Umbilical Termination Assembly (UTA) Selection and Sizing Recommendations

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Introduction

General

This document was compiled by the UMSIRE Joint Industry Project (JIP) group with the aim of addressing the increasing difficulties in installation of high-functionality subsea umbilical terminations (SUTs). The document focuses on highlighting the implications of increasing size and weight on installation. The JIP committee was composed of a representative cross section of experienced industry personnel from umbilical and umbilical termination assembly (UTA) manufacturers, installation contractors, and operators. UTA is a subassembly of SUT.

While there are widely accepted codes and standards for the design of UTA and its subsystems, such as materials, core connector type, tubing specification, corrosion protection, and lifting arrangements, none of these standards specifically address the substantially increased risks incurred during packing, handling, and installing umbilicals with large UTAs.

The JIP deliverables are two API documents, API Technical Report 17TR9, *Umbilical Termination Assembly (UTA) Selection and Sizing Recommendations*, and API Technical Report 17TR10, *Subsea Umbilical Termination (SUT) Design Recommendations*.

NOTE API 17TR10 deals in more depth with umbilical and UTA installation and the differing style and restrictions of installation lay spread types.

Use of the Document

This document is intended to be used as a reference guide by end users and operators, UTA and umbilical manufacturers, installers, and front-end engineering design (FEED) companies. The intention is that the document will enable the currently inherent installation difficulties to be addressed up front by the UTA designers, prior to commencing SUT design and functionality definition. It is also intended to be used as a reference document to enable reviews to be undertaken to ensure that installation risk has been properly considered as part of SUT design and operations reviews on a case-by-case basis.

This document assumes that the reader has a good level of understanding of the design, engineering, and installation of UTAs and other related components. API 17TR10 may be referred to for educational purposes and for additional technical information on UTAs. API 17TR10 can also be referred to for understanding and highlighting installation vessel and lay-spread restrictions that are compounded if unnecessary dimension and weight increases are made without a full awareness of these areas.

Applicability

In recent years, the size and complexity of umbilical terminations have grown considerably, driven by increasing umbilical functionality and additional flexibility and redundancy capability, as well as the need to integrate with functions found on subsea SUTs, manifolds, wellheads, subsea trees, booster pumps, etc. Due to some of the existing lay spreads and their long service life, the equipment has been unable to keep pace with these UTA changes. It also appears that the difficulties and increased risk implications incurred during installation of excessively large UTAs are not given due consideration during early planning stages. Historically, in some cases, the design has been such that the UTA cannot be easily deployed when connected to the umbilical by conventional installation methods.

This emerging trend poses severe challenges to installers and appears to be compounded by the increased functionality and higher expectations of parties in the supply chain (FEED contractors, termination designers, operators, and manufacturers). This trend has led to occurrences where the SUT cannot be installed through conventional lay equipment, which results in the necessity for higher specification lay spreads and vessels and proportionately increased risk to personnel, equipment, schedule, and overall impact on the project cost.

Without full consideration of these collective impacts, this trend of higher functionality and proportionately larger UTAs is expected to continue.

It is acknowledged that having a separate subsea distribution unit (SDU) may have an impact on the overall cost. However, the costs of the UTA/SDU alone is not the deciding factor in increasing the UTA proportions and weight to achieve an all-encompassing single UTA. Further analysis is undertaken for the whole life cycle of the UTA, which may include the following:

— packing, transporting, and increased installation costs of the larger unit in conjunction with a risk analysis;

— assessment of the aforementioned factors with detailed examination of the increased risks in offshore handling, deployment, and lay-down on the seabed.

This final UTA design approval may be made following close scrutiny of these analyses and assessments.

API 17TR9 applies during all stages of UTA concept selection, design, and installation.

Be aware that integration of distribution leads typically leads to increase in size of the UTA; however, it is required in some cases (e.g. integrated umbilical termination and distribution units) and can be a valid technical solution for smaller developments. Wherever it is required, the size of the UTA should the kept within the category sizes detailed within this document. For the purpose of this document, it is assumed that the termination does not provide distribution.

Umbilical Termination Assembly (UTA)
Selection and Sizing Recommendations

1 Scope

This technical report identifies and describes:

— technical, commercial, and installation risks associated with high-functionality umbilicals and umbilical terminations [resulting in large and heavy umbilical termination assemblies (UTAs)], especially with respect to installation;

— implications of decisions made early in the umbilical and subsea umbilical termination (SUT) planning, selection, and design phases, to ease the manufacturing, handling, and final umbilical/UTA installation;

— guidance on specification and sizing of umbilical terminations, including overall size, weight, and handling requirements.

This document is intended to aid with informed decision making and selection of optimal choices during the early design phase of field development.

The primary purpose of this document is to be a reference guide during the early field development planning stage to ensure that due consideration is given to the implications of the size of UTAs and possible consequences during installation.

Guidelines for the design of UTAs are included in API 17TR10.

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.

API Specification 17E, *Specification for Subsea Umbilicals*, Fourth Edition, October 2010

API Technical Report 17TR10, *Subsea Umbilical Termination (SUT) Design Recommendations*

ASME/ANSI B16.5, *Pipe Flanges and Flanged Fittings: NPS ½ through NPS 24 Metric/Inch Standard*

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

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

3.1.1
bend restrictor
(Definition as per API 17E.)

Device for limiting the bend radius of the umbilical by mechanical means (*from API 17E*).

NOTE 1 The definition of bend restrictor and bend stiffener are very similar; the two terms are commonly used in the industry and hence have been defined separately.

NOTE 2 A bend restrictor is typically composed of a series of interlocking metallic or molded rings, applied over the umbilical. It is sometimes referred to as a bend strain reliever (BSR) or bend limiter.

3.1.2
bend stiffener
bend strain reliever
Device for controlling bending strain in the umbilical by providing a localized increase in stiffness; usually a molded device, sometimes reinforced depending on the required duty, applied over the umbilical.

NOTE 1 The stiffener is usually a molded device, sometimes reinforced, depending on the required duty, applied over the umbilical.

NOTE 2 This is sometimes referred to as a "*bend strain reliever*."

3.1.3
rigid length
Sum of the combined lengths of the UTA and subsea termination interface (STI) and any other component that increases the axial rigid length and cannot easily be removed or reinstalled offshore.

NOTE Further details are provided in 6.2.6 and Figure 5, Figure 6, and Figure 7.

3.1.4
subsea distribution unit
SDU
Separately installed structure that receives hydraulic and/or electric and/or optical functions from the UTA and distributes those functions to multiple locations such as manifolds or trees.

3.1.5
subsea termination interface
STI
Mechanism that forms the transition between the umbilical and the subsea termination (*from API 17E*).

NOTE The interface is composed typically of an umbilical armor 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/fiber optics, then penetrator(s) and/or connectors may also be incorporated.

3.1.6
subsea umbilical termination
SUT
Mechanism for mechanically, electrically, optically and/or hydraulically connecting an umbilical or jumper bundle to a subsea system (*from API 17E*).

NOTE Functional components within the umbilical may include hoses, tubes, and electrical or fiber-optic cables, as stated in API 17E.

3.1.7
umbilical
Group of functional components, such as electric cables, optical fiber 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 (*from API 17E*).

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

3.1.8
umbilical termination assembly
UTA
Mechanism for connecting an umbilical or jumper bundle to a subsea system, mechanically, electrically, optically, and hydraulically, as required.

3.1.9
UTA yoke

A frame attached to a UTA, typically at its sides, by hinged or swiveling joints and provided with a central attachment point for lifting rigging.

3.2 Acronyms, Abbreviations, and Symbols

ABR	allowable bend radius
BSR	bend strain reliever (bend stiffener)
CoG	center of gravity
FAT	factory acceptance test
FBC	free board clearance
FEED	front-end engineering design
FMEA	failure mode effects analysis
FTA	fault tree analysis
Hs	higher limiting sea state
HSE	health, safety, and environment
ID	inner diameter
JIP	Joint Industry Project
MBR	minimum bend radius
MQC	multiple quick connects
OD	outer diameter
NPS	nominal pipe size
RHD	reel hub drive
ROV	remotely operated vehicle
SDU	subsea distribution unit
SIT	systems integration test
STI	subsea termination interface
SUT	subsea umbilical termination
UMSIRE	umbilical termination size reduction
UTA	umbilical termination assembly
VLS	vertical lay system

4 Functionality and Distribution of Umbilicals

4.1 Umbilical Functionality

Functionality is generally limited by the actual umbilical specification rather than the UTA size.

The functionality versus umbilical limitations is evident very early in the umbilical design process. Once the final umbilical design specification is reached, then the design of the UTA must be fully optimized to minimize external dimensions and the overall weight of the UTA (including the STI and BSR/bend restrictor weights).

An important consideration to fulfill the requirements of this document (also see API 17TR10) is enabling precise routing of functions within the UTA by having well-designed cable and fluid core distribution routes.

4.2 Subsea Distribution Unit (SDU)

SDUs can substantially reduce the overall UTA dimensions by encompassing the distribution paths and outlet ports. It is acknowledged a separate SDU may have an impact on the overall manufacturing cost in order to connect the units together, but the additional design and manufacture costs of separate UTA and SDU arrangements should not be the sole reason for opting for an all-encompassing UTA. Factors such as complicated handling, packing, transporting, increased installation costs, elevated risk of installation damage, and possible replacement of an umbilical with subsequent schedule impact must be thoroughly analyzed and assessed to make an informed decision about the split or combined arrangement of UTA and SDU. These risks should be evaluated against the consequences associated with using a separate SDU arrangement, such as additional equipment lead time, additional installation time, and the risk of additional subsea leak paths.

The application of this document should be from the inception of the umbilical manufacturer's initial design. Subsequently, the UTA designers should interface closely with highly experienced installation engineers who know installation possibilities, lay spread, and vessel specifications. Figure 1 shows the optimum interfacing of relevant parties who will play a part in achieving a successful umbilical/UTA installation project.

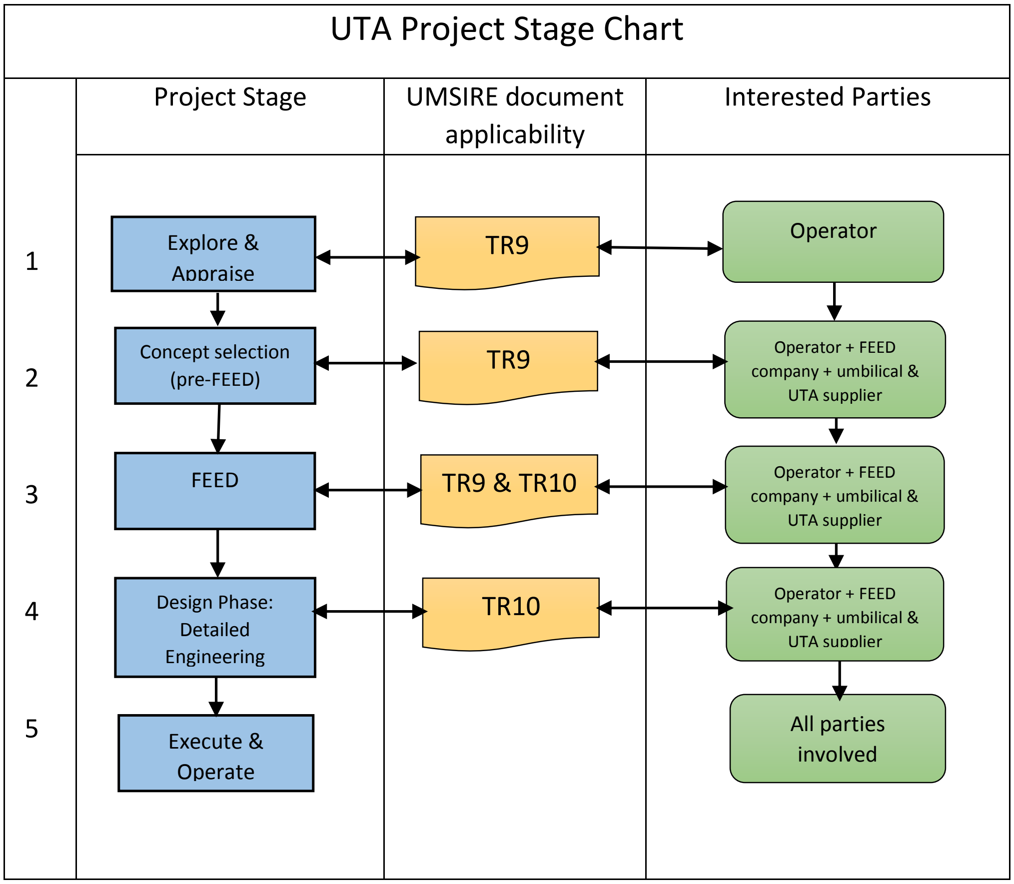
The intent with describing these project stages is to clarify when within the umbilical project timeline each umbilical termination size reduction (UMSIRE) document should be referenced and the interested parties that should be involved in discussions during each stage.

5 Drivers for UTA Size

5.1 General

The trend of increasing functionality of topside, subsea, and downhole equipment over the past decade has created increasing requirements for additional fluid, electrical, and optical lines to be routed from the platform to the subsea equipment. This has resulted in a greater number of functionalities required through control umbilicals and consequently the UTAs.

There is competition for space between umbilicals and production risers. If it is assumed that one large umbilical is more space efficient than multiple smaller umbilicals, then larger umbilicals are generally the best option.



NOTE Front-end engineering design (FEED) company includes subsea facility manufacturer.

Figure 1—Project Stage Chart

5.2 Pros and Cons of a Greater Functionality Umbilical/UTA

5.2.1 General

Although it is widely acknowledged that increased functionality, size, and weight of the UTA poses challenges with installation, there are several important drivers and advantages of using umbilicals/UTAs with greater functionality. If increased functionality is balanced correctly with consideration of installation requirements and potential difficulties, this may certainly outweigh the option with reduced functionality. This document and 17TR10 will support the design evaluation process by taking into account the pros and cons of having a higher-functionality UTA and result in a robust outcome with due consideration of risks versus costs.

5.2.2 Pros

The main advantages of a higher-functionality umbilical/UTA are as follows:

— more compact subsea field layout in otherwise congested areas where multiple umbilicals may result in additional complexity and higher risk;

— less vessel time requiring subsequent installs, fewer vessels used during mobilization, does not require second SDU for functionality, decrease number of flying leads;

— spare philosophy for future tie-in to new step-outs, which are in approved but deferred future field architecture;

— spare cores available during single installation for use in the case of core failure;

— better flexibility if additional sensor or fluid/chemical requirements are required;

— operational benefits.

5.2.3 Cons

The main disadvantages of a higher-functionality umbilical/UTA are as follows:

— higher possibility of umbilical damage if UTA is larger and heavier, e.g. the weight of the UTA can easily overbend the umbilical during installation;

— installation vessel specification;

— may need greater deck space due to increased minimum bend radius (MBR);

— deck cranes must be suitable and have sufficient hook height and reach to handle large and heavy UTAs;

— lay spread functions to handle the large UTAs may require redesign or substantial modification;

— closed tensioner systems will be unusable;

— flexibility in vessel choice not possible;

— schedule delay in waiting for vessel and lay spread availability;

— increased vessel cost.

5.3 Consequences

Increasing functions within an umbilical possibly due to the drivers identified above have consequences for the design, manufacturing, and most importantly the installation of resultantly large and heavy UTAs.

Figure 2 shows the consequence of increasing the size of UTAs (from Category A to Category D, as described in 8.3) on the overall risk and complexity of the installation operation and availability of suitable installation vessels, which can handle these units without damaging their incumbent umbilicals. A damaged or broken umbilical can delay field commissioning and the first oil or gas, a critical milestone of every project.

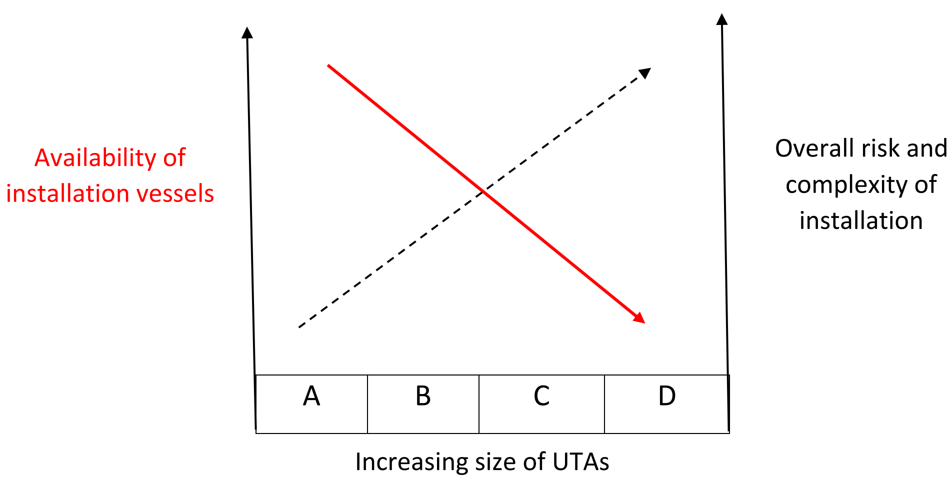


Figure 2—Consequence of Increasing Size of UTAs

Consequences in terms of design, schedule, and technical risks include the following, all of which can affect project cost.

— Design

  — Oversize terminations often require a bespoke solution.

  — Packing and handling the UTA on installation reels may no longer be possible where infield umbilicals have similar sized UTAs on both ends that will prevent turning of the reel (see Annex A).

  — A carousel equipped vessel or individual transportation of carousels only will require additional engineering activities and extensive mobilization and installation.

  — Handling and transportation difficulties.

— Schedule

  — Increase in lead time.

  — Longer fabrication and assembly.

  — Complex SIT/FAT.

  — Increase in vessel mobilization/demobilization and installation time.

  — Limited availability of suitable specification installation vessel.

— Technical risk

  — Together with terminations, bend stiffeners and bend restrictors have grown in size and weight.

  — Lack of clear definition of acceptable level of risk resulting in overengineering.

  — UTAs that are not designed with installation and overboarding restraint requirements.

  — Handling of heavy UTA connected to weak umbilicals, both onshore and offshore, which increases the probability of damage to the umbilical.

— HSE (health, safety, and environment)

  — The consequences due to increased size of umbilicals and UTAs can also be understood by an analytical method such as FTA (fault tree analysis) and/or FMEA (failure mode effects analysis). It is recommended to carry out such analysis on a project basis for getting a better understanding of the main risks, associated parameters, and potential consequences.

Increased size and weight of UTAs leads to handling difficulties, greater complexity of rigging arrangements, increased requirements for restraint against vessel motions and increased energy imparted by any accidental collisions. This has safety implications during loadout and lay of umbilicals, which involve the following operations:

— loadout from manufacturer’s facilities onshore;

— transpooling from one vessel to another;

— maneuvering through and into restricted spaces, e.g. underdeck carousels, deck openings, and tensioners;

— lifting to a considerable height and changing orientation to enter and pass through vertical lay system (VLS) towers.

5.4 Forward Planning

During field architecture concept definition and the design phase, consideration must be given for future expansion and limitations of the field and it is recommended to have provision for additional future J-tube slots for umbilicals.

Careful consideration of the number of umbilical functions required (including any functions in line with the project's sparing and possible expansion requirements) and the resultant installation feasibility should be made at every stage of the subsea production system design. Reducing the number of umbilical functions will reduce the size of the umbilical and UTA installation.

Reducing the size of the UTA is encouraged wherever practical.

UTAs can be installed and recovered independently of their support frame or SDU and incur simpler interface points with which to dock and engage the UTA onto the support/SDU. Multibore hubs can bring all the required functions to the SDU where the full function distribution and outlet ports are incorporated. If a SDU installation is selected, it can:

— enable a much simpler deployment of SDU and umbilical individually,

— alleviate complex handling,

— mitigate much of the installation/recovery and/or reinstallation risks.

It is important to note that a subsea arrangement utilizing a separate SDU may:

— increase the number of vessel mobilizations,

— require higher-specification installation equipment (e.g. crane),

— increase the number of flying leads.

6 Installation Systems

6.1 Installation Methods

There are several industry standard umbilical installation methods such as the following.

a) Horizontal lay tensioner and overboarding chute for low-tension installation.

b) Horizontal lay tensioner with vertical overboarding system for low-/medium-tension installation of umbilicals with ancillary components such as buoyancy modules, clamps, and bend restrictors.

c) Closed tensioner VLS for low-, medium-, or high-tension installations whether or not requiring additional ancillary item installations. These systems have limitations due to UTA having to pass through the closed tensioner aperture while ancillary items may be installed beneath the tensioner units.

d) Open tensioner VLS for low-/medium- or high-tension generally do not require additional ancillary items; however, every project needs to assess this requirement. These systems do have some advantages over closed tensioner systems due to UTA not having to pass through the closed tensioner aperture, potentially removing the need to remove ancillary equipment. The UTA can be lowered past the bottom of the tensioner unit prior to closing the tensioner tracks onto the umbilical. When passing the UTA/umbilical through the lay system, the MBR of the umbilical should not be compromised. Depending on the specific size of the assembly, installation technique, and the vessel used, additional lifting (crane, slings, spreader beam, etc.) or support lifting equipment may be needed.

e) Rigid pipe lay system (open or closed) used for installation of umbilicals, normally as part of rigid pipelay installation using large-diameter rigid pipe storage reel and near-vertical laying tower complete with opening tensioner units.

NOTE Regardless of the system used, the handling of the UTA over the umbilical deployment chute or VLS top arch is the activity with the highest likelihood of damaging the umbilical/UTA.

More detailed descriptions of the above installation methods are presented in API 17TR10. Figure 3 and Figure 4 show the typical operational sequence and geometric limitations of a VLS.

6.2 Vessel Implications and Consequences

6.2.1 General

The installation-related consequences of increasing UTA size are identified in Table 2. There may be additional consequences.

6.2.2 Water Depth

Water depth should not have a significant impact on the size of UTA; however, there will be some installation constraints, some of them are summarized as follows:

— the top tension will increase with a potential consequence to laying spread,

— the crane/winches involved will have to reach deeper and possibly will require higher capacity,

— the time to deploy and install the umbilical system is likely to increase.

The length of the umbilical increases with the increase in water depth, resulting in heavier loads imposed on the UTA frame. This will have an impact on the size of the interface between the umbilical and the UTA and components such as shackle and padeye. Consequently, this will result in increasing the size of STI. Special consideration must be given to the dynamic loading on the UTA during a second end installation.

6.2.3 Limiting Sea State Lay Spread Limitations and Consequences

A higher limiting sea state (Hs) gives increased flexibility in terms of schedule and planning, as well as less exposure to reduced weather windows.

A low limiting sea state may give constraints in installation methodology, risk of waiting on weather, risk to product during installation, etc.

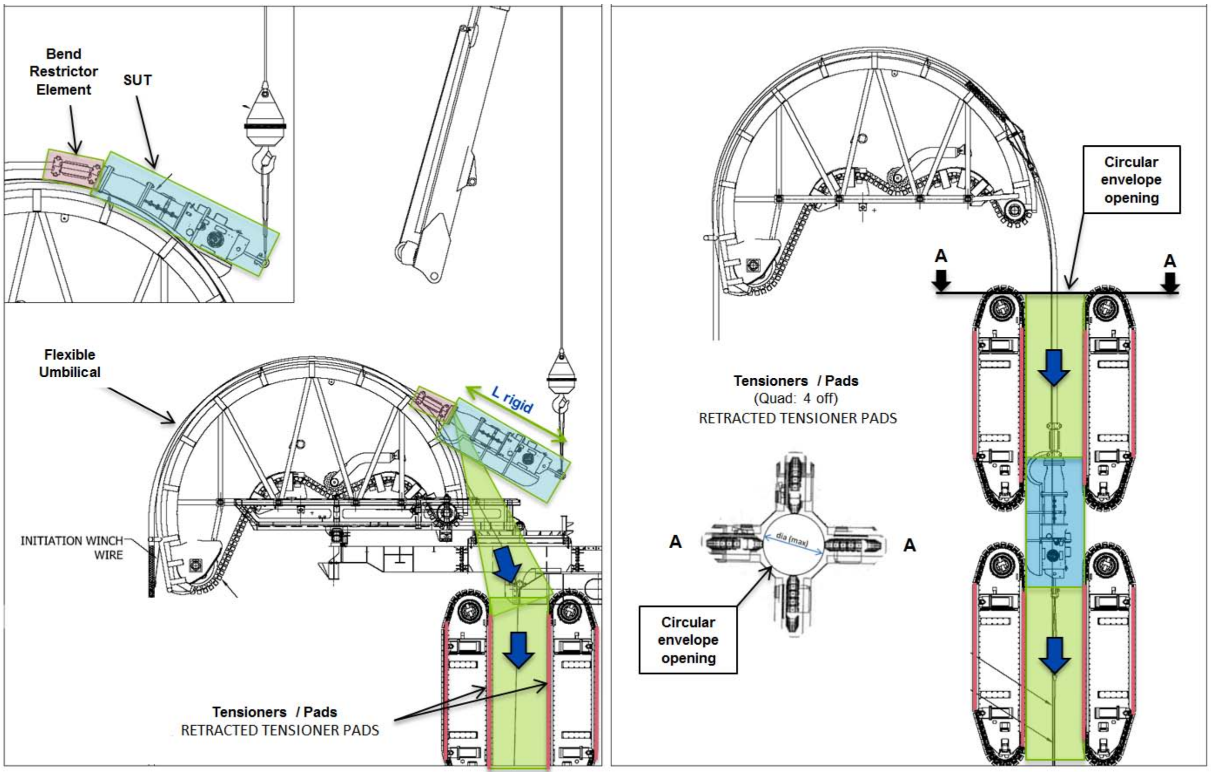


Figure 3—Vertical Lay Installation, First End

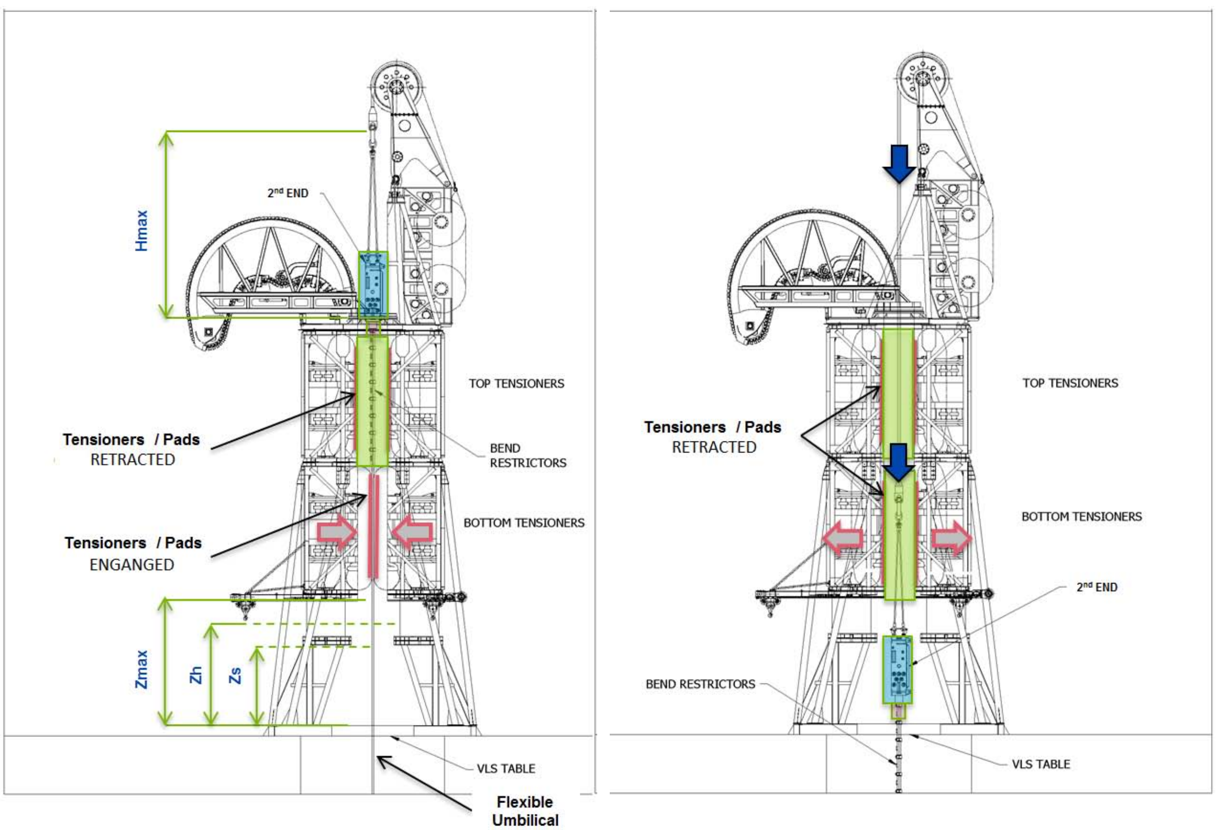


Figure 4—Vertical Lay Installation, Second End

6.2.4 Handling Restrictions

The factors in Table 1 should be considered during UTA design to best comply with handling constraints and difficulties experienced by installation contractors.

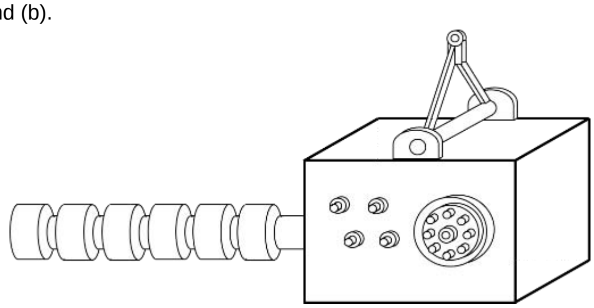
Table 1—SUT Design Factors

	Factor	Reasons for Importance
1	UTA width and height	— Ability for UTA to pass through closed tensioner units. — Ability to pass through deck openings in the case of vessels with beneath deck carousels. — Ability to stow both UTAs on installation reels and/or on carousels.
2	Handling points on UTA considering installation through the lay system and sea-fastening	— Lift points must consider handling on deck and handling the UTA during reel or carousel loading. — Restraining points during handling UTA over the top of in the case of VLS systems. — Lift and pulling points relevant to deploying through a horizontal tensioner lay system. — Due consideration to simplification of sea-fastening of the unit, e.g. its own support skid on deck and/or subsea. — Deck handling, lift planning, and lift rigging design. — Re-orientating the UTA when just above the seabed to horizontal position for docking (e.g. hinge-over docking probes). — Designer must take into account when designing lift and handling aids that in some cases, with lighter umbilicals and/or in heavier sea states, the installer may need to add pull-down weight to the front of UTA in order to stabilize the umbilical reactions in the water column and synchronize them with the lay spread rise and fall speed.
3	Weight and center of gravity of UTA	— Overboarding and landing operations. — It is greatly advantageous if the UTA can be suspended purely by the umbilical to avoid crane/winch support during deployment to depth, due to the UTA being outside of maximum dynamic linear tension capability of the umbilical. — An off-center CoG when suspended from the umbilical may result in excessive fatigue for the umbilical in a short length of time and result in use of crane/winch to counteract the impact of fatigue.
4	UTA total rigid length	— Ability to accommodate UTA on reels and on carousels. — Ability to lift UTA over VLS top and into the VLS.
5	UTA and umbilical structural design	— UTA and umbilical to be designed in conjunction with each other to withstand the loads imposed during handling and installation and to accommodate the flexibility for either direction of umbilical installation (i.e. first or second end UTA).
6	Umbilical length and weight	— UTA must be designed to withstand the loads imposed by the umbilical during handling and installation. — First and second ends (apart from umbilical risers with totally different end UTAs) must be design to withstand the forces they will be subject to during installation in both directions and recovery operations.
7	Design of UTA bend stiffeners and UTA yokes	— Ability to accommodate UTA and BSRs/lifting yokes on reels and/or on carousels. — Ability to lift UTA and BSRs/lifting yokes over arch and into VLS. — Suitable for preinstallation of BSRs/restrictors at manufacturer's premises or for subsequent installation on installation vessel permissible deck space. — Suitable for overboarding and seabed landing or preinstalled SDU docking operations. — Consideration needs to be given to second end installation. For example, the yoke needs to be designed in order for the vertical axis of the umbilical to be in line with the axis of the crane wire during deployment in the water column. This is required to mitigate excessive bending moment at the umbilical/UTA interface. — For the second end lay it shall be considered that the umbilical and related bend limiter can only take limited bending moments. UTA shall have lifting points in line with the umbilical for the vertical lift. The yoke may be designed to fulfil this application.

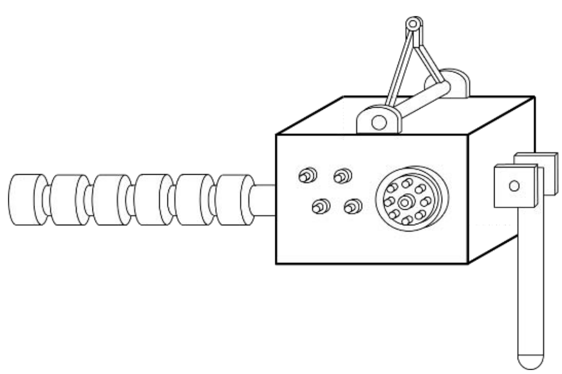
	Factor	Reasons for Importance
8	Installation/recovery of mudmats or subsea UTA support structures	— Design of UTA docking facilities, latching arrangements, and support structures. — To avoid excess dynamic loads during installation, it is not recommended to attach mudmats or support structure to the UTA prior to lowering through the water column. The recommendation is to lower the foundation first, followed by the UTA. — However, if the project requires mudmats or the support structure to be attached to the UTA while installing, proper risk assessment must be carried out by taking into account the relevant aspects such as the sea state, to ensure that all safety aspects are in place and that the operation is carried out satisfactorily. — Installation/recovery of mudmat structures should be taken into account during initial design.
9	Critical installation parameters — Maximum umbilical tension < allowable value — Maximum umbilical compression < allowable value — Umbilical MBR > allowable value	— Conformance with product integrity.
10	UTA access for testing during FAT, transportation monitoring, and installation testing	— UTA may be secured on a reel or on the top of a carrousel with limited access. Ability to test all umbilical lines shall be evaluate as part of the design, with consideration of providing proper access to personnel and equipment including secure points as needed.

NOTE 1 The convention for outer diameter (OD) and inner diameter (ID) in the document is in line with common industry practices; therefore, the umbilical dimensions are expressed as ID and tubing (control lines) as OD. The reader is advised to consult further to convert dimensions to ID/OD as required (recommend this action is added to the projects interface management table).

NOTE 2 The yoke allows the UTA to rotate during installation and may be fitted to a UTA with or without a docking probe. The yoke is mainly used for horizontal handling of UTAs such as a second end stab and hinge over operation. The UTA without and with a docking probe respectively is shown in (a) and (b).



(a) UTA Without a Docking Probe



(b) UTA With a Docking Probe

Table 2—Installation-related Consequences

	Consideration	Explanation and Potential Consequences
1	**Safety implications**	— The larger and heavier the UTA the higher the risk factors with regard to safety of personnel and the product(s) (UTA and umbilical). This applies onshore as well as offshore.
1a	Danger in handling a large/heavy load at height	— If UTA proportions are beyond the installation vessel crane and handling equipment capacity, it may necessitate a port call to enable quayside crane intervention (first end lay) or second vessel crane (first or second end lay). — If both end UTAs are of similar proportions, it may not be possible to overboard the last end if a shoreside crane had placed the first end UTA in position. — With VLS systems, the top arch may be so high there is no suitable way of restraining the UTA during installation over the VLS.
1b	Danger from vessel motions caused by the sea state	— If the sea state is worse than that acceptable for safe handling of the UTA, there may be delays associated with waiting for improvement or sailing to port or sheltered water. — If environmental parameters change during the lay of a long umbilical, a large UTA may not be capable of overboarding and mean holding the final umbilical deployment until conditions abate suitably to overboard the oversized UTA, during which the umbilical will be subjected to excessive fatigue.
2	**Cost (associated with vessel capacity)**	— Increasing UTA proportions size leads to increased handling complexity resulting in the need for higher specifications for installation systems (and vessels) along with additional UTA handling and deployment equipment. — Larger UTAs may lead to more complex lay spreads and vessels with capacity to accommodate such lay spreads for UTA handling, deck footprint, and power requirements.
2a	Reel/carousel capacity	— Influenced by UTA functionality, umbilical length, water depth, weight of umbilical, MBR, and rigid length. — Increasing capacity requirements can lead to restricted choice of vessel, or additional port calls and remobilizations. — The decision of choosing the installation method (reel vs carousel) is mainly governed by the functionality, length, and weight per meter of the umbilical and consequently the size and weight of the UTA. — Increasing any of these parameters can rule out simple reeled installation, which many vessels are capable of, while substantially reducing a carousel or rotating basket’s available umbilical length capacity. This results in only a handful of vessels available worldwide with a lay spread specification suitable with which to execute the installation or joined sections of umbilical, additional port calls, and interim mobilizations.
2b	Required tensioner length/VLS capacity	— Choice of tensioners and lay spread is driven by top tension (UTA dimensions/weight, umbilical weight, water depth) and installation method. Large UTAs place more onerous demands on VLS/lay spread and can lead to restricted choice of vessel specification and charter costs.
2c	Handling method requirements	— A need to handle a larger/heavier UTA may tend to result in a need for higher rated equipment, more items of equipment, more complicated equipment. — Consequences of handling a large/heavy load at height have been described in Item 1a.
3	**Schedule**	— Increasing the UTA size may tend to increase the risk of extension to schedule due to complexity in handling, intervention, and installation. It is possible for a small growth in size to cause a large schedule impact.
3a	Vessel availability	— A restricted choice of vessel can lead to schedule delay owing to the reduced availability of suitable vessels. Such a restricted choice could be caused by the need for a VLS, an open tensioner VLS, or a larger capacity carousel.
3b	Safe handling weather window	— The acceptable weather conditions for UTA and umbilical installation will be diminished and less frequent as UTA size increases could result in impact on project schedule. Consideration should be given during early design phase as to handling and lifting operations.
3c	Geographical location	— Large UTAs, as mentioned previously, can restrict the choice of vessel, which could result in a schedule delay owing to transit time for suitable vessel to the work locations.
4	**Technical risk**	— Some of the key technical risks are described in 5.2 of this document.

6.2.5 Type of Laying System

The optimum scenario is that the umbilical system can be installed with any available system (i.e. over the stern, open/closed VLS, other—see API 17TR10 for description of laying systems). In a less than optimum scenario, the umbilical system can only be installed by certain systems, e.g. open VLS if the UTA is very large, etc. or for purpose built systems.

The type of laying system still depends on the choice of the installer and the vessel spread availability. It should also be noted that various geometrical constraints linked with the various laying systems may influence the optimal choice of system. (See API 17TR10.)

6.2.6 Rigid Length

The total rigid length of the SUT assembly (including attached rigid elements) is defined in 3.1.3. Depending on the configuration, rigid length can be calculated in three different ways, as outlined below.

— If the SUT is equipped with a bend stiffener, the rigid length will be the sum of length of UTA, STI, and $^{1}/_{3}$ of the length of bend stiffener, as shown in Figure 5.

 — Rigid length = UTA + STI + (BSR/3)

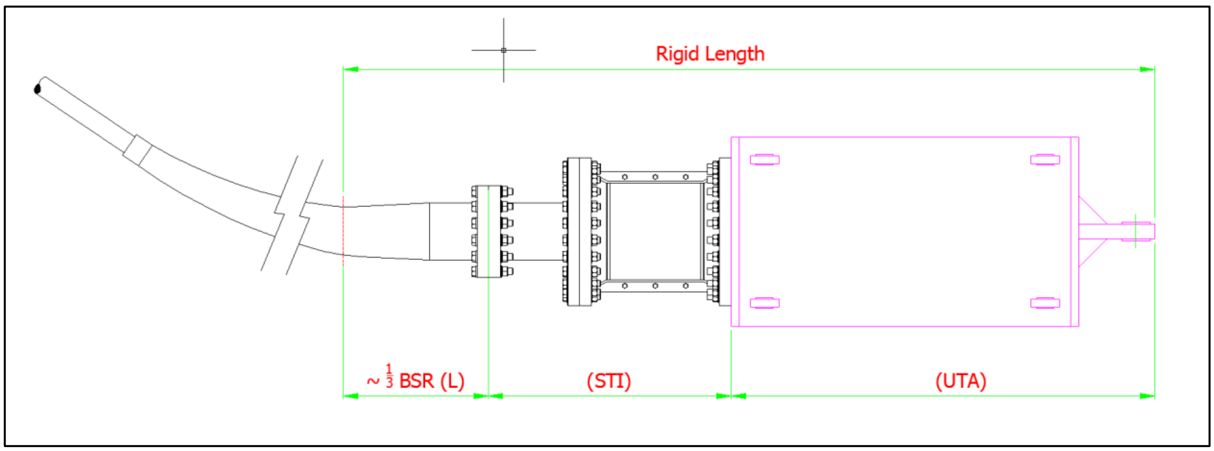


Figure 5—Rigid Length with a Bend Stiffener

— If the SUT is equipped with a bend restrictor, the rigid length will be the sum of length of UTA, STI, and the length of first interface flange (axial rigid length of bend restrictor), as shown in Figure 6.

 — Rigid length = UTA + STI + *L*

— If the SUT is not equipped with a bend stiffener or bend restrictor, the rigid length will be the sum of length of UTA and STI, as shown in Figure 7. It is recommended that either a bend stiffener or bend restrictor is always used.

 — Rigid length = UTA + STI

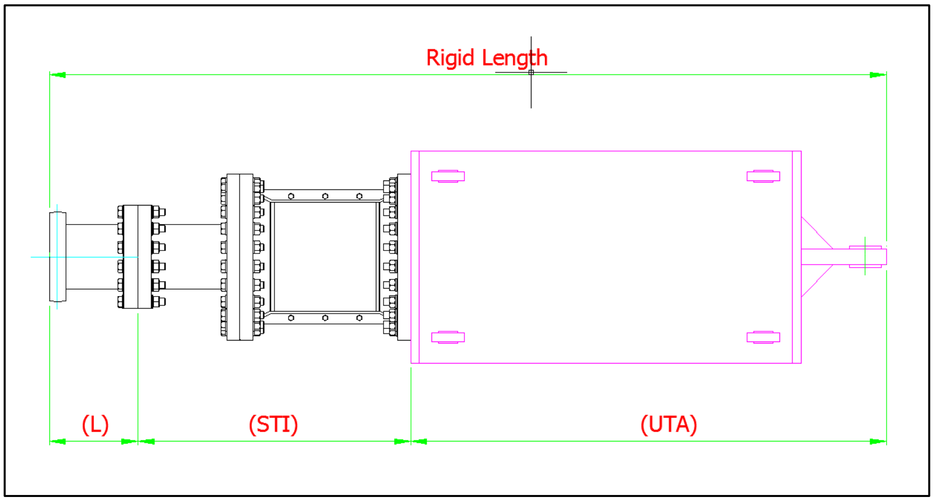


Figure 6—Rigid Length with a Bend Restrictor

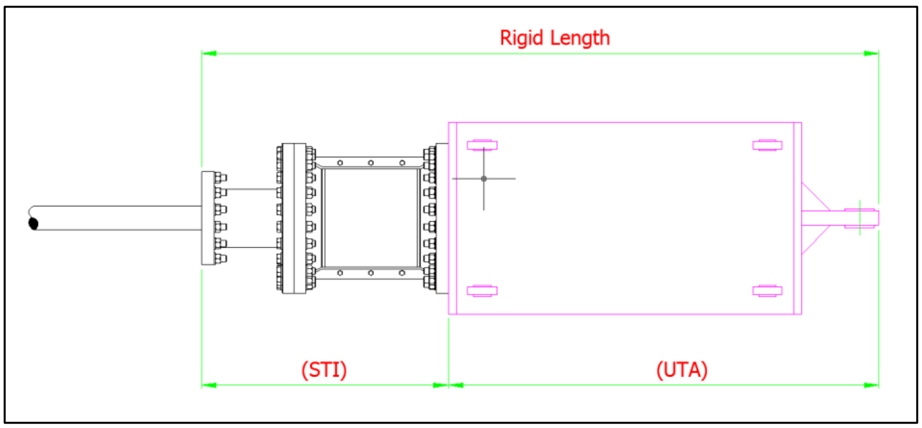


Figure 7—Rigid Length Without Bend Restrictor or Stiffener

A shorter length of UTA is preferable for handling and installation. It may improve the choice of alternative laying systems available (see API 17TR10).

6.2.7 Umbilical MBR

Minimum bend radius (MBR) relates to the minimum radius to which an umbilical, at zero tensile load, can be bent to without infringing the stress criterion or suffering loss of performance.

Allowable bend radius (ABR) relates to the minimum radius to which an umbilical, at a given tension, may be bent to without infringing design criteria or suffering loss of performance.

Further details on the correlation between MBR and ABR can be found in API 17E.

Both MBR and ABR are mainly driven by the configuration of the umbilical characterized by the following aspects:

— number and functions required within the umbilical;

— physical properties of the subcomponents used (e.g. MBR of cables, hydraulic lines);

— physical properties of supporting elements (e.g. interstices fillers, tensile strengthening elements, outer sheath properties, etc.);

— umbilical manufacturing process (cross section layout, spiral bundling, etc.).

Typically, the MBR and ABR are defined within the manufacturer's handling and operating specification.

Both MBR and ABR directly impact on the specification of installation vessel, lay spread, installation methods, overboarding, and seabed lay-down complexity. Umbilicals with smaller MBR and ABR provide substantial advantages in passing them through the lay spread components and availability of suitable vessels and lay spreads.

However, besides the MBR/ABR criteria, a further and equally relevant umbilical characteristic is the "bending stiffness" or better described, "bending resistance." This characteristic can equally impact heavily on the handling of an umbilical and its SUT. As there is no direct correlation between the bending radius and the bending resistance of an umbilical, both aspects need to be considered when preparing for the manufacture, handing, transportation, and final installation of the umbilical and SUT, as shown in Figure 8. For example, an umbilical with a higher number of tensile strength elements, typical of dynamic umbilicals, requires larger MBR/ABR and an inherently higher stiffness/resistance. However, an umbilical with a high number of functions and/or sensitive subcomponents can result in a larger MBR/ABR, but equally have a lesser bending stiffness/resistance.

Therefore, the MBR/ABR and bending stiffness/resistance should be considered during initial control system FEED studies with relevance to possibility of additional bend stiffeners/restrictors and STIs being required, particularly where a SUT is dimensionally larger and of substantial weight in order to protect a weaker umbilical structure.

The STI interface shall be used to provide the transition between the umbilical and its SUT. Within this termination, the tensile-strength members of the umbilical, such as armor wires, rods, or metallic tubes themselves, are physically coupled to the unit using an approved method. At such an interface, there is a transition in stiffness, which normally requires the use of a bend restrictor or stiffener in order to protect the umbilical from excessive localized bending during handling or deployment.

The design of the interface shall be such that the components are not subjected to detrimental stresses when they are connected to the SUT. This additional length and complexity can have an unwelcome impact during the umbilical and SUT handling, packing, transportation, passing the SUT through the lay spread components, and final overboarding and lay-down on the seabed.

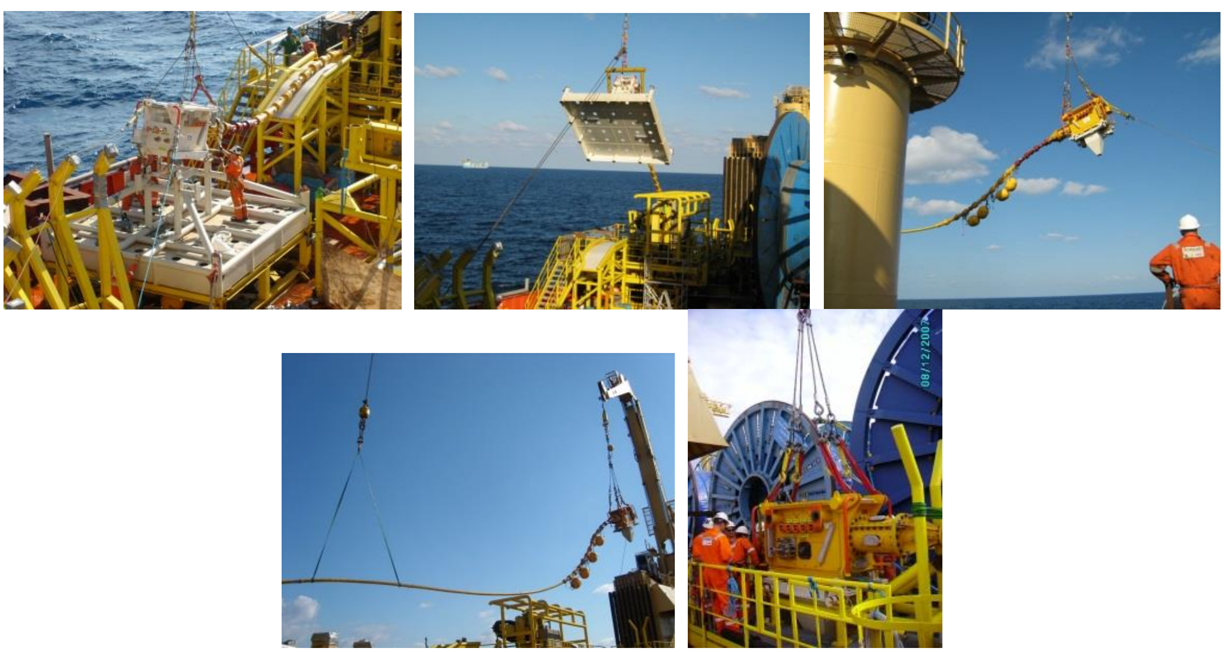


Figure 8—Illustration of Impact of MBR/ABR During Various Stages of Installation

7 Guidance for UTA Optimization

7.1 General

The size and complexity of the UTA can have enormous impact on the duration of the installation of umbilicals and their UTAs and might lead to:

— bespoke, time-consuming installation methods and lengthy onshore trials;

— specific requirements on installation vessel and equipment;

— reduced installation window due to the limited acceptable environmental installation conditions;

— limited availability of suitable installation vessels;

— time-consuming and complex packing, transporting, mobilization, and offshore deployment.

As the impact of the UTA size can be significant, it is recommended to perform an optimization of the UTA size during the conceptual definition phase of the system layout.

It is recommended to consult and engage with the installation contractor early during the design phase to provide inputs on the installability and optimize the design. This will ensure that the challenges and complexities faced during installation are known, fully understood, and accounted for during the design process. This will minimize the delays and schedule/cost overruns during project execution. There might be technical and/or commercial considerations for selecting the installation contractor for early engagement/consultation; it is recommended to address these on a project-by-project basis. Recommendations on the participation of all parties involved is included in Annex D.

The optimization model provides the method of optimizing the size of the UTA during the concept stage of the development of a system. The model provides the opportunity to perform an optimization of the UTA size considering key aspects of the system layout.

The model is structured in three elements:

— optimization process,

— key optimization aspects,

— optimization matrix.

7.2 Optimization Process

Once the first draft of the system is present, the optimization exercise can be started based on the following process, in combination with the information contained in earlier sections of this document. After each optimization process step, the key system questions should be answered and documented within the optimization matrix. Once modifications of the UTA and/or system have been implemented, the process shall either be continued at the same level or restarted at one of the previous levels (see Figure 9).

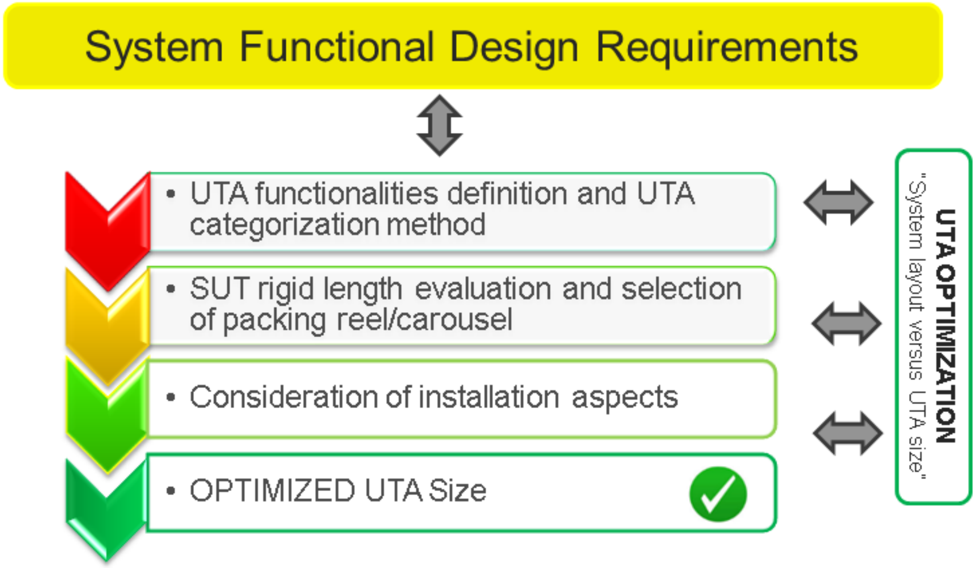


Figure 9—UTA Optimization Process

7.3 Key Optimization Aspects

During the concept phase for the development project, not all details about the proposed equipment are available. As a result, the optimization process concentrates on a few key aspects, as follows.

— Field architecture:

 — arrangement of drill centers and system layout;

 — umbilical system and umbilical function;

 — field environmental conditions, e.g. seabed load-bearing capacity, tide, sea state, visibility condition;

 — use of SDU in conjunction with UTA.

— UTA functionality:

 — termination of the umbilical services;

 — distribution (e.g. teeing of lines, electrical distribution units, etc.);

 — isolation, reconfiguration option (gate/ball valves, logic caps).

— Line size:

 — flow assurance,

 — bending radius.

— Spare philosophy:

 — number of spare lines/cables,

 — accessibility of spare lines.

— Level of technology.

— New technology development.

— Qualification (for product and/or system).

— Foundation arrangement:

  — type of foundation structures (e.g. mudmat, suction pile, single or combined foundation);

  — installation method (combined or separate, permanent attached, disconnectable subsea).

In early conceptual and front-end engineering phases of field layout, strong consideration should be given to the number of wells to be served by a single umbilical. This directly influences the required number of functional elements in the umbilical and ultimately is truly what governs the size of the UTA. Limiting the number of functional elements to a practical amount is a preferred method of limiting the size of a UTA, as opposed to limiting or eliminating the ability to utilize spare lines or compromising on design reliability with respect to materials of construction, minimum bend radii, and the number of welded fittings.

7.4 Optimization Matrix

The optimization matrix (Table 3) has been developed:

— to perform the optimization process systematically,

— to gain overview and awareness of which system design aspects influence the UTA size/complexity,

— to document the decisions/assumptions being made during FEED/tender stage.

Table 3—Suggested Optimization Matrix (for High-level Assessment During Planning Phases)

Key Aspects	Why Is the UTA Large/Complex?	Can the Size/Complexity Be Reduced? Yes?/No?	If Yes, HOW? If Not, WHY?	
Field architecture				**Process step:** UTA categorization
UTA features				
Line size				
Sparing philosophy				
Level of technology				
Foundation arrangement				
Field architecture				**Process step:** Evaluation of packing option
UTA features				
Line size				
Sparing philosophy				
Level of technology				
Foundation arrangement				
Field architecture				**Process step:** Consideration of installation aspects
UTA features				
Line size				
Sparing philosophy				
Level of technology				
Foundation arrangement				

The matrix has been developed as a high-level checklist for guidance during planning phase. It is recommended that a detailed assessment is carried out based on project specific circumstances and requirements.

This matrix should be used during all the stages of the optimization process. For the different process steps, the matrix can be extended as needed, as this list is not exhaustive.

Upon completion of this process, the UTA size should be optimized as much as the system allows. The matrix also provides an overview of the aspects that influence the system layout aspects, size, and complexity of the UTA.

During project execution, the matrix should be used to develop mitigation plans when the size and complexity can be optimized no further. This should instigate critical activities such as development work, qualification, and vessel selection to address the challenging installation scenarios.

The details about impact on the subcomponent level can be found in API 17TR10.

8 Workflow for Selection and Sizing of the UTA

8.1 General

The aim of the workflow is to guide the user through a sequence of steps to understand the implications of the decisions made during early design phase. The workflow comprises a selection of UTA category and packing, followed by an optimization assessment leading to optimized UTA size, design, and installation. Figure 10 shows the five subcomponents of the workflow.

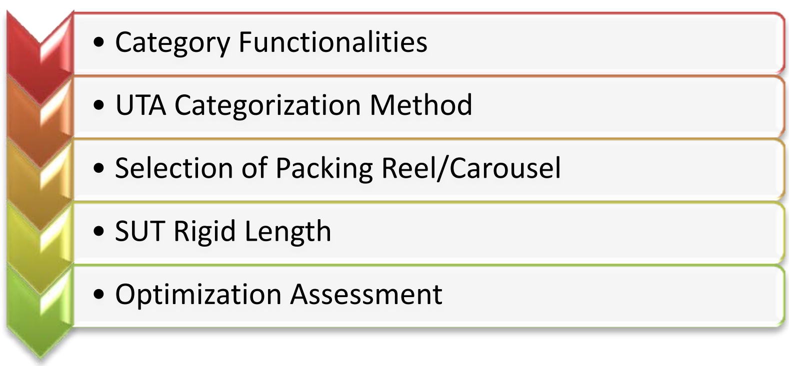


Figure 10—Workflow of the Selection and Sizing of the UTA

8.2 Category Functionalities

Table 4 indicates typical maximum functionalities that can be specified for each category of UTA, with the categories defined as in Figure 11. The minimum radial clearance to tensioner aperture should typically be 50 mm (for Category A to Category C), depending on geometrical layout and handling constrains (see Figure 11).

Table 5 gives an indication of typical STI dimensions.

The table gives an indication of typical STI dimensions where it has not been possible to integrate the STI into the main UTA body. In some cases STI may be integrated in the UTA, thereby the length of STI will be much shorter than the indicative figures in the table above.

The total STI length may include the first joint in the bend restrictor interface when it is included as a machined part of the armor body. The total rigid length is included in this interface as shown in Figure 6.

8.3 UTA Categorization Method

8.3.1 UTA Categories

The convention used in the document is based on categorizing UTAs based on installation systems, as this has the most impact. Functionality of UTAs is covered in API 17TR10.

This section describes the methodology for UTA size categorization adopted by the UMSIRE Joint Industry Project (JIP).

UTAs have been classified into four categories depending on the limiting factors of installation systems. Each category of UTA has been based on the level of functionality that can be incorporated within each envelope as described in Table 4.

Four UTA categories are defined as follows.

— Category A: up to 1.2 m closed tensioner diameter.

— Category B: up to 1.4 m closed tensioner diameter.

— Category C: up to 1.6 m closed tensioner diameter.

— Category D: >1.6 m (requires open tensioner).

Table 4—Functionalities of UTA Categories A, B, C, and D

UTA Functionalities	Category A UTA	Category B UTA	Category C UTA	Category D UTA
Maximum diameter of closed tensioner opening for UTA to fit	1.2 m (47 in.)	1.4 m (55 in.)	1.6 m (63 in.)	>1.6 m (63 in.) (requires an open tensioner)
SUT max. diameter (with 50 mm clearance)	1.1 m (43 in.)	1.3 m (51 in.)	1.5 m (59 in.)	>1.6 m (63 in.) (requires an open tensioner)
MQC plates	2 MQC plates with 7 lines each [2 up to 19 mm (0.75 in) OD and 5 up to 13 mm (0.5 in.) OD]	2 MQC plates with 10 lines each [4 up to 19 mm (0.75 in.) OD and 6 up to 13 mm (0.5 in.) OD]	4 MQC plates with a total of 24 lines [maximum of 4 up to 25 mm (1 in.) OD, 8 up to 19 mm (0.75 in.) OD, and 12 up to 13 mm (0.5 in.) OD]	>4 MQC
Cables	A total of 6 optical and electrical umbilical cables, each terminating at a single connector, of which a maximum of 2 are fiber optics	6 electrical umbilical cables, each terminating at a single connector, and 2 fiber-optic umbilical cables, each split into 3 connectors	6 electrical umbilical cables each terminating at a single connector, and 2 fiber-optic umbilical cables each split into 3 connectors	More than 6 electrical umbilical cables, each terminating at a single connector, and more than 2 fiber-optic umbilical cables, each split into 3 connectors
Valves	No	No	Not recommended	Possible
Distribution	No	No	Possible	Possible
Max. UTA length (including the padeye)	3 m (118 in.)	3 m (118 in.)	3.5 m (138 in.)	>3.5 m (depending on handling limitations)
ROV operable	Yes	Yes	Yes	Yes

NOTE 1 The UTA length may exceed these recommended values while optimizing the all-over length of the SUT or rigid length with the length of the STI and bend limiter properties.

NOTE 2 “Distribution” refers to teeing of lines, electrical distribution units etc. Smaller UTAs generally do not have enough space to cater these components.

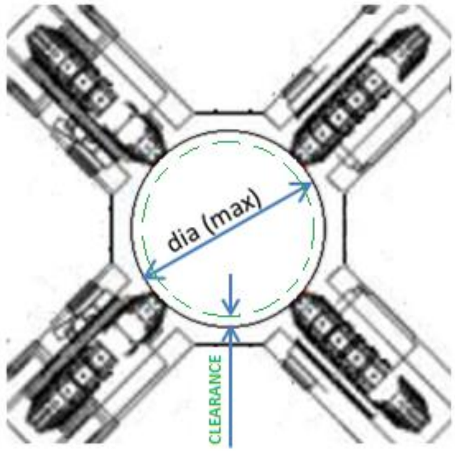


Figure 11—Closed Tensioner Opening

Clearance must be considered to allow the SUT to pass through the tensioner without issue. Certain items may be temporarily removed to allow the SUT to pass freely through the tensioner. The minimum radial clearance to tensioner aperture should typically be 50 mm (for Category A to Category C), depending on geometrical layout and handling constrains (see Figure 11).

The categories are defined by the closed tensioner aperture as shown in the diagram below. The UTA cross section must stay within the aperture and be free to rotate within the circle enclosed by the aperture. Figure 11 shows a 4-track tensioner, although other designs exist in the industry.

Certain items, such as protective covers, may be temporarily removed to allow the SUT to pass freely through the tensioner.

8.3.2 Physical Interface of UTA

Table 5 describes the physical interface between the UTA and the umbilical with recommendations for a standardized flange size. The advantage of this standardization is the minimization of the required interface clarification between the UTA and umbilical supplier.

Recommended flange interface/type according to ASME/ANSI B16.5 flange class and diameter must be chosen to suit installation load requirements.

NOTE Figures are indicative based on experience within the UMSIRE JIP.

The recommendations for 20 in. flange for the UTA is included for guidance with the intention to help the industry work toward standardized interfaces; however, every project will need to assess the best sizes to use to suit their specific requirements, particularly small umbilical designs that may utilize a Category A UTA.

The values, ranges, and tolerances in Table 5 are based on the past experience of umbilical manufacturers; however, the recommended default values in Table 4 should be used as these are in line with the expectations with the size of the UTA.

Table 5—Typical STI Dimensions and Recommendations for a Standard Flange Interface Between UTA and Umbilical

UTA Category	Typical STI Dimensions (Based on Past Experiences for All Types of UTAs)			Recommended Default for Flange Interface Between UTA and Umbilical (for UTA Types A–C)	
	Maximum Total STI Length (X); See Figure 12	Maximum STI Flange Outside Diameter (Y)	Minimum Opening Diameter in UTA (Z)	Recommendation for Standard Flange Interface	Recommendation for Opening Diameter in UTA (Inlet Diameter for Umbilical Tubes/Hoses)
A (steel tube)	1400 mm (55 in.)	710 mm (28 in.)	390 mm (15.4 in.)	ASME/ANSI B16.5 Class 150–300	See note below table
A (thermoplastic hose) [a]	370 mm [a] (14.5 in.)	650 mm [a] (25.6 in.)	390 mm [a] (15.4 in.)	ASME/ANSI B16.5 Class 150–300	See note below table
B (steel tube)	1800 mm (71 in.)	775 mm (30.5 in.)	480 mm (18.9 in.)	ASME/ANSI B16.5 Class 300–NPS 20	510 mm (20 in.)
B (thermoplastic hose) [a]	420 mm [a] (16.5 in.)	650 mm [a] (25.6 in.)	390 mm [a] (15.4 in.)	ASME/ANSI B16.5 Class 300–NPS 20	510 mm (20 in.)
C (steel tube)	1900 mm (75 in.)	838 mm (33 in.)	490 mm (19.3 in.)	ASME/ANSI B16.5 Class 300–NPS 20	510 mm (20 in.)
C (thermoplastic hose) [a]	510 mm [a] (20 in.)	650 mm [a] (25.6 in.)	390 mm [a] (15.4 in.)	ASME/ANSI B16.5 Class 300–NPS 20	510 mm (20 in.)
[a] Thermoplastic hose STI dimensions are examples from one umbilical designer only.					

UTA dimensions X, Y, and Z are listed in Table 5 and shown in Figure 12, for different categories of UTA and type of umbilical (steel and thermoplastic).

8.4 Selection of Packing Reel or Carousel

8.4.1 General

Figure 15 shows the methodology and the main criteria for selection of packing, which includes UTA category, type of tensioner, total system weight, maximum rigid length, and the length of the umbilical.

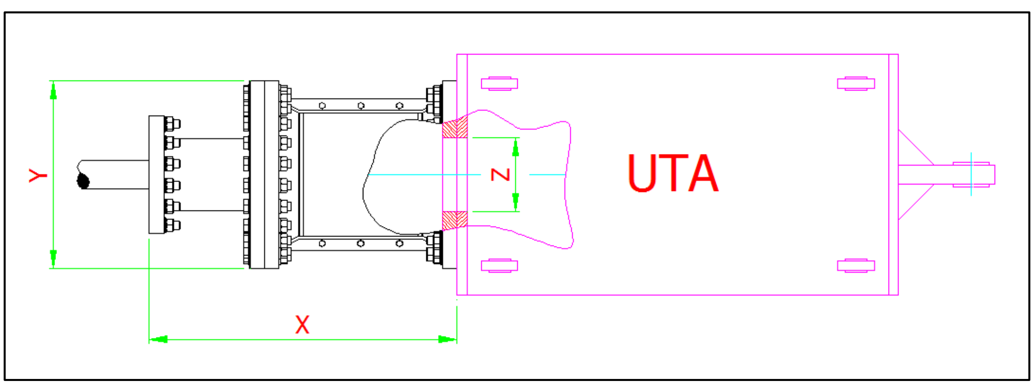


Figure 12—UTA Dimensions X, Y, and Z (as per Table 5)

Figure 13 and Figure 14 show the cross section of steel tube and thermoplastic umbilical. The details of design and installation of different types of umbilical have been described in API17E and API17I.

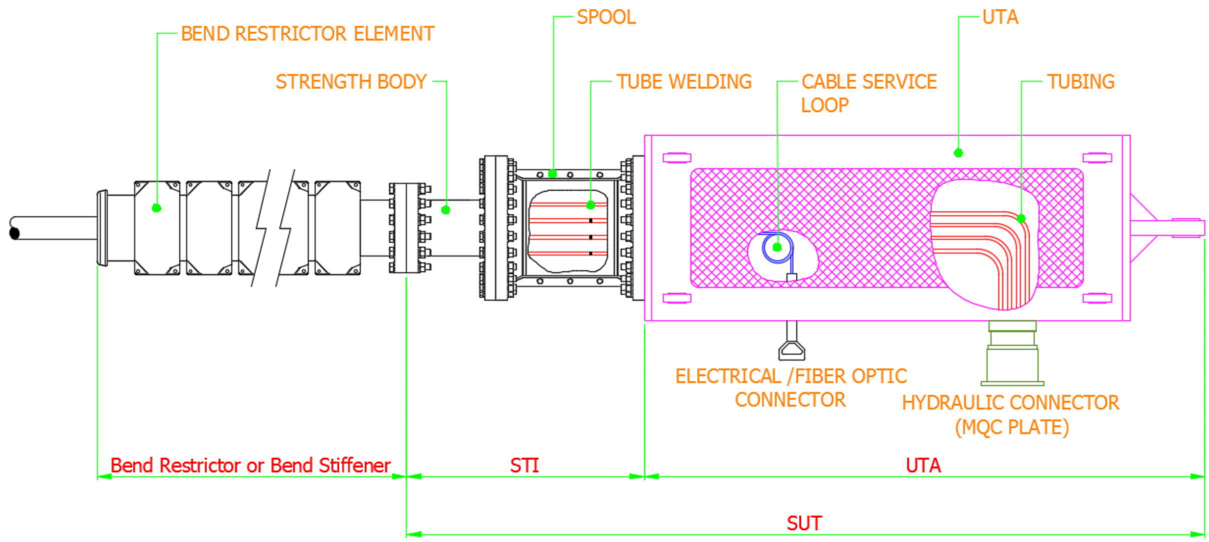
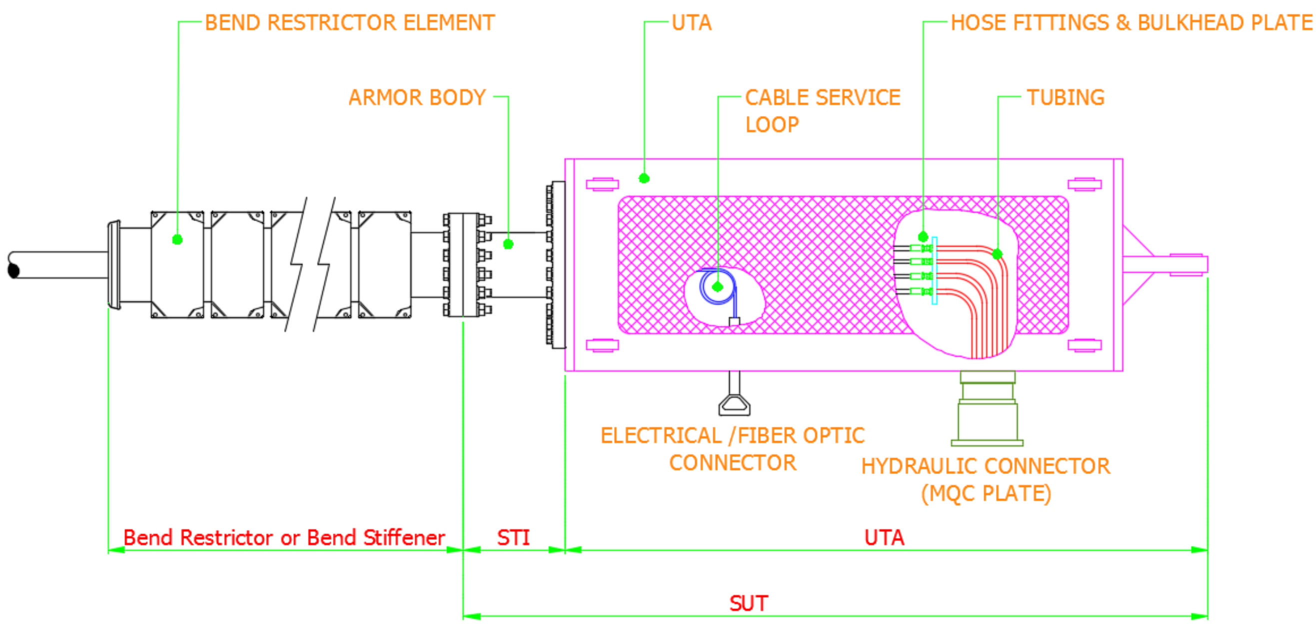
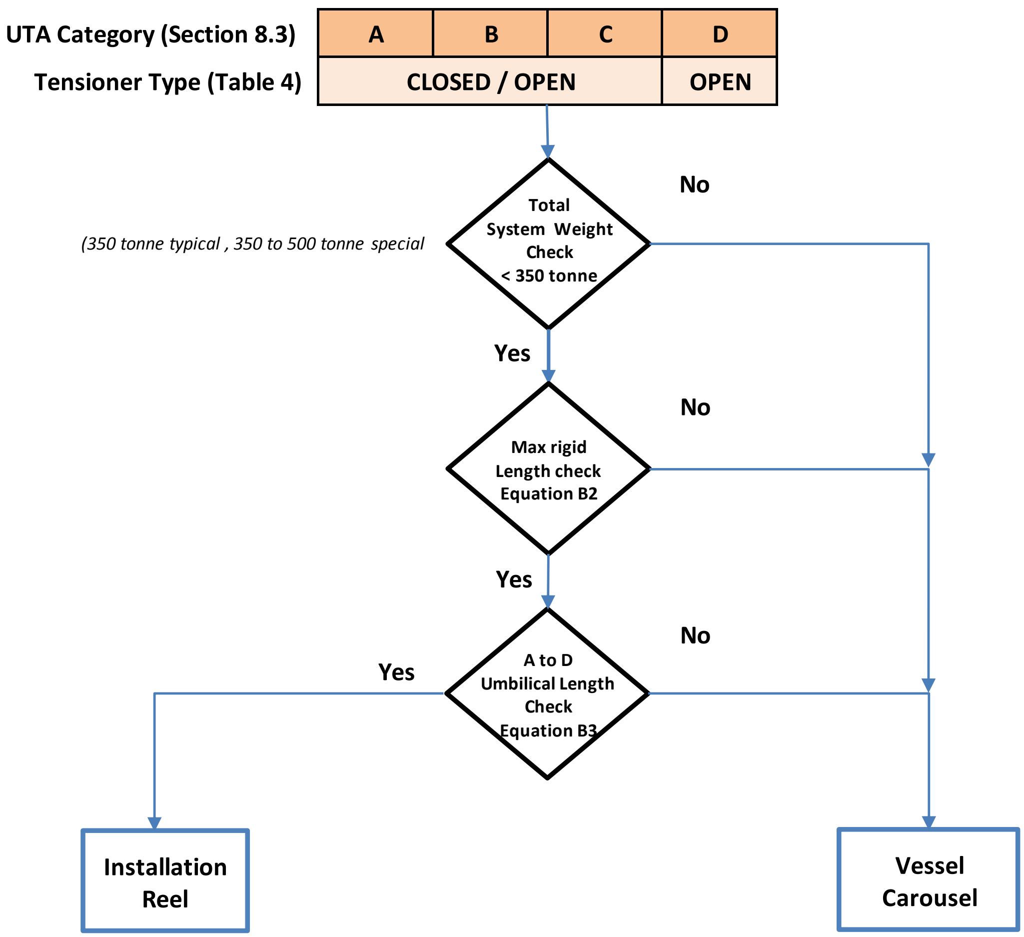


Figure 13—Steel Tube Umbilical or Thermoplastic Umbilical Without Spool



NOTE Steel tubing has larger MBR than thermoplastic umbilical.

Figure 14—Thermoplastic Umbilical



NOTE Reeled installation requires a simpler lay spread and vessel specification.

Figure 15—Flow Chart for Selection of Packing Reel/Carousel

Equation (B.2) and Equation (B.3) have been included in Annex B.

8.4.2 Installation Reels

The use of carousels is recommended once the following reel criteria are exceeded, as illustrated in Figure 16.

— The overall combined product (cores filled or empty) and reel weight exceeds the maximum reel design capacity.

— The reel simply cannot accommodate the overall length of the umbilical, which can simply be the result of having to accommodate a dimensionally wide SUT, leaving the remaining space on the drum for umbilical severely diminished.

— The reel inner drum cannot be packed out to a suitable radius that complies with the umbilical's MBR (typically large-diameter steel-cored umbilicals).

The total system weight refers to the weight of umbilical, fluid, terminations, reel (including cradle), and the partitions. The maximum rigid length check and the umbilical length check can be carried out with the help of calculations such as described in Annex B.

Figure 16—Typical Installation Reels Setup

Various reel capacities are available, such as the industry standard 280–300 Te design that comes in 7.4 m, 8.6 m, and 9.2 m diameters with standard 4.4 m diameter drums and 5 m internally between side flanges. There are also 350 Te rated reels available but these are quite sought after and therefore, like bespoke reels, may have to be fabricated specifically for the project under design.

8.4.3 Carousels

Due to their larger dimensions and maximum load capacities, carousels pick up where reels prove unfeasible. This will take several products, and the "last end" SUTs are accommodated with relevant ease upon their roof sections (see Figure 17).

Figure 17—Typical Carousel Setup During Installation

8.5 SUT Rigid Length

8.5.1 General

The SUT rigid length is calculated based on the UTA dimensions and the STI length. The UTA dimensions are obtained from 8.1, and the following section describes STI length calculations.

Figure 18 shows the rigid length with a bend stiffener connected with the STI. As described in 6.2.6, the rigid length will differ in other cases depending on if the SUT is connected with either a bend stiffener or a bend restrictor, or none of them.

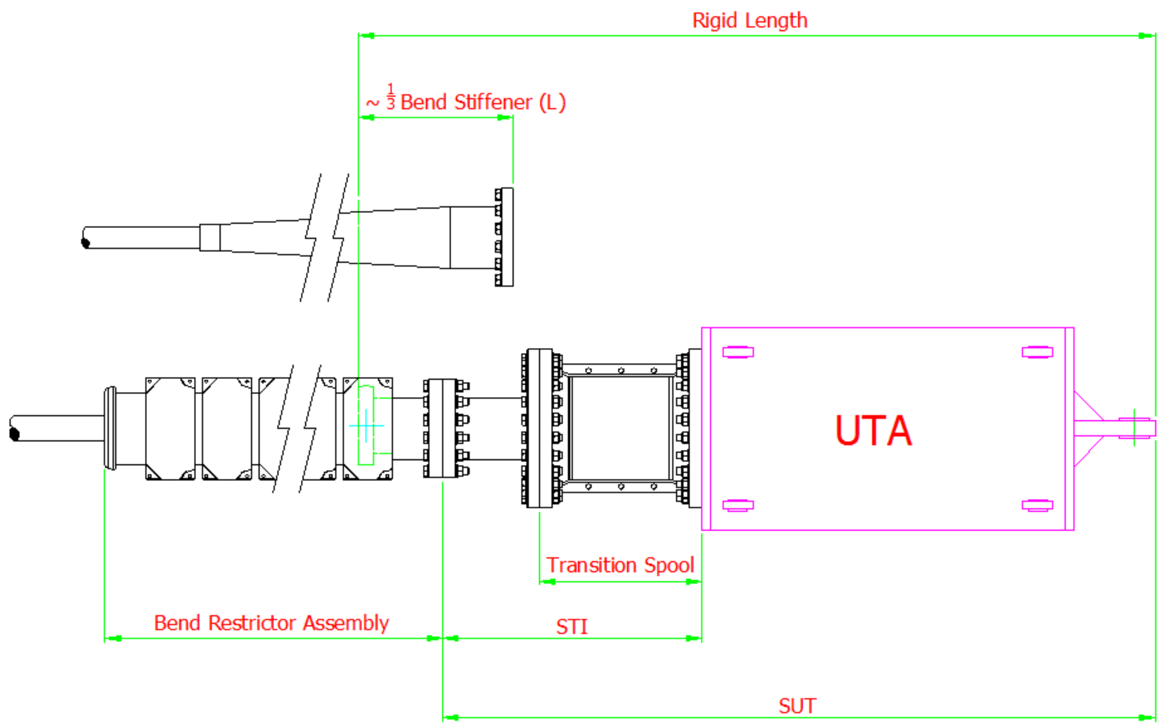


Figure 18—Rigid Length

The maximum permissible rigid length should be considered for two operational cases: storage and as installed.

— *Storage Rigid Length*—The total length of the UTA taken from the end of any padeyes or hold-down points plus the STI (if not incorporated into the UTA) with the bend restrictor or BSR not attached. This will allow a longer UTA to be stored on the reel prior to deployment.

— *As-installed Rigid Length*—The total length of the UTA taken from the end of any padeyes or hold-down points plus the STI (if not incorporated into the UTA) plus the bend restrictor interface or $^1/_3$ BSR length installed in position. This allows overboarding and deck handling requirements for the different lay methods to be reviewed with the umbilical in the installed condition. The remaining bend restrictor elements are attached prior to overboarding in a suitable location as determined by the installer.

Further details on rigid length and STI have been provided in Section 6.11.1 of API 17TR10.

8.5.2 STI Length Calculation

The formulas for calculating length of STI have been included in Annex B (STI and SUT length calculations). The formulas are intended to provide an initial sizing of the STI length based on the reel diameter, umbilical (MBR and diameter), and UTA size (L and H).

Some of the important assumptions incorporated in the calculation method are as follows:

— the umbilical MBR should be less than the reel barrel radius;

— the UTA is box shaped (side view) and does not have large extending brackets or components on the top, base, or front;

— the free board clearance (FBC) is the same for both the umbilical and UTA;

— packing configuration is per Figure 15 and Figure 20.

The rigid length in Figure 19 is indicated without a bend stiffener or a bend restrictor for packaging purposes only. Although it is recommended that a bend stiffener or a bend restrictor is used, for packaging purposes the bend restrictor or stiffener can be temporarily relocated on the umbilical.

The maximum STI length can be obtained from Figure 19 or can be calculated by using the equations mentioned in Annex B.

In some cases the barrel radius can be increased by adding a suitable packing structure to increase the barrel radius. This may also be extended into both Bay (A) and Bay (B) (as shown in Figure B.1).

If pressure and/or electrical monitoring is required during the transit or installation operations, installation contractor may request temporary test-plates to enable external monitoring. Typically these are installed before packing the UTA on the reel.

The positioning of topside equipment or first end UTA are not shown in Figure 21 as this equipment is not required to rotate within the confines of the reel rim envelope. Typically this equipment is suspended under the umbilical or termination compartments, positioned on the reel support cradle, or suspended outside of the reel envelope. At all times the loaded reel and support cradle balance, clearance of the vessel reel drive system/structure, and equipment protection must be considered.

Equation (C.1) in Annex C contains the details of false barrel diameter calculations and the symbols used (see Figure 20).

During early stages of designing, it is helpful to understand the implications of selecting a particular material and set of dimensions of the umbilical and UTA, on installation aspects such as the size of reel and barrel.

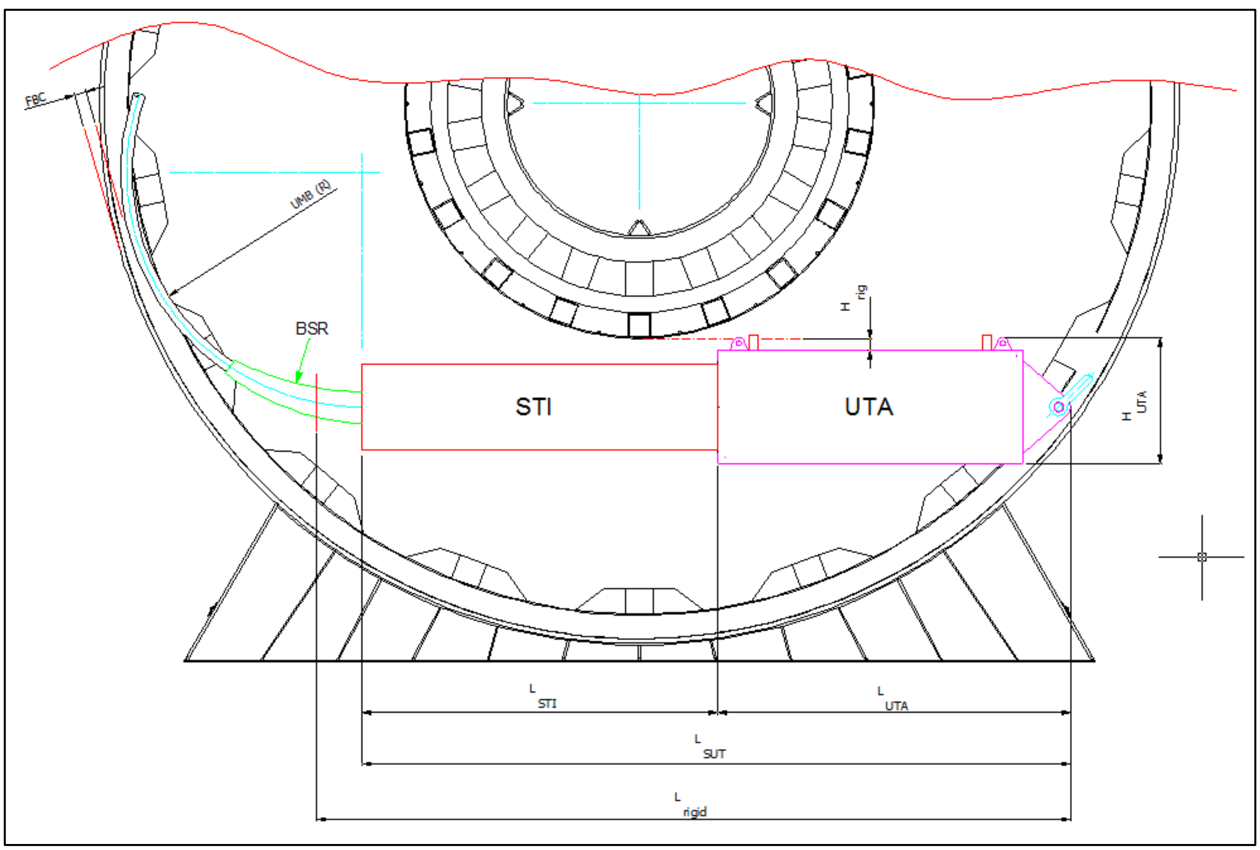


Figure 19—UTA Packed Within Reel Flanges (to Allow Second End Lay)

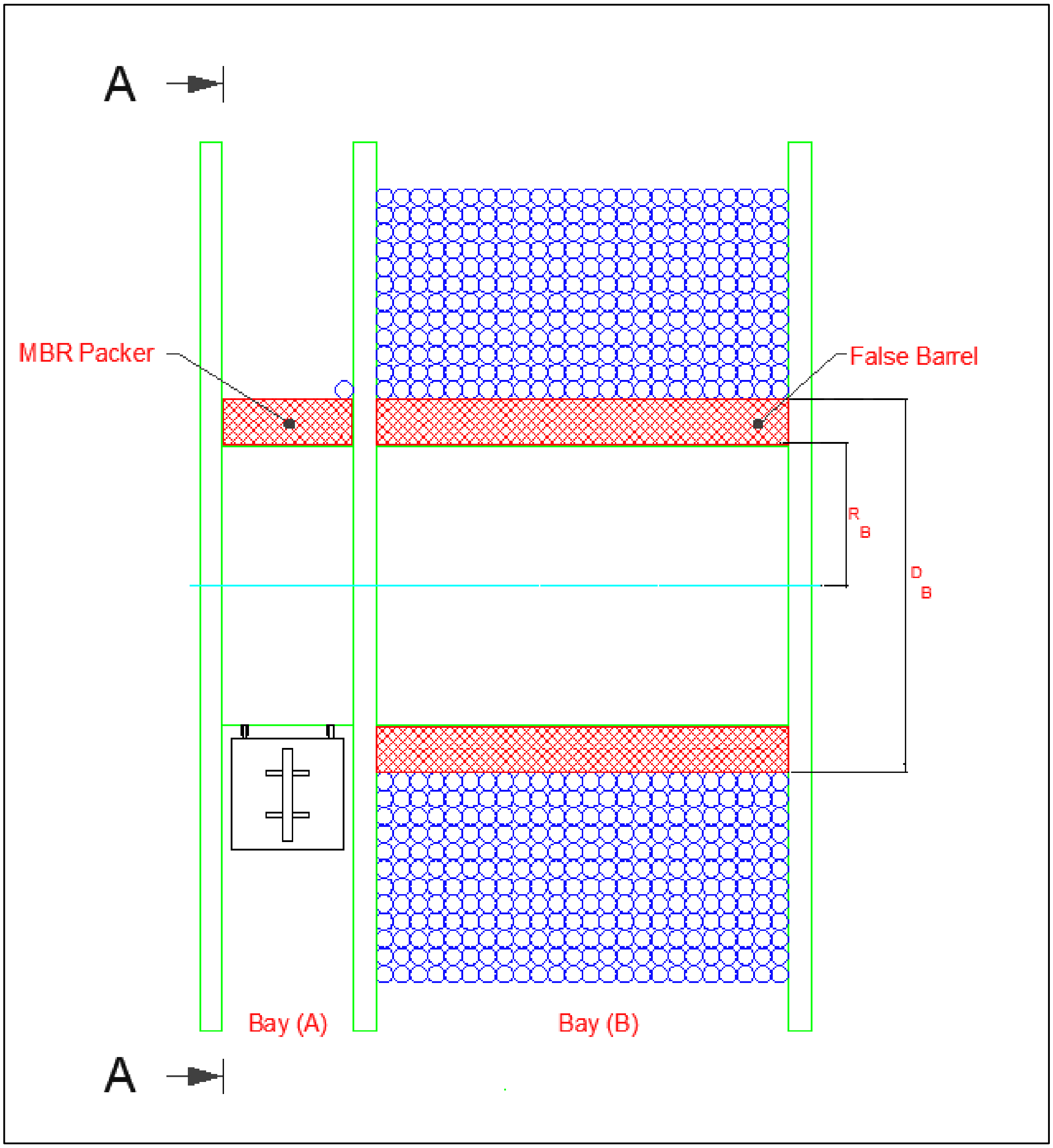


Figure 20—Illustration to Show Increased Barrel Radius by Using Packing Structure (Side View)

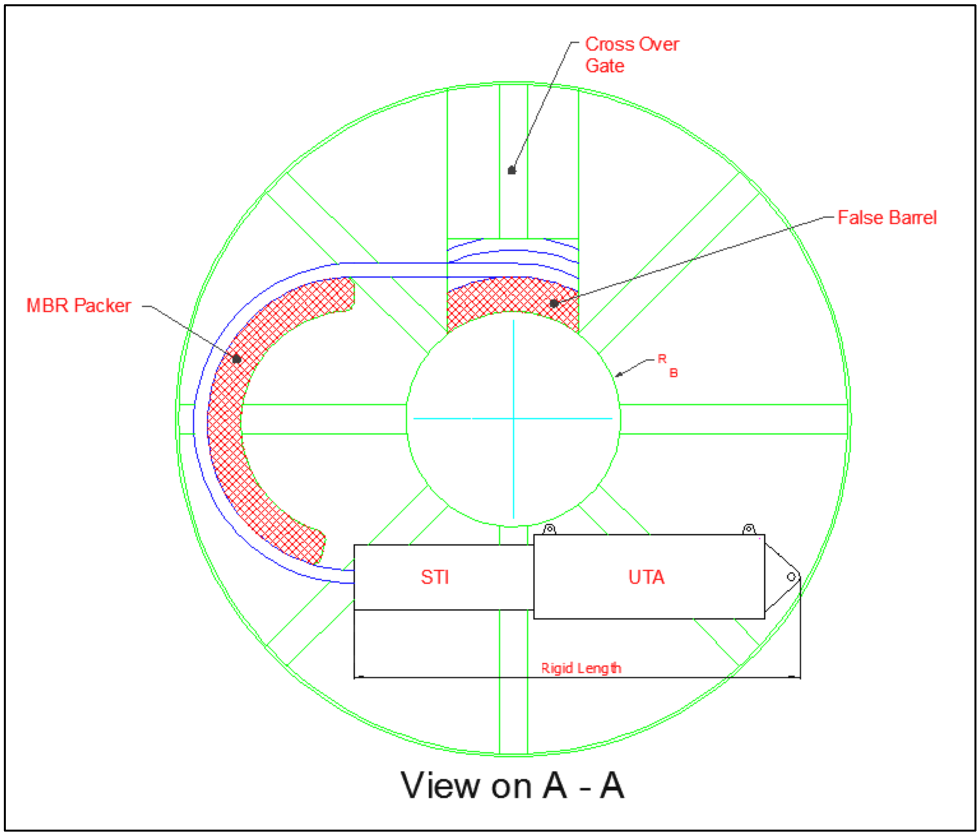


Figure 21—Illustration to Show Increased Barrel Radius by Using Packing Structure (Front View)

Table 6 acts as a quick reference guide (yet not comprehensive) for checking whether the results of preliminary evaluation of umbilical length and the UTA dimensions will fit on the desired packing (reel/carousel). The range of MBR, reel diameter, and barrel diameter in the table has been chosen on the basis of project experience and represent typical standard sizes available, with the aim to provide an example of how such an exercise could be conducted. The recommendation to the reader of the document is that an equivalent table must be constructed for field-specific requirements, with a range of possible umbilical and UTA dimensions. The values provided in the table are estimated based on the assumptions made in this document.

The intended use of Table 6 is not to act as a comprehensive guide, but to be used as an approach for making a systematic methodology, which can be effectively used on projects. The table can be expanded or modified to suit individual project requirements. The table also shows the range of barrel diameters for which a false barrel will be required. Following the table, there are two examples on how the information in the table may be used.

Table 6 refers to technical terms such as reel, false barrel. A reel used for umbilical storage, transportation, or installation has a cylindrical barrel fitted with larger-diameter flanges at each end. An intermediate circular partition may be provided to divide the usable space on the reel into two compartments, one of which may be used for storing the main quantity of umbilical and the other used for containing a UTA. The partition is provided with a crossover gate (aperture) to allow the umbilical to pass between one compartment and the other. A false barrel may be fitted to increase the effective central diameter of the reel when its use is dictated by the MBR of the umbilical being carried. The edges of the flanges are reinforced to allow the reel to rest on deck or under-rollers. The barrel usually projects slightly outboard of the flanges to allow slings to be passed round it for lifting purposes.

Table 6—Estimated Variation of Rigid Length with Varying Reel Diameter and UTA Size Category (Dimensions in Meters)

		Rigid Length, L_{rigid}								
		UTA Size Category								
		A			B			C		
Reel, m (in.)		*Umbilical storage MBR value, m (in.)*			*Umbilical storage MBR value, m (in.)*			*Umbilical storage MBR value, m (in.)*		
Ø Rim	*Ø Barrel*	*1.0 (39.4)*	*2.5 (98.4)*	*4.0 (157.5)*	*1.0 (39.4)*	*2.5 (98.4)*	*4.0 (157.5)*	*1.0 (39.4)*	*2.5 (98.4)*	*4.0 (157.5)*
6 (236.2)	2 (78.7)	3.37 (132.7)			3.42 (134.6)					
	3 (118.1)	3.37 (132.7)								
7 (275.6)	3 (118.1)	4.4 (173.2)			3.42 (134.6)			4.01 (157.9)		
	4 (157.5)	3.37 (132.7)			3.42 (134.6)					
8.6 (338.6)	4 (157.5)	4.4 (173.2)	[4.4] [(173.2)]		4.8 (189.0)	[3.42] [(134.6)]		5.4 (212.6)	[4.01] [(157.9)]	
	5 (196.8)	4.4 (173.2)	3.37 (132.7)		4.8 (189.0)	3.42 (134.6)		4.01 (157.9)	4.01 (157.9)	
	6 (236.2)	3.37 (132.7)	3.37 (132.7)		3.42 (134.6)					
9.2 (362.2)	4 (157.5)	4.4 (173.2)	[4.4] [(173.2)]		4.8 (189.0)	[4.8] [(189.0)]		5.4 (212.6)	[4.01] [(157.9)]	
	5 (196.8)	4.4 (173.2)	4.4 (173.2)		4.8 (189.0)	4.8 (189.0)		5.4 (212.6)	4.01 (157.9)	
	6 (236.2)	4.4 (173.2)	4.4 (173.2)		3.42 (134.6)	3.42 (134.6)		4.01 (157.9)		
9.8 (385.8)	4 (157.5)	4.4 (173.2)	[4.4] [(173.2)]		4.8 (189.0)	[4.8] [(189.0)]		5.4 (212.6)	[5.4] [(212.6)]	
	5 (196.8)	4.4 (173.2)	4.4 (173.2)		4.8 (189.0)	4.8 (189.0)		5.4 (212.6)	5.4 (212.6)	
	6 (236.2)	4.4 (173.2)	4.4 (173.2)		4.8 (189.0)	4.8 (189.0)	[3.42] [(134.6)]	5.4 (212.6)	4.01 (157.9)	
11.2 (440.9)	4 (157.5)	4.4 (173.2)	[4.4] [(173.2)]		4.8 (189.0)	[4.8] [(189.0)]		5.4 (212.6)	[5.4] [(212.6)]	
	5 (196.8)	4.4 (173.2)	4.4 (173.2)	[4.4] [(173.2)]	4.8 (189.0)	4.8 (189.0)	[4.8] [(189.0)]	5.4 (212.6)	5.4 (212.6)	[5.4] [(212.6)]
	6 (236.2)	4.4 (173.2)	4.4 (173.2)	[4.4] [(173.2)]	4.8 (189.0)	4.8 (189.0)	[4.8] [(189.0)]	5.4 (212.6)	5.4 (212.6)	[4.01] [(157.9)]
	8 (315.0)	4.4 (173.2)	4.4 (173.2)	3.37 (132.7)	4.8 (189.0)	4.8 (189.0)	3.42 (134.6)	4.01 (157.9)	4.01 (157.9)	[4.01] [(157.9)]
11.4 (448.8)	5 (196.8)	4.4 (173.2)	4.4 (173.2)	[4.4] [(173.2)]	4.8 (189.0)	4.8 (189.0)	[4.8] [(189.0)]	5.4 (212.6)	[5.4] [(212.6)]	[5.4] [(212.6)]
	6 (236.2)	4.4 (173.2)	4.4 (173.2)	[4.4] [(173.2)]	4.8 (189.0)	4.8 (189.0)	[4.8] [(189.0)]	5.4 (212.6)	5.4 (212.6)	[5.4] [(212.6)]
	8 (315)	4.4 (173.2)	4.4 (173.2)	3.37 (132.7)	4.8 (189.0)	4.8 (189.0)	3.42 (134.6)	5.4 (212.6)	4.01 (157.9)	4.01 (157.9)

NOTE 1 Table 6 shows the maximum rigid length for a set of UTA categories, umbilical MBR, and the size of reel and barrel. The table can also be used to show the maximum STI length by adding the relevant formulae. The table provides guidance for STI lengths based on MBR values of 1.0 m, 2.5 m, and 4.0 m, which have been chosen as examples for how to use the Annex B equations. For specific project requirements, the user can refer to the length equations in Annex B.

NOTE 2 Rigid length is calculated from the combined maximum values for STI length from Table 5 and UTA length from Table 4.

	Steel tube or thermoplastic STI
[…..]	Steel tube or thermoplastic STI, umbilical requires false barrel
	Thermoplastic STI only
[…..]	Thermoplastic STI only, umbilical requires false barrel
	Insufficient space for STI and UTA or MBR

The dimensions given in Table 6 are the maximum rigid lengths for either steel or thermoplastic umbilicals for a given UTA category and MBR.

The two examples below show how the above approach can be used.

EXAMPLE 1

If the project has a Category “C” UTA and a steel tube umbilical with 2.5 m MBR, the smallest standard size of reel would be a 9.8 m diameter and a 5 m barrel diameter, with an estimated rigid length of 5.4 m.

EXAMPLE 2

If the same project’s installation campaign is reliant on a vessel of opportunity, the same umbilical is likely to fit in the following configuration with some additional prework.

If the available vessel had a 9.8 m diameter reel with only a 4 m barrel diameter, then the reel will have to be modified by the installation of a false barrel. (See Figure B.1.)

These examples provide a quick reference to the reader and gives guidance to how the table can be used. The table can also indicate if the original design falls outside the typical standard reel sizes and could indicate if a project specific reel(s) will be required. Such information may prove to be helpful during early stages of making selection and planning.

8.6 Optimization Assessment

The optimization assessment aims to guide the user through the process for optimizing the process of installation of umbilical and UTA. The methodology takes into account several factors such as the environmental conditions (water depth, sea state), installation system, size, and weight of the structure.

The aim of this table is to provide guidance to the user for being aware of the consequences of UTA size relating to optimization and installation operation. Table 7 should be used to assess the implications in terms of cost, schedule, and risk.

Table 7—Optimization Assessment

Cost and Schedule Impact	Low	High
UTA class	A	D
Water depth	<100 m	3000 m+
Limiting sea state	>3 Hs	<1 Hs
Type of lay system	Any	Open VLS
Rigid length	Short (<3 m)	Long (>5 m)
Minimum bend radius	<1 m	>3 m
SUT weight	<3 Te	>15 Te
Size of foundation structure	Small (installable with the umbilical)	Large (preinstalled foundation)
Time until installation	>24 months	<3 months
Delivery method	Any	Carousel
Installation complexity	Simple	Complex

Annex A
(informative)

Packing of a UTA with the Confines of an Installation Reel or Carousel

A.1 Design Considerations

A.1.1 Packing Design

When considering the packing of a UTA within the confines of a transport/installation reel, the design engineer shall assess the methods required for handling and onshore storage and also loadout onto an installation vessel for installation with consideration to the following.

— Safe access to ALL rigging when onshore and offshore with minimal working at height.

— The project offshore lifting standard and certification requirements.

— SUT first and second end lay. Note that for first end of the reel or carousel lay, the SUT supporting mechanism can be designed to allow the SUT to extend outside of the reel flanges. In the case of a carousel, the SUT is normally positioned on the carousel roof.

— Reel hub drive (RHD) system or under-roller for rotating the reel.

— Load rating/testing of the reels' UTA support structure and rigging attachment points.

— Routing and anchorage of the umbilical.

— Positioning of bend stiffeners or limiters and anchorage, with particular attention to long-term bending of bend stiffeners.

— Design of rigging considering dynamic and rotational acceleration.

— Clearance of the umbilical and UTA from reel rim and driving system.

NOTE When using RHDs, the reel cradles can be higher to enable SUTs that protrude past the outer rim to pass between the higher cradles.

— Second end holdback anchorage of the UTA and umbilical or cable, with particular attention to both tension and compression of the umbilical or cable at the point of partition crossover.

— Environmental protection of partially dis-assembled equipment.

— Accessibility to install and use pressure and electrical monitoring equipment.

— Reel weight distribution.

— Radial offset weight balance of the reel for lifting and rotation.

— Reel lifting beam/rigging offset loading.

— Packaging of removed equipment, i.e. remotely operated vehicle (ROV) grab bars, dummy connectors, etc.

— Drawings and procedures.

A.1.2 Reel and Drive System

Reels shall be sized for the total weight of the umbilical, UTA(s), and all ancillary equipment. The designer should also consider the following:

— load distribution of product on the reel and lifting equipment, to ensure compliance with the reel load/test certification;

— uneven weight distribution;

— drive system, where under-rollers may extend beyond the inner edge of the reel rim;

— low support structures, where access may be limited due to reel support cradles;

— structural strength of the rigging points;

— not welding rigging points to critical structural members of the reel.

Reel design may require additional structural analysis. Industry standards such as DNV 2.7-3 can provide guidance on the design and design margins for these units.

A.1.3 Carousel Installation (See Section 8.4—Selection of Packing a Reel or Carousel)

Where carousels are used, the requirement for the SUT to be of minimal dimensions and weights become largely invalid. The SUTs are almost always placed on the roof of the carousel, which has a large area capable of holding several SUTs or flexible riser/flowline end fittings.

While reels are relatively easily loaded and transported, and leave flexibility in installation lay-spread and vessel, carousels are not. The manufacturer generally has to set aside a carousel for the duration of the storage period, and the installation vessel must have a carousel on board or have a temporary carousel installed on deck, which is very time-consuming and has cost implications due to extensive marine engineering man-hours and vessel specification.

A.1.4 SUT Support Structure

The UTA support structure should be designed with consideration to the following and the prevailing offshore lifting standard and certification requirements.

— The structure should be easy to install and ideally adaptable to allow for a SUT loading tolerance.

— Ideally the structure should be designed and positioned to remove the need for disassembly offshore.

— If removal is required offshore, adequate lifting points should be provided and component weights marked.

— If any hot work (e.g. welding of sea-fastening brackets and supports) is being carried in the proximity of the SUT, adequate protection shall be used to prevent damage to the SUT and umbilical.

A.1.5 Rigging Equipment

All rigging equipment should be designed to prevailing offshore lifting standard and certification requirements and consideration of the following.

— Dynamic loading of the rigging and padeyes.

— Generally chain falls (chain block hoists) are the preferred lifting/lowering system offshore; this allows the deck crew to work at deck level and clear of the descending UTA.

— Ratchet lever hoists are generally used to rig fore and aft of the UTA.

— Once installed, chain falls and ratchet lever hoists should have chain lockers attached to secure.

— Long-term effect of high-grade steel rigging in an offshore environment.

A.1.6 Umbilical Packing

The routing of the umbilical through the packing should consider the following.

— Maintaining the MBR.

— Preventing damage to the outer sheath or roving from chafing, axial moment, or overtightening of the securing system.

— Stored energy in umbilical or cable when released.

A.1.7 Bend Stiffeners

Consideration shall be given to the amount of bending the bend stiffener is subjected to and the duration; typically to prevent a permanent set a bend stiffener should not be bent for more than the maximum period specified by the manufacturer.

As a rule of thumb, the bend stiffener should not be bent more than $^1/_3$ of its length for packing purposes; in all cases the bend stiffener manufacturer must advise the amount of bend vs duration.

A.1.8 Transportation and Installation Core Monitoring Systems

The UTA designer should take into consideration the packing, transportation, and installation monitoring requirements and make allowance for this in ensuring that the UTA test ports can be safely accessed in order to install the monitoring system sensors. If the UTA is easily accessed but on the roof of a carousel prior to sail-away, technicians can install wireless transmitters with which to send the sensor values remotely to a control cabin. Where the UTA is packed within the confine of an installation reel partition, designer should allow for extension of test ports to ground level for direct connection of monitoring hoses and cables or safe and ease of access to install a similar wireless monitoring system as per that on top of a carousel.

Annex B
(informative)

STI and SUT Length Calculations

B.1 Equation

Case A: Maximum permissible STI length = L_{STI}

(For a UTA with a front padeye length that equals 1/2 the UTA height.)

$$L_{\mathrm{STI}} = \left(\left(\sqrt{\left(R_{\mathrm{R}} - \mathrm{MBR} - \mathrm{FBC} + \frac{D_{\mathrm{prod}}}{2}\right)^{2} - (H_{1} - \mathrm{MBR})^{2}}\right) + \left(\sqrt{(R_{\mathrm{R}} - \mathrm{FBC})^{2} - {H_{1}}^{2}}\right)\right) - L_{\mathrm{UTA}} \quad \text{(B.1)}$$

Case B: Maximum permissible STI length = L_{STI}

(For a UTA with no front padeye or a padeye length less than 1/2 the UTA height.)

$$L_{\mathrm{STI}} = \left(\left(\sqrt{\left(R_{\mathrm{R}} - \mathrm{MBR} - \mathrm{FBC} + \frac{D_{\mathrm{prod}}}{2}\right)^{2} - (H_{1} - \mathrm{MBR})^{2}}\right) + \left(\sqrt{(R_{\mathrm{R}} - \mathrm{FBC})^{2} - {H_{1}}^{2}}\right)\right) - \left(L_{\mathrm{UTA}} + \frac{H_{\mathrm{UTA}}}{2}\right) \quad \text{(B.2)}$$

where

R_{R} is the reel rim radius (m);

R_{B} is the reel barrel radius (m);

FBC is the free board clearance (m);

L_{UTA} is the length of UTA including padeye (m);

H_{UTA} is the overall height of UTA (m);

D_{prod} is the diameter of product (umbilical or cable) (m);

MBR is the minimum bend radius of product (umbilical or cable) (m);

H_{rig} is the height of support rigging between barrel and UTA (m);

H_{1} is the distance between reel center to UTA centerline (m);

$$H_{1} = R_{\mathrm{B}} + H_{\mathrm{rig}} + \left(\frac{H_{\mathrm{UTA}}}{2}\right).$$

B.2 Umbilical or Cable Length Calculator

Total storage capacity (m) of umbilical or cable to be placed in Bay (B); see Figure B.1:

$$L_{\mathrm{prod}} = \left(k_1 * k_2 * \pi * \left(D_{\mathrm{b}} + k_2 * D_{\mathrm{prod}}\right)\right) * k_3 \tag{B.3}$$

where

L_{prod} is the total length of product (umbilical or cable (m);

D_{prod} is the diameter of product (umbilical or cable) (m);

FBC is the free board clearance (m);

D_{f} is the reel flange diameter (m);

D_{b} is the barrel diameter (m);

W_{t} is the reel traverse width;

W_{p} is the partition width (m);

W_{UTA} is the maximum width of UTA (m);

W_{c} is the UTA to reel clearance (each side) (m);

k_1 is the width fill factor (unitless),

$$k_1 = \mathrm{round}\left(\frac{(W_{\mathrm{t}} - (W_{\mathrm{UTA}} + W_{\mathrm{P}} + W_{\mathrm{c}} * 2))}{D_{\mathrm{prod}}}, 0\right);$$

k_2 is the height fill factor (unitless),

$$k_2 = \mathrm{round}\left(\frac{\left(\frac{(D_{\mathrm{f}-2*\mathrm{FBC})-D_{\mathrm{b}})}}{2}\right)}{D_{\mathrm{prod}}}, 0\right);$$

k_3 is the product fill factor (%) (typically 80%).

Figure B.1 shows an illustration of storage of umbilical or cable placed in a bay.

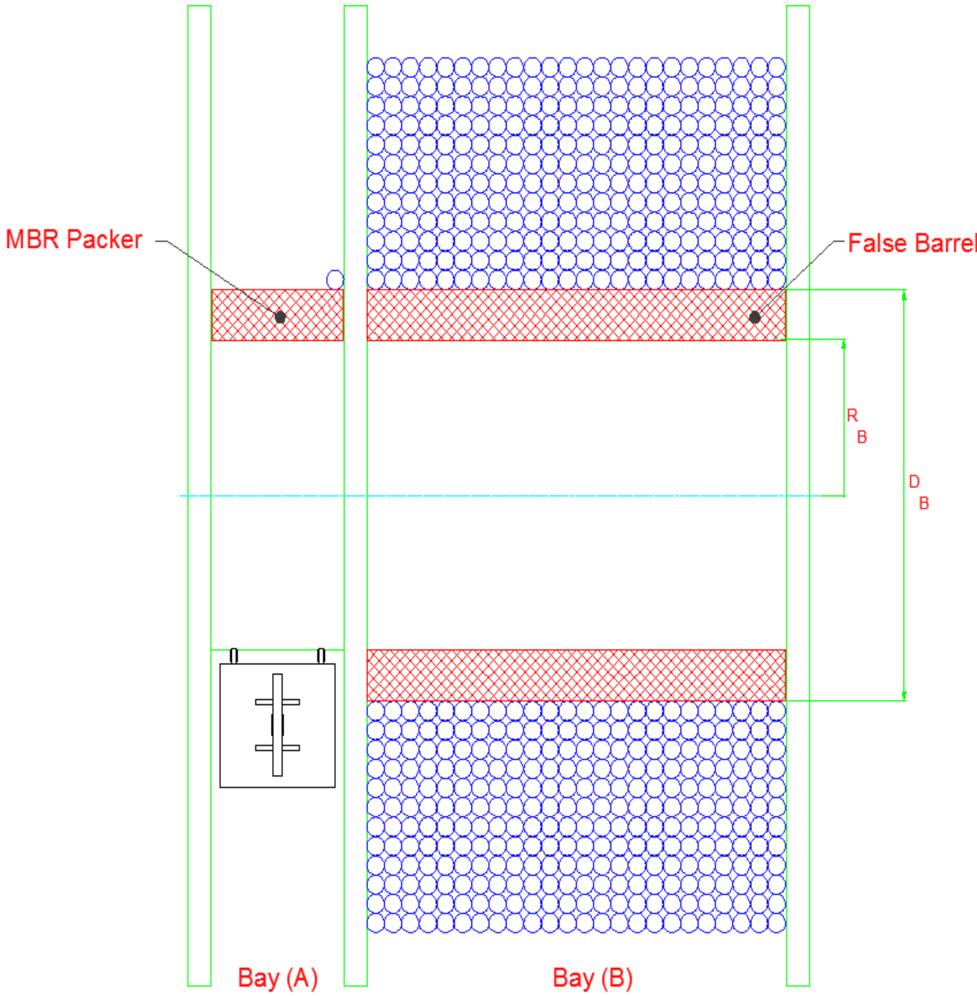


Figure B.1—Storage of Umbilical or Cable Placed in a Bay

Annex C
(informative)

False Barrel Diameter Calculations

The false barrel build up diameter required (see Figure 14 and Figure C.1) to maintain the umbilical manufacturer's stated MBR

$$D_{\mathrm{B}} = (\mathrm{MBR} * 2 - H_1) * 2 + D_{\mathrm{prod}} \tag{C.1}$$

where

D_{B} is the false barrel diameter;

R_{B} is the reel barrel radius (m);

H_{UTA} is the overall height of UTA (m);

D_{prod} is the diameter of product (umbilical or cable) (m);

MBR is the minimum bend radius of product (umbilical or cable) (m);

H_{rig} is the height of support rigging between barrel and UTA (m);

H_1 is the distance between reel center to UTA centerline (m),

$$H_1 = R_{\mathrm{B}} + H_{\mathrm{rig}} + \left(\frac{H_{\mathrm{UTA}}}{2}\right).$$

Annex D
(informative)

Responsibility Matrix

The responsibility matrix (Table D.1) includes the typical roles and responsibilities of multiple parties involved in the design, development, manufacture, and installation of UTAs. The matrix is for informative purpose and can be used through the field planning and development phase.

Table D.1—Responsibility Matrix

Typical Umbilical System Design, Manufacturing, and Installation Roles				
Activity	**Operator**	**Umbilical Manufacturer**	**UTA Manufacturer**	**UTA Installer**
Umbilical system requirements	Establishes and monitors communication between the umbilical and UTA manufacturers. Transmits umbilical system configuration, functional, and operational requirements.	The umbilical manufacturer is presented with the umbilical system configuration.	The UTA manufacturer is presented with the umbilical system configuration.	N/A
Umbilical system configuration	Establishes and monitors communication between the umbilical and UTA manufacturers. Approves the design solution and manufacturing process.	Designs umbilical bundle, structural, and mechanical interfaces to the UTA to meet project requirements.	The UTA manufacturer is provided the umbilical configuration.	The installer is presented with the umbilical system configuration and properties for review and comments from installation perspective to ensure configuration is installable.
UTA design	Establishes and monitors communication between the umbilical and UTA manufacturers. Approves the design solution and manufacturing process.	Reviews the UTA design and provide feedback to operator and UTA manufacturer.	Designs UTA to accommodate interfaces to the umbilical bundle and meet project requirements transmitted.	The installer is to be informed about design parameters and layout/interfaces of the UTA.
Umbilical bundle and UTA components	Takes ownership of the equipment designed and manufactured in compliance with the project technical requirements.	Coordinates with the operator the acceptance activities of the equipment manufactured.	Coordinates with the operator the acceptance activities of the equipment manufactured.	The installer witnesses the acceptance activities where practicable and is made aware of any technical issues associated with the components to assess installation implications.
Umbilical bundle and UTA Assembly process and FAT	N/A	Assembles the umbilical bundle to the UTA in accordance with the project requirements.	Provide support as requested by the operator.	N/A

Typical Umbilical System Design, Manufacturing, and Installation Roles				
Activity	**Operator**	**Umbilical Manufacturer**	**UTA Manufacturer**	**UTA Installer**
Umbilical bundle and UTA SIT	Establishes the site integration test requirements, issues the test specification, and is responsible for coordinating all activities.	Supports the SIT activities and can provide labor and resources.	Supports the SIT activities and can provide labor and resources.	The installer witnesses the acceptance activities where practicable and is made aware of any technical issues arising during SIT to assess installation implications and for warranty.
Umbilical system assembly Post loadout	Takes ownership of the equipment designed and manufactured in compliance with the project technical requirements.	Coordinates with the oil field developer and acceptance activities of the equipment manufactured.	N/A	Takes custody of the designed, manufactured, and tested equipment in compliance with the oil field operator's project technical requirements and installs items in line with installation design criteria.
Installation	Takes ownership of the equipment designed and manufactured in compliance with the project technical requirements and free issues where appropriate to installer and monitors where appropriate via manufacturers installation activities in accordance with class design requirements. Will also include post-installation tests.	Coordinates with the installer the acceptance activities of the equipment manufactured in accordance with oil field/company requirements.	Coordinates with the installer the acceptance activities of the equipment manufactured in accordance with oil field/company requirements.	Takes custody of the designed, manufactured and tested equipment in compliance with the oil field operator's project technical requirements and installs items in line with installation design criteria.
System commissioning	Takes ownership of the post-installation activity and verification of functionality prior to system's start-up.	Supports the commissioning activity and can provide labor and resources.	Supports the commissioning activity and can provide labor and resources.	Supports the commissioning activity.

Bibliography

[1] API 17I, *Installation of Subsea Umbilicals*

[2] DNV 2.7-3, *Portable offshore units*

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