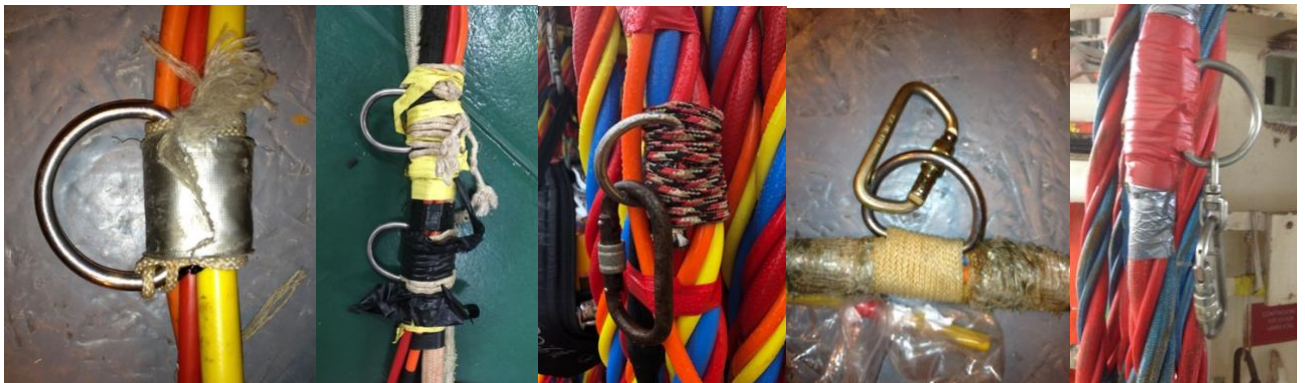


# Diver to Umbilical Attachment Hazard Observation

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Date: October 2019



1.0 Introduction ..... 1

    1.1 Purpose ..... 1

    1.2 Objectives ..... 1

    1.3 Limitations..... 1

2.0 Umbilical Tension Relief: Description of Assembly and Considerations ..... 2

    2.1 Diver Harness ..... 3

    2.2 Load-Bearing Connector ..... 4

    2.3 D-Ring..... 6

    2.4 D-Ring Attachment Binding ..... 7

    2.5 Diver Umbilical..... 9

3.0 Testing Criteria ..... 10

    3.1 Current Testing Requirements ..... 10

    3.2 Current Testing Practices ..... 10

    3.3 Suggested Testing Requirements ..... 10

4.0 Recommendations ..... 11

Appendix 1 Draft Detail Sheet for IMCA D18 ..... 13

Appendix 2 References and Source Material ..... 14

## 1.0 Introduction

A diver's umbilical arrangement comprises various components; umbilical, harness, D-ring bound on the umbilical and a link connector between the D-ring and harness.

Industry seeks to minimize the effects of any potential equipment failure by setting testing criteria; however, this report identifies that the industry should go further in the choice of components, testing and inspection of this safety-critical connection.

There are standards for harnesses and umbilical manufacture and testing; however, there are no standards or guidelines for the D-ring or binding of it to the umbilical nor selection of clip linking the diver to the D-ring. There are no in-service test criteria for D-ring security or the competency of person binding any D-ring, if indeed the D-ring is still a valid method of attachment.

The attachment of the diver to their umbilical is safety-critical, although the failure is low probability the impact would be high consequence.

### 1.1 Purpose

The purpose is to highlight to the industry that there are gaps in the procedural, selection of equipment and testing of the connection assembly between the divers umbilical and the divers harness.

### 1.2 Objectives

- Highlight that there are inconsistencies in the method of attaching the diver to their umbilical, the equipment used, testing, and competencies of those in securing the D-ring to the umbilical.
- Suggest best working practices to commercial diving industry bodies for discussion and workgroups.
- Industry workgroups seek to implement uniformity throughout and conclude a rational outcome to changes to guidance notes and therefore improve diver safety.
- Suggest another method of attachment that is approved lifting equipment.
- Update practice and thinking on how and where the diver and umbilical are connected.

### 1.3 Limitations

No physical testing of equipment has been carried out by the author.

A primary reference is a British Standard / European Standard; BS EN 15333. This standard does not cover saturation diving systems nor mini bell systems; however, it is used as best practice because the referenced sections are not just 'air range' topics.

Another primary reference is the USN Umbilical Manual. This manual deals with US Navy equipment. The author has used this as best working practice as it is the only source material found for umbilical to diver attachment arrangements.

## 2.0 Umbilical Tension Relief: Description of Assembly and Considerations

The diver is connected to their umbilical by the harness they are wearing which is connected by a steel connector to a D-ring that is bound to the umbilical.

Standard industry references for the strength properties of the umbilical and tension relief assembly:

- EN15333: *'The apparatus shall have a lifeline that can be used to help recover a diver in distress. It may be a separate line or can be the umbilical. The lifeline, including any connectors, shall be capable of withstanding a tensile load of 3500N ( approx.360kgf) without damage.'*
- NORSOK implies that a diver may be recovered by their umbilical *'The umbilical shall be of sufficient strength to ensure intact vital functions during emergency recovery.'*
- IMCA D22: *'The umbilical also acts as a lifeline and should be strong enough to lift a fully equipped diver from the water.'*

Industry allows the recovery of a diver by their umbilical, necessitating the requirement for tested, certified lifting equipment.

KMDSI sum it nicely, in a non-specific way:

*'The umbilical must now be hooked to the diver's harness utilizing a suitable clip that is bound to the umbilical. Some divers and companies prefer a quick release clip and others prefer a clip that is screwed together so the diver cannot easily remove it from his harness. The securing of the umbilical keeps any tensile force at the diver's harness and not on the helmet.'*

*'Never dive without attaching the umbilical to some type of harness or clip on the diver's body. Never allow the umbilical to pull on the helmet directly, or the diver could suffer a neck injury.'*

## 2.1 Diver Harness

Standard industry references for divers personal harnesses are:

- IMCA D18 *Code of Practice for The Initial and Periodic Examination, Testing and Certification of Diving Plant and Equipment* requires; 'Manufactured to an appropriate national or international standard and fit for the purpose for which it will be used for.'
- EN 15333 which requires, 'The body harness shall provide a method to securely attach the umbilical to the diver. Each securing point on the body harness shall withstand a tensile load of 3 500 N (Approx. 360kgf) for 5 minutes. EN15333
- ADCI: Harness, 'Is equipped with at least one attachment point for the umbilical that is rated to at least the same breaking strength as the lifeline or strength member in the umbilical bundle. If the harness has multiple attachment points of different strengths, those suitable for umbilical attachments are to be clearly identified. Each securing point intended for attaching an umbilical or lifting a diver out of the water in an emergency shall withstand a tensile of at least 2,000 pounds' (907kg)

Currently, IMCA does not clearly state that a personal harness or 'lift harness' is to be worn by a diver. IMCA D22 implies that a 'lift harness' is to be worn for SRP diving operations: 'There should be two full sets of diving equipment, including appropriate harnesses to aid diver recovery.'

- Note: EN15333 makes a distinction between the 'Body Harness' and the 'Lift Harness'. The body harness carries the independent emergency supply; therefore in commercial diving, the body harness is the bailout harness/jacket, stab jacket or SLS system
- The lift harness is the harness worn closest to the diver's body and used to recover an incapacitated diver
- Note: There should be no 'personally owned' harnesses on-site; all harnesses should be tracked through the company PMS and comply with IMCA D18 Detail sheet 35

Further investigation should be carried out to see if the industry should advise on where the umbilical should be connected to the diver, or if contractors should risk assess and state in their diving operations manual.

Consider the advantages and disadvantages:

- Surface supplied divers typically connect their umbilical to their body harness, the harness that carries the emergency reserve. Connecting to the bail-out harness most likely is custom and practice in case the diver needs to ditch their equipment and carry out a free ascent, also attaching to the bailout harness saves time when undressing when carrying out Sur-D-O<sub>2</sub>.
- EN15333 states; 'The body harness shall provide a method to securely attach the umbilical to the diver. Each securing point on the body harness shall withstand a tensile load of 3500 N for 5 minutes'. Therefore the bailout harness, SLS and Stab jacket should conform to EN15333. Typically this is not the case; bailout harnesses comply with EN250:2000 Respiratory equipment; open circuit, self-contained air diving apparatus. There is no lifting/D-ring pull requirement in EN250:2000; however, manufacturers may have tested the tensile load themselves.

Note EN250:2000 has been withdrawn and replaced by EN250:2014

- Closed bell divers typically attach their umbilical to their lift harness. This practice is so, if required, they can remove the bailout before entering the bell trunk during standard and emergency operations. The bellman only wears a lift harness; therefore, the umbilical attaches to it.

## 2.2 Load-Bearing Connector

The universally accepted method of attaching the umbilical to the diver and providing tension relief to the individual hose ends on the diver's helmet, is utilising a load-bearing connector between the diver's harness and a D-ring that has been bound on to the umbilical with cordage.

Load-bearing, gated 'carabiners', are used to connect the diver's harness to the diver's umbilical. The carabiners are commonly rated for a safe working load of 5kN or more (equivalent to approximately 500 kg).<sup>Wiki</sup>

Standard industry references for load-bearing connectors are:

- IMCA DESIGN: 'The diver's end of the umbilical should be fitted with a means which allows it to be securely fastened to the diver's safety harness without putting any strain on the individual whip ends.'
- EN15333: 'The umbilical shall be attached to the diver such that it cannot inadvertently be released underwater by the diver, fouling or other incidents.'
- The USN require a snap shackle (Gibbs Clip) assembly at the diver end.

IMCA does not state the type of load-bearing connector that goes between the diver's harness and the D-ring. In the commercial diving industry, it is typically a carabiner or snap shackle.

Picture 2



Picture 3



Picture 4



Picture 5



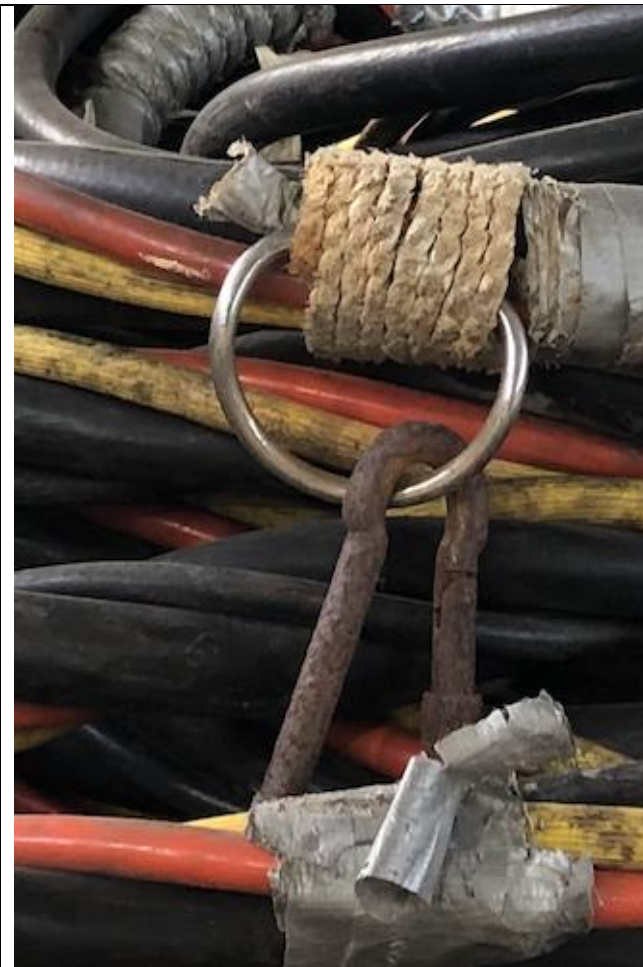
<p>Screw-gate, non-stainless oval carabiner. The screw gate will eventually fail due to dissimilar metals and exposure to seawater/air</p>	<p>Seized oval screw-gate carabiner with 'snap-shackle' The carabiner has suffered fretting and dissimilar metal corrosion. In this example, the diver had the connectors permanently attached to the harness.</p>	<p>Screw-gate stainless D shaped carabiner. This assembly has a swivel arrangement fitted. The D-ring would have been cut to allow the swivel to be fitted. It was not known if the D-ring was re-welded.</p>	<p>D type stainless carabiner with webbing lanyard and unmounted stainless two-part shackle.  In this example, the diver had the connectors permanently attached to the harness.</p>
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IMCA is non-specific in DESIGN how the following is achieved; “*The diver’s end of the umbilical should be fitted with a means which allows it to be securely fastened to the diver’s safety harness without putting any strain on the individual whip ends* “

- Consider a study detailing the exact type of carabiner that is required. Some manufacturers have options for carabiners with short lengths of chain or carabiners/snap shackles that are fixed within the D-ring. Different shaped carabiners are available, made from different materials.
- Consideration should be given to any locking mechanism. A non-locking carabiner has the potential to come unattached in a similar method as a ‘latch’ or ‘snap’ hooks can become accidentally detached/reattached during subsea lifting (IMCA D60 Item A-1 8.1)
- Contractors should consider where the load-bearing connector is permanently attached. It could be permanently attached to the umbilical and be inspected as part of the umbilical PMS or permanently attached to the diver’s lift harness and be included in the harness inspection. Both have advantages and disadvantages.

EN15333 states: “*The umbilical shall be attached to the diver such that it cannot inadvertently be released underwater by the diver, fouling or other incidents.*” This statement would indicate that any carabiner shall be screw-gate. Some diving equipment suppliers, supply snap shackles with cord lanyards for easy release, this would be contrary to the EN15333 requirement above.

Picture 6



- Mild steel screw-gate connector
- Connector not load-bearing
- This connector is seized
- Incorrect size of binding material
- The incorrect type of binding material
- Binding not protected by tape

This type of gated connector is commonly used to secure netting in food containers offshore.

### 2.3 D-Ring

The carabiner is clipped into the D-ring. D-rings are generally 2"-3" long by 3/16" stainless steel and some manufacturers state SWL of 500kg or more. (Picture 7)

The USN's Umbilical Manual requires:

- If, during repair or assembly, the D-ring and shackle assembly have been welded or otherwise altered, or if not procured from the original manufacturer as a D-ring and shackle assembly, then the D-ring must be pull tested to 500 pounds(227kg) and support the weight for a minimum of 10 minutes without distortion, bending, or other damage
- The USN Umbilical Manual requires the following criteria for a D-ring; *"If not procured as a D-ring and shackle combination, or if cut and welded during construction, the D-ring must be load tested."* Diving contractors should procure certified D-rings or carry out testing before attaching it to the umbilical.
- The USN Umbilical Manual gives various sizes of D-ring; 1/4" and 3/8" diameter

Picture 7



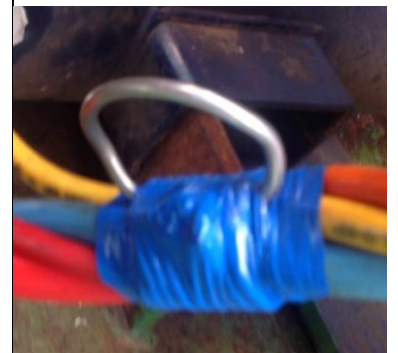
Heavy-duty 2" x 1/4" D-Rings  
 Manufacturer states;  
 SWL 500kg  
 Breaking load 1,350kg

Picture 8



Two different sized D-Rings on the same umbilical

Picture 9



Nickle plated light-weight D-ring with 55o bend, commonly used as a strap-down strong-point



### 2.4 D-Ring Attachment Binding

The D-ring is typically attached to the diver's umbilical by a rope binding.

The only industry reference found for the installation of the D-ring is the USN Umbilical Manual (Summary):

- The USN Umbilical Manual gives the procedure for binding the D-ring to the umbilical using 3/16" nylon cord.
- On no occasion should tie-wraps/cable-ties be used to attach the D-ring to the umbilical
- The USN Umbilical Manual requires the umbilical hoses to be pressurized to normal system pressure while seizing to account for the expansion required during operation. USN hoses are rubber; this might not be required on a modern spiral wound high-performance polymer umbilical
- The USN Umbilical Manual recommends that the binding to be finished by wrapping the completed assembly with two layers of Polyken (preferred) or duct (alternate) tape.
- There is no requirement within the USN Umbilical Manual to bind on top of duct tape

Picture 10



D-ring attached by binding and cable-tie. USN Umbilical Manual recommends Polyken or duct tape cover not electrical tape

Picture 11



Binding is exposed and damaged. USN Umbilical Manual recommends Polyken or duct tape cover not electrical tape

Picture 12



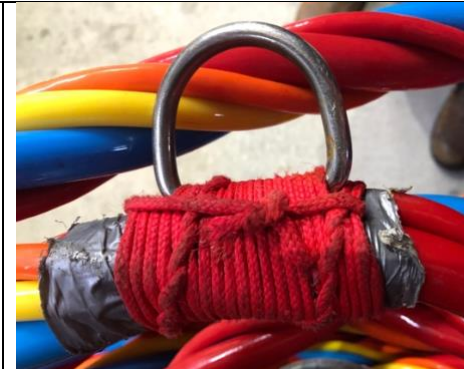
Inappropriate material for binding, the rope diameter is too large for effective binding. Binding not protected by tape

Picture 13



Damage to the binding. Binding is on a layer of duct tape. Binding not protected by tape.

Picture 14



Poor method of binding with an exposed reef knot. Binding on a layer of duct tape. Binding not protected by tape.

Picture 15



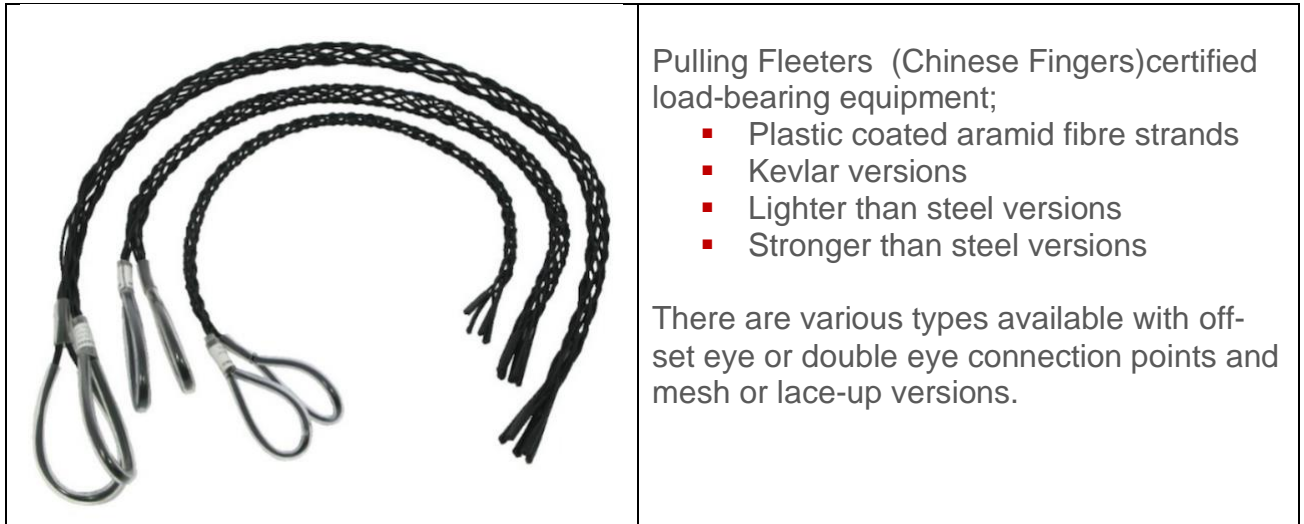
No Comment

A nylon cord binding is not a rated piece of equipment for lifting. There is propriety lifting equipment available for strain relief on flexible hoses/umbilical (Pictures 16, 17 and 18).

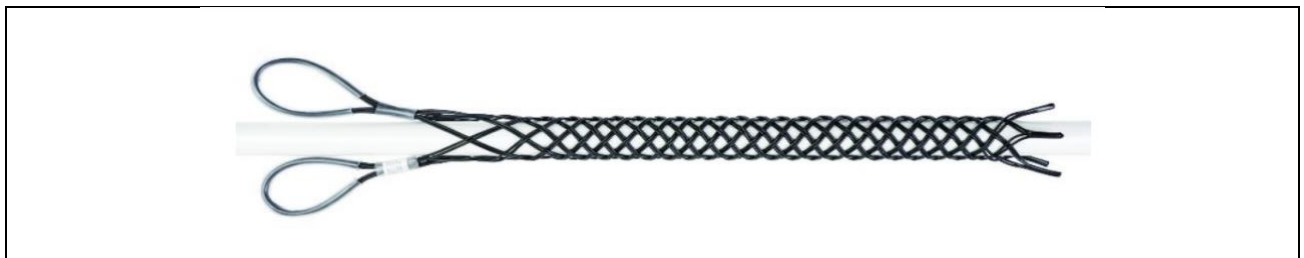
Consideration should be given to these and remove the non-rated D-ring and binding as the primary attachment point.

A further consideration is required for the attachment of intermediate D-rings when utilising an extended umbilical and when attaching the diver's umbilical to a LARS wire to prevent bellowing.

Picture 16



Picture 17



Picture 18



## 2.5 Diver Umbilical

The diver's umbilical is the connection from the surface control system. It may consist of a single hose or multiple lines, gas supply and if fitted, voice communication and depth measuring system together with other services such as heating, power for lighting and camera video signals. EN15333

The basic umbilical assembly consists of a 3/8" breathing gas hose, a 1/4" pneumofathometer hose, and a communication cable to a larger umbilical with an additional hot water hose, reclaim hose, tracking hose and video and lighting cables.

The umbilical assemblies presently in use are of two basic constructions; spiral- wound and parallel.

- A spiral wound umbilical is generally the choice of diving contractors. These offer significant advantages including greater flexibility and strength while resisting kinking and abrasion due to the inherently strong 'rope-like' structure and do not generally have a strength member.
- The parallel umbilical is made up of component hoses laid parallel and either taped together or bound together. The parallel umbilical may have either a combination strength/communication member or a separate strength member and communication cable. If a separate strength member is incorporated, the strength member must terminate at the divers D-ring (Picture 19).
- EN15333 states: '*The apparatus shall have a lifeline that can be used to help recover a diver in distress. It may be a separate line or can be the umbilical. The lifeline, including any connectors, shall be capable of withstanding a tensile load of 3 500 N without damage.*'
- The distance between the gas hose fitting and the umbilical attachment point is undefined in documentation and is left for individual contractors to decide. It is a common sight to see two D-rings attached to an umbilical to cater to the height difference between dive team members (Pictures 20 and 21).

Picture 19



Unusual set-up. Wire rope strength member on a spiral wound umbilical.

Picture 20



Picture 21



## 3.0 Testing Criteria

### 3.1 Current Testing Requirements

IMCA D22 states; *'All diving plant and equipment, including all diver umbilical's, require regular inspection, maintenance and testing to ensure every item is fit for purpose and safe to use, e.g. that it is not damaged or suffering from deterioration. Regular maintenance is an important factor in ensuring the safe operation of diving equipment. The diving contractor will need to have an effective system for planned maintenance and should have on-site an adequate supply of spares for all plant and equipment'*.

IMCA D 018 contains comprehensive guidance on the frequency and extent of examination, testing and certification required for all items of diving plant and equipment used in a diving project, together with the levels of competence required of those carrying out the work. Specific guidance on the examination, testing and certification of divers' umbilical is set out in IMCA D 018 detail sheets 11 *Electrical Equipment* and 28 *Umbilical's – Hose Components only; including end terminations and fittings but excluding electrical components*.

There is nothing within IMCA 18 that requires binding or connectors to be inspected or examined.

IMCA DESIGN D23, D24, D37 and D40 do have line items in regard umbilical strain relief, however the requirement does not involve any form of testing or inspection.

### 3.2 Current Testing Practices

There are no testing or certification criteria for a completed binding. When a spiral wound umbilical (or rope) comes under strain, the umbilical will stretch, and the diameter/circumference will reduce. The reduced diameter/circumference may then lead to the binding becoming less effective with the potential of the 'anchor point' becoming ineffective; the strain will go to the hose end fittings at the divers breathing apparatus. As recovery of a diver on their umbilical is an unplanned possibility, the attachment arrangement should be tested as if it were lifting equipment.

### 3.3 Suggested Testing Requirements

Add an initial binding weight load test to all components and a 6 monthly formal examination within IMCA D18 and appropriate DESIGN.

Contractors should amend their pre-dive checklists to include any binding and attachment accessories.

All components within the strain relief assembly should be traceable within the PMS.

## 4.0 Recommendations

This Hazard Observation has highlighted several areas which merit further investigation or actions by others:

Currently, there is no industry requirement to assure that the linkage between the diver's harness and the umbilical is fit for purpose. This link is safety-critical.

- 5.1 IMCA / IOGP should state within appropriate documentation that all divers *shall* wear a personal lift harness. The lifting harness shall be a separate system to the harness that carries the divers bailout system. In any event, it shall be possible to easily remove the bailout system without removal of the lifting harness.
- 5.2 Contractors to state, after risk assessment, where the umbilical is attached to the diver during each different diving technique.
- 5.3 IMCA to state that the load-bearing connector between the diver's harness and D-ring (or other assemblies) *shall* be a rated, stainless screw-gate carabiner with minimum 5kN rating.
- 5.4 Contractors to risk assess if the carabiner attachment assembly is 'permanently attached' to either the umbilical or rated D-ring on the harness. The assembly will either be inspected with the umbilical or harness PMS. The assembly shall be individually identified.
- 5.5 Industry should give guidance on the minimum size, strength and properties of D-rings attached to the divers umbilical; all D-rings have a safety-critical function such as:
  - The primary D-Ring that the diver attaches to
  - D-rings used during extended umbilical diving
  - D-rings used to connect the divers umbilical to a LARS wire to prevent 'bellowing' towards thrusters
- 5.6 IMCA to add line item within IMCA D18 to confirm D-ring and binding are secure and IMCA D23, D24, D37 and D40 confirming that any D-ring/attachment and their binding has been confirmed suitable and secure and fit for purpose by a competent person and each component is traceable within the PMS
- 5.7 IMCA to contact umbilical manufacturers and request information such as:
  - When binding on a D-ring to an umbilical does the umbilical need to be under pressure for expansion as recommended in the USN Umbilical Manual?
  - Should there be a layer of tape or heat shrink under the binding to protect the umbilical or/and increase friction between the binding and umbilical?
  - The recommended D-ring for attachment to their umbilical.

5.8 IMCA to develop a binding procedure. To include;

- Umbilical surface preparation
- Type of cord (Kern-mantle, stranded, size, properties)
- Direction of lay (Binding to lay with or against the spiral direction)
- Length of binding (Only inside the D-ring or before and after?)
- Type of seizing/binding/whipping (West Country or Common)
- Competencies of those carrying out the binding
- Type of protection over the binding on completion
- Testing criteria

5.9 IMCA to develop testing criteria for load-bearing attachment points. Testing should be for a minimum load of 150kg and should consider stretching umbilical under tensile load and subsequent reduction in diameter and slippage of binding.

6.0 IMCA to investigate the use of a Fleeter/Chinese finger as a diver-umbilical attachment point.

## Appendix 1 Draft Detail Sheet for IMCA D18

# Detail Sheet 28.1

**Diver Umbilical – Strain Relief Components**

**Strain relief: Diver umbilical including any bindings, D-rings, snap shackles, shackles, karabiners or pulling fleeter (Chinese Fingers) between an umbilical and the rated attachment point on the divers harness**

Note: This includes subsea end divers surface supplied and closed bell excursion umbilical

**When new**

Examination/Test	Category of Competent Person
All individual components to be manufactured in accordance with a recognised code or standard or to manufacturer’s standard specification and fit for the purpose it will be used for.	1, 2, 3 or 4
Any binding to be attached and certified to lift the intended man -riding SWL	2, 3 or 4
Function test at SWL	2, 3 or 4

**When in Service**

Examination/Test	Validity Period	Category of Competent Person
If binding or fleeter is replaced test as if new		1,2, 3 or 4
Thorough visual examination of bindings/fleeter check the integrity of shackles and components	6 months	1,2, 3 or 4
Load test to maximum safe working load	12 months	2, 3, or 4

**Immediately Before Use**

Visual check for damage and abrasion

1. When New, An umbilical may be bought from supplier with attachment point already fitted. The umbilical should be supplied with certification that the attachment point has undergone testing and the certificate should state the SWL.
2. If an umbilical is supplied without an attachment point, an appropriately competent person can fit the attachment to the umbilical. Any cord bindings should be applied by a competent person following a company approved procedure with available data attesting that the binding will be fit for purpose.
3. All individual components such as D-rings, snap-shackles, shackles and karabiners shall have a manufacturer’s certificate.
4. Any D-ring should have a manufacturer’s Minimum Breaking Force (MBF). The MBF is the value below which the manufacturer guarantees that the D-ring will not break when new
5. If individual components have to be replaced such as karabiner or shackles then this does not require retesting provided the change is done on a like-for-like basis and the new component is supplied with its own relevant examination and proof load test certificate.
6. The SWL of the umbilical strain relief is at the discretion of the competent person. It is suggested that a risk assessment is conducted to ascertain any potential weight loading during different diving techniques. For example it would be possible that a surface supplied diver would, in an extreme case, be recovered by their umbilical where as a closed bell diver is unlikely to be suspended by their umbilical. For calculations a divers weight is 150kg. Company approved load/strain testing procedure to be in place
7. If a steel fleeter is used consideration should be given to galvanic corrosion of any less noble crimping ferrules.
8. Any individual component that is cut or modified without a manufacturers certificate should not be used.

## Appendix 2 References and Source Material

### References

US Navy	U.S. Navy Diving Umbilical manual
BS EN 15333-1:2008	Respiratory equipment. Open-circuit umbilical supplied compressed gas diving apparatus. Demand apparatus
EN 250:2014 EN 250:2000	Respiratory equipment - Open-circuit self-contained compressed air diving apparatus - Requirements, testing and marking
IMCA	DESIGN
IMCA D60	Guidelines for Lifting Operations
IMCA D22	Guidance for Diving Supervisors
KMDSI	Kirby Morgan 37 & 57 Operations manual Chapter 3.0 Operating Instructions
NORSOK	U100
ADCI	International Consensus Standards For Commercial Diving And Underwater Operations

### Photographs and Pictures

1-6	Author
7	Wikipedia
8-15	Author
16-18	<a href="http://www.nova.sub.com">www. nova.sub.com</a>
19-21	Author