## Guidance on the

# Use of Whip Checks (Hose Restraints)

International Marine Contractors Association

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**IMCA D 065**
July 2020

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- Competence & Training
- Contracts & Insurance
- Health, Safety, Security & Environment
- Lifting & Rigging
- Marine Policy & Regulatory Affairs

The Association is organised through four distinct divisions, each covering a specific area of members' interests – Diving, Marine, Offshore Survey and Remote Systems & ROV.

There are also five regions which facilitate work on issues affecting members in their local geographic area – Asia-Pacific, Europe & Africa, Middle East & India, North America and South America.

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| July 2020 | Initial publication |

# Guidance on the Use of Whip Checks (Hose Restraints)

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# 1 Background

In the event of a pressurised hose or hose fitting failure, the escaping gas or liquid and subsequent hose whip effect has the potential to cause severe injury to personnel and damage to equipment.

Although hose whipping incidents may be caused by the accidental severing of pressurised lines, such incidents most often occur when hoses become detached from hose-end fittings or when the hose end fittings themselves fail.

Incidents involving pressurised hose-end fittings becoming detached, and then whipping out of control due to missing or unsuitable whip checks, have highlighted the need for diving industry guidance on the use of appropriate pressurised hose restraints.

This guidance replaces Information Note IMCA D 03/11 which has now been withdrawn.

# 2 Aims

The main aims of this document are to provide information and guidance to IMCA Diving Division members on:

- The risk of harm due to a failed hose or fitting from the hose end flailing uncontrollably whilst expelling its stored energy (gas or liquid).
- How to identify and select the correct restraint for the hose or fittings at the Maximum Working Pressure (MWP) of the hose in service.
- Additional procedures that may be used to mitigate and control the risk from a hose failure.

**Note:** Although this guidance has been produced for Diving Division members, it is likely to be of interest to members in the other IMCA Divisions.

# 3 Application

This guidance is intended to apply internationally, but it is recognised that some countries will have legislation that requires different standards or practices to be followed. Where local or national laws are more stringent than the advice contained herein, they will always take precedence over this guidance.

Some regulatory authorities such as the US Occupational Safety and Health Administration (OSHA) have made the use of hose restraints a mandatory requirement. Others such as the UK Health and Safety Executive (HSE) recommend their use. Many national and international standards also advocate their use.

# 4 Types of Hose-End Restraints

A whip check is a mechanical restraint used to prevent inadvertent and uncontrolled movement in fluid or gas hoses in the event of hose or coupling failure.

Several types of whip checks exist that are suitable for use as hose end restraints in the diving industry. The type of whip check can differ depending on the pressure of gas, hose type, fitting requirements and anchor point availability. A whip check restraint needs to be considered for its length, material, strength and security.

Some examples are shown below.

| | | |
|---|---|---|
| a) | Wire and Spring.<br><br>Commonly seen in the offshore and diving environments. They are easy to fit to hose ends before connecting the hose to the fitting. It should be checked they are close fitting around the hose to reduce the risk of slip along the hose should the hose become detached from the fitting. A shackle, snap hook or carabiner might be required to attach one end to a suitable anchor point. |   |
| b) | Wire and Eyelet Clamps.<br><br>This method uses eyelets which are clamped to the hose at regular intervals along the whole length of the hose. Wire is fed through the eyelets and each end fitted with a snap hook for securing. |   |
| c) | Choke.<br><br>These are made of a steel wire coated in Kevlar and polyester material. One end is choked over the hose end before the hose is connected to the fitting. The other end is connected to a suitable anchor point. |  |
| d) | Whip Sock (Chinese Finger)<br><br>These are generally used for larger diameter hoses and umbilicals. |  |
| e) | Hose Halter.<br><br>A suitably rated soft webbing strop or round-sling choked around hoses. Shown here fitted with rubber type grommets to stop sliding if the hoses become parted. |  |

## 5 Methods of Anchoring Restraints

The most common failure that highlights the need for the use of hose whip check restraints is the failure of the hose material at or near the fitting end, as this is the area of the hose that experiences most fatigue whilst in service.

If a hose or fitting fails, then the resultant thrust caused by the escaping gas or fluid could potentially lead to the hose flailing horizontally and vertically even with the fitting restrained at the connection point if the hose is not restrained along its length.
Reference IMCA D24. DESIGN for Saturation (Bell) Diving Systems. Details sheets section 12, Item 6.2 security; 'All hoses other than charging whips must be appropriately supported and secured at intervals not exceeding 2m'

Factors to consider when installing flexible hoses and whip checks (hose restraints);

- Ensure restraints do not introduce additional stress or wear points on the hose or fittings.
- Compressed gas can be hot causing hoses to soften therefore increasing the risk of failure.
- Always select the correct Minimum Breaking Load (MBL) rated whip check restraint.
- Always follow manufacturers' instructions for all components in the system.

As shown in the three images below, both High Pressure (HP) [Up to 1700 bar/25,000 psi] and Low Pressure (LP) [Less than 34 bar/500 psi] hose restraints should always be anchored to a suitable dedicated securing point or to a strong point on the structure around the fitting to which the hose is connected.

Whip check shown correctly attached by carabiner to a bracket on the frame of a gas storage rack.

Whip check shown correctly attached to a dedicated point on the base plate of a valve panel.

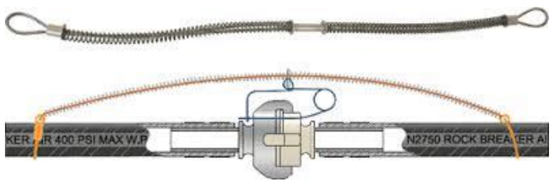
Whip check correctly attached around a bar that is part of the frame of a gas quad/rack

- Hoses should always be secured by a whip check in line with the hose and fitting where possible.
- The shortest restraint available should be used to inhibit the recoil distance of travel should the hose part whilst under pressure.
- Hoses should always be routed away from pedestrian access areas or areas subjected to vehicular (e.g. Forklift) access and that present a Line of Fire hazard.
- Valves, pipe fittings and pipe work should never be used as an anchor point for a whip check restraint.
- Always visually inspect for frayed, damaged or worn hoses and specifically for cuts, blisters, kinks or wire showing through the outer cover before using. If damaged do not use.
- Check the hose end connections for wear, rust, cracks or other deterioration which could cause the fitting to fail.
- Know the maximum safe working pressure (SWP) and minimum bend radius (MBR) of all hoses before using them.
- Always confirm that the hose to be used has a current test certificate in accordance with IMCA D18 detail Sheet #28

## 6 Coupling of Hoses

In some circumstances the requirement to couple two pressurised hoses together may arise. In such a scenario a suitably rated whip check should be used to restrain the movement of the hoses should they become uncoupled or separated, thus minimising potential damage to equipment and injury to personnel. Images below show whip checks in use at the coupling point of two pressurised hoses.

**Note 1:** The use of whip checks does not replace the need for other manufacturer recommended requirements such as safety pins or locking nuts.
**Note 2:** If a hose or fitting fails, then the resultant thrust caused by the escaping gas or fluid could potentially lead to the hose flailing horizontally and vertically even with the fitting restrained at the connection point if the hose is not restrained along its length.
Reference IMCA D24. DESIGN for Saturation (Bell) Diving Systems. Details sheets section 12, Item 6.2 security; 'All hoses other than charging whips must be appropriately supported and secured at intervals not exceeding 2m'

| | | |
|---|---|---|
| a) | Wire and Spring.<br>Commonly seen in the offshore and diving environments. They are easy to fit to hose ends before connecting hose to hose. It should be checked they are close fitting around the hose to reduce the risk of slip should the hose become detached from the fitting. |  |
| b) | Choke.<br>These are made of a steel wire coated in Kevlar and polyester material and can be placed over the hose ends before coupling of the fittings. If the hoses part at the coupling point the hoses will be restrained from whipping. |  |

| | | |
|---|---|---|
| c) | Hose Halter.<br><br>A suitably rated soft webbing strop or round-sling can be choked around hoses. Shown here fitted with rubber type grommets to stop it sliding if the hoses become parted. |  |
| d) | Whip Socks (Chinese Fingers) connected together.<br><br>Whip Socks are effective when fitted correctly as per manufacturer guidelines. If not, they could slip if the hoses part. They might need be secured at the outer ends using a worm drive hose clip, clamp, or suitable cable tie. |  |

## 7 Summary

- It is the responsibility of the contractor to make sure that any hose restraints purchased are supplied with relevant information such as fitting instructions and a statement of the MBL the restraint can withstand, preferably also with maintenance and inspection guidance. This will ensure that the hose restraint is fit for purpose.
- Any additional items such as shackles, snap hooks, carabiners or other securing mechanism should also be suitably rated.
- All pressurised hoses should be correctly secured and coupled using properly rated hose whip check restraints.
- All hoses and fittings should be visually inspected prior to use and should be examined regularly in service for wear and should be changed out as necessary or as part of a planned maintained schedule
- Activities involving pressurised hoses should be carried out by competent personnel wearing appropriate personal protective equipment (PPE).
- An appropriate task risk assessment should be undertaken and/or reviewed before commencing work.
- A table to assist with selection of a suitable whip check can be found in Appendix 1
- Formulas for calculating for the correctly rated whip check can be found in Appendix 2

## 8 References


1. UK HSE Diving Information Sheet No 10, 12/07 - *Diving cylinders: Guidance on internal corrosion, fitting valves and filling.* https://www.hse.gov.uk/pubns/dvis10.pdf

2. UK HSE Guidance Note GS4 (Fourth edition) 08/12 Safety Requirements for Pressure Testing

3. CRR168/1998: Pressure test safely. HSL Contract Research Report
www.hse.gov.uk/research/crr_pdf/1998/crr98168.pdf

4. ISO/TR 17165-2 (2018): International Standards Organisation Hydraulic fluid power – Hose assemblies www.iso.org
5. BS EN ISO 4413 (2010): International Standards Organisation Hydraulic fluid power – General rules relating to systems www.iso.org
6. BS EN ISO 4414 (2011): International Standards Organisation Pneumatic fluid power – General rules relating to systems www.iso.org
7. OSHA 29 CFR 1926.603 Pile driving systems. Paragraph (a)(10)
8. OSHA 29 CFR 1926.302 Power-operated hand tools. Paragraph (b)(1)
9. IMCA Safety Flashes, 13/01, 06/03, 09/03, 02/04, 10/07, 07/13, 12/13, 31/16, 10/18, 18/18
10. IMCA D 011 – *Guidance on auditing of diving systems*
11. IMCA D 018 – Code of practice for the initial and periodic examination, testing and certification of diving plant and equipment

# Selection Guide for Suitable Whip Checks

The following tables can be used to help select suitable whip checks. Metric and imperial formulas for calculating MBL whip check requirements for other hose sizes and/or pressures appear in Appendix 2.

## Metric Table for Selection of Suitable Holdback MBL

Below is a table showing the resultant MBL in kg for some of the more common metric hose bores and pressures.

| Hose Bore | Pressure (bar) | | | | | |
|---|---|---|---|---|---|---|
| | **50** | **100** | **150** | **200** | **250** | **300** |
| **6** mm | 72 | 144 | 216 | 288 | 360 | 432 |
| **8** mm | 128 | 256 | 384 | 512 | 640 | 769 |
| **10** mm | 200 | 400 | 600 | 801 | 1,001 | 1,201 |
| **12** mm | 288 | 576 | 865 | 1,153 | 1,441 | 1,729 |
| **16** mm | 512 | 1,025 | 1,537 | 2,050 | 2,562 | |
| **18** mm | 648 | 1,297 | 1,945 | 2,594 | | |
| **20** mm | 801 | 1,601 | 2,402 | | | |
| **25** mm | 1,251 | 2,502 | | | | |
| **32** mm | 2,050 | 4,099 | | | | |
| **36** mm | 2,594 | | | | | |

## Imperial (US) Table for Selection of Suitable Holdback MBL

Below is a table showing the resultant MBL in lb for some of the more common imperial hose bores and pressures.

| Bore | Pressure (psi) | | | | | |
|---|---|---|---|---|---|---|
| | **1000** | **1500** | **2000** | **3000** | **3500** | **4000** |
| **¼”** | 245 | 368 | 490 | 735 | 858 | 980 |
| **3/8”** | 550 | 825 | 1,100 | 1,650 | 1,925 | 2,200 |
| **½”** | 980 | 1,470 | 1,960 | 2,940 | 3,430 | 3,920 |
| **5/8”** | 1,535 | 2,303 | 3,070 | 4,605 | 5,373 | 6,140 |
| **¾”** | 2,210 | 3,315 | 4,420 | 6,630 | 7,735 | |
| **1”** | 3,925 | 5,888 | 7,850 | 11,775 | | |
| **1 ¼”** | 6,135 | 9,203 | 12,270 | | | |
| **1 ½”** | 8,835 | 13,253 | 17,670 | | | |
| **2”** | 15,710 | 23,565 | | | | |

# Formulas

The following formulas may be used for calculating MBL whip check requirements for hose bores and pressures not covered in the tables in Appendix 1.

In order to fit a correctly rated whip check, the thrust force generated by the liquid or gas ejecting from the relevant hose needs to be found and converted into a mass. This value of mass can then be used as the minimum Safe Working Load (SWL) required for the whip check. However, some whip checks or restraints are not supplied with an SWL, they are only supplied with a Minimum Breaking Load (MBL). In that case the MBL required for the whip check can be calculated by multiplying the SWL by a Safety Factor.

MBL is calculated by using the three-step equations below, with examples of both metric and imperial calculations:

### Metric Units.

**Thrust Force** = Hose Pressure (bar) x Hose Cross Sectional Area (mm$^2$) x 0.1

**Whip Check SWL** = Thrust Force / 9.81 (Acceleration due to gravity)

**Whip Check MBL** = Whip Check SWL x Factor of Safety

Where:

- Thrust Force: The force generated from pressurised fluid or gas ejecting from a damaged hose, in Newtons.
- Hose Pressure: The internal gauge pressure of the specified hose, in bar.
- Hose Cross Sectional Area – The cross-sectional area of the nominal bore of the specified hose, in mm$^2$. Calculated by using: $\pi \times r^2$ (see note*)
- Whip Check SWL: The minimum Safe Working Load (SWL) that is required for the whip check for a specified hose, in kg.
- Gravitational Acceleration: 9.81 m/s$^2$.
- Whip Check MBL: The Minimum Breaking Load (MBL) that is required for the whip check for a specified hose, in kg.
- Factor of Safety: A Safety Factor of 5 should be used, aligned with rigging and lifting protocol. This safety factor also covers any increased test pressure requirements of hoses needing to be restrained whilst under test.

### Notes.

* The number $\pi$(pi) is a mathematical constant. It is defined as the ratio of a circle's circumference to its diameter. It is calculated as 3.142 (to three decimal places)

An example calculation is shown below to determine the minimum breaking load (MBL) required for a whip check fitted to a 6.35 mm hose.

**Metric Units Example Calculation.** For a 6.35 mm nominal bore certified gas hose pressurised to 200 bar:

> Thrust Force = Hose Pressure × Hose Cross Sectional Area
>
> Hose Cross Sectional Area = ($\pi$ x $r^2$) = 31.67 $mm^2$
>
> Thrust Force = 200 bar × 31.67 $mm^2$ x 0.1= 633.4 N
>
> Whip Check SWL = Thrust Force / 9.81 = 633.4 / 9.81 = 64.57 kg
>
> Whip Check MBL = SWL × Factor of Safety = 64.57 × 5 = 322.83 kg
>
> Therefore, the whip check required to restrain the hose in this example must have a minimum SWL of 65 kg, or an **MBL of 323 kg.**
>
> All restraint accessories (hooks, shackles, carabiners) must also meet this SWL/MBL.

## Imperial Units.

MBL is calculated by using the three-step equation below.

**Thrust Force** = Hose Pressure x Hose Cross Sectional Area

**Whip Check SWL** = Thrust Force (see ***Note on units** below)

**Whip Check MBL** = Whip Check SWL x Safety Factor

Where:

- ♦ Thrust Force: The force generated from high pressure fluid or gas ejecting from a damaged hose, in lbf.
- ♦ Hose Pressure: The internal gauge pressure of the specified hose, in psi.
- ♦ Hose Cross Sectional Area – The cross-sectional area of the nominal bore of the specified hose, in $in^2$. Calculated by using: $\pi \times r^2$ (see note**)
- ♦ Whip Check SWL: The minimum Safe Working Load (SWL) that is required for the whip check for a specified hose, in lb.
- ♦ Whip Check MBL: The Minimum Breaking Load (MBL) that is required for the whip check for a specified hose, in lb.
- ♦ Factor of Safety: A Safety Factor of 5 should be used, aligned with rigging and lifting protocol. This safety factor also covers any increased test pressure requirements of hoses which will also need to be restrained whilst under test.

**Notes on units –**

*The imperial unit of Thrust Force should be defined in Slugs. The slug is a unit of mass associated with British Imperial or United States customary units. It is a mass that accelerates by 1 $ft/s^2$ when a force of one pound is exerted on it. (1 Slug has a mass of 32.174 lb). Therefore, in the second equation, the operation to convert the force into slugs cancels out the gravitational acceleration of 32.174 $ft/s^2$, meaning the SWL equals the Thrust Force.

** The number $\pi$(pi) is a mathematical constant. It is defined as the ratio of a circle's circumference to its diameter. It is approximately calculated as 22/7 (or 3.142 to three decimal places)

An example calculation using imperial units is shown below to determine the MBL required for a whip check fitted to a ¼" hose.

**Imperial Units Example Calculation.** For a 1/4" nominal bore certified gas hose pressurised to 2900 psi:

| |
|---|
| Thrust Force = Hose Pressure × Hose Cross Sectional Area<br>Hose Cross Sectional Area = ($\pi$ x $r^2$) = 0.049 $in^2$<br>Thrust Force = 2900 psi × 0.049 $in^2$ = 142.1 lbf<br><br>Whip Check SWL = Thrust Force = 142.1 lb<br>Whip Check MBL = Whip Check SWL × Factor of Safety = 142.1lbf × 5 = 710.5 lb<br><br>Therefore, the whip check required to restrain the hose in this example must have a minimum SWL of 143 lb, or an **MBL of 711 lb.**<br><br>All restraint accessories (hooks, shackles, carabiners) must also meet this SWL/MBL. |

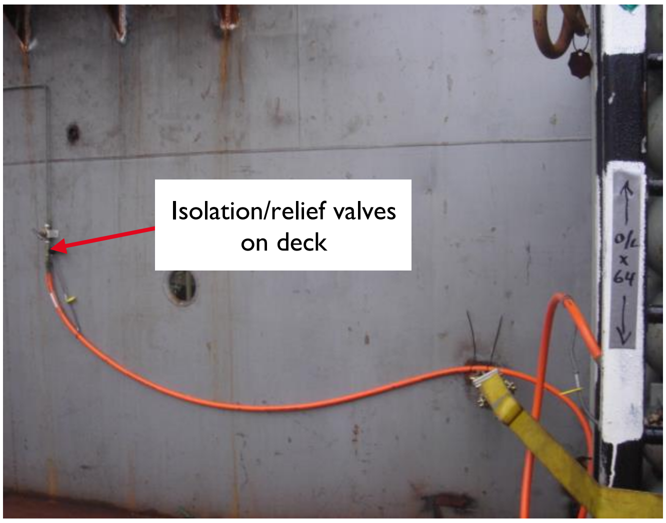
# Failure of High Pressure (HP) Gas Charging Hose

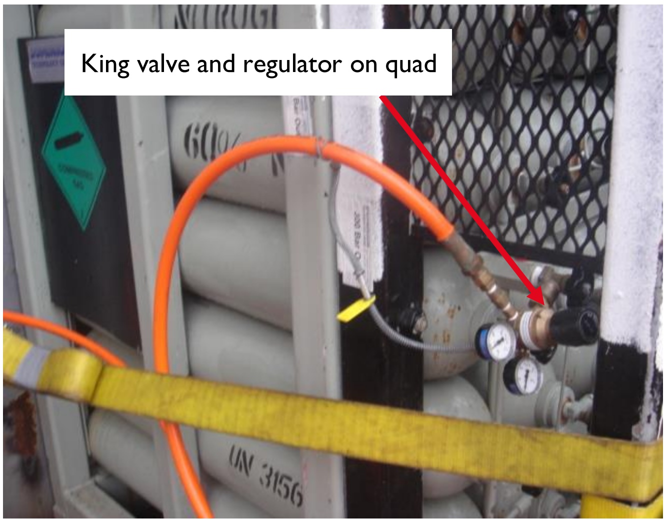
**(Excerpt from IMCA Safety Flash 10/07 Failure of HP Gas Charging Hose)**

A member has reported the failure of a HP gas charging hose during routine gas decanting to top up the gas banks of a mobile surface supplied diving system which had been installed into a small craft used for remote diving operations.

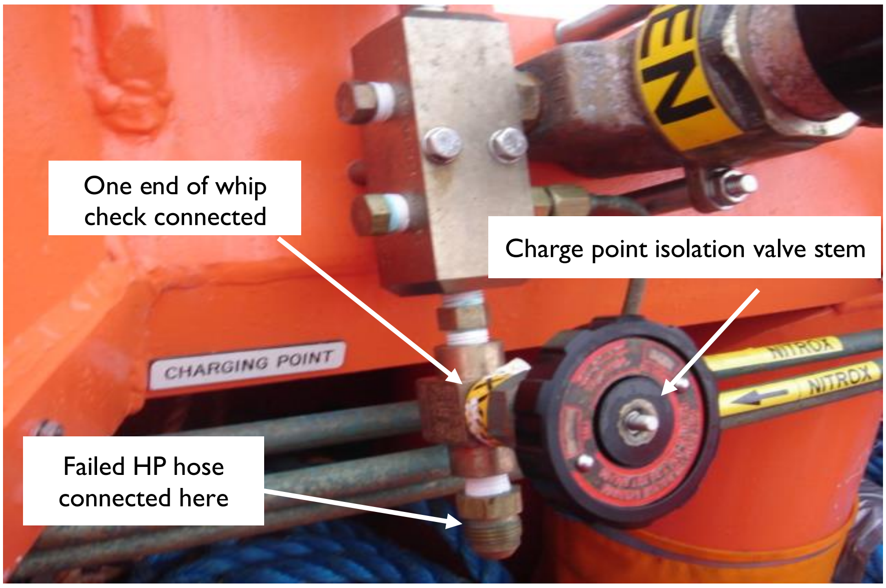
During the gas bank decanting, an HP gas charging hose ruptured and its recoil force caused shear failure of an isolation valve fitting which was serving as an anchor for the HP hose whip check.

The resulting failure of the valve fitting connection caused a restrained flailing of the hose and valve fitting which became entangled on the structure of the small craft. All gas banks were immediately isolated, which prevented any personnel injury or further equipment damage.

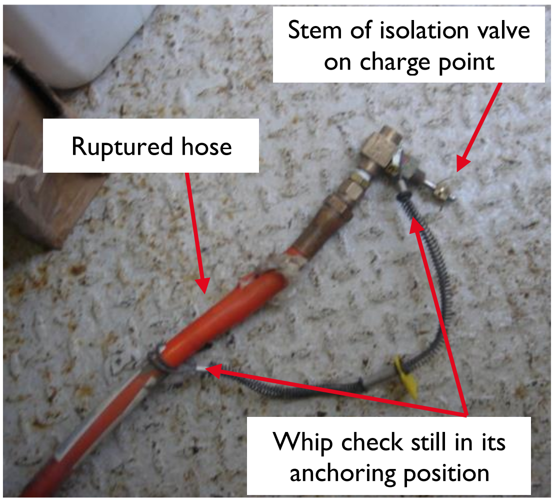



*HP charging hose from supply quad used for decanting*




*Charging point assembly in small craft*




*Ruptured hose with sheared fitting/valve attached*


*¼" NPT Nipple snapped off from diver charging manifold*

After investigation by the company involved, the following points were highlighted:

- The whip check was anchored on a pressurised valve;
- There was a failure to recognise the force of recoil and effect on the whip check anchor point;
- The safe positioning of personnel performing the operation was inadequate.

Members are urged to consider the following:

- A review of whip check anchoring methods on all HP hoses;
- An inspection of all hoses for any indication of defect;
- The use of dedicated anchor connection points for whip checks;
- An alternative design of whip check that ensures the whip is held at the very end of its length i.e. Chinese finger style;
- A review of the service life for high pressure flexible hoses looking at the original date of whip manufacture and how many pressurisation cycles the whip has had.