

**DIN EN ISO 13628-5**

ICS 75.180.10

**Erdöl- und Erdgasindustrie –  
Auslegung und Betrieb von Unterwasser-Produktionssystemen –  
Teil 5: Unterwasser-Versorgungskabel (ISO 13628-5:2009);  
Englische Fassung EN ISO 13628-5:2009, nur auf CD-ROM**

Petroleum and natural gas industries –  
Design and operation of subsea production systems –  
Part 5: Subsea umbilicals (ISO 13628-5:2009);  
English version EN ISO 13628-5:2009, only on CD-ROM

Industries du pétrole et du gaz naturel –  
Conception et exploitation des systèmes de production immergés –  
Partie 5: Faisceaux de câbles immergés (ISO 13628-5:2009);  
Version anglaise EN ISO 13628-5:2009, seulement en CD-ROM

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Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN

## Nationales Vorwort

Dieses Dokument (EN ISO 13628-5:2009) wurde vom ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“, Subkomitee SC 4 „Drilling and production equipment“ in Zusammenarbeit mit dem Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ (Sekretariat AFNOR, Frankreich) erarbeitet.

Für Deutschland hat hieran der Arbeitskreis NA 109-00-01-04 AK „Bohr- und Fördereinrichtungen“ im Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) des DIN Deutsches Institut für Normung e. V. mitgearbeitet.

Diese europäische Norm enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung der ISO Norm.

Diese Norm enthält neben den gesetzlichen Einheiten auch die Einheiten „°F“, „ft“, „inch“, „kip“, „ksi“, „lb“, „ppm“, „psi“, die im Deutschen Normenwerk nicht zugelassen sind. Es wird ausdrücklich darauf hingewiesen, dass die Anwendung dieser Einheiten im nationalen amtlichen und geschäftlichen Verkehr aufgrund des Gesetzes über Einheiten im Messwesen nicht zulässig ist.

### Umrechnung:

| Nicht-SI-Einheit | SI-Einheit | Umrechnung |                   |
|------------------|------------|------------|-------------------|
| °F               | °C         | °C         | = (5/9) (°F-32)   |
| ft               | m          | 1 ft       | = 0,304 8 m       |
| in (inch)        | mm         | 1 in       | = 25,4 mm         |
| kip              | N          | 1 kip      | = 4 448,22 N      |
| ksi              | MPa        | 1 ksi      | = 6,894 757 MPa   |
| lb (pound)       | kg         | 1 lb       | = 0,453 592 37 kg |
| ppm              | mg/kg      | 1 ppm      | = 1 mg/kg         |
| psi (psig)       | kPa        | 1 psi      | = 6,894 757 kPa   |

Für die in diesem Dokument zitierten Internationalen Normen wird im Folgenden auf die entsprechenden Deutschen Normen hingewiesen:

|               |       |                  |
|---------------|-------|------------------|
| ISO 527-1     | siehe | DIN EN ISO 527-1 |
| ISO 527-2     | siehe | DIN EN ISO 527-2 |
| ISO 527-3     | siehe | DIN EN ISO 527-3 |
| ISO 527-4     | siehe | DIN EN ISO 527-4 |
| ISO 527-5     | siehe | DIN EN ISO 527-5 |
| ISO 4080      | siehe | DIN EN ISO 4080  |
| ISO 4672      | siehe | DIN EN ISO 4672  |
| ISO 6801      | siehe | DIN EN 26801     |
| ISO 7751      | siehe | DIN EN ISO 7751  |
| IEC 60228     | siehe | DIN EN 60228     |
| IEC 60793-1-1 | siehe | DIN EN 60793-1-1 |
| IEC 60793-2   | siehe | DIN EN 60793-2   |
| IEC 60794-1-2 | siehe | DIN 60794-1-2    |

ISO 13628 *Petroleum and natural gas industries — Design and operation of subsea production systems* besteht aus den folgenden Teilen:

- *Part 1: General requirements and recommendations*
- *Part 2: Unbonded flexible pipe systems for subsea and marine applications*
- *Part 3: Through flowline (TFL) systems*
- *Part 4: Subsea wellhead and tree equipment*
- *Part 5: Subsea umbilicals*
- *Part 6: Subsea production control systems*
- *Part 7: Completion/workover riser systems*
- *Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems*
- *Part 9: Remotely Operated Tool (ROT) intervention systems*
- *Part 10: Specification for bonded flexible pipe*
- *Part 11: Flexible pipe systems for subsea and marine applications*
- *Part 15: Subsea structures and manifolds*

## Nationaler Anhang NA (informativ)

### Begriffe, Definitionen und Abkürzungen

Folgende Begriffe, Definitionen und Abkürzungen werden in der Norm verwendet:

#### 3.1 Begriffe

##### 3.1.1

##### **zulässiger Biegeradius**

kleinster Radius, auf den ein Versorgungskabel bei einer gegebenen Zugspannung gebogen werden darf, ohne dadurch die Auslegungskriterien zu verletzen oder einen Verlust des Leistungsvermögens zu erleiden

Siehe Bild 1.

ANMERKUNG 1 Die Biegeradius wird mit Bezug auf die Mittellinie des Versorgungskabels gemessen.

ANMERKUNG 2 Der zulässige Biegeradius nimmt mit steigender Zugbeanspruchung zu und variiert in Abhängigkeit vom Innendruck und der Beschaffenheit, d. h. dem Sicherheitsniveau.

##### 3.1.2

##### **zulässige Zugbeanspruchung**

maximale Zuglast, mit der ein Versorgungskabel bei einem gegebenen Biegeradius belastet werden kann, ohne dadurch die Auslegungskriterien zu verletzen oder einen Verlust des Leistungsvermögens zu erleiden

Siehe Bild 1.

ANMERKUNG Die zulässige Zugbeanspruchung verringert sich mit abnehmendem Biegeradius und variiert in Abhängigkeit vom Innendruck und der Beschaffenheit, d. h. dem Sicherheitsniveau.

##### 3.1.3

##### **Zusatzeinrichtung**

Zubehör des Versorgungssystems, das nicht zur hauptsächlichen funktionalen Zweckbestimmung zählt

BEISPIELE Sollbruchstelle, Auftriebseinrichtungen, Schutzrohr-Abdichtungen, VIV-Stringer (Einrichtungen zur Reduzierung wirbelinduzierter Schwingungen), Zentrierer, externe Anker-Spannvorrichtungen.

##### 3.1.4

##### **Krümmungsbegrenzer**

Einrichtung, die dazu dient, den Biegeradius des Versorgungskabels durch mechanische Mittel zu begrenzen

ANMERKUNG Ein Krümmungsbegrenzer besteht normalerweise aus einer Reihe von metallischen oder geformten Verbindungsringen, die über das Versorgungskabel verteilt angeordnet sind. Er wird manchmal auch als Zugentlastungseinrichtung mit Biegeschutz (BSR, en: bend strain reliever) bezeichnet.

##### 3.1.5

##### **Biegeversteifung**

Einrichtung zur lokalen Erhöhung der Biegesteifigkeit, um den Mindest-Biegeradius des Versorgungskabels unter definierten Biegemoment-Bedingungen zu erhalten

ANMERKUNG Bei der Versteifung handelt es sich normalerweise um ein Formteil, das in Abhängigkeit von der erforderlichen Betriebsart manchmal verstärkt ist und über dem Versorgungskabel angebracht wird. Es wird manchmal auch als Zugentlastungseinrichtung mit Biegeschutz (BSR, en: bend strain reliever) bezeichnet.

### 3.1.6

#### Korbbildung

Erscheinung, bei der sich infolge von akkumulierten axialen und radialen Spannungen in den Bewehrungslagen Bewehrungsdrähte lokal mit einem zunehmenden und/oder abnehmenden Teilkreisdurchmesser neu anordnen

### 3.1.7

#### Bündel

verseilte Funktionsbauteile und zugehörige Füllinlagen im Versorgungskabel vor der weiteren Verarbeitung

ANMERKUNG Zu den typischen Funktionsbauteilen in einem Bündel zählen Schläuche, Rohre, Elektrokabel, Glasfaserkabel.

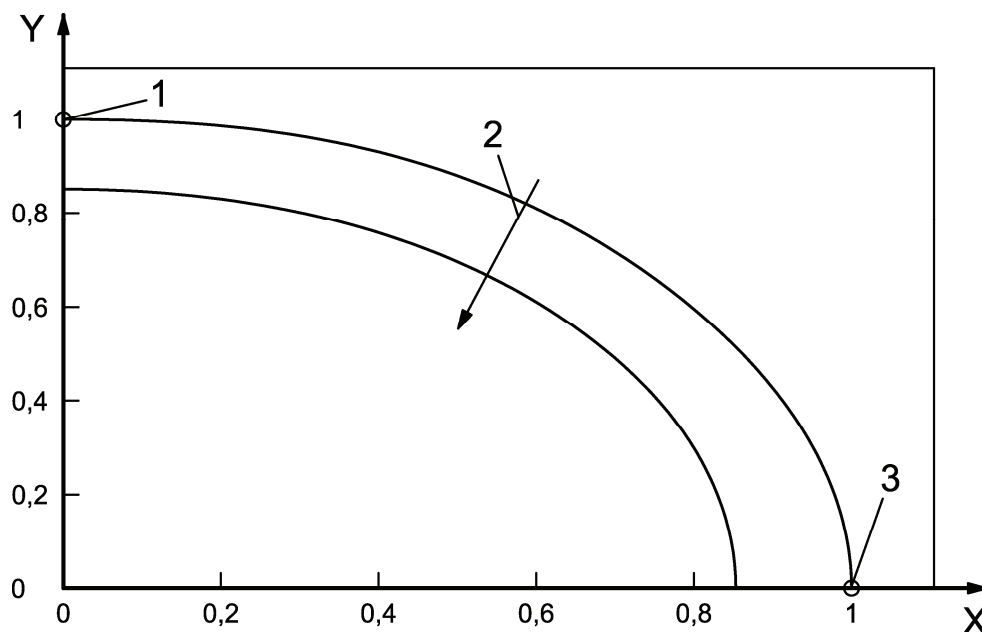
### 3.1.8

#### Belastungskurve

Linie, die das Verhältnis zwischen dem zulässigen Biegeradius und der zulässigen Zugbeanspruchung für eine Innendruck-Bedingung definiert

Siehe Bild 1.

ANMERKUNG Die Kurven können sich deshalb in Bezug auf Lagerung, Prüfung, Montage und Betriebszenarien unterscheiden.



#### Legende

- X Kehrwert des normierten Biegeradius, MBR je Radius
- Y normierte zulässige Zugbeanspruchung, Zugkraft je MTL
- 1 maximale Zugbeanspruchung (MTL) ohne Biegung
- 2 zunehmender Druck und/oder zunehmendes Sicherheitsniveau
- 3 Kehrwert des Mindest-Biegeradius (MBR) ohne Zugbeanspruchung

ANMERKUNG 1 Bei einer Erhöhung des Sicherheitsniveaus erhöht sich im Allgemeinen der zulässige Biegeradius und verringert sich die zulässige Zugbeanspruchung, d. h. die Belastungskurven nähern sich dem Ursprung.

ANMERKUNG 2 Bei einer Erhöhung des Innendrucks erhöht sich im Allgemeinen der zulässige Biegeradius und verringert sich die zulässige Zugbeanspruchung, d. h. die Belastungskurven nähern sich dem Ursprung.

**Bild 1 — Belastungskurven**

### 3.1.9

#### **Karusell**

Lagerbehälter, der mit Hilfe eines Antriebs um eine vertikale Achse gedreht werden kann

### 3.1.10

#### **Legeraupe**

Einrichtung, die das Versorgungskabel zwischen Bändern oder Platten hält und axial-lineare Antriebskraft auf das Versorgungskabel überträgt

ANMERKUNG Eine Legeraupe wird auch als linearer Kabelantrieb oder Raupenabzug oder als Spanneinrichtung bezeichnet.

### 3.1.11

#### **Kenndaten**

Daten, die sich auf ein Bauteil oder ein Versorgungskabel beziehen und Angaben zum Leistungsvermögen machen, ohne jedoch spezifische Abnahme-/Rückweisungskriterien festzulegen

### 3.1.12

#### **chinesischer Finger**

Bauart eines Greifers, der dazu dient, das Versorgungskabel an dessen Außendurchmesser zu halten; er besteht aus einer Reihe von spiralförmig verwobenen Drähten oder einem Kunststoffseil, das/die an einer eingebauten Verankerungseinrichtung befestigt ist/sind

### 3.1.13

#### **Ader**

Oberbegriff, der zur Beschreibung eines einzelnen elektrisch isolierten Leiters verwendet wird

### 3.1.14

#### **seitliche Verlegung**

Installationstätigkeit, bei der sich das Installationsschiff am Verlegungsweg seitlich entlang bewegt oder an dessen Ende

### 3.1.15

#### **Quetschlast**

in radialer Richtung wirkende Last, die entlang des Umfangs möglicherweise nicht gleichmäßig verteilt und entlang des Versorgungskabels in der Länge begrenzt ist

ANMERKUNG Eine Quetschlast wird üblicherweise während der Installation verursacht.

### 3.1.16

#### **Tiefwasser**

Wassertiefe, die im Allgemeinen von 610 m (2 000 ft) bis 1 830 m (6 000 ft) reicht

### 3.1.17

#### **Auslegungs-Lebensdauer**

Betriebslebensdauer, die mit einem entsprechenden Faktor multipliziert wird, der größer oder gleich eins ist

### 3.1.18

#### **Auslegungs-Betriebsdruck**

##### **DWP**

maximaler Betriebsdruck, für den eine Schlauch- oder Rohrleitung im Dauerbetrieb ausgelegt ist

### 3.1.19

#### **Auslegungs-Zugbeanspruchung**

maximale Zugbeanspruchung, die mit einem entsprechenden Faktor multipliziert wird, der kleiner oder gleich eins ist

**3.1.20****Endanschluss**

Formstück für mechanische Verbindungen, das am Ende eines Versorgungskabels angebracht ist und zur Übertragung von Installations- und Betriebslasten, Fluid und elektrischen Diensten an eine Anschlusseinheit dient, die auf der Unterwasseranlage oder oberirdischen Anlage montiert ist

**3.1.21****Werksabnahme**

Reihe von Prüfungen, die am vollständigen Bauteil des Versorgungskabels oder dem gesamten Versorgungskabel erfolgt, um die Integrität der zu prüfenden Einheit nachzuweisen

**3.1.22****Füllstoff**

Element, dass die Hohlräume zwischen den **Funktionsbauteilen** (3.1.23) ganz oder teilweise ausfüllt, um die relative Lage der Bauteile und die Form des Querschnitts zu erhalten, das Gewicht-Durchmesser-Verhältnis zu beeinflussen, Bauteile im Hinblick auf den Verschleiß voneinander zu trennen oder eine bestimmte radiale Steifigkeit zu erhalten

**3.1.23****Funktionsbauteil**

in einem Versorgungskabel enthaltene Schlauchleitungen, Rohre, Elektrokabel und Glasfaserkabel, die erforderlich sind, um die betrieblichen Anforderungen zu erfüllen

**3.1.24****Funktionsspezifikation**

Dokument, in dem die Gesamtheit der Anforderungen durch Kenndaten, Merkmale, Prozessbedingungen, Grenzen und Ausschlüsse zur Definition des Leistungsvermögens eines Produktes oder einer Dienstleistung festgelegt ist, einschließlich Anforderungen an die Qualitätssicherung

**3.1.25****Hauptanlage**

ortsfixe oder schwimmende Anlage, mit der das Versorgungskabel mechanisch und funktional verbunden ist und die die Funktionen und Dienstleistungen bereitstellt, die durch das Versorgungskabel übertragen werden

BEISPIELE Plattform, Boje, schwimmendes Produktionssystem.

**3.1.26****Wasserstoff-Scavenger**

Gelmaterial, das im Rohr (aus Metall oder Polymer), das den Glasfaserleiter hält, aufgebracht wird, damit Wasserstoff-Ionen absorbiert werden, die eine „Verdunkelung“ der Faser und damit einer Verringerung der Übertragungsmöglichkeiten verhindern

**3.1.27****unabhängige Verifizierungsstelle**

Partei oder Gruppe, die sowohl vom Hersteller als auch vom Käufer unabhängig ist

**3.1.28****Verseilen**

Vorgang des schraubenförmigen Zusammenbaus (SZ sofern zutreffend) von elektrischen Adern oder Glasfasern in ein Kabel oder von Schläuchen, Elektrokabeln, Glasfaserkabeln in ein Bündel oder Teilbündel

ANMERKUNG Der Vorgang wird manchmal auch als „Verdrillen“ bezeichnet.

**3.1.29****Schlagwinkel**

Winkel zwischen der Achse des spiralförmigen Elements (z. B. Armierungsdrähte) und einer Geraden, die parallel zur Längsachse des Versorgungskabels verläuft

### 3.1.30

#### **Verladen**

Verbringen eines Versorgungskabels oder eines Versorgungssystems von einem Lager auf ein Installations-/ Transportschiff; entweder durch Übertragung mittels Spulen oder durch Heben des auf seiner Installations-/ Transporttrommel gelagerten Produkts

### 3.1.31

#### **schriftliche Spezifikation des Herstellers**

vom Hersteller in Übereinstimmung mit den vom Käufer festgelegten Anforderungen sowie dem vorliegenden Teil der ISO 13628 verfasste Spezifikation für das Versorgungskabel, die Bauteile des Versorgungskabels und deren Fertigung

ANMERKUNG Die Spezifikation darf aus einer Vielzahl von Dokumenten bestehen (Gestaltungsplan, Inspektions- und Prüfplan, Prüfverfahren usw.).

### 3.1.32

#### **maximale Zugbeanspruchung**

höchste Zugbeanspruchung, der ein Versorgungskabel mit Nullkrümmung standhalten kann, ohne das Spannungskriterium zu verletzen oder einen Verlust des Leistungsvermögens zu erleiden

Siehe Bild 1 und 3.1.8.

### 3.1.33

#### **Tragseil**

in ein Schutzrohr installierte oder vormontierte Einrichtung, die zum Verbringen der Hauptzugvorrichtung, normalerweise ein Drahtseil, in die Rohrleitung dient, damit ein Versorgungskabel durch die Rohrleitung gezogen werden kann

### 3.1.34

#### **Mindest-Biegeradius**

kleinster Radius, auf den ein Versorgungskabel gebogen werden darf, das nicht auf Zug beansprucht wird, ohne das Spannungskriterium zu verletzen oder einen Verlust des Leistungsvermögens zu erleiden

Siehe Bild 1 und 3.1.8.

### 3.1.35

#### **Multikoppler**

Mehrweg-Verbinderanordnung, die sich aus zwei Unterbaugruppen von Anschluss-Stabplatten zusammensetzt, die jeweils aus einer Anzahl von hydraulischen und/oder elektrischen und/oder optischen Kupplungshälften besteht, die jeweils einen separaten Dienst übertragen, die gleichzeitig in die Kupplungshälften auf der anderen Unterbaugruppe greifen, sobald die beiden Unterbaugruppen miteinander verbunden werden

### 3.1.36

#### **Einzugskopf**

Vorrichtung, die dazu dient, das Ende eines Versorgungskabels anzuschließen, damit es von einem Schiff abgeladen und über den Meeresboden und/oder durch ein Schutzrohr gezogen werden kann

ANMERKUNG Bei einigen Konstruktionsweisen können die Bewehrungen zur Befestigung des Versorgungskabels am oberen Ende des Schutzrohres verwendet werden. Der Einzugskopf besteht normalerweise aus einem geglätteten zylindrischen Gehäuse, in dem die Bewehrung des Versorgungskabels angeschlossen wird und innerhalb dessen die Enden der Funktionsbauteile enthalten sind. Er kann normalerweise schnell demontiert werden, um einen Zugang zu den Bauteilen für Prüfungen nach dem Einbau und zur Überwachung zu ermöglichen. Eine Form eines Einzugskopfes kann auch an dem unter Wasser befindlichen Ende des Versorgungskabels verwendet werden.

### 3.1.37

#### **Spule (Kabeltrommel)**

Vorrichtung zum Lagern, Transportieren oder Installieren von Versorgungskabeln oder Bauteilen, die aus zwei Flanschen besteht, die durch einen Zylinder voneinander getrennt sind, wobei die Zylinderachse normalerweise waagerecht verläuft

ANMERKUNG Spulen werden entsprechend des vorgesehenen Verwendungszwecks konstruiert.

### 3.1.38

#### Lebensdauer

festgelegte Zeitdauer, während der das Versorgungssystem in der Lage sein muss, die Anforderungen an die Funktionstüchtigkeit zu erfüllen

### 3.1.39

#### Wöhlerdaten

Daten, die durch Auftragen des zyklischen Spannungsniveaus über der Bruch-Schwingspielzahl gewonnen werden

### 3.1.40

#### Spleißen

Verbinden von Teillängsstücken oder Unterbaugruppen, um die erforderliche Fertigungslänge zu erreichen

### 3.1.41

#### statische Anwendung

Anwendung, bei der die Lasteinwirkung(en) infolge dynamischer Lasten (z. B. Seegang, induzierte Schwingungen usw.) nach dem Einbau vernachlässigt werden können

ANMERKUNG Freie Spannweiten bei einem ansonsten statischen Versorgungskabel sollten als dynamische Anwendung betrachtet werden.

### 3.1.42

#### Unterwasser-Anschlussschnittstelle

Mechanismus, der den Übergang zwischen dem Versorgungskabel und der Unterwasser-Abschlusseinrichtung bildet

ANMERKUNG Die Schnittstelle besteht üblicherweise aus einem Versorgungskabel-Bewehrungsabschluss und/oder einer mechanischen Vorrichtung zur Befestigung der Rohrleitungen, Biegeversteifung/-begrenzung und von Rohr- und Schlauchverschraubungen. Falls das Versorgungskabel Elektrokabel oder Glasfaserkabel enthält, können auch Leitungseinführungen und/oder Steckverbinder eingebaut sein.

### 3.1.43

#### Unterwasser-Versorgungskabelanschluss

Mechanismus zum mechanischen, elektrischen, optischen und/oder hydraulischen Anschließen eines Versorgungs- oder Überbrückungskabels an ein Unterwassersystem

### 3.1.44

#### Zugbewehrung

Konstruktionsschicht, die z. B. aus Stahldrähten, faserverstärkten Kunststoffstäben usw. besteht und dazu dient, die Zuglasten im Versorgungskabel aufzunehmen

ANMERKUNG Bei einigen Anwendungen kann die Zugbewehrung auch Zusatzfunktionen übernehmen, wie beispielsweise für zusätzliches Gewicht und/oder Aufprallschutz zu sorgen.

### 3.1.45

#### Zugbruchkraft

Kraft, bei der das schwächste Bauteil des Versorgungskabelbündels versagt, wenn die Last auf das gerade verlaufende Versorgungskabel aufgebracht wird

### 3.1.46

#### extremes Tiefwasser

Begriff, der für Tiefen von mehr als 1 830 m (6 000 ft) verwendet wird, die eine Erwägung alternativer Konstruktionsweisen und/oder Technologien erforderlich machen können

### 3.1.47

#### **Versorgungskabel**

Gruppe von Funktionsbauteilen wie beispielsweise Elektrokabeln, Glasfaserkabeln, Schlauch- und Rohrleitungen, verseilt oder gebündelt oder miteinander kombiniert, die im Allgemeinen für die Hydraulik, Fluidinjektion, Stromversorgung und/oder für Kommunikationsdienste sorgen

ANMERKUNG Weitere Elemente oder Bewehrungen können aus Gründen der Festigkeit, des Schutzes oder des Gewichts einbezogen sein.

### 3.1.48

#### **Versorgungskabel-Verbinder**

Hilfsmittel zum Verbinden zweier Längen eines Versorgungskabels zur Reparatur oder um die erforderliche Produktionslänge zu erreichen

### 3.1.49

#### **Versorgungssystem**

vollständiges Versorgungskabel mit Endanschlüssen und sonstigen Zusatzeinrichtungen

### 3.1.50

#### **ungealterte repräsentative Probe**

unversehrtes Probestück eines Versorgungskabels oder eines Bauteils, das nicht zuvor Betriebs- oder Montagelasten, Spannungen, erhöhter Temperatur und/oder anderen Bedingungen ausgesetzt war, die dessen Qualität verringert haben können

BEISPIELE Elektrokabel, Schläuche, Rohre und Glasfasern.

### 3.1.51

#### **Abnahmeprüfung**

Prüfung, die durchgeführt wird, um die Konstruktion und Fabrikation der Einheit im Hinblick auf deren Einsatz in der Praxis zu überprüfen sowie um Kenndaten zu gewinnen

### 3.1.52

#### **Sollbruchstelle**

Einrichtung, die sicherstellen soll, dass sich das Versorgungskabel bei einer bestimmten Last an einer festgelegten Stelle löst oder reißt

## 3.2 Abkürzungen

|     |                                                             |
|-----|-------------------------------------------------------------|
| AC  | Wechselstrom                                                |
| AVE | scheinbare Volumenausdehnung                                |
| CP  | Korrosionsschutz                                            |
| DC  | Gleichstrom                                                 |
| DWP | Auslegungs-Betriebsdruck (mathematisches Symbol: $p_{DW}$ ) |
| FAT | Werksabnahme                                                |
| FD  | Frequenzbereich                                             |
| FE  | finites Element                                             |
| FEM | Finite-Elemente-Modellierung                                |
| ID  | Innendurchmesser (mathematisches Symbol: $d$ )              |

|      |                                                                           |
|------|---------------------------------------------------------------------------|
| LTD  | linearisierter Zeitbereich                                                |
| MBR  | Mindest-Biegeradius bei Null-Zuglast                                      |
| MTL  | maximale Zugbeanspruchung                                                 |
| NDE  | zerstörungsfreie Untersuchung                                             |
| NTD  | nichtlinearer Zeitbereich                                                 |
| OD   | Außendurchmesser (mathematisches Symbol: $D$ )                            |
| OTDR | optisches Zeitbereichsreflektometer                                       |
| PMI  | Portable Metallidentifikation                                             |
| PRE  | Wirksumme                                                                 |
| RAO  | Übertragungsfunktionen                                                    |
| ROV  | ferngelenktes Fahrzeug                                                    |
| SF   | Sicherheitsfaktor                                                         |
| SMYS | festgelegte Mindest-Streckgrenze (mathematisches Symbol: $\sigma_{SMY}$ ) |
| TDR  | Zeitbereichsreflektometrie                                                |
| TVE  | wahre Volumenausdehnung                                                   |
| UT   | Ultraschall-Prüfung                                                       |
| UV   | ultraviolett                                                              |
| VIV  | wirbelinduzierte Schwingung                                               |
| WT   | Wanddicke $t$                                                             |

## Nationaler Anhang NB (informativ)

### Literaturhinweise

DIN EN 26801, *Gummi- und Kunststoffschläuche — Bestimmung der Volumenzunahme*

DIN EN 60228, *Leiter für Kabel und isolierte Leitungen*

DIN EN 60793-1-1, *Lichtwellenleiter — Teil 1-1: Mess- und Prüfverfahren — Allgemeines und Leitfad*

DIN EN 60793-2, *Lichtwellenleiter — Teil 2: Produktspezifikationen — Allgemeines*

DIN EN 60794-1-2, *Lichtwellenleiterkabel — Teil 1-2: Fachgrundspezifikation — Grundlegende Prüfverfahren für Lichtwellenleiterkabel*

DIN EN ISO 527-1, *Kunststoffe — Bestimmung der Zugeigenschaften — Teil 1: Allgemeine Grundsätze*

DIN EN ISO 527-2, *Kunststoffe — Bestimmung der Zugeigenschaften — Teil 2: Prüfbedingungen für Form- und Extrusionsmassen*

DIN EN ISO 527-3, *Kunststoffe — Bestimmung der Zugeigenschaften — Teil 3: Prüfbedingungen für Folien und Tafeln*

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## **Foreword**

This document (EN ISO 13628-5:2009) has been prepared by Technical Committee ISO/TC 67 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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### **Endorsement notice**

The text of ISO 13628-5:2009 has been approved by CEN as a EN ISO 13628-5:2009 without any modification.

## **Introduction**

This part of ISO 13628 is based on the first edition of ISO 13628-5, which was based on API Spec 17E, second edition and API RP 17I, first edition. The first edition of ISO 13628-5 was adopted by API as API Spec 17E, third edition. It is intended that API Spec 17E, fourth edition, will be identical to this International Standard.

It is important that users of this part of ISO 13628 be aware that further or differing requirements can be needed for individual applications. This part of ISO 13628 is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment engineering solutions for the individual application. This can be particularly applicable if there is innovative or developing technology. If an alternative is offered, it is the responsibility of the vendor to identify any variations from this part of ISO 13628 and provide details.

In this part of ISO 13628, where practical, US Customary (USC) and other units are included in parentheses for information.

## 1 Scope

This part of ISO 13628 specifies requirements and gives recommendations for the design, material selection, manufacture, design verification, testing, installation and operation of umbilicals and associated ancillary equipment for the petroleum and natural gas industries. Ancillary equipment does not include topside hardware. Topside hardware refers to any hardware that is not permanently attached to the umbilical, above the topside hang-off termination.

This part of ISO 13628 applies to umbilicals containing components, such as electrical cables, optical fibres, thermoplastic hoses and metallic tubes, either alone or in combination.

This part of ISO 13628 applies to umbilicals for static or dynamic service, with surface-surface, surface-subsea and subsea-subsea routings.

This part of ISO 13628 does not apply to the associated component connectors, unless they affect the performance of the umbilical or that of its ancillary equipment.

This part of ISO 13628 applies only to tubes with the following dimensions: wall thickness,  $t < 6$  mm, internal diameter,  $ID < 50,8$  mm (2 in). Tubular products greater than these dimensions can be regarded as pipe/linepipe and it is expected that they be designed and manufactured according to a recognised pipeline/linepipe standard.

This part of ISO 13628 does not apply to a tube or hose rated lower than 7 MPa (1 015 psi).

This part of ISO 13628 does not apply to electric cable voltage ratings above standard rated voltages  $U_0/U(U_m) = 3,6/6(7,2)$  kV rms, where  $U_0$ ,  $U$  and  $U_m$  are as defined in IEC 60502-1 and IEC 60502-2.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 527 (all parts), *Plastics — Determination of tensile properties*

ISO 1402, *Rubber and plastics hoses and hose assemblies — Hydrostatic testing*

ISO 4080, *Rubber and plastics hoses and hose assemblies — Determination of permeability to gas*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 4672:1997, *Rubber and plastics hoses — Sub-ambient temperature flexibility tests*

ISO 6801, *Rubber or plastics hoses — Determination of volumetric expansion*

ISO 6803:2008, *Rubber or plastics hoses and hose assemblies — Hydraulic-pressure impulse test without flexing*

ISO 7751, *Rubber and plastics hoses and hose assemblies — Ratios of proof and burst pressure to design working pressure*

ISO 13628-8, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems*

ISO 8308, *Rubber and plastics hoses and tubing — Determination of transmission of liquids through hose and tubing walls*

IEC 60228, *Conductors of insulated cables*

IEC 60502-1, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV ( $U_m = 1,2$  kV) up to 30 kV ( $U_m = 36$  kV) — Part 1: Cables for rated voltages of 1 kV ( $U_m = 1,2$  kV) and 3 kV ( $U_m = 3,6$  kV)*

IEC 60502-2, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV ( $U_m = 1,2$  kV) up to 30 kV ( $U_m = 36$  kV) — Part 2: Cables for rated voltages from 6 kV ( $U_m = 7,2$  kV) up to 30 kV ( $U_m = 36$  kV)*

IEC 60793-1-1, *Optical fibres — Part 1-1: Measurement methods and test procedures — General and guidance*

IEC 60793-2, *Optical fibres — Part 2: Product specifications — General*

IEC 60794-1-1, *Optical fibre cables — Part 1-1: Generic specification — General*

IEC 60794-1-2, *Optical fibre cables — Part 1-2: Generic specification — Basic optical cable test procedures*

EN 10204:2004, *Metallic products — Types of inspection documents*

ASTM A240, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A480, *Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*

ASTM A789/A789M, *Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service*

ASTM A1016/A1016M-04A, *Standard Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel and Stainless Steel Tubes*

ASTM E8/E8M, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E92, *Standard Test Method for Vickers Hardness of Metallic Materials*

ASTM E213, *Standard Practice for Ultrasonic Examination of Metal Pipe And Tubing*

ASTM E273, *Standard Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing*

ASTM E309, *Standard Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation*

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

ASTM E426, *Standard Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys*

ASTM E562, *Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count*

ASTM E1001, *Standard Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves*

ASTM E1245, *Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis*

ASTM G48-03, *Standard Test Methods for Pitting And Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferritic Chloride Solution*

BS 5099, *Electric cables. Voltage levels for spark testing*

ITU-T G.976, *Test methods applicable to optical fibre submarine cable systems*

### 3 Terms, abbreviated terms and definitions

#### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

##### 3.1.1

##### **allowable bend radius**

minimum radius to which an umbilical, at a given tension, may be bent to without infringing design criteria or suffering loss of performance

See Figure 1.

NOTE 1 The bend radius is measured to the centreline of the umbilical.

NOTE 2 Allowable bend radius increases with increasing tensile load and varies depending on internal pressure and condition, i.e. safety level.

##### 3.1.2

##### **allowable tensile load**

maximum tensile load that an umbilical, at a given bend radius, can be loaded to without infringing design criteria or suffering loss of performance

See Figure 1.

NOTE Allowable tensile load decreases with decreasing bend radius and will vary depending on internal pressure and condition, i.e. safety level.

##### 3.1.3

##### **ancillary equipment**

accessory to the umbilical system that does not form part of the main functional purpose

EXAMPLES Weak link, buoyancy attachments, I-tube or J-tube seals, VIV strakes, centralizers, anchors external clamps.

##### 3.1.4

##### **bend restrictor**

device for limiting the bend radius of the umbilical by mechanical means

NOTE A bend restrictor typically is comprised of a series of interlocking metallic or moulded rings, applied over the umbilical. It is sometimes referred to as a bend strain reliever (BSR).

##### 3.1.5

##### **bend stiffener**

device for providing a localized increase in bending stiffness, preserving the minimum bend radius of the umbilical under defined bending moment conditions

NOTE The stiffener is usually a moulded device, sometimes reinforced, depending on the required duty, applied over the umbilical. It is sometimes referred to as a bend strain reliever (BSR).

##### 3.1.6

##### **bird-caging**

phenomenon whereby armour wires locally rearrange with an increase and/or decrease in pitch-circle diameter as a result of accumulated axial and radial stresses in the armour layer(s)

##### 3.1.7

##### **bundle**

laid-up functional components and associated fillers in the umbilical prior to further processing

NOTE Typical functional components in a bundle include hoses, tubes, electric cables, optical fibre cables.

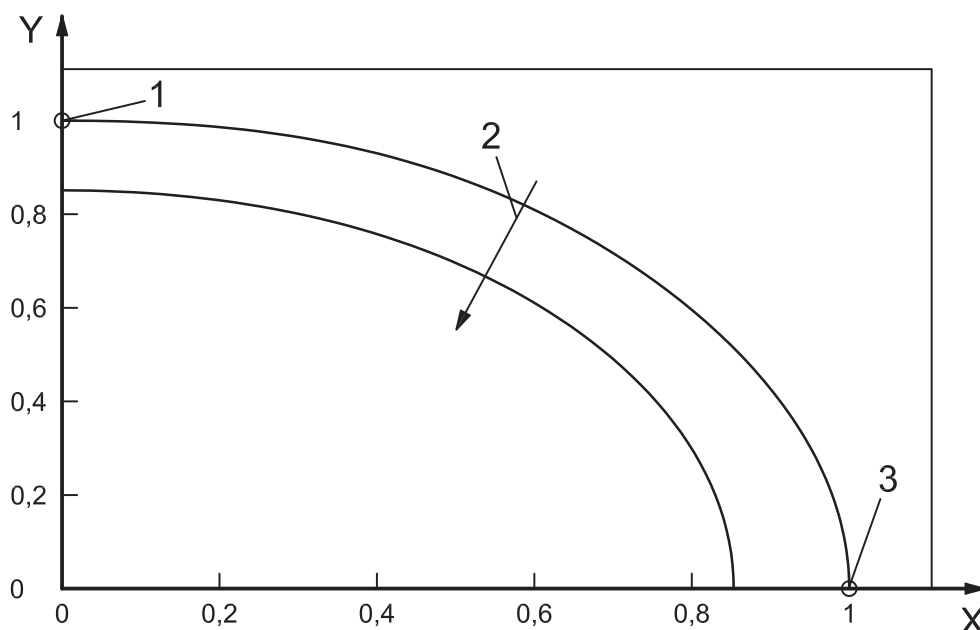
### 3.1.8

#### capacity curve

curve that defines the relationship between the allowable bend radius and allowable tension for an internal pressure condition

See Figure 1.

NOTE Curves can, therefore, differ for storage, testing, installation and operation scenarios.



#### Key

- X inverse of the normalized bend radius, MBR per radius
- Y normalized allowable tensile load, tension per MTL
- 1 maximum tensile load (MTL) with no bending
- 2 increasing pressure and/or increasing safety level
- 3 inverse of minimum bend radius (MBR) with no tension

NOTE 1 Increasing the level of safety generally increases the allowable bend radius and decreases the allowable tensile load, i.e. moves the capacity curves towards origin.

NOTE 2 Increasing the internal pressure generally increases the allowable bend radius and decreases the allowable tensile load, i.e. moves the capacity curves towards origin.

Figure 1 — Capacity curves

### 3.1.9

#### **carousel**

storage container that can be rotated by a drive about a vertical axis

### 3.1.10

#### **caterpillar**

device that holds the umbilical between belts or pads and which transfers axial linear motive power to the umbilical

NOTE A caterpillar is also known as an in-line cable engine, or haul off, or tensioner.

### 3.1.11

#### **characterization data**

data relating to a component or an umbilical giving an indication of performance but not giving specific acceptance/rejection criteria

### 3.1.12

#### **chinese finger**

type of gripper used to hold the umbilical via its outer diameter, comprised of a number of spirally interwoven wires or synthetic rope attached to a built-in anchorage arrangement

### 3.1.13

#### **core**

generic term used to describe an individual electrically insulated conductor

### 3.1.14

#### **crab lay**

installation deployment activity whereby the installation vessel moves sideways along, or at the end of, the installation route

### 3.1.15

#### **crushing load**

load that acts in the radial direction that might not be evenly distributed along the circumference and that is limited in length along the umbilical

NOTE A crushing load is typically induced during installation.

### 3.1.16

#### **deep water**

water depth generally ranging from 610 m (2 000 ft) to 1 830 m (6 000 ft)

### 3.1.17

#### **design life**

service life multiplied by an appropriate factor that is equal to, or greater than, one

### 3.1.18

#### **design working pressure**

##### **DWP**

maximum working pressure at which a hose or tube is rated for continuous operation

### 3.1.19

#### **design tensile load**

maximum tensile load multiplied by an appropriate factor that is equal to, or less than, one

### 3.1.20

#### **end termination**

mechanical fitting that is attached to the end of an umbilical and that provides a means of transferring installation and operating loads, fluid and electrical services to a mating assembly mounted on the subsea facility or surface facility

### 3.1.21

#### **factory acceptance test**

series of tests carried out on the completed umbilical component or complete umbilical to demonstrate the integrity of the item under test

### 3.1.22

#### **filler**

item wholly or partially filling the voids between the **functional components** (3.1.23) with the purpose(s) of maintaining the relative location of the components, maintaining the shape of the cross-section, influencing the weight-to-diameter ratio, separating components for wear considerations, or providing a certain radial stiffness

### 3.1.23

#### **functional component**

hoses, tubes, electric/optical fibre cables included within an umbilical which are required to fulfil the operational service needs

### 3.1.24

#### **functional specification**

document that specifies the totality of needs expressed by features, characteristics, process conditions, boundaries and exclusions defining the performance of a product or service including quality assurance requirements

### 3.1.25

#### **host facility**

fixed or floating facility to which the umbilical is mechanically and functionally connected and that provides the functions and services transmitted through the umbilical

EXAMPLES Platform, buoy, floating production system.

### 3.1.26

#### **hydrogen scavenger**

gel material applied inside the tube (metal or polymer) holding the optical fibre to absorb hydrogen ions that prevent fibre from “darkening” and from reducing transmission capabilities

### 3.1.27

#### **independent verification agent**

party or group independent from the manufacturer and the purchaser

### 3.1.28

#### **lay-up**

operation of helically assembling (SZ where appropriate) electrical cores or optical fibres into a cable, or hoses, tubes, electric cables, optical fibre cables into a bundle or sub-bundle

NOTE Sometimes referred to as “cabling”.

### 3.1.29

#### **lay angle**

angle between the axis of a spiral-wound element (e.g. armour wires) and a line parallel to the longitudinal axis of the umbilical

### 3.1.30

#### **load-out**

transfer of an umbilical or umbilical system from a storage facility onto an installation/shipping vessel, either by transfer spooling or by lifting the product stored on its installation/shipping reel

### **3.1.31**

#### **manufacturer's written specification**

specification for the umbilical, the umbilical components and their manufacture, generated by the manufacturer in compliance with requirements specified by the purchaser and this part of ISO 13628

NOTE The specification may be comprised of a multiplicity of documents (design plan, inspection and test plan, test procedures, etc.).

### **3.1.32**

#### **maximum tensile load**

maximum tensile load that an umbilical, with zero curvature, can withstand without infringing the stress criterion or suffering loss of performance

See Figure 1, and 3.1.8.

### **3.1.33**

#### **messenger wire**

device installed or pre-fitted into an I-tube or J-tube for transferring the primary pulling device, usually a wire rope, into the tube to provide means of pulling an umbilical through the tube

### **3.1.34**

#### **minimum bend radius**

minimum radius to which an umbilical, at zero tensile load, can be bent to without infringing the stress criterion or suffering loss of performance

See Figure 1 and 3.1.8.

### **3.1.35**

#### **multi-coupler**

multi-way connector arrangement comprised of two mating stabplate sub-assemblies, one of which is made of a number of hydraulic and/or electric and/or optical coupler halves, each carrying a separate service, that mate simultaneously with corresponding coupler halves on the other sub-assembly when the two sub-assemblies are brought together

### **3.1.36**

#### **pull-in head**

device used for terminating the end of an umbilical so that it can be loaded/offloaded from a vessel and pulled along the seabed and/or through an I-tube or J-tube

NOTE In some designs, the terminated armours can be used to anchor the umbilical at the top of the I-tube or J-tube. It normally is comprised of a streamlined cylindrical housing into which the umbilical armouring is terminated and within which the ends of the functional components are contained. It is usually capable of rapid disassembly to access the components for post-pull-in tests and monitoring. A form of pull-in head may also be used at the subsea end of the umbilical.

### **3.1.37**

#### **reel**

device for storing, transporting, or installing umbilicals or components comprised of two flanges, separated by a barrel, with the barrel axis normally being horizontal

NOTE Reels are designed for the intended use.

### **3.1.38**

#### **service life**

specified time during which the umbilical system shall be capable of meeting the functional requirements

### **3.1.39**

#### **S-N data**

data obtained by plotting cyclic stress level versus number of cycles to failure

### **3.1.40**

#### **splice**

join together component lengths or sub-components to achieve the required production length

### **3.1.41**

#### **static application**

application for which the load effect(s) due to dynamic loads (e.g. wave action, induced vibrations, etc.) when installed can be neglected

NOTE Free spans, in an otherwise static umbilical, should be considered as a dynamic application.

### **3.1.42**

#### **subsea termination interface**

mechanism that forms the transition between the umbilical and the subsea termination

NOTE The interface is comprised typically of an umbilical armour termination and/or a mechanical anchoring device for the tubes, bend stiffener/limiter, and tube or hose-end fittings. If the umbilical contains electric cables/fibre optics, then penetrator(s) and/or connectors may also be incorporated.

### **3.1.43**

#### **subsea umbilical termination**

mechanism for mechanically, electrically, optically and/or hydraulically connecting an umbilical or jumper bundle to a subsea system

### **3.1.44**

#### **tensile armour**

structural layer consisting of e.g. steel wires, fibre reinforced plastic rods, etc. that is used to sustain tensile loads in the umbilical

NOTE For some applications, the tensile armour may also have the additional function of providing additional weight and/or impact protection.

### **3.1.45**

#### **ultimate tensile load**

load at which the weakest component of the umbilical bundle fails when the load is applied with the umbilical in a straight condition

### **3.1.46**

#### **ultra-deep water**

term used to imply depths exceeding 1 830 m (6 000 ft), which can necessitate the consideration of design and/or technology alternatives

### **3.1.47**

#### **umbilical**

group of functional components, such as electric cables, optical fibre cables, hoses, and tubes, laid up or bundled together or in combination with each other, that generally provides hydraulics, fluid injection, power and/or communication services

NOTE Other elements or armouring may be included for strength, protection, or weight considerations.

### **3.1.48**

#### **umbilical joint**

means of joining together two lengths of umbilical to effect a repair or to achieve the required production length

### **3.1.49**

#### **umbilical system**

umbilical, complete with end terminations and other ancillary equipment

### 3.1.50

#### **unaged representative sample**

non-degraded sample of umbilical, or component that has not previously been subjected to operational or installation loadings, stresses, elevated temperature, and/or other conditions that can degrade the sample

EXAMPLES      Electric cables, hoses, tubes and optical fibres.

### 3.1.51

#### **verification test**

test performed to qualify the design and manufacture of the item for its use in service as well as to provide characterization data

### 3.1.52

#### **weak link**

device that is used to ensure that the umbilical parts or severs at a specified load and location

## 3.2 Abbreviated terms

|      |                                                                         |
|------|-------------------------------------------------------------------------|
| AC   | alternating current                                                     |
| AVE  | apparent volumetric expansion                                           |
| CP   | corrosion protection                                                    |
| DC   | direct current                                                          |
| DWP  | design working pressure (mathematical symbol: $p_{DW}$ )                |
| FAT  | factory acceptance test                                                 |
| FD   | frequency domain                                                        |
| FE   | finite element                                                          |
| FEM  | finite element modelling                                                |
| ID   | inside diameter (mathematical symbol: $d$ )                             |
| LTD  | linearized time domain                                                  |
| MBR  | minimum bending radius at zero tensile load                             |
| MTL  | maximum tensile load                                                    |
| NDE  | non-destructive examination                                             |
| NTD  | nonlinear time domain                                                   |
| OD   | outside diameter (mathematical symbol: $D$ )                            |
| OTDR | optical time-domain reflectometer                                       |
| PMI  | portable metal identification                                           |
| PRE  | pitting resistance equivalent                                           |
| RAO  | response amplitude operator                                             |
| ROV  | remotely operated vehicle                                               |
| SF   | safety factor                                                           |
| SMYS | specified minimum yield strength (mathematical symbol: $\sigma_{SMY}$ ) |
| TDR  | time-domain reflectometry                                               |
| TVE  | true volumetric expansion                                               |
| UT   | ultrasonic testing                                                      |
| UV   | ultra-violet                                                            |
| VIV  | vortex-induced vibration                                                |
| WT   | wall thickness (mathematical symbol: $t$ )                              |

## 4 Functional requirements

### 4.1 General requirements

#### 4.1.1 Umbilical

The umbilical, and its constituent components, shall have the following characteristics:

- a) be capable of withstanding specified design loads and load combinations and perform its function for the specified design life;
- b) be capable of storage and operation at the specified temperatures during the design life;
- c) be composed of materials compatible with the environment to which they are exposed, including permeating fluids, and in conformance with the corrosion control and compatibility requirements;
- d) have electric cables capable of transmitting power and signals with the required characteristics;
- e) have optical fibres capable of transmitting signals at the required wavelengths within the attenuation specified;
- f) have hoses and/or tubes capable of conveying fluids at the required flow rate, pressure, temperature and cleanliness levels;
- g) be capable of venting, in a controlled manner, if permeation through components can occur;
- h) be capable of being installed, recovered and reinstalled as defined in the manufacturer's written specification.

#### 4.1.2 End terminations and ancillary equipment

End-termination interfaces with the umbilical components are a critical area and should be addressed during the design review stage.

End terminations and ancillary equipment shall, as a minimum, meet the same functional requirements as the umbilical. If applicable, the following shall be demonstrated.

- a) The end termination shall provide a structural interface between the umbilical and the support structure.
- b) The end termination can provide a structural interface between the umbilical and bend restrictor/bend stiffener device.
- c) The end termination shall not downgrade the service life of the umbilical or the system performance below the functional requirements.
- d) CP shall meet the design life requirement.
- e) Contingency or planned recovery of the end termination to the surface during installation shall not downgrade the service life or system performance of the umbilical.
- f) The materials in the end terminations shall be compatible with any specified fluids with which they come into contact (including potential permeation).

## 4.2 Project-specific requirements

The purchaser shall specify the functional requirements for the umbilical.

Functional requirements neither specifically required nor specified by the purchaser but which can affect the design, materials, manufacturing, testing, installation and operation of the umbilical shall be specified by the manufacturer. If the purchaser does not specify a requirement and its absence does not affect any of these activities, the manufacturer may assume there is no requirement.

NOTE Annex A provides a basis for such specifications.

## 5 Safety, design and testing philosophy

### 5.1 Application

Clause 5 applies to umbilical systems, including umbilicals, terminations and auxiliary equipment that are built in accordance with this part of ISO 13628.

### 5.2 Safety objective

An overall safety objective shall be established, planned and implemented covering all phases from conceptual development until retrieval or abandonment.

All companies have policy regarding human aspects and environment issues. These are typically on an overall level, but more detailed objectives and requirements in specific areas can follow them. These policies should be used as a basis for defining the safety objective for a specified umbilical system.

### 5.3 Systematic review

A systematic review or analysis shall be carried out for all phases (e.g. manufacture, load-out, installation and operation) in order to identify and evaluate the consequences of single failures and series of failures in the umbilical, such that necessary remedial measures can be taken. The consequences include consequences of such events for people, for the environment and for the entire subsea system and financial interests.

The operator shall determine the extent of risk assessments and the risk assessment methods, and it should be the operator's responsibility to perform the systematic review.

### 5.4 Fundamental requirements

#### 5.4.1 General

The following fundamental requirements apply.

- The materials and products shall be used as specified in this part of ISO 13628 or in the relevant material or product specification.
- Adequate supervision and quality control shall be provided during manufacture and fabrication.
- Manufacture, fabrication, handling, transportation and operation shall be carried out by personnel having the appropriate skill and experience. Reference is made to recognized standards for personnel qualifications.
- The umbilical shall be adequately maintained including inspection and preservation when applicable.

- The umbilical shall be operated in accordance with the design basis and the installation and operating manuals.
- Design reviews shall be carried out where all contributing and affected disciplines (professional sectors) are included to identify and solve any problems.
- Verification shall be performed to check compliance with provisions contained herein in addition to purchaser requirements and national and international regulations. The extent of the verification and the verification method in the various phases, including design and fabrication, shall be agreed with the purchaser. As a minimum, the manufacturer shall issue an inspection and test plan with planned surveillance and QC and shall issue this to the purchaser. The inspection and test plan shall include plans for sub-supplier and sub-contractor activities when applicable.
- Relevant information between personnel involved in the design, manufacture, fabrication, installation and operation shall be communicated in a clear manner to avoid misunderstandings.

#### 5.4.2 Quality assurance

Equipment manufactured in accordance with this part of ISO 13628 shall conform to a certified quality assurance program. The manufacturer shall develop written specifications that describe how the quality assurance program will be implemented.

### 5.5 Design philosophy

#### 5.5.1 Design principles

The umbilical system shall be designed according to the following basic principles.

- The umbilical system shall satisfy functional and operational requirements as given in the design basis.
- The umbilical system shall be designed such that an unintended event does not escalate into an accident of significantly greater extent than the original event.
- The umbilical system shall permit simple and reliable installation, retrieval and be robust with respect to use.
- The umbilical system shall provide adequate access for replacement and repair.
- Design of structural details and selection of materials shall address the effects of corrosion, ageing, erosion and wear.
- A conservative design approach shall be applied for the umbilical mechanical components. Redundancy may be considered for essential components.

#### 5.5.2 Design basis

A design basis document shall be established in the initial stages of the design process. The design basis should contain or reference all relevant information required for design of the umbilical system. The design basis normally includes

- specifications supplied by the purchaser as specified in Annex A (e.g. functional requirements, field data, host data);
- procedures for load-effect analyses for the umbilical and associated components; see Annex F; and
- load-case matrices, as specified in Annex A (e.g. temporary conditions, installation, extreme conditions, fatigue conditions).

### **5.5.3 Design methodology**

#### **5.5.3.1 General**

The design methodology shall include, as a minimum, the following.

- a) A description of the theoretical basis, including calculation procedures and methods for evaluating the umbilical design parameters and the criteria that it is necessary to satisfy in order to meet the functional requirements shall be included.
- b) Documentation of the fatigue life and extreme stress assessment methodology shall be provided.
- c) Verification shall be provided of the theoretical basis via verification or qualification tests on component samples and on samples of the complete umbilical as specified in 5.6 and Annex B. The testing or documentation shall include the capacity of all umbilical structural components.
- d) Simplified conservative analysis methods for checking of non-critical components, such as anti-wear layers, shall be acceptable if the method does not influence the reliability of the calculation of stresses in the other components.
- e) The documented basis for the effect of internal friction on stresses and the basis for stress concentration factors to account for the geometry of metallic structural components, including stress concentrations at and within the end-termination interface, clamped accessories, contact with rigid surfaces, manufacturing tolerances, and load-induced gaps shall be documented.
- f) Manufacturing and design tolerances, manufacturing-induced stresses, internal friction, welds and other effects that influence structural capacity shall be provided.
- g) The design methodology shall clearly state the range and application limits to which it applies.

The design methodology shall account for the effects of wear, corrosion, fretting, manufacturing processes, installation loads, dimensional changes, creep and ageing (due to mechanical, chemical and thermal degradation) in all layers, unless the umbilical design is documented to not suffer from such effects.

If the umbilical design is outside the envelope of previously qualified designs, then the manufacturer shall perform qualification tests to test the design methodology for this new design. The qualification tests shall validate fitness-for-purpose for those design parameters that are outside the previously validated envelope. The requirements on when qualification testing shall be performed are stated in 5.6.

For steel structural parts of the end termination, recognized standards, such as BS 5950, EN 10027 and EN 10025, or equivalent shall apply.

#### **5.5.3.2 Independent agent verification**

If required by purchaser, an independent verification party should review, evaluate, and report on the design methodology to establish the range of applications for which it is suitable.

### **5.6 Testing**

#### **5.6.1 General**

All tests specified in this part of ISO 13628 can be sorted into three categories: qualification, verification and acceptance testing. The selection of test methodology shall be agreed between the purchaser and manufacturer and shall account for the risks involved in the intended application and the practicality of the test programme in relation to the project schedule.

Guidance on the responsibility of identifying the need for qualification testing is given in A.2.9.

### 5.6.2 Qualification testing

Qualification testing are tests performed on a prototype component or prototype umbilical to prove that it can withstand the environment and/or loads for which it is designed and that it has the properties that it is predicted to have. It is not necessarily performed only on new designs or components, but a testing philosophy is chosen based on the purchaser's risk profile and the manufacturer's design/testing statistics. Choosing this testing philosophy reflects high project risk or low purchaser risk willingness. See also A.2.9.

For umbilicals and/or components which represent new technology or high risk, qualification testing should be performed according to a structured methodology as defined in the manufacturer's written specification, DNV RP-A203 or equivalent.

NOTE DNV RP-A203 (September 2001) defines proven and new technology as follows. Proven technology (definition): in the field, proven technology has a documented track record for a defined environment. Such documentation shall provide confidence in the technology from practical operations, with respect to the ability of the technology to meet the specified requirements. New technology (definition): new technology is technology that is not proven. This implies that the application of proven technology in a new environment or an unproven technology in a known environment, are both new technology. The degree of new technology can be classified in categories to be used as input to risk assessments (see DNV RP-A203).

It is the responsibility of the manufacturer to document the track record for, and to identify the need for, qualification testing. The evaluation of existing data and the extent of qualification testing shall be approved by the purchaser.

The above implies that qualification testing should be carried out in cases where no relevant track record or test data exist for the umbilical design, component and/or environment in question.

Whenever a new component is used and the properties of this component affect the global properties of the umbilical, qualification testing of the umbilical, and not only the individual component, shall be carried out.

Analysis may be used to compare umbilical and component designs and to judge the relevance of data from previous testing and operation experience. Such analysis shall be carried out according to the requirements of this part of ISO 13628; see Clause 6.

Unless otherwise agreed, all qualification testing shall be performed prior to manufacture of the umbilical.

Qualification testing should also be considered for the end terminations and midline connectors and ancillary equipment, if applicable.

### 5.6.3 Verification testing

Verification tests performed on an umbilical component, or a production length of umbilical, are designed to determine conformance with specified design requirements, or predicted properties.

Verification tests shall include end terminations and midline connectors and ancillary equipment.

### 5.6.4 Acceptance testing

Acceptance testing is testing performed to ensure that the umbilical or components meet the design values/criteria specified by the purchaser and stated in the design basis, i.e. to ensure that the sample subjected to verification testing is representative for the manufactured components. Acceptance testing includes testing performed on the actual delivery component or umbilical, e.g. tests that are performed to document that a welded tube string can withstand the test pressure over a defined time period, or to verify that an electrical/optical signal element has the characteristics it is designed to have. These tests are normally performed several times per product. Required acceptance tests for common components are outlined in Annex B.

Acceptance tests shall also be carried out for the end terminations and midline connectors and ancillary equipment.

## 6 Design requirements

### 6.1 General

The umbilical and its constituent components shall be designed to meet the functional and technical requirements of this part of ISO 13628. The requirement for analysis shall result from a risk evaluation for the umbilical. The factors that shall be considered are, amongst others, the environmental and service conditions for the umbilical and the consequences of non-performance.

Fatigue analyses shall include fatigue at operating temperature, a prediction of load cycles and translation of load cycles into nominal stress or strain cycles. The load cycles shall include reeling, handling, construction, installation, unplanned events such as partial recovery and reinstallation, as stated in the design basis.

The effect of mean stresses, internal (service) and external (environmental) plastic pre-strain and rate of cyclic loading shall be considered when determining fatigue resistance.

Assessment of fatigue resistance may be based on either S-N data obtained on representative components or a fracture mechanics fatigue-life assessment. The selection of safety factors shall take into account the inherent sensitivity in fatigue-resistance predictions for such designs.

Account shall be taken of the effect of the strain accumulated during manufacturing, handling and installation on the umbilical fatigue performance.

Guidance on fatigue testing is given in Annex E.

### 6.2 Loads

#### 6.2.1 Load classification

Loads are classified as functional, environmental (external) or accidental, and defined as follows.

- a) Functional loads are all loads acting on the umbilical during manufacture, installation and operation, including those loads that can act on the umbilical in still water, with the exception of wind, wave or current loads.
- b) Environmental loads are those loads induced by external forces caused directly or indirectly by all environmental parameters acting on the umbilical, including those induced by waves, currents and vessel motion.
- c) Accidental loads are those loads caused directly or indirectly by unplanned activities. Accidental loads shall be understood as loads to which the umbilical can be subjected in case of abnormal conditions, incorrect operation or technical failure as defined by purchaser.

#### 6.2.2 Functional loads

The functional loads of relevance for the actual umbilical system shall be identified. Examples of functional loads are

- a) loads due to weight and buoyancy of the umbilical, its contents and attachments, both temporary and permanent;
- b) marine growth based on information for the actual geographical location;
- c) pressure within hoses and tubes;
- d) thermal loads resulting from radiant heat, hot injected gas/fluids, or from adjacent hot riser(s);

- e) external hydrostatic pressure;
- f) testing pressures, including installation, commissioning and storage pressures;
- g) external soil or rock reaction forces for trenched, buried or rock-dumped umbilicals;
- h) static reaction and deformation loads from supports and protection structures;
- i) temporary installation or recovery loads, including applied tension and crushing loads, impact loads and guidance induced loads;
- j) displacements due to pressure- and tension-induced rotation;
- k) interaction effects of clamping the umbilical;
- l) loads due to rigid or flexible pipe crossings, or spans;
- m) loads due to positioning tolerances during installation;
- n) loads from inspection and maintenance tools.

### 6.2.3 Environmental loads

The environmental loads of relevance for the actual geographical location shall be identified. Examples of environmental loads are

- a) waves;
- b) current;
- c) wave-frequency host motions;
- d) low-frequency host motions due to wave drift and wind loading and station-keeping system characteristics;
- e) vortex-induced host motions due to current loading;
- f) host offset from nominal position due to environmental loading;
- g) ice;
- h) earthquake;
- i) subsea landslides.

### 6.2.4 Accidental loads

The accidental-load scenarios of relevance for the actual umbilical system shall be identified. Examples of accidental loads are

- a) dropped objects;
- b) trawl-board impact;
- c) anchor-line failure;
- d) fire and explosion;

- e) compartment damage or unintended flooding of support vessel or other buoyancy device (e.g. subsea arch structure);
- f) loss of buoyancy modules in lazy-wave umbilical configuration;
- g) failure of thrusters;
- h) dynamic-positioning failure
- i) net external pressure (due to flooding, crushing, incorrect installation rate, etc.);
- j) net internal pressure;
- k) failure of turret drive system.

### **6.2.5 Load combinations and conditions**

#### **6.2.5.1 General**

The umbilical shall be designed to withstand the most onerous load combinations of functional, environmental and accidental loads selected from the extreme design and fatigue environment specified by the purchaser. The load combination selection shall cover all relevant loading conditions that can be applied to the umbilical during factory-acceptance testing, installation, operation and any temporary condition specified by the purchaser as defined in Annex A. Variation of the loads with respect to time shall be addressed.

#### **6.2.5.2 Extreme load combinations**

The extreme load combinations shall reflect the most probable extreme combined load effect over a specified design time period. Extreme load combinations shall be defined for permanent as well as temporary design conditions as follows.

- a) Normal operation: This applies to the permanent operational state of the umbilical, considering functional and environmental loads. Design conditions with a  $10^{-2}$  annual exceedence probability (i.e. 100 year return period) shall be applied.
- b) Abnormal operation: This applies to the permanent operational state of the umbilical considering functional, environmental and accidental loads. Combined design conditions with an annual exceedence probability between  $10^{-2}$  and  $10^{-4}$  shall be considered.
- c) Temporary conditions: This applies to temporary conditions, such as installation, retrieval, pressure testing and other intermediate conditions prior to permanent operation, e.g. temporary in-field configurations prior to platform tie-in of umbilicals in dynamic service or burial of static umbilicals. The applicable return period for the design conditions depends on the seasonal timing and duration of the temporary period. The return periods shall be defined such that the probability of exceedence in the temporary state is no greater than that of the permanent normal operational state.

Accidental loads in terms of frequency of occurrence and magnitude should be determined based on risk analyses and relevant accumulated experiences. Account shall be taken of other loads that can reasonably be present at the time of the accidental event. Further, accidental loads shall be determined with due account of the factors of influence. Such factors may be personnel qualifications, operational procedures, the arrangement of the installation, equipment, safety systems and control procedures. Combined design conditions with an annual exceedence probability higher than  $10^{-2}$  should be considered as normal operation. Load combinations with an annual exceedence probability lower than  $10^{-4}$  may normally be ignored.

Recommended load combinations for assessment of the extreme-load effect are summarized in Table 1.

**Table 1 — Load combinations**

| Load type     | Temporary conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Normal operation                           | Abnormal operation                                                                                                                                                                                                                                   |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Functional    | Expected, specified or extreme                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Expected, specified or extreme             | Expected, specified or extreme                                                                                                                                                                                                                       |
| Environmental | <p>Probability of exceedence according to season and duration of the temporary period.</p> <p>If more information is not available, the following return period values may be applied for temporary conditions:</p> <p>a 100 year return period if duration in excess of 6 months;</p> <p>a 10 year return period for the actual seasonal environmental condition if duration is in excess of 3 days but less than 6 months.</p> <p>For temporary conditions with a duration less than 3 days or operations that can be terminated within a 3 day window, an extreme load condition may be specified and start-up /shut down of the operation is then based on reliable weather forecasts.</p> | Annual exceedence probability of $10^{-2}$ | <p>Annual exceedence probability of <math>10^{-2}</math> to <math>10^{-4}</math></p> <p>If combined with accidental loads, the environmental load may be established so that the combined annual exceedence probability is <math>10^{-4}</math>.</p> |
| Accidental    | As appropriate to the actual temporary condition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Not applicable                             | Individual considerations. Annual exceedence probability $\geq 10^{-4}$ .                                                                                                                                                                            |

### 6.2.5.3 Fatigue load conditions

Fatigue damage shall be calculated considering all relevant cyclic loading imposed on the umbilical over its design life covering fabrication, temporary conditions including installation as well as in-place operation. Consideration shall be given to the long-term probabilistic nature of the fatigue loading. The following principal sources of fatigue damage shall be evaluated:

- wave-frequency response of the umbilical due to direct wave loading as well as wave induced (first-order) host motions;
- slow drift (second-order) host motions including variation of mean position;
- VIV response of the umbilical under steady current conditions;
- possible VIV motions of the host hull where applicable (typically spar platforms);
- cyclic loading during fabrication and installation, e.g. reeling/unreeling;
- cyclic loading due to operation of the umbilical, e.g. variation in temperature and pressure.

The interfaces to the supporting rigid structures are normally the most critical locations for fatigue loading on in-place dynamic umbilicals operated from a floating host. The fatigue performance of the umbilical is in most situations governed by the bend limiting devices installed at the rigid supports, e.g. bend stiffener or bellmouth.

Consideration shall be given to the long-term operation/performance of the host/station-keeping system, e.g. variation of loading conditions/draft, change in mooring pretension, change in restoring due to additional riser

tie-ins, re-location, connected/disconnected operational mode for loading systems, etc. Conservative assumptions shall be made in case of lack of precise information.

Average values may be applied for functional loading unless more precise information is available regarding the long-term variation of functional loading.

Calculation of fatigue stresses shall address wear/corrosion.

Calculation of fatigue stresses should, unless more precise information is available, be based on nominal component dimensions minus half the corrosion/wear allowance. In a uniform thickness degradation environment, this corresponds to the average wall thickness over the umbilical service life.

## **6.3 Load effect analysis**

### **6.3.1 General**

The manufacturer shall, as part of the design evaluations, consider the results of any installation, dynamic service and structural analysis that might have been carried out in relation to the umbilical design. The output of the analyses shall be used to demonstrate that the umbilical is suitable for installation and will remain fit for service during its design life.

The analysis results shall be verified either during qualification or verification testing. In lieu of physical testing of the components/umbilical, representative historical data may be offered by the manufacturer to verify the models or calculations used; see Clause 5.

All load-effect analyses shall be based on accepted physical/numerical principles for modelling of the umbilical response in all relevant static- and dynamic-loading scenarios. All of the software tools used for the umbilical global and local analysis should be

- verified against closed-form analytical solutions;
- verified by a range of simulations or by an independent verification agent that the generic model/software tool is internally consistent and that it does not contain detectable flaws; and
- calibrated against full-scale tests by means of manipulating the independent variables of the software model to obtain a match between the observed and simulated distributions of the dependent variables.

The validity range of the calibration shall be documented.

The accuracy/validity range of the software should be specified based on a correlation to observed values from the physical testing (full scale/model tests).

The manufacturer shall demonstrate to the purchaser supporting verification, validation and confirmation documentation for all global and local analysis tools, including those developed in-house, used for the umbilical analysis and design.

The main types of load-effect analyses in Table 2 may be required, depending on the actual concept.

**Table 2 — Load-effect analysis**

| Type of analysis             | Description                                                                                                                                        | Main application                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Global analysis              | Static- and dynamic-load effect analysis due to static and dynamic environmental loading (current, waves and host offset/motions)                  | Extreme-load analyses of umbilicals in dynamic service<br>Fatigue-load analyses of umbilicals in dynamic service<br>Analyses of installation scenarios to establish limiting criteria for the operations                                                                                                                                                                                                                                                                                                                                                                                          |
| On-bottom stability analyses | Analyses to assess the displacement of on-bottom umbilicals exposed to functional and environmental loading                                        | Stability analysis of umbilicals in static service<br>Stability analysis of laying operations<br>Stability analysis of on-bottom part of umbilicals in dynamic service                                                                                                                                                                                                                                                                                                                                                                                                                            |
| VIV analyses                 | Analysis of VIV in steady current                                                                                                                  | Fatigue analyses of umbilicals in dynamic service<br>Fatigue analyses of umbilicals during installation operations<br>Assessment of requirement for VIV suppression devices<br>Considered as a sensitivity assessment of the effect on drag coefficients for application to global analyses and interference analyses where these analyses are critical                                                                                                                                                                                                                                           |
| Interference analyses        | Analysis to determine minimum distance or contact loads/forces between adjacent structures exposed to static and dynamic environmental loading     | Assessment of minimum distance to neighbouring risers, umbilicals and mooring lines; applies to in-place analyses of umbilicals in dynamic service as well as installation scenarios                                                                                                                                                                                                                                                                                                                                                                                                              |
| Free-spanning analyses       | Analysis of VIV of free spans in steady current and establish product curvature                                                                    | Fatigue analyses of free spans of umbilicals in static service                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Pull-in analyses             | Analysis of pull-in installation operations                                                                                                        | Analysis of I/J tube pull-in operations of umbilicals in dynamic/static service                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Installation analysis        | Analyses to establish the lay limits of installation operations and to assess and compare the variables for all planned and contingency operations | Assessment of allowable environmental criteria for first-end initiation, initial lay, normal lay, curve lay, second-end approach, second-end installation; either end may be a subsea termination, an I/J tube pull-in operation or a landfall approach<br>Assessment that planned handling routes and loads are within manufacturer's recommendations or limitations (combinations of bend radius, contact force, tension, squeeze load from caterpillar, internal pressure)<br>Analysis of the installation scenario and comparison with assumptions used for the calculation of fatigue damage |
| Structural analyses          | Establish loads and/or load sharing between the components of the umbilical cross-section                                                          | Establish combined tension/curvature capacity for the umbilical cross-section (basis for global capacity checks)<br>Establish stress/strain in individual components of the umbilical cross-section for a given tension/curvature combination (basis for, e.g., fatigue analyses)<br>Establish cross-sectional stiffness (bending, axial, torsional) for application to global analyses<br>Analyses of installation scenarios to establish limiting criteria for the operations (e.g., assessment of load effects due to crushing loads from caterpillars)                                        |

### **6.3.2 Global load-effect analysis**

The purpose of global load-effect analyses is to describe the overall static and dynamic structural response of the umbilical. The global analyses shall be based on accepted principles of static and dynamics analysis, with the use of discrete modelling, strength of materials, environmental loading and soil mechanics to determine reliable load effects on the umbilical system. Global load-effect analyses should be based on numerical simulations by means of FE, or similar, analyses with due regard to the following issues.

- The global response model shall include the complete umbilical system considering accurate modelling of stiffness, mass, damping and hydrodynamic load effects along the umbilical in addition to top and bottom boundary conditions.
- Appropriate drag and inertia coefficients for the selected method shall be applied. Effects of marine growth shall be considered. Recognized principles shall be applied to assess possible drag magnification due to VIV.
- The global cross-sectional properties shall be representative of the stiffness and damping properties of the actual umbilical cross-section.
- The umbilical shall be modelled with a sufficient number of elements to represent environmental loading and structural response and to resolve load effects in all critical areas. Time and/or frequency discretization shall be verified to ensure that the desired accuracy is obtained. The principles for model validation as outlined in Annex F, Appendix F of DNV OS-F201, or equivalent may be applied.
- Sensitivity studies should be considered to investigate the influence of uncertain system parameters (e.g. soil data, hydrodynamic coefficients, marine growth, structural damping and stiffness, host draft, current modelling in fatigue analysis, etc.). The main purpose is to quantify model uncertainties, support rational conservative assumptions and identify areas where a more thorough investigation is needed.
- Any use of simplified modelling and/or analysis techniques shall be verified by more advanced modelling and/or analyses for representative (critical) load cases.

For further details, reference can be made to Annex F.

### **6.3.3 On bottom stability analysis**

The umbilical shall be designed to be sufficiently stable, when laid on the seabed, to meet the requirements of Clause 4. The need for additional ballast and impact on other installation activities shall be evaluated, if required.

DNV RP-F109 is an example of a standard suitable for assessing the lateral stability of umbilicals exposed to current and wave loading.

### **6.3.4 Pull-out analysis**

Routing of the umbilicals on the seabed often requires that static service umbilicals are arranged in a predefined, curved configuration. Pull-out analyses shall be performed to document that the geometry of curved on-bottom sections of the umbilical remains stable for the maximum apparent effective tension in the umbilical. It shall be documented that the axial and sideways soil resistance is sufficient to support the tension in a curved, on-bottom configuration. Static analyses using analytical expressions for the holding capacity of straight and curved umbilical sections as given in DNV RP-F109 should be applied. Sensitivity studies shall be performed to support rational, conservative assumptions for the governing parameters (e.g. soil friction coefficients and submerged weight).

Pull-out analyses shall be performed to assess the capacity of the seabed portion of an in-place dynamic service umbilical system, in terms of its ability to absorb the bottom tension generated by the dynamic part of the umbilical system. Pull-out analyses shall also be conducted to document the stability of curved sections during lay installations.

### 6.3.5 Vortex-induced vibration analysis

The effect of vortex-induced vibration (VIV) shall be considered for all umbilicals exposed to current and/or waves. For cases where VIV is likely to represent a design problem, refined assessment according to the methods outlined in this subclause is required. The requirement for qualification testing shall be assessed in accordance with 5.6.

In most cases the focus of this assessment is to evaluate whether the fatigue capacity is sufficient. Accordingly, a simplified conservative VIV analysis suffices if the resulting fatigue damage is within the tolerated limit. If the simplified analysis indicates insufficient fatigue capacity, more sophisticated methods should be chosen. The method should be chosen according to the specific case investigated.

Important parameters for VIV response are cross-sectional diameter, mass, damping, bending stiffness and effective tension. Mass ratio, reduced damping and number of natural frequencies within the bandwidth of the vortex shedding frequency can be important for a determination of lock-in behaviour and VIV amplitude.

Methodology for the prediction of fatigue damage due to VIV on other slender elements such as pipelines and risers may be applied with special attention to umbilical-specific properties. In particular, cross-sectional stiffness and damping properties shall be selected to represent the umbilical VIV (typically small amplitude) response. VIV analyses are in most cases carried out using a modal approach. The eigenmodes/eigenfrequencies applied in such analyses shall reflect the physical umbilical configuration (i.e. geometrical configuration, tension, boundary conditions, etc.). The number of modes shall be sufficient to determine the umbilical response at the highest VIV frequency. For further guidance on VIV analysis methodology, reference can be made to ANSI/API RP 2RD, DNV RP-F204, or other recognized industry standards.

The increase in the drag coefficient due to cross-flow VIV for application in global response analyses may be estimated in accordance with DNV RP-F203.

If vortex-suppression devices are used for the mitigation of VIV, their efficiency shall be qualified. In most cases, vortex-suppression devices increase the in-line drag of the umbilical. This shall be accounted for in other design analyses, such as global load-effect analyses.

### 6.3.6 Interference analysis

The system design shall include a check of possible interference with other adjacent structures (e.g. host hull, mooring lines, risers, umbilicals or any other obstacles). Critical loading conditions are normally governed by extreme current events. The interference assessment shall include relevant installation scenarios. Normal operation as well as accidental scenarios shall be considered for the in-place condition.

Interference analysis requires information on the entire host/umbilical/riser/mooring system and it is the purchaser's responsibility to provide the required information; the responsibility to carry out the analysis is defined in Annex A; see Table A.2.

The basic design strategy should be that no impact with other structures is allowed. In this case, interference analyses shall document sufficient spacing between the umbilical and adjacent structures for all critical-load cases. Due regard shall be given to hydrodynamic interaction in terms of wake effects on the downstream configuration (i.e. reduced drag force and non-zero lift force as function of distance from upstream configuration). Effects from possible VIV on the drag coefficients for the upstream and downstream configurations shall be evaluated and implemented in a conservative way supported by sensitivity studies.

The minimum clearance between two adjacent slender structures should be greater than  $D_1 + D_2$ , where  $D_1$  and  $D_2$  are the outer diameters of the slender structures.

Umbilicals in dynamic service operated from hosts are normally placed close to other dynamic structures such as risers. The static and dynamic response characteristics of the adjacent slender structures should be as similar as possible to avoid interference. This may be accomplished, to some extent, by assigning a common target value for the weight-diameter ratio for the adjacent slender structures. The weight-diameter ratio is defined as  $\gamma = W/D$ , where  $W$  is the submerged weight per unit length and  $D$  is the outer diameter. It should be noted that the weight-diameter ratio can be significantly influenced by variable functional loading due to, for

example, marine growth and the internal fluid content of risers. Sensitivity studies shall be performed to support assumptions regarding functional loading for application in interference analyses.

Account shall be taken of installation tolerances and length manufacturing tolerances.

The same basis for selection of drag coefficients shall be applied for umbilicals and neighbouring risers that can interfere with each other. It is the responsibility of the purchaser to ensure that there is sufficient distance in instances where neighbouring risers are delivered by different manufacturers.

The interference analyses are essentially global load-effect analyses with due regard to the modelling of hydrodynamic interaction. Industry standards, such as outlined in DNV RP-F203 or equivalent should be adhered to. Hydrodynamic interaction models for new applications (e.g. different diameters of the adjacent structures, VIV-suppression devices, etc.) shall be validated on the basis of physical testing.

An alternative design strategy that may be applied is to allow for structural impact in the most extreme load conditions. In this case, it shall be documented that the structural integrity is not endangered due to impact loads. Wear fatigue and extreme impact load shall be considered.

The engineering efforts required to qualify an umbilical system for structural impact is hence substantially more demanding compared to that for a no-impact design criterion. Load-effect models to account for structural impact should be validated with basis in physical testing.

Structural impact should be avoided in the buoyancy section of wave-type configurations.

#### **6.3.7 Free spanning analysis**

As-laid umbilicals on the seabed can suffer VIV in a steady bottom current under span-length and tension combinations. For umbilicals at the seabed, reference is made to DNV RP F-105 or equivalent. Due consideration shall be made to the specific properties of the umbilical. In particular, empirical equations for natural frequencies and unit amplitude stress levels are not directly applicable to umbilicals. FE analysis should be applied for determination of eigen modes with due regard to boundary conditions and multi-span scenarios.

Umbilicals are normally more tension-dominated than pipelines due to the low bending stiffness. Effective as-laid tension is, hence, important for the prediction of participating modes. The uncertainty in the tension can be large, causing large uncertainties in the VIV fatigue-damage prediction. Sensitivity studies shall be performed to support rational, conservative assumptions.

#### **6.3.8 Pull-in analyses**

The purpose of a pull-in analysis is to provide an estimate of the required pulling force for the installation of the umbilical in I- and J-tubes or other supporting structures. The pull-in analysis should in general be comprised of

- an estimation of the friction force due to the weight of the umbilical;
- an estimation of the friction force due to the bends around corners, if relevant;
- an estimation of the required pulling force due to bending of the umbilical, if relevant;
- an estimation of reverse pull-in analysis for contingency scenarios or for future removal and/or abandonment.

Pull-in analyses may be conducted by means of conservative analytical formulas or by FE-based computer analyses.

Analytical expressions can be found in literature for the friction force due to weight, due to pulling around corners and due to bending (e.g. the equation for bending around corners is given in DNV RP-E305). The contributions from friction forces and bending of the umbilical should be added together in a conservative manner.

Computer analyses by use of general purpose FE code should be applied in the case of complex pull-in scenarios. Such analyses should be performed as non-linear static analyses. The load application shall represent the actual pull-in scenario. Due regard shall be given to the modelling of constraints and contact forces from the supporting structure (e.g. bend geometry with appropriate friction-force modelling). A contact formulation is required in order to estimate the friction force and, accordingly, the required pulling force.

### **6.3.9 Structural analysis**

#### **6.3.9.1 General**

The purpose of the structural analysis is to establish a design for the umbilical and its constituent components that shall be capable of withstanding the design loads and conditions envisaged during manufacture, load-out, recovery, repair, installation and also for the operational conditions throughout the design life.

Details relating to structural analyses of umbilical components are provided within 7.2 to 7.5 for individual component design.

The structural analysis includes a description of the load-sharing between components in the cross-section to determine the stresses and strains in each component and to establish the stiffness parameters required for global analyses. The results from structural analyses can be grouped into the following main categories:

- capacity curves in terms of tension versus curvature at a specific pressure, if applicable;
- assessment of maximum allowable crushing loads;
- stresses and strains used for fatigue calculations;
- cross-sectional stiffness parameters for application as input to global load effect analyses.

The structural analysis should be based on accepted principles of structural mechanics and strength of materials and may be based on empirical, analytical or numerical (FE) methods that are qualified by structural testing. See Clause F.3 for an overview of the fatigue-analysis strategies.

Maximum allowable stress/strain and usage factor for each component (tube, electric cable, strength member, sheath, etc.) in the installation, in the in-place pressure test and in the operation phase shall be clearly indicated and justified by the manufacturer.

#### **6.3.9.2 Modelling and analysis requirements**

The analysis shall demonstrate and justify that the structural and functional materials used within the umbilical system are designed to satisfy the application requirements of the material throughout the umbilical design life. This shall be performed using recognized standards and applicable factors of safety if they are available.

The following shall be considered:

- a) deterioration of material properties and degradation as a result of ageing throughout the service life;
- b) materials selection, including corrosion of metallic elements, cathodic attack and delamination of bonded elements;
- c) fatigue of structural and functional components (e.g. metallic tubes, armour wires, copper conductor, fillers, bend stiffeners, polymers);

- d) contact pressure and friction among different umbilical components;
- e) effects of environmental conditions, (for example UV radiation, temperature, ozone and long-term exposure to seawater and permeated fluids);
- f) cumulative effects of strain of copper conductors, armour wires, metallic tubes and fibres throughout the manufacturing processes, handling, and installation operations;
- g) strain of optical fibres;
- h) assessment of lateral deformations and stress/strain of the individual components due to crushing loads during storage and installation.

The load effects in the umbilical cross-section may be documented by qualification or verification testing. Numerical methods may also be used to predict local stresses. If numerical analysis is used, the analysis results may be qualified as described in Clause 5 and F.3.

Design formulas are related to the specific umbilical design and may be validated for those specific designs by strain-gauge results from prototype tests. Justification for extrapolation of results shall be documented. When considering the use of analytical methods, the actual load situation in the umbilical shall be considered, especially with regard to combined loading.

Models for structural analysis should be capable of describing the load sharing between each component of the cross-section based on evaluating the stiffness contribution from each component.

The load-sharing analysis shall be based on nominal dimensions. It is necessary to take dimensional tolerances, including effects from corrosion and wear, into account in the stress and fatigue analysis.

Tolerances shall be considered in wall-thickness sizing of steel tubes.

The internal frictional resistance resulting from internal contact forces shall be applied to calculate the friction stresses that are added to the elastic axial and bending stresses in fatigue and extreme stress calculations. Sensitivity studies should be conducted on the internal friction factor as part of the fatigue analysis.

**NOTE 1** Friction can influence the global damping and stiffness behaviour and it is, therefore, necessary to consider it in global dynamic analyses.

In cases where fretting and wear due to a combination of internal contact forces, metal-to-metal contact and relative deformations can occur, it is necessary to take this into account as part of the fatigue calculation.

It is necessary to give special attention to the terminations of dynamic umbilicals in operation. Due to high bending gradients, end effects can occur due to the helically layered umbilical structure. It is necessary to evaluate or document by testing (qualification or verification testing according to Clause 5) the stress amplification due to this effect. This governs for both extreme stress and fatigue evaluations.

**NOTE 2** For standard service-life tests of dynamic umbilicals, the umbilical components are normally terminated by end fittings providing axial fixation. Provided that the length of the specimen is shorter than the real length from the dynamically curved section to the end termination, such tests are normally conservative with respect to end effects. To avoid such conservatism, validated 3D structural analysis models can be used to adjust the test program to simulate the real loading conditions.

## **6.4 Installation analysis**

All transport, load transfer, lifting, subsea operations shall be performed according to company requirements, DNV Rules for Planning and Execution of Marine Operations or other equivalent standard.

Installation analysis shall demonstrate that suitable installation equipment (tensioners, pads, chutes, etc.) and procedures will be used to install the umbilical without risk of damage. In particular, load transfer, friction between umbilical components, crushing resistance and friction between umbilical and pads shall be evaluated and accounted for in the installation analysis.

In addition, a recovery analysis shall be performed. Conditions of recovery shall be identified. The analysis shall be conducted in the same way as for the installation analysis. The utilization factors identical to those for the installation case shall be taken.

## **6.5 Fatigue life**

The umbilical shall be designed with fatigue life that is equal to, or greater than 10 times the service life. The service life is determined on a project-specific basis.

Qualification or verification testing can be considered necessary to confirm that the manufacturer's design methodology, analysis methodologies and software tools are mature and accurate for the prediction of fatigue damage and fatigue life.

## **7 Component design, manufacture and test**

### **7.1 General**

#### **7.1.1 Design verification**

The umbilical components shall be designed and manufactured to meet the umbilical functional and technical requirements. Conformance shall be demonstrated by verification and acceptance testing.

For new component designs that are similar to previously verified designs and whose performance can be predicted with a high level of confidence, design verification tests may be included with some or all of the component FATs. For unusual designs or designs significantly different from previously verified designs, design verification testing shall be undertaken as a separate program.

If the component design is similar to a previously validated design and the umbilical is being installed under similar environmental and service conditions, design verification may be substituted by previous historical design verification data.

The performance of verification and acceptance tests shall also be considered for the end terminations and midline connectors and ancillary equipment, if applicable.

**NOTE** Verification and acceptance tests that it is necessary to perform during and on completion of component manufacture specified in this subclause are summarized in Annex B.

#### **7.1.2 Quality plan**

Before production commences, the manufacturer shall prepare a quality plan. The quality plan shall demonstrate how the specified properties can be achieved and verified through the proposed manufacturing route. The quality plan shall address all factors that influence the quality and reliability of production. All main manufacturing steps from control of received raw material to shipment of the finished product, including all examination and check points, should be covered in detail. References to the procedures established for the execution of all steps shall be included. The quality plan shall be approved by the purchaser and shall, as a minimum, contain the following information:

- plan(s) and process flow description/diagram;
- project-specific quality plan;
- manufacturing process;
- manufacturer(s) of functional components and any supplier quality plans;
- handling, loading and shipping procedures.

### 7.1.3 Materials selection

The choice of the materials shall be made with a consideration of the following:

- a) installed environment;
- b) installed duty;
- c) processability;
- d) in-service repair;
- e) degradation related to the seawater environment and service fluids.

NOTE The EEMUA publication No. 194 includes guidance on materials selection for umbilicals and subsea equipment.

## 7.2 Electric cables

### 7.2.1 General

Electric cables shall be capable of continuous operation with the insulated conductors operating in a fully flooded seawater environment.

The design of the electric cables shall recognize that the cables may be terminated in some form of water blocking arrangement(s), which shall function throughout the design life.

### 7.2.2 Operating voltages

The following definitions shall be used.

- a)  $U_0$  is the rated power-frequency voltage between conductor and earth or metallic screen, for which the cable is designed;
- b)  $U$  is the rated power-frequency voltage between conductors, for which the cable is designed;
- c)  $U_m$  is the maximum value of the "highest system voltage" for which the equipment may be used; see IEC 60038.

The standard voltage ratings shall be as described in IEC 60502-1 and IEC 60502-2, such as 0,6/1 (1,2) kV, 1,8/3 (3,6) kV and 3,6/6 (7,2) kV.

Whether a cable is intended for a power or signal application shall be defined in the purchaser's functional specification.

This definition shall be used to identify which type of tests and conditions normally apply as described.

In the event cables are used for "Signal on Power", then both sets of conditions apply.

### 7.2.3 Power cables

Power-cable voltage ratings shall be selected up to the standard rated voltages  $U_0/U(U_m) = 3,6/6 (7,2)$  KV rms, where  $U_0$ ,  $U$  and  $U_m$  are as defined in IEC 60502-1 and IEC 60502-2.

#### 7.2.4 Signal cables

Signal cables shall be designed to transmit electrical control and communication signals in the voltage range 0 V rms to  $U_0/U(U_m) = 0,6/1(1,2)$  kV rms, where  $U_0$ ,  $U$  and  $U_m$  are as defined in IEC 60502-1 and IEC 60502-2.

#### 7.2.5 Construction

##### 7.2.5.1 General

Various cable constructions are acceptable for use in a subsea umbilical, however the chosen design shall be verified according to requirements defined in Clause 4.

Cables shall be manufactured in accordance with the manufacturer's written specification.

Some cables may include screening and/or armouring depending on intended service or for other reasons.

Electric cores and cables should be manufactured as continuous lengths.

If splices are necessary to achieve the final length requirements, these shall be carried out in accordance with the qualified procedures by qualified personnel specified in the manufacturer's written specification. Splices shall also be subject to the same qualification and acceptance criteria as the insulated conductors and cables.

In a multi-core cable, the construction shall ensure that the cores can be readily separated for termination purposes and do not adhere or do not bond to the sheath, fillers, binder tape or adjacent cores.

As cable cores are, in many cases, sealed by boot-seal methods, the surface of the insulation shall be round, smooth and free from marks, indentations and surface defects that can affect sealing.

On a design-specific basis, consideration shall be given to conductor-strain relief due to compressive and tensile forces and the potential for damaging crushing forces that can arise in the laid-up components, particularly for deepwater service.

Designs shall take into consideration the effects and mitigation of gas migration in electric cables.

##### 7.2.5.2 Construction material

Electric-cable construction materials (such as insulation, fillers, sheathing, etc.) shall be oil/dielectric-fluid-resistant in order to avoid deterioration of their electrical and physical properties if terminations/connectors are of the pressure-compensated type that normally uses electrical or hydraulic oil/dielectric fluid as an equalizing fluid.

##### 7.2.5.3 Conductor

The conductors shall be fabricated from high-conductivity copper wire and shall comply with the relevant conductivity and material requirements of IEC 60228. The conductors shall be manufactured from annealed circular copper wire.

If stranded, each conductor shall be comprised of a minimum of seven strands. The minimum nominal cross-sectional area shall be 2,5 mm<sup>2</sup> (0,004 in<sup>2</sup>). The nominal cross-sectional area for the conductor shall meet the functional requirements of Clause 4. The relationship between conductor size, strand count and stiffness should be considered.

#### **7.2.5.4 Insulation**

The insulation material shall be suitable for immersion in seawater.

The chosen insulation material shall be of virgin stock applied as a continuous seamless circular single/multiple extrusion and shall meet the requirements of IEC 60502-1 and IEC 60502-2.

Materials that have been used successfully, e.g. thermoplastic polyethylene and various grades of ethylene propylene rubber, may be used. These materials shall keep their insulating properties for the full service life and be proven to keep the required mechanical properties under the actual temperature and pressure conditions. During the material selection process, consideration shall be given to the operating temperature.

The minimum allowable insulation thickness shall be stated in the manufacturer's written specification.

Depending on voltage rating, insulation material and thickness, non-metallic conductor and insulation screening may be required, as specified in IEC 60502-1 and IEC 60502-2.

#### **7.2.5.5 Insulation coding**

The insulated conductors shall be identified either by colour or by numbers. If numbers are employed, these shall be printed at regular intervals not exceeding 100 mm (4,0 in) along the length of each core. The numbers and/or colours employed shall be cited in the manufacturer's written specification.

Coding shall be stable under heat ageing and shall not cause a failure to satisfy the requirements of Clause 4.

Embossed printing is not permitted.

#### **7.2.5.6 Core lay-up**

The process of twisting individual cores shall be qualified for the specific application.

If an alternative lay-up technique is used, then it shall be qualified for the service.

For an intermediate lay-up operation, the cabled cores may be bound with a helically applied overlapping tape to ensure bundle stability and a circular cross-section.

The lay-up operation shall minimize compressive forces between the cores to minimize the extent of deformation of the insulation.

#### **7.2.5.7 Fillers**

To achieve a circular consolidated arrangement, fillers or extruded filling shall be included in the interstices. Any filler and binder tape materials shall be compatible with other materials in the cable. In particular, the effect on electrical insulation shall be considered. The materials shall be as stated in the manufacturer's written specification. The binder tape can be longitudinally applied or helically applied depending on whether or not a screen is applied.

#### **7.2.5.8 Screening**

If required, the cable shall be screened with a suitable metallic tape, or a two-component tape comprised of a thin metallic film, bonded to a polymer-based substrate. The thickness and number of layers shall be as stated in the manufacturer's written specification. The screen shall be electrically continuous throughout the cable length, and should be applied in such a manner that its electrical continuity shall not be broken throughout its design life.

Plain metal tape screens, for electric cables or individual power cores, shall provide 100 % coverage of the enclosed electrical cores. They shall be applied helically with an overlap. The screen shall not be applied directly over the twisted cores without due consideration for the cores beneath.