Comparison of Steel Tubes and Thermoplastic Hoses in Umbilical Service

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COMPARISON OF STEEL TUBES AND THERMOPLASTIC HOSES FOR UMBILICAL SERVICE

Umbilicals used for the control of subsea production systems contain fluid conduits for the provision of hydraulic power and transportation of chemical injection fluids (corrosion / scale / hydrate inhibitors / methane, etc.). They may also be used to vent well produced fluids from the annulus of a well head arrangement. Two types of fluid conduits are utilised in umbilicals, steel tubes and thermoplastic hoses with widely differing characteristics. Thermoplastic hoses were first used in umbilical service in the mid 1970's, with steel tubes being seriously considered in the late 1990's with the advent of higher strength and more corrosion resistant grades of Stainless Steel.

Thermoplastic hoses are relatively flexible and of low tensile strength; steel tubes are relatively stiff and of high tensile strength. To those not involved in the engineering and design of umbilicals these opposing characteristics can appear confusing. It is, however, these opposing characteristics which gives the umbilical designer a wide scope in order to technically and commercially optimise the fluid conduits and umbilical design specific to a project requirement. Such optimisation includes combinations of steel tubes and thermoplastic hoses in an umbilical (hybrid design).

In order to better appreciate the differences between the two types of fluid conduits this UMF Guidance Note document has been developed to illustrate the differences between the two types of fluid conduits.

Subject	Steel Tube	Thermoplastic Hoses
Construction	"Seam welded" from strip or "seamless" from hollows. Seamless only available in relatively short lengths, necessitating welding to achieve production lengths. Depending on base material of construction, tubes may be metallic or polymer sheathed for corrosion resistance requirements.	Seamless inner thermoplastic tube (liner) acting as a diaphragm seal, one or more layers of high tenacity yarn (reinforcement) acting as pressure retaining element, extruded sheath providing mechanical and environmental protection. In some instances the liner may incorporate an internal support arrangement (carcass) to resist external hydrostatic pressure.
Materials of Construction (Typical)	Tube: Carbon Steel, Stainless Steel (Duplex, Super Duplex, etc). Sheath: Zinc or polyethylene bonded to the tube in both instances for corrosion protection. May be non-bonded thermoplastic for mechanical protection or geometrical conformance.	Liner: Polyamide 11, polyethylene. Reinforcement: High strength fibre, (aramid). Sheath: Polyamide 11, polyethylene. Carcass: Stainless Steel (316L) Note: May be oversheathed with suitable thermoplastic polymer for geometrical conformance.
Maximum Continuous Component Manufacturing Length (Typical)	Seamless: 10-30m depending on bore size/tube wall thickness Seam Welded: 3,000 – 8,000m depending on bore size / tube wall thickness.	Non-carcass: 5,000 - 24,000m depending on bore size / pressure rating Carcass: 3,000 - 18,000m depending on bore size / pressure rating.
Typical Bore Size Range	13 – 50mm, production umbilical service 13 – 100mm, integrated production umbilical service (IPU)	6 – 50mm, production umbilical service.
Design Working Pressure (DWP)	Stainless Steels:- • 316L : 862 bar / 12,500 psi • 19D : 1,207 bar / 17,500 psi • Super Duplex : 1,517 bar / 22,000 psi • Carbon Steel : 1,207 bar / 17,500 psi Note: The above values are general indicators only as other issues such as pressure test factor, service conditions, lay-up, etc., all	862 bar / 12,500 psi Note: as bore size increases, DWP decreases.

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	influence maximum practical wall thickness and hence the DWP.	
Safety Factor	Normally 1.25-1.50 based on minimum yield strength. Note: Unlike the hose criteria for burst pressure to design work pressure (DWP) ratio, steel tubes are designed based on mechanical properties of the tube material, principally its specified minimum yield strength (SMYS).	4:1 based on minimum burst pressure to DWP ratio.
Design Standard	ISO 13628-5 Petroleum and natural gas industries – Design and operation of subsea production systems – Part 5, subsea umbilicals API 17E Specification for Subsea Production Control Umbilicals Note: ISO 13628-5 and API 17E are basically the same document under a sharing agreement.	
End Connections	Welded fittings or welded to mating tube forming part of the umbilical termination arrangement. Note: Following installation, access to end connections is a major issue. The issue of heavy duty fittings with a secondary sealing arrangement is strongly recommended, if screwed connections are employed.	Permanently attached fittings by means of crimping or swaging. Note: Following installation, access to end connections is a major issue. The issue of heavy duty fittings with a secondary sealing arrangement is strongly recommended.
Welding	Butt weld: 100% X-ray inspection. Thick walled tubes require multiple welding passes (typically 2-4 depending on bore size / wall thickness), 100% X-ray after each weld pass. Seam Welds: Continuous eddy current inspection. This may also be combined with ultrasonic inspection. Stainless Steels require the tubes to be purged with inert gas to ensure the welds are to the correct specification.	Welding is only applicable if end fitting is designed to be welded to mating tube / end fitting.

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Corrosion / Compatibility	Carbon and Duplex steels (and Super Duplex where the surface temperature will exceed a critical limit) require the presence of external corrosion protection for service in a marine environment. For fluids of a corrosive nature, the material of construction will need to be confirmed as suitable for the intended fluid. Generally 'Stainless Steel' materials of construction offer very high levels of corrosion resistance. However, it is known that seawater containing sulphite reducing bacteria can result in corrosion of welds.	The use of polymers with high levels of chemical and fluid resistance generally ensures compatibility with fluids is not normally an issue. Where new and / or untested service fluids are proposed these should be subject to a compatibility screening programme.
Permeability	No permeability.	To be considered where the fluid is of low molecular weight. The issue of permeability has been addressed by the use of ultra-low permeation hose liner materials and appropriate venting of trace amounts of permeated fluid.
Collapse Resistance	Very high due to the inherent strength of the tube, further increased if fluid filled with a specific gravity of 1.0 or greater.	For standard hoses filled with fluids of specific gravity of less than that of seawater (1.024), collapse may be an issue, in particular as bore size and / or water depth increase. Where collapse is an issue this may be overcome by the use of a carcass reinforced hose. Where the internal fluid specific gravity is >1.024 thermoplastic hoses can generally be used in deepwater applications. Note: where collapse is an issue and cannot be resolved by the use of

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		an equivalent carcass construction with a specific hose, the use of a steel tube may offer the optimum technical and commercial solution.
Crush Resistance	Resistance to crushing is very high. Notes: 1. Tubes having a relatively thin wall compared to tube diameter (i.e. typically D/t>20) may need special care in handling, throughout the various manufacturing processes. 2. During the laying-up operation, crushing of weaker components (e.g., optical fibre cables) may be an issue.	Low resistance to crushing in the unpressurised state, but with functionality unimpaired unless repeated total collapse. Note: During lay-up and installation hoses are pressurised during those operations to ensure crushing is not an issue.
Volumetric Expansion	Very low, useful where fast pressure pulse response time is a major requirement. Also minimises size of fluid reservoir in topside hydraulic power units.	Typically 7-10% at DWP reducing by about 10% in a short period of time in service due to ‘normalising’ of the hose structure. Some very high DWP hoses may have values in excess of 10%. Volumetric expansion of a thermoplastic hose provides an accumulator effect eliminating the requirement for, or reducing the size of, subsea accumulators.
Track Record	In the early use of Super Duplex some issues with tube properties below specification due to incorrect heat treatment. Some instances of seam welded tubes failing at the seam. With the lessons learnt and investigation programmes, the industry now has a high level of confidence in selected steel tube designs for umbilical service. Over 15 years experience in umbilical service.	Initially some issues associated with the use of an inappropriate hose liner material and methanol permeation. The change of material and appropriate venting has eliminated these issues. With the change of material of construction and hose / umbilical design criteria, thermoplastic hoses provide a reliable and versatile means of conveying fluids at high pressure in umbilical service. Over 30 years experience in umbilical service.

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Flex Fatigue	A large bore centrally located steel tube in an umbilical can restrict areas of usage and / or installation configuration. For dynamic service, tubes need to be oversheathed or prevented for coming into direct contact with each other to prevent wear and potential for premature failure.	Very high level of resistance to flex fatigue and, generally, ideal for severe dynamic service (floating production facility, etc).
Typical Areas of Usage	Medium and deepwater with resultant medium to high hang-off loads during installation / dynamic service.	Shallow / medium depth installation or deepwater with appropriate service fluids and / or suitable collapse resistant design of hose. Light and heavy duty dynamic service.
Minimum Bend Radius (MBR)	Larger than thermoplastic hose equivalent umbilical and for arduous dynamic service increases significantly. Also increases as umbilical loading increases.	Typically 10 x umbilical diameter for storage. Increases as umbilical loading increases.
	Note: MBR is a factor in determining the installation spread required to install an umbilical.	
Installation	Larger MBR may impact on size / capacity of installation spread. Deepwater installations result in high hang-off loads and high gripping loads by the installation cable hauler. Resistance to crush in a consolidated umbilical is very high. Steel tube umbilicals frequently unarmoured. Where the umbilical is to be trenched there is an increased risk of sheath removal and damage / contamination of the underlying functional components.	Larger diameter / heavier weight may impact on size / capacity of installation spread, Thermoplastic hose umbilicals are invariably double wire armoured. Reduced risk of damage to underlying functional components during deployment and trenching operations
Offshore Repair	Offshore repair may not be possible necessitating recovery of the umbilical and transportation to a dockside location.	Invariably, repair can be effected on the deck of the installation / recovery vessel.
Design Life (typical)	Up to 30 years achievable with a factor of safety of 10 in respect of	Up to 20 years achievable with a 4:1 safety factor in respect of

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	fatigue life.	pressure capability, and a factor of 10 in respect of fatigue life.
Seabed Stability	Unarmoured steel tube umbilicals may need additional ballast to achieve seabed stability requirements; may be in the form of a steel rope(s) or steel rods incorporated in the umbilical or one or more layers of armour wires. Such armouring may also be required where an umbilical is laid over rock out-crops on the seabed.	If seabed stability is an issue, generally resolved by increasing the gauge (diameter) of the armour wires or adding additional layers of armour wire and / or high density fillers with the bundled functional components.
Tensile Strength	Very high allowing the tubes to act as the tensile strength member in the umbilical as well as the pressure retaining member. This results in a smaller and lighter umbilical compared with its thermoplastic hose equivalent provided that additional ballasting / protection is not required.	Very low requiring the umbilical to be provided with a tensile strength member, usually in the form of double wire armouring. An important secondary benefit of armouring is protection to the umbilical functional components during umbilical handling, installation and service.
Temperature Limit-Marine Environment	Zinc clad: up to 100^{0}C Polymer sheathed: up to 80^{0}C Super Duplex – non sheathed: 55^{0}C	40^{0}C max typically, up to 60^{0}C intermittent.
Cleanliness	Carbon steel requires extensive flushing with descaling agents, followed by chemical passivation in order to achieve required cleanliness. Flexing of the tube can cause the fluid to go out of specification, which may be critical for control lines but acceptable for chemical injection lines. Stainless Steels readily flushed clean and do not require descaling agents. Cleanliness maintained during flexing.	High levels of cleanliness achieved without the requirement to purge with cleaning agents. Cleanliness maintained during flexing.
Conduit Sizing	Use of multiple smaller bore tubes preferable to single large bore tube resulting in:- • Reduced umbilical bending stiffness	Only an issue when DWP requirement for a required bore size cannot be satisfied. Two or more smaller bore hoses in parallel may offer a solution.

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	• Enhanced fatigue life • Elimination of multi-pass welding • Increase in system contingency availability	