exceed the stated certified SWL for the tool.

Guidance note 1:
Lifting tool is in this sub-section defined as a hydraulic tool that is internally or externally connected to a tubular receptacle. The receptacle could be a pile or a purpose built lift point.

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Guidance note 2:

The lifting tool may have different WLL (SWL) for vertical and horizontal lifting.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.3.2 It shall be ensured that the lifting tool (tubular) receptacle's material quality, dimensions and geometry are compatible with the tool.

Guidance note:

As a minimum and where relevant, the following should be checked and documented:

- Steel hardness should be sufficiently low to ensure adequate grip.
- Dimension/s (normally the diameter and wall thickness) is/are within the tool specification.
- No weld seams or other imperfections that could jeopardize the tool functionality.
- The gripping surface should be free for loose rust, grease and paint.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.3.3 If used, hydraulic systems should be 'fail-safe' in nature, i.e. in the event of hydraulic power loss, the tool will continue to transmit normal operating loads.

4.3.3.4 Relevant test certificates shall be issued or endorsed by a body approved by an IACS member.

4.3.3.5 Operating and monitoring procedures should be adequate to ensure the prevention of all critical and foreseeable operational errors.

Guidance note:

External and internal hydraulic lifting tools should have:

- a remote monitoring system close to/visible from the crane driver's cab
- a pressure gauge (or indicator) in the system, showing when the tool is closed or open
- a duplicate pressure gauge (or indicator), as close as safely possible to the tool to avoid influences in pressure reading
- a secondary method of release in the event of hydraulic system failure.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

4.3.3.6 Automatic lifting tools shall incorporate systems to control the stress in lifted items, to prevent excessive local over-stress. Redundant and mechanical back-up systems must be in place, in case of power loss.

SECTION 5 STRUCTURES

5.1 Design conditions

5.1.1 General

5.1.1.1 General recommendations regarding structural design and fabrication are given in DNV-OS-H102.

5.1.1.2 Loadcases and analysis of forces are described in [3.4] For design of padeyes and other structural elements, additional design factors as described in [5.1.2] should be applied.

5.1.1.3 Tolerances which may result in excessive lateral or skew load components should be avoided.

5.1.2 Design factors – base case

5.1.2.1 Design forces for structural elements should be calculated as described in [3.4], with the basic load combination defined in [3.4.2] and application of design factor defined as γdesign = γ_f γ_c.

where:

γ_f : load factor
γ_c : consequence factor

5.1.2.2 The consequence factor, γ_c, shall be selected according to Table 5-1 below.

Table 5-1 Consequence factors

Element category	γ_c
Lift points including attachments to object (single critical elements supporting the lift points, is defined within this category).	1.3
Lifting equipment not subjected to load testing (e.g. spreader frames or beams, plate shackles).	1.3
Main elements supporting the lift point.	1.15
Other elements of lifted object.	1.0

Note: γ_c is intended to account for severe consequences of single element failure; categorisation of elements according to the table above should consider redundancy of elements accordingly.

5.1.2.3 The load factor γ_f, should normally be taken as 1.3.

Guidance note:

A reduced load factor of 1.2 may be considered applicable with respect to G (and Q) loads; see DNV-OS-H102, Section 5 B202. In this case γ_f, = 1.2 may be applied if dynamic load caused by E-loads is less than the static (P-load).

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.3 Design factors – alternatives

5.1.3.1 Assuming all loads have been suitably categorized, member design forces may be calculated based on the two ULS load conditions “a” and “b”; see DNV-OS-H102, Sec. 3B. Consequence factors according to Table 5-1 shall be applied.

Guidance note:

This approach is not applicable if the DAF has been based on [3.2.2.4] and Table 3-1.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.3.2 Structural element forces calculated as described in [3.4] could be used in a WSD check, see DNV-OS-H102 Sec.2 D200. Consequence factors according to Table 5-1 shall be applied.

5.1.4 Lift points

5.1.4.1 Lift points and their attachments to the structure should be designed for the maximum sling load, any possible sling angles and local load effects, as specified in [3.4.3.4].

5.1.4.2 The lift point design load in the sling direction, F_{ds}, shall include design factors according to [5.1.2] (or [5.1.3]) as stated in [3.4.2.6]. Design force components in other directions shall be based on F_{ds}, see App.B for guidance.

5.1.4.3 Lift point designs which may fail as a result of moderate deviations in sling force direction should be avoided.

5.1.4.4 Padeyes should normally be aligned such that lifting forces act in-plane with the main padeye plate.

Guidance note:

Not aligned padeyes may be acceptable provided that this is properly considered in the design calculations.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.4.5 The load bearing capacity of lift points shall be calculated based on a recognised code/method.

Guidance note:

The calculation method described in App.B may, as one acceptable alternative, be adopted for padeyes.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.4.6 It is recommended that lift points are designed with the main connections in shear rather than tension. High tensile forces acting through the thickness direction of rolled steel material shall be avoided.

Guidance note:

It is recommended that padeye plates are slotted through horizontal flanges and welded directly to vertical web plates. If through thickness tension cannot be avoided, materials with guaranteed through thickness properties should be used. Actual material quality requirements should be based on the stress level and guidance from recognized codes, e.g. EN 10164 and NORSOK N-004 (Sec. 5.2 including comment in sec. 12). At site, UT inspections of the material to verify the through-thickness properties may be found acceptable as documentation. UT inspection should be carried out after (and if found beneficial also before) welding. The stress level should be maximum 50% of allowable.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.4.7 The geometry and position of lift points shall ensure proper functionality of the rigging, including alignment, adequate load distribution on shackles/slings and connection / disconnection.

Guidance note:

The following normally apply:

— The required padeye hole diameter should be selected considering both shackle-pin and hole fabrication tolerances, as well as allowable bearing pressure. See also App.B.
— For shackles see [4.2.2.1] and [4.2.2.2].
— For trunnion/pin type lift points: To allow for expected sling/grommet ovalisation under load the width available for the sling shall be not less than $1.3 \times D$ (limited to 1.25D + 25mm), where D is nominal sling diameter. It the ovalisation is reduced by a curved contact surface the width available for the sling could be less, typically$1.15 \times D$.
— There should be adequate clearances for connection and dis-connection of lift rigging; see also [2.3.4.3].

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5.1.5 Dedicated lifting equipment

5.1.5.1 Dedicated lifting equipment is normally designed and manufactured for the purposes of lifting one particular object.

Guidance note:

Dedicated lifting equipment can include:

— spreader bars
— spreader frames
— plate shackles
— sling guiding structures, see [3.4.3.3].

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.5.2 Dedicated lifting equipment shall as a minimum fulfil all applicable requirements to design and fabrication of structures given in this section.

5.1.5.3 Eccentricities considering maximum possible deviations in sling angles should be duly considered in spreader bar and frame verifications.

5.1.6 Lifted object

5.1.6.1 Appropriate consequence factors (see Table 5-1) should be applied to primary and secondary structural elements.

5.1.6.2 Appropriate consideration should be given to skew load cases, as the load effects caused by these are normally not covered by in service design conditions.

5.1.6.3 Attention should be paid to possible horizontal load components acting on the lift points.

5.1.7 Bumpers and guides

5.1.7.1 The lay-out and size of the guiding system should be detailed with consideration given to:

— Functional requirements, e.g. protection of surrounding structures, ease of installation and installation accuracy.
— Operational procedure and details, e.g. tugger lines, etc.
— Maximum calculated/allowable relative motions between lifted object and guides.
— Maximum calculated or allowable tilt of the object in all relevant directions.

Guidance note 1:

Typical values for maximum tilt and motions are:

a) vertical movements ± 1.0 m
b) horizontal movements ± 1.5 m
c) longitudinal tilt ± 2°
d) transverse tilt ± 2°
e) plan rotation ± 3° (object close to final position).

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 2:

Further guidance on guides and bumpers (especially for removal projects) can be found in DNV-RP-H102 Sec.3.3.5.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.7.2 The design strength requirements for bumpers and guides are given in DNV-OS-H101, Section 6C.

5.1.8 Rigging lay-down and securing

5.1.8.1 The lifted object shall be equipped with a rigging lay-down and securing arrangement, providing safe and optimal handling of the rigging, before and after the lift.

Guidance note:

See and DNV 2.7-3 Sec.3.3.2 for further guidance. See also [4.1.6.1].

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.8.2 Special considerations shall be made for the easy release of lifting equipment, and allowing a smooth and unobstructed rigging tightening before lifting. Welding to special elements shall be avoided.

5.1.8.3 The lay down structure and securing arrangements should support the lifting equipment for maximum static and horizontal/vertical dynamic loads before and after lifting.

Guidance note:

Dynamic loads to be considered may be transportation loads, impact loads (from the lifting equipment) and environmental loads after installation.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.8.4 Special attention should be paid to the security of rigging during sea transport; effects of cyclic loads shall be duly considered.

Guidance note:

Note that the horizontal accelerations may be considerably larger at the top of an object than in the CoG.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

5.1.8.5 Adequate strength of the lay down structure and securing arrangements should normally be documented by calculation; for rigging with a self-weight exceeding 5 tonnes calculations shall be made.

5.1.9 Object seafastening and grillage

5.1.9.1 General requirements for design of seafastening and grillage for transportation of objects is covered in DNV-OS-H202.

5.1.9.2 Seafastening and grillages should allow easy release of objects being lifted. In addition, they should provide adequate support and horizontal restraint, until such time that the object can be lifted clear of the transportation vessel/barge.

Guidance note:

The seafastenings should normally be capable of being released in stages, such that the cargo is secure for a 10 degree static angle until the release of the final stage. The release of seafastenings, and the removal of any one item, should not disturb the seafastenings of any other item.

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5.1.9.3 Elements providing horizontal and/or vertical support after cutting/removal of seafastening shall be verified for environmental conditions applicable for the operation.

5.2 Fabrication and inspection

5.2.1 Materials and fabrication

5.2.1.1 Materials and fabrication of lift points and lifting equipment should comply with the requirements given for “special structural steel” in DNV-OS-H102, Section 6A.

5.2.2 Inspection

5.2.2.1 Inspection of lift points and lifting equipment should comply with the requirements given for “special structural steel” in DNV-OS-H102, Section 6B.

5.2.2.2 Lift points shall be adequately inspected for each subsequent lift.

Guidance note:

Adequate inspection should be based on the information available for the lift point, including load history and original NDT. If information is inadequate or unavailable, the inspection should be as for a new lift point, see [5.2.2.1].

Lift points can be accepted for subsequent lifting based on a visual inspection if:

a) the load history (since last MPI/UT inspection) of the lift points is known,
b) no abnormal loading of the lift points has occurred or has been suspected during previous lifts, and
c) no damage is evident during the visual inspection.

In the absence of a), lift points should be subject to 100% (min) MPI before any subsequent lifting.

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SECTION 6 YARD LIFTS

6.1 General

6.1.1 Application

6.1.1.1 This section is applicable to lifts and other crane assisted operations (roll-up) in connection with erection and assembly. It also applies to load-out and load-in operations by onshore cranes.

6.1.1.2 Relevant requirements in sections 1 to 5 apply for major yard lifts, roll-up operations and load out operations by lifting. This section describes exemptions and additional requirements for such operations.

6.2 Loads

6.2.1 Weight and CoG

6.2.1.1 The weight of a yard lifted item is often based on calculation only. In such cases, a weight contingency factor of 1.1 (min) should be used to define the design weight.

6.2.1.2 The effect of extreme positions of the CoG should be evaluated.

6.2.2 Special loads

6.2.2.1 For roll-up operations special loads may be of significant importance and should be thoroughly evaluated.

6.2.2.2 As applicable, special loads for roll up operations include:

— winch/tugger line loads
— support reaction loads (vertical and horizontal)
— friction loads (at supports and slings)
— wind loads.

6.2.3 Dynamic loads

6.2.3.1 Table 3-1 relating to dynamic effects for onshore lifts.

6.2.3.2 For crawler cranes travelling with load, possible dynamic effects should be evaluated thoroughly. Crane speeds and surface conditions should be considered. If no documentation is presented the minimum factors for “inshore lifts” in Table 3-1 should be used.

6.2.4 Skew loads

6.2.4.1 Yard lifts may involve three or more cranes. Extreme crane loads, i.e. worst possible load distributions within the cranes, should be calculated considering at least:

— support lay-out defined by the cranes
— flexibility of the lifted object
— crane types
— limiting environmental conditions
— lifting procedure
— monitoring system/tolerances.

A sensitivity analysis considering possible crane load variations should be considered.

6.2.4.2 The design of lifting equipment (and lifted/upended objects) should in some cases be based on the crane extreme load capacity, e.g. overturning load for crawler crane.

Guidance note:
This is particularly relevant for lifting with several (highly utilised) crawler cranes in a statically indeterminate system, where exact crane load may be difficult to control.

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6.2.5 Additional loads

6.2.5.1 For operations involving multiple cranes the maximum out of plumb of hoist lines should be defined/calculated and considered in the calculations.

6.2.5.2 The effect of swinging of the lifted object due to travelling crane movements should be evaluated.

6.2.6 Loadcases

6.2.6.1 Loadcases for yard lifts should be based on the general guidelines in [3.4] and the loads described in the paragraphs above.

6.2.6.2 For multi-crane operations sensitivity analysis with respect to possible crane load distributions, (see [6.2.4.1]) should be carried out.

6.2.6.3 Analysis shall be performed for an adequate number of roll-up angles. See [3.4.1.1] and [3.4.1.2].

6.3 Lifting equipment

6.3.1 Slings and grommets

6.3.1.1 The nominal safety factor for slings and grommets for yard lifts should be calculated as described in 4.1.5.1

Guidance note:
Yards-slings are normally used repeatedly, thus exposed to wear and tear - a wear factor $\gamma_w > 1.00$ should be used (1.20 is recommended).

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6.3.1.2 If slings made of soft ropes are used, special precautions may be required, see [4.1.4].

6.3.1.3 Attention should be paid to the effect of object rotation (roll-up) on sling connections.

6.3.2 Shackles

6.3.2.1 Shackles with SWL ≤ 50 tonnes without certification may be accepted, assuming:

— the SWL is stamped on the shackle
— the original Manufacturer is recognised
— calculated dynamic shackle load ≤ SWL
— the shackle is thoroughly inspected before use.

6.4 Structures

6.4.1 Lift points

6.4.1.1 The local strength capacity of some non-purpose-built lift points may have significant strength reserves; a consequence factor of 1.0 may in such cases be applicable, see Table 5-1.

Guidance note:
Typical examples are elastic hoop stresses for a tubular member where supporting a sling, compared with the total plastic capacity of the hoop.

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6.5 Cranes

6.5.1 Documentation

6.5.1.1 Yard cranes should normally possess an approval, issued by a recognised authority.

Guidance note:
In Norway this is “Arbeidstilsynet”.

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6.5.1.2 It should be documented that regular maintenance is carried out of all parts important for the safety of the lift.

6.5.2 Allowable loads

6.5.2.1 Allowable crane loads should be based on load-radii curves/tables. These should, as applicable, clearly state:

— Crane boom type and length.
— Counter weight position(s) and minimum number of hoist line legs.
— Maximum load, limited by overturning or structural strength.

— Crane equipment, e.g. hook, block, hoist lines and jib, to be included in crane hook load.
— Operational limitations.

6.5.2.2 For multiple crane operations involving travelling, effective crane radii should be calculated considering maximum out of plumb for hoist lines. The crane capacities should be calculated based on these radii, see [6.2.5].

6.5.2.3 Adequate sub-structure / ground strength should be documented for crawler crane operations; special attention should be given to toe peak loads.

6.5.2.4 If there is insufficient information regarding ground capacity, load testing (including the complete crane track) shall be carried out.

Guidance note:

The capacity could e.g. have been reduced locally due to an excavation that has been refilled without appropriate compaction.

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6.5.2.5 Operational limitations for travelling counter weights should be considered; position and weight should be checked.

6.6 Operational aspects

6.6.1 Clearances

6.6.1.1 Assuming all effects have been assessed, a calculated minimum clearance to the crane boom of 0.5m is normally acceptable.

Guidance note:

For roll-up operations planned hoist line angles need to be considered when the minimum clearances are calculated.

Possible deviations from vertical hoist lines (see [6.5.2.2]) need to be considered when establishing minimum clearances for lifts involving travelling.

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6.6.1.2 Crane boom lengths shall be sufficient to fulfil the clearance requirements.

6.6.2 Crane tracks

6.6.2.1 Crane tracks should be marked and the surface levelled/improved if required. See also [6.5.2.3] and [6.5.2.4].

6.6.3 Survey and monitoring

6.6.3.1 A thorough check for obstructions in way of the cranes, structure and rigging should be carried out.

6.6.3.2 It shall be ensured by surveys and monitoring (e.g. of crane radius/boom angle) that all crane allowable load assumptions, see [6.5.2], are properly accounted for.

6.6.3.3 For roll-up operations continuous monitoring should include:

— lifted/upended object deflections
— hoist line angles
— crane positions
— reaction loads/behaviour in roll up cells
— roll-up angle.

APPENDIX A LIFT CALCULATIONS

A.1 Calculation of SKL

A.1.1 Hook load

A.1.1.1 Direct calculation of the SKL_{sl} may be based on a sling load of 1.3 times that determined from the DHL.

A.1.2 Sling length tolerances

A.1.2.1 It is recommended not to select too strict strength tolerances when skew load calculations are performed. SKL_{sl} below 1.1 should normally not be applied for a statically indeterminate lift of a relatively rigid object.

A.1.3 Recommendations and assumptions

A.1.3.1 The following apply:

— A 4 point symmetric lift rigging is assumed.
— The load-deflection curves of the slings may be approximated as linear for the purpose of calculating the SKL_{sl}.
— The indicated E-modulus for slings may be inaccurate and should if possible be verified.
— It is recommended to assume the lifted object infinitely stiff. However, as a further refinement the object flexibility and possible crane hook rotation may be taken into account. The indicated value for ε_{add} is based on a reasonably stiff box type lifted object.

A.1.4 Calculations

A.1.4.1 The SKL_{sl} will decrease with increasing load since the relative difference between the sling loads will decrease. This effect is illustrated in Figure A-1.

A.1.4.2 The below formula may be used for calculation of the SKL_{sl} for a 4 point statically indeterminate lift with approximately a double symmetric single sling arrangement, and $\varepsilon \geq \varepsilon_0$.

$SKL_{sl} = 1 + \varepsilon_0 / (\varepsilon + \varepsilon_{add})$

where

ε	:	average strain in the slings at hook load 1.3 DHL (no skew load assumed).
ε	:	1.3 DHL/(A E sin(θ)).
DHL	:	dynamic hook load in N.
A	:	$3.14\ d^2$
d	:	diameter of sling in mm.
E	:	Young's modulus for the sling, could for cable laid slings be taken as 20 000 MPa based on A as defined above. For steel rope slings E = 70 000 MPa is normally acceptable.
ε_{add}	:	equivalent additional strain to include the effect of object deflection. For most lifts $\varepsilon_{add} = 0{,}0035 \times \cos(\theta)$ could be considered.
θ	:	average sling angle from a horizontal plane.
ε_0	:	total sling and padeye fabrication tolerances (or possible length deviation) as a function of the sling length, i.e. ε_0 = total tolerance/sling length.

Guidance note:

For lifting with grommets, the sling area A should be taken as the total sling cross sectional area, i.e. sum of both parts of all 4 grommets.

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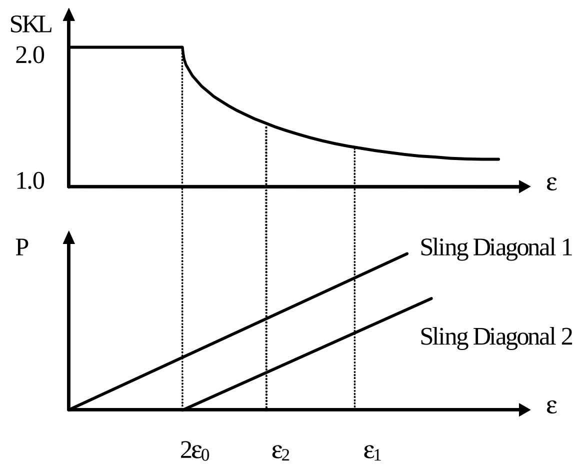


P	load in sling
ε	average strain in sling (elongation/sling length)
ε_o	sling length fabrication tolerance
ε_1	average strain in sling diagonal 1
ε_2	average strain in sling diagonal 2

Figure A-1
Determination of SKL_{sl}

APPENDIX B PADEYE CALCULATIONS

B.1 Padeyes

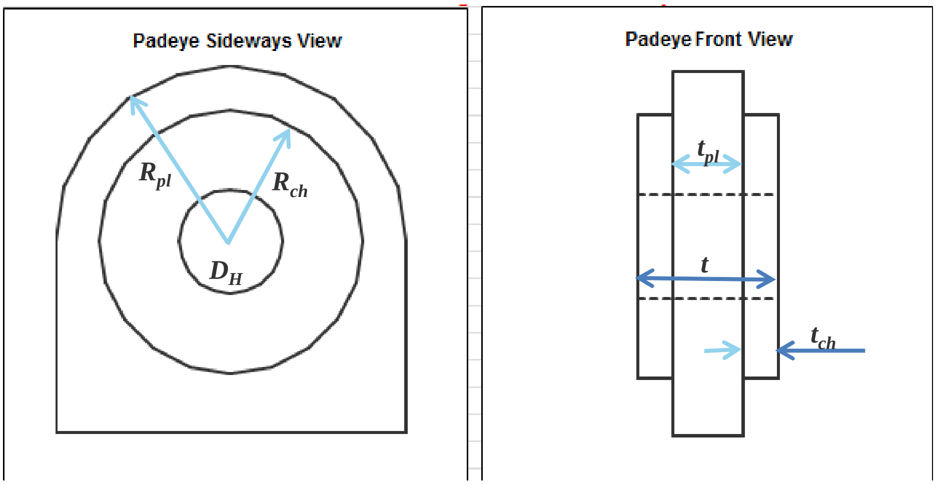
B.1.1 General

Design calculations for padeyes could be based on;

— finite element analysis or
— hand calculations.

For both these types of calculations input assumptions, calculation method and accept criteria need to be carefully evaluated.

A typical padeye layout is shown below. The calculation method in [B.1.2] applies for this type of padeye.



B.1.2 Element analysis

Typical important items to be thoroughly evaluated for linear (elastic) element analyses are:

— Load input (distribution) from shackle (pin and body if out-of-plane).
— Element types and sizes.
— Peak stresses – What is allowed of magnitude and extension?

B.1.3 Calculations

By hand calculations the actual stress distribution will be impossible to predict accurately. Hence, such calculations should include capacity evaluations based on an assumed stress distribution. At least adequate capacity of the following items should be documented:

a) Bearing pressure/capacity in the pin hole.

b) Tear out from the pin hole.

c) Cheek plate welds, if applicable.

d) Combined axial, shear and bending in the padeye (plate + stiffeners, if applicable).

B.2 Padeye calculation method

B.2.1 General

Normally the design checks listed below are sufficient to verify a padeye design. However, for special padeye designs additional checks may be necessary, and the need for such checks should hence be evaluated in each case.

For padeyes the following design considerations normally apply:

— The outside radius of the padeye main plate shall be no less than the diameter of the pin hole.
— The pad eye thickness at the hole shall not be less than 75% the inside width of the shackle.
— The padeye hole diameter should be carefully selected to fit the shackle pin diameter. For strength purposes the difference in hole and pin diameter should be as small as possible, but shackle pin maximum diameter including tolerance should be considered in order to ensure that the pin will enter the hole.
— For padeyes with significant (i.e. > 10%) out of plane loading, it is recommended that the shackle pin

diameter is not less than 94% of the padeye hole diameter.
— Nominal shackle pin- and hole diameter should/could be applied in the strength calculations.

B.2.2 Definitions

In the equations in this subsection the following definitions are applied:

F_{ds} Design load in sling direction, see [5.1.4.2].
F_d Padeye design load in line with padeye plate
F_{dl} Lateral padeye design load
M_e Design moment in centre of padeye hole
σ_y Yield stress of padeye material
γ_m Material factor
E Elastic modulus
D_{pin} Diameter of shackle pin
D_H Diameter of pinhole
β Adjustment factor – Bearing pressure
δ Adjustment factor – Lateral load
υ Sling out-of-(padeye)plane angle
t Total thickness of padeye at hole including cheek plates ($t = t_{pl} + 2 \times t_{ch}$)
R_{pad} Radius of padeye, taken as:

$$R_{pad} = \frac{R_{pl} \times t_{pl} + 2 \times R_{ch} \times t_{ch}}{t}$$

Where:

R_{pl} *is minimum distance form centre hole to edge of plate*

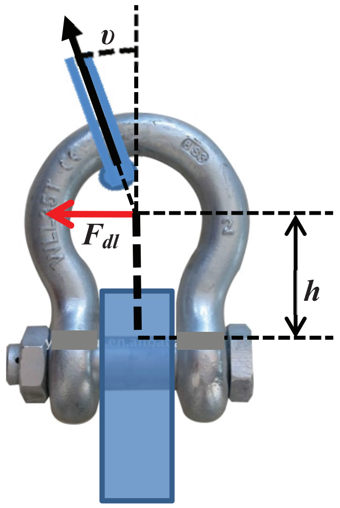
R_{ch} *is radius of cheek plates (two equal plates assumed)*

t_{pl} *is the thickness of the padeye plate*

t_{ch} *is the thickness of the cheek plates*

B.2.3 Design loads

The design loads on the padeye may be calculated as indicated below. The following assumptions apply:



— The sling load (F_{ds}) is transferred to the padeye through a shackle as indicated on the sketch.
— No friction between sling and shackle.
— The shackle is positioned centric in the padeye.
— Lateral load (F_{dl}) is transferred to the padeye through contact pressure between shackle body and padeye and/or as friction force between pin and padeye. Load resultant is assumed to work at top of pin.
— Moment (M_e) is transferred to the padeye through contact pressure between shackle pin and padeye.

$F_d = F_{ds} \times Cos(\upsilon)$	$F_{dl} = F_{ds} \times Sin(\upsilon)$	$Me = F_{dl} \times h$

B.2.4 Bearing pressure

The equations given below could be used to find limiting average bearing pressure. If the out-of-plane loading is significant (i.e. $\delta > 1.3$) the bearing pressure will be unevenly distributed. This should be considered. It is recommended that this is done by substituting β with β' in the following equations where $\beta' = \beta \times (\delta - 0.3)$ and $\delta \geq 1.3$. See [B.2.6] for calculation of δ.

For $D_{pin} / D_H < 0.96$ the following criterion applies:

$$\sigma_y / \gamma_m \geq 0.18 \times \sqrt{\frac{F_d \times \left(\frac{1}{D_{pin}} - \frac{1}{D_H} \right) \times E \times \beta}{t}}$$

For D_{pin} / D_H ≥ 0.96 the following criterion applies:

$$\sigma_y / \gamma_m \geq 0.036 \times \sqrt{\frac{F_d \times E \times \beta}{D_H \times t}}$$

The allowable bearing pressure is adjusted according to the use of the padeye. This is taken into account by applying the factor β as indicated:

— β = 1.0 if the (shackle) pin will rotate in the hole during lift (upending).
— β = 0.7 for padeyes that will be used for multiple lifts without pin rotation.
— β = 0.5 for single lift use without pin rotation.

B.2.5 Tear out

A tear out check is normally considered sufficient to check the padeye material above (i.e. in the load direction) the hole. The following criterion shall be fulfilled:

$$\sigma_y / \gamma_m \geq \frac{1.7 \times F_d}{(2 \times R_{Pad} - D_H) \times t}$$

B.2.6 Cheek plate welds

The cheek plate welds should fulfil the following criterion:

$$\sigma_{yw} / \gamma_m \geq \frac{F_d \times t_{ch}}{1.5 \times t \times D_{ch} \times a} \times \delta$$

$$\delta = \frac{4 \times \tan(\upsilon) \times h}{t} + 1$$

The above equation is based on the following assumptions:

a) The cheek plate welds will be fillet welds all around the outer edge of the cheek plate with a throat of “a”.
b) The cheek plate will be so stiff (in plane) that it is reasonable to assume that the complete weld will be active in transferring load.
c) The fillet welds stress components will vary all around the weld. Pure shear on the throat has been assumed.
d) Possible uneven (bearing) load distribution between cheek plates and main plate has been accounted for. (Factor ≈ 1,2)
e) The factor δ has been included to take into account increased loading on the cheek plate due to out-of-plane loading.

B.2.7 Combined stress

All relevant sections of the padeye from center hole and below including (weld) connections to object main structure (or to spreader bar/frame), shall be checked for combined stresses. It shall be documented / justified that the most critical section(s) has been considered in the design calculations.

Combined stresses should be checked according to a recognized code, see also DNV-OS-H102.