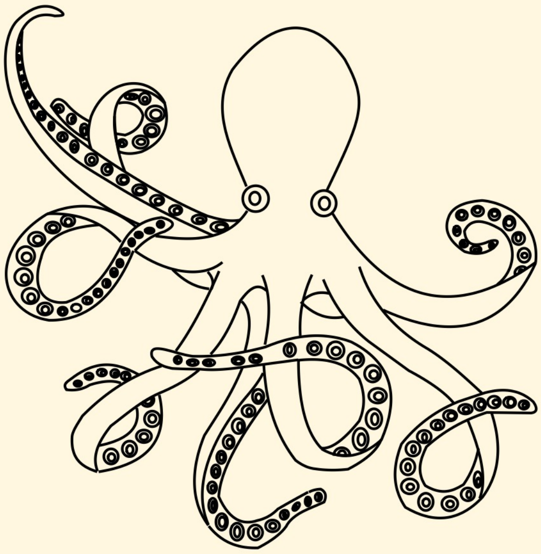


Diving & ROV specialists

Basic rigging & lifting procedures handbook

09 July 2023

Diving & ROV specialists is a branch of CCO ltd

Important note

This handbook is written to inform people interested in diving and ROV activities of the elements to take into account to prepare for successful lifting operations. However, implementing the procedures discussed is the reader's sole responsibility.

Christian CADIEUX - Document Author

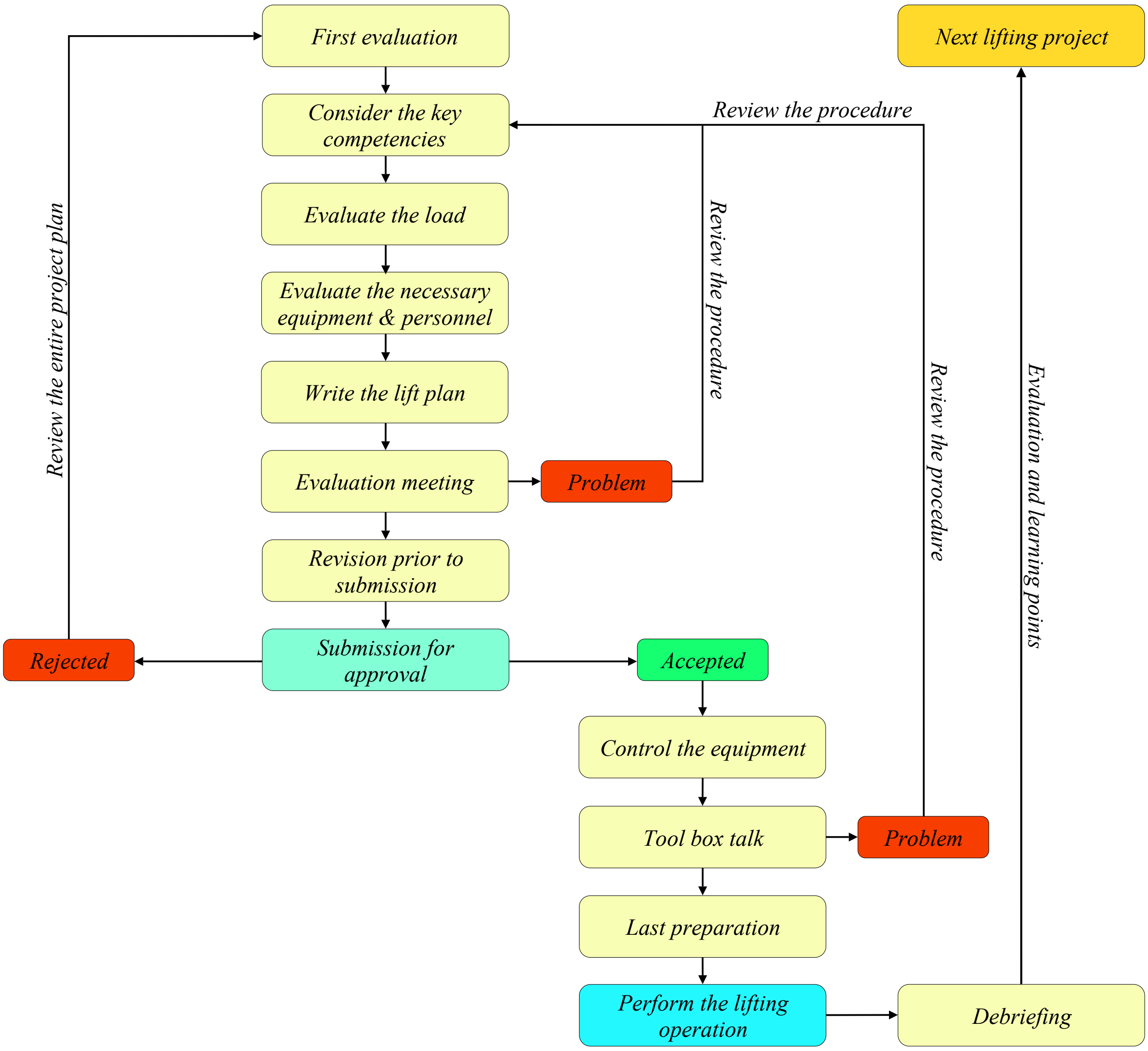
Page left blank intentionally

Purpose

This document aims to promote the essential principles for organizing the lifting of various loads to diving & ROV teams for the operations they may undertake during the construction projects they are involved in. It is based on national and international standards and guidelines.

As the function of diving and ROV teams is to work underwater, the difficulties of organizing lifting operations that consist of transferring a load stored on the dive support's deck into the water or the opposite are to be considered with those where the crane or winch operator has no visibility on the load. Based on this fact, these operations are more complex than those performed only at the surface with direct visibility on the load. Therefore such lifting conditions must result in the implementation of reinforced management methods with personnel having adequate competencies. For this reason, most standards and guidelines recommend a process similar to the following:

1. Evaluate the task
2. Consider the key competencies necessary for the operation (competent persons & engineers).
3. Evaluate the load
4. Evaluate the necessary equipment and evaluate the necessary complementary personnel.
5. Write the lift plan.
6. Carry on an evaluation meeting.
7. Review the lift plan according to the risk assessment findings.
8. Submit the lift plan for approval.
9. Control the the lifting equipment and ensure that the team is ready to operate
10. Carry on a toolbox talk. In case of a problem is detected, the procedure is reviewed.
11. Last preparation (Rigging installation, lifting device inspection, pre dive checks, etc.)
12. Perform the lifting operation
13. Debriefing



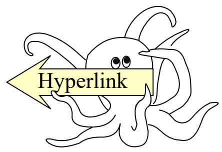
The process described above will be inefficient if the people in charge of the lifting project have insufficient knowledge of the devices they can use and how to select them. For this reason, in support of the guidelines for writing and implementing the lifting procedures, descriptions of the main lifting and rigging devices used for such operations are provided in this handbook. These descriptions include the systems specific to ROVs and are mainly based on ISO, EN, ASME, ASTM, OSHA, and HSE standards, listed in the "bibliography" at the end of this handbook. Nevertheless, other norms are also used occasionally.
Note that the reference documents and their authors are indicated in the texts where they are used. Also, some descriptions are based on several standards used together. The reason is that, contrary to what some who do not know such documents believe, standards from different organizations usually do not conflict. Their difference is that some are more stringent on some points, and some highlight some elements better than others. It must be considered that many manufacturers proceed this way to ensure that the equipment they produce can be sold in a maximum of countries without modifications.
Because standards are official documents with the status of laws according to which lifting devices are built, they are also the references to follow by people using these tools. In addition, they can be used to determine whether a suspicious device is genuine. Regarding this point, we must highlight that dishonest manufacturers and resellers sell copies that look very similar to the originals with false manufacturing certificates. However, these often have slight differences in their dimensions to those provided in the standards, which can allow people aware of the official measurements to detect them. All these elements are grouped in “Part #1”

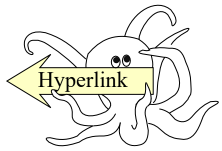
“Part #2” groups the development of the management procedures described on the previous page.
In addition to the step-by-step description of the elements to consider, elements for evaluating the weather conditions and protecting the divers from dropped objects, already published in the diving documents, are included to avoid the reader looking for them in the said handbooks. Note that topics regarding the effect of the wind, temperatures, and lightning strikes on cranes have been added to reinforce them. Also, the specific requirements for personnel transfer are provided.

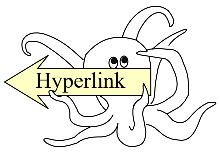
However, even though efforts have been made to include the maximum elements allowing diving and ROV teams to organize safe and efficient lifting operations, This document does not include details for the design of lifting devices such as cranes and winches, and also for the calculation processes to transfer exceptional loads, which require complex engineering calculations by competent and experienced engineers and must be part of the quality assurance process of the company and its client. Thus, these engineering studies are not the responsibility of divers and ROV pilots, whose function is to proceed to install such complex pieces safely and efficiently but without taking responsibility for these designs and calculations.

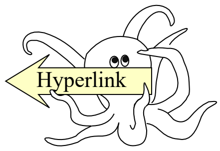
Part #1 - Devices used for lifting operations

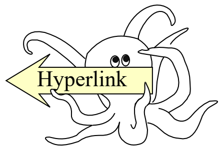
Table of contents

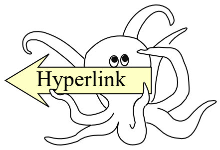


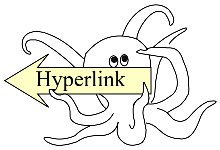

Hyperlink


Hyperlink


Hyperlink


Hyperlink


Hyperlink


Hyperlink

Page left blank intentionally

A - Powered lifting devices

In the handbook "Powered lifting devices" consist of cranes, winches, A-frames, and other systems motioned by electric motors or thermal engines.

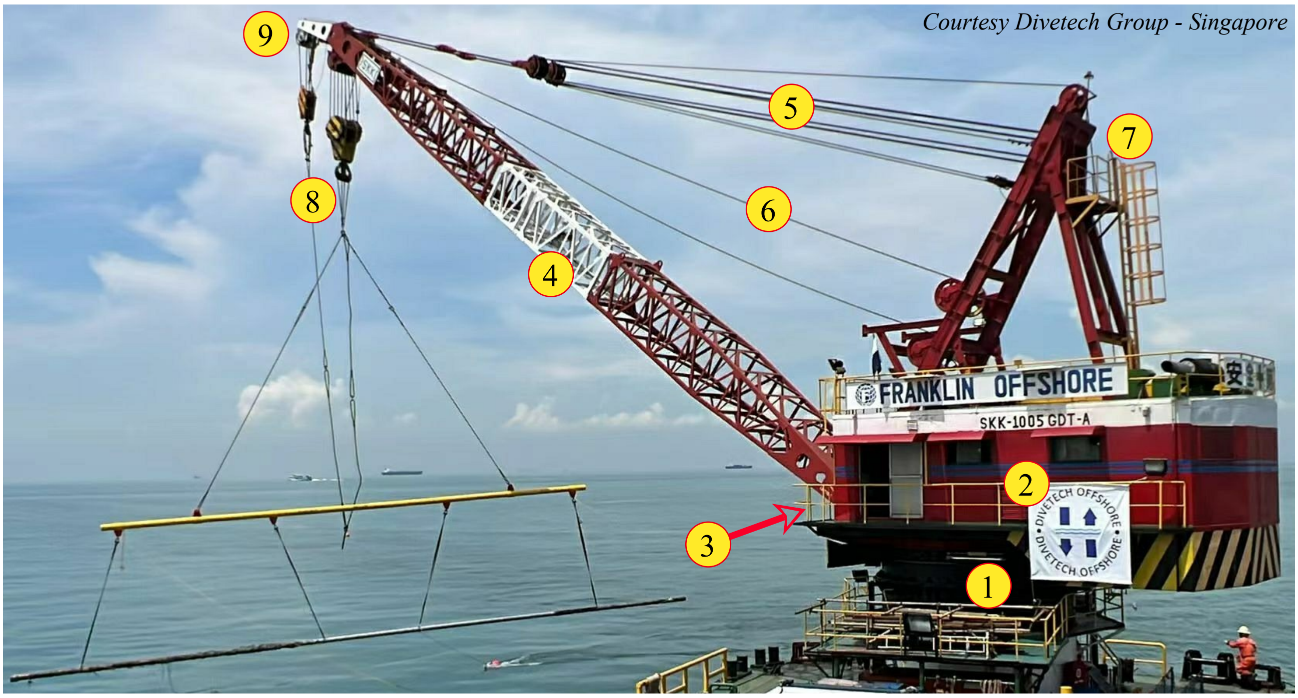
1 - Cranes

European standards define cranes as machines for cyclic lifting or cyclic lifting and handling of loads suspended on hooks or other load-handling devices, whether manufactured to an individual design, in series, or from prefabricated components.
Manufacturers provide many crane models adapted for the various construction jobs undertaken at sea and inland. This article limits only to models frequently encountered in diving and ROV operations for simplicity and clarity. Thus lifting devices commonly used during the mobilization and demobilization phases and load transfer or personnel transfer during operations at sea, in ports, rivers, and lakes.

1.1 - Main parts & Identification

1.1.1 - Main parts

Cranes can be fixed on a pedestal, a mobile unit installed on a wheeled or crawler vehicle, or a specific structure guided by rails. Depending on the model, they are powered electrically or by thermal engines.
They are composed of the following main elements:



1. Slewing bearing:
   They are the rings on which the crane rotates. They are composed of an inner ring and an outer ring, one of which usually incorporates a gear that enables power transmission to turn the crane in the desired direction. They are designed to withstand loads acting in any directions.
2. Machinery house & counterweight:
   As the name suggests, the machinery house is where the engines, motors, winches, hydraulic devices, and other systems are grouped and protected from environmental conditions. The counterweight function is to balance the weight of the lifted object and prevent the crane from tipping over. It is at the extremity of the machinery house.
3. Operator's cabin:
   It is the place from where the crane is operated. It should be adequately designed to protect the operator from falling objects, the environmental conditions and give him a general view of the lifting site.
4. Boom:
   The boom is the arm that is used to move the loads. Its length determines a crane's maximum reach. Manufacturers provide a variety of designs adapted to the function of each crane.
5. Luffing winch & rope:
   They are used to adjust the angle of the boom. They are replaced by hydraulic cylinders on many modern cranes.

7. A-frame
   The A-frame holds the pulleys of the luffing ropes. So it is of a calculated height and oriented to the back of the machinery house to allow for a sufficient angle to erect the boom to its maximum vertical angle. On some models of cranes, the A-frame is replaced by a vertical mast. Also, it is unnecessary on models that use hydraulic cylinders to replace the luffing winches and their pulley system.
8. Hooks:
   Depending on their side, cranes can have a main hook for heavy loads and a secondary hook for lighter loads.
9. Jib:
   A jib is a secondary arm extending off a boom's end to allow the crane an extra reach. Such a system, which is not in the photo on the previous page, usually extends only the secondary hook. It can be mounted on a pivot and oriented by hydraulic cylinders on modern cranes.

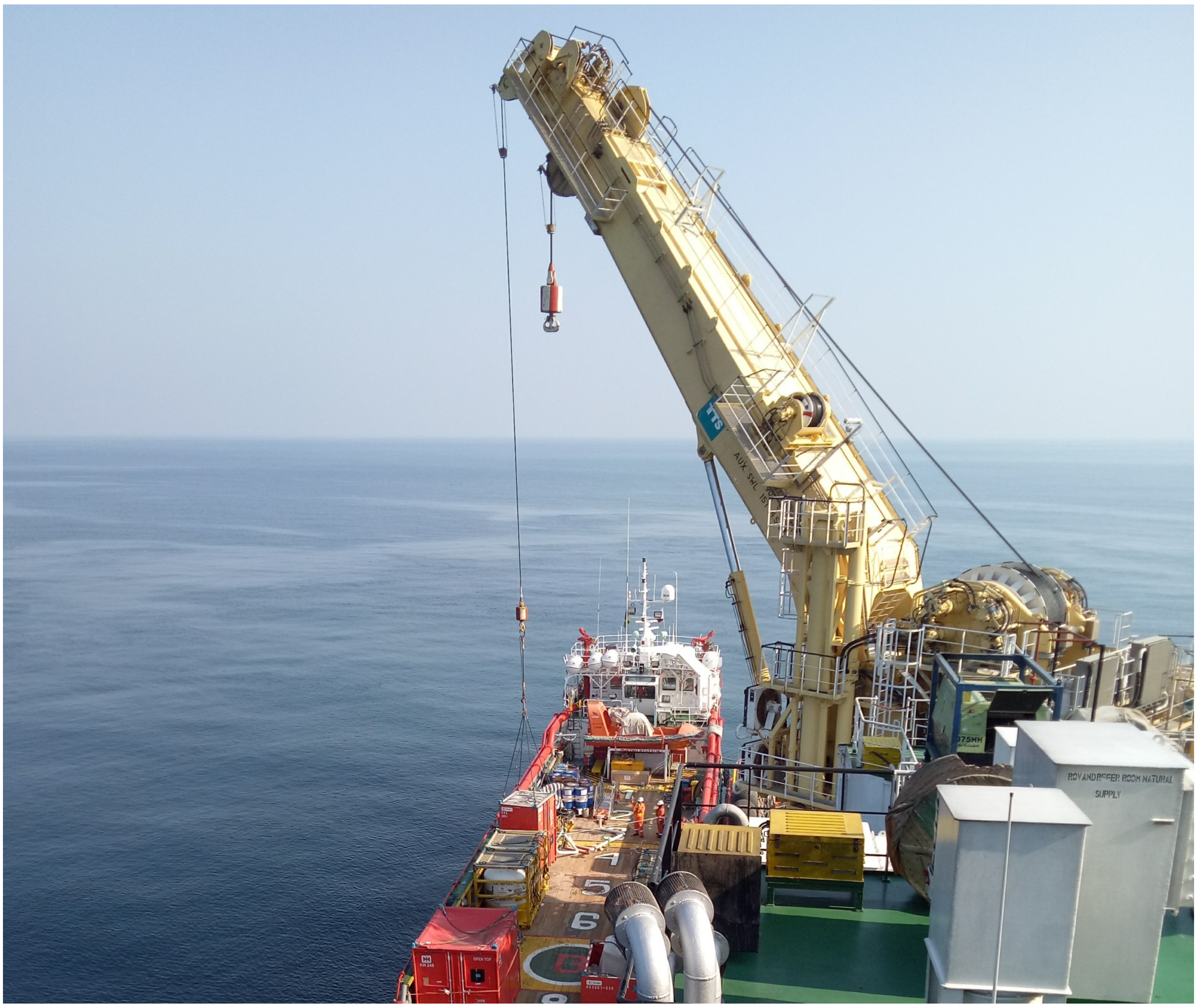
1.1.2 - Identification

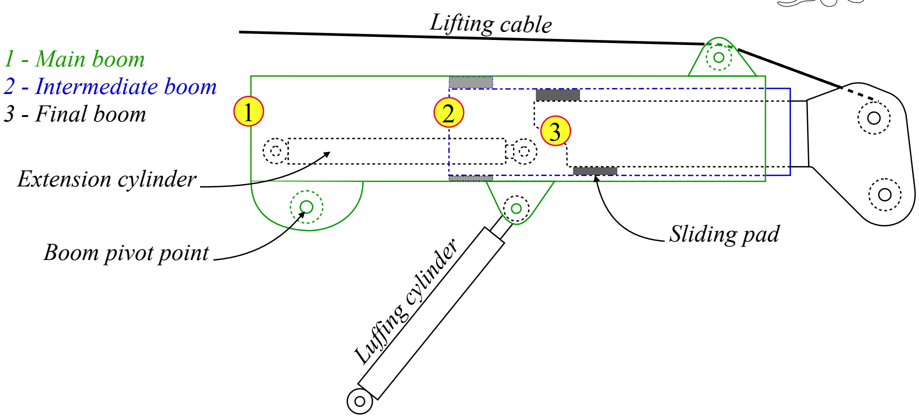
As already said, depending on the operations, the cranes used for underwater activities can be mobile units or fixed units mounted on pedestals.
Mobile units can be used during mobilization alongside a jetty, and diving and ROV activities launched from a quay, a bank, or a pontoon in calm waters. They should not be used for projects at sea as they have not been designed for this purpose. It is true that mobile cranes are commonly used on lay barges. However, their function is not to transfer loads in the water but to be used to access the parts of the deck difficultly accessible by the main crane and activities such as moving pipeline sections to the welding tunnel.
In addition to the fact they can be fixed pedestal offshore or mobile units, the cranes used for underwater activities can be identified by the models of boom used.

- Lattice boom:
  Lattice booms are made up of multiple steel bars welded together in a "W" or "V" pattern. This design, which has been used since the middle of the 19th century, allows for minimizing the boom's weight without affecting its strength. This technology is used for heavy-load cranes. However, lattice booms' length cannot be varied. For this reason, the distance of the load from the crane is adjusted by pulling or slacking the luffing winches.

- Single box boom:
  These booms are made of welded thick metal sheets forming a hollow caisson. This design offers good stiffness and easy maintenance. For this reason, they are commonly used on offshore platforms and vessels. Their inconvenience is that they have a fixed length. Thus, similarly to lattice booms, the operator must adjust their angle to adjust the distance of the load from the crane. Note that most cranes using this boom type are equipped with hydraulic cylinders instead of Luffing winches and cables.

- Telescopic boom:
  Telescopic booms are composed of elements arranged in the same manner as Russian dolls that can extend to different lengths and retract for transport. This system works with hydraulic cylinders that push or pull the sections out or in, allowing the boom to extend or retract. The obvious advantages of such systems are their compacity and the fact that the boom can be adjusted in length. The crane below allows lifting to 100 tonnes.





- Knuckle boom
  A knuckle boom is a "single box boom" at the end of which an articulated jib motioned by hydraulic cylinders is mounted. This relatively new design allows for more flexibility than traditional lattice booms regarding the control of the distance of the load from the crane. This concept is commonly used for cranes designed to lift to 300 T, which is why many companies working offshore use these cranes.

- Foldable boom
  These booms combine telescopic and knuckle boom technologies. Their advantage is their compactity when folded, which is the reason they are used on boats and delivery trucks. However most models are limited to light loads (≤ 15 T). The model below is the AK-30-LH designed by HS-Marine (Website: https://hsmarine.net/).

1.2 - Design and safety requirements

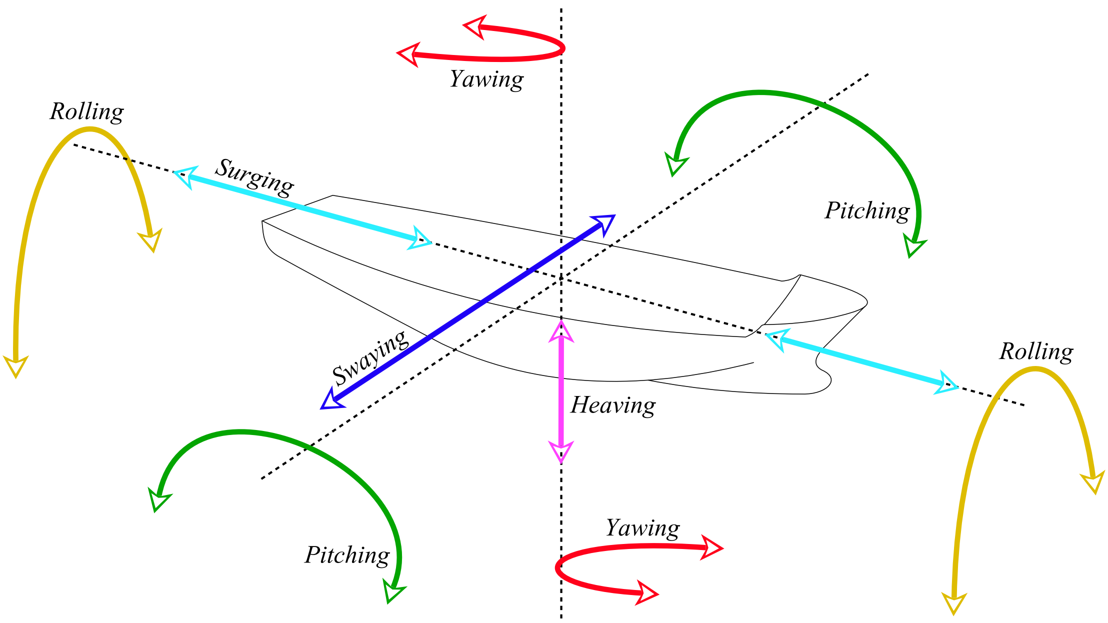
1.2.1 - Structure and stability

The standards EN 13000, EN 13001, and EN 13853 say that the crane must be sufficiently robust and stable not to be damaged or displaced by the action of loads acting on its supporting sections, including dead weights, additional loads, test loads, and special loads during erection or dismantling of mobile units. Note that the European standards classify the loads as follows:

- Regular loads are those that occur frequently under normal operations:
    - Hoisting and gravity effects acting on the mass of the crane.
    - Inertial and gravity effects acting vertically on the hoist load.
    - Loads caused by travelling on uneven surfaces.
    - Loads caused by acceleration of all crane drives.
    - Loads induced by displacements.
- Occasional loads are mostly those resulting from the environmental conditions:
    - Loads due to the in-service wind.
    - Snow and ice loads.
    - Loads due to temperature variation.
    - Loads caused by skewing.
- Exceptional loads are those resulting from circumstances such as:
    - Damaging winds.
    - Use of test loads.
    - Buffer forces.
    - Tilting forces.
    - Emergency cut-out.
    - Mechanism or components.
    - Crane foundation instability.
    - Erection and dismantling.

In addition, the crane, including all its safety systems, must be designed for safe operation within its in-service operational limitations.

- For systems operating at sea The operational limitations in terms of wave induced motions of the load must be included in the load charts for a realistic set of environmental conditions.
- The boom must be capable of being lowered from minimum radius. against the in-service design mean wind velocity increased by 5% and acting in the most unfavourable direction. In addition, a rope luffed boom must not stall when the crane is operated within its operational limits. To prevent it, an active push-out device can be installed. It is also considered acceptable to provide an alarm/warning on danger of stalling as long as this is sufficient to enable the operator to avoid the danger.
- Cranes installed on floating units should be designed to take into account the effects of the unit's static and dynamic motions. That includes establishing the unit's motions at different wave heights for the crane in and out of service by testing or analysis considering the effects of the mooring system.
  The crane, in its stowed position and the stowage arrangements, must be designed to withstand the combination of motions and wind forces.

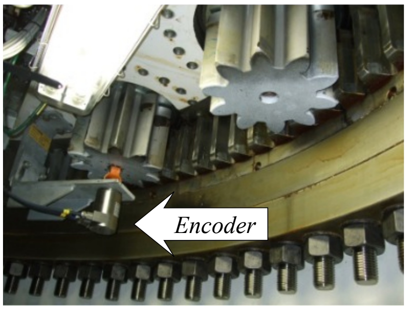


- In addition to the wind and waves, thermal effects should be also considered:
    - Wire ropes and electric cabling may be subject to heat from flares, turbine exhaust, extreme weather, etc. EN 13853 says that precautions should be taken to minimize these thermal effects. The maximum heat exposure limits for safe operations and stowage of the crane should be stated in the Information for use.
    - The additional load resulting from the accumulation of ice should be included in the load calculations. Also, wind loads should be determined on the basis of the increased area of the structural members, due to ice. In-service, no ice on the crane is allowed.
- European standards say that steel should be used for structural members of cranes. Specific requirements for structural members subjected to compressive or tensile stresses may be considered. These structural components must be protected from corrosion. In addition, the bolts must be galvanized or made of corrosion-resistant steel for those equal to or smaller than 10 mm. The European standards say that special corrosion protection measures should be provided in case other steel qualities are used.

1.2.2 - Slewing system

The slewing system consists of a ring with internal gear and slewing gearboxes with integrated fail-safe multi-disc brakes. The slew gearbox pinions mesh with the geared inner ring of the slew bearing, allowing the boom to rotate 360°. On modern cranes, the angle and the speed of rotation is monitored by absolute encoders, which are feedback devices providing information by outputting a digital data stream or an analogue signal.
Hydraulic motors usually drive these gearboxes. Pilot valves are provided on their ports to stop the slewing motion in case of hydraulic pressure drop. Also, a slewing-overload-protection system is integrated into the hydraulic slewing circuit to prevent severe damage to the crane if an external force, such as mighty winds, forces the crane to slew. The the protection system is triggered to allow the crane to slew before it is seriously damaged.

Slew Ring



Slew ring gear & absolute encoder

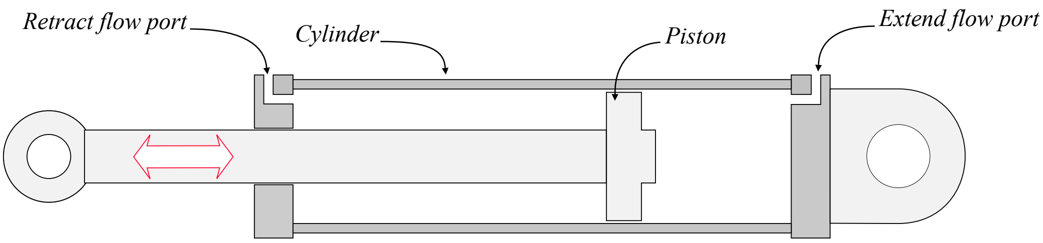
Slew gearbox & motor

Regarding slewing systems, standards EN 13853 and EN 1300 say the following:

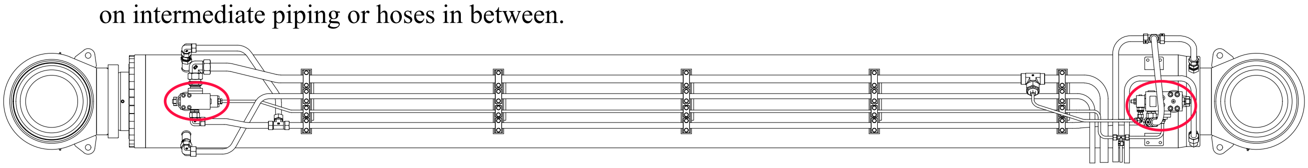
- The manufacturer must specify the properties of the slewing bearing, its fasteners (chemical composition, mechanical properties, heat treatment, etc.), and their installation procedures. These elements should be greased and sealed against corrosion.
- The slewing drive system must be designed to hold at least 1,3 times the static design slewing torque resulting from the wind, the crane base inclination, and the side load effects. If the holding capacity is less than this, the crane must be equipped with a slew torque indicating device giving continuous information of the actual slew moment to the crane operator.
- In case of a restricted slewing range, due to the vessel or the platform layout, the crane should be equipped with a slewing limiter, which automatically stops the slewing motion when the limit is reached.

1.3.2 - Luffing cylinders

A lot of models of cranes described above have their boom luffed and adjusted in height by double acting hydraulic cylinders. They are composed of a piston that moves out and retracts in a cylinder as a result of the injection of oil in one side or the other, which creates motion in a straight line.



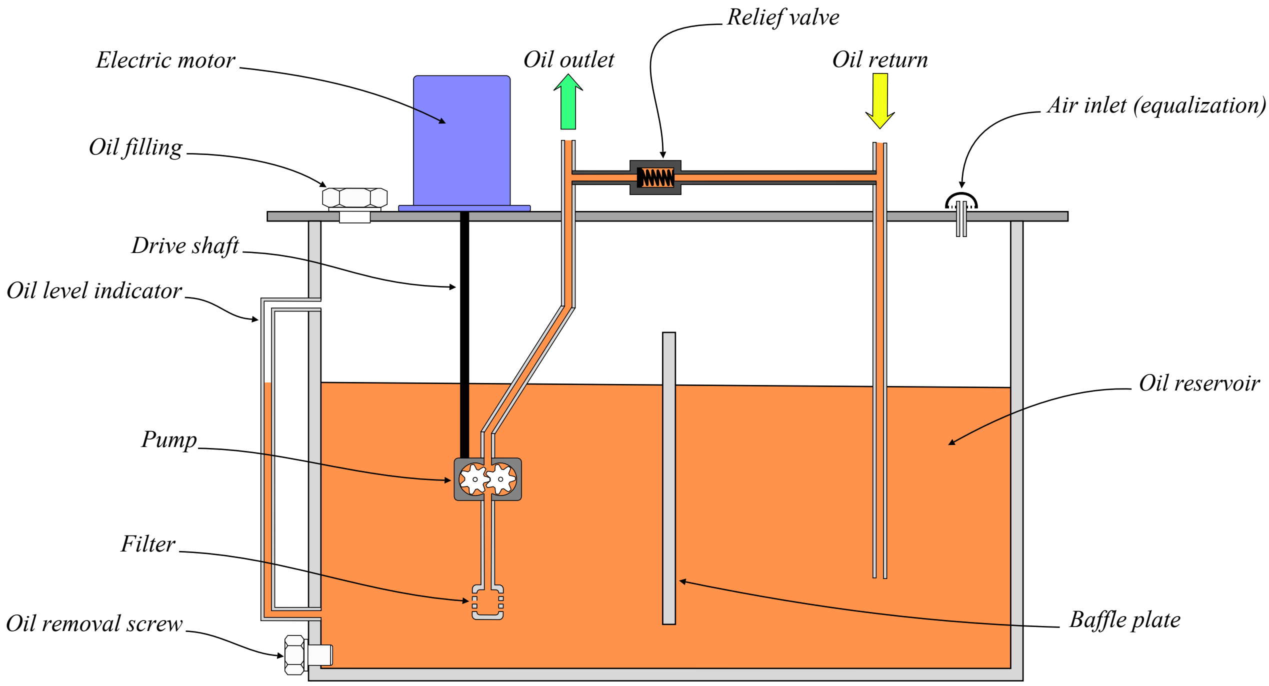
- European standards say that the hydraulic cylinders used for lufling, folding, or telescoping, must be fitted with a device that holds the boom in position in the event of loss of hydraulics pressure to the cylinder or hose/pipe burst. This device must be directly connected to the cylinder *(see the red circles in the drawing below)* and not on intermediate piping or hoses in between.



- Hydraulic cylinder designs must be based on the maximum pressures and dynamic forces acting in-service and out-of-service. Also, they must be designed to withstand the environmental conditions of the crane.

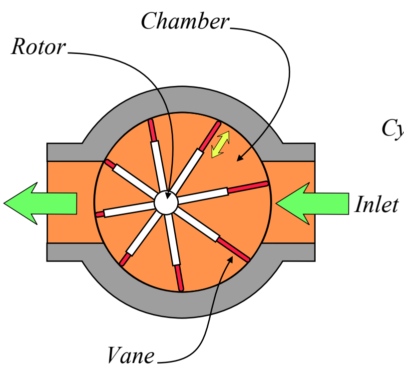
1.2.4 - Hydraulic Power Unit (HPU) & direction control valve

Hydraulic cylinders and motors cannot be operated if there is no pressure in the circuit that feed them with oil. It is the function of the Hydraulic Power Unit, also called Hydraulic Power Pack.
The Hydraulic Power Unit is composed of a hydraulic pump that is driven by an electric motor, an oil reservoir, pipework with pressure relief valves and a filter.

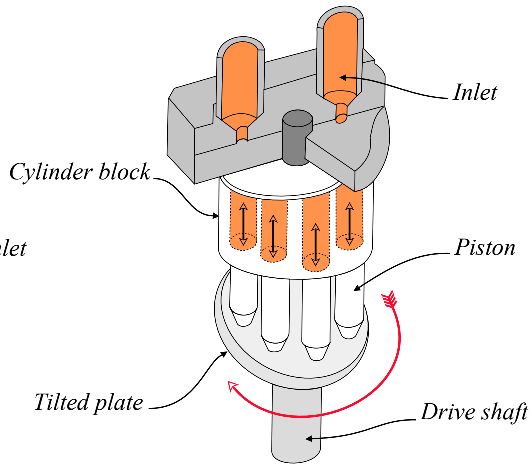


The pumps usually used are positive displacement pumps that are sufficiently powerful to power the tools they supply. Three types of pumps are commonly found:

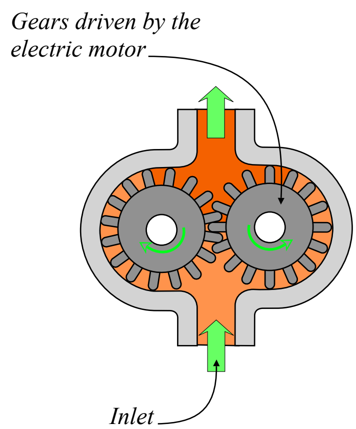
- Gear pumps produce a flow of oil by using the teeth of two meshing gears to move the fluid. They are reputed robust and can transmit high amounts of hydraulic fluid.
- Piston pumps are also used for this purpose. They contain one or more pistons that convert the rotary shaft motion into an axial reciprocating motion. They are composed of a tilted plate that rotates, causing the pistons to move up and down, and thus, take the fluid and expel it each shaft rotation *(See the scheme below)*.
- Vane pumps are also found. They consist of a rotor rotating inside a circular cavity where its centre of rotation is eccentric. Several vanes are in place at the periphery of this rotor, creating chambers that vary in volume as the rotor turns. The intake of the pump is where the chambers are the largest. The outlet is where the size of the chambers is smaller.



Vane pump



Piston pump



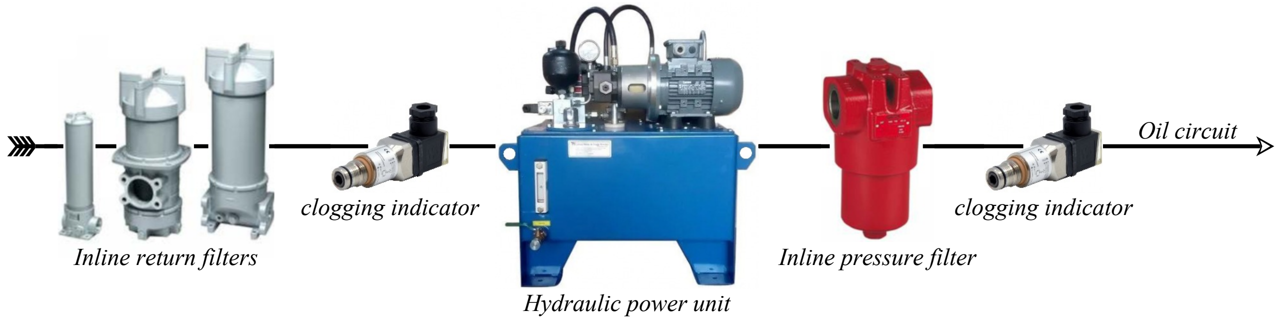
Gear pump

The the oil reservoir is designed to:

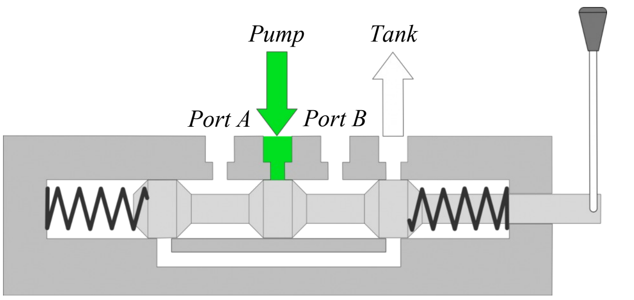
- Hold enough fluid to adequately supply the hydraulic system: For this reason, it must have a sufficient volume to supply the elements connected to it and collect the returning fluid from these elements. Note that fluids expand when they are hot, and this phenomenon must be taken into account when the volume of the tank is calculated.

- Provide communication to the external atmosphere, and sufficient space above the fluid to let the air compressed when it is hot to escape to the atmosphere and vice versa.
- Provide a surface that is large enough to transfer the heat from the fluid to the ambient environment by radiation and convection.
- Avoid fluid turbulence at the pump inlet: It is the function of the "baffle plate" that forces the fluid from the return line to take an indirect path to the pump inlet. The baffle plate also limits the movements of the stored hydraulic oil linked to the sea conditions encountered by the boat.
- Provide a gauge to check the volume of oil and means of access to top-up if necessary, and change it when it is too old or dirty.

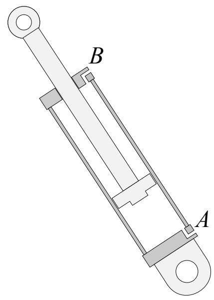
Many modern cranes have HPU equipped with oil heaters to reach a suitable operating temperature faster. The system has an onscreen warning and a thermostat that deactivates it when the recommended temperature is reached.
A relief valve is usually installed at the pump outlet. Other relief valves may be provided in the hydraulic circuit.
A filter is usually installed at the pump inlet. However, many manufacturers also provide filters to clean the oil returning to the tank and the communication of the tank with air. Clogging indicators indicating when a filter change is necessary are provided to ensure the optimum quality of the oil.

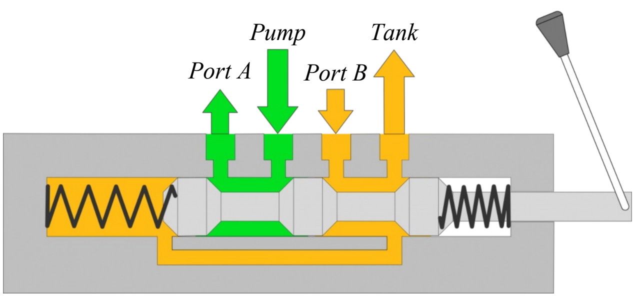


The hydraulic circuits of cranes are provided with accumulators that provide a reserve of oil under pressure that regulate the delivered pressure and allow for an immediate response of the system to requests. They consist of a container where the oil is separated from pressurized neutral gas by a flexible membrane or a piston, so the pressure of the neutral gas applies to the liquid.
Linear hydraulic directional control valves are usually employed to operate the double-acting cylinders and motors of small cranes because they combine ergonomic and ease of maintenance. They are made of a rod with lands and grooves which slides inside a cylinder with the help of a lever acting as a directional command. Lands (large diameters sections) close inlets and outlets, that are opened by the grooves (small diameter areas). The distribution of the ports according to the diameters of the rod allows obtaining various open and closed combinations, as in the example below:

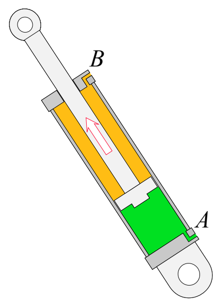


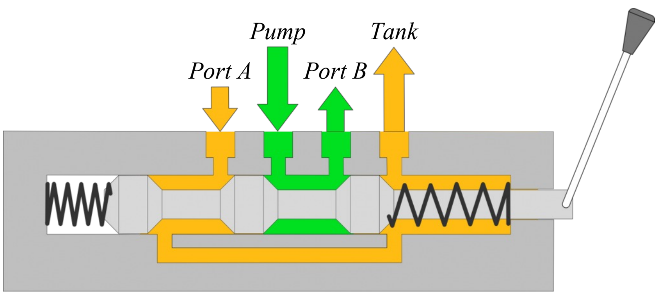
Standby position:
The inlet from the pump and the outlet to the tank are closed as well as the ports to the hydraulic cylinder. As a result, the hydraulic cylinder is not activated. Note that the overpressure valve of the oil inlet (not figured) is activated, so the oil returns to the tank. The springs are of the same force and maintain the arrangement in this neutral position.



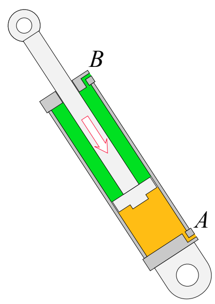


Luffing the boom:
When the lever is pushed, the inlet flux from the pump goes to port A, and port B communicates with the tank. As a result, pressured oil is injected into the cylinder through port A, so the piston is pushed from A to B and expels the oil from the other side of the cylinder through port B. The cylinder rod extends, and thus the boom is luffed.





Lowering the boom:
When the lever is pulled, the inlet flux from the pump goes to port B, and port A communicates with the tank. As a result, pressured oil is injected into the cylinder through port B, so the piston is pushed from B to A and expels the oil from the other side of the cylinder through port A. The rod of the cylinder retracts, and thus the boom lowers.



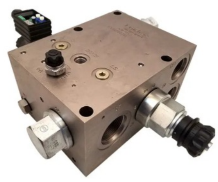
Note that a single valve controls both hydraulic cylinders

Hydraulic directional control valves are arranged alone or in blocks depending on the number of elements to control. They should be installed such that they are protected from shocks and undesired maneuvering and that the lever returns to the neutral position when not maneuvered. Also, highlighted labels indicating to the operator the effects of the commands' positions should be in place so that the operator knows it before operating them.

Important:
On big modern units, the luffing and orientation of the crane are controlled via a joystick. This joystick acts through solenoid valves activated by electric signals that replace the traditional manual-acting valves.

Block 3 valves
(https://www.comeo-france.fr)

Block 2 valves
(https://www.ubuy.co.th/en/)

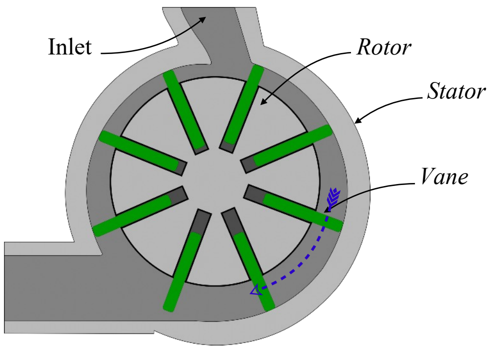


Solenoid valve
(https://www.directindustry.com/)

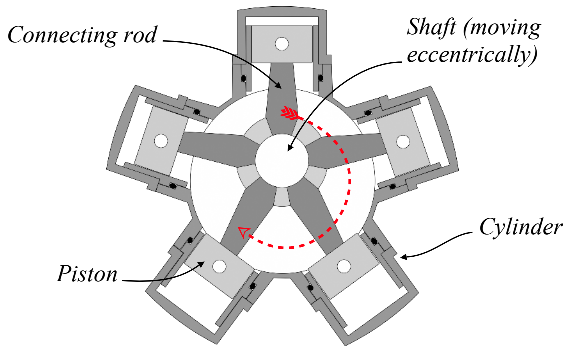
1.2.5 - Winches

Electrical or hydraulic winches are used to lift and lower the load and luff the boom of some cranes. They are composed of a motor, gears providing reduction, a drum, brakes to stop and secure the drum, and a clutch system.

- Hydraulic motors are designed like the hydraulic pumps discussed in point 1.1.6, except they receive the hydraulic flux instead of producing it.
  Radial pistons motors convert the reciprocating motion of pistons arranged radially into the rotary shaft motion: The liquid is fed to the top of the cylinders, pushing the pistons one by one, which produces the rotation of the shaft, which incorporates an offset from the centre of rotation. This turning motion creates the mechanical power which drives the winch. As suggested above, vane motors receive a hydraulic flux that rotates its stator, and gear motors, not represented below, are based on the previously described gear pumps' principle working opposite.
  Note that vane and radial pistons motors are also used with pneumatic winches.

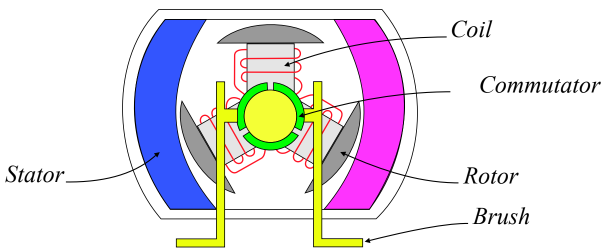


Vane motor

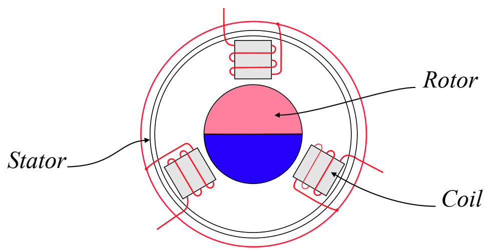


Radial pistons motor

- Electric winches with heave compensation have become usual with some model offshore cranes. These winches are usually powered with 440 volts Alternative Current (AC), and brushed or brushless electric motors are used.
  As a reminder, the difference between brushed and brushless motors is that the current passes through coils mounted on the rotor with brushed motors. This assembly rotates because each coil generates a magnetic field that is pushed away from the pole of the stator of the same polarity and is pulled toward the one of opposite polarity. The power to these coils is supplied through fixed conductive brushes that make contact with a rotating commutator. With brushless motors, the coils are located on the stator instead of the rotor that is made of two separate polarities permanent magnets. As a result, the coils do not rotate, and there is no need for brushes and a commutator.

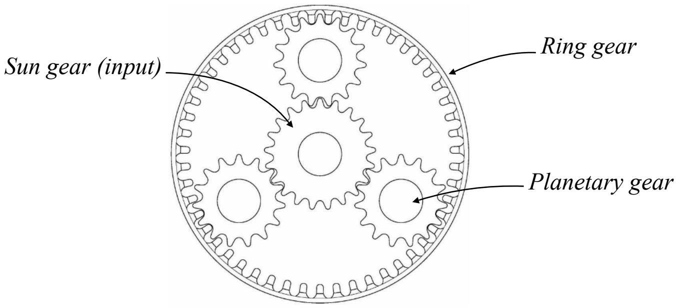


Brushed Motor

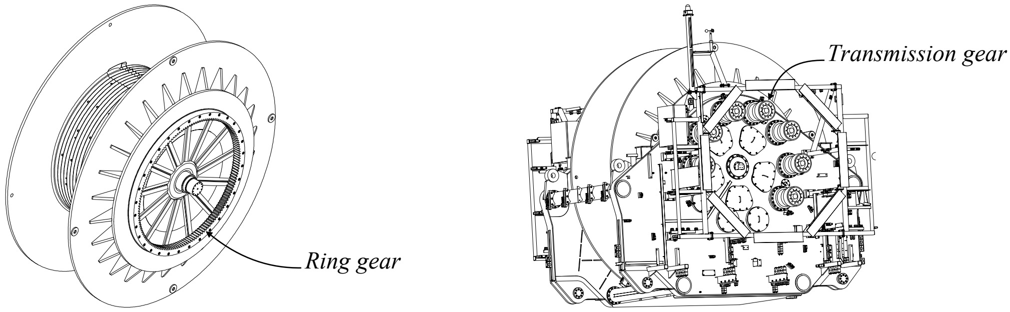


Brushless motor

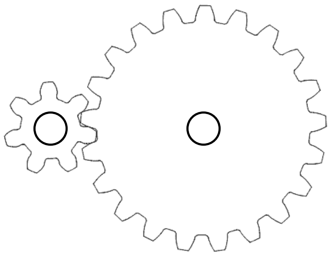
- Gears are used to transmit the motion of the motor to the drum. Among the numerous arrangements available, the solutions below are frequently used:
  - "Planetary gears transmission", also called "epicyclic system", is the most commonly used system with winches installed on surface supplied diving LARS.
    An advantage of this system, which is also used in automatic gearboxes of cars, is that it allows for numerous combinations and, according to manufacturers, transmits approximately 95% of the motor's energy. In addition to its excellent efficiency, this technical solution is reputed to be strong, smooth to operate, and compact. However, this type of transmission does not immobilize the drum when the motor is stopped; therefore, a braking mechanism that automatically does is to be added.



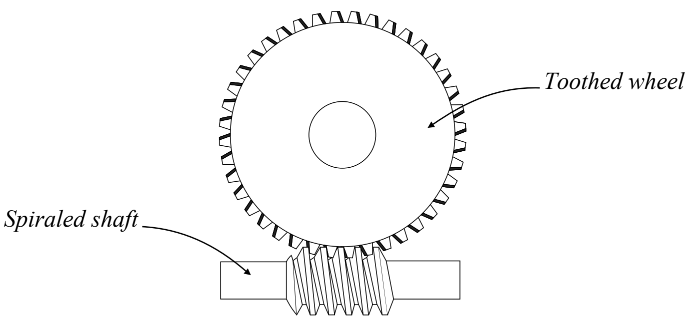
  - A derivation of planetary transmission consists of several transmission gears (Input gears) installed in place of the planetary gears. This system is often used with big cranes.



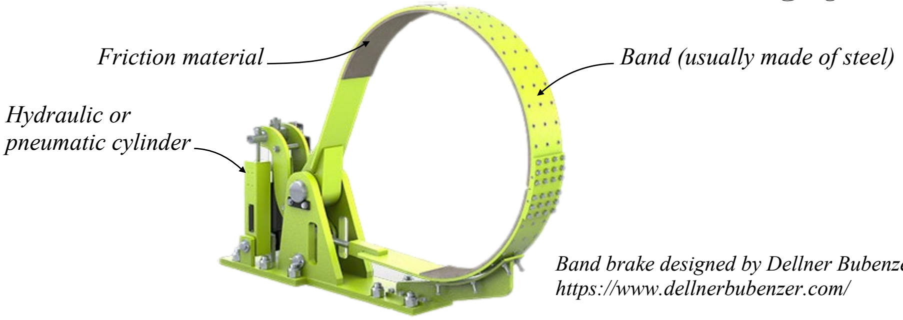
  - Spur gear systems are transmission systems used in various industries for a very long time. They are more simple, but less compact as planetary gear systems, and have an efficiency that, again, according to manufacturers, is comparable. However, it is said that a planetary gear system is more effective to transmit high speed and high torque. Like planetary gears systems, this type of transmission does not immobilize the drum when the motor is stopped; Therefore, an automatic brake is to be added.



  - Worm gear transmissions consist of a spiraled shaft that drives a toothed wheel. They offer high reduction, good reliability, and a built-in braking mechanism associated with their design, as the gear cannot move if the worm does not rotate. However, it is said that they transmit less energy than the planetary and spur gear solutions and provide a slower winching speed.

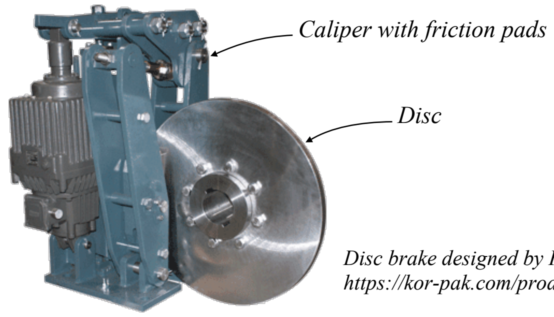


- Many braking systems can be used. Their work principle is based on friction, which slows down or stops the winch and converts kinetic energy into heat energy. Thus, the effectiveness of a brake depends on the surface of friction and the force applied to this surface. Three types of brakes are commonly found on crane winches:
  - “Band or drum brakes” consist of friction material that tightens concentrically around a large cylindrical piece. The system can be operated through a lever, a clamping screw, or a pneumatic or hydraulic cylinder.



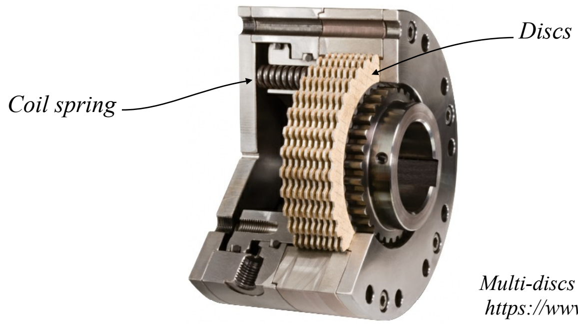
Band brake designed by Dellner Bubenzer
https://www.dellnerbubenzer.com/

- Simple disk brakes use one or several calipers to squeeze pads against a disc, creating friction that slows the rotation. This disc is sometimes the edge of the drum. Specialists say that disc brakes provide a more predictable response at high temperatures and wet conditions than drum brakes.



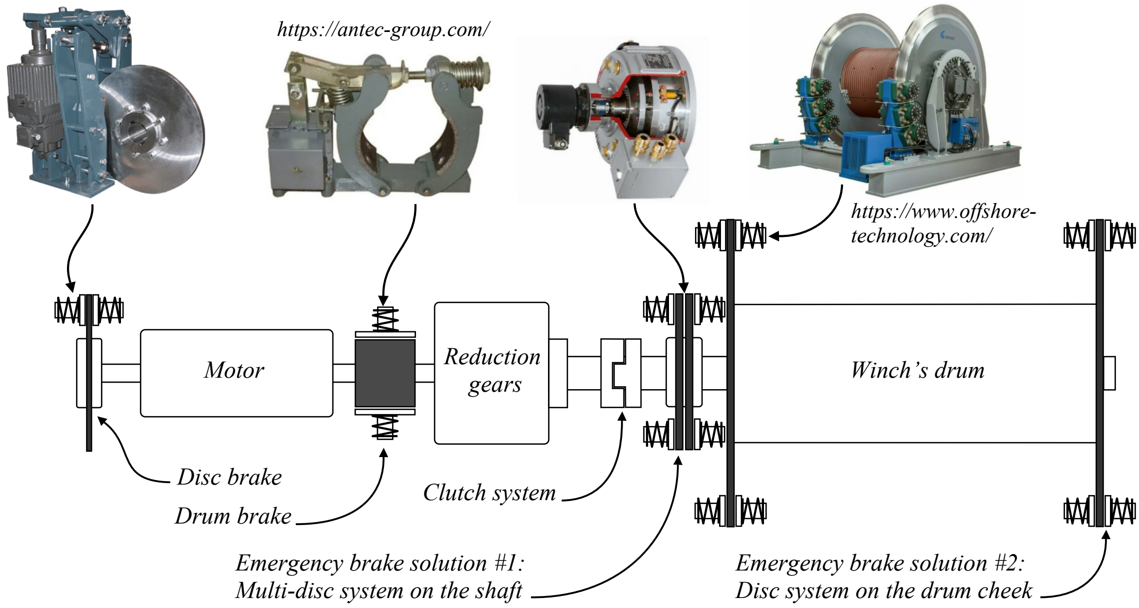
Disc brake designed by Kor Pak Corporation
https://kor-pak.com/product/thruster-disc-brakes/

- Multi-Disc Brakes are fully enclosed units that use coil springs and multiple friction discs to slow down or stop the winch's drum. The pressure on the discs is applied by the coil springs and released using hydraulic pressure, with a maximum braking torque when hydraulic release pressure is zero. As a result, the brake is automatically activated when the winch is not supplied with fluid. For this reason, these brakes are often associated with planetary and spur gear transmission systems. Note that the surface of friction can be increased by multiplying the number of discs.



Multi-discs brake designed by Altra Motion
https://www.altramotion.com/

- Depending on their function, winch brakes are typically positioned near the motor and the reduction gears. Emergency brakes are also placed on the shaft or the cheeks of the winch drum.



- Most regulations regarding winches and their braking systems are similar. For this reason, we can refer to the requirements of EN 13852-1 regarding the minimum safety requirements:

- Brakes activation systems:
  Crane brakes must automatically be activated without undue delay when the motion control lever is returned to the neutral position, at power failure, control failure, or at an emergency stop. An exception may be made for the hoist winch and sewing system during off-board lifts when the hook is near the supply vessel. Also, operational brakes must be designed to retard, stop and hold the crane and the load at all standard operating speeds, configurations, and situations, regardless of any braking effect from the drive system. In addition, brakes of the self-locking type must only be used as parking brakes, and particular attention must be paid to the effect of the moment of inertia from the motors for electrical driven mechanisms. Note that lowering the load and/or boom by use of friction brakes only, is not allowed.
- Brakes installation:
  Mechanical brakes must preferably be placed directly on the winch drum. If a geared transmission is placed between the brake and the drum, the transmission components must be considered brake components. The number of load-carrying components should be kept at a minimum.
- Ease of inspection:
  Brake mechanisms must be easy to inspect.
- Mechanical design:
  Brake springs must be of the compression type. Reduction of braking capacity due to foreseeable wear in between maintenance intervals must be taken into account.
  The lowest expected coefficient of friction is to be applied in the design calculations of the braking capacity, but this coefficient of friction is not to be taken higher than 0,3. Note that brake linings must be made of asbestos-free material.
  All brake components, except those for slewing brakes, snail be designed for a load of at least 1,6 times the maximum actual loads.
  Brake components for slewing motions must be designed for a torque of at least 1,3 times the maximum actual load torque from operational wind, side load, and crane base inclination. The components must be designed so that moisture, oil, and other contamination cannot reduce the braking capacity below the design value. The brake system must not prevent the operation of the overload protection systems.
  The braking system must be designed not to cause dynamic effects that may damage the crane or its components and shall not cause overheating. Also, brakes based on hydraulic restrictions, such as shutoff valves or similar must be capable of withstanding the pressure shocks due to brake impacts. For this reason the following components should be in place:
  - The hydraulic motor must have a closing valve directly at the high~pressure (load) connection. This closing valve is not on the pipe or hose connection in between.
  - The closing valve must be designed to close in case of pressure loss at the low-pressure connection (inlet connection during lowering). This is done by direct bore or piping between the closing valve and the low-pressure connection.
  - The hydraulic motor must be supplied sufficient working fluid, also in the event of power failure.
- Fail safe brakes:
  All hoisting machinery, luffing, folding, telescoping, and slewing must be provided with fail-safe brakes. The purpose of this system is that a failure of the brake's control system automatically leads to the application of the brake. These brakes must be based on mechanical principles or hydraulic restrictions.
- Additional requirements for personnel transfer:
  In addition to the standard working brake, hoisting winches must be equipped with a mechanically and operationally independent backup brake with separate control circuits. This backup brake must preferably act directly on the winch drum, but a fully independent load path will be considered acceptable. The backup brake must be designed such that independent testing can be performed.

1.2.6 - Lifting wire rope and hook

Construction requirements of hooks and wire ropes and their maintenance have been described in points #C- 5 & #D. For this reason, this point focus only on safety requirements from EN and OSHA standards

- Wire rope termination:
  EN -13852-1 says that wire rope termination of cranes should be a wedge socket, a poured socket (metal or resin), or ferrule-secured eyes (with thimble only).

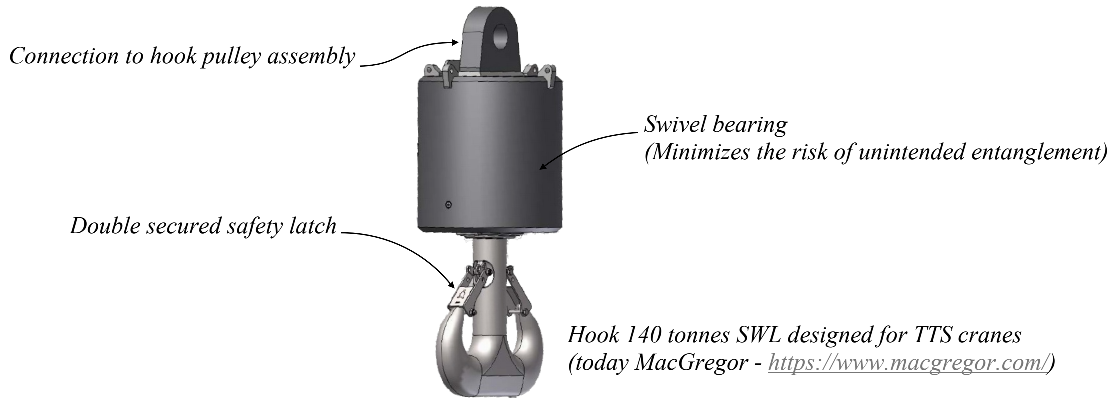
Wedge socket

Poured socket

Ferrule-secured eyes

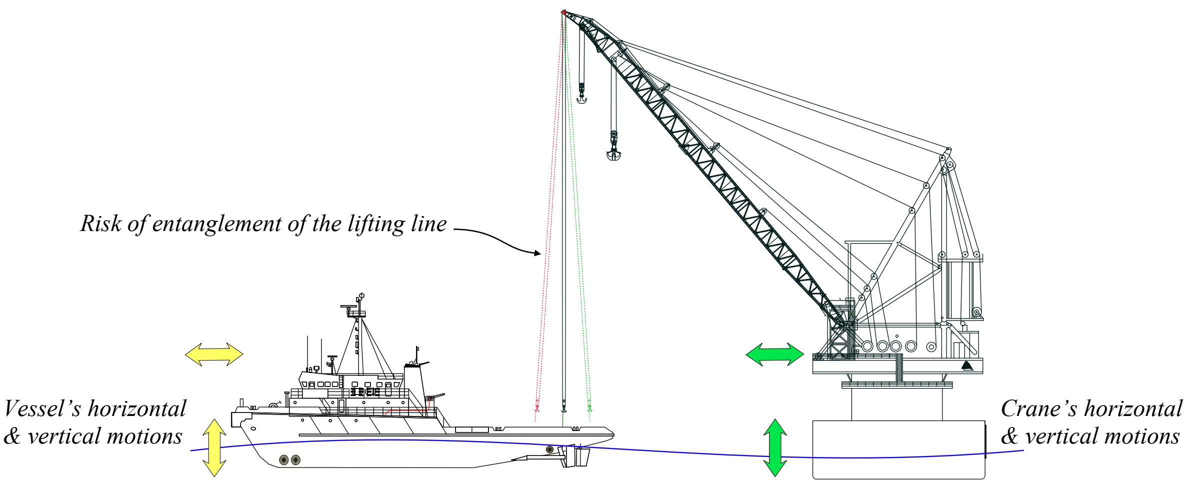
As they are usually exposed to motions or impacts, these terminations must have double means of locking to avoid accidental loosening and detachment during operation. Also, attachments such as wire rope terminations, shackles, swivels, hooks, and similar components should be designed and equipped to minimize the risk of unintended entanglement.

- Rope fastening to the drum:
  The wire rope anchorage must be designed for a minimum breaking out force equal to the minimum breaking load of the rope minus the amount of the friction effect from remaining wire rope.
  EN -13852-1 says that there must be a minimum of 3 turns of wire rope left on the winch drum with the hook and the boom at their most adverse positions.
  The distance between the top of the outer layer of the wire rope on the drum and the outer edge of the drum flanges shall be at least 2,5 times the diameter of the wire rope, except in cases where guards are fitted to prevent over spilling of the wire rope.
- Wire rope safety factor
  The safety factor of wire ropes must be calculated by the crane manufacturer and approved by the certification body for each particular crane reeving configuration and based on the maximum rated capacity for each configuration.
  OSHA says that the wire rope and the replacement wire rope must be of the same size, same or better grade, and same construction as originally furnished by the equipment manufacturer or contemplated in the design, unless otherwise recommended by the equipment or the wire rope manufacturer due to actual working condition requirements. In the absence of specific requirements as noted, wire rope shall be of a size and construction suitable for the purpose, and a safety factor of 4 shall be adhered to, and verified by wire rope test certificate.
- Hooks
  The crane must be designed so as to prevent structural damages from hook blocks impacts. Also, a hook block impact must not lead to a possible dropped object. For this reason, safety latches shall be provided on all hooks. Regarding this last point, the safety latches which have a spring loaded closing mechanism only, must have additional means to prevent accidental opening.



1.2.7 - Protection systems against entanglement, load bouncing, and overloading

Offshore cranes must be equipped with an "Automatic Overload Protection System (AOPS)" and a "Manual Overload Protection System (MOPS)" to overcome entanglement situations during off-board lifts in case the hook is tangled as a result of vertical and horizontal motions of the vessel. Constant Tension (CT) systems are complement of AOPS.



- The "*Automatic Overload Protection System (AOPS)*" is designed to monitor the loads and load moments of the crane continuously. It must be operational in all normal conditions and for all reeving configurations. It is automatically activated when the hook is entangled with any moving object. In this case, the hold-back force is at least equal to the allowed safe working load (SWL), meaning low enough to ensure the integrity of all structural components and yet high enough to prevent an accidental load release at any operating radius. Note that this system, mandatory with offshore cranes under EN standards, is not imposed by all regulations.
- A *"Constant Tension (CT)*" system allows the operator to set a fixed setting to obtain a certain wire tension to help him to lift loads mainly from other ships. This function, which can be activated or deactivated by the crane operator, can be seen as a complement of the Automatic Overload Protection System to avoid uncontrollable

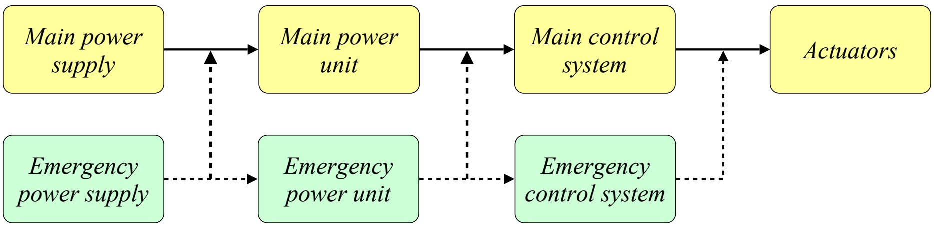
bouncing of the load during its lifting or landing. It can also be used to set the rope tension for lifting objects on the seabed or lift partially embedded loads that are difficult to recover due to suction.

- The *"Manual Overload Protection System (MOPS)"* protects offshore cranes from loads higher than those they have been designed for when an overload occurs gradually enough for the operator to react.
  The MOPS is designed to be operational in all configurations and be activated anytime, including after an emergency stop and power failure.
  After activation, the MOPS disengages the hoisting brakes, and maintains a retaining force between 10 % to 20 % of the maximum rated capacity for onboard lifting, allowing the crane to pay out wire with low tension, and the wire rope to be spooled completely off the drum, without causing significant damage to the crane.
  This means that the load may be dropped once activated in the wrong situation. For this reason, the system must include an activation button to protect against unintended use, operation during personnel lifting, and its use in places other than the sea. The activation switch or handle must be readily accessible in the control station, protected against accidental use, and be able to be deactivated by the crane operator. For this reason, it should be marked with yellow colour against a contrasting background and preferentially located on the left-hand side of the crane operator.
- Cranes should be equipped with an automatic protection system to prevent lateral overload of the boom or overload on the slewing mechanism if sideload loads occur outside the design limits.
  Overload protective devices work by sensing the force of the load. When the load exceeds a preset percentage of rated capacity (usually 100 to 125%), this device temporarily inhibits the hoist so that the crane can only lower the load. The system can be mechanical, electrical, electronic, or a mix of several solutions.

1.2.8 - Emergency Operation System (EOS)

General-purpose cranes should also be equipped with an Emergency Operation System (EOS). This system allows the operation of the crane with reduced speeds in case of a single-point failure or interruption of the main power supply, main power unit, or control system:

- Backup power supply:
  To cover any single point failure or interruption of the main power supply, the crane shall be equipped with or have means of connection to an independent emergency power supply. The emergency power supply may be a redundant main power supply or an emergency power supply from the installation, or a "stand-alone" emergency power supply in the crane, e.g. a diesel driven generator.
- Backup power unit:
  A backup power unit should be provided in case of a single point failure in the main power unit put the crane out of operation. The backup power unit might be a separated power unit or a system that uses the redundancy of the main power unit, providing that any single point failure in the main power unit do not compromise the EOS. If a single point failure in the main power unit will not put the crane out of operation, an emergency power unit is not required.
- Emergency control system:
  An emergency control system must be provided to control the main functions of the crane (hoisting, luffing, slewing, knuckling and telescoping), if a single point failure in the main control system can put the crane out of operation. The emergency control system might be a fully separated control system or it might be a system that makes use of the redundancy in the main control system, providing that any single point failure in the main control system shall not compromise the EOS. If there is no risk that a single point failure in the main control system put the crane out of operation, this emergency control system is not required.
  The Emergency Operation System should be capable of moving the crane from any position with any hook load to a safe position.

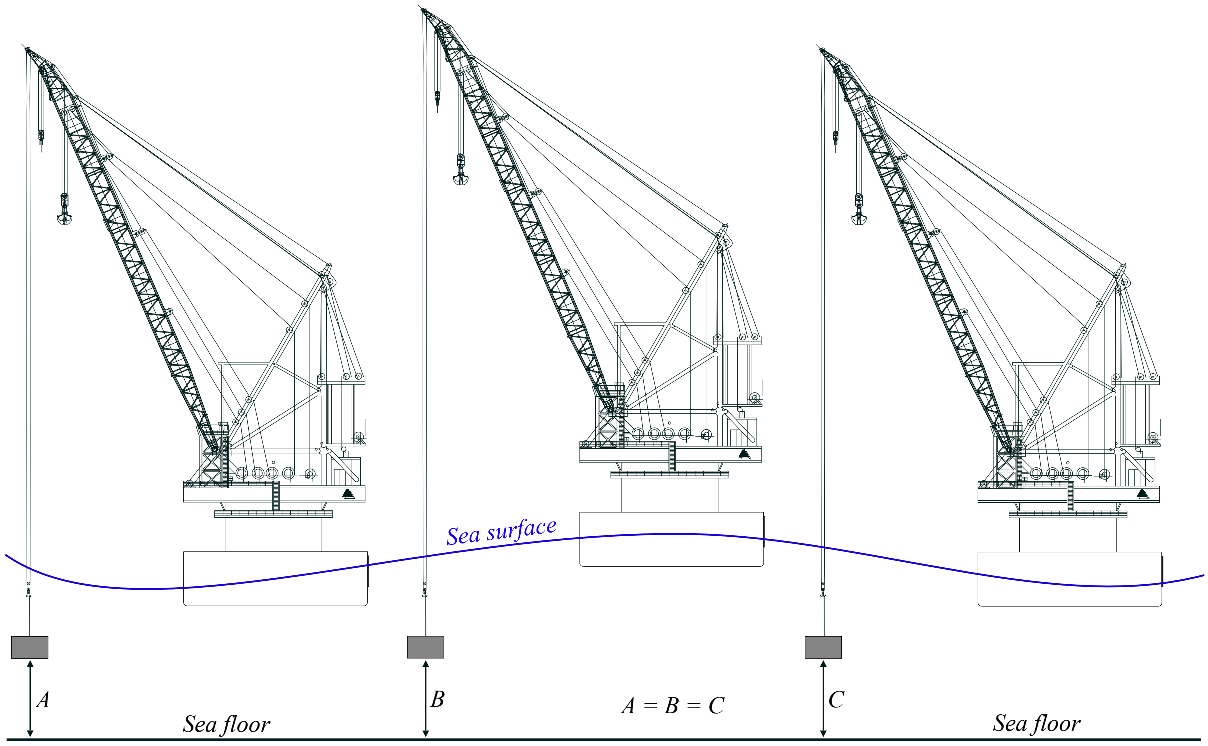


- Cranes must be equipped with an emergency stop system, which activation causes all the motions and motors to stop and all the brakes to be applied.
  An emergency stop actuator (button) should be readily accessible by the crane operator, preferably located on his right-hand side. Additional emergency stop actuators, connected in series, should be installed in places such as on the starter cabinet, near the winches, at the entrance of the machinery house, on the pedestal, etc.
- A fire alarm system in combination with a manual discharge extinguishing system should, as a minimum, be provided. The fire alarm includes a siren and visual alarms in visible areas of the crane.
  Smoke and heat detectors should be installed in critical parts of big cranes and designed to trigger extinguishers. In addition to the active firefighting systems, the units should be built with noncombustible, fireproof, or reduced flammability materials.
  Of course, small units do not have integrated firefighting systems. In this case, portable extinguishers should be provided near the crane.

1.2.9 - Heave Compensation

Heave compensation systems counteract the heave motion of the ship on the crane and the load. They consist of passive and active systems described in point #7.5.2 of chapter #7*"Evaluate and manage the Weather conditions and currents"*. This chapter includes them because such systems allow lifting operations during adverse weather conditions for cranes not equipped with them.

- Passive Heave Compensation (PHC) systems accumulate kinetic energy from the ship's movements and use this energy to compensate for the position variation between the vessel and the load. They are reactive devices, not consuming external power, to be inserted between the hook of the crane and the load, and thus are not part of the crane. These systems limit the dynamic loads due to heave motion and avoid crane overloading due to extra weight caused by the sudden change in lifting speed. Thus they are not maintaining the load at a set distance from the seabed.
- Active Heave Compensation (AHC) systems utilize a Motion Reference Unit (MRU), which is an inertial measurement unit with multi-axis motion sensors that actively measures all the movements of the vessel. Based on the data collected, a computer calculates the necessary counter motion of the system and controls it in real time. As a result, the length of the cable is permanently adjusted to counteract the vertical movements of the vessel, and there is no variation in the distance of the load from the bottom; thus, its depth is kept constant. The systems that adjust the length of the cable can be based on hydraulic cylinders and also rotary hydraulic motors or electric motors that directly move the winch.



Animations from manufacturers explaining Active Heave Compensation are available on or website through the following links:

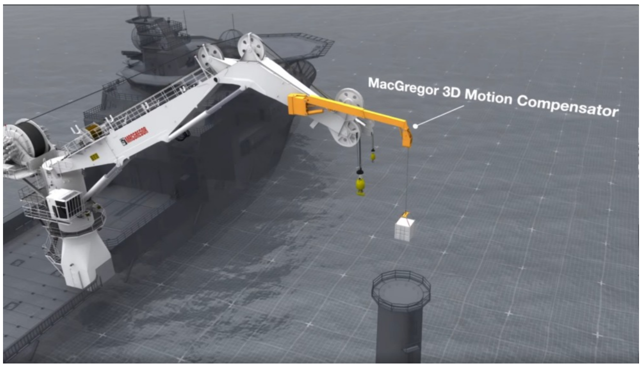
- Videos & animations Lifting systems and winches Diving and ROV Specialists.com website:
  https://diving-rov-specialists.com/viseos%20&%20animations%20-%20page%201.htm
- Hydac system:
  https://diving-rov-specialists.com/index_htm_files/ls7_hydac-heave-compensation-systems.webm
- TTS Systems:
  https://diving-rov-specialists.com/index_htm_files/ls8_tts-active-heave-compensation.mp4
  https://diving-rov-specialists.com/index_htm_files/ls9_tts-subsea-crane-active-heave-compensation.mp4

1.2.10 - 3D motion and Ship to ship compensation systems

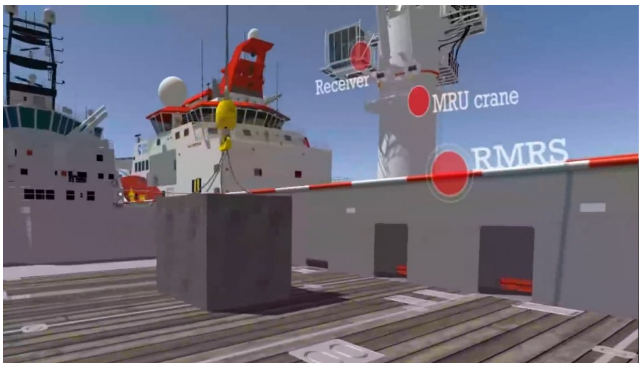
The "3D motion compensation system" is a new system, developed by MacGregor, that compensates for a vessel's movements in the horizontal axes (pitch and roll) as well as along the vertical axis, in addition to standard AHC systems that use the crane's winch to compensate for vertical movements
This new technology that consists of an additional jib that can be added to any telescopic or knuckle boom, can securely keep a suspended load in a fixed position regardless of sea conditions.

The "Ship to Ship" compensation system, also designed by MacGregor, employs a motion reference unit on the deck of the second vessel that transmits motion data to the crane on the primary ship via a high-speed, redundant wireless link. Combining motion data from both vessels, the system calculates and applies the winch compensation necessary to minimize hook movement at the load-handling zone on the secondary vessel.
This system, which can be seen as an improvement of the "Control Tension", and "Automatic Overload Protection" systems, allows for precise tension and position control for accurate load hook-on, pick-up landing, and hook-off. As a

result, the safety of the deck crew is improved, and the load pick-up and landing are more precise, fast, and smooth. It allows handling the load in any given sea state more safely.



3D motion compensation system



"Ship to Ship" compensation system

Animations about "3D motion" and "Ship to Ship" are available in the same section of Diving and ROV specialists website through the following links:

- 3D motion compensation system:
  https://diving-rov-specialists.com/index_htm_files/ls3_mac-gregor-3d-motion-ompensatorI.webm
- Ship to ship compensation system
  https://diving-rov-specialists.com/index_htm_files/ls2_macgregor-ship-to-ship-compensation-system.webm

1.2.11 - Design for the lifting of personnel

- Winch design for the lifting of personnel is already indicated in point 1.1.7:
  Hoisting winches must be equipped with a mechanically and operationally independent backup brake with separate control circuits. This backup brake must preferably act directly on the winch drum, but a fully independent load path will be considered acceptable. The backup brake must be designed such that independent testing can be performed.
  Also, the brakes must be designed such that they are automatically activated when the controls are in the neutral position.
- Cylinders used for luffing, folding or telescoping, must have two independent cylinders, and each cylinder must be independently capable of holding the rated capacity for personnel lifting. Alternatively a single cylinder can be used, provided that no single point failure can lead to uncontrolled motion.
- The capacity of the crane should be lowered to 50%. Also, the crane must be designed to prevent the activation of the Automatic Overload Protection System (AOPS), the Manual Overload Protection System (MOPS), and the Active Heave Compensation (AHC) during such operations.
- Note that cranes used for personnel transfer must have a certificate delivered by the manufacturer and the certification body.

1.2.12 - Control station

The control station is the place from where the crane operator controls it. It is usually situated near the connection of the boom with the slewing bearing at a sufficient height to allow a panoramic view of the lifting site to the operator.

- The control station of small cranes is in the open air. In this case, the control board is usually limited to linear hydraulic directional valves and a minimum of gauges. The operator is not protected from weather conditions and operates standing or seated. Note that some new models are provided with a portable remote control allowing the operator to monitor the load at its direct proximity. These remote panels can be wired or wireless. In both cases, the operated valves are solenoid valves.
  Small cranes are usually not used for underwater lifting operations offshore. However, they are often used for such operations in harbours and inland. They are also employed during the mobilization phases.
  During underwater operations, the operator must communicate directly with the diving supervisor. That is usually done through wired communications and a headset. A VHF radio is also provided as a backup.
  The control station of medium size and big cranes is located in a cabin that must be waterproof and provided with means for heating, cooling, and fresh air supply. This cabin must be equipped with windows that give a vision of the load, the boom, and the operation area of the crane. EN-13852-1 says that the minimum view angles from the operator position should be 100º.
  Means of defrosting and demisting the windows should be provided. In addition, the front, roof, and floor (if any) windows must be equipped with wipers and washing systems, suitable for the environmental conditions and providing sufficient coverage, not impairing the operator's position. Access to clean the windows and the maintenance of the wipers should be provided.
  Also, the cabin and its windows should be protected from dropped objects and shocks.
  Also, adequate lighting should be provided.
  The control cabin should have a fully adjustable operator seat with arm supports that are used to accommodate the joysticks, essential commands and emergency stops on modern units.

A board should provide at least the following essential functions that should be readable by night:

- Rated capacity indicator.
- Motion limit indicators.
- Machinery status indicators.
- Crane position indicators.
- Power system failure.
- Wind speed indicator.
- Alarm system with clear text.
- Control system failure indicator.

The following typical additional instrumentation can be included:

- Drum motion indicator.
- Hydraulic tank level gauge.
- Hydraulic fluid low level alarm.
- Hydraulic fluid temperature gauge.
- Fuel tank level gauge.
- Air start receiver pressure indicator.
- Tachometer, lube oil pressure, jackets-water temperature, fuel oil pressure.
- Dynamic shock absorber cylinder pressure.
- Fire and gas status.
- Platform status indicator.
- Annunciation panel for shut down logic and alarms with “First up” features.

Note that most last-generation cranes have information provided on digital touch screens, which advantage is that more information than mentioned above can be displayed through screen buttons. As an example, the screen below from a crane model GPOKa 5000-140-36 - 140T AHC Subsea Crane, fabricated by TTS, today MacGregor (https://www.macgregor.com/) , provide the following information:

- Load chart for the selected winch (aux or main).
- Safe Working Load (SWL) for the selected winch according to the selected load chart.
- Load: The sum of the load in the hook and the weight of the paid-out wire rope for the selected winch.
- Radius: The distance between the hook and the centre of the pedestal.
- Wire Out: Length between the hook of the selected winch and crane boom-tip.
- Counter: Relative wire paid out, configurable trip meter.

Additional information, such as the crane mode, Safety system online, control systems, and Hydraulic Power Unit (HPU), are provided at the top of the page.

The combo of the crane mentioned previously allows you to open other pages providing menus and information related to the following topics through the touch screen buttons:

- The Active Heave Compensation (AHC) system page *(see #2 in the picture on the previous page).*

- The Hydraulic Power Unit (HPU) page *(See #3)*.
- The setup page *(See #4)*.
- The service (maintenance) pages *(see #5)*.
- The alarm page *(see #6)*.

Control station in the open air

Control station in a cabin

1.2.15 - Maintenance and inspection

Maintaining the crane is the responsibility of the people in charge. It is also the responsibility of company managers to ensure that the people they employ are protected from an accident that may arise from the devices they use. EN-13852-1 says that the following operations, but not limited to, should be considered and performed by competent persons:

- Lubrication, oil, and filter change.
- Replacement of wire ropes and rope sheaves.
- Change of reeving arrangements.
- Replacement of boom or change of boom configuration.
- Replacement of prime mover/gearboxes.
- Replacement of winch/winch drum.
- Replacement and/or adjustment of brake linings/pads.

Inspection intervals, methods, and acceptance criteria of the systems should be laid down in the instruction and maintenance manual. Regarding this point, note that load tests must be carried out to verify the integrity of the crane's structure and components, as well as the supporting structure. The Test load applied must exceed the Safe Working Load in accordance with class, country regulations, and also the convention ILO 152.

EN-13852 provides a list of methods that can be used to verify conformity with the safety requirements and protective Measures. This list can be used as a guideline by teams in charge of cranes and company managers.

Ref.	***Safety requirements***	***Method of verification***				
1	***General***					
2	***Strength and stability***			*Testing*	*Calculation*	*Engineering*
2.1	*Selection of classification parameters*			*Testing*	*Calculation*	*Engineering*
2.2	*In-service loads*			*Testing*	*Calculation*	*Engineering*
2.3	*Out of service loads*			*Testing*	*Calculation*	*Engineering*
2.4	*Failure mode analysis*				*Calculation*	*Engineering*
2.5	*Seismic loads*				*Calculation*	*Engineering*
2.6	*Load combinations*				*Calculation*	*Engineering*
2.7	*Load chart*				*Calculation*	*Engineering*
2.8	*Materials*	*Visual*			*Calculation*	*Engineering*

	Safety requirements	*Method of verification*				
3	***Equipment and components***	*Visual*		*Testing*		*Engineering*
3.1	*Electrotechnical equipment*	*Visual*	*Measurement*	*Testing*		*Engineering*
3.2	*Non-Electrotechnical equipment*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.3	*Power requirements*		*Measurement*	*Testing*	*Calculation*	*Engineering*
3.4	*Slewing drives*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.5	*Slewing bearings*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.6	*Slewing bearing fasteners*	*Visual*	*Measurement*	*Testing*	*Calculation*	*Engineering*
3.7	*Winches and brakes*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.8	*Wire rope termination*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.9	*Wire rope fastening to the drum*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.10	*Wire ropes*	*Visual*	*Measurement*	*Testing*	*Calculation*	*Engineering*
3.11	*Blocks and hooks*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.12	*Hydraulic cylinders*	*Visual*		*Testing*	*Calculation*	*Engineering*
3.13	*Constant tension systems / motion Compensators / shock absorbers*		*Measurement*	*Testing*	*Calculation*	*Engineering*
4	***Drive systems***					
4.1	*Electromagnetic compatibility*		*Measurement*	*Testing*		*Engineering*
4.2	*Pneumatic systems*	*Visual*	*Measurement*	*Testing*		*Engineering*
4.3	*Hydraulic systems*	*Visual*	*Measurement*	*Testing*	*Calculation*	*Engineering*
4.4	*Electrical systems*	*Visual*	*Measurement*	*Testing*	*Calculation*	*Engineering*
5	***Control station***	*Visual*				*Engineering*
5.1	*General*	*Visual*				*Engineering*
5.2	*Control cabin*	*Visual*				*Engineering*
5.3	*Windows*	*Visual*				*Engineering*
5.4	*Crane operator's seat*	*Visual*		*Testing*		*Engineering*
5.5	*Cabin interior*	*Visual*				*Engineering*
5.6	*Cabin instrumentation*	*Visual*	*Measurement*	*Testing*		*Engineering*
5.7	*Communications*	*Visual*		*Testing*		*Engineering*
5.8	*Machinery house and other enclosed spaces*	*Visual*				*Engineering*
5.9	*Lighting*	*Visual*		*Testing*		*Engineering*
6	***Noise reduction***	*Visual*	*Measurement*			*Engineering*
6.1	*Noise reduction at source by design*	*Visual*	*Measurement*			*Engineering*
6.2	*Noise reduction by information*	*Visual*	*Measurement*			*Engineering*

	Safety requirements	Method of verification				
7	**Access. guards etc.**	Visual	Measurement			Engineering
7.1	Access	Visual				Engineering
7.2	Guards	Visual				Engineering
7.3	Hazardous substances	Visual				Engineering
7.4	Dropped objects	Visual		Testing		Engineering
7.5	Lifting arrangements for maintenance	Visual			Calculation	Engineering
8	**Controls, indicators and limiting devices**	Visual		Testing		Engineering
8.1	General	Visual		Testing		Engineering
8.2	Controls	Visual		Testing		Engineering
8.3	Indicators	Visual		Testing		Engineering
8.3.1	General	Visual		Testing		Engineering
8.3.2	Hated capacity indicator	Visual		Testing		Engineering
8.3.3	Slack wire rope indicator	Visual		Testing		Engineering
8.3.4	Drum motion indicator	Visual		Testing		Engineering
8.3.5	Indicator for failures in the power system	Visual		Testing		Engineering
8.3.6	Wind speed indicator	Visual	Measurement			Engineering
8.3.7	Crane inclinometer	Visual	Measurement			Engineering
8.3.8	Slewing torque indicator	Visual	Measurement			Engineering
8.3.9	Mechanical radius indicator	Visual		Testing		Engineering
8.4	Limiting devices	Visual		Testing		Engineering
8.4.1	General	Visual		Testing		Engineering
8.4.2	Motion limiters	Visual	Measurement	Testing		Engineering
8.4.3	Slack wire rope preventer	Visual		Testing		Engineering
8.4.4	Slewing limiter	Visual		Testing		Engineering
8.4.5	Rated capacity limiter	Visual	Measurement	Testing		Engineering
8.4.6	Boom backstop	Visual		Testing		Engineering
9	**Protection system**	Visual		Testing	Calculation	Engineering
9.1	Overload and over -moment protection	Visual		Testing	Calculation	Engineering
9.1.2	Automatic overload protection system	Visual		Testing	Calculation	Engineering
9.1.3	Lateral boom protection system	Visual		Testing	Calculation	Engineering
9.1.4	Manual overload protection system	Visual		Testing	Calculation	Engineering
9.2	Emergency operation system	Visual		Testing	Calculation	Engineering

	Safety requirements	*Method of verification*				
9.3	*Emergency stop*	*Visual*		*Testing*	*Calculation*	*Engineering*
9.4	*Fire protection*	*Visual*		*Testing*		*Engineering*
9.5	*Protective earthing*	*Visual*	*Measurement*			*Engineering*
10	***Lifting of personnel***	*Visual*		*Testing*	*Calculation*	*Engineering*
10.1	*General*	*Visual*		*Testing*	*Calculation*	*Engineering*
10.2	*Rated capacity*	*Visual*		*Testing*	*Calculation*	*Engineering*
10.3	*Back-up brakes*	*Visual*		*Testing*	*Calculation*	*Engineering*
10.4	*Cylinders*	*Visual*		*Testing*	*Calculation*	*Engineering*
10.5	*Mode selection for personnel lifting*	*Visual*		*Testing*		*Engineering*

ILO " Register of ships' lifting appliances and cargo handling gear":
This document is the international standard recommended by the International Labour Organization conventions No. 152 & 160. These conventions are intended to ensure that ships' lifting appliances are initially certified by a competent person and to establish periodically that they continue to be in safe working order to the satisfaction of a competent person acceptable to the competent authority. As this document is an international standard, it is applicable offshore and by all signatory states.
A Register of Lifting appliances and items of loose gear must be kept in a form prescribed by the competent authority, account being taken of this model recommended by the International Labour Office. This Register and related certificates must be kept and be available to any person authorised by the competent authority. The Register and certificates for gear currently aboard the ship shall be preserved for at least five years after the date of the last entry.

- Initial examination and certification:
  - Every lifting appliance must be certified by a competent person before being taken into use for the first time to ensure that it is of good design and construction and of adequate strength for the purpose of which it is intended.
  - Every item of loose gear shall, before being taken into use for the first time be tested, thoroughly examined and certified by a competent person in accordance with national law or regulations.
  - Upon satisfactory completion of the procedures indicated above the competent person shall complete and issue the Register of Lifting Appliances and attach the appropriate certificates.
  - A rigging plan showing the arrangement of lifting appliances is to be provided.
- Periodic examinations and re-testing:
  - All lifting appliances and every item of loose gear must be thoroughly examined by a competent person at least once every 12 months. The particulars of these thorough examinations must be entered in the Register.
  - Re-testing and thorough examination of all lifting appliances and every item of loose gear is to be carried out after any substantial alteration or renewal, or after repair of any stress-bearing part, and in the case of lifting appliances at least once every five years.
  - The re-testing referred to in the paragraph above may be omitted provided the part which has been renewed or repaired is subjected by separate test to the same stress as would have been imposed on it if it had been tested in situ during testing of the lifting appliance.
  - The thorough examinations and tests referred to in the paragraph above are to be entered in the Register. No new item of loose gear shall be manufactured of wrought iron. Heat treatment of any existing wrought iron components should be carried out to the satisfaction of the competent person. No heat treatment should be applied to any item of loose gear unless the treatment is in accordance with the manufacturer's instruction; to the satisfaction of the competent person. Any heat treatment and the associated examination are to be recorded by the competent person in the Register.
- Regular visual inspections of every item of loose gear shall be carried out by a responsible person before use. A record of these regular inspections is to be entered in the register, but entries need only be made when the inspection has indicated a defect in the item.
  - Every lifting appliance should be tested with a test load which should exceed the safe working load (SWL) as follows:
    Up to 20 tonnes Safe Working Load: 25 per cent in excess
    20 to 50 tonnes Safe Working Load: 5 tonnes in excess
    Over 50 tonnes Safe Working Load: 10 per cent in excess

- The test load of cranes is to be hoisted, slewed and luffed at slow speed. Gantry and travelling cranes together with their trolleys, where appropriate, are to be traversed and travelled over the full length of their track.
    - In the case of variable load-radius cranes, the tests are generally to be carried out with the appropriate test load at maximum, minimum and at an intermediate radius.
    - In the case of hydraulic cranes where limitations of pressure make it impossible to lift a test load 25 per cent in excess of the safe working load, it will be sufficient to lift the greatest possible load, but in general this should not be less than 10 per cent in excess of the safe working load.
- As a general rule, tests should be carried out using test loads, and no exception should be allowed in the case of initial tests. In the case of repairs, replacement or when the periodic examination calls for re-test, consideration may be given to the use of spring or hydraulic balances provided the SWL of the lifting appliance does not exceed 15 tonnes. Where a spring or hydraulic balance is used it shall be calibrated and accurate to within ± 2 per cent and the indicator should remain constant for five minutes.
    - Every item of loose gear is to be tested and thoroughly examined before being put into use for the first time and after any substantial alternation or repair to any part liable to affect its safety. The test loads to be applied should be in accordance with the following table *(In this table, 1 tonne = 1000 kg)*:

Items	*Test load (Tonnes)*
Single sheave blocks (see note #1)	*4 x SWL*
Multi sheave blocks SWL ≤ 25 tonnes (See note #2)	*2 x SWL*
Multi sheave blocks SWL ≤ 160 tonnes	*(0.933 x SWL) + 27*
Multi sheave blocks SWL ≤ 160 tonnes	*1.1 x SWL*
Chains, hooks, rings, shackles, swivels, etc.: SWL ≤ 25 tonnes	*2 x SWL*
Chains, hooks, rings, shackles, swivels, etc.: SWL > 25 tonnes	*(1.22 x SWL) + 20*
Lifting beams, spreaders, frames and similar devices: SWL ≤ 10 tonnes	*2 x SWL*
Lifting beams, spreaders, frames and similar devices: 10 tonnes < SWL ≤ 160 tonnes	*(1.04 x SWL) + 9.6*
Lifting beams, spreaders, frames and similar devices: SWL > 160 tonnes	*1.1 x SWL*

Notes:
- #1: The SWL for a single sheave block, including single sheave blocks with beckets, is to be taken as one half of the resultant load on the head fitting.
- #2: The SWL of a multi-sheave block is to be taken as the resultant load on the head fitting.

    - Wire rope must be tested by sample, a piece being tested to destruction. The test procedure should be in accordance with an international or recognised national standard.
      The SWL of the rope is to be determined by dividing the load at which the sample broke, by a coefficient of utilisation, determined as follows:

Items	*Coefficient*
Wire rope forming part of a sling: SWL ≤ 10 tonnes	*5*
Wire rope forming part of a sling: 10 t < SWL ≤ 160 tonnes	*10^4 / (8.85 x SWL) + 1 910*
Wire rope forming part of a sling: SWL > 160 tonnes	*3*
Wire rope as integral part of a lifting appliance: SWL ≤ 160 t	*10^4 / (8.85 x SWL) + 1 910*
Wire rope forming part of a sling: SWL > 160 tonnes	*3*

1.2.14 - Operational check lists

The operational checklists should recapitulate the duties of the crane operator and the elements to verify before, during, and after the lifting operations. EN standards say that the following elements should be verified.

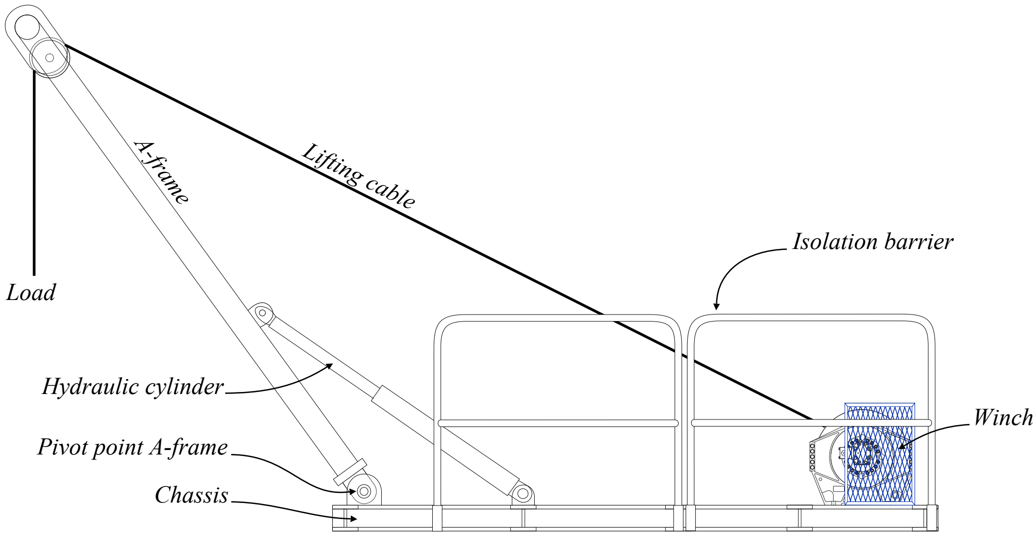
- Before starting the operations:
    - The environmental conditions.

  - The hoisting ropes, winches, sheaves, and hooks.
  - The condition of the indicators (e.g., loading condition, fluid level, engine operation, hydraulic pressure, electric power supply, wear limits, wind speed).
  - The view of the load and the working area, in addition to the communications with the signalman. Also, the communication system between the supervisor and the crane operator must be checked for underwater operations and those without visibility.
  - The required capacity of the crane (load chart)
  - The correct function of the controls, indicators and limiting devices
  - The correct function of the protection systems, AOPS, MOPS, etc.
- During the operations:
  - The evaluation of the loading condition before lifting a load.
  - The correct use of slings (rope or chain), hook vertical over centre of gravity of load.
  - The requirements for starting and stopping movements, including in emergency
  - The management of combined movements, and limiting conditions.
  - The precautions to avoid contact between the load or the load lifting accessories and the structure.
- Stopping the crane:
  - The out of service position of the crane and lifting accessories.
  - Stop the engine, cut off the power supply.
  - Locking the cabin (if fitted) or securing the control equipment.
  - Maintenance, sea transit and storm conditions.
  - Lifting of objects weighing more than 25 kg to and from the crane.

2 - Deck winches and A-frames

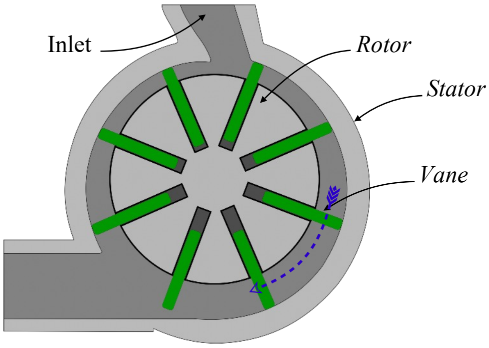
2.1 - Description

Equipment and objects to install are often transferred to the divers or ROVs using lifting A-frames. These devices, which have been employed in construction since antiquity, and perhaps before, are similar to those used to deploy diving bells, baskets, or ROVs. Thus, they consist of an A-frame and a winch mounted on a chassis. The deployment angle of the A-frame is being performed by cables on old models or, more often today, by a pair of hydraulic cylinders. They are usually installed in the most favourable area of the deck for the planned underwater operation.

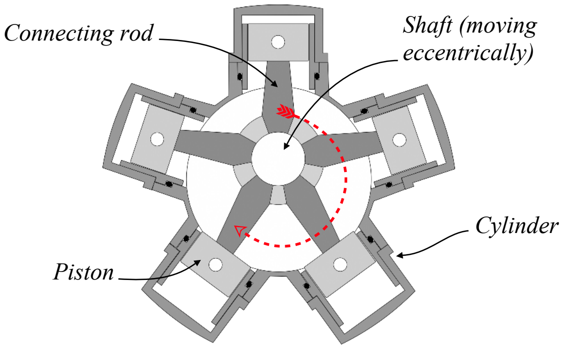


As for cranes, the winches used to energize lifting A-frame devices can be electrical or hydraulic. However, pneumatic winches are also frequently used.
Pneumatic motors use the same working principles as hydraulic ones described in point #1.1.7, except they receive an air flux instead of a hydraulic one:

- Radial pistons motors convert the reciprocating motion of pistons arranged radially into the rotary shaft motion: The liquid is fed to the top of the cylinders, pushing the pistons one by one, which produces the rotation of the shaft, which incorporates an offset from the centre of rotation. This turning motion creates the mechanical power which drives the winch.
- Vane motors receive a hydraulic flux that rotates their stator, and gears, in a similar manner to water mils.



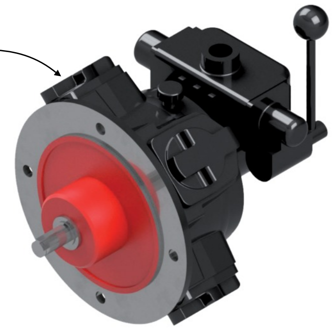
Vane motor



Radial pistons motor

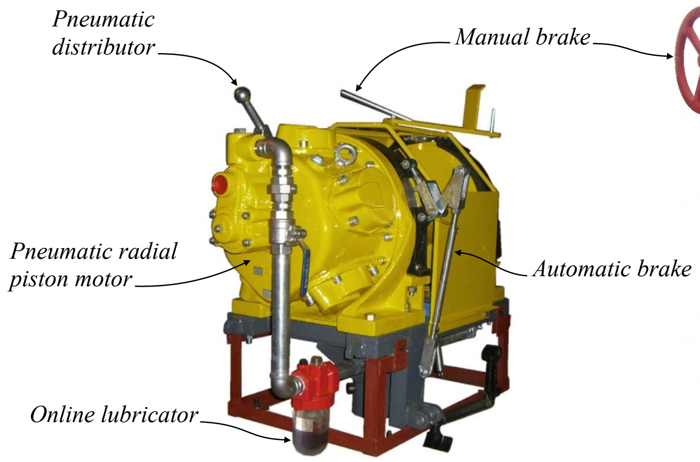
Similarly to the other winch systems, pneumatic winches are equipped with gears providing reduction, a drum, brakes to stop and secure the drum, and a clutch system. Note that vane and radial piston motors can be easily differentiated as the cylinder heads of radial piston motors are visible on their periphery. See the pictures below from "Tecnologie Speciali Applicate Srl (https://tsabologna.com/)", a hydraulic and pneumatic motor manufacturer based in Italy.

Vane motor

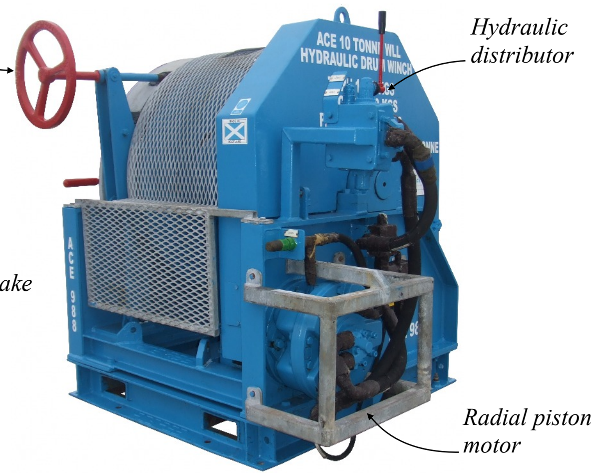


Radial piston motor

A significant difference of pneumatic winches compared with hydraulic winches is the size of the canalizations, that are wider with pneumatic winches. This is due to the fact that depending on the size and the model of the motor a certain flux of air is necessary. That can be observed on the two models below

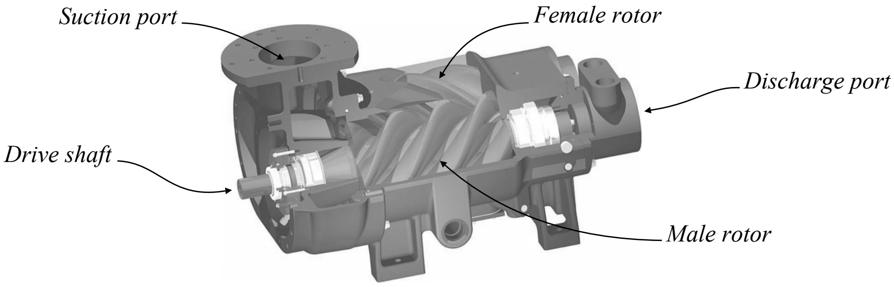


Pneumatic winch 5 tonnes designed by ITETON, a company based in China (https://www.iteton-machinery.com/)

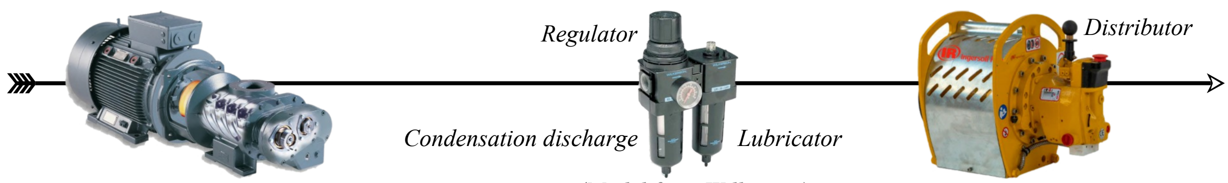


Hydraulic winch 10 tonnes designed by ACE, a company based in Scotland (https://www.ace-winches.com/)

Screw industrial air compressors are used to energize pneumatic winches. They can be integrated in the ship, or be a portable unit when the systems in place on the vessel are insufficient and for inland projects. These machines are designed to provide air at average pressures between 8 - 14 bar for the majority of the models in service. The volumes of air delivered vary from 1 m³ / min to 23 - 25 m³ /min. Most built-in machines are driven electrically, and the majority of mobile industrial compressors are powered by diesel engines. Such compressors cannot deliver elevated pressures, but have been adopted by most industries because they can deliver a large volume of air at the pressures mentioned above, that are the pressures used by the tools they are designed to energize.
These compressors consist of two screw male and female rotors that give a continuous pulsating-free discharge. Two shafts usually activate the rotors: One is the driving shaft which is part of the male rotor, and the other is the driven shaft which is part of the female rotor. The driving shaft is connected to the driven shaft via timing gears, so both rotors rotate at the same speed. The driving shaft is powered by an electric motor or a thermal engine. The two rotors are enclosed in an airtight casing. They rotate at high speed and, for this reason, provide high output.



Similarly to hydraulic systems, the lines supplying pneumatic winches must be provided with filters, condensation discharge, and lubricators. Many manufacturers recommend to use a regulator.



(Model from Wilkerson) *Winch (model from Ingersoll Rand)*

2.2 - Safety requirements

The construction and safety requirements of winches operated on deck with A-frames or to pull objects are those of cranes. It is also the same for construction of the A-frames and the chassis, whose conception and inspection requirements are those applied to cranes. Thus, the requirements of the ILO conventions No 152 & No 160 apply.

However, note the following:

- Guards should be provided to winches to prevent limbs or other parts of the operator's body and people working near the winch from being swallowed by its mobile features (see on the previous page).
- Barriers should be erected to prevent unauthorized people from crossing the operating area.
- Winches used for pulling horizontally and not equipped with a remote station must be provided with a frame and grilles sufficiently robust to protect the operator from the spring effect of the rope in case of a snapping. Note that the same arrangement must be installed to protect the remote control station if it is on the way of a possible spring effect of the broken cable.
- The system must be designed and constructed so that components and controls are located where they are easily accessible for use, adjustment and maintenance without causing hazard. Also, it should be designed to facilitate positive isolation from energy sources. That can be done by:
  - Isolating the supply with a suitable shut-off device, which should be lockable, and shall be accessible without causing a hazard, or isolating and dissipating pressure from the system with a suitable shut-off device(s) having a pressure-release feature, which can need to be lockable;
  - Releasing or supporting mechanical loads when the system is depressurized.
  - Protection from electricity: The precautions indicated for the electrical generators should apply to electrically powered compressors.

It is recommended that components and piping that supply the air winch are made in accordance with recognized international standards should be used. These components should be selected or specified so that the users are safe when the compressor and winches are used. They should operate within their rated limits. Designers and installers should focus on their reliability, and the hazards they can create in case of failure or malfunction should be considered.

- If used, rigid piping should be mounted to minimize stresses; they should be protected against foreseeable damage and should not restrict access for adjustment, repairs, or replacement of components. The piping should not be used to support features that can impose undue loads. These excessive loads can arise from component mass, shock, vibration, and pressure surges.
- The flexible air supply hoses should conform to EN ISO 2398 “Rubber hoses, textile-reinforced for compressed air. specification”. They must be regularly checked and changed if necessary.
- Ropes should be installed along the air hoses, and be secured to them at least every 20 cm. The aim of this system is to keep the hoses in one piece and prevent whipping in case of rupture of the hose under pressure.
- “Hose arresters” should be installed at each coupling to prevent whipping in case of a connection failure *(see the picture on the side).*

- The coupling used should conform to a recognized standard and to the maximum pressure delivered by the compressor.
- The flow rate through piping should not create hazards due to temperature change or pressure drop. Variations in the flow rate should be minimized by avoiding sudden changes in internal diameters of piping.
- The length of the piping/hose between actuators and their directional control valves should be kept to a minimum to optimise the response time. Also, the number of connections should be kept to a minimum.
- Installation of flexible hose assemblies should:
  - Have the minimum length necessary to avoid sharp flexing and straining of the hose during the component operation. Flexible hoses should not be bent with a radius smaller than the recommended minimum bending radius.
  - Minimize torsional deflection of the hose during the installation and use, e.g. as the result of a rotating connector jamming.
  - Be located or protected to minimize abrasive rubbing of the hose cover.
  - Be supported, if the weight of the hose assembly could cause undue strain.
- Piping/hoses should be identified or located in such a manner that it is not possible to make an incorrect connection that can cause a hazard or malfunction.
- The manifolds should be rigidly and securely mounted, and should not malfunction due to distortion when operated within the intended range of operating pressures and temperatures. Mechanically and manually operated valves should be installed so that they cannot be damaged by foreseeable operating forces.
- Rigid pipes and/or rubber hoses across access ways should not interfere with the normal use of the access way. They should be located either below or well above the floor level and in accordance with site conditions. The hoses/pipes should be readily accessible, rigidly supported, and where necessary, protected from damage.
- Exposed openings in pneumatic systems and components, in particular tubes and hoses, should be protected during transportation either by being sealed or by being stored in an appropriately clean and closed container. Male threads should be protected. Any protective device used should be of the type that prevents reassembly until it is removed.

The installation of A-frame and winches on deck can be done during the construction of the vessel, or during the mobilization of the project.

- Devices installed during the construction of the vessel are considered part of the vessel and have been normally verified during the classification process of the vessel. For this reason, they are verified by the technicians and engineers in charge during each inspection linked the the certification process associated with the classification of the vessel.
- In addition to conform with what has been previously said, the devices installed for the needs of a project must be checked by a recognized certification body agreed by the administration of the country where the mobilization is carried out, and also where the work is undertaken. It is the reason most companies use the services of certification bodies recognized internationally. This process of certification is similar to those in force for the launch and recovery systems (LARS) of diving systems, and should include engineering studies of the fastenings, non destructive techniques (NDT) inspection of the welds, and dynamic and static load tests performed according to the requirements of the Labour Organization conventions No. 152 & 160:
    - Up to 20 tonnes Safe Working Load: 25 per cent in excess
    - 20 to 50 tonnes Safe Working Load: 5 tonnes in excess
    - Over 50 tonnes Safe Working Load: 10 per cent in excess

3 - Powered chain hoists and A-frames used underwater

3.1 - Powered chain hoists

3.1.1 - Description

Powered chain blocks are hand chain hoists, such as those described in the chapter "Hand powered lifting equipment" of this handbook, equipped with a hydraulic or a pneumatic motor instead of the hand chain wheel. These devices are covered by many standards, among which the following should be considered:

- ASME B30.16 *"Overhead Underhung and Stationary Hoists - Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings"*. Note that this standard does not discusses hydraulically powered chain hoists
- EN 14492-2 *"Cranes - Power driven winches and hoists - Part 2: Power driven hoists"*.

Note that the standard EN 13157 *"Cranes - Safety - Hand powered cranes"* should be considered for the internal parts and the load chain of chain hoists. Also, powered chain hoists intended for use by ROVs in the offshore industry should be built according to the following standards:

- ISO 13628-1 *"Petroleum and natural gas industries - Design and operation of subsea production systems - Part 1: General requirements and recommendations"*.
- ISO 13628-8 *"Petroleum and natural gas industries - Design and operation of subsea production systems - Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems"*.

Two main designs are applied regarding the protection from the effects of salt water: The 1st one consists of protecting the hoist mechanism and the motor from water ingress, and the 2nd one consists of treating the mechanism against degradation due to the salt water and isolating only the motor.

Three examples of existing machines can be taken as references to illustrate the solutions mentioned above:

- The air hoists Profi 3 TI & 6 TI are air-powered lever hoists designed to carry 3.2 or 6.3 tonnes at up to 70 metres of water depth, fabricated by J.D. Neuhaus, a company based in Germany (Website: https://www.jdngroup.com/)
  The manufacturer says these machines can be used diagonally and horizontally, and their lifting and lowering speeds can be controlled.
  Their working air pressure is approximately 6 bar for flows between 4 and 5,5 m³/minute.
  Their weights vary between 150 kg (3 TI) and 161.5 kg (6 TI), and they are delivered with a 3 m lifting chain.
  We can see that they are provided with a manifold with an inlet and outlet hose for each direction.

- Ingersoll Rand, a well-known producer of winches headquartered in the USA (Website: https://www.ingersollrand.com/en), sells a series of hydraulic subsea lever hoists designed to lift loads of 6, 12, 25, and 50 tonnes at depths up to 30 metres.
  The particularity of these machines is that all their moving parts are protected from water ingress. Also, as they are designed to stay a long time underwater, they are provided with zinc anodes.
  The working supply pressures of their motors vary from 120 to 135 bar, depending on the model, and they need a flow between 40 and 50 l/min.
  Their lifting and lowering speed can be controlled by the diver
  Their weights with a 3 m chain vary from 185 kg (6 tonnes model) to 940 kg (50 tonnes model). The manufacturer provides lifting chains allowing lifting 49 m height for the models up and 25 tonnes and 24 m for the 50 tonnes device.

- Tiger Lifting (website: https://tigerlifting.com/), a company based in the United Kingdom known for its hand lever and chain hoists designed for underwater operations, sells a series of subsea chain hoists specifically studied for ROVs.
  The range proposed to clients comprise machines designed to lift 3, 6, 8, 10, 15, 20, and 30 tonnes.
  They are powered by hydraulic motors supplied at a pressure of 210 bars and a flow rate of 4 to 8 litres per minute. These hydraulic motors are connected to mechanisms designed to withstand the effects of prolonged exposure to deep salt water, which are also used with manual chain hoists. These machines are equipped with chassis allowing their handling by ROV manipulators. They are also equipped with connecting and control panels designed for ROV manipulators.
  Note that the lifting chain is housed in a specific tray to prevent it from entangling during lowering and installation. The chains' lengths are comparable to those of the equipment above and are adjusted according to the customer's wishes.
  The manufacturer does not indicate the maximum depth in the brochure and user manuals. However, this tool is already used on projects at deep depths.

3.1.2 - General safety requirements

These safety requirements are those required by certification bodies to all manufacturers, whether the device is planned to be used underwater or at the surface. Note that there is currently no safety requirements specific to underwater powered chain hoists. However, as with the other tools described in this manual, the tool's fabrication and safety elements should be documented so the certification body can analyze them. The following elements must be in place:

- EN 14492 requires that manual starting and stopping controls of hoists are fitted with hold-to-run control elements so that the drive energy supply is interrupted when the actuating elements are released.
  Actuating elements of control devices shall incorporate features that prevent unintentional operation or unwanted movements of the load. The actuating elements of control devices must incorporate features and be arranged and marked so that their assignments, their direction of operation, and their switching state are unmistakably recognizable, using symbols where appropriate.
- ASME B30.16 says that drive or welded chains can be used. However, units designed for underwater operations use only welded chains as drive chains require continuous lubrification. The load sprockets must have pockets or teeth to allow for the engagement of the load chain. In addition, the components of the chain drive must match each other in terms of dimensions and materials and should also be guarded against jamming of the load chain within the hoisting mechanism under standard operating conditions. In addition the load chain must be proof tested by the chain or hoist manufacturer with a load at least equivalent to 11/5 times the hoist's rated load divided by the number of chain parts supporting the load.
  EN 14492 adds that the chain anchorage must withstand four times the static chain tensile force at the hoist's rated capacity without rupture. It must be locked to prevent the chain from running off the hoist.
  ASME B30.16 also requires that the hooks are equipped with latches unless the use of the latch crates a hazardous condition. When required, a latch shall be provided to bridge the throat opening of the hook, and retain,under slack conditions,such items as,but not limited to, slings and chains. Note that hooks of swivelling type, should rotate freely.
- EN 14492 says that the gears and reducers should be supported and connected to the driving and driven mechanisms in such a way that no impermissible and uncontrolled stresses or deformations are produced in the gears or bearings. In addition,l hoists with a rated capacity of 1 000 kg or more must be fitted with a limiter designed to prevent overloading. It must also limit the forces transmitted to the supporting structure. This limiter must be triggered by loads greater than 1,1 times the rated capacity.
  Powered hoists must also be provided with an emergency stop function available and operational at all times, regardless of the operating mode.
  In addition, hoists must be designed with brakes designed such that movements of the load can be decelerated, and the load can be held with unintended movements avoided. These brakes should engage automatically when:
    - The control device returns to its neutral position.
    - The emergency stop function is activated.
    - The external power supply to the brake is interrupted.
    - The power supply of the motor is interrupted or switched off.

  EN 14492 also says that if the braking force is supplied by pre-stressed springs, the failure of any spring in the braking system must not reduce the available braking torque by more than 20 %. EN 14492 suggest to fulfill this point by using at least five springs, or if less than five helical springs are used, their size must such that the wire diameter is greater than the distance between the windings in the working condition to prevent screwing in the two spring parts in the event of a wire break. It should be possible to check, adjust and replace the brake or the brake linings.

3.2.2 - Specific requirements for pneumatic systems

The component of the pneumatic system must be compatible and suitable for the anticipated ambient conditions. EN 14492 says that due to the pneumatic drive characteristics, significant lowering and lifting speed differences may exist. Also, the following design requirements should be fulfilled:

- The pneumatic motor must not create hazards by heating up or by icing up.
- Pneumatic-powered hoists should be provided with brakes, as indicated in the previous point. If they are used, pneumatically released brakes should be designed to prevent unexpected load lowering. EN 14492 suggests that the brake releases only when the motor provides a sufficient moment for holding the load or controlling the load movement.
- The control devices should be designed such that the actuator-displacement increases or decreases the speed of the load. They also must be designed such that no pressure and flow disturbances can occur and their level of performance is kept, and their design should prevent unintended movements.
  Also, in the case of a power failure, the controls must be brought into a neutral position. For direct-controlled hoists, this requirement applies only when the actuators are released. Note that the reaction times must be reduced to a minimum.
  EN 14492 also says that triggering machine movements by venting control lines is not permissible.
  The control device should be provided with an emergency stop system that interrupt the main air circuit.
- The disconnection of the machine from the air supply must not result in load dropping
- The movable parts must be arranged or covered to avoid hazards to the operator.

3.2.3 - Specific requirements for hydraulic systems

It must be noted that hydraulic pumps and motors are commonly used for various applications on ROVs designed to descend to depths deeper than 2000 m. Thus, they are an obvious choice for powering chain hoists designed for depths greater than 50 metres.

- EN 14492 says that hydraulic systems must be built with components that are compatible with each other and ensure correct functioning under the anticipated environmental conditions:
  - The materials used must be compatible with each other. For example, the materials used for seals, flexible and semi-rigid lines, and for coating several components must be compatible with the other materials of components and systems and withstand the system pressures.
  - If greases that can come into contact with the pressure liquid after, for example, the rupture of a seal, are used, they must be compatible with the pressure liquid.
  - The pressure liquids must be selected to minimize the effects of leakages, and not be hazardous to the operators.
- A device must be fitted to ensure that the load does not move as a result of internal leakage of the motor. EN 14492 suggests using mechanical spring loaded brakes or self-locking gears to fulfill this requirement. Also, note that the pressure to the motor must never be less than 1 bar to avoid vacuum.
- The piping must be designed to ensure that additional impermissible loads due to pressure, bending, temperature, and other reasons do not occur during the operations and that wear and corrosion are avoided. Note that the connection to energy converters should also be designed to minimize vibration and noise.
  The hose fittings must be designed to avoid torsional strain during assembling, and their bending radius and installation requirements must follow the specifications provided by the manufacturer to prevent excessive fatigue and wear.
- The reservoir of the Hydraulic Power Unit (HPU) must be designed not to overflow and be equipped with a level gauge. It must be located so that the necessary inflow to the pump is ensured and be of sufficient size to ensure proper liquid flow within the permissible temperature. An air inlet should be provided to avoid depression or overpressure.
- EN 14492 requires a cooler to be fitted to the hydraulic circuits if the operating temperature is above the permissible one for the type of oil used. Also, the manufacturer must provide a heating system if the device is to be used at ambient temperatures lower than the suitable temperature of the oil. Nevertheless, EN 14492 authorizes warming up the system without load.
  Filters must be provided to avoid contamination of the oil. They must be equipped with a bypass with a specific opening pressure to keep the installation working in the case of clogging. A warning system must be provided to indicate that the bypass is open.
- The control devices should be designed such that the operating speeds of the motors are proportional to the controlling range of the control. They also must be designed such that no pressure and flow disturbances can occur and their level of performance is kept. Also, their design should prevent unintended movements.
  In the case of a power failure, the switching positions must be reached automatically, and the installation stopped. In addition, there must be a protection against overpressure of the fluid and over speed of the load. They must act on the hydraulic circuits and elements so that the flow rate and pressure are limited to permissible values. Note that the hydraulic connections between the load-holding valves and the motor must consist of steel tubing; flexible hoses must not be used.
  As every machine, an emergency stop system must be provided that interrupts directly the primary hydraulic circuit or the actuating elements.
- The moveable parts of the system must arranged or covered so that hazards for persons or objects are excluded. Also, the system must be designed such that fluid leaks cannot cause a fire. Devices reaching high temperatures when operated must be thermally separated from devices carrying oil by suitable enclosures to avoid ignition. EN 14492 says that if thermal separation is not possible, a flame-retardant hydraulic liquid must be used.
  In addition, to prevent explosion risks, EN 14492 requires that hydraulic systems with chambers or hollows are equipped with aeration equipment. Note that only flame-retardant hydraulic liquids must be used if hydraulic systems are used in an environment with an explosion hazard.

3.2.4 - Specific requirements for chain hoists designed for ROV use

Chain hoists used with ROVs at deep depths are expensive and long to transfer and install, resulting in difficulties in organizing regular replacements as organized for hand-powered hoists. As a result, these tools may be at depth for some time. For this reason, chain hoists designed to be installed and used by ROVs must comply with ISO 13628-1 & 13628-8 requirements regarding corrosion, handling, and interface operationality. Note that these standards discuss the construction of subsea facilities, not specifically the construction of chain hoists designed to work on them. However, among the numerous requirements provided, the following guidelines should be taken into account:

- According to ISO 13628-8, when developing the design philosophy for the intervention interfaces, the designer should consider the type of tasks involved. In general, for component replacement or where lifting operations are required, vertical access should be provided. For valve operation and other types of light work, horizontal access is preferred where possible. Tools designed specifically for the processes involved should be used, where the ROV can dock onto the interface and be held firmly in place while the task is being performed. In designing the interface, care should be taken to avoid the necessity for rigid design requiring complicated tooling.

Any ROV manipulator or tooling operation that requires the pilot to control the ROV during the performance of the task actively should be avoided.

- The factors to be considered when selecting a material for the construction of the interface assembly should include the following:
  - The interface mounted on the subsea production system should exhibit greater inherent strength than the interface carried by the ROV/ROT, such that in the event of a mishap during operations, the interface cannot be damaged or made inoperable.
  - The interface should be designed to operate correctly throughout the entire period of submersion and should broadly equate to the design life of the equipment to which it is attached.
  - Corrosion-resistant materials, suitable coatings, and cathodic protection systems to prevent corrosion should be used. Intervention equipment, used only a limited number of times throughout the life of the subsea production system, may be designed to use materials suitable only for intermittent immersion in seawater.
- Quick-connect fittings requiring the pulling back of the retaining ring at the same time as pushing the fitting onto the connector should be avoided. The reason is that a single manipulator does not have the dexterity to perform both operations at the same time. However, there are several connectors that do not require the retaining ring to be pulled back to make the connection.
- Remote interface operation often requires supplementation by a visual means to the ROV operator. This visual indication can be achieved by several means, but it the indication system should conform to the following. All valve, connector elevation and position indicators on individual modules or components involving ROV interfaces should have visual indicators. The visual indicators should be designed such that they are:
  - Self-explanatory, giving the operator a clear indisputable indication of the equipment status.
  - Visible from the location where the work is to be performed during the operations.
  - Easily read from different angles with standard ROV camera systems.
  - Easily read from at least 0,5 m (1,64 ft) in normal visibility.
  - Substantial and robust enough to last for the design life of the subsea component/equipment.
  - Protected from mechanical damage, and, where appropriate, capable of counting functions.
- An interface should be provided to allow ROV stabilization during operations based upon grasping. Grasping intervention interfaces shall be designed to withstand a minimum force of 2,2 kN (500 lbf) applied from any direction and a gripping force of 2,2 kN (500 lbf) applied from any direction. The method of attachment is optional. The handles can also be designed as bumper bars to provide protection to the interface panel.
- Designers should take into consideration the potential difficulties involved with sliding operational tasks (e.g. pushing a lever up, down or along). Because of the orientation of the mechanical linkage of the manipulators and their control systems it is at present difficult for ROVs to operate sliding lever handles where the operation is in a vertical (up/down) or horizontal (push/pull) orientation. Operation of the slide/lever type from the side (Ieft/right) is possible, providing there is room for the manipulator to be inserted to the left or right of the handle.

3.2.5 - Maintenance

The maintenance of powered chain hoists depends on the frequency of use and the conditions of use. ASME B30.16 provides guidelines regarding this point on which many manufacturers have built their recommendations. However, these guidelines apply to chain hoists not used underwater. Considering that underwater works are performed in an environment aggressive for mechanical parts, it will be necessary to reinforce the frequency of inspection and preventive maintenance of the devices submitted to such working conditions. The procedures provided by manufacturers can be used for this purpose.

The maintenance of chain hoists involves troubleshooting, periodic inspections, preventive maintenance, and commissioning procedures before returning the device to service. It is therefore essential that the technician in charge has the technical level for these tasks. ASME provides the following examples of source of training material:

- Information outlined in the manual provided with the equipment. Note that this documentation is mandatory.
- Information from trade associations
- Government training resources such as labour and educational ministries
- Organized labour groups
- Courses, seminars, and literature offered by manufacturers of lever hoists, consultants, trade schools, continuing education schools, and employers.
- Requirements and recommendations found in national consensus standards.
- Note that a technician competent for diving or ROV systems has normally the required level for such inspections and maintenance tasks.

As mentioned for other lifting tools, it is recommended to organize a preventive maintenance based on:

- The recommendations from standardization bodies
- The recommendations outlined in the hoist manufacturer’s manual.
- The recommendations from specialists.

- Reports regarding defect or weaknesses of the equipment
- Safety flashes

ASME classifies the inspections to be organized as follows:

- Initial inspection:
  It is the examination to be performed before committing to service new, altered, or modified hoists.
- Pre-operation Inspection:
  It is performed before the first use of each shift with records not required. It consists of visually examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - Hoist limit devices of hoists without a load on the hook. The load block shall be inched into its limit device or run at a slow speed on multi speed or variable speed hoists. When travel-limiting clutches are used as limit devices, following the methods for inspecting the travel-limiting clutch in the manual provided with the hoist.
  - The hooks, including the latches.
  - The damage and correct reeving of the load line.
  - The over-travel restraint attachment.
  - Whether deformations, cracks, and other damages are visible.
- Frequent Inspection:
  They are visual inspections not required to be documented, that should be scheduled as follows:
  - Normal service: monthly
  - Heavy service: weekly to monthly
  - Severe service: daily to week

  They consist of examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - Hoist limit devices of hoists without a load on the hook. The load block shall be inched into its limit device or run at a slow speed on multi speed or variable speed hoists. When travel-limiting clutches are used as limit devices, following the methods for inspecting the travel-limiting clutch in the manual provided with the hoist.
  - The hoist braking system for proper operation.
  - Lines, valves, and other parts of air or hydraulic systems for leakage.
  - The hooks, including the latches.
  - The chain must be function tested under load, and closely inspected for damages, wear, and elongation.
  - The over-travel restraint attachment.
  - Whether deformations, cracks, and other damages are visible.
- Periodic Inspection:
  It is a documented visual inspection. It can be indicated by a coded mark on the device, and should be organized as follows:
  - Normal service - yearly:
    Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
  - Heavy service - semiannually:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
  - Severe service - quarterly:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The following elements should be inspected:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - Hoist limit devices of hoists without a load on the hook. The load block shall be inched into its limit device or run at a slow speed on multi speed or variable speed hoists. When travel-limiting clutches are used as limit devices, following the methods for inspecting the travel-limiting clutch in the manual provided with the hoist.
  - The hoist braking system for proper operation.
  - Evidence of loose bolts, nuts, or rivets
  - Evidence of worn, corroded, cracked, or distorted parts such as load blocks, suspension housing, chain attachments, clevises, yokes, suspension bolts, shafts, gears, bearings, pins, rollers, and locking and clamping devices.
  - Evidence of damage to hook retaining nuts or collars, and pins and welds or rivets used to secure the retaining members.
  - Evidence of damage or excessive wear of load sprockets or idler sprockets

    - Evidence of worn, glazed, or oil contaminated friction disks; worn pawls, cams, or ratchets; corroded, stretched, or broken pawl springs in brake mechanism.
    - The presence of the required labels and marks.
    - End connections of load chain, including over-travel restraints, rope, or web strap.
- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

Post dive maintenance guidelines from manufacturers
The powered chain hoists discussed in this section are specific for underwater operations. For this reason, the following guidelines, based on those of the manufacturers, have to be rigorously applied.
When the immersed chain hoist is back on deck, it must be rinsed with fresh water (not using HP jets) and immediately dismantled for a throughout cleaning and inspection. The reason is that the salted water and foreign objects may be present in sensitive internal parts, and corrosion or exaggerated wear may be present. Note that in the presence of air, the conditions for accelerated corrosion may be fulfilled to result in the device being out of order quickly.
When the internal parts of the chain hoist have been rinsed and filly dried, they must be adequately lubricated using the lubricants recommended by the manufacturer, and the device must be reassembled.
Consider that because the chain hoist has been dismantled, it must be load tested before being returned to operations, as recommended by ASME standards. This procedure applies to all hoists (used underwater or not) and is explained in the next point.
If after being considered good to service, the chain hoist is not used, it must be inspected according the the "ASME rules for devices not in regular service" or a similar process.

3.2.6 - Chain hoist testing

ASME B30.16 says that the hoist manufacturer must test all new hoists with a load test of at least 125% of the rated load.
ASME B30.16 also says that all altered or repaired hoists or hoists placed in service that have not been used within the preceding 12 months must be tested by, or under the direction of, a designated person to ensure compliance with the manufacturing standards. These tests can be static or dynamic, and a written report should be issued and classified on file.

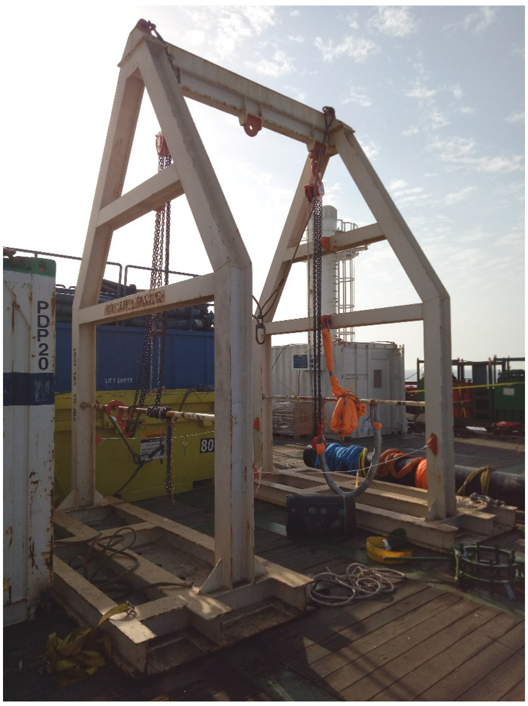
A. A qualified person must approve the anchorages or suspensions for the tests before starting the operation.
B. The functions of the hoist must be checked with the hoist suspended in the unloaded state, taking into account that some hoists may require a nominal load or pull on the load hook to test the lowering motion.
C. A qualified person must determine the need to load test the hoist.
D. The test must not be less than 100% of the rated load of the hoist or more than 125% of the rated load of the hoist unless otherwise recommended by the hoist manufacturer or a qualified person.

The replacement of the chain is excluded from the load test. However, an operational test of the hoist should be made in accordance with step "B" before placing the hoist back in service.

3.2 - Underwater A-frames

3.2.1 - Description

These A-frames are often used by divers to lift and adjust the flange of pipelines and spools. They are designed for using manual lifting gears such as hand chain blocks. Also, because they are often used on soft sea beds, they are provided with large skates whose function is to prevent them from being sucked in the mud.
They are also provided with lifting pad eyes that allow connecting the crane to transfer them to and from the bottom of the sea.



3.2.2 - Safety requirements

The construction and safety requirements of A-frames designed to lift objects underwater are those of cranes and A-frames installed on the deck. Thus, the provisions of the ILO conventions No 152 & No 160 apply.
It is preferable to build them using I-profiles or similar, like the model in the photo, instead of hollow pipes and square profiles where water ingress is possible and may result in invisible internal corrosion.
In addition, the transferring and removing from the seabed, where they can be sucked due to the weight of the pipeline and the softness of some soil, result in more stress than calculated and may be applied to the various part of the frame, particularly the lifting pad eyes. For this reason, their structure is to be reinforced and closely inspected before starting the operations and after the recovery to the deck.

Page left blank intentionally

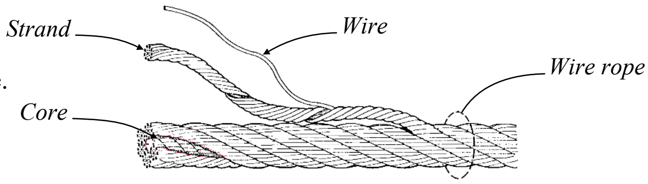
B - Wire ropes and end sockets

1 - Description

1.1 - Components and design

Wire rope, or cable, is a type of rope which consists of several strands of metal wire laid (or 'twisted') into a helix. Initially wrought iron wires were used, but today steel is the main material used for wire ropes.
Wire rope consists of three essential components. These, while few in number, vary in both complexity and configuration so as to produce ropes for specific purposes or characteristics. Basically, these three components of a standard wire rope design are:

- Wires that form the strand.
- The core.
- The multi-wire strands laid helically around the core.



1.1.1 - Core

The " core " is made of materials that will provide proper support for the strands under normal bending and loading conditions. Core materials include fibres (natural or synthetic) or steel. The steel core consists either of stranded wires or of another independent wire rope. EN 12385-2 provides the following classifications:

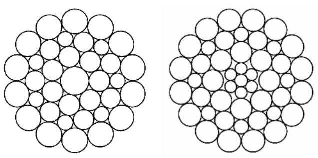
- Fibre cores (FC), are made of natural fibres (NFC) or synthetic fibres (SFC)
- Steel cores (WC) are arranged as a wire strand (WSC) or are independent wire rope cores (IWRC)
- Solid polymer cores (SPC) consist of polymer materials having a round shape or a round shape with grooves. They may also contain an internal element of wires or fibres.

Catalogue descriptions of the various available ropes include these abbreviations to identify the type of core.

1.1.2 - Strands

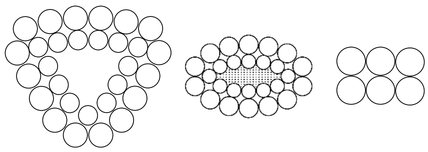
"Strands" are made up of two or more wires, laid in one of many specific geometric arrangements, or a combination of steel wires with other materials such as natural or synthetic fibres. They are laid in spiral around the core. The standard EN 12385-2 indicates the following strands construction and lay characteristics:

- Round strand:



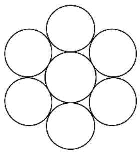
This type of strand shows a perpendicular cross-section which is approximately the shape of a circle.

- Triangular, oval, and flat ribbon strands



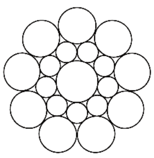
These types of strands have a perpendicular cross-section

- Single lay strand



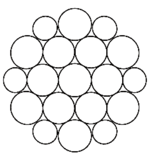
Strand which contains only one layer of wires

- Seale - Parallel lay strand



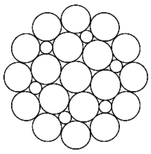
Parallel lay strands have at least two layers of wires all of which are laid in one operation (in the same direction). The "seale construction" is a parallel lay strand construction characterized by the same number of wires in both layers

- Warrington - Parallel lay strand



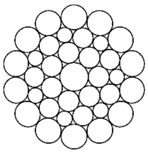
parallel lay strand construction having an outer layer containing alternately large and small wires and twice the number of wires as the inner layer

- Filler - Parallel lay strand



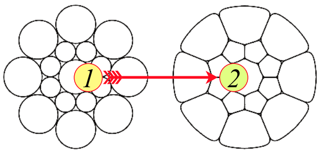
parallel lay strand construction having an outer layer containing twice the number of wires than the inner layer, with filler wires laid in the interstices between the layers.

- Combined parallel Lay



parallel lay strand construction having three or more layers laid in one operation and formed from a combination of Filler & Seale strands

- Compacted strand



A compacted strand has been subjected to a process such as drawing, rolling or swaging whereby the metallic cross-sectional area of the wires remains unaltered whereas the shape of the wires and the dimensions of the strand are modified.
#1: Before compacting - #2: After compacting

- Multiple operation lay, cross lay, compound lay strands
  A Multiple operation lay strand contains at least two layers of wires in which successive layers are laid in more than one operation.
  A Cross-lay strand contains more than one layer of wires, all laid in the same direction. The wires of superimposed wire layers cross one another and make point contact.
  A Compound lay strand contains a minimum of three layers of wires, the outer layer of which is laid in a separate operation, but in the same direction as the others, over a parallel lay forming the inner layers.

1.1.3 - Lays

The term lay refers to the direction of the twist of the wires in a strand and to the direction that the strands are laid in the rope. In some instances, both the wires in the strand and the strands in the rope are laid in the same direction; and in other instances, depending on the intended use of the rope, the wires are laid in one direction and the strands are laid in the opposite direction.

- The following types of lays are commonly used in wire rope:

- Right Regular Lay: In right regular lay rope, the wires in the strands are laid to the left, while the strands are laid to the right to form the wire rope.

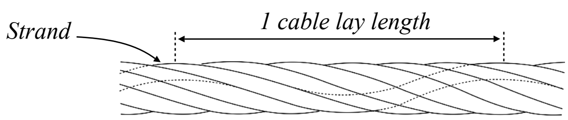
- Left Regular Lay: In left regular lay rope, the wires in the strands are laid to the right, while the strands are laid to the left to form the wire rope. In this lay, each step of fabrication is exactly opposite from the right regular lay.

- Right Lang Lay: In right lang lay rope, the wires in the strands and the strands in the rope are laid in the same direction; in this instance, the lay is to the right.

- Left Lang Lay: In left lang lay rope, the wires in the strands and the strands in the rope are also laid in the same direction; in this instance, the lay is to the left (rather than to the right as in the right lang lay).

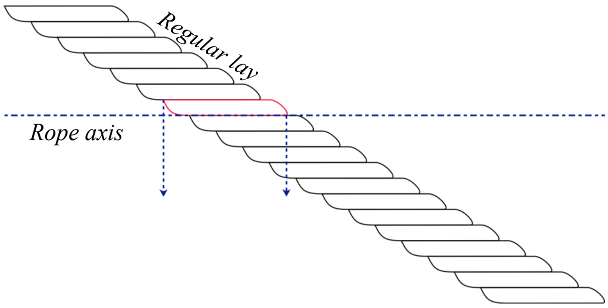
- Reverse Lay: In reverse lay rope, the wires in one strand are laid to the right, the wires in the nearby strand are laid to the left, the wires in the next strand are to the right, and so forth, with alternate directions from one strand to the other. Then all strands are laid to the right.

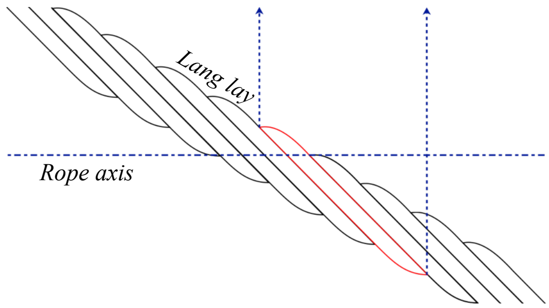
- Lay length
  The "length of a rope lay" is the distance measured parallel to the centre line of a wire rope in which a strand makes one complete spiral or turn around the rope.



- Right versus left lay.
  Right lay rope is standard. If lay direction is not designated, right lay drum. If the correct lay is not used in this case, the rope will not wind smoothly against its previous wrap.
- Regular lay versus Lang lay.
  The wires in regular lay wire rope appear to line up with the axis of the rope. In contrast, the wires in Lang lay wire rope appear to form an angle with the axis of the rope.
  Regular lay wire rope is used for the widest range of applications. It has a somewhat better resistance to crushing than Lang lay wire rope and does not rotate as severely under load when used in an application where either end of the rope is not fixed.

Lang lay wire rope has better resistance to both fatigue and abrasive wear. Lang lay rope has a longer exposed length of exterior wires. Bending of Lang lay rope results in less axial bending of the outer wire, but greater torsional flexure. Overall, Lang lay wire rope displays a 15 to 20 percent superiority in service life over Regular lay when bending is the principal factor affecting service life. Also, because of the longer exposed length of the exterior wires, the ropes are exposed to less pressure which decreases the rate of abrasive wear on wires, drums, and sheaves.
There is no difference in breaking strength between Lang and Regular lay rope.





- Reverse lay wire rope *(Also called "Alternate Lay Wire")*
Reverse lay wire rope has the extra flexibility of lang lay in combination with the structural stability of regular lay. It unites the best features of both types of wire rope. Alternate lay is made with relatively large outer wires to provide increase of abrasion resistance to scrubbing against sheaves and drums. Finer inside wires and flexibility enable alternate lay ropes to absorb severe bending stresses. It is well suited to winding applications where abrasion and crushing can occur. Alternate lay wire rope applications include boom hoists and numerous types of excavating equipment like clamshells, shovels, cranes, winches and scrapers.

1.1.4 - Inserts and rope lubrication and protection

The European standard EN 12385-2 explains that inserts made of fibre or solid polymers can be positioned to separate adjacent strands or wires in the same or overlying layers or fill the interstices of the rope.
The rope must be lubricated to reduce internal friction and protect against corrosion. For this reason, a lubricant is applied during the fabrication of the core and strands, in addition to impregnating agents that are used for inhibiting the rotting and decay of natural fibre cores. Blocking compounds are also applied during and after the manufacture of the rope to protect it against corrosion.

1.2 - Common types of wire ropes

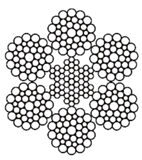
The wire arrangement in the strands and how the strands are laid determines the rope's functional characteristics, so its capacity to meet the operating conditions to which it will be subjected. There are many basic design constructions around which standard wire ropes are built. They are identified by a nomenclature that references:

- The number of strands in the rope and their orientation.
- The number (nominal or exact) and arrangement of wires in each strand.
- The design of the core.

1.2.1 - Stranded ropes (Non rotation resistant)

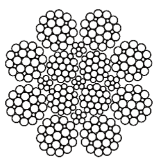
According to *EN 12385-2,* Stranded ropes are composed of several strands laid helically in one or more layers around a core (single-layer ropes) or centre (parallel-closed ropes).

- Single-layer ropes:



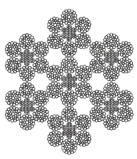
Single-layer ropes are made of one layer of strands laid helically around a core

- Parallel-closed ropes:



They are stranded ropes consisting of at least two layers of strands laid helically in one closing operation around a strand or fibre centre.

- Cable-laid ropes:

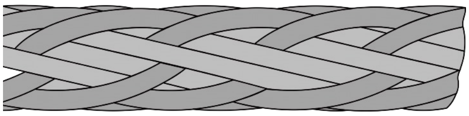


According to EN 12385-2, these ropes are assemblies of several round stranded ropes closed helically around a core.

- Compacted strand ropes & Swaged ropes:

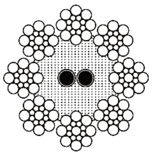
These ropes have been subjected to a compacting process to reduce their diameter.
Compacted stand ropes are composed of strands subjected to a compacting process such as drawing, rolling or swaging. Thus, the compacting process is done prior to closing the rope.
The compacting process of Swaged ropes consist of compacting them (usually by swaging) after closing them.

- Braided ropes:



These ropes are assemblies of several round strands braided in pairs.

- Electro-mechanical ropes:

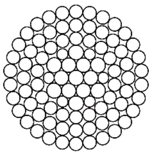


They are ropes containing electrical conductors or optic fibres

1.2.2 - Spiral ropes *(EN 12385-2)*

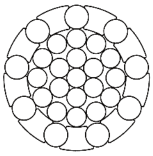
Spiral wire ropes are made of one or several layers of wires which are wound helically around a core wire. Remember that, opposite to this design, the stranded ropes described above are made of one or several layers of strands.

- Spiral strand ropes:



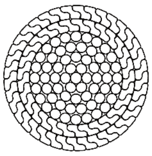
These ropes are composed of only round wires

- Half-locked coil rope:



These spiral ropes have an outer layer of alternate half-lock (H-shaped) and round wires.

- Full-locked coil ropes

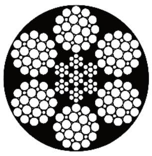


These spiral ropes have an outer layer of full-lock (Z-shaped) wires.

1.2.3 - Polymer covered and filled ropes *(EN 12385-2)*

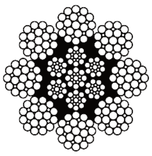
These ropes are coated or/and filled with polymers

- Solid polymer filled ropes & Solid polymer covered and filled ropes



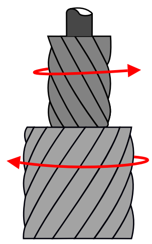
The free internal spaces of these ropes are filled with a solid polymer that extends to, or slightly beyond the outer circumference of the rope, or cover the outer circumference of the rope.

- Cushioned core rope



These ropes have their core coated, or filled and coated with a solid polymer

1.2.4 - Rotation Resistant ropes *(RR)*



In a conventional rope, a load creates a force that tries to untwist the rope, resulting in a rotation.
A " Rotation Resistant wire rope " has an independent internal rope, sometimes with two layers, with strands in the opposite direction to the outer strands. Under load, the internal rope tries to twist the rope in one direction, the outer strands try to twist it in the opposite direction. This geometrical design results that the forces in the core and the outer strands compensate each other over a wide load spectrum so that even with great lifting heights, no rope twist occurs.
Organizations such as ASME classify these wire ropes into three categories: Category 1 has little or no rotation; Category 2 has significant resistance to rotation; Category 3 has limited resistance to rotation.

1.3 - Elements of identification

Standardization bodies say that the wire rope must be selected by the equipment manufacturer, the rope manufacturer, or a recognized qualified person. Thus, it is not the function of the diving and ROV teams to decide which type of wire ropes are to be installed on lifting gears. However, having a notion of how wire ropes are classified allows the team to understand better the identification systems of the wire ropes installed on winches or proposed by the reseller.
Note that the identification systems of wire rope may vary from one country to another, which, even though these systems are similar, may oblige to refer to the system used by the manufacturer to find a wire rope with equivalent characteristics when changing it.
The systems of identification implemented by standardization bodies are based on the following:

- The rope construction
- The surface finish
- The lay type and direction
- The dimensions
- The breaking force and grade
- The rope class

1.3.1 - Identification system of ropes and cores construction (EN 12385-2)

Standardization bodies identify the design of wire ropes by sequences of symbols and numbers. As an example, the European standards use the following system:

Cross-sectional shape of wire, strand and rope			
Cross sectional shape	***Symbol***		
	Wire	***Strand***	***Rope***
Round	*No symbol*	*No symbol*	*No symbol*
Triangular	*V*	*V*	–
Built-up centre (a)	–	*B (1)*	–
Rectangular	*R*	–	–
Trapezoidal	*T*	–	–
Oval	*Q*	*Q*	–
Z-shaped	*Z*	–	–
H-shaped	*H*	–	–
Flat or ribbon	–	*P*	–
Compacted (b)	–	*K (2)*	*K (2)*
Braided	–	–	*BR*
(a): The symbol B indicates that the strand centre is built-up from a number of wires and succeeds the symbol for strand shape, e.g. a triangular strand of 25 wires with a built-up centre is designated as V25B. *(b): The symbol K indicates an additional compacting process and precedes the symbol for strand or rope shape, e.g. a compacted round strand or rope is designated as K and a compacted oval strand is designated as KQ.*			

Symbols of common types of stands	
Construction type	***Symbol***
Single lay	*No symbol*
Parallel lay - Seale *Parallel lay - Warrington* *Parallel lay - Filer*	*S* *W* *F*
Combined parallel lay	*WS*
Multiple operation lay - cross lay *Multiple operation lay - compound lay (1)*	*M* *N*
(1): N is additional and precedes the basic type symbol, e.g. Compound Seale is NS and Compound Warrington is NW	

Symbols for cores, centres of parallel-closed ropes and centres of rotation-resistant ropes	
Construction type	***Symbol***
Single layer rope fibre core: • *Natural fibre core* • *Synthetic fibre core* • *Solid polymer core*	*FC* *NFC* *SFC* *SPC*
Single layer steel fibre core: • *Wire strand core* • *Independent wire rope core* • *Independent wire rope core with compacted strands* • *Independent wire rope core covered with a polymer*	*WC* *WSC* *IWRC* *IWRC(K)* *EPIWRC*
• *Parallel wire rope centre* • *Parallel wire rope centre with compacted strands*	*PWRC* *PWRC(K)*
Rotation-resistant rope: • *Fibre centre* • *Wire strand centre* • *Compacted wire strand centre*	 *FC* *WSC* *KWSC*

The construction of stranded ropes is designated in the following sequences.

- Single layer rope:
  - the number of outer strands
  - multiplication sign (x)
  - the number of wires in each of the outer strands and the corresponding strand designation
  - connecting symbol dash (-)
  - the core designation,
  - Example: 6 × 36WS - IWRC = 6 outer strands x 36 cables in combined "parallel lay" stands - Steel fibre independent wire rope core
- Parallel-closed rope:
  - the number of outer strands
  - multiplication sign (×)
  - the number of wires in each of the outer strands and the corresponding strand designation;
  - connecting symbol dash (-), and
  - the designation of the rope centre indicating that it is laid parallel to the outer strands in one closing operation,
  - Example: 8 × 19S - PWRC
- Rotation-resistant rope 10 or more outer strands *(ASME category 1 ≥ 15 stands; ASME category 2 ≥10 strands)*.
  - either, the total number of strands in the rope excluding the central element; or, if the construction of the central element is the same as that of the outer strands, the total number of strands in the rope
  - in brackets ( ) the designation corresponding to how the inner strands are laid up where there are more than two layers of strands
  - multiplication sign (×)
  - the number of wires in each of the outer strands and the corresponding strand designation
  - connecting symbol dash (-), and
  - the designation of the central element,
  - Example: 18 × 7 - WSC or 19 × 7
- Rotation-resistant rope 8 or 9 outer strands *(ASME category 3)*
  - the number of outer strands;
  - multiplication sign (x);
  - the number of wires in each of the outer strands and the corresponding strand designation;
  - connecting symbol colon (:) signifying a contra-lay core; and
  - IWRC,
  - Example: 8 x 25F: IWRC

The construction of spiral strands is indicated as follows:
1 × number of wires in the strand, where "x" is the multiplication sign. Example: 1 x 61

1.3.2 - Identification of surface finish, and types of lay *(EN 12385-2)*

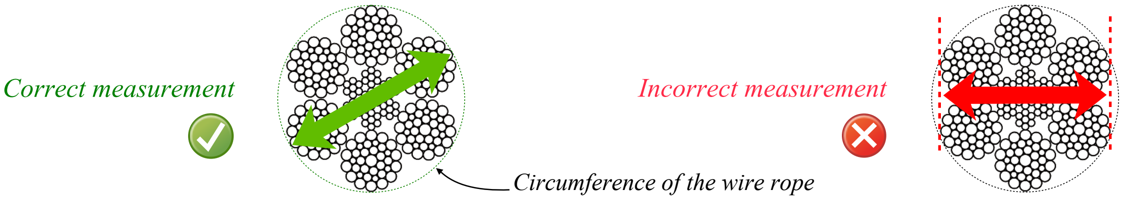
The European standards symbols for the surface finish of the outer wires and types of lay are the following:

Surface finish of wire	
Designation	***Symbol***
Uncoated (or bright)	*U*
Zinc coated class A	*A*
Zinc coated class B	*B*
Zinc coated class A	*A(Zn/Al)*
Zinc alloy coated class B	*B(Zn/Al)*

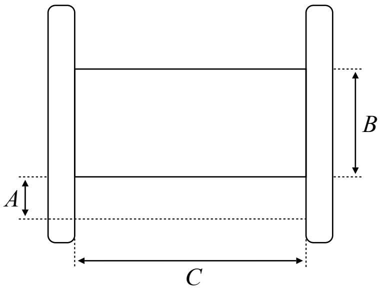
Type of lay and direction	
Designation	***Symbol***
Spiral ropes:	
• *Right lay*	*Z*
• *Left lay*	*S*
Stranded ropes:	
• *Ordinary lay, right*	*sZ*
• *Ordinary lay, left*	*zS*
• *Lang lay, right*	*zZ*
• *Lang lay, left*	*sS*
• *Alternate lay, right*	*aZ*
• *Alternate lay, left*	*aS*
The first letter of the ordinary and Lang types denotes the direction of the wires in the strands and the second letter denotes the direction of the strands in the rope. *The second letter of the alternate types denotes the direction of the strands in the rope.*	

1.3.3 - Elements for the calculation of the dimensions and weight of wire ropes

Knowing the diameter and mass of the wire rope is essential.
The diameter of a wire rope is necessary to calculate its strength and whether it can be installed on the winch's drum. The diameter (δ) is the largest distance of the perpendicular cross-section of the wire. Thus, it is calculated according to the rope wire's outer circumference (*see the drawing on the next page*).



Note the following common formula to calculate the winch's drum capacity under normal tension and uniform winding:



$$L = \frac{(A + B) \times A \times C}{K}$$

L = Length of rope (metres)

A = Desired depth of winding (mm)

ASME B30.30 says that the drum flange should extend a minimum of 1.5 the diameter of the rope over the rope's top layer, but not less than 13 mm. Other organizations recommend 2.5 the rope diameter instead of 1.5.

B = Diameter of the barrel (mm) *C = Width between flanges (mm)*

K = A constant developed according to the diameter of the rope (see below).

Constant K values according to rope diameters in millimetres							
Rope Ø	***K***	***Rope Ø***	***K***	***Rope Ø***	***K***	***Rope Ø***	***K***
2	*1274*	*9*	*25700*	*18*	*103100*	*26*	*215200*
4	*5093*	*11*	*38520*	*19*	*114900*	*28*	*249600*
6	*11470*	*13*	*53800*	*20*	*127400*	*32*	*326000*
7	*15600*	*14*	*62400*	*22*	*154100*	*35*	*389900*
8	*20370*	*16*	*81490*	*24*	*183300*	*38*	*459700*

The following elements of calculation are also necessary for the description of the ropes:

- Fill factor (f) & Nominal metallic cross-sectional area factor (C):
  The fill factor is the ratio between the sum of the nominal metallic cross-sectional areas of all the wires in the rope (A) and the circumscribed area (A_u) of the rope based on its nominal diameter (d). It is expressed as follows: $f = A/A_u$
  The Nominal metallic cross-sectional area factor is derived from fill factor and used in the calculation to determine the nominal metallic cross-sectional area of a rope. It can be expressed as follows: $C = f \times (\pi/4)$
- Rope length mass factor (W) & Nominal rope length mass:
  The rope length mass factor takes into account the mass of core and lubricant as well as the metallic elements.
  The nominal rope length mass is a value derived from the product of the length mass factor and the square of the nominal diameter. It is expressed as follows: $M = W \times d^2$
- Rope length mass factor (W)
  The rope length mass factor (W) takes into account the mass of core and lubricant as well as the metallic elements.
- Measured rope length mass (M_m)
  It is the mass of 1 m of rope determined by weighing.

1.3.4 - Rope breaking force, and grade

Elements for the calculation of the minimum breaking force:

- Minimum breaking force factor:
  It is an empirical factor used in the determination of minimum breaking force of a rope and obtained from the product of fill factor (f) for the rope class or construction, spinning loss factor (k) for the rope class or construction and the constant $\pi/4$. It is expressed as follows: $K = \pi f \times k / 4$
- Minimum breaking force (F_{min}):
  It is a specified value in kN, below which the measured breaking force (F_m) is not allowed to fall in a prescribed breaking force test and is normally obtained by calculation from the product of the square of the nominal diameter (d), the rope grade (R_r) and the breaking force factor (K). Thus: $F_{min} = (d^2 \times R_r \times K)/1000$
  EN 12385-2 says that the rope grade (R_r) is the level of requirement of breaking force which is designated by a number.

Definition of the rope grade:

EN 12385-4 says that for rope sizes up to and including 60 mm diameter, the rope grade is to be 1770, 1960, or 2160 or an intermediate grade as specified by the manufacturer, but not exceeding 2160. This document also says that ropes larger than 60 mm may not have a rope grade.
Note that other standardization bodies also use the values above It is for example the case of ASTM.

These values correspond to the values of the following wire tensile strength grades:

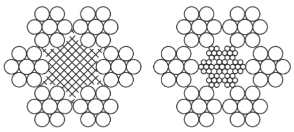
Rope grade	*Wire tensile strength grades (N/mm²)*	
	Minimum	*Maximum*
1770	*1570*	*1960*
1960	*1770*	*2160*
2160	*1960*	*2160*

The permitted variations of tensile strength grades are specified in EN 10264-1. These values are the lower limits for tensile strength of each wire grade.

Nominal dimension wire diameter: d or profile: h (mm)	*Permitted plus tolerance over the numerical value of tensile strength grade (Mpa)**
0,2 ≤ d or h < 0,5	*390*
0,5 ≤ d or h < 1,0	*350*
1,0 ≤ d or h < 1,5	*320*
1,5 ≤ d or h < 2,0	*290*
2,0 ≤ d or h < 3,5	*260*
3,5 ≤ d or h < 8,0	*250*
*Note * 1 Mpa = 1 N/mm²*	

1.3.5 - Rope class

A rope class is a group of ropes of similar mechanical properties and physical characteristics.
The manufacturer identifies the related rope class by referring to the elements of construction discussed above, and summarized by the organizations in standardization that publish reference tables, such as the one below of the "Class 6 x 7" as published in the Standard ISO 2408 *(the ISO system is similar to the EN one)*.



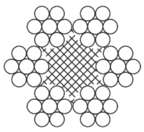
6 x 7-FC *6 x 7-IWRC*

Typical cross section

Typical construction			
Rope construction	***Strand construction***	***No of outer layer wires***	
		Total	***Per strand***
6 x 7	*1 - 6*	*36*	*6*

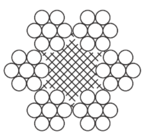
***Nominal diameter** (Mm)*	***Approximate weight** (Kg/100 m)*		***Rope grade***					
			1570		***1770***		***1960***	
			***Minimum breaking force** (Kn)*					
	FC	***IWRC***	***FC***	***IWRC***	***FC***	***IWRC***	***FC***	***IWRC***
2	*1.38*	*1.54*	*2.08*	*2.25*	*2.35*	*2.54*	*2.6*	*2.81*
3	*3.11*	*3.46*	*4.69*	*5.07*	*5.29*	*5.72*	*5.86*	*6.33*
4	*5.52*	*6.14*	*8.34*	*9.02*	*9.40*	*10.2*	*10.4*	*11.3*
6	*12.4*	*13.8*	*18.8*	*20.3*	*21.2*	*22.9*	*23.4*	*25.3*
7	*16.4*	*18.8*	*25.5*	*27.6*	*28.8*	*31.1*	*31.9*	*34.5*
8	*22.1*	*24.6*	*33.4*	*36.1*	*37.6*	*40.7*	*41.6*	*45*
9	*27.9*	*31.1*	*42.2*	*45.7*	*47.6*	*51.5*	*52.7*	*57*
10	*34.5*	*38.4*	*25.1*	*56.4*	*58.8*	*63.5*	*65.1*	*70.4*
11	*41.7*	*46.5*	*63.1*	*68.2*	*71.1*	*76.9*	*78.7*	*85.1*
12	*49.7*	*55.3*	*75.1*	*81.2*	*84.6*	*91.5*	*93.7*	*101*
13	*58.3*	*64.9*	*88.1*	*95.3*	*99.3*	*107*	*110*	*119*
14	*67.6*	*75.3*	*102*	*110*	*115*	*125*	*128*	*138*
16	*88.3*	*98.3*	*133*	*144*	*150*	*163*	*167*	*180*
18	*112*	*124*	*169*	*183*	*190*	*206*	*211*	*228*
20	*138*	*154*	*208*	*225*	*235*	*254*	*260*	*281*
22	*167*	*186*	*252*	*273*	*284*	*308*	*315*	*341*
24	*199*	*221*	*300*	*325*	*338*	*366*	*375*	*405*
26	*233*	*260*	*352*	*381*	*397*	*430*	*440*	*476*
28	*270*	*301*	*409*	*442*	*461*	*498*	*510*	*552*
32	*353*	*393*	*534*	*577*	*602*	*651*	*666*	*721*
36	*447*	*498*	*676*	*730*	*762*	*824*	*843*	*912*
40	*552*	*614*	*834*	*902*	*940*	*1020*	*1040*	*1130*

By comparison, note the "Class 6 x 7" published in the standard EN 12385-4, and which values are identical to those provided by ISO, despite a few differences in the presentation.
Note the breaking, mass, and cross-sectional factors that ISO does not indicate. However, note that the "Grade 1570" values are not shown. Also, the fibre core FC (Single layer fibre core) is labeled "Fibre core", and the Single layer steel fibre core WC is labeled "Steel core" (labeled "IWRC - Independent wire rope core" in the ISO table). The WC cross-section is also not displayed.

Construction cross section example	*Construction of core*			*Construction of strand*		
	Item		*Quantity*	*Item*		*Quantity*
 6 x 7-FC	*Strands* *Outer strands* *Layer of strands* *Wires in rope (excluding metallic core)*		6 6 1 30 to 54	*Wire* *Outer wires* *Layer of wires*		5 to 9 4 to 8 1
	Typical example			*No of outer wires*		*Outer wire factor*
	Rope		*Strand*	*Total*	*Per strand*	
	6 x 7		1-6	36	6	0.166
	Minimum Breaking force factor: *Nominal mass factor:* *Nominal metallic cross-sectional area factor:*			$K_1 = 0.332$ $W_1 = 0.354$ $C_1 = 0.369$	$K_2 = 0.359$ $W_2 = 0.384$ $C_2 = 0.432$	$K_3 = 0.388$
Nominal rope diameter	*Approximate nominal length mass (Kg/100 m)*		*Minimum breaking force (Kn)*			
			Rope grade 1770		*Rope grade 1960*	
	Fibre core	*Steel core*	*Fibre core*	*Steel core*	*Fibre core*	*Steel core*
2	1.38	1.54	2.35	2.54	2.6	2.81
3	3.11	3.46	5.29	5.72	5.86	6.33
4	5.52	6.14	9.40	10.2	10.4	11.3
6	12.4	13.8	21.2	22.9	23.4	25.3
7	16.4	18.8	28.8	31.1	31.9	34.5
8	22.1	24.6	37.6	40.7	41.6	45
9	27.9	31.1	47.6	51.5	52.7	57
10	34.5	38.4	58.8	63.5	65.1	70.4
11	41.7	46.5	71.1	76.9	78.7	85.1
12	49.7	55.3	84.6	91.5	93.7	101

Be continued up to 40 mm nominal rope diameter

Another presentation of the "Class 6 x 7" is published in the standard ASTM A1023/A1023M, and which metric values displayed are identical to those provided by ISO and EN standards, despite differences in the presentation and the use of the imperial system in parallel of the metric system.

Cross section example		*Construction of rope*				*Construction of strand*			
		Item			*Quantity*	*Item*			*Quantity*
 6 x 7-FC		*Strands* *Outer strands* *Layer of strands* *Wires in rope (excluding metallic core)*			6 6 1 30 to 54	*Wire* *Outer wires* *Layer of wires*			5 to 9 4 to 8 1
		Typical example		*No of outer wires*					
		Rope		*Strand*		*Total*		*Diameter range*	
		6 x 7		1-6		36		0.166	
Diameter		*Approximate mass*		*Minimum breaking force*				*Diameter range*	
in	*Mm*	*Lb/ft*	*Kg/m*	*IPS (Tons*	*1770 (kN)*	*EIP (Tons)*	*1960 (kN)*	*in*	*in*
	6	0.08	0.124		21.2		23.4	0.236	0.248
¼		0.09	0.139	2.64		2.90		0.250	0.263
	7	0.11	0.169		28.8		31.9	0.276	0.289
5/16		0.15	0.217	4.10		4.51		0.313	0.328
	8	0.15	0.221		37.6		41.6	0.315	0.331
	9	0.19	0.279		47.6		52.7	0.354	0.372
3/8		0.21	0.313	5.86		6.45		0.375	0.394
	10	0.23	0.345		58.8		65.1	0.394	0.413
	11	0.28	0.417		71.1		78.7	0.433	0.455
7/16		0.29	0.426	7.93		8.72		0.438	0.459

Be continued up to 1½ inches & 36 mm rope diameters

The table below summarises the factors explained in points 1.3.3 & 1.3.4, and used in calculating the minimum breaking force of the ropes covered by the class tables provided by the standardization bodies mentioned above.

Type of rope	*Class*	*Ropes with fibre core or fibre centre*			*Ropes with steel core or wire stand centre*					
		Nominal length mass factor (approx.)	*Nominal metallic cross-sectional area factor*	*Minimum breaking force factor*	*Nominal length mass factor*		*Nominal metallic cross sectional area factor*		*Minimum Breathing force factor*	
		W_1	C_1	K_1	W_2	W_3	C_2	C_3	K_2	K_3
Single layer round strand	*6 x 7*	*0.345*	*0.369*	*0.332*	*0.384*	*0.384*	*0.432*	*0.432*	*0.359*	*0.388*
	8 x 7	*0.327*	*0.335*	*0.291*	*0.391*	–	*0.439*	–	*0.259*	–
	6 x 19	*0.359*	*0.384*	*0.330*	*0.400*	–	*0.449*	–	*0.356*	–
	8 x 19	*0.340*	*0.349*	*0.293*	*0.407*	–	*0.457*	–	*0.356*	–
	6 x 36	*0.367*	*0.393*	*0.330*	*0.409*	–	*0.460*	–	*0.356*	–
	8 x 36	*0.348*	*0.357*	*0.293*	*0.417*	–	*0.468*	–	*0.356*	–
	6 x 35N	*0.352*	*0.377*	*0.317*	*0.392*	–	*0.441*	–	*0.345*	–
	6 x 19M	*0.346*	*0.357*	*0.307*	–	*0.381*	–	*0.418*	*0.332*	*0.362*
	6 X 37M	*0.346*	*0.357*	*0.295*	*0.381*	*0.381*	*0.418*	*0.418*	*0.319*	*0.346*
Rotation resistant	*18 x 7*	*0.382*	–	*0.328*	–	*0.401*	–	*0.433*	–	*0.328*
	34(M) x7	*0.390*	–	*0.318*	–	*0.401*	–	*0.428*	–	*0.318*
	35(W) x7	–	–	–	–	*0.454*	–	*0.480*	–	*0.360* 0.350***
** Up to and including rope grade 1960 ** Greater than rope grade 1960 up to and including rope grade 2160*										

1.3.6 - Coating and protection against corrosion

Depending on the technical design of the lifting gear it is designed for, the wire rope can be bright or coated. The coatings generally used are zinc and zinc alloy. It must be noted that zinc is the material used for sacrificial anodes installed to protect underwater structures against corrosion. Hence, the zinc layer of the wire rope acts as sacrificial protection against corrosion. Also, it provides additional protection against wear and provides a lubricant effect.
The coating should have a minimum mass per unit of surface area, usually expressed in g/m². The standard EN 10264-1 recommends referring classes A & B of EN 10244-2 below.

Mass of coating in g.m² - classes A & B - Standard EN 10244-2											
Ø (mm)	*A*	*B*	*Ø (mm)*	*A*	*B*	*Ø (mm)*	*A*	*B*	*Ø (mm)*	*A*	*B*
0.15 < 0.20	–	*15*	*0.60 < 0.70*	*115*	*60*	*1.40 < 1.65*	*195*	*100*	*3.20 < 3.80*	*265*	*135*
0.20 < 0.25	*30*	*20*	*0.70 < 0.80*	*130*	*60*	*1.65 < 1.85*	*205*	*100*	*3.80 < 4.40*	*275*	*135*
0.25 < 0.32	*45*	*30*	*0.80 < 0.90*	*145*	*70*	*1.85 < 2.15*	*215*	*115*	*4.40 < 5.20*	*280*	*150*
0.32 < 0.40	*60*	*30*	*0.90 < 1.00*	*155*	*70*	*2.15 < 2.50*	*230*	*125*	*5.20 < 8.20*	*290*	–
0.40 < 0.50	*85*	*40*	*1.00 < 1.20*	*165*	*80*	*2.50 < 2.80*	*245*	*125*	*8.20 < 10.00*	*300*	–
0.50 < 0.60	*100*	*50*	*1.20 < 1.40*	*180*	*90*	*2.80 < 3.20*	*255*	*135*	–	–	–

If another class of coating is requested or if other metallic coatings are required, these must be the subject of agreement at the time of ordering.
The standard EN 10264-1 says that when protection against rust is requested, the two parties should define the appropriate anti-corrosive protection to be used.

1.3.7 - Marking and inspecting the rope and documents

The marking of the wire rope should indicate the elements previously described. Regarding this point, the standard EN 1285-4 says that, at least, the following information should be supplied with an enquiry or order. This information should also be available with the lifting gear:

- Standard of reference
- Quantity and length;
- Nominal diameter;
- Minimum breaking force required.
- Rope class or construction (see point 1.3.5);
- Core type;
- Rope grade;
- Wire finish;
- Lay direction and type;

- Preformation *(The outer strands of single layer and parallel-closed ropes are normally preformed during manufacture)*.;
- Lubrication *(At least the strands are lubricated during manufacture);*
- Coating & anticorrosion protection;
- Any particular marking requirements;
- Any particular packaging requirements
- Type of inspection document

Document EN 12385-3 says that the wire rope should be unwrapped and examined immediately after delivery to check its identity and condition and to ensure that it is compatible with the model requested on order.
The Certificate of conformity should be provided and kept safe until the wire rope is installed. When installed, it will be available with the crane's or lifting gear's handbook as long as it is in service.
Note that the rope should not be used without the user having the certificate of conformity in his possession.
Damages to the rope or its package may be present. They should be recorded on the delivery note and may result that the wire rope is to be rejected.

1.3.8 - Storing

Wire ropes are commonly stored in the prevention of an unplanned change or a sufficient time before a planned change not to be in trouble due to unavailability problems. Incorrect storage may result in the wire rope being damaged or contaminated. We can refer to the guidelines from EN 12385-3 and the manufacturers' recommendations to avoid that.

- The wire rope should be stored in a clean, well-ventilated, dry, dust-free, and undercover place. It should be covered with waterproof material if it cannot be stored inside. However, tightly sealed protections should be avoided as condensation between rope strands may occur and cause corrosion problems when the rope is stored in an unheated area.
- The place of storage should not be likely to be affected by chemical fumes, steam or any other corrosive agents. Places where elevated temperatures are likely should also be avoided as that may affect its future performance.
- The wire rope should be protected from accidental damage during the storage period or when handling it. Also, it should not be in direct contact with the floor, and the reel should be so positioned that there is a flow of air under it. The reel should preferably be supported in an A-frame or cradle standing on the ground, which can safely support the total mass of the rope and reel.
- If the wire rope is on a reel, this device should be rotated periodically during the long storage periods, particularly in warm environments, to prevent lubricant migration from the wire rope. In addition, it should be inspected regularly, and when necessary, a suitable rope dressing, compatible with the manufacturing lubricant, should be applied. Most companies organize it at least every 6 months.

1.4 - Elements for selection

As previously said, in the introduction of point 1.3, it is not the function of the diving and ROV teams to decide which type of wire ropes are to be installed on lifting gears. These calculations are to be done by the lifting gear manufacturer, the wire rope manufacturer, a specialized technician, or an engineer. Thus, for companies members of IMCA, they should be competent persons categories 3, and 4. Except for winches to be adapted for a new application, the recommendation is to keep the wire rope model selected by the device’s manufacturer. Also, remember that a winch used for another application than the original must be certified for this new application by a classification society, which results that only the wire rope model approved by the certification body is to be installed. For this reason, in addition to understanding the elements of identification previously discussed, it is also essential to understand the factors for the rope selection, so the reasons a wire rope must not be replaced by another model without a certification process.

1.4.1 - Stresses affecting the wire ropes life

Lifting gears' manufacturers select the wire ropes to minimize the effects of the various stresses they will be submitted during the operations. These stresses vary according to the working conditions and the design of the equipment and may result in premature wear and fatigue of a wire rope not adequately selected.

- Tensile stress:
  When under load, the wire rope tends to stretch due to the mass of the load and the forces exerted on it. It is the reason the “tensile strength”, which is the maximum stress that wire rope can bear before breaking when it is stretched and is expressed in Newton/mm², is calculated and used to calculate the breaking force and grade of the wire rope. An inadequate selection of the grade may result in a failure of the wire rope.
- Bending
  Each time the wire rope passes in a sheave, it passes from a straight state to a bent state and then returns to its initial state. That creates external and internal wire fatigues, which are not visible outside. Studies show that wire breakage starts in the outer wires and progresses to the second layer, eventually leading the strands to rupture. For this reason, the construction of the wire ropes plays a vital role in bending fatigue control. Also, it is said that a well-lubricated wire rope allows for more bending cycles than a poorly lubricated similar rope.
- Torsion fatigue:
  Wire ropes are assemblies of wires helically laid around their core that combine tensile stiffness with bending

flexibility. However, this design offers a low torsional rigidity that may result in the load rotating and wire rope damages, such as wires and strands exhibiting looseness so that they are no longer closely laid around the core and thus result in weakness and an over-thickness. Non-rotating ropes are a common solution to this problem.

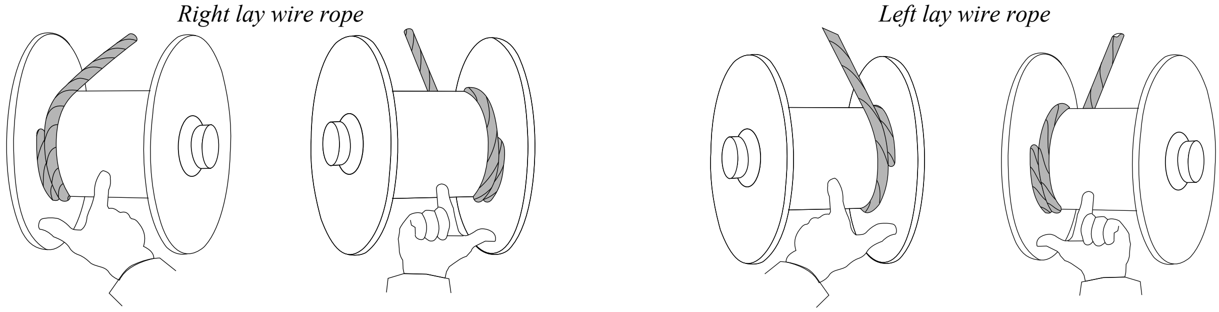
- Abrasion and wear:
  In annex B of EN 12385-3, it is said that the wire rope will become progressively weakened due to contact with other materials when it passes through sheaves, rollers, and coils onto a drum or is dragged through or along abrasive material. In addition, although expected to take place mainly on the crowns of the wires, wear may also occur at the strand-core and strand interfaces within the rope.
  Where abrasion is known to be the primary mode of deterioration, selecting a rope with outer wires as large as possible is recommended. However, additional needs, such as bending fatigue requirements, may have to be considered. EN 12385 also says that Lang lay ropes (subject to both ends of the rope being fixed and prevented from rotating) and compacted strand ropes can be advantageous under abrasive conditions.
- Crushing:
  EN 12385 says that crushing can occur for several reasons but is more likely when the rope is subject to multi-layer coiling at the drum. Also, greater radial pressure will be experienced between the rope and a smooth or plain-faced drum than with a grooved drum.
  EN 12385-3 also recommends not to use stranded ropes containing fibre when coiling extends into multi-layers. On the opposite, ropes with steel cores and compacted strand ropes are more resistant to crushing and distortion.
- Corrosion:
  Corrosion is a significant source of damage when the wire rope is stored and in service.
  Sacrificial protection against corrosion, such as zinc coating, is previously explained in point 1.3.6, and precautions to implement to protect the wire ropes during their storage periods are discussed in point 1.3.8.
  EN 12385-3 says that when corrosion is expected or known to be a primary mode of deterioration, it is preferable to use a rope containing zinc (or zinc alloy Zn95/Al5) coated wires. For this reason, lifting cables of diving bells and baskets are often coated with Zinc or Zinc alloy. Another well known method to fight corrosion is frequent lubrification.
  In addition to the above, EN 12385-3 says that a rope with a large number of small wires is more susceptible to corrosion than a rope with a small number of large wires. For this reason, it is recommended to select ropes with as large wires as possible, considering whether there is any additional need to fulfill any bending fatigue requirements.

1.4.2 - Lay type, direction of coiling, and diameter of the rope

The correct direction of lay is essential for adequately functioning a reeving system. A wrong direction of lay results in torque build-up, resulting in the first layer of rope not winding evenly or tightly, causing the second layer to pinch down between the wraps of the first layer. This problem will increase with each additional layer, so the rope is piling up, causing abnormal wear and other structural damages.
The “hand rule” is a convenient method to check the correct lay for an installation that most organizations have adopted. The extended thumb points to the flange to which the rope is terminated, while the extended forefinger represents the rope leaving the drum. A palm up hand represents underwind and palm down overwind. That results in the following:

1. For a right lay rope installed "overwind", start the installation at the left-hand side of the flange.
2. For a right lay rope installed "underwind", start the installation at the right-hand side of the flange.
3. For a left lay rope installed "overwind", start the installation at the right-hand side of the flange.
4. For a left lay rope installed "underwind", start the installation at the left-hand side of the flange.

Right lay wire rope *Left lay wire rope*



1 - Overwind: Right hand palm down *2 - Underwind: Right hand palm up* *3 - Overwind: Left hand palm down* *4 - Underwind: Left hand palm up*

Note that EN 12385-5 says that the rope diameter should never be greater than the drum's pitch. In addition, the relationship between the actual rope diameter and the pitch should be assessed in the case of multi-layer coiling. Note that the method for calculating the length of rope in the drum is discussed in point #1.3.3.

Also, many winch manufacturers have moved from smooth winch drums to ones with grooving. The grooves' purpose is to help the rope to wind smoothly and sit on the previous wrap rather than alongside it to avoid untidy wire rope spooling and, thus, damage. However, the direction of the wire rope cannot be modified and must be the one of the groovings. Also, the wire rope size should conform to the grooves. Regarding this point, ASME B30.30 says that the grooves of a new drum must be 6 to 10% larger than the nominal rope diameter. In addition, EN 12385-3 says that the effective groove diameter should be at least 5 % above the nominal rope for ropes working on cranes, and ISO 16625 says that this

diameter should be between 5 and 10% with an optimum value or 7.5%.
Similar values are applicable to the sheaves. Regarding this point, note that a too small diameter of the sheaves will result in structural defects of the wire rope due to the increased pressure on the parts of the rope in contact with the edges of the sheave and that the bottom of the rope is not sustained. A too large groove will result in an increased and abnormal pressure to part of the wire rope in contact as the contact with the edges is missing. That will also result in structural deformations reducing the life of the wire rope.

1.4.3 - Rotation resistant wire ropes

The document ASME B30.30 provides the following recommendations regarding the selection of rotation resistant wire ropes:

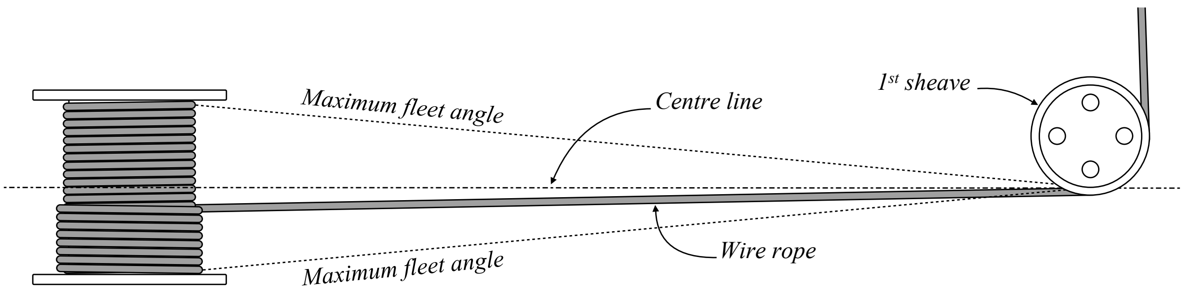
- For remembering, ASME classifies these ropes into 3 categories:
  - Category 1 displays little or no tendency to rotate and has at least 15 outer strands.
  - Category 2 has significant resistance to rotation and has at least ten outer strands.
  - Category 3 has limited resistance to rotation and has no more than nine outer strands.
- Wire rope with fibre core should not be used for boom hoist or luffing attachment reeving *(This does not preclude using hybrid rope).*
- Category 2 and 3 rotation-resistant rope should not be used on single-layer drums unless approved by the lifting equipment's manufacturer or a qualified person.
- Rotation-resistant rope and fibre core rope must not be used for the following:
  - Boom support, boom hoist, or boom extension system rope, except for the configurations in the note below.
  - Boom support or boom hoist rope during erection, except for the configurations in the note below.
  - Standing rope that is used as live rope during.

  Note: Rotation-resistant rope may be used as a boom hoist reeving when load hoists are used as boom hoists for attachments, such as luffing attachments or boom and mast attachment systems under specific conditions.

Like the other standardization bodies, ASME says that the wire rope should be selected by the equipment manufacturer, the rope manufacturer, or a qualified person.

1.4.4 - Fleet angle

What is called "fleet angle" is the largest angle of the rope between the first sheave and the drum flange relative to the centre line of the drum. This angle depends on the distance of the sides of the drum to the centre line and the distance from the drum to the 1st sheave.



Excessive fleet angles can result in considerable abrasive damage to both sheave flanges and rope and considerably reduce the life of the rope and the equipment. Also, Excessively high fleet angles can return the rope across the drum prematurely, creating gaps between rope wraps close to the drum flanges and increasing the pressure on the rope at the cross-over positions. As a result, structural damage to the wire rope such as a “birdcage” or “core protrusion” may be visible. As the fleet angle increases, so does the problem.
In summary, a maximum fleet angle improperly calculated may result in damages that may be confused with those linked to the rope's quality or design.
The maximum wire rope float angle is calculated by the manufacturer of lifting devices such as cranes and A-frames. However, the dive team may be more involved when implementing temporary installations composed of portable winches and snatch blocks to lift or pull various loads in various parts of underwater facilities that are not reachable using cranes or lifting bags.
The values for the maximum fleet angles vary slightly from one organization to another. EN 12385-3 says that the angle should be no greater than 2° for rotation-resistant ropes and no greater than 4° for single-layer ropes.
EN 12385-3 also says that when spooling onto a drum, the fleet angle is generally recommended to be limited between 0,5° and 2,5°. If the angle is too small, so less than 0,5°, the rope tends to pile up at the flange of the drum and fails to return across the drum in the opposite direction. In this situation, the problem may be alleviated by increasing the fleet angle by introducing a sheave or spooling mechanism. Also, even where the drum is provided with helical grooving, large fleet angles inevitably result in localised areas of mechanical damage as the wires "pluck" against each other. This is often referred to as "rope interference", which can be reduced by selecting a Lang lay rope, if the reeving allows, or a compacted strand rope.

1.4.5 - To summarize the elements above

The selection of a wire rope is a complex process that takes into account the stresses the wire rope will have to withstand and the design of the lifting or pulling gear. Thus, as already said, it is not a wise idea to change the wire rope model selected for another one without consulting the lifting device and rope manufacturers. For this reason, and in addition to the fact that such a change will be rejected by the certification body in charge of the inspection of the lifting or pulling

device without proper supporting documentation, the only acceptable policy for users is to comply with the recommendations provided by the manufacturer strictly, and of course, to use the device within the conditions it is designed for.
A condition that may trigger the change of the wire rope model is when excessive abrasion, wear, and other damages are visible. However, as suggested in the previous points, these damages may not be the fact of the wire rope itself but a misconception of the lifting device or a combination of the two. For this reason, such problems must be investigated by specialists before being corrected by the manufacturers implicated, which highlights that regular inspections are essential.
Because the construction of wire ropes and lifting devices are based on complex technologies, hasty conclusions are unsuitable for solving problems.

1.4.6 - Comparison between metric and imperial rope sizes - ISO 2408

ISO 2408 displays a table similar to the one below that compares the differences between metric and imperial nominal rope diameters and their respective diameter tolerances to assist in rope size selection.
Note that the minimum tolerances are equal to the nominal diameters.

Nominal diameter		***Diameter tolerances***			***Nominal diameter***		***Diameter tolerances***	
		Minimum	***Maximum***				***Minimum***	***Maximum***
Metric (mm)	***Imperial (in)***	***mm***	***mm***		***Metric (mm)***	***Imperial (in)***	***mm***	***mm***
6 *	–	6	6.36		26 *	1	26	27.3
6.35	1/4	6.35	6.73		28 *	–	28	29.4
7	–	7	7.42		28.6	1-1/8	28.6	30
7.94	5/16	7.94	8.42		31.8	1-1/4	31.8	33.3
8 *	–	8	8.4		32 *	–	32	33.6
9 *	–	9	9.45		34.9	1-3/8	34.9	36.7
9.53	3/8	9.53	10		35	–	35	36.8
10 *	–	10	10.5		36 *	–	36	37.8
11 *	–	11	11.6		38 *	–	38	39.9
11.1	7/16	11.1	11.7		38.1	1-1/2	38.1	40
12 *	–	12	12.6		40 *	–	40	42
12.7	1/2	12.7	13.3		41.3	1-5/8	41.3	43.3
13 *	–	13	13.7		44 *	–	44	46.2
14 *	–	14	14.7		44.5	1-3/4	44.5	46.7
14.3	9/16	14.3	15		45 *	–	45	47.3
15.9	5/8	15.9	16.7		47.6	1-7/8	47.6	50
16 *	–	16	16.8		48 *	–	48	50.4
18 *	–	18	18.9		50.8	2	50.8	53.3
19 *	–	19	20		51	–	51	53.6
19.1	3/4	19.1	20		52 *	–	52	54.6
20 *	–	20	21		54	2-1/8	54	56.7
22 *	–	22	23.1		56 *	–	56	58.8
22.2	7/8	22.2	23.3		57.2	2-1/4	57.2	60
24 *	–	24	25.2		60 *	–	60	63
25.4	1	25.4	267		* Preferred size			

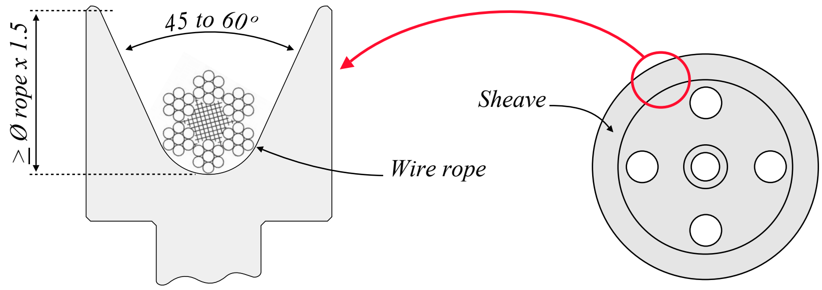
2 - Wire rope handling, installation, and maintenance

2.1 - Preparing and installing the wire rope

2.1.1 - Checking the condition of the lifting or pulling gear and the wire rope and transferring it to the work site

The following elements should be taken into consideration:

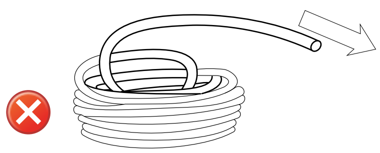
- EN 12385-3 says that before installing the new rope, the condition and dimensions of rope-related parts (drums, sheaves, rope guards, etc.) should be checked and be within the operating limits specified by the equipment manufacturer. Shear grooves should have circular and smooth profiles. The common rule is that their depth should at least be 1.5 times the rope's inner diameter, and their opening angle between 45° and 60°. Groove gauges should be used for their inspection.



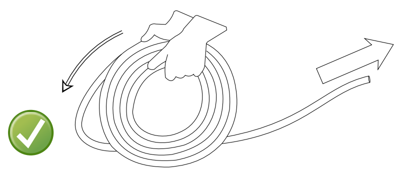
- Note that parts with abnormal wear should be reported and closely documented because they indicate design problems that must be corrected.
- ASME B30.30 says that before installing wire rope, the documents that accompany the reel or the rope should be checked to ensure the wire rope being installed on the equipment is correct.
- The rope should be checked to verify that it is not damaged when unloaded and when transported to storage compound or site. During these operations, the rope should not come into contact with any part of the lifting device, such as the hook of a crane or a fork of a fork lift truck. EN 12385-3 says that webbing slings may be used. In addition to textile slings manufacturers say that steel rods can be used when the wire rope is coiled on a reel.

2.1.2 - Preparation and transfer of a wire rope to the lifting or pulling gear

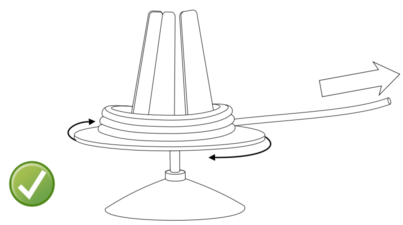
Wire ropes delivered in coils should not be removed from the side, as that creates a torsion for each winding in the rope that can result in loops that can cause irreparable kinks if this rope is then pulled tight. For this reason, the rope should be rolled out like a tire on a clean floor so that it does not become contaminated with dust, grit, moisture, or other harmful material. However, large coils can be difficult to handle. In this case, it is advisable to install it on a turntable which can allow the rope to be paid out as the end of the rope is pulled out.



Incorrect procedure

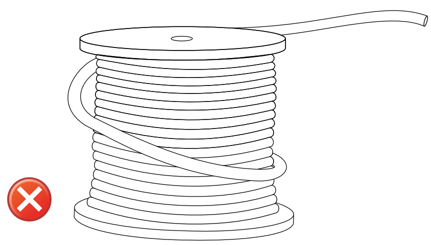


Correct Procedure

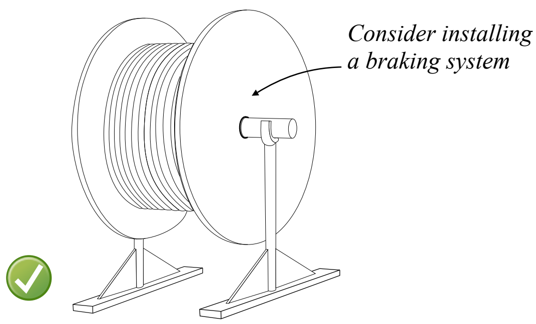


Correct procedure

Wire ropes delivered in reels should also not be removed from reels laid on their side on the floor, as similar damages to those resulting when removing the wire ropes from coils laid on their side may happen (see above). Standardization bodies recommend using a frame or winding block to unwind the wire ropes from large reels. Such systems consist of a shaft of suitable strength passed through the reel bore, which is installed on the frame or the winding block to easily rotate on this axle and be braked to control the unwinding during the transfer to the drum of the lifting or pulling gear. Also, according to many manufacturers, a turntable similar to the one described above can be used for removing the wire ropes from small reels.



Incorrect procedure



Correct procedure

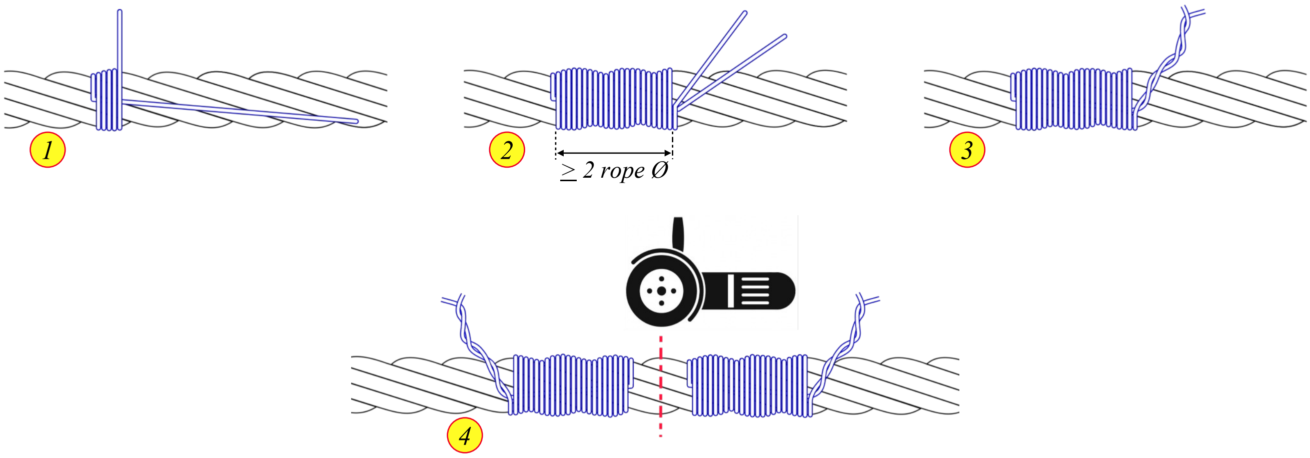
Also, EN 123385-3 gives the following recommendations:

- Where multi-layer coiling is involved, the rope should be placed in equipment capable of providing back tension in the wire rope as it is transferred from the supply reel to the drum. This ensures that the underlying laps of wire rope, particularly in the bottom layer, are wound tightly on the drum.
- The supply reel should be positioned so that the fleet angle during installation is minimal *(see in point #1.4.4 "Fleet angle ")*.
- If a loop forms in the rope, it should not be allowed to tighten to form a kink.
- The correct direction of lay is to be considered *(see in point #1.4.2)*.
- Releasing the outboard end of the rope from the supply reel or coil should be controlled to avoid the wire rope suddenly straightening and causing injury.
- If installing the new rope with the aid of the old rope, one method is to fit a wire rope sock to each of the rope ends to be attached. The open end of the sock should be securely attached to the rope by a serving or a suitable clip. The two ends should be connected via. a length of fibre rope of adequate strength to avoid turns being transmitted from the old rope into the new rope. If a wire rope is used, it should be a rotation-resistant type or have the same lay type and direction as the new rope. Alternatively, a fibre or steel rope of adequate strength may be reeved into the system for use as a pilot/messenger line. Swivels should not be used for the installation of the rope. Also, in addition to what EN 12385-3 says, welding the ropes' ends to each other is forbidden.
- The rope should be carefully monitored as it is being pulled into the system that must not be obstructed by any part of the structure or mechanism that may damage the rope and result in a loss of control.

In addition, all competent bodies say that the preferred winding of the wire rope should be considered when transferring the new wire rope from the reel to the winch's drum. The reason is that wire ropes have a preferred bending direction resulting from their manufacturing process. For this reason, the wire rope must have the same position during the transfer from the reel to the drum. Thus, from the bottom to the bottom or the top to the top. If the rope is transferred in the opposite direction to its preferred bending direction, so diagonally, there is a risk that twists happen between the reel and the drum and that the wire rope tends to regain its preferred position during lifting or pulling operations, resulting in structural damages.

2.1.3 - Cutting wire ropes

It may happen that, for operational reasons, a wire rope has to be cut.
In this case, it is necessary to tie up the strands of the wire rope on both sides and at direct proximity of the place where the cut is planned to prevent the strands from unwinding and core slippage, thus, damaging the rope on substantial lengths, which can result that these lengths or the entire wire rope will have to be discarded.
The standard rule, also recommended by EN 12385-3, is that each seizing length should equal two rope diameters for a stranded rope. Standardization bodies and manufacturers recommend using steel wire for this purpose. Note that adhesive tape, does not withstand heat and is not strong enough to prevent the unwinding of the strands and should be banished for these reasons. In addition, it must be taken into account that for non-preformed ropes, rotation-resistant ropes, and parallel-closed ropes, EN 12385-3 recommends a minimum of two ties up each side of the cut.
The standard seizing procedure indicated by rope manufacturers and standardization bodies is based on the traditional "whipping knot" that sailors have used to seize rope ends for generations. It consists of taking a small string and rolling it on the rope at a distance from its end between two and five centimetres to maintain its integrity and secure the string's extremities by a knot hidden under the whipping. The process is similar when using the steel wire, except its extremities are stranded using pliers to secure the assembly.



Depending on the equipment and competencies available, the wire rope can be cut using a high-speed abrasive disc cutter or a cutting torch. This last procedure, called "fusing", consists of melting the wires so that the metal in fusion welds the wire and strand extremities to each other. It requires training to be perfectly controlled.
After the cut, the extremity of the cable can be left seized, or seized with the ends fused, or tapered and welded, or provided with a cap or a fitting.

2.1.4 - Commissioning

Wire rope manufacturers and standardization bodies recommend performing several cycles with a reduced load (ISO 4309 recommends 10% of the maximum Safe Working Load), and at a slow speed to adjust the new wire rope to its working conditions gradually. During this period, the team must ensure that the wire rope is spooling and running through the various sheaves correctly.
In the handbook “Care, installation and maintenance of wire ropes”, K. P. Shah says that, depending on rope type and construction, some rope stretch and a slight reduction in rope diameter will occur as the strands and core are compacted. The initial stretch (constructional stretch) is a permanent elongation due to slight lengthening of the rope lay and associated slight decrease in rope diameter. Constructional stretch generally occurs during the first 10-20 lifts, increasing the rope length by approximately ½ % for fiber core rope, ¼ % for 6-strand steel core rope, and approaching zero % for compacted wire ropes.
EN 12385-3 recommends never running such initial operations with the maximum working load of the lifting/pulling device or above to avoid creating permanent structural damages. That means load tests should not be performed immediately after changing the wire rope.

2.2 - Maintain the wire rope during the operations

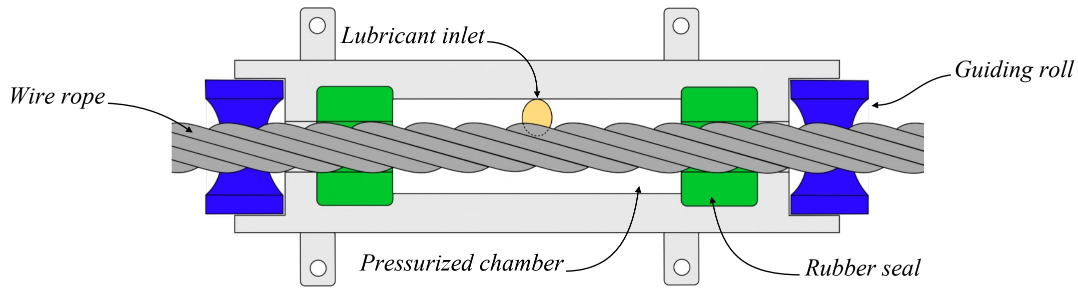
2.2.1 - Lubrification and cleaning

The purpose of lubrication is explained in point 1.1.4. Although the wire rope is lubricated during the manufacturing process, most documents from standardization bodies such as ISO 4309 recommend that the wire rope is coated with grease or oil at the time of installation.
The rope should be cleaned and re-lubricated at regular intervals when it is in service to keep its characteristics intact and protect it against corrosion. The frequency for such operation depends on the conditions the lifting or pulling gear is used and may vary according to the state of the wire rope. Note that diving organizations, such as, for example, IMCA, recommend such an operation every six months for the bells and baskets launch and recovery systems. However, this is a very minimum that may not be sufficient during intensive operations and operations in aggressive weather conditions. So, more frequent schedules are to be considered.

The properties of the lubricant used for maintenance must conform with those recommended by the wire rope manufacturer:

- Similar penetrating characteristics
- Similar lubrification performances
- Similar protection against corrosion

Regarding this point, ISO 4309 says that the user should seek advice from the rope manufacturer if the lubricant is not identified in the lifting/pulling device manual.
Lubricants are commonly applied using paint brushes or swabs. Other methods can be pulverization, continuous dripping, or bathing. However, none of these methods is considered able to provide maximum penetration. For this reason, pressurized lubrification is recommended to guarantee the lubrification of all parts of the rope. Pressure lubricators consist of a sleeve composed of two halves with rubber sealings clamped around the wire rope, capable of withstanding a pressure of approximately 30 bar without leaks and supplied in lubricant by a rubber hose connected to a pump. The system is pressurized while the wire rope passes into it *(See the drawing below)*.

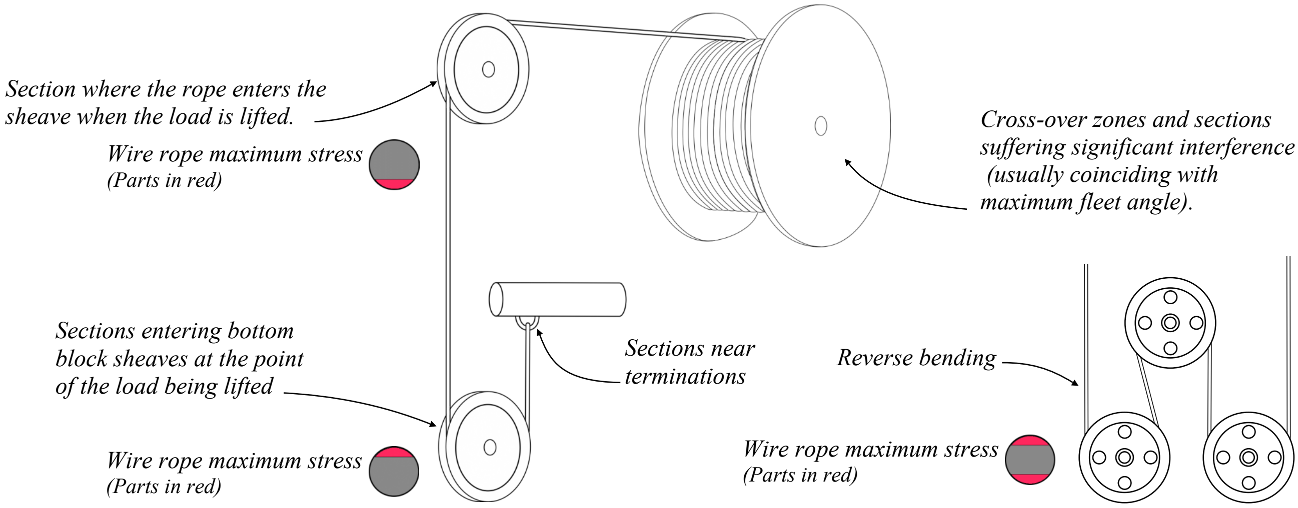


In addition to the above, it must be taken into account that applying too much lubricant is not recommended. EN 12385-3 says that it may lead to an accumulation of foreign debris on the wire rope's surface, which can result in abrasive damage to the rope, the sheaves, and the drum. It may also make it difficult to determine the rope's condition for evaluation against discard criteria. EN 12385-3 also says that a wrong lubricant can result in the same problems.
Wire ropes should be cleaned regularly and according to their condition, as accumulated dirt results in the problems abovementioned. Doing this manually takes considerable time and often results in limited efficiency. To avoid losing time and clean the wire ropes efficiently without too much effort, wire ropes and lubricant manufacturers provide tools specifically designed for this purpose. They usually consist of sleeves equipped with brushes and scrappers into which the wire rope passes and are often installed before the pressure lubricators.

2.2.2 - Daily wire rope examinations

OSHA 1926.1413 says that a competent person must begin a visual inspection prior to each shift the equipment is used, which must be completed before or during that shift.
As many organizations OSHA does not provide a precise description of the required technical level of the competent person in charge of these checks. However, ISO 4309 says that the driver/operator of the crane (or another lifting / pulling device) can be appointed to carry out daily checks to the extent that he is sufficiently trained and considered competent to carry out this action.

This inspection consists of only observing the wire ropes (running and standing) likely to be used during the shift for apparent deficiencies, so untwisting (opening) the wire rope is not required. ISO 4309 says that the wire rope should be checked to ensure it is sitting correctly on the drum and over the sheave(s) and has not been displaced from its normal operating position. ISO highlights the sensitive areas using a scheme similar to the one below *(The parts of the rope where the stress is the most significant are figured in addition)*.



2.2.3 - Periodic examinations

Periodic detailed inspections should be carried out by a competent person with a technical level above those of crane operators. It is usually a technician specialized in wire ropes and appointed by a recognized organization or an engineer who is also competent in wire ropes.

ISO 4309 says that the information gained from a periodic inspection is used to assist in deciding whether a crane rope can safely remain in service and by which latest time it shall undergo its next periodic inspection, or needs to be withdrawn immediately or within a specified timeframe.
ISO 4903 also says that the severity of deterioration must be assessed through an appropriate method, and expressed as a percentage of the particular individual discard criteria or in words.
Any damage that might have occurred to the rope before it was run in and entered service must be assessed by a competent person, and observations must be recorded.
The table below lists the more common modes of assessment of deteriorations as agreed by ISO. This table does not consider Non Destructive Examination procedures despite ISO 4309 considers that electro magnetic means can be used as an aid to visual inspection. These techniques are more discussed in point 2.2.6.

Mode of deterioration	***Assessment method***
Number of visible broken wires (including those which are randomly distributed, localized groupings, valley wire breaks and those that are at, or in the vicinity of, the termination)	*By counting*
Decrease in rope diameter (resulting from external wear/abrasion, internal wear and core deterioration)	*By measurement*
Fracture of strand(s)	*Visual*
Corrosion (external, internal and fretting)	*Visual*
Deformation	*Visual and by measurement (wave only)*
Mechanical damage	*Visual*
Heat damage (including electric arcing)	*Visual*

OSHA 1926.1413 recommends that these periodic thorough examinations of the wire rope are organized monthly and annually. For information, the UK Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) recommends to thoroughly examine every lifting device every year and those used to transfer personnel every six months.

ISO does not give a precise schedule regarding the inspection frequency and says it should conform with the statutory requirements covering the application in the country of use. Thus, even though ISO 4309 considers that dates scheduled by law are to be taken into account, it promotes a frequency determined by the competent person according to:

- The type of lifting device and the environmental conditions in which it operates.
- The classification group of the mechanism.
- The results of previous inspections.
- Experience gained from inspecting ropes on comparable cranes.
- The time the rope has been put in service.
- The frequency of use of the lifting device.

Based on the above, ISO 4309 considers that the competent person can find it prudent to initiate or recommend more frequent periodic inspections than those required by legislation. This decision can also be influenced by circumstances, such as an incident or a change in operating conditions.
Note that ISO rules state that the wire rope of a crane that has been out of service for more than three months must be thoroughly examined before being returned to service. Also, the wire rope must be thoroughly examined following an incident that may have damaged it and its terminations.
A rope inspection record that states the condition of the wire rope and the maximum time interval before the next periodic inspection is to be issued by the competent person when the wire rope examination is completed.

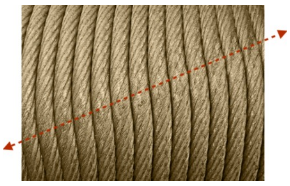
Standardization bodies all recommend that the wire rope is inspected along its entire length. However, it may happen that due to particular conditions and a very long wire rope not used at its entire length, this inspection is challenging to organize. In this case, ISO 4309 says that the competent person can decide to limit the wire rope examination to the working length plus at least five wraps on the drum. However, ISO says that in such a case, and where a greater working length is subsequently foreseen, the non-examined length should be inspected before it is used and prior to the subsequent scheduled examination.
As mentioned previously for daily inspections, ISO recommends focusing on the following parts:

- The anchorage on the drum
- Wire rope sections at and in the vicinity of rope terminations.
- Wire rope sections traveling through one or more sheaves.
- Wire rope sections traveling through safe load indicators that incorporate sheaves.
- Parts of the wire rope that are traveling through the hook block.
- In the case of cranes performing repetitive operations, the parts of the rope that lie over a sheave while the crane is in a loaded condition. Also, the parts of the rope that lie over a compensating sheave.
- Wire rope sections traveling through spooling devices, particularly cross-over zones associated with multi-layer spooling.
- Sections that are subjected to abrasion by external features and any part of rope that is exposed to heat.
- It is said that the competent person can open the rope to check internal parts, however ISO recommends doing it with extreme care.
- The parts of the wire rope near terminations must also be inspected as these areas are vulnerable to the onset of wire breaks due to vibrations and other dynamic effects, in addition to corrosion. Probing with a spike may be done to establish whether loosenesses are present in the wires, so the existence of broken wires within the termination.
  The termination should also be inspected for excessive distortion and wear. In addition, the ferrules used to secure eyes or loops must be visually inspected for cracks and evidence of slippage between the ferrule and the rope. Detachable terminations, such as symmetrical wedge sockets and eye splices, must also be checked.

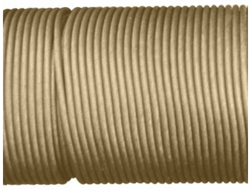
2.2.4 - Visible improper spooling of the wire rope

An improper spooling is easily visible and indicates a technical problem, such as an inadequate wire rope model, an incorrect installation procedure, or a structural defect if the wire rope is in place for some time. Taking it into account prevents a new wire rope from damages such as those described in the next point and protects the team from incidents or accidents. It also avoids discarding a brand-new wire rope in case of a new installation.

- Inclined pattern:
  what is defined as an "inclined pattern" in a multi layer spooling consists of a wire rope spooled on the winch's drum with an angle instead of being parallel to the drum's edge. It usually indicates an incorrect wire rope diameter.
  A wire rope with such an abnormality should be removed from the winch and replaced by a proper model. If needed, a study is undertaken to select it.



- Spooling with crossover zones
  Crossover zones are areas where one layer of rope climbs on and crosses over the previous layer of a wire rope spooled on a drum. It occurs when the wire rope is spooled onto the drum, reaches the flange, and begins to wrap back in the opposite direction. It can be caused by improperly tightening the first layer or an inappropriate wire rope. The rope should be properly reinstalled. If the problem persists, it should be removed, and a more suitable rope is to be installed.



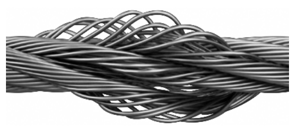
2.2.5 - Wire rope defects that can be found visually

Even though their systems show slight differences, standardization bodies classify the visible damages of wire ropes similarly. These distortions usually result from uneven stress distribution in the wire rope in the deformation area. Depending on the damages and their localization, some parts of the wire rope or the entire item may have to be discarded. Also, correction should be undertaken to ensure that the problem does not happen again.
The distortions below are mainly those listed in OSHA 1926 1413 and ISO 4309.

- Kinks *(also called Tightened loops)*:
  A kink is a deformation created by a loop, bend, or twist resulting from improper handling. Kinks can also appear during service if a heavy load is released suddenly or the wire rope bends around a too tight sheave.
  These defects result in an imbalance, causing excessive wear and loss of strength. EN 4309 recommends discarding wire ropes with such deformation.

- Crushing *(also called Flattening)*:
  Crushings/Flattenings usually result from improper installation of the wire rope on the winch's drum, cross winding, an inappropriate diameter, or a too-long rope. Flattened rope portions deteriorate more quickly when running through the sheaves and show broken wires. In such cases, but depending on the extent of the flattening, consideration may be given to discarding the rope.

- Birdcage *(also called basket or lantern deformation)*
  A birdcage is a distortion resulting from a difference in length between the rope core and the outer layer of strands. A mismatch between the rope diameter and the drum and the sheave grooves, incorrect installation or cutting, or a manufacturing default can produce this defect. Ropes with such deformation must be discarded or have the affected section removed, provided the remaining length is serviceable.



- Core or strand protrusion:
  Core or strand protrusion is a type of birdcage from rope imbalance, resulting in core protrusion between the outer strands or protrusion of strands that occur on the side opposite to which makes contact with the sheave groove. As mentioned above, ropes with such deformation must be discarded or have the affected section removed, provided the remaining length is serviceable.

- Waviness
  Waviness is a periodic deviation of the wire rope in the shape of a helix from its axis. It can be due to a manufacturing defect or an unsuitable design of the lifting device, such as the wrong diameter of the rope or an incorrect arrangement of the sheaves. It not necessarily results in a loss of strength but can promote the onset of abnormal stresses, resulting in premature wear and broken wires.

- Wear
  Wire rope wear results from its contact with metal sheaves, drums, and other guiding components. It depends on the size of the drum and sheaves, the number of sheaves, The fleet angle, the condition of the crane, the lifting speed during operations. ISO 4309 gives the following discard criteria: 6 & 8 strands / Fibre core ropes =10%; 6 & 8 strands/steel core ropes = 7.5%; Rotation resistant ropes = 5%.

- Wire breaks
  Wire breaks are caused by fatigue due to improper installation, lack of lubrication, exposure to heat and moisture for extended periods, constant bending, wear with sheaves and drums, freezing working conditions, overloading, etc. They typically occur on the crowns of the strands, or on the spaces between the strands (valleys). Tables #1, #2, #3, & #4, displayed on the next page, allow evaluating discarding.

- Increase in rope diameter
  This defect usually results from shock loading or moisture absorption in the case of fibre main core ropes. It creates an imbalance in the outer strands, which become incorrectly oriented on a relatively long length. ISO recommends investigating the reasons for the defect, and considering discarding when the diameter is $\geq$ 5% with a steel core and if the diameter is $\geq$ 10% with a fibre core.

- Corrosion:
  Corrosion reduces the rope's strength by diminishing its metallic cross-sectional area, making its surface irregular, causing stress cracking, and decreasing the materials' elasticity. Internal corrosion is more difficult to detect than external corrosion, although this might not always be obvious from a visual inspection of the rope. Discard criteria are given in table #5 on the next page.

- Reduction in rope diameter:
  The wire rope diameter is expected to decrease slightly during its commissioning, resulting from its adjustment to the elements of the lifting gear. Also, there is a typical continuous slight decrease in diameter throughout the rope's service life. However, significant local reduction indicates core or centre failure. In this case, the affected

lengths should be discarded. Also, wire ropes may present an abnormal uniform decrease resulting from excessive abrasion, core/inner wires failure, corrosion, and abrasion. Table #6 for discarding criteria is published on the next page.

- Electric arc or heat damage:
  Heat damage happens in wire ropes used in temperatures they have not been designed for. They can be identified by the change of colour of the metal, and result in a loss of lubricant.
  An electric arcing results from an incorrectly grounded welding device, or arcing made by mistake during welding operations. A change of colour and crevices at the point of contact with the welding rod can identify it. Wire rope lengths damaged by heat or arcing should be discarded.

Tables #1, #2, #3, and #4 for "Wire breaks" discard criteria (see above) are based on the system proposed by ISO 4309: Table #1 provides general criteria; Table #2 offers references to discarding a wire rope according to the number of wire breaks reached or exceeded on a specified distance of single-layer and parallel-closed ropes; Table #3 explains the ISO hoisting mechanisms classes mentioned in Table #2; Table #4 provides the references for discarding rotation resistant ropes. These tables can be used with every existing system of classification.

Table 1 - Discard criteria for visible broken wires (Based on ISO 4309)

	Nature of visible broken wire	*Discard criteria*
1	*Wire breaks occurring randomly in sections of rope which run through one or more steel sheaves and spool on and off the drum when single-layer spooling or occurring at sections of rope which are coincident with cross-over zones when multi-layer spooling.*	*See Table #2 for single-layer and parallel-closed ropes and Table #3 for rotation-resistant ropes.*
2	*Localized grouping of wire breaks in sections of rope which do not spool on and off the drum.*	*If grouping is concentrated in one or two neighbouring strands it might be necessary to discard the rope, even if the number is lower than the values over a length of 6 d, which are given in Tables #2 and #3.*
3	*Valley wire breaks.*	*Two or more wire breaks in a rope lay length (approximately equivalent to a length of 6 d)*
4	*Wire breaks at a termination*	*Two or more wire breaks*

Table 2 - Number of wire breaks, reached or exceeded, of visible broken wires occurring in single-layer and parallel-closed ropes, signalling discard of rope

Total number of load-bearing wires in the outer layer of strands in the rope (n)*	*Number of visible broken outer wires ***					
	Sections of rope working in steel sheaves and/or spooling on a single-layer drum (wire breaks randomly distributed)				*Sections of rope spooling on a multi-layer drum ****	
	*ISO hoisting mechanism classes M1 to M4 or class unknown *****				*All classes*	
	Ordinary lay		*Lang lay*		*Ordinary and Lang lay*	
	Over a length of 6d [e]	*Over a length of 30d* [e]	*Over a length of 6d* [e]	*Over a length of 30d* [e]	*Over a length of 6d* [e]	*Over a length of 30d* [e]
N ≤ 50	*2*	*4*	*1*	*2*	*4*	*8*
51 ≤ n ≤ 75	*3*	*6*	*2*	*3*	*6*	*12*
76 ≤ n ≤ 100	*4*	*8*	*2*	*4*	*8*	*16*
101 ≤ n ≤ 120	*5*	*10*	*2*	*5*	*10*	*20*
121 ≤ n ≤ 140	*6*	*11*	*3*	*6*	*12*	*22*
141 ≤ n ≤ 160	*6*	*13*	*3*	*6*	*12*	*26*
161 ≤ n ≤ 180	*7*	*14*	*4*	*7*	*14*	*28*
181 ≤ n ≤ 200	*8*	*16*	*4*	*8*	*16*	*32*
201 ≤ n ≤ 220	*9*	*18*	*4*	*9*	*18*	*36*
221 ≤ n ≤ 240	*10*	*19*	*5*	*10*	*20*	*38*
24 ≤ n ≤ 260	*10*	*21*	*5*	*10*	*20*	*42*
261 ≤ n ≤ 280	*11*	*22*	*6*	*11*	*22*	*44*
281 ≤ n ≤ 300	*12*	*14*	*6*	*12*	*24*	*48*
n < 300	*0.04 x n*	*0.08 x n*	*0.02 x n*	*0.04 x n*	*0.08 x n*	*0.16 x n*

Table #2 continuation - ISO 4309 says: *Ropes having outer strands of Seale construction where the number of wires in each strand is 19 or less (e.g. 6 × 19 Seale) are placed in this table two rows above that row in which the construction would normally be placed based on the number of load bearing wires in the outer layer of strands.*
** : ISO 4309 says that filler wires are not regarded as load-bearing wires and are not included in the values of n.* *** : A broken wire has two ends (counted as one wire).* **** : The values apply to deterioration that occurs at the cross-over zones and interference between wraps due to fleet angle effects (and not to those sections of rope which only work in sheaves and do not spool on the drum).* ***** : Twice the number of broken wires may be applied to ropes on mechanisms whose classification is M5 to M8 (see below).* *e : Nominal diameter of rope.*

Table #3 - ISO hoisting mechanisms classification system mentioned in table #2

	Average daily operating time in hours	**≤ 0.25 h**	**0.25 to 0.5 h**	**0.5 to 1 h**	**1 to 2 h**	**2 to 4 h**	**4 to 8 h**	**8 to 16 h**	**16 to 24 h**
	Total operating time in hours	**200 to 400 h**	**400 to 800 h**	**800 to 1600 h**	**1600 to 3200 h**	**3200 to 6300 h**	**6300 to 12500 h**	**12500 to 25000 h**	**25000 to 50000 h**
Loading rate	**Light** 1/3 WLL & rarely WLL	M1	M1	M2	M3	M4	M5	M6	M7
	Medium 1/3 to 2/3 WLL & sometimes WLL	M1	M2	M3	M4	M5	M6	M7	M8
	Heavy 2/3 WLL & often WLL	M2	M3	M4	M5	M6	M7	M8	M8
	Very Heavy Usually at WLL or near WLL	M3	M4	M5	M6	M7	M8	M8	M8

ISO classifies the "hoisting mechanisms" according to the load spectrum of the lifting gear and the total operating time in hours or the average daily working time. For example, a system often used at its WLL between 8 and 16 hours per day is classified as "M8 ".

Table 4 - Number of wire breaks, reached or exceeded, of visible broken wires occurring in rotation-resistant ropes, signalling the discard of a rope

Number of outer strands and total number of load-bearing wires in the outer layer of strands in the Rope (n) *	**Number of visible broken outer wires ****			
	Sections of rope working in steel sheaves and/or spooling on a single-layer drum (wire breaks randomly distributed)		**Sections of rope spooling on a multi-layer drum *****	
	Over a length of 6d e	**Over a length of 30d e**	**Over a length of 6d e**	**Over a length of 30d e**
4 strands n ≤ 100	2	4	2	4
3 or 4 strands n ≤ 100	2	4	4	8
At least 11 outer strands				
71 ≤ n ≤ 100	2	4	4	8
101 ≤ n ≤ 120	3	5	5	10
121 ≤ n ≤ 140	3	5	6	11
141 ≤ n ≤ 160	3	6	6	13
161 ≤ n ≤ 180	4	7	7	14
181 ≤ n ≤ 200	4	8	8	16
201 ≤ n ≤ 220	4	9	9	18
221 ≤ n ≤ 240	5	10	10	19
241 ≤ n ≤ 260	5	10	10	21
261 ≤ n ≤ 280	6	11	11	22
281 ≤ n ≤ 300	6	12	12	24
n < 300	6	12	12	24

Table #3 continuation - ISO 4309 says: *Ropes having outer strands of seale construction where the number of wires in each strand is 19 or less (e.g. 6 × 19 Seale) are placed in this table two rows above that row in which the construction would normally be placed based on the number of load bearing wires in the outer layer of strands.*
** : For the purposes of this International Standard, filler wires are not regarded as load-bearing wires and are not included in the values of n.* *** : A broken wire has two ends.* **** : The values apply to deterioration that occurs at the cross-over zones and interference between wraps due to fleet angle effects (and not to those sections of rope that only work in sheaves and do not spool on the drum).* *e : Nominal diameter of rope.*

Table #5 for evaluating the discard of a corroded wire rope is based on the visual aspect of the corrosion and its nature (external, internal, and fretting), expressed in a percentage where 100% means discarding.

Table 5 - Discard criteria for corrosion and intermediate severity ratings (Based on ISO 4309)

Type of corrosion	***Condition***	***Severity rating***
External corrosion	*Signs of surface oxidation but can be wiped clean* *Wire surface rough to touch* *Wire surface heavily pitted and slack wires **	*Superficial - 0 %* *High - 60 % *** *Discard - 100 %*
Internal corrosion	*Obvious visible signs of internal corrosion (corrosion debris exuding from the valleys between the outer strands ***)*	*Discard -100 %* *or internal examination if deemed practicable by the competent person*
Fretting corrosion	*Fretting involves the removal of fine particles of steel from the wires due to dry wires and strands constantly rubbing together and then oxidizing and creating internal corrosion debris, which manifests itself as a dry powder, similar to a red rouge.*	*Evidence of such a characteristic should be further investigated and if there is any doubt about its severity, the rope should be discarded (100 %).*
** : For any other intermediate condition, an assessment should be made as to its severity rating (i.e. contribution towards the combined effect).* *** : The oxidation of zinc-coated wires can result in a wire surface which is also rough to the touch, but the overall condition might not be as serious as wires which are not coated. In such cases, the inspector may consider applying a lower contribution towards the combined effect to that given above in this table.* **** : Assessment of internal corrosion is subjective; however, if there is any doubt about the seriousness of any internal corrosion, the rope should be discarded.*		

Table #6 shows the equivalent uniform decreases in diameter, expressed in percentage of the nominal diameter of the wire rope (see "reduction in rope diameter" in the point above). The severity ratings are expressed in 20 % increments (20 %, 40 %, 60 %, 80 %, and 100%). Other severity ratings expressed in increments of 25 % (25 %, 50 %, 75 %, and 100 %) may also be selected.

Table 6 (based on ISO 4309) - Uniform decrease in diameter signalling discard of rope
- Rope spooling on a single-layer drum and/or running through a steel sheave

Wire rope type	***Uniform decrease in diameter (expressed as % of nominal diameter)***	***Severity rating***	
		Description	***Percentage***
Single-layer rope with fibre core	*Less than 6 %*	*—*	*0*
	6 % and over but less than 7 %	*Slight*	*20*
	7 % and over but less than 8 %	*Medium*	*40*
	8 % and over but less than 9 %	*High*	*60*
	9 % and over but less than 10 %	*Very high*	*80*
	10 % and over	*Discard*	*100*
Single-layer rope with steel core or parallel-closed rope	*Less than 3,5 %*	*—*	*0*
	3,5 % and over but less than 4,5 %	*Slight*	*20*
	4,5 % and over but less than 5,5 %	*Medium*	*40*
	5,5 % and over but less than 6,5 %	*High*	*60*
	6,5 % and over but less than 7,5 %	*Very high*	*80*
	7,5 % and over	*Discard*	*100*
Rotation-resistant rope	*Less than 1 %*	*—*	*0*
	1 % and over but less than 2 %	*Slight*	*20*
	2 % and over but less than 3 %	*Medium*	*40*
	3 % and over but less than 4 %	*High*	*60*
	4 % and over but less than 5 %	*Very high*	*80*
	5 % and over	*Discard*	*100*

The formula for calculating the percentage is: (Reference diameter - Measured diameter) / Nominal diameter x 100%.

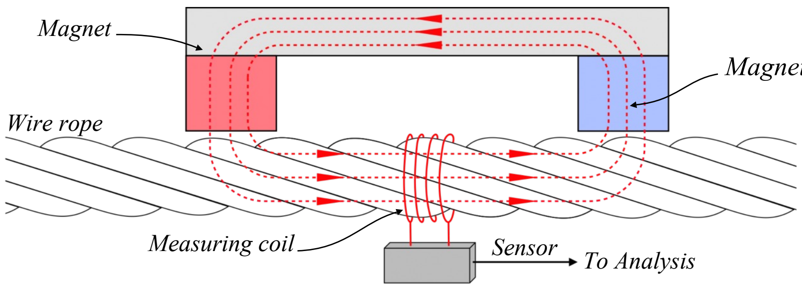
- The reference diameter is the value indicated in the wire rope specifications provided by the manufacturer.
- The nominal diameter is the diameter of the rope after the 1st commissioning (so the normal diameter diminution after installation).
- The measured diameter is the actual diameter measured by the competent person during the inspection.

2.2.6 - Non-destructive testing

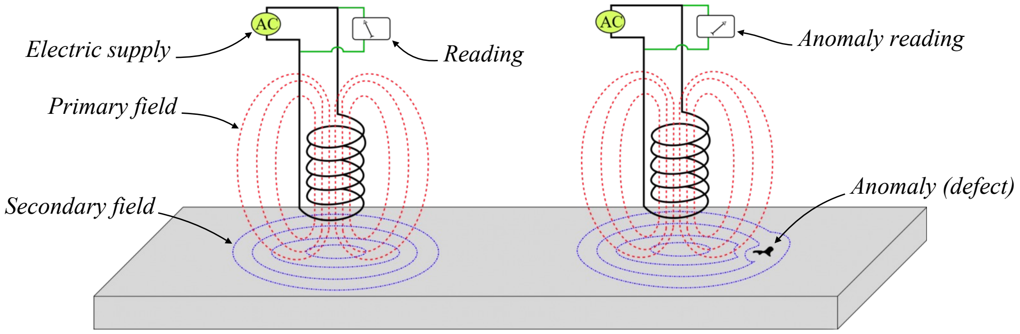
ISO 4309 says that Non-Destructive Testing (NDT) by electromagnetic means may be used as an aid to visual inspection to determine the location of those sections of rope which could be suffering deterioration. ISO 4309 also says that if such a technique is planned to be used, it should be implemented at the earliest of the rope's lifetime, which might be at rope manufacture, during the installation of the wire rope, or, preferably, after the wire rope has been installed. This 1st NDT inspection is considered the datum point for future comparison and is called "rope signature".

It must be noted that ISO 4309 considers only magnetic non-destructive testing methods and indicates that they are limited to ferromagnetic steel ropes. However, other non-destructive testing techniques are documented and commonly used by specialists and should not be ignored. This is the reason they are added to the list below:

- Magnetic Flux Leakage (MFL):
  Magnetic flux leakage systems utilize permanent magnets or electromagnets to magnetize the part of the wire rope to inspect. This magnetic field will have distortions if defects are present in the wire rope. An induction coil or an integrated sensor then detects the signal. The extent of damages can be determined via additional processing and analysis of the signal.
  This method can detect anomalies such as broken wires and stands, wear, and corrosion.
  - Advantages: Inexpensive, easy to implement, and reliable. A competent operator can quantify the defects.
  - Inconveniences: The defects inside the wire rope are difficult to distinguish.



- Eddy current (ECT):
  Eddy currents, also called "Foucault currents", are based on Faraday's law of induction: When an alternating electric current (AC) is passed through a conductor, a circular magnetic field is generated around the conductor that vectors into a longitudinal flux if the conductor is twisted into a coil. When this coil is brought near a conducting material, this magnetic field, called the "primary field", passes through the material, and induces another magnetic field with an opposite orientation, called the secondary field, that interacts with it. This reaction results in variations in the impedance of the current, which can be measured through a voltmeter and read on a screen.
  When the probe moves across anomalies of the tested material, such as, for example, cracks or pits, the secondary magnetic field becomes disrupted, changing the impedance, which can be measured.
  The penetration of the eddy currents through materials depends on their conductivity, permeability, and frequency of the alternating field. High frequencies of eddy currents concentrate at the surface, while lower frequencies penetrate deeper within the tested sample.
  Based on the above, this method is mainly used for surface defects.
  - Advantages: Sensitive to metal and allow for fast detection.
  - Inconveniences: Its limited to surface inspection. Also, it detects the defects but cannot give more information regarding their nature and size.

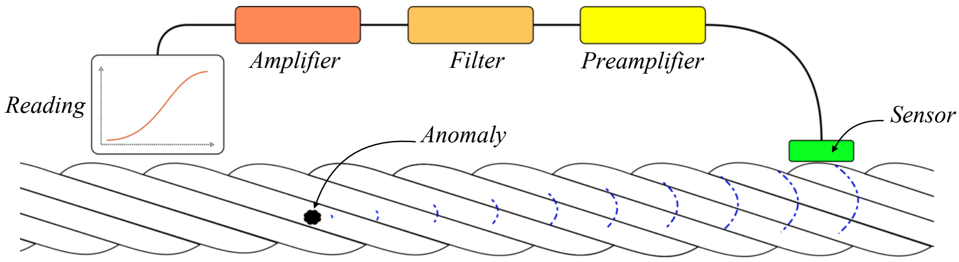


- Acoustic emission (AE):
  The principle of acoustic emission is based on the fact that an external stimulus on a structure, such as a shock, triggers a release of energy, in the form of elastic stress waves, which propagate to the surface of the structure

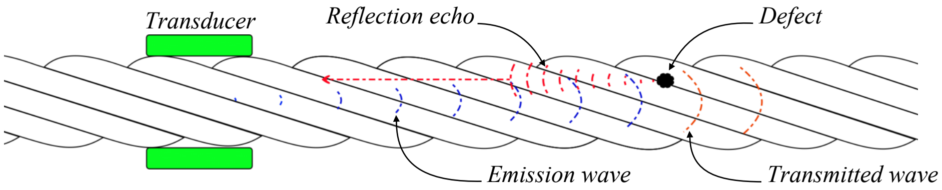
due to the redistribution of the stress in the material. These stress waves can be read by sensors, then filtered, amplified, and changed in electronic signals. If a discontinuity is present in the material, the propagation of the stress wave differs and is detected by the sensor. However, these systems can only gauge whether damages are present, but cannot provide more information.

This system is used to detect broken wires and strands, stressed areas, and corrosion

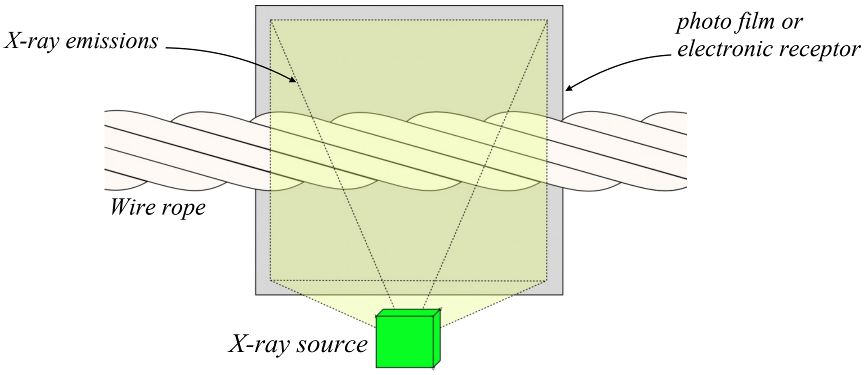
- Advantages: It can work with composite materials, and can detect defects at their early stage
- Inconveniences: The system is reputed slow. Also, it does not provide precise measurement of the defects.



- Ultrasonic Guided Wave (UGW)
  "Ultrasonic-guided waves (UGW)", also called "long-range ultrasonic testing (LRUT)", is a technique that is commonly used to check long structures such as pipelines from one place.
  This system is based on the propagation of ultrasonic acoustic waves through structures whose sides act as guides and thus prevent dispersion of the ultrasonic signal and, thus, allow the ultrasonic signal to travel long distances. The frequency used depends on the thickness of the structure. However, the higher the frequency, the lower the range.
  This system is used to detect broken wires and strands, and also corrosion
  - Advantages: Defects inside the rope are detected, and the system allows to inspect long distances from one place.
  - Inconveniences: The system does not provide precise measurement of the defects detected.



- Radiography
  Radiographic testing uses the properties of X-rays or gamma rays. Such systems are commonly used to examine industrial components' internal structures and identify their defects, in addition to well-known medical applications. The system, which is based on the penetration of X-rays through materials, consists of providing black-and-white images that are then interpreted.
  The item to check is placed between the radiation source and the reception photo film or an electronic receptor. During the process of emission of the X-rays, the penetration of the radiation is attenuated by the density and thickness differences of the elements tested through interaction processes involving scattering and absorption. The differences in absorption are then recorded on the photo film or the electronic imaging system. A trained technician then interprets the images.
  This system is used to detect broken wires and strands.
  - Advantages: This system provides precise information and is considered reliable.
  - Inconveniences: Radiography system are expensive, voluminous, and require trained technicians. In addition, they emit radioactive rays, which require specific precautions to be in place.



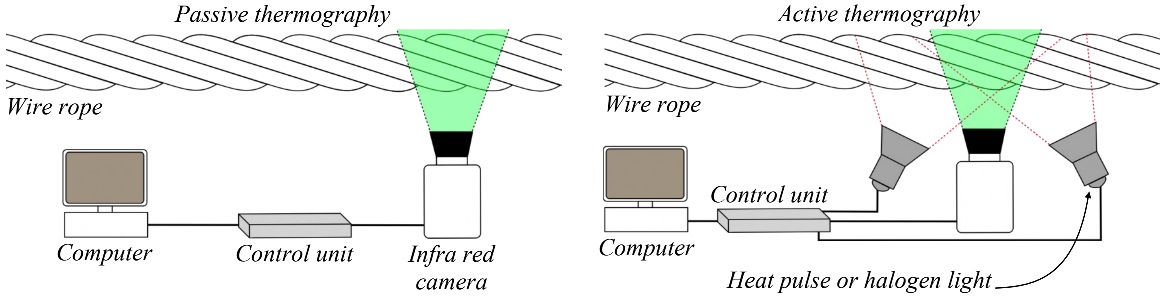
- Thermography:
  Thermography consists of monitoring the surface temperature variation of the object examined during its cooling phase after thermal stimulation. Infrared cameras that detect and measure temperature differences are used for this purpose. Colour or black-and-white pictures showing these thermal variations are then processed on a computer. As with radiography, a trained technician interprets the images to evaluate the anomalies.

Two methods of thermography are used:

- Passive thermography uses only an infrared camera that provides thermal images of the piece inspected.
- Active thermography also uses an infrared camera to record the variation of temperatures in the piece to inspect. However, it involves additional thermal stimulation of the object by using heaters that quickly heat the sample's surface to measure.

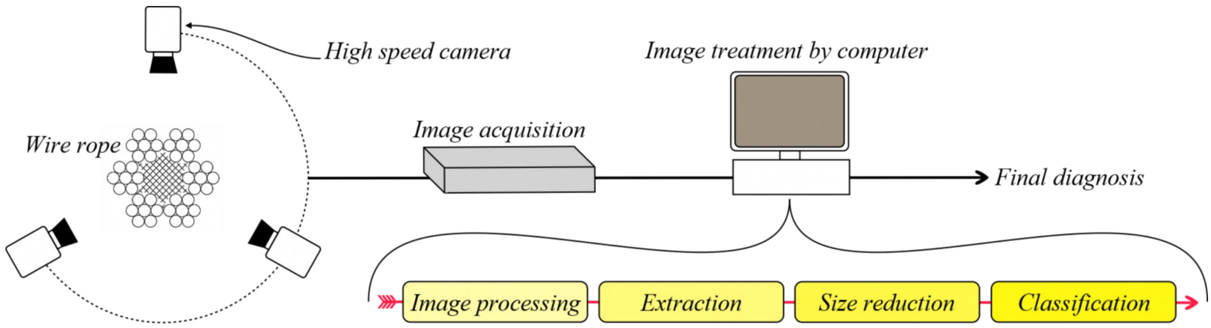
These systems are used to find broken wires and stands, and also corrosion.

- Advantages: This system has high efficiency, is not expensive compared to others, and easy to implement.
- Inconveniences: The system is limited to near surface defects. Also, these surfaces must be cleaned and good lighting is necessary. A trained technician is required for the interpretation of the pictures.



- Optical Detection:
  Many systems classified in this category are experimental. However, they prove to be already efficient and must not be ignored.
  In a paper titled "A review of non-destructive damage detection methods for steel wire ropes" Ping Zhou, Gongbo Zhou, Zhencai Zhu, Zhenzhi He, Xin Ding, and Chaoquan Tang explain that the optical detection method can efficiently grasp surface damage of a wire rope.
  These systems generally consist of digital image acquisition and then the diagnosis of damages.
  - The image acquisition is usually made by a high-speed camera that collects images of the surface of the wire rope.
  - The damage diagnosis includes image preprocessing and pattern recognition: The collected images are first processed by pretreatment methods like cutting or filtering. Then, extraction methods (such as local binary pattern and grey level co-occurrence matrix) extract features. Next, dimensionality reduction is carried out on the established data. Finally, machine learning classifiers (such as support vector machines, artificial neural networks, etc.) are used to obtain robust classifiers for recognizing unknown images.

  Many other papers, some of them have been used by these authors discuss these procedures that can be found on the “Diving and ROV Specialists.com” website.
  - Advantages: Intuitive, and high accuracy of detection.
  - Inconveniences: Influenced by environmental factors, data size, and machine learning algorithm performance.



To conclude this presentation, it is essential to consider that it is not usually the function of the diving or ROV team and the person in charge of the daily checks to perform investigations with Non-Destructive Testing (NDT) procedures. However, at minimum, these people should understand the technique proposed by the competent person in charge of the periodic examination of the wire ropes.
Also, although most standardization bodies do not make NDT techniques mandatory, many classification bodies require their use to support the classical visual examination. Thus, we must consider that the two techniques are complementary and that NDT techniques provide additional information on defects that may not be seen during a visual examination. We must also consider that offshore cranes have very long wire ropes, and complex reeving, which makes visual inspection challenging.
Note that the competent person examining the wire rope may use several NDT techniques to investigate problems.
We can also see that new promising techniques arrive on the market that must be taken into account.

3 - Wire rope end sockets

3.1 - Scope

The end fitting connections must be able to transfer great static and dynamic forces and must also be compact and light. There are a lot of models of efficient end connections on the market, and the purpose of this chapter is to describe only the “asymmetric wedge sockets”, and the “metal and resin sockets” (Also called Spelter sockets), which are the two main end connections used in the diving industry.
The description of the “asymmetric wedge socket” is based on the European standard EN 13411- 6, and the description the “Metal and resin sockets” is based on the standard EN 13411-4.

3.2 - Asymmetric wedge sockets

The asymmetrical wedge sockets are highly popular because they can easily be fitted on site which is a great advantage. There is a wide variety of design which can be slightly different than those indicated in the document EN 13411-6 on the market. Nevertheless the operating mechanism is the same for all the models.

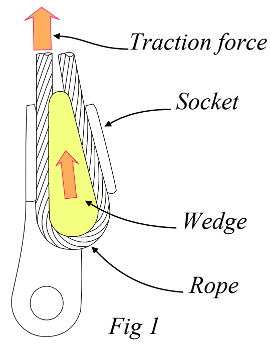


Fig 1

3.2.1 - Operating mechanism

By means of a wedge, the rope end is jammed into a tapered socket. With increasing load, the wedge is pulled deeper and deeper into the socket and exercises normal clamping force on the rope.
The traction force in the wire rope is transferred by the friction between the rope and the wedge and by the friction between the rope and the socket. *(See fig. 1)*

3.2.2 - Geometry and security of the pin

Asymmetric wedge socket termination's for ropes should conform to the following geometrical criteria:

- The longitudinal axis of the live portion of the rope should be perpendicular to the longitudinal axis of the pin.
- The difference between the wedge angle *(α)* and the socket angle (β) should be not greater than 2°.
- The internal side surfaces of the socket body and the wedge in contact with the rope should be straight.
- The clamping length between socket body and the wedge in contact with the live portion of the rope should be a minimum length *(P)* equal to 4.3 times the nominal rope diameter.
- The rope groove in the socket body and the wedge should not exhibit protrusions, marks, or casting joints that would affect the intimate contact with the rope.

The pin should be provided with a means for securing it in position *when in operation.*

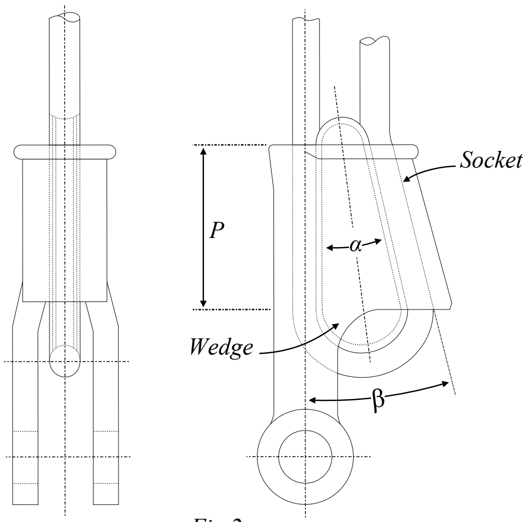


Fig 2

3.2.3 - Mechanical properties

The socket body and pin should be designed to have an efficiency of at least 80% of the minimum breaking force of the rope used.
The socket body and pin should be designed to withstand a test with a minimum of 75000 load cycles from 15% to 30% of the minimum breaking force without any indication of cracks and deformation.
The socket body and the pin must be designed to ensure that there will be no movement between the rope and the termination, monitored either as movement of the tail of the rope, or as relative movement between the rope and the wedge after a short period of settlement.

3.2.4 - Design and sizes from EN 13411-6

En 13411-6 indicates two designs

- Design 1:

- The material for the socket bodies should be spheroidal graphite cast iron having mechanical properties conforming to EN 1563. The material for wedges should be malleable cast iron conforming to EN 1562. The material for the pins should be quenched and tempered steel conforming to EN 10083.
- The rope groove in both the wedge and the socket body should not exhibit marks or joints in the clamping area.
- Dimensions, in millimetres, should be in accordance with Figure 3 and Table 1 next page:
  - The socket angle in the body (R) should be (14 ± 0.5)°.
  - The wedge groove angle (a) should be (14 ±2)° .

- The pin should have its limits conforming to EN 20286

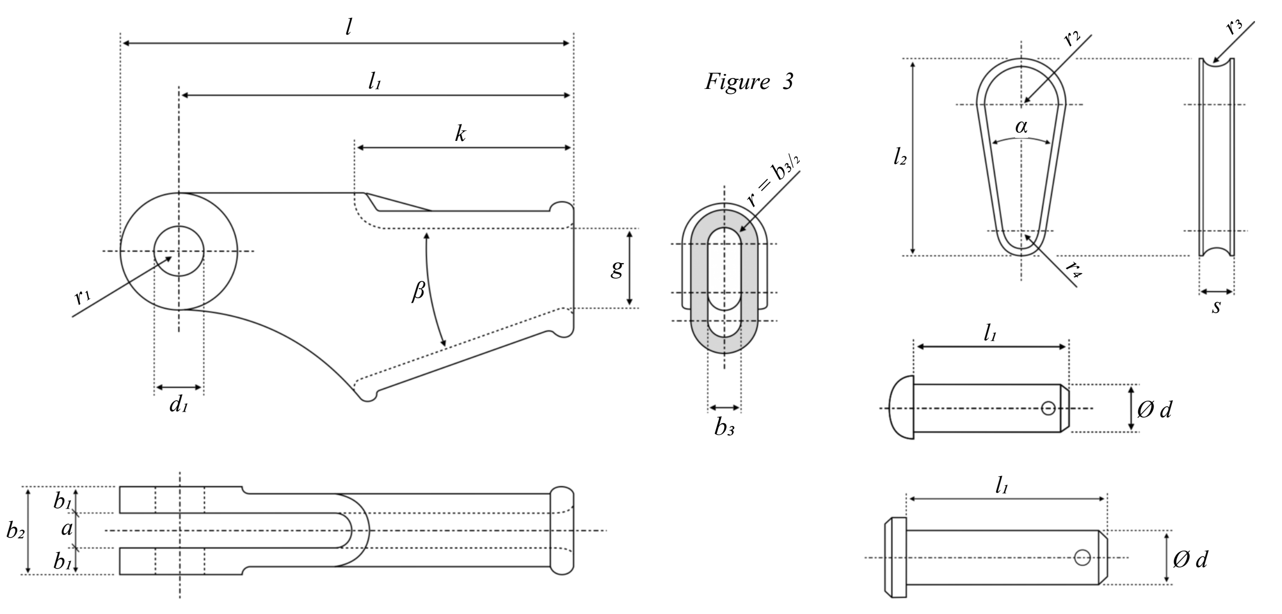


Figure 3

Table 1: Dimensions in millimetres for asymmetric socket with cast socket body

Nominal size of the wedge socket (mm)	***Socket body***										***Wedge***			***Pin***	
	a	***b_1***	***b_2***	***b_3***	***d_1***	***g***	***k***	***l_1***	***l***	***r_1***	***r_2***	***r_3***	***s***	***l_1***	***d***
6 to 7	*14*	*6*	*26*	*14*	*14*	*25*	*75*	*130*	*150*	*18.5*	*9.5*	*6*	*12*	*40*	*13*
8	*14*	*6*	*26*	*14*	*14*	*25*	*75*	*130*	*150*	*18.5*	*10.5*	*6*	*13*	*40*	*13*
9 to 10	*14*	*6*	*26*	*14*	*14*	*31*	*75*	*130*	*150*	*18.5*	*13*	*7.5*	*13*	*40*	*13*
11	*17*	*7*	*31*	*16*	*17*	*35*	*75*	*140*	*164.5*	*22*	*14.5*	*7.5*	*13*	*45*	*16*
12	*17*	*7*	*31*	*16*	*17*	*42*	*75*	*140*	*164.5*	*22*	*16*	*7.5*	*13*	*45*	*16*
13 to 15	*20*	*10*	*40*	*17*	*20*	*43*	*115*	*190*	*220*	*27*	*19.5*	*8*	*16*	*50*	*19*
16 to 17	*23*	*14*	*51*	*23*	*25.5*	*60*	*146*	*237*	*275*	*38*	*22.5*	*9*	*21*	*68*	*25*
18	*23*	*14*	*51*	*23*	*25.5*	*60*	*146*	*237*	*275*	*38*	*23.5*	*10*	*22*	*68*	*25*
19 to 20	*29*	*16.5*	*62*	*29*	*25.5*	*60*	*146*	*237*	*275*	*38*	*26*	*10*	*26*	*78*	*25*
21	*30*	*18*	*66*	*30*	*33.5*	*85*	*200*	*325*	*370*	*42*	*29*	*13*	*26*	*88*	*33*
22 to 25	*30*	*18*	*66*	*30*	*33.5*	*85*	*200*	*325*	*370*	*42*	*32.5*	*13*	*26*	*88*	*33*
26 to 32	*38*	*27*	*92*	*38*	*48.5*	*95*	*224*	*425*	*486*	*56*	*42*	*16*	*32*	*119*	*48*
Note: The nominal wedge socket sizes are equivalent to the nominal rope diameters for which the wedge sockets are designed.															

- Design 2:
  - The material for socket bodies should conform to ASTM A-148 90/60 and ASTM A-220, 60004 alternatively ASTM A-27, grade 65-35 for the wedges.
  - The material for the pin should conform to SAE 1035.
  - The inner edges of the basket should be rounded at the bottom to prevent damaging the rope.
  - Dimensions, in millimetres, should be in accordance with Figure 4 and Table 2 below. The socket angle in the body 03 should be (15 ± 1)°. The wedge groove angle (a) should be (15 ± 1)° .

Figure 4

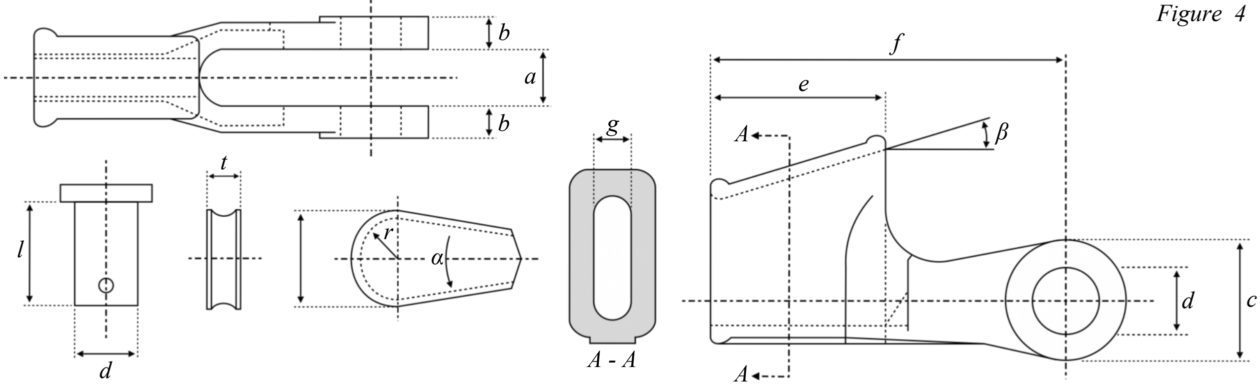


Table 2 - Dimensions in millimetres for asymmetric socket with cast socket body

Nominal size of the wedge socket		***Socket body***								***Wedge***			***Pin***	
Mm	***Inch***	***a***	***b***	***c***	***d***	***e***	***f***	***g***	***β***	***t***	***r***	***v***	***d***	***i***
9 - 10	*3/8”*	*20.6*	*11.2*	*39.6*	*22.6*	*57.2*	*121*	*14.2*	*15°*	*11.2*	*15.9*	*35*	*20.6*	*54*
11 - 13	*1/2”*	*25.4*	*12.7*	*49.3*	*27.4*	*76.2*	*146*	*17.5*	*15°*	*13.5*	*22.3*	*48*	*25.4*	*61*
14 - 16	*5/8”*	*31.8*	*14.2*	*57.2*	*32.5*	*93.7*	*176*	*22.4*	*15°*	*17.5*	*25.5*	*55.5*	*30.2*	*76*
18 - 19	*3/4”*	*38.1*	*16.8*	*66.5*	*37.3*	*111*	*212*	*25.4*	*15°*	*19.8*	*29.5*	*65*	*35*	*87*
20 - 22	*7/8”*	*44.5*	*19.1*	*79.5*	*48.7*	*127*	*241*	*28.4*	*15°*	*22.4*	*34.2*	*74.5*	*41.3*	*103*
24 - 26	*1”*	*50.8*	*22.4*	*95.3*	*53.6*	*146*	*273*	*33.3*	*15°*	*26.2*	*36.5*	*83.5*	*50.8*	*116*
28	*1 1/8”*	*57.2*	*25.4*	*108*	*60.5*	*165*	*308*	*38.1*	*15°*	*30.2*	*39.8*	*90.5*	*57.2*	*127*
30 - 32	*1 ¼”*	*63.5*	*28.7*	*121*	*66.8*	*184*	*343*	*41.4*	*15°*	*33.3*	*43*	*97*	*63.5*	*143*

Notes: The nominal wedge socket sizes are equivalent to the nominal rope diameters for which the wedge sockets are designed.
For intermediate wire rope sizes, it is recommended to use next larger size socket.

3.2.5 - Marking

The following indications should be visible on each asymmetric wedge socket :

- The manufacturer’s name, symbol, trade mark or other unambiguous identification.
- The traceability code.
- The standard applied.
- The reference of the model allowing to find the rope grade, class and type for which the termination is suitable.

3.2.6 - Certificate

The certificate should include at least the following information:

- The name and address of the manufacturer or authorized representative, including the date of issue of the certificate and authentication.
- The standard applied.
- Traceability code.
- The manufacturing tolerances.
- The reference of the termination.
- Details of the rope grade, class and type for which the termination is suitable.

3.2.7 - Recommendations for safe usage and inspection of wedge socket terminations. *(EN 13411-6)*

In addition to guidelines regarding the conception of wedge sockets, EN 13411-6 provides valuable recommendations for installing and inspecting wedge socket terminations by onsite technicians that have been used to establish the processing list below.

- Close examination of the socket before starting the assembly:
  This phase is essential as incorrect socket selection can result in the rope pulling through the fitting, or in the failure of the wire rope and the termination. The elements provided in point 3.2.4 should be used in support.
  - The socket body and the pin should be free from any defect from manufacturing or previous use.
  - The wedge and a socket body must be the correct dimensions and strength for the steel wire rope to terminate, and the manufacturer's marks and the fit of the wedge (with the rope) in the socket body should always be checked: An oversize wedge, or a wedge of incorrect taper, will not enter the socket body sufficiently to give a secure termination; too small a wedge will protrude too far through the socket body and the high localised loading may cause the socket body to crack and open out, allowing the wedge to pull through.
  - The socket body or wedge should never be modified, and components of different designs should not be mixed.
  - Socket bodies and wedges from different manufacturers should not be assembled together, even though they may be designed for the same size of rope.
  - To reduce the risk of confusion of a body and wedge of different sizes or manufacture, the socket body, pin, and wedge should be secured together during storage and transport of the termination.
- Wire rope installation:
  Incorrect fitting may result in premature failure of the wire rope or the termination disconnecting.
  - In case of a re-termination, no part of any previous flattening or damaged rope should be on the rope's standing part or within the clamping area between either side of the socket body and the wedge. The strict

rule is that the parts previously in the socket must be discarded. Thus, the wire rope must be shortened before re-terminating it.

- The rope should pull directly in line with the point of attachment of the socket. So the standing part should not be kinked where it leaves the socket body. Also, the tail-end of the rope left protruding should be long enough for whatever securing method is used.
- Rotation-resistant ropes tend to be distorted when bent around small radii, which may require temporary serving, such as tape, while fitting the socket body. As much as possible, the serving should be removed to allow for rope inspection.
- The technicians must ensure that the rope is properly seated in the socket body before the equipment is put into service to avoid it pulling through the fitting or having the wedge sprung out of the body.
  EN 13411-6 recommends tension be applied to the two parts of the rope to pull the rope and wedge into the socket body, and the wedge is hammered home using a wooden packer to protect the fitting and rope against damage. A load of at least equivalent to 10 % of the minimum breaking force of the rope should be applied and maintained, but not left unattended, to seat the wedge and rope firmly into the socket body. Special care is necessary when the tension of the rope is released, as there is a possibility that the wedge may become loosened when a load is set down.
- EN 13411-6 recommends two methods to deal with the tail-end length of rope protruding from the socket depending on the use circumstances. The purpose is to prevent the wire rope from being pulled through when making the rope termination or in the event of accidental loosening of the wedge during operation.
  1. The tail-end is looped back on itself and secured by a U-bolt wire rope grip. The loop should then be lashed to the standing part of the rope by suitable means, such as soft binding wire, to prevent flexing of the rope in service.
  2. Where the looped back tail-end described above interferes with an obstruction which might cause the wedge to loosen and the rope runs free, the tail-end length of the rope should not be looped back but should be laid parallel to the standing part of the rope. A distance piece or short length of rope of the same diameter and a U-bolt wire rope grip will be necessary to ensure that the tail-end is adequately secured. If necessary, the tail-end may be attached to the standing part with soft binding (serving) wire. The wire rope grip is used to ensure that the rope cannot slip through the socket body before the wedge has had a chance to seat adequately. The clamp or wire rope grip should not be allowed to encroach on the fused end of the rope. The distance X of the grip from the nearest part of the socket body should be no more than 75% of the overall length of the wedge to avoid deforming the rope.

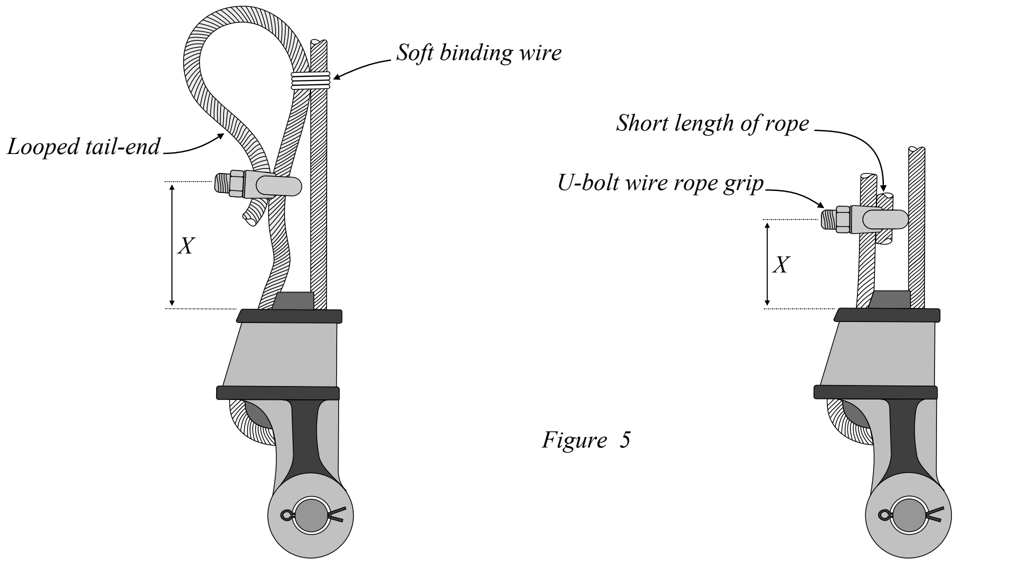
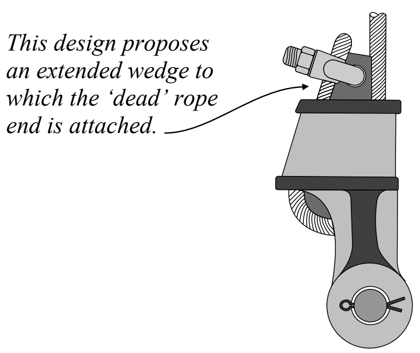
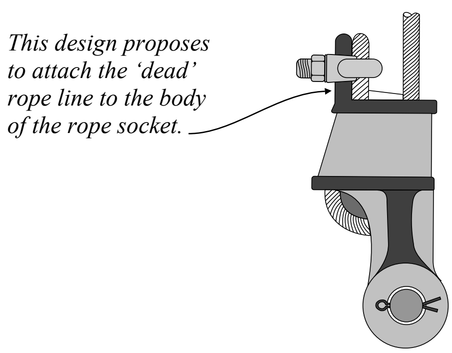


Figure 5

Some other designs than those above are proposed by manufacturers that are similar, but not limited to the examples below:





- The pin should be secured in such a way that it cannot move from its position during operation.

3.3 - Metal and resin sockets *(Also called spelter sockets)*

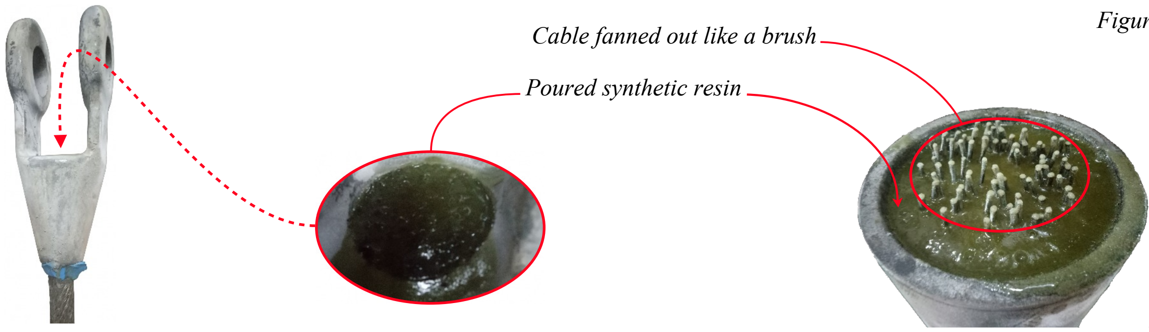
3.3.1 - Description

The metallic spelter sockets are rope end connections that can withstand the full breaking strength of the wire ropes and are reputed to achieve the highest number of tension cycles of all rope end connections regarding tension fatigue tests. Note that many manufacturers make them according to the standard BS 463. Also, the Standard EN 13411-4 "Terminations for steel wire ropes - metal and resin socketing" provide guidelines to take in reference for their installation, which requires trained personnel and specific material. However, other criteria such as standard ISO 17558 or national standards exist.

These systems consist of a conical socket into which the wire rope is inserted, and the end is fanned out as a brush with a conic shape. A metallic or synthetic resin is then cast to mix with the wires and blocks them, so that, when the chemical reaction is completed, a rigid block in the form of a cone that perfectly fits the socket's edge is in place.

When the cone is in place, increasing pulling force in the line results in the metallic cone being drawn deeper and deeper into the socket, generating increasing transverse clamping forces so that the system can withstand 100% of the wire rope capacity if well realized.

Figure 7



1. *Length of tapered basket plus any parallel portion(s) including any radius at rope entry.*
2. *Small end of tapered basket.*
3. *Large end of tapered basket.*
4. *Included angle of tapered basket.*
5. *Internal diameter at rope entry..*
6. *Pin hole*
7. *Length of tapered basket*
8. *Length of parallel portion including any radius at rope entry*
9. *Protruding wires*
10. *Length of brush*
11. *Root of brush & permanent serving*
12. *Tempoerary serving*

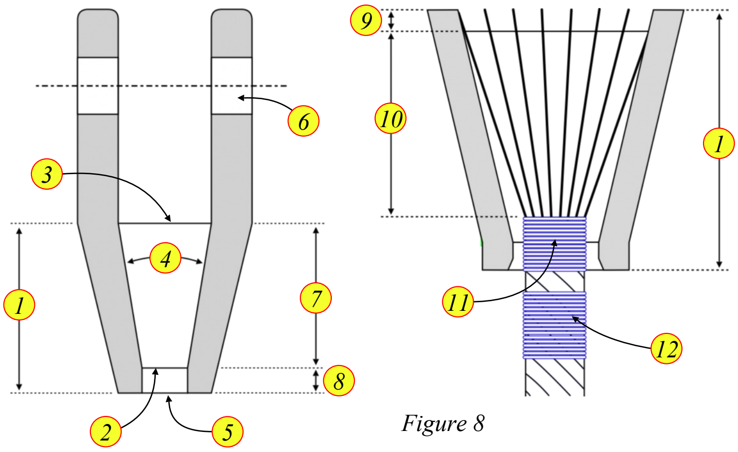


Figure 8

3.3.2 - Socketing process

It often happens that socketing has to be carried out should be carried out on the worksite due to various reasons. EN 13411-4, which recommendations and those of manufacturers are listed below says that such an operation should be performed by a competent person. On board vessels, it is often the chief engineer or the diving or ROV systems lead technician. For onshore projects it could be a competent person from the company, or an external technician.

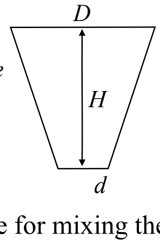
- 1st preparation of the rope and the socket:
    - The part of the wire rope not involved in the socketing should not be touched during the operation and, thus, protected against damages.
    - Hot cutting systems such as oxyacetylene torches or similar should not be used due to the risk of heat damage to the wires.
    - The technician measures and marks the wire rope to the required length, taking into account:
        - The size of the socket basket;
        - The length of the brush and any additional brush length for the hooking of wires;
        - If used, the depth of any centralizing clamp.
        - The permanent seizing that should be made at a distance from the end equal to the length of the socket's basket.
        - The length of the sizing that should be the diameter of the wire rope x 2
    - The technician uses a tinned or galvanized soft steel wire or strand to make the permanent serving. However, this seizing must allow for the penetration of the metallic or synthetic resin between the served rope and the socket bore.

  - Before the next step, the technician should ensure that the inside of the socket basket is clean and not contaminated. EN 13411-4 says that does not preclude using a releasing agent when socketing with resin.
- Preparing the "brush"
  - When the sizing is completed and checked to fulfill the above requirements, the wire rope is inserted in the socket and then unlaid to form an open brush. Where appropriate, that may include steel core. Note that it is highly recommended to avoid excessive bending of the wire, particularly at the root of the brush (see #11 in Figure #8 above).
    If the wire rope has a fibre core it must be removed on the entire length of the brush. In addition, it recommended to protect the residual part of the fibre core from the effects of heat if the socketing is planned with molten metal
  - Hooking is a procedure consisting of bending backward the extremities of the wires of the brush to form little hooks. EN 13411-4 says that it may happen that type testing may show that this procedure is necessary. If it is used, the following precautions should be in place:
    - The dimensions of the hooked portion should not obstruct the flow of the molten metal or resin during the pouring phase
    - The embedded length of the brush in the socketing medium should not be reduced

    Note that in a report called "Resin Socketing of steel wire rope" , published by Millfield Enterprises, it is said that it is not necessary to hook wires when resin socketing except in the case of coarse construction wire rope such as 6 x 7.
  - When the brush is completed, it should be degreased to remove all traces of contaminants. EN 13411-4 recommends doing by using either by liquid or vapour methods. However, the technician should ensure that this operation is limited to only the brush. Waiting until the brush is dry before pouring the resin or metal is also recommended.
    In addition, lead-based alloys may require that bright rope wires be pre-treated with a zinc chloride solution to improve the adhesion. Dipping the two third of the brush length in such a solution for approximately 1 minute is recommended.
  - When the brush is degreased and, if required, treated for lead alloy pouring, the socket is positioned over the broom until it reaches the seizing on the wire rope. Note that the distance between the end of the brush and the large end of the socket basket should be no greater than 5 % of the length of the socket basket. EN 13411-4 also says that if the ends of the wires at the top of the brush do not protrude beyond the large end of the socket basket, the actual position of the wire ends in relation to the large end of the basket should be measured and documented. When the socket is adjusted, the technician should also ensure the wires are evenly distributed within it.
    The wire rope should be aligned with the socket for a minimum length. Some manufacturers recommend a distance of 30 diameters.
  - To complete the socket preparation, the technician must seal the rope entry. Clay or putty can be used with resins, and clay or another heat-resistant sealant should be used when metal pouring is planned. It is essential to prevent leaks that, in addition to the loss of resin or metal, can result in the creation of voids in the neck area of the socket and, thus, diminished assembly performances that will have to be redone.
- Resin socketing
  The resin socketing process is more straightforward to implement than the molten metal procedure, which explains why offshore teams often prefer it. Other reasons are explained in the report called "Resin Socketing of steel wire rope", previously mentioned, where the author, J. M. Dodd says: "*In use, the resin socketed assembly offers a higher achievable tensile strength and a better fatigue performance of the assembly. In general, this can be attributed to two factors; the excellent penetration of resin, ensuring a complete cone, and the fact that there is no annealing of the wires due to heat from molten metal. A further benefit that is derived from the lack of heat, is that the lubricant in the rope remains intact and is not burned off It is an easy matter to replace the lubricant on the outside of the rope but very difficult to replace the lubricant in the centre of the rope. It is, as it does not require any heat, acid etching or neutralising, an inherently safe method, for the rigger to use both in the shop and on site.*
  Finally, the quality and reliability of this method is, without question, superior to other methods of socketing. It also avoids the damage caused to ropes by other mechanical methods of attachment of end fittings, which may affect both their tensile and fatigue potential."
  - Only the type of resin is to be used. Thus, mixing resins of different kinds or from several manufacturers is unacceptable. Usually, the manufacturers provide tables that indicate the volume of resin to plan for each socket model. If not, the formula below can be used to calculate the necessary volume:

$(D + d / 4)^2 \times H \times \Pi$ = *Necessary volume*

Note: $\Pi = 3.14159$



d = Small end of tapered basket.
D= Large end of tapered basket.
H= Length of tapered basket.

  - The manufacturer usually provides the procedure for mixing the resin components and pouring the mix obtained into the socket, with the time necessary for the mixture to cure after gelling. These procedures

must be scrupulously applied. If such information is missing, it should be requested from the manufacturer.
  - The technician should watch for leaks from the early time to the end of the pouring process; if some, they should be stopped immediately for the reasons mentioned before.
  - When the resin is confirmed cured, the sealing is removed, and the wire rope is ready for commissioning. EN 13411-4 says that where necessary, and following inspection, a suitable corrosion protection compound can be applied to the rope and the socket.
- Molten metal socketing *(Lead based alloy; Zinc based alloy; Pure Zinc)*
  As suggested in the resin socketing explanations, metal socketing requires more equipment, precautions, and skills. Even though these operations are rarely done by diving and ROV teams, people organizing lifting operations or in charge of lifting devices should not ignore the complexity of this task as they may have to manage it.
  - Competent bodies and manufacturers say that new metal should be used for this purpose. Three alloys are recommended: Lead-based alloys, zinc-based alloys, and zinc. The manufacturers usually provide instructions for pouring them and information on the volume necessary. If such information is missing, it should be required. Also, the equation previously provided for resin socketing can be used to calculate the volume needed. It is commonly recommended that the pouring ladle holds at least 20% more metal than required to fill the socket basket.
  - It is recommended that the metal of the containers used for melting and pouring the socketing metal should not influence the molten metal. EN 13411 says:
    - Galvanized containers should not be used with lead-based metals.
    - Containers previously used for melting one family of metals should not be used for other metals.
  - The heating of the crucible should be even, and the pouring the temperature should be within limits set by the specifications provided by the supplier of the metal.
    The socket should also be pre-heated according to the instructions of the metal provider. This ensures that the metal will fill the socket without solidifying prematurely. The heating of the crucible should be even, and the pouring temperature should be within the limits set by the metal supplier.
  - The socket should also be pre-heated according to the instructions of the metal provider. This ensures that the metal will fill the socket without solidifying prematurely. EN 13411 says that without manufacturer specifications, the socket temperature should be at least 50% of the metal. As for the crucible, the heating of the socket should be even. without manufacturer specifications, the socket temperature should be at least 50% of the metal. As for the crucible, the heating of the socket should be even.
  - The socket and brush should be completely dry to avoid the explosive generation of steam. It is also the case for the pouring ladle that should be preheated by immersing it in the pot. EN 13411 also says that The brush wires can be fluxed by introducing a suitable fluxing compound to the socket basket before pouring in the molten metal.
  - Immediately before pouring, the molten metal should be stirred to prevent the separation of the constituents and to ensure that an accurate temperature measurement can be obtained. The temperature should be checked. For information, the melting point of the pouring alloys is approximately 240 °C for Lead-based alloys, 380 °C for Zinc-based alloys, and 419 °C for pure zinc.
  - The dross should be removed from the surface of the molten metal before pouring. The molten metal should be poured slowly and into one side of the socket basket to permit the escape of gases. The pouring must be continuous until the basket is full. Also, it is said that tapping the socket while the metal is still molten may help to prevent the entrapment of gases within the basket.
  - Gas bubbles may be entrapped, and shrinkage holes may form if the metal solidifies too quickly. For this reason, it is advisable to slow down the cooling phase by heating the device for some time after pouring when filling large sockets. Also, although such a situation must be avoided, It may happen that even due to miscalculation or other reasons, there is insufficient socketing metal in one container. EN 13411 says that changing the container or re-filling the ladle should not influence the metal's natural solidification and cooling process.
  - Shrinkage sometimes occurs in the metal at the top of the basket. In these cases, sufficient additional metal should be poured to fill the depression. This should be carried out as the metal solidifies, and where necessary, the surface metal should be re-liquefied before pouring commences.
  - The socket must not be cooled with water during the cooling cycle; the socketing metal should be undisturbed until it reaches ambient temperature in the air so that it solidifies naturally. A suitable corrosion preventive compound should be applied to the "cleaned" length of the rope after ensuring the exposed wires are protected, and the socket's mouth is sealed.
    The seizing must be removed when the cooling and protection against corrosion are completed.
- Whatever the pouring medium, the socket must be visually inspected when the pouring phase is completed to ensure that:
  - The socket is fully filled without visual defects such as cracks, gaps, etc.
  - The wire rope is perfectly centralized at the socket entry, and the gap is filled with the socketing medium unless the socket manufacturer requires another process.
  - The socket is aligned with the wire rope

3.3.3 - Reusing the rope socket

Crosby manual indicated the following procedure for spelter sockets filled with resin:

- Cut the rope close to the base of the socket (approximately at 1/2" - 1 cm), and press the rope and cone out of the socket
- If the procedure above does not work, heat the surface of the socket to 177°C (350°F), leave for 5-10 minutes, and force out the rope and cone with a drift pin and hammer.

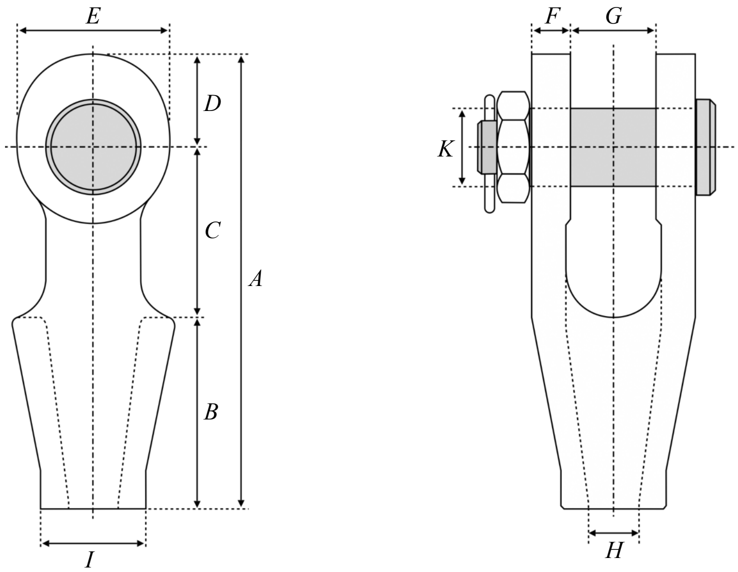
Spelter sockets filled with metal can be reheated until the metal flows out of the socket.
Before reusing a socket, the technician must ensure that no trace of the previous pouring medium is present.

3.3.4 - Common sizes of spelter sockets

Two models of spelter sockets are currently sold, which allow for different applications.

- Closed sockets are rounded with a hole for a pin or a bolt. They are mostly used with mooring systems.
- Open sockets are closed by a pin so that they can be attached to another type of fitting, and are the most used with lifting systems.

The dimensions below are average and can slightly vary from one manufacturer to another



Dimensions open end spelter socket - Metric system (Note: MBL=minimum Breaking Load)

MBL tonnes	Wire rope Ø (mm)	Structural strand Ø	Approx. resin vol.	Dimension (mm)										Weight (Kg)
				A	B	C	D	E	F	G	H	I	K	
8	6 - 7	–	10	105	46	40	19	34	9	18	10	20	17.5	0.4
12	8 - 10	–	20	122	54	45	23	40	11.2	20.6	13.5	26	20.6	0.8
20	11 - 13	–	35	142	64	51	27	48	12.7	25.6	15	30	25.4	1.1
25	14 - 16	12 - 13	50	171	76	63	32	56	14.5	32	18.5	38.5	30	1.9
40	18 - 19	14 - 16	80	205	89	76	40	68	16.5	38	22.5	46	35	3.2
55	20 - 22	18 - 19	125	238	101	89	48	80	20.5	45	26.8	55	41	5.3
80	23 - 26	20 - 22	160	273	114	101	58	98	22.5	51	29.5	62	51	8.4
100	27 - 30	24 - 26	210	306	127	114	65	110	25	57	34	70	57	11.3
130	31 - 36	27 - 28	350	338	139	127	72	124	28	63	40	83	63	16
160	37 - 39	30 - 32	425	394	152	162	80	140	30	76	44.5	90	70	23
200	40 - 42	33 - 35	500	415	165	165	85	148	33.5	76	48	97	76	29
250	48 - 48	36 - 40	700	467	191	178	98	1700	39	89	53	112	89	43
300	49 - 54	42 - 45	1250	552	216	228	108	186	46	101	58.5	125	95	64
375	55 - 60	46 - 48	1425	603	229	254	120	210	53	113	68.5	135	108	85
450	61 - 68	50 - 54	1850	654	248	273	133	230	60	127	77.5	150	121	119
500	69 - 75	56 - 62	2300	696	279	279	138	240	73	133	83	160	127	158
600	76 - 80	64 - 67	3400	736	305	286	145	250	76	146	89	170	133	186
650	81 - 86	70 - 73	4100	790	330	300	160	275	79	159	95	180	140	227
750	87 - 93	76 - 80	5200	849	356	318	175	300	82	172	99	200	152	280
900	94 - 102	88 - 96	7700	922	381	343	198	336	89	191	110	215	178	375
1000	103 - 108	98 - 102	9000	995	406	381	208	356	95	203	118	240	185	435
1200	108 - 115	104 - 111	10500	1110	440	450	220	370	100	205	128	250	195	525
1400	120 - 128	112 - 121	1400	1185	490	440	255	430	113	225	143	270	220	680

Dimensions open end spelter socket - Imperial system (Note: MBL=minimum Breaking Load)

MBL tonnes	Wire rope Ø (inch)	Structural strand Ø	Resin vol. (Cc)	Dimension (inch)										Weight (lbs)
				A	B	C	D	E	F	G	H	I	K	
8	1/4	–	10	4.13	1.81	1.6	0.75	1.34	0.35	0.71	0.39	0.78	0.69	0.9
12	5/16 - 3/8	–	20	4.8	2.16	1.8	0.9	1.57	0.44	0.81	0.53	1.02	0.81	1.8
20	7/6 - 1/2		35	5.6	2.52	2	1.1	1.89	0.5	1	0.6	1.18	1	2.4
25	9/16 - 5/8	1/2	50	6.7	3	2.5	1.3	2.2	0.57	1.26	0.73	1.52	1.19	4.2
40	3/4	9/16 - 5/8	80	8.1	3.5	3	1.6	2.76	0.65	1.5	0.89	1.81	1.38	7
55	7/8	11/16 - 3/4	125	9.4	4	3.5	1.9	3.15	0.81	1.75	1.05	2.17	1.63	11.7
80	1	13/16 - 7/8	160	10.7	4.5	4	2.3	4	0.89	2	1.16	2.44	2	18
100	1 1/8	15/16 - 1	210	12	5	4.5	2.6	4.33	1	2.25	1.39	2.76	2.25	25
130	1 ¼ - 1 3/8	1 1/16 - 1 1/8	350	13.3	5.5	5	2.8	4.8	1.1	2.5	1.57	3.27	2.5	35
160	1 ½	1 3/16 - 1 1/4	425	15.5	6	6.4	3.15	5.52	1.18	3	1.75	3.5	2.75	51
200	1 5/8	1 5/16 - 1 3/8	500	16.3	6.5	6.5	3.35	5.9	1.3	3	1.9	3.8	3	64
250	1 ¾ - 1 7/8	1 7/16 - 1 5/8	700	18.4	7.5	7	3.86	6.7	1.53	3.5	2.1	4.4	3.5	95
300	2 - 2 1/8	1 11/16 - 1 3/4	1250	21.7	8.5	9	4.25	7.3	1.81	4	2.3	4.9	3.75	141
375	2 ¼ - 2 3/8	1 13/16 - 1 7/8	1425	23.7	9	10	4.72	8.27	2.1	4.5	2.7	5.3	4.25	190
450	2 ½ - 2 5/8	1 15/16 - 2 1/8	1850	25.7	9.7	10.7	5.23	9.1	2.36	5	3.05	5.9	4.75	260
500	2 ¾ - 2 7/8	2 3/16 - 2 7/16	2300	27.4	11	11	5.43	9.45	2.9	5.25	3.25	6.3	5	348
600	3 - 3 1/8	2 ½ - 2 5/8	3400	29	12	11.3	5.7	9.84	3	5.75	3.5	6.7	5.25	410
650	3 ¼ - 3 3/8	2 ¾ - 2 7/8	4100	31.1	13	11.8	6.3	10.84	3.12	6.25	3.75	7.1	5.5	500
750	3 ½ - 3 5/8	3 - 3 1/8	5200	33.4	14	12.5	6.9	11.8	3.25	6.75	3.9	7.9	6	615
900	3 ¾ - 4	3 ½ - 3 3/4	7700	36.3	15	13.5	7.8	13.2	3.5	7.5	4.33	8.5	7	825
1000	4 - 4 ½	3 7/8 - 4	9000	39.2	16	15	8.2	14	3.75	8	4.65	9.5	7.28	960
1200	4 ¼ - 4 ½	4 1/8 - 4 3/8	10500	43.7	17.3	17.7	8.7	14.6	4	8.1	5	9.8	7.7	1150
1400	4 ¾ - 5	4 7/16 - 4 3/4	14000	46.7	19.3	17.3	10	17	4.4	8.9	8.6	10.6	8.7	1500

3.4 - Socket testing after reinstallation

A common procedure applied by teams and applicable to the two models of sockets is given in the standard EN 12385-1:

- A force equal to 80% of the breaking force of the wire rope assembly is 1st applied.
- Then the applied force is increased at a rate of not more than 0,5 % per second of the minimum breaking force.
- The test is terminated when the minimum breaking force value is achieved or exceeded without breaking the rope.

Another procedure provided in the study “Resin Socketing of Steel Wire Rope” , published by Millfield enterprises, is to apply two times the working load limit of the rope (WLL x 2).

4 - U bolt wire grips *(EN 13411-5)*

4.1 - Scope

A "U-bolt wire rope grip" assembly consists of a U-bolt, bridge, and nuts that allow two rope parts to be pressed together when the nuts are tightened.
"U-bolt wire grips" (also commonly called "bulldogs") are widely used to secure wire rope terminations (see 3.2 Asymmetric wedge sockets), and as for all the lifting devices, this point must be covered by standards.

The European Standard EN 13411-5 specifies the minimum requirements for U-bolt wire rope grips manufactured from ferrous materials and the safe behaviour of eye terminations secured by U-bolt wire rope grips for use as intended by the manufacturer.

Suitable uses include suspending static loads and single use lifting operations which have been assessed by a competent person taking into account appropriate safety factors.

Warning:

- U-bolt wire rope grips are not suitable for use with spiral ropes.
- The standard selected does not cover U-bolt wire rope grips as the primary securing devices on crane hoists or eye terminations for slings for general lifting service.

4.2 - Wire grip design 1

4.2.1 - Material

The material of the U-bolt should be "property class 5.8" EN ISO 898-1. The finish should be as in EN ISO 4042 *"Fasteners - electroplated coatings"*. They are tested according to EN ISO 898-1.

The bridge's material and finish should be "malleable" cast iron grade W40-05 or B35-10, and conform with the standard EN 1562. The finish should be as said in EN ISO 4042 *"Fasteners - electroplated coatings"*. The testing phase should be in accordance with EN 1562.

The material, finish, and testing of the nut should be "property class 5" in accordance with EN 20898-2, and product grade "A" should conform with EN ISO 4759-1. The finish should conform with EN ISO 4042 *"Fasteners - electroplated coatings"*. The testing phase should be in accordance with EN 20898-2.

4.2.2 - Dimensions

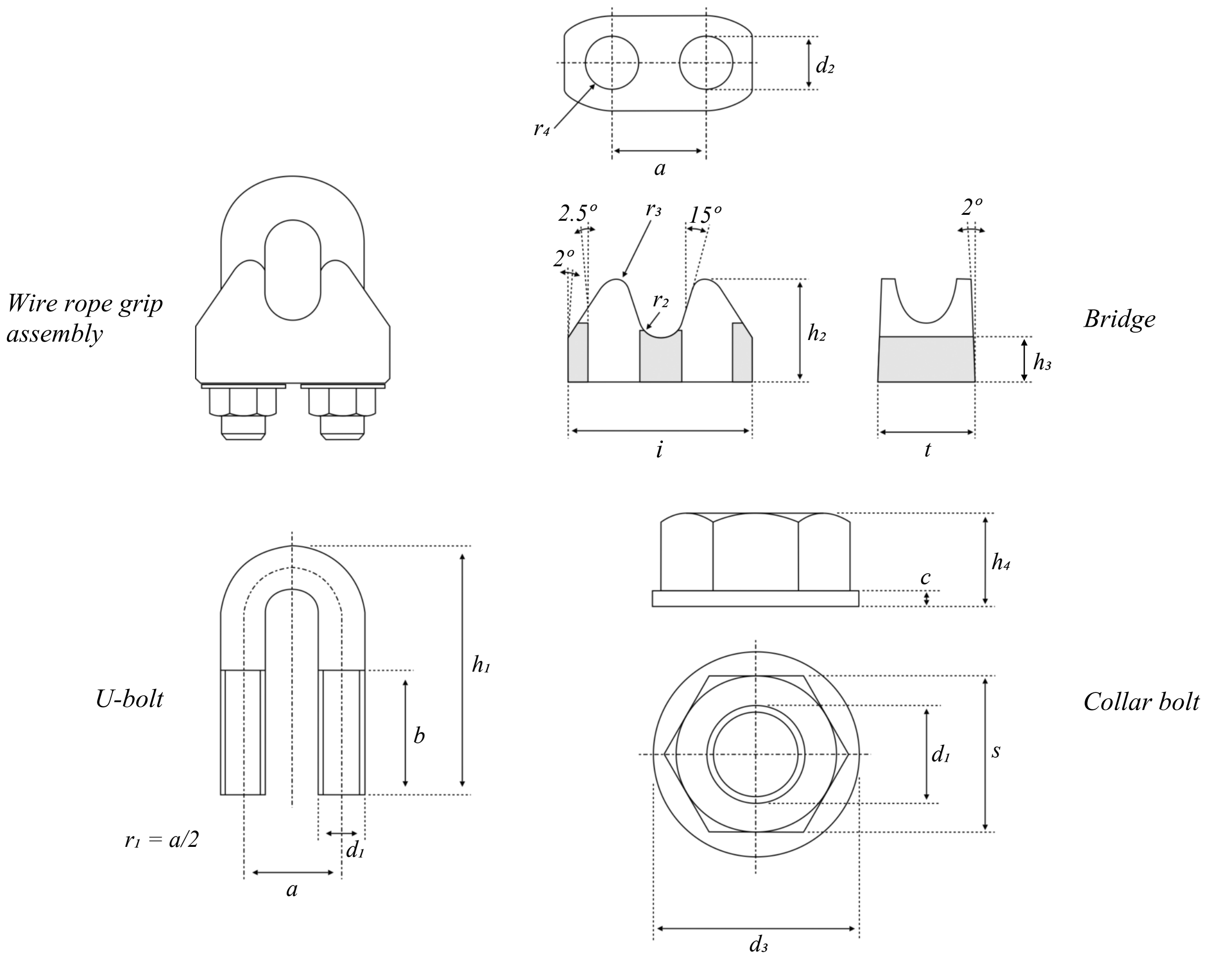


Table 1: Dimension wire grips design 1

Grip nominal size	*U-Bolt (mm)*				*Bridge (mm)*									*Collar nut (mm)*				
	*a**	*b*	*d_1*	*h_1***	*a*	*d_2*	*h_2*	*h_3*	*I*	*r_2*	*r_1*	*r_3*	*t*	*c*	*d_1*	*d_3*	*h*	*s*
5	12	13	M5	25	12	5.8	13	5	25	2.5	2	6.5	13	1	M5	10	5	8
6.5	14	17	M6	32	14	7	14	6	30	3.5	2	8	16	1.6	M6	12.5	6	10
8	18	20	M8	41	18	10	18	8.5	39	4	3	10	20	1.6	M8	17	8	13
10	20	24	M8	46	20	10	21	9	40	5	3	10	20	1.6	M8	17	8	13
12	24	28	M10	56	24	12	25	11	50	6	3	12	24	1.9	M10	20	10.5	16
14	28	31	M12	66	28	15	30	13	59	7	4	14	28	2.5	M12	24	12.5	18
16	32	35	M14	76	32	17	35	16	64	8	4	16	32	2.5	M14	28	13.5	21
19	36	36	M14	83	36	17	40	17	68	9.5	4	16	32	2.5	M14	28	13.5	21
22	40	40	M16	96	40	19	44	20	74	11	4	17	34	3	M16	30	16	24
26	46	50	M20	118	46	24	51	22	84	12	5	19	38	5	M20	37	24	30
30	54	55	M20	131	54	14	59	27	95	15	5	20.5	41	5	M20	37	24	30
34	60	60	M22	150	60	26	67	30	105	17	5	22.5	45	7	M22	45	30	34
40	68	65	M24	167	68	28	77	33	117	20	5	24.5	49	7	M24	45	30	34

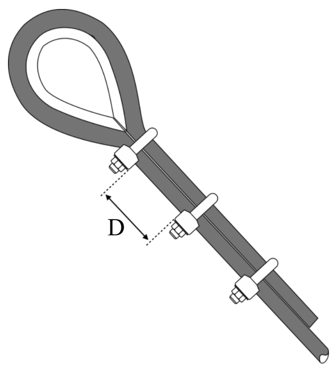
a : Equates with the maximum nominal diameter of rope, For intermediate nominal diameters, use the next larger grip size. Nominal size 5 applies only to nominal rope 5 mm

** : Tolerances in accordance with EN 22768 - grade C*

***: Tolerances in accordance with ISO 8062 - grade CT10*

4.2.3 - Fitting instructions

The distance "D" between grips should be at least 1.5, and not more 3 times the width of the bridge.



When using a thimble in the eye assembly, the first wire rope grip should be placed immediately against the thimble. The bridge should always be placed on the load bearing part of the rope.

When making the assembly and before bringing into service, the collar nuts should be tightened to the torque given in Table 2 below.
The recommended tightening torques are for grips with greased bearing surfaces and nut threads. After load is applied for the first time, the torque should be checked again and, if necessary, corrected. The wire rope end termination should be inspected by a competent person.

Table 2: Recommended number of grips and torque to be used relative to rope size.

*Grip nominal size **	*Tightening torque (Nm)*	*Number of grips*
5	2	3
6.5	3.5	3
8	6	4
10	9	4
12	20	4
14	33	4
16	49	4
19	68	4
22	107	5
26	147	5
30	212	6
34	296	6
40	363	6

** : Equates with the maximum nominal diameter of rope, For intermediate nominal diameters, use the next larger grip size. Nominal size 5 applies only to nominal rope 5 mm*

4.3 - Wire grip design 2

4.3.1 - Dimensions

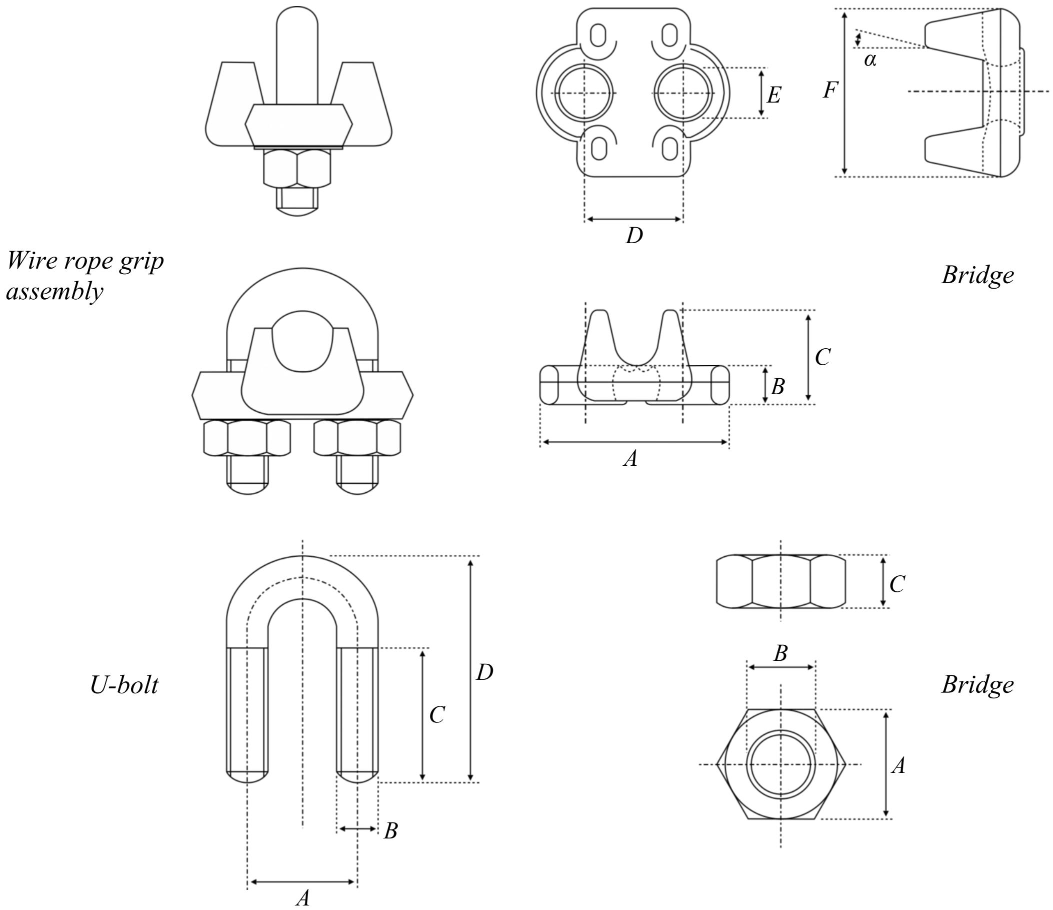


Table 3: Dimension wire grips design 2

Grip nominal size	Nominal rope size (mm)	Bridge (mm)							U-Bolt (mm)				Collar nut (mm)		
		A	B	C	D	E	F	α	A	B	C	D	A	B	C
1/8	3 - 4	25	4.3	9.4	12	7.2	20.5	12°	12	12-24 UNC	11	23	9.4	12-24 UNC	4.7
3/16	5	30	5.6	12.7	15	8.3	24	12°	15	1/4-20 UNC	14	30	11	1/4-20 UNC	5.6
1/4	6 - 7	36.5	7.1	16.8	19	9.9	30	12°	19	5/16-18 UNC	12.5	31	14.1	5/16-18 UNC	7.5
5/16	8	42	7.9	18.5	22.5	11.6	33.5	12°	22.5	3/8-16 UNC	19	43	17.2	3/8-16 UNC	9.1
3/8	9 - 10	49	9.5	23	25.5	13.3	41.5	12°	25.5	7/16-14/UNC	19	47.5	18.8	7/16-14/UNC	10.7
7/16	11	58	11	28.5	30	15.2	48.5	11°	30	1/2-13 UNC	25.5	58.5	21.9	1/2-13 UNC	12.3
1/2	12 - 13	58	11	28.5	30	15.2	48.5	11°	30	1/2-13 UNC	25.5	58.5	21.9	1/2-13 UNC	12.3
9/16	14 - 15	63.5	12	34	33.5	16.8	52.5	10°	33.5	9/16-12 UNC	32	69.5	23.4	9/16-12 UNC	13.9
5/8	16	63.5	12	34	33.5	16.8	52.5	10°	33.5	9/16-12 UNC	32	69.5	23.4	9/16-12 UNC	13.9
3/4	18 - 20	72	12	35.5	38	18.7	57	10°	38	5/8-11 UNC	36.5	84	26.6	5/8-11 UNC	15.5
7/8	22	80.5	13	40	44.5	22	62	10°	44.5	3/4-10 UNC	41	96	31.3	3/4-10 UNC	18.6
1	24 - 26	88	14.2	45	48	22	66.5	10°	48	3/4-10 UNC	46	106	31.3	3/4-10 UNC	18.6
1 1/8	28 - 30	91	14.2	48.5	51	22	71.5	10°	51	3/4-10 UNC	51	115	31.3	3/4-10 UNC	18.6
1 ¼	32 - 34	105	17.5	55	58.5	25.5	79.5	10°	59	7/8-9 UNC	56	133	36	7/8-9 UNC	21.8
1 3/8	36	106	17.5	59	60.5	25.5	79.5	10°	59	7/8-9 UNC	56	133	36	7/8-9 UNC	21.8
1 1/2	38 - 40	113	19	62	65.5	25.5	86.5	10°	65.5	7/8-9 UNC	60.5	145	36	7/8-9 UNC	21.8
1 5/8	41 - 42	121	19	67.5	70	28.5	92	10°	70	1-8 UNC	66.5	160	40.6	1-8 UNC	25
1 3/4	44 - 46	135	22.5	74	77.5	32.5	97	10°	77.5	1 1/8-7 UNC	70	174	45.3	1 1/8-7 UNC	28.5
2	48 - 52	149	24	83	86	36	113	10°	86	1 1/4-7 UNC	76	195	50	1 1/4-7 UNC	31
2 ¼	56 - 58	162	28.5	81	99	36	116	9°	98.5	1 1/4-7 UNC	81	213	50	1 1/4-7 UNC	31
2 ½	62 - 65	168	28.5	94	105	36	119	9°	105	1 1/4-7 UNC	87.5	227	50	1 1/4-7 UNC	31
2 ¾	68 - 72	175	33	124	111	36	127	9°	111	1 1/4-7 UNC	90.5	243	50	1 1/4-7 UNC	31
3	75 - 78	194	40	113	121	41.5	135	9°	121	1 1/2-6 UNC	99	272	59.5	1 1/2-6 UNC	37.5
Note: 12-24 UNC number size tread indicates a nominal diameter of 0.2078 / 0.22150 inches with a pitch of 24 threads per inch															

4.3.2 - Material

The material of the U-bolt should be carbon steel the properties of which are to withstand without distortion the recommended torque load. The finish should be: Plate in accordance with EN 12329, and mechanical in accordance with

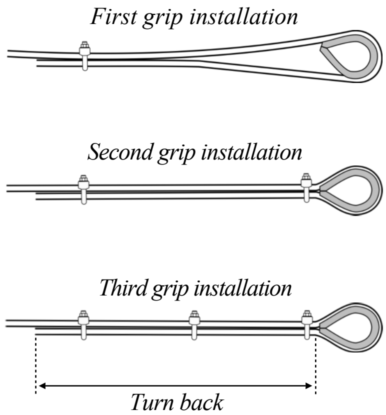
ASTM B-695 or hot dip galvanized in accordance with ASTM A-153. Magnetic particle inspection in accordance with EN 1677-1 is the recommended process of testing.

The material of the bridge should be forged from carbon steel, the properties of which are to withstand without distortion the recommended torque load. The Finish should be: Plate in accordance with EN 12329; mechanical in accordance with ASTM B-695, or hot dip galvanized in accordance with ASTM A-153. The markings should be: Manufacturers identification and size are to be legible. Distinctive roddles are to be present.

The material, finish and testing of the nut should be ASTM A563 G-a or better. The finish should be galvanized in accordance with ASTM A-153.

4.3.3 - Fitting instructions

The example below is with a grip for use with six stranded right-hand lay ropes in 6 x 19 and 6 x 36 classes. Refer to Table 4 below regarding the grips' size and number, and the amount of wire rope to turn back from the thimble or loop, according to the wire rope's diameter.



Apply first grip one bridge width from the dead end of the rope. Apply the U-bolt over the dead end of the wire rope. The saddle rests over the live end. Tighten nuts evenly. Alternate from one nut to the other until reaching the recommended torque.

When two grips are required, apply the second grip as near the loop or thimble as possible. Tighten nuts evenly, alternating until reaching the recommended torque.

When more than two grips are required, apply the second grip as near the loop or thimble as possible; turn the nuts on the second grip firmly, but do not tighten. Proceed to the next step.

When three or more grips are required, space the additional grips equally between the first two - take up rope slack - tighten the nuts on each U-bolt evenly, alternating from one nut to the other until reaching the recommended torque.

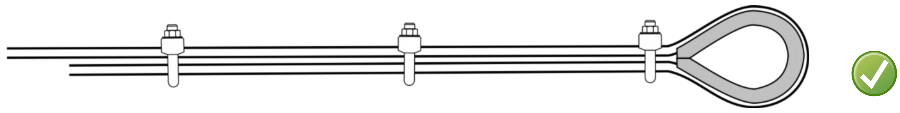
Table 4: Recommended number of grips and torque to be used relative to rope size.

Grip nominal size	*Nominal diameter*	*Minimum no of grips **	*Amount of rope to turn back (mm)*	*Torque (Nm) ***
1/8	3 - 4	2	85	6.1
3/16	5	2	95	10.2
1/4	6	2	120	20.3
5/16	8	3	133	40.7
3/8	9 - 10	3	165	61
7/16	11 - 12	3	178	88
1/2	13	3	292	88
9/16	14 - 15	3	305	129
5/8	16	3	305	129
3/4	18 - 20	4	460	176
7/8	22	4	480	305
1	24 - 25	5	660	305
1 - 1/8	28 - 30	6	860	305
1 - 1/4	32 - 34	7	1120	488
1 - 3/8	36	7	1120	488
1 - 1/2	38 - 40	8	1370	488
1 - 5/8	41 - 42	8	1470	583
1 - 3/4	44 - 46	8	1550	800
2	48 - 52	8	1800	1017
2 - 1/4	56 - 58	8	1850	1017
2 - 1/2	62 - 65	9	2130	1017
2 - 3/4	68 - 72	10	2540	1017
3	75 - 78	10	2690	1627

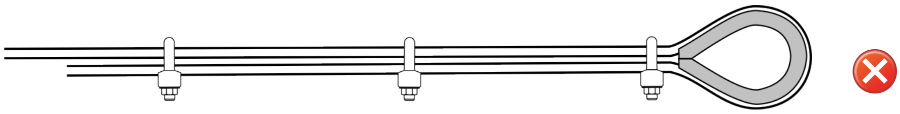
** : If a greater number of grips are used than shown in the table, the amount of turn back should be increased proportionately*
*** : The tightening torque values shown are based upon the threads being dry and free of lubrification.*

Notes:

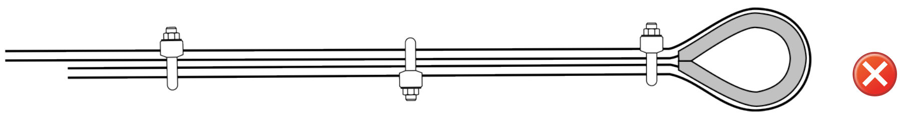
- The number of clips is based upon using RRL or RLL wire rope, 6 x 19 or 6 x 37 Class, FC or IPS, IWRC, or XIP.
- If Seale construction or similar large outer wire type construction in the 6 x 19 Class is to be used for sizes 1 inch and larger, add one additional clip.
- The number of clips shown also applies to rotation-resistant RRL wire rope, 8 x 19 Class, IPS, XIP, sizes one and a half inch and smaller, and to rotation-resistant RRL wire rope, 19 x 7 Class, IPS, XIP, sizes 1 - 3/4 inch and smaller.
- Apply the first load to test the assembly. This load should be of equal or greater weight than loads expected in use. Next, check and retighten the nuts to recommended torque.
- Periodically retightening of the nuts can occur at 10 000 cycles (heavy usage), 20 000 cycles (moderate usage), or 50 000 cycles (light usage). If the number of cycles is unknown, a period could be used: For example, every three months, six months, or annually.
- The wire rope end termination should be inspected periodically for wear, abuse, and general adequacy.
- Warning regarding the orientation of the grips:
  It is common to discover grips incorrectly positioned when inspecting wire connections, and this, despite the recommendation of EN 13411-5 and other documents, says that "the U-bolt should be over the dead end of the wire rope".
  It must be remembered that incorrect orientation of the grips can result in the rope sliding or being damaged, so a connection failure. For this reason, the diving team must be aware of and focus on the following:



Correct assembly: The u-bolts are all as recommended in EN 13411-5



Incorrect assembly: The saddles are over the dead end of the wire rope



Incorrect assembly: One saddle is over the dead end of the wire rope

Page left blank intentionally

C - Hooks, shackles, horizontal beams, and mattress installation frames

1 - Hooks

1.1 - Norms and standards applied *(EN 1677)*

This part is based on the European Standard EN 1677 which specifies the requirements related to safety of forged steel lifting hooks with latch of grade 8 having eye or clevis and pin up to 63 t WLL, mainly for use in:

- Chain slings according to EN 818-4;
- Steel wire rope slings according to EN 13414-1:1999;
- Textile slings according to EN 1492-1:2000, EN 1492-2:2000;

This part also specifies the requirements related to safety for forged steel lifting hooks of grade 4 having latch and eye up to 31.51 t WLL, mainly for use in:

- Chain slings according to EN 818-5;
- Steel wire rope slings according to EN 13414-1:1998;
- Textile slings according to EN 1492-1 EN 1492-2;

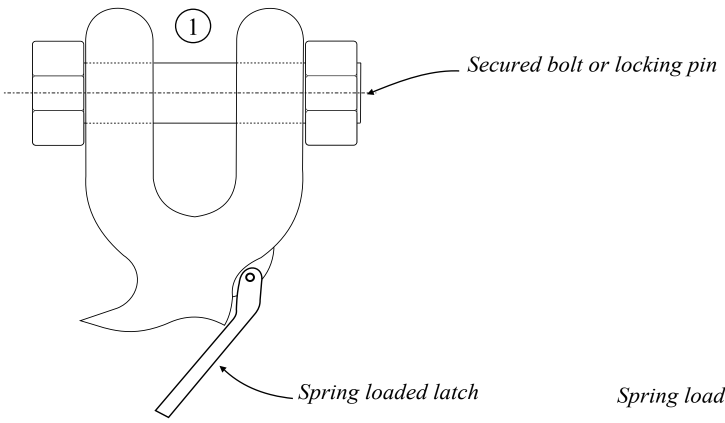
- This part does not apply to hand forged hooks.

1.2 - Design

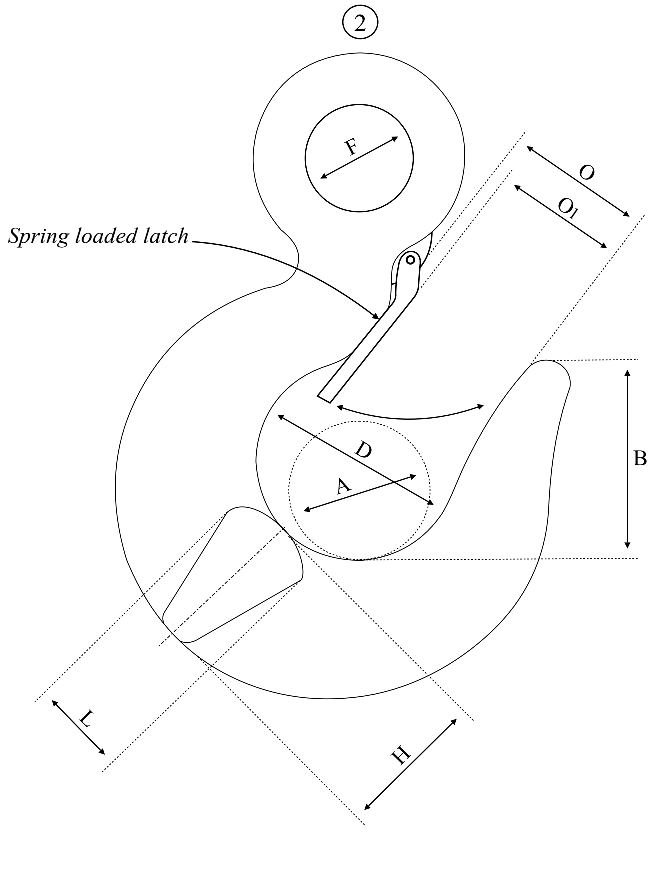
1.2.1 - Design hook grade 8

Each hook must have a spring loaded latch to ensure that the load cannot become accidentally unhooked.

The form of the upper end should be either of the eye type or the clevis type as designated in the table and the figure below.



No	*Connection type*	*Connected to*
1	*Clevis type*	*Mechanically assembled chain sling*
2	*Eye type*	*Chain slings, wire rope slings & textile slings*



The following requirements should be met:

- The actual point height “B” must be equal to or greater than the full throat opening O.
- The full throat opening O must not exceed 95 % of the actual seat diameter D.
- The hook latch must be capable of closing over the maximum diameter of bar A, as indicated in figure 1, that can be admitted through the actual throat opening O_1.

The dimensions should be as in the table below:

Code number	Working Load Limit (tonnes)	D minimum (mm)	O minimum (mm)	O1 minimum (mm)	F minimum (mm)	H maximum (mm)	L maximum (mm)
3	0.25	11	8	8	6	12	8
4	0.5	15	11	11	8	17	11
5	0.8	19	14	14	10	21	14
6	1.12	22	17	16	12	25	17
7	1.5	26	20	18	14	29	20
8	2	30	23	21	16	34	23
9	2.5	34	26	24	18	38	26
10	3.15	38	29	27	20	43	29
11	4	42	32	30	23	48	32
13	5.3	49	37	35	26	55	37
14	6	52	40	37	28	59	40
16	8	60	46	43	32	68	46
18	10	67	51	48	36	76	51
19	11.2	71	54	51	38	80	54
20	12.5	75	57	53	40	85	57
22	15	82	63	58	44	93	63
23	16	85	65	60	46	96	65
25	20	95	72	68	51	107	72
26	21.2	98	75	70	52	111	75
28	25	106	81	76	57	120	81
32	31.5	119	91	85	64	135	91
36	40	134	102	96	72	152	102
40	50	150	115	107	81	170	115
45	63	168	129	120	90	190	129

NOTES:

- With an eye type hook, connecting devices may be required between the hook and the rest of the sling.
- For direct use in wire rope slings and textile slings, the dimension of the eye *("F" in the figure previous page)* should be larger than the minimum value given in the table

1.2.2 - Design hook grade 4

The design of a hook grade 4 is identical to a hook grade 8.

The dimensions should be as in the table below:

Code number	Working Load Limit (tonnes)	D minimum (mm)	O minimum (mm)	O1 minimum (mm)	F minimum (mm)	H maximum (mm)	L maximum (mm)
5	0.56	22	17	16	12	25	17
7	0.75	26	20	18	14	29	20
8	1	30	23	21	16	35	23
9	1.25	34	26	24	18	38	26
10	1.6	38	29	27	20	43	29
11	2	42	32	30	23	48	32
13	2.65	49	37	35	26	55	37
14	3	52	40	37	28	59	40
16	4	60	46	43	32	68	46
18	5	67	51	48	36	76	51
19	5.6	71	54	51	38	80	54
20	6.3	75	57	53	40	85	57
22	7.5	82	63	58	44	93	63
23	8	85	65	60	46	96	65
25	10	95	72	68	51	107	72
26	10.6	98	75	70	52	111	75
28	12.5	106	81	76	57	120	81
32	16	119	91	85	64	135	91
36	20	134	102	96	72	152	102
40	25	150	115	107	80	170	115
45	31.5	168	129	120	90	190	129

1.2.3 - Quality of materials

The steel shall be produced by an electric process or by an oxygen blown process.

The steel shall be stabilized against strain age embrittlement, and have an austenitic grain size of 5 or finer when tested in accordance with EN ISO 643:2003 *"Steels -Micrographic determination of the apparent grain size".* This should be accomplished by ensuring that the steel contains sufficient aluminium (minimum 0,025 %) to permit the manufacture of components stabilized against strain age embrittlement during service.

The steel should contain alloying elements in sufficient quantities so that the finished component possesses adequate ductility in order to work satisfactorily in the temperature range -40 °C to 400 °C.

1.2.4 - Manufacture

Each hook body should be forged hot in one piece. Excess metal from the forging operation should be removed cleanly leaving the surface free from sharp edges. After heat-treatment, furnace scale should be removed, and the hook body should be free from harmful surface defects, including cracks.

Edges of machined surfaces shall be rounded to eliminate cutting edges and to ensure attainment of mechanical properties of the component.

Welding should not be used during the manufacture of components unless:

- None of the parts to be welded are load bearing.
- The area affected by the weld is not to be subjected to load under normal operating conditions or under any foreseeable misuse of the component, and the welding is completed before heat treatment.
- Care should be taken during welding to ensure that the mechanical properties of any load bearing parts of the finished component are not affected.
- All welds shall be smoothly finished.

The finished condition of components should include any surface finish. Note: Components are supplied in various surface finishes, e.g. descaled, electroplated or painted.

1.2.5 - Characteristics of the Latch

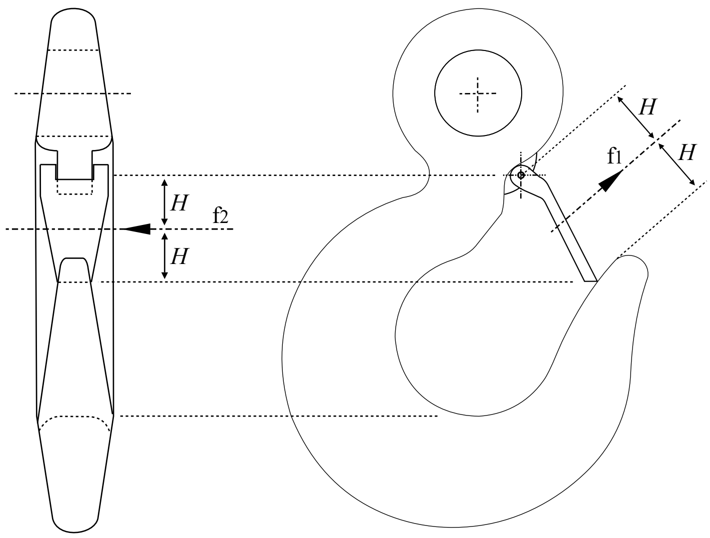
The latch should engage in the point of the hook to form a complete closure of mating surfaces. With the hook in any orientation the spring should ensure that the latch is held positively in the closed position. Latches operated solely by gravity should not be used.

The spring should be constructed from corrosion protected material and shall be able to withstand at least 10 000 complete openings of the latch without fracture.

The force required to fully open the latch should not exceed that which can be applied manually *(see table below)*.

Note:

- The latch should be able to withstand force f_1, applied across the width of the latch, equidistant between the point of the hook and the centre of rotation of the latch, and force f_2 which shall be applied across the thickness of the latch laterally to f_1 .
- Both f_1 and f_2 should be equivalent to 300 kg or 10 % of the working load limit of the hook, whichever is the greater, but f_2 should not exceed 20 kN.



Code number	*Minimum initial torque (Nm)*	*Minimum initial torque (Nm)*
From 3 up to and including 5	*0.05*	*0.1*
From 6 up to and including 7	*0.1*	*0.2*
From 8 up to and including 10	*0.2*	*0.4*
From 11 up to and including 14	*0.3*	*0.6*
From 16 up to and including 18	*0.75*	*1.5*
From 19 up to and including 23	*1*	*2*
From 25 up to and including 28	*2*	*4*
From 32 up to and including 45	*3.5*	*7*

1.2.6 - Marking

Each component should be legibly and indelibly marked in a place where the marking will not be removed by use and in a manner that will not impair the mechanical properties. The marking should include the following Information:

- Code number which identifies the Working Load Limit of the hook.
- The grade number.
- The manufacturer's name, symbol or mark.
- The traceability code.

1.2.7 - Manufacturer's certificate

The certificate should include at least the following information:

- The name and address of the manufacturer or authorized representative, including the date of issue of the certificate and authentication.
- The number and relevant part of the Standard applied.
- Code number.
- The quantity and description of the hook.
- The grade number.
- The working load limit, in tonnes.
- The manufacturing proof force, In kilonewtons.
- Confirmation that the specified minimum breaking force was met or exceeded.
- An identification of the quality system to EN ISO 9002 when in place and operating.

The manufacturer should keep a record, for at least 10 years after the last certificate has been issued, of the material specification, heat treatment, dimensions, test results, quality system in use, and all relevant data concerning the components that have satisfied the type tests, including records of sampling. This record should also include the manufacturing specifications that should apply to subsequent production.

1.3 - Inspection of hooks in service

1.3.1 - Before first use of the sling

The hook corresponds precisely to that specified on the order;

The manufacturer's certificate is on hand.

The identification and Working Load Limit marked on the hook correspond with the information on the certificate.

Full details of the hook are recorded.

1.3.2 - When in use

1.3.2.1 - Examination should be similar to what is practiced for chain slings:

A thorough examination should be carried out by a competent person at intervals not exceeding twelve months. This interval should be less where deemed necessary in the light of service conditions. Records of such examinations should be maintained.

Hooks should be thoroughly cleaned so as to be free from oil, dirt and rust prior to examination. Any cleaning method which does not damage the parent metal is acceptable. Methods to avoid are those using acids, overheating, removal of metal or movement of metal which may cover cracks or surface defects.

Adequate lighting should be provided and the hook should be examined to detect any evidence of wear, cracks or other visible damage. The latch must conform to the guidance of the point 5.2.5.

The hook should be withdrawn from service and referred to a competent person for examination if any of the following are observed:

- The identification marks are not visible *(code number indicating the WLL , Traceability code…).*
- Any visible damage such cracks, gouges, damaged latch, excessive corrosion, heat discoloration…
- Dimensions not corresponding to those agreed by the standard applied *(see points 5.22 & 5.23).*

1.3.2.2 - Maintenance should be similar to what is practiced for chain slings:

When not installed (on a sling or a lifting gear), the hook should be stored in clean, dry and well ventilated conditions, at ambient temperature, away from any heat sources, contact with chemicals, fumes or corrodible surfaces. They should not be left on the ground where they may be damaged.

Hooks which have become wet in use, or as a result of cleaning, should be hung up and allowed to dry naturally.

Prior to placing in storage, hooks should be inspected for any damage which may have occurred during use. Damaged hooks should be withdrawn from service.

Where hooks have come into contact with acids or alkalis, dilution with water or neutralization with suitable media is recommended prior to storage. Contact with acids or acidic fumes causes hydrogen embrittlement to grade 8 materials.

For hooks delivered painted, the protective paint has to be renewed periodically, or the chain may be painted in another colour for identification purpose. Because the paints designed for metal use harmful and extremely flammable solvents, this operation has to be performed in a well ventilated area. The hook can be returned to storage only when the paint is fully dry with no noticeable emission of solvents.

Hooks without paint or galvanization: Some hooks can be delivered with oil lubrication as protection against corrosion. This protective film has to be renewed periodically, or after exposure in aggressive medium (salt water). The oil to use for this purpose should have similar characteristics than the one used for metal slings:

- It should be free from acids and alkalis.
- It should have sufficient adhesive strength to remain on the chains.
- It should not be soluble in the medium surrounding it under the actual operating conditions.
- It should have a high film strength.
- It should resist oxidation.

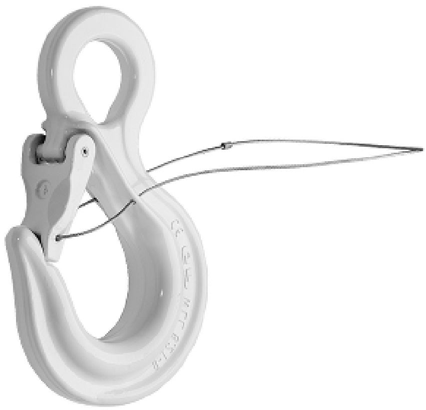
Improper use of diesel: Some teams commonly use diesel to lubricate their lifting devices.
If used, this practice must be stopped:

- Diesel is a hydrocarbon designed to run engines and is very volatile and flammable. There is a high risk of fire in the store in addition to the fact that hydrocarbons are dangerous for health.
- Diesel dissolves the oil protection and has poor adhesive strength, particularly when exposed to seawater. As a result, it will not remain on the chain that is no longer protected.

1.4 - Hooks designed for ROVs

Some models of hooks are adapted to be used by Remote Operated Vehicles. These items are built according to the same norms as “classical” hooks, but their systems of opening and installation have been designed to be handled using ROV manipulators. Of course, these hooks can also be used by divers.
Many models exist that use various designs, which mechanisms can be classified as described below. In addition, they are often provided, but not consistently, with a stem between the connecting eye and the hook, providing more space to grab and orient them using one of the manipulators of the ROV.

- Some models can be operated through a small cable connected to the latch, like the example #1 below, designed by Green Pin (https://www.greenpin.com/). A rope terminated by a ball knot is usually connected to the cable to allow for handling by the manipulator.
- Other systems are designed with the part forming hook mounted on a pivot, thus being the mobile part, resulting in the latch being the fixed part connected to the crane. Such hooks are called "Latchlock hooks". The locking mechanism is often integrated into the hook's body, such as the example #2 below, designed by Nautilus Rigging (https://www.nautilusrigging.com/).
- RUD (https://www.rud.com/) provides a system with a double locking mechanism. It unlocks only when the two unlocking systems, located on the stem between the eye to the hook, are pressed simultaneously.



Example #1
https://www.greenpin.com/

Example #2
https://www.nautilusrigging.com/

Example #3
https://www.rud.com/

2 - Shackles *(ISO 16857)*

2.1 - Norms and standards applied

This part is based on the Standards ISO 16857:2013 which specifies requirements for forged steel Dee and bow shackles for general lifting purposes on ships. The standard EN 13889:20W *"forged steel shackles for general lifting purpose"* is not applicable for the construction of shackles designed for boats. Some of its recommendations regarding the safe use of shackles are introduced in this document.

2.2 - Design

2.2.1 - Materials

Shackle materials should use solid steel manufactured by Martin furnaces, electric furnaces, or oxygen top blown converters; it is recommended to use the electroslag remelting process. The mechanical properties of a shackle should be as indicated below:

Materials	*Mechanical properties*						
	Tensile strength Rm (MPA)	*Yield point ReH (MPA)*			*Elongation A (%)*		*Energy impact Ak (Joules)*
	Diameter or thickness of steel						
	≤ 100	*≤ 16*	*> 16 - 40*	*> 40 - 60*	*≤ 50*	*≤ 100*	*≤ 60*
Carbon steel	*402 - 490*	*255*	*245*	*235*	*–*	*22*	*48*
Carbon-manganese steel	*510 - 608*	*353*	*343*	*333*	*22*	*–*	*41*

Note #1: The values listed in the table refer to mechanical properties at normal temperature
Note #2: For diameters or thicknesses > 60 mm, the impact energy and yield point under strain aging conditions are determined by the supplier and purchaser based on demand.
Note #3: If materials have no obvious yield points, the yield point Reh shall be the yield strength Rpo,2.

2.2.2 - Manufacturing

Shackle bodies need to be forged with seamless solid blanks, and two pinholes should be coaxial and concentric with two outsides of eyes; pins shall be cut from bars, and machined after forging.

Heat treatment should be made after shackle forging to achieve the properties specified for materials with no more than three times of heat treatment.

The surface of shackles should be smooth and clean without any defect such as burrs, cracks, folding, and burning.

Defects in shackles cannot be re-welded.

Shoulders or heads of pins after assembly should fit into the bodies. When thread pins are screwed up, visible residual threads between dimensions of shackles (*W*) should not be more than 1 pitch. After the correct assembly of pins, the inner width (*W*) of the bodies should never be obviously reduced.

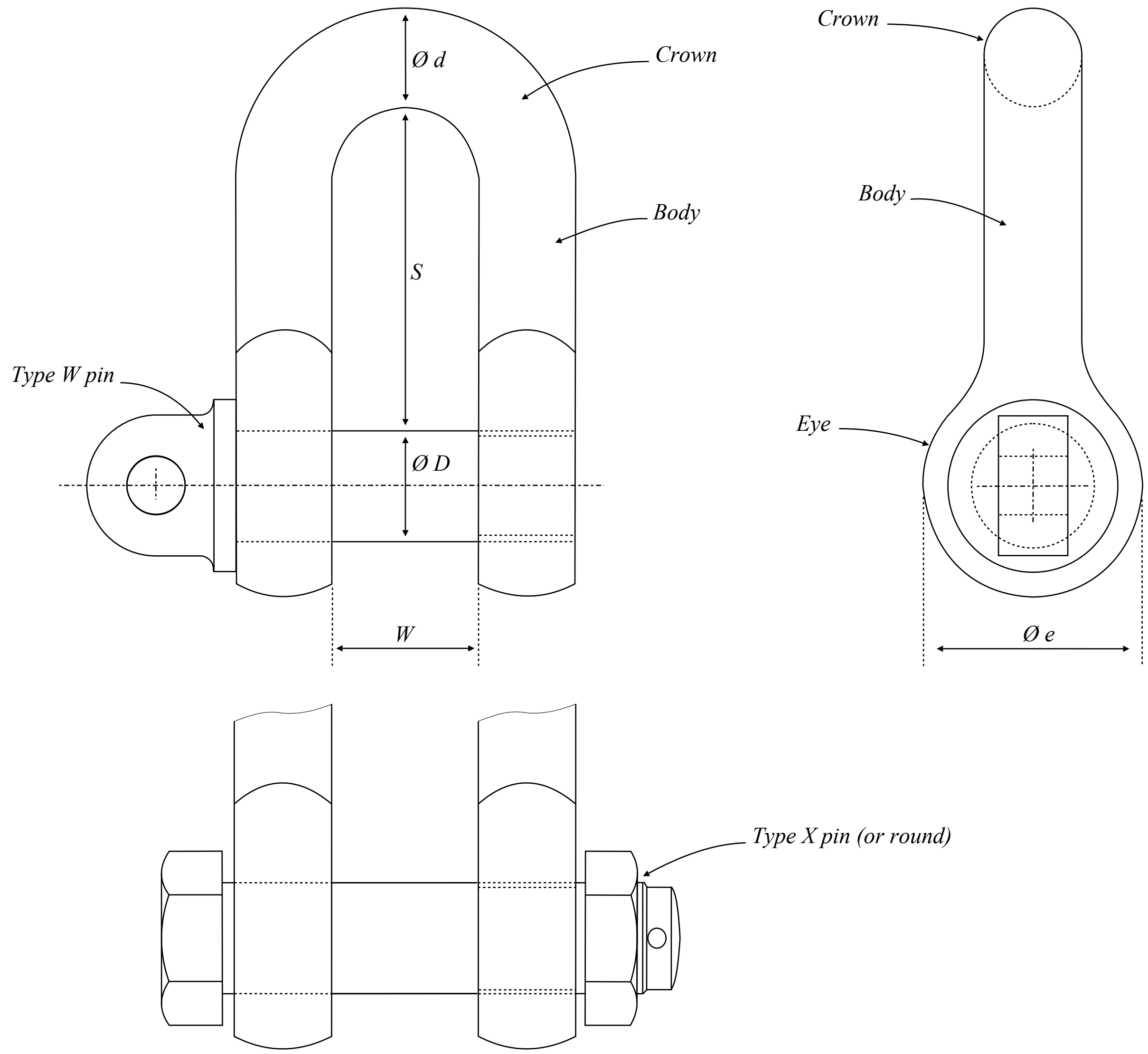
2.2.3 - Manufacturer's certificate

The certificate should include at least the following information:

- The name and address of the manufacturer or authorized representative, including the date of issue of the certificate and authentication;
- The number of the Standard applied
- Traceability code
- The quantity and description of the shackle
- The grade number (Should be 6)
- The working load limit, in tonnes
- The manufacturing proof force, In kilonewtons;
- Confirmation that the specified minimum breaking force was met or exceeded;
- An identification of the quality system to EN ISO 9001 when In place and operating.

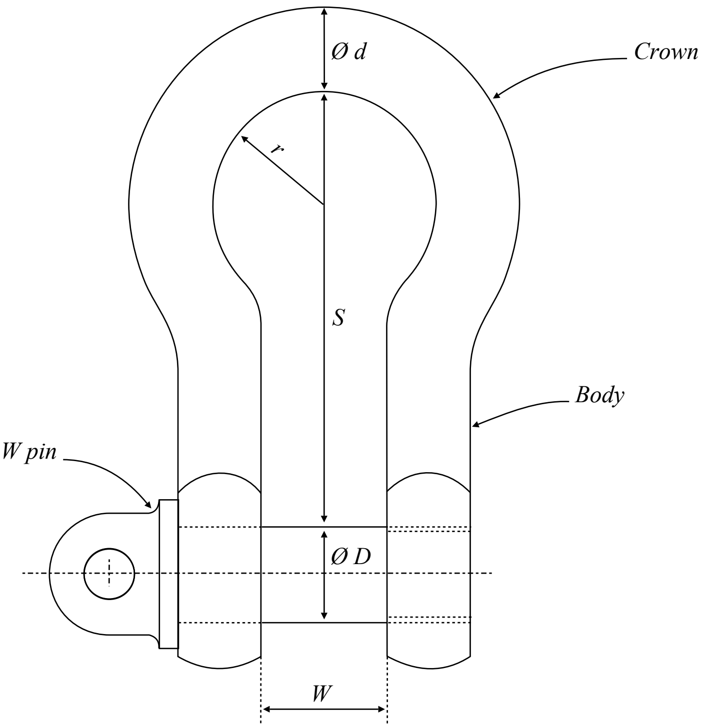
The manufacturer should keep a record, for at least 10 years after the last certificate has been issued, of the material specification, heat treatment, dimensions, test results, quality system In use, and all relevant data concerning the components that have satisfied the type tests, including records of sampling.
This record should also include the manufacturing specifications that should apply to subsequent production

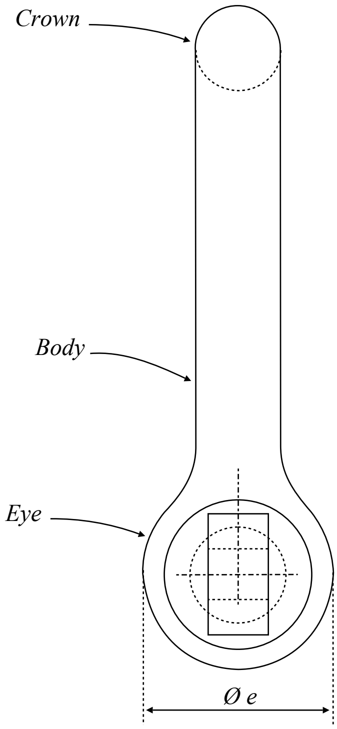
2.2.4 - Dimensions of "D" Shackle

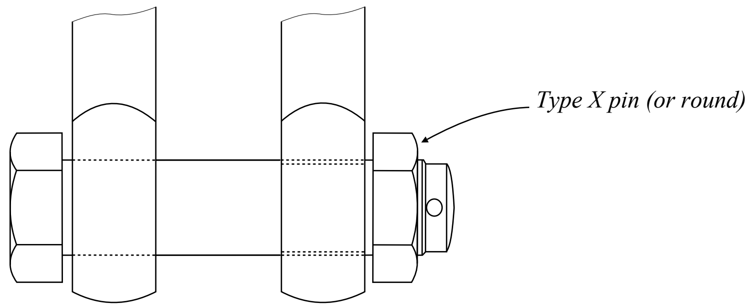


Safe Working Load (tonnes)	*D - maximum (mm)*	*D - maximum (mm)*	*e - maximum (mm)*	*S - minimum (Mm)*	*W - minimum (Mm)*
1	14	16	35.5	31.5	16
2	20	22.4	49.28	45	22.4
3.2	25	28	61.8	56	28
5	31.5	35.5	78.1	71	35.5
8	40	45	99	90	45
10	45	50	110	100	50
12.5	50	56	123.32	112	56
16	56	63	138.6	125	63
20	63	71	156.2	140	71
25	71	80	178	160	80
32	80	90	198	180	90
40	90	100	220	200	100
50	100	112	246.4	224	112
63	112	125	275	250	125
80	125	140	308	280	140
100	140	160	352	315	160

2.2.5 - Dimensions of bow Shackle



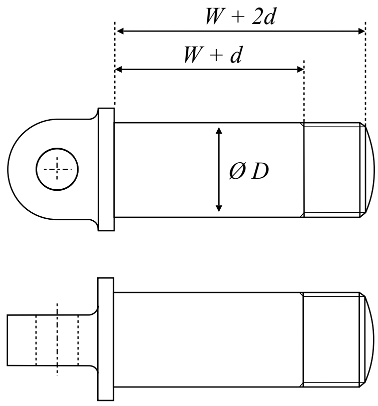




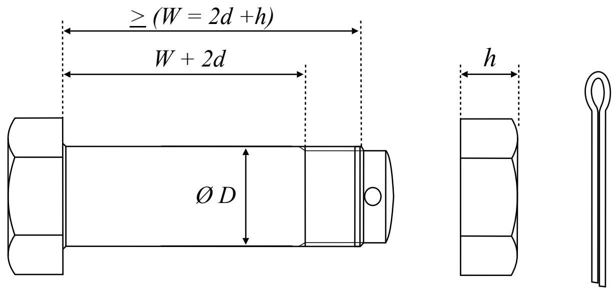
Safe Working Load (tonnes)	*d - maximum (Mm)*	*D - maximum (mm)*	*e - maximum (mm)*	*2r - minimum (mm)*	*S - minimum (mm)*	*W - minimum (mm)*
1	16	18	38.6	28	40	18
2	22.4	25	55	40	56	25
3.2	28	3105	69.3	50	71	31.5
5	35.5	40	88	63	90	40
8	45	50	110	80	112	50
10	50	56	123.2	90	125	56
12.5	56	63	138.6	100	140	63
16	63	71	156.2	112	160	71
20	71	80	176	125	180	80
25	80	90	198	140	200	90
32	90	100	220	160	224	100
40	100	112	246.4	180	250	112
50	112	140	275	200	280	125
63	125	160	308	224	315	140
80	140	180	352	224	355	160
100	160		396	280	400	180

2.2.6 - Pins of shackles

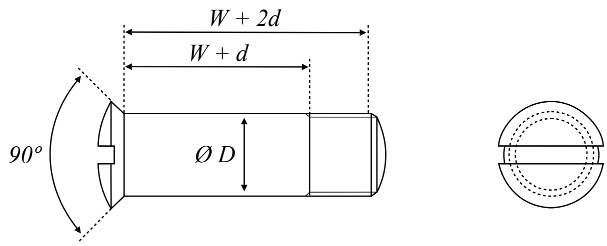
*- 1 - **Type W**: screwed with eye and collar.*



*- 2 - **Type X**: bolt with hexagon or round head, hexagon nut, and split cotter pin.*



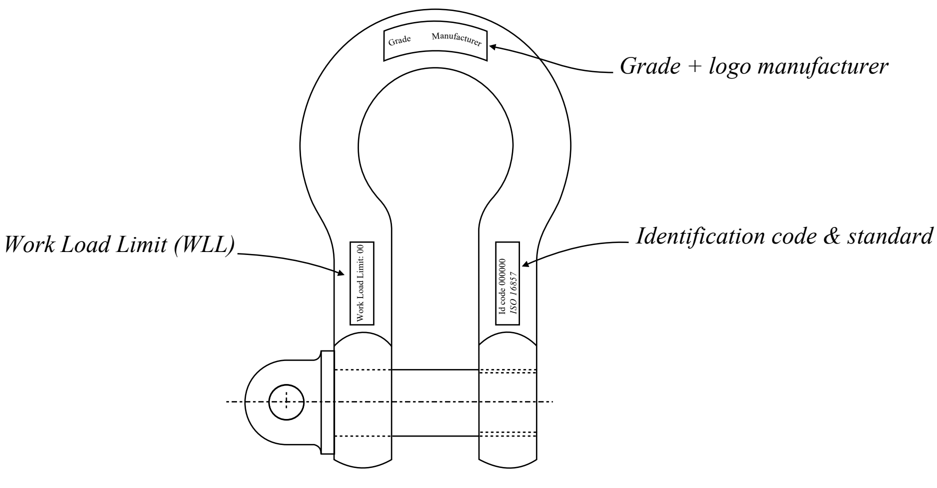
*- 3 - **Type Y**: countersunk and slotted head.*



- The diameters of pinholes of shackles should not exceed the following values:
  - For *D* <_ 20 mm, the hole diameter is (*D* + 1) mm.
  - For 20 mm < *D* <_ 45 mm, the hole diameter is (*D* + 1,5) mm.
  - For *D* > 45 mm, the hole diameter is (*D* + 2) mm.

2.2.7 - Marking

- Each shackle should be legibly and indelibly marked in a place where the marking will not be removed by use and in a manner that will not impair the mechanical properties. The marking should include the following information:
  - Working Load Limit in tonnes (if not metric tonne, it should be indicated whether it is long or short Ton).
  - The grade number (Should be “6”) and standard (CE).
  - The manufacturer's name, symbol or code.
  - The traceability code.
  - Pin above 13 mm should be marked with grade number, traceability code and manufacturer symbol.
  - Pin below 13 mm should be marked with at least the grade number and traceability code



2.3 - Inspection of shackles in service

2.3.1 - Before first use

The shackle corresponds precisely to that specified on the order.

The manufacturer's certificate is on hand.

The identification and Working Load Limit marked on the shackle correspond with the information on the certificate.

Full details of the shackle are recorded.

2.3.2 - When in use

A thorough examination should be carried out by a competent person at intervals not exceeding twelve months. This interval should be less where deemed necessary in the light of service conditions.

Records of such examinations should be maintained.

Shackles should be thoroughly cleaned so as to be free from oil, dirt, and rust prior to examination. Any cleaning method which does not damage the parent metal is acceptable. Methods to avoid are those using acids, overheating, removal of metal or movement of metal which may cover cracks or surface defects.

Adequate lighting should be provided and the shackle should be examined to detect any evidence of defects. The shackle should be withdrawn from service and referred to a competent person for examination if any defect is observed:

- The body and the pin of the shackle should be both identifiable as being of the same size, type and make;
- All markings should be readable.
- The threads of the pin and the body should be undamaged.
- The body and pin should not be distorted.
- The body and pin should not be unduly worn.
- The body and pin must be free from nicks, gouges, cracks and corrosion.
- The pin should be of the correct length so that it should penetrate the full depth of the screwed eye and should allow the collar of the pin to bed on the surface of the drilled eye. In all cases, when the pin is correctly fitted in the body of the shackle, the jaw width W should not be significantly reduced.
- Incorrect seating of the pin may be due to a bent pin, the thread fitting too tightly, or misalignment of pin holes.

Never replace a shackle pin except with one of the same size type and make as it may not be suitable for the loads imposed.

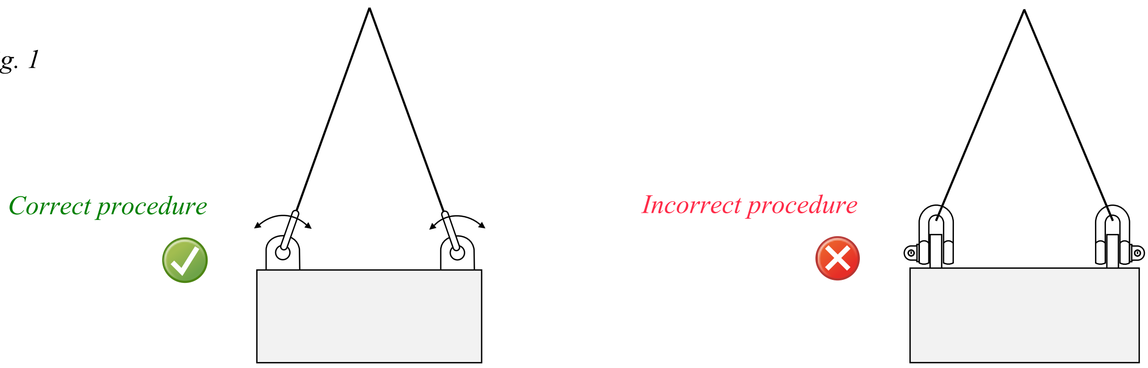
2.4 - Selection and use of shackles

It is essential that the mass of the load to be lifted is known. If the mass is not marked, the information should be obtained from the consignment notes, manuals, plans etc. If such information is not available, the mass should be assessed by calculation.

Select the correct type of shackle for a particular application from the information given in points 6.1 & 6.2.

Shackles should not be used in a manner that imposes a side loading unless specifically permitted by the manufacturer. In general this means that the shackle body should take the load along the axis of its centreline. *(See fig. 1 below)*

Fig. 1



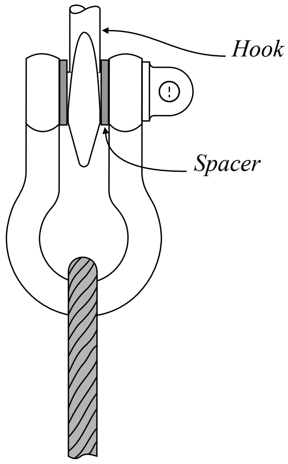
When using shackles in conjunction with multi-leg slings, due consideration should be given to the effect of the angle between the legs of the sling. As the angle increases, so does the load in the sling leg and consequently in any shackle attached to the leg.

When a shackle is used to connect two slings to the hook of a lifting machine, it should be a Bow type shackle assembled with the slings in the shackle body and the hook engaged with the shackle pin. The angle between the slings should not exceed 120°.

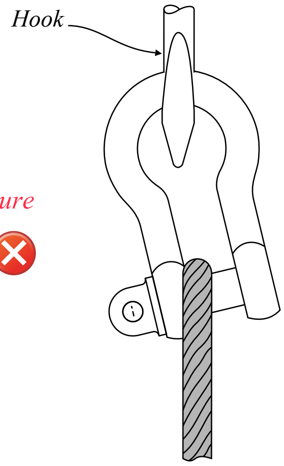
To avoid eccentric loading of the shackle a loose spacer may be used on either end of the shackle pin *(see Figure 2 below)*. Do not reduce the width between the shackle jaws by welding washers or spacers to the inside faces of the eyes or by closing the jaws, as this will have an adverse effect on the properties of the shackle.

Fig. 2

Correct procedure



Incorrect procedure

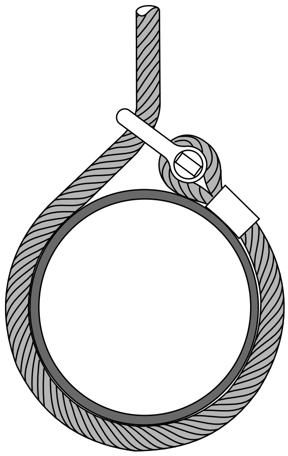


When a shackle is used to secure the top block of a set of rope blocks, the load on this shackle is increased by the value of the hoisting effect.

Avoid applications where due to movement, the shackle pin can roll and possibly unscrew *(see fig. 3 underneath)*.

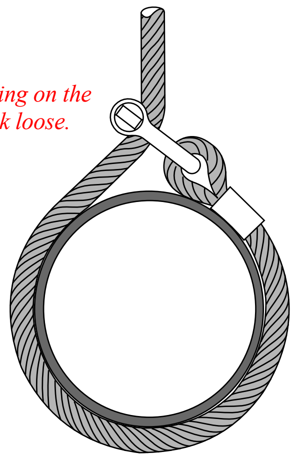
Fig. 3

Correct procedure



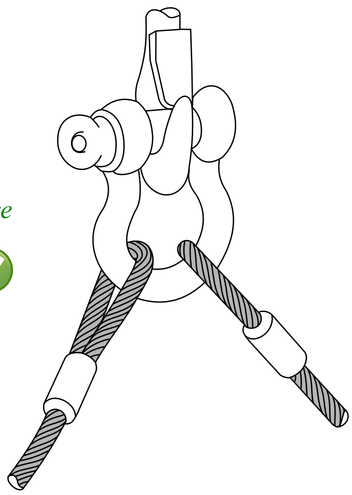
The shackle pin bearing on the running line can work loose.

Incorrect procedure

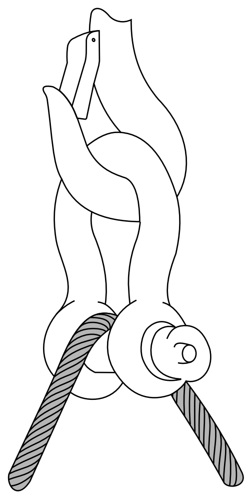


Avoid applications where the load is unstable *(see fig. 4 below)*

Correct procedure



Incorrect procedure



Important:

Type X pin should be used in priority for the following applications:

- Where the shackle is to be left in place for a prolonged period
- Where maximum pin security is required.
- For underwater lifting operations

Shackles should not be modified, heat treated, galvanised, or subject to any plating process without the approval of the manufacturer.

Shackles should not be immersed in acidic solutions or exposed to acid fumes or other chemicals without the approval of the manufacturer.

2.5 - Shackles designed to be operated by ROVs

Specific shackles have been developed for ROVs that can be opened using classical manipulators so that the pin is not designed to be screwed and is secured by one or more split pins or similar systems. Some models are provided with a handle allowing easy grabbing by the ROV manipulator and have their pin with a tapered end to allow for easy underwater assembly. It is the case of Example #1 below, designed by Green Pin (https://www.greenpin.com/en), and Example #2, designed by Crosby (https://www.thecrosbygroup.com/)
Other models, designed for release only, are provided with a compressed spring that ejects the pin when the split pin is removed, such as the model in Example #3 below, also sold by Green Pin.

Example #1
Tapered pin ROV shackle D
https://www.greenpin.com/

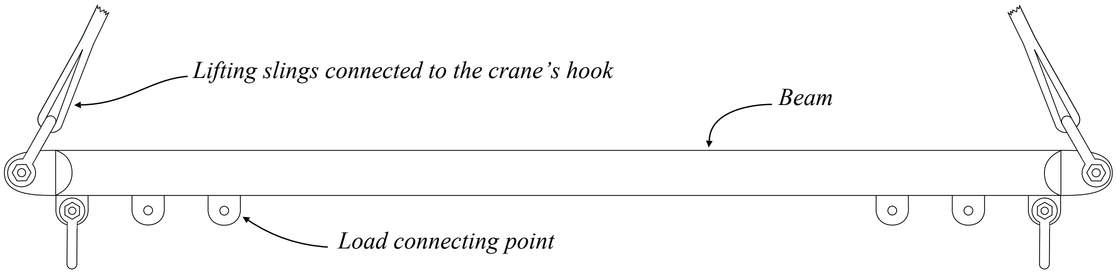
Example #2
Release & retrieve shackle
https://www.thecrosbygroup.com/

Example #3
Spring release ROV shackle
https://www.greenpin.com/

3 - Horizontal lifting beams & mattress installation frames

3.1 - General description

“Horizontal lifting beams”, also called “spreader bars”, are devices consisting of one or more members equipped with attachment points to facilitate the handling of loads that require support at several points. Depending on their function, they may comprise one or several beams handled by the centre or their sides with connecting points that can be fixed, as in the drawing below, or adjustable on some models. They are a wide variety of models. Some are specifically built for a particular type of application, and some are designed for a single operation.



Mattress installation frames are a category of lifting beams specifically designed to install protection mattresses on sensitive parts of an underwater installation that must be protected from dropping loads and all sorts of physical aggressions.

Lifting beams and mattress installation frames are covered by the European standard *EN 13155* “*Cranes - Safety - Non-fixed load lifting attachments”* and ASME B30.20 *“Below-the-Hook Lifting Devices”*

3.2 - Horizontal lifting beams

3.2.1 - Mechanical strength

“Lifting beams” cannot be built on the worksite to adapt to a situation at the last minute. They must be made according to safety norms from a recognized standardization body, and a certificate of conformity, which summary and references are indicated on an identification plate, must be issued by a certification body. They must be designed according to the following requirements:

- The components of the lifting beam to add or remove should be designed to be locked before lifting. These components must de designed to prevent dangerous conditions during the coupling or uncoupling phases.
- The attachment points should be designed to withstand the forces resulting from the load and the load + the frame for those connected to the crane. For this reason, they should withstand a static load of two times the working load limit without permanent deformation. Also, when the limit above is passed, and a permanent deformation occurs, they must be able to withstand a static load of three times the working load limit without releasing it. The mechanical strength of the ensemble should be comparable to the attachments and verified by calculation or a load test.
  Specific attachments systems should be designed such that they cannot move or fall and their state of locking or unlocking is visible.
- The lifting beam should be designed with tolerances of use that should be indicated by the manufacturer. EN 13155 says that lifting beams intended for horizontal use should tolerate a tilt of up to 6° from the horizontal.

3.2.2 - Procedures for use and marking

EN 13155 requires that the lifting beam’s manufacturer provides an instruction handbook regarding the methods for attaching the load, so the user is ensured that the combined lifting beam and load are stable when lifted. The information provided should identify the centre of rotation of the lifting beam to the crane, the centre of rotation of the suspension points to the load, and the vertical distance between them.

All lifting beams should bear, in a clearly visible place, a durable identification with the following information:

- The business name and full address of the manufacturer, and where applicable, his authorised representative.
- Designation;
- Serial number;
- The year of construction, that is the year in which the manufacturing process is completed.
- Working load limit in tonnes or kg. When the attachment is used in several configurations, the resulting working load limits shall also be indicated.

The certificate should indicate the references indicated above plus :

- The test references;
- The identity of the person authorized to sign the certificate on behalf of the manufacturer and date of signature.

3.2.3 - Maintenance and inspection frequencies

The manufacturer should indicate the inspections and verifications that are necessary before commissioning, after repair , and during the equipment’s service life. He should also provide sufficient information to ensure the proper maintenance of the attachment, that should include:

- Instructions for periodic maintenance.
- Instructions for repair.
- Precautions to implement during repairs.
- Recommendations regarding spare parts.
- The list of parts requiring particular operation and checking.
- The use of special lubricants.
- The maintenance records.

ASME B30.20 classifies the inspections to be organized as follows:

- Initial inspection:
  It is the examination to be performed before committing to service new, altered, or modified hoists.
- Pre-operation Inspection:
  The device should be inspected by the operator before and during every lift for any indication of damage.
- Frequent Inspection:
  They are visual inspections not required to be documented, that should be scheduled as follows:
  - Normal service: monthly
  - Heavy service: weekly to monthly
  - Severe service: daily to week

  They consist of examining the following:
  - Structural members for deformation, cracks, or excessive wear on any part of the lifter.
  - Loose or missing guards, fasteners, covers, or nameplates.

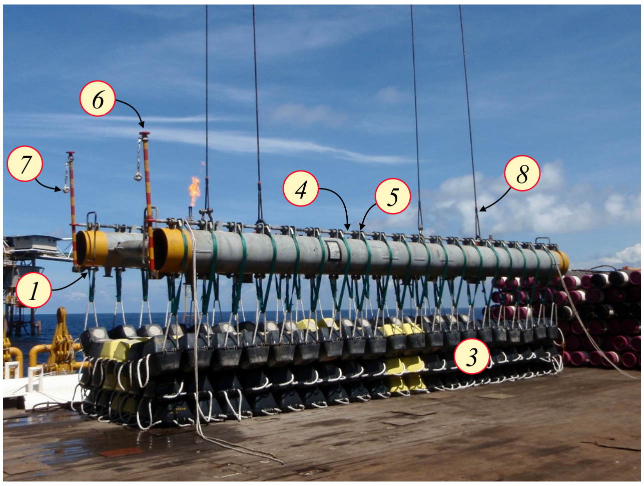
- Misadjustments interfering with operations
- missing or illegible operating control markings.

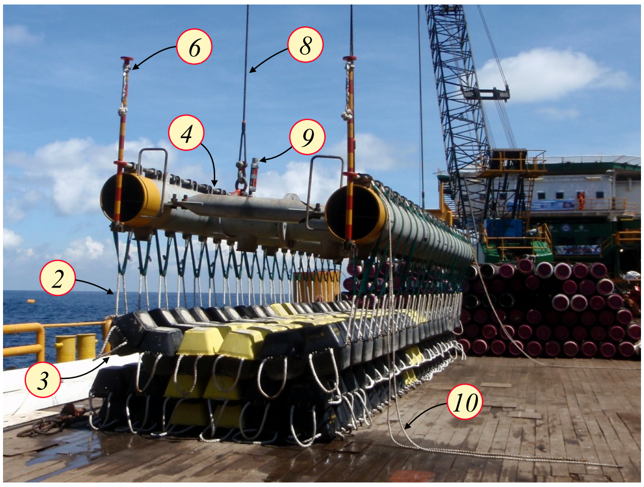
- Periodic Inspection:
  It is a documented visual inspection. It can be indicated by a coded mark on the device, and should be organized as follows:
  - Normal service - yearly:
    Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
  - Heavy service - semiannually:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
  - Severe service - quarterly:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The following elements should be inspected:
  - Evidence of loose bolts, nuts, or fasteners
  - Evidence of excessive wear.
  - Evidence of excessive wear at hoist hooking points and load support clevises or pins.
  - Missing or illegible product safety labels required.
- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

3.3 - Mattress installation frames

Mattress installation frames are used by divers and ROVs. As mentioned in the presentation, they are lifting frames specifically designed to install concrete mattresses on the seabed. These mattresses consist of square blocks of concrete linked to each other by ropes, resulting in a protection that follows the elements' shapes to protect and the bottom when laid. They should be built according to the same standards as spreader bars.
Their most common mechanism consists of slings passing through the ropes holding the mattress with one end secured to a fixed point of the frame and the other end's loop secured by sliding pins. These sliding pins are welded to a main sliding bar installed on the top of the frame. The divers or the ROV trigger the opening of these locks by pulling on a lever attached to the main sliding bar to open all the sliding pins simultaneously. As a result, the extremities of the slings previously secured by the sliding pins are freed. The crane operator then slowly lifts the frame to release the slings from the mattress ropes before recovering the frame to the surface on the instruction of the diving or ROV supervisor.





1 - Fixed point sling	*3 - Mattress*	*5 - Sliding pin*	*7 - Rope ball grip*	*9 - Beacon*
2 - Rope mattress	*4 - Sliding bar*	*6 - Lever*	*8 - Lifting sling*	*10 - Tag line*

The maintenance process of these devices is similar to spreader bars. The sliding bar and pins must be lubricated before each mattress installation. It is recommended to use motor oil, or better, a specific oil or grease instead of regular motor grease that will become stiff and sticky in the water, disturbing the movement of the sliding bar by the divers or the ROV.

Page left Blank intentionally

D - Hand-powered lifting devices

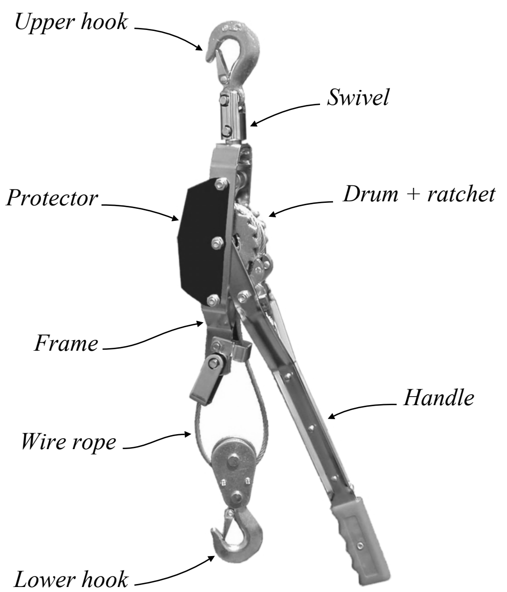
This part specifies requirements for the following hand powered lifting equipments

1. Lever hoists
2. Hand chain blocks
3. Jaw winches
4. Drum winches
5. Pulley blocks and deflection pulley

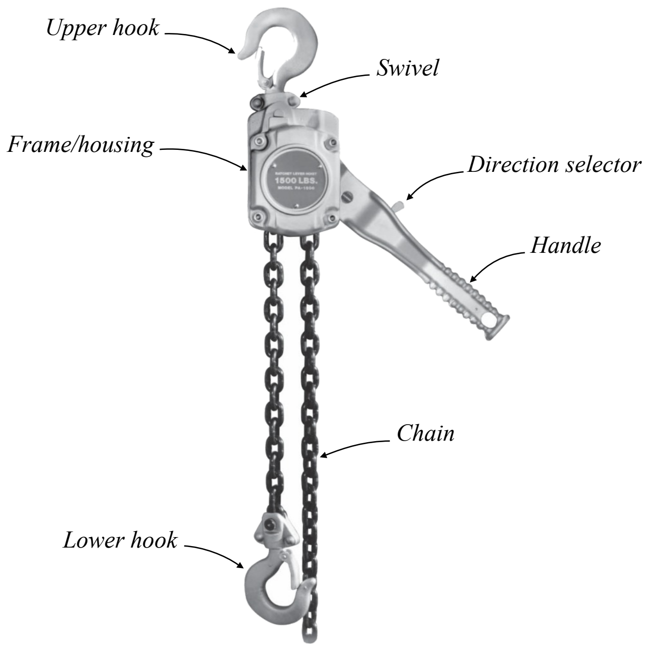
1 - Lever hoists

1.1 - General description

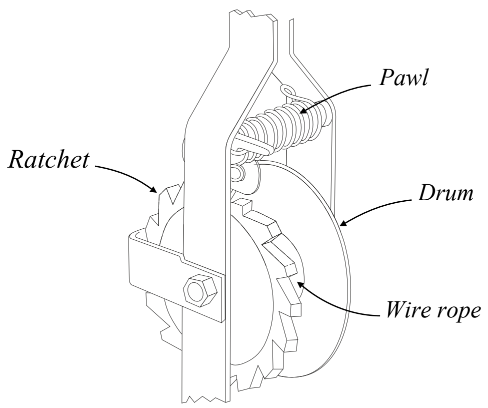
Lever hoists are devices designed for lifting and lowering a load suspended using human effort applied to a lever and holding it using a braking device. These lifting devices, also commonly called "come along", are usually built according to the standards "EN 13157 " and "ASME B30.21," which also provide guidelines regarding their maintenance. Lever hoists using chains, wire ropes, ropes, and webbing are described in these two standards, which recommendations should be considered as references.
The same guidelines and standards cover their use above the surface as those of cranes, as they are considered lifting devices. However, their use underwater requires additional working and maintenance precautions to be implemented.
The working principle of these devices consists of a lever acting on a load sheave or a drum through gears. A ratchet maintains the load in position between two lever movements, which is the reason these devices are called "Ratchet lever hoists" by some manufacturers. Depending on the system, friction brakes keep the load in place, in addition to the ratchet.

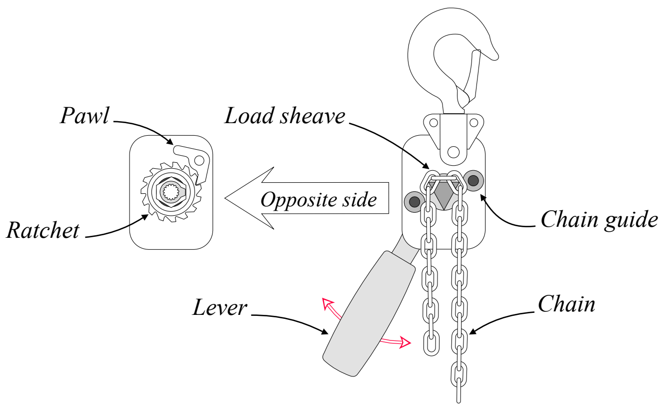


Lever operated wire rope hoist



Lever operated chain hoist





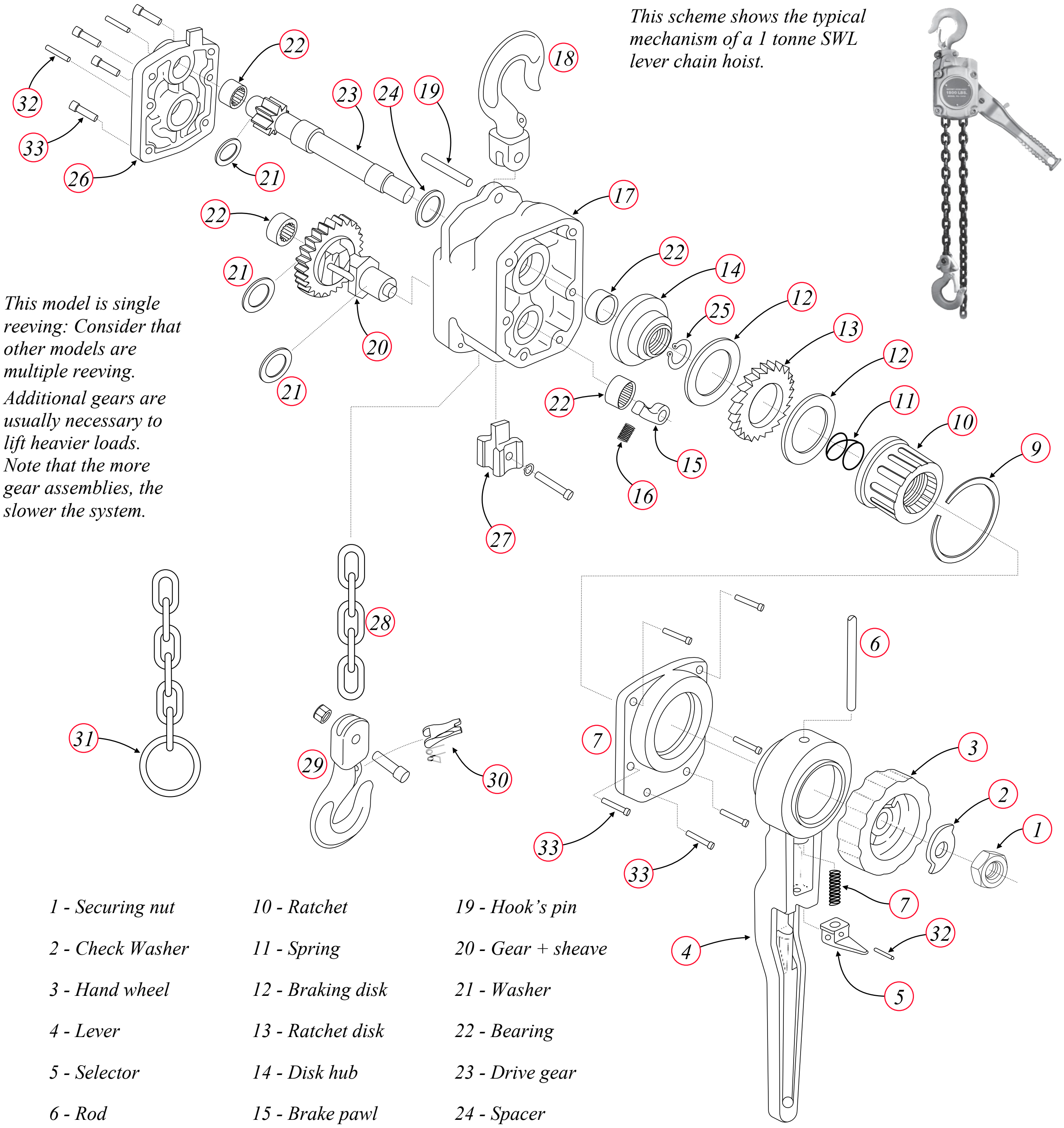
Based on the above, we can see that the mechanisms of lever hoists using chains differ from those using wire ropes, also used for ropes and webbing. Thus we must consider that even though they can be used for similar tasks, their design difference results in their being employed differently. Both systems have their advantages and inconvenience, and for this reason, they complement instead of competing.

1.2 - Design and construction requirements

Choosing the right equipment and implementing associated safety procedures implies knowing how they are designed and the construction requirements from standardization bodies. For this reason, this part is based on EN 13157 & ASME B30.21 standards, in addition to manufacturers' brochures. Note that these standards do not conflict.

1.2.1 - Lever operated chain hoists

The lever-operated chain hoists models commonly sold are capable of lifting from 500 kg to 10 tonnes, using drive chains or classical welded-link chains.
These lever hoist systems are designed to transmit the muscular energy of the operator to the lifting chain through a lever (see #4) that action a shaft (see #23), gears, and the load sheave (#20). The number of gears depends on the weight the device can lift. Bearings (see #22) are in place for the smooth rotation of the shaft and gears. A ratchet (#13 + #15) allows moving the shaft in the selected direction (lifting or lowering) and keeps it static when the operator does not act the lever.
A selector (#5), positioned on the handle, allows the operator to select the direction of the move or be neutral to run the chain through freely and thus adjust it in length quickly. Braking disks (#12) are pressed to the disk hub (#14) to control the load's lowering and keep it static when the lever is not operated.



This scheme shows the typical mechanism of a 1 tonne SWL lever chain hoist.

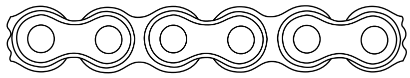
This model is single reeving: Consider that other models are multiple reeving.

Additional gears are usually necessary to lift heavier loads. Note that the more gear assemblies, the slower the system.

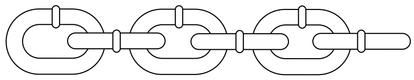
1 - Securing nut
2 - Check Washer
3 - Hand wheel
4 - Lever
5 - Selector
6 - Rod
7 - Spring
8 - Housing cover
9 - Securing ring
10 - Ratchet
11 - Spring
12 - Braking disk
13 - Ratchet disk
14 - Disk hub
15 - Brake pawl
16 - Spring
17 - Housing
18 - Top hook
19 - Hook's pin
20 - Gear + sheave
21 - Washer
22 - Bearing
23 - Drive gear
24 - Spacer
25 - Snap ring
26 - Housing cover
27 - Chain stripper
28 - Chain
29 - Bottom hook
30 - Latch kit
31 - Chain stopper
32 - Roll pin
33 - Screw

The selection of the chain depends on the area the device is planned to be used.

- Drive chains are typically utilized to transfer mechanical energy from an engine or an electrical motor. They are commonly found on bicycles, motorbikes, engines, and many industrial applications where energy transfer is required without loss. They usually consist of several short cylindrical rollers connected by side links and driven by a toothed wheel known as a sprocket.



- The welded chains described by ISO and ASME are also called “oval welded chains“ by manufacturers. They are the classical chains used for mooring applications or to fabricate slings. They are made of round steel bars cut at the necessary lengths, heated to be processed into chain links, bent, assembled to form the chain, welded, aligned, and heat treated. They are driven by a load sheave.



There is no difference regarding the maximum load that models equipped with welded or drive chains can withstand on manufacturers' catalogs selling lever hoists that can be used with the two types of chains. The difference is that drive chains are initially designed to transmit energy (99% of the energy transferred) and are, of course, more efficient than classical welded chains regarding this point. However, these chains have no lateral flexibility and, thus, must be perfectly aligned. Also, they require lubrification, and are more expensive than classical welded chains. These inconveniences explain why lever hoists with welded chains are more common on diving worksites.

ASME B30.21 & EN 13157 give the following construction requirements:

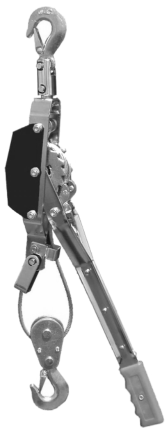
- Mechanical strength:
  The device must be designed to withstand all stresses imposed under normal operating conditions while handling loads within the rated load.
  - EN 13157 requires that they can be operated within an ambient temperature range of - 10°C to + 50°C.
  - ASME B30.21 says that the load suspension parts of lever hoists must be designed so that the calculated static stress for the rated load shall not exceed 25% of the minimum ultimate tensile strength, which corresponds to the minimum safety factor of 4:1 required by EN 13157, and applied by most manufacturers.
  - In addition, EN 13157 requires that the lever hoist is designed to withstand 1 500 cycles with 110% of the rated capacity with no failure, replacement of parts, and no resting time, except for lubrication.
  - ASME B30.21 also says that visible warnings of severe overload by permanent deformation while operating the hoist should be designed to show obvious deformation before other load suspension parts fail.
- Braking & load controlling mechanism:
  The hoist must be equipped with a mechanism allowing a full control of the load.
  - EN 13157 requires that the lever hoists have an automatic braking function that operates when the operating force ceases, whether the motion is lifting or lowering. The braking device must allow for a regular descent automatically controlled whatever the position of the load, which also conforms with ASME requirements. In addition, EN 13157 says that the fracture of a spring must not lead to a failure of the braking system. ASME adds that the brake mechanism must be adjustable.
  - Free spooling must be possible only when the lever hoist is not loaded. EN 13157 requires that the brake system automatically applies when the load is greater than 30 kg for capacities up to 1 000 kg and greater than 3% of the rated load above 1 000 kg. The brake system must be designed not to allow the load to descend more than 300 mm before acting, and it must not be possible to declutch or disengage the chain wheel, the drive shaft, and other components.
  - To comply with environmental and health requirements, EN 13157 says that the brake systems must not contain asbestos.
- Operating efforts:
  The lever hoist should be designed not to require too much effort from the operator. For this reason, EN 13157 requires that the operating effort on the lever should be less than 55 daN at the end of the lever. However, the system must be designed for a minimum effort, not less than 20 daN. If it is the case, a protection system against overloading caused by excessive operating effort on the lever must be provided. (Note that 1 daN = 1.02 kgf)
- Protection:
  The gears of the lever hoist are to be protected. It is usually done by closed housings.
  EN 13157 also says that there should not be sharp ends that can injury the operator.
- Loading chains:
  The chains must comply with recognised standards. Also it must be installed such to prevent disfunction.
  - ASME B30.21 requires that welded chains are specifically designed. Also, that roller load chains comply with ASME B29.24 “Roller load chains for overhead hoists”. EN 13157 requires to refer to EN 818-7 “Fine tolerance short link chains (grade T)”, and ISO 606, “Short pitch transmission precision roller chains and chain wheels”. In addition, ASME B30.21, requires that the chains provided by the manufacturers are proof tested with a load at least equivalent to l ½ times the hoist's rated load divided by the number of chain parts supporting the load.
  - The load chain must be provided with an over-travel restrain to prevent it from running out of the hoist. ASME says that it must be able to withstand an operating lever force of twice the force required to lift the rated load.

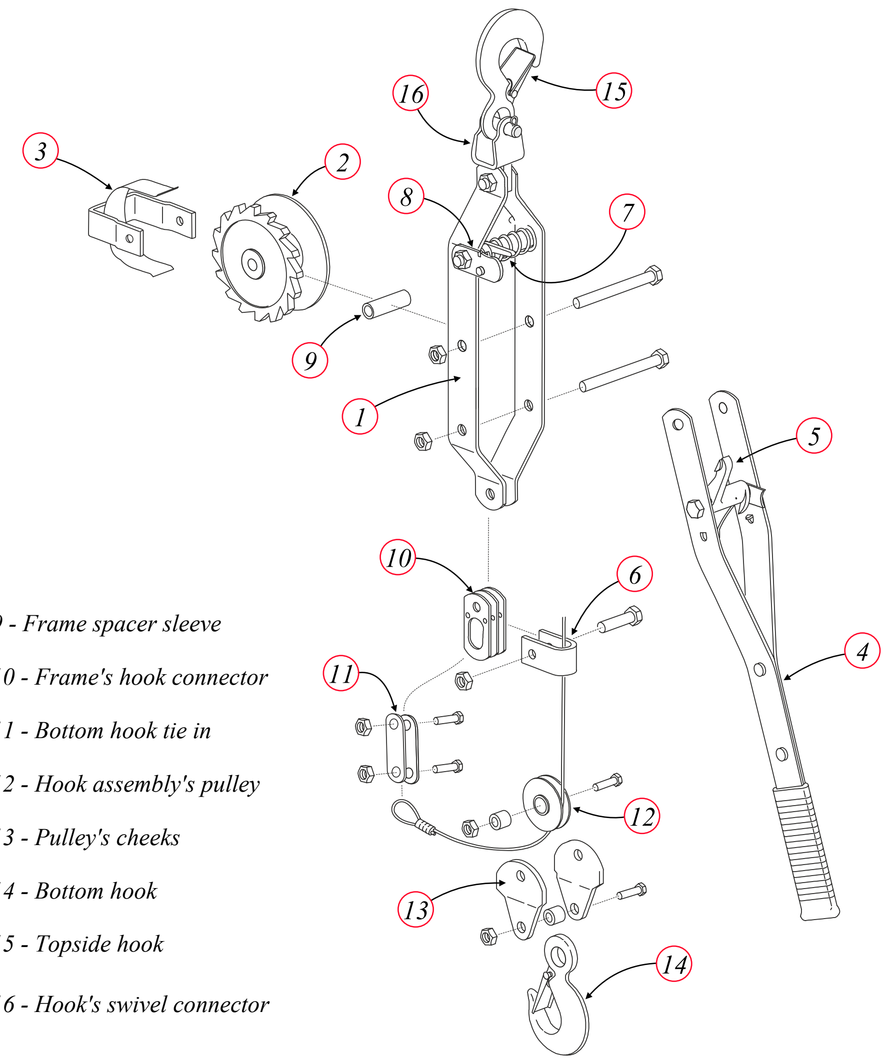
- The chain must be guided to prevent the load chain from jumping off. EN 13157 requires chain guides to be in place for this purpose. They should be made in one piece.
- ASME B30.21 requires that the load chain links that pass over the hoist load sprocket on edge (alternate to those that lie flat in the pockets) shall be installed with the welds away from the centre of the sprocket unless otherwise recommended by the hoist manufacturer. This precaution is not required in idler sprockets that change the direction but not the tension in the chain.

- Hooks
  Hooks must comply with recognized standards and, thus, be fitted with safety latches to prevent unintentional detachment. Regarding this point, refer to the dedicated chapter about hooks in this document.
  EN 13157 requires top hook must be capable of swivelling. ASME B30.21 add that swivelling hooks should rotate freely.
- Marking
  The hoist must be marked with at least the following information
  - The name and address of the manufacturer, the model, serial number, & year of manufacture.
  - The safe working load, direction of movement, and if applicable, the direction of winding of the rope.
  - Basic safety requirements regarding the correct use of the tool

1.2.2 - Lever operated wire rope hoists and lever operated rope or webbing hoists

As suggested in point 1.1, ”General description”, lever-operated wire rope hoists use a similar mechanism to lever hoists operating with webbing or ropes. Thus, many models use wire ropes, webbing, or synthetic fibre ropes with only minor modifications. The models commonly sold are limited to 3 tonnes for the more powerful.
These systems' mechanisms are more straightforward than those of the lever chain hoists and consist of a drum (see # 2) into which the wire rope (or webbing or synthetic fibre rope) is spooled. This drum is provided with one or two ratchets and is operated by the handle (see #4). A dogging system (see #7) prevents the ratchet from moving back while the device is under load. There is no friction brake system on such devices. So, to lower the load, the operator pushes the handle to operate the driving dog (see #5), which opens the dogging only tooth by tooth. As a result, lowering a charge is done safely but is quite long. It is the reason these tools are mainly used to pull. The operator's force is multiplied by the length of the handle, the small diameter of the ratchet the handle acts, and the pulley above the bottom hook, as there is usually no gear with such systems. Note that the pulley above the hook can be removed to use a longer cable length. In this case, the multiplication of the force it provides is lost. Free spooling can be obtained when the system is not under load by operating the dog assembly handle (see #8).





1 - Frame | *9 - Frame spacer sleeve*
2 - Drum + Ratchet | *10 - Frame's hook connector*
3 - Drum guard | *11 - Bottom hook tie in*
4 - Handle | *12 - Hook assembly's pulley*
5 - Driving dog | *13 - Pulley's cheeks*
6 - Rope guide | *14 - Bottom hook*
7 - Dogging system | *15 - Topside hook*
8 - Dog assembly's handle | *16 - Hook's swivel connector*

The selection of the lifting rope of the lever hoist depends on the application for which the lifting/pulling device will be selected. Wire ropes are reputed to offer good wear and temperature resistance. In addition, they are less easily cut by sharp surfaces than textiles ropes and are easy to store on the drum. They remain the most employed with these types of lever hoists. However, they are sensitive to corrosion that may not be visible from the external, and surface damages may result in wires constituting the strands being cut and becoming sources of injuries if the device is handled without reinforced gloves. Synthetic ropes and webbing do not have this inconvenience and are not sensitive to corrosion despite the fact they are more susceptible to wear and can be more easily cut by sharp objects.

As for lever chain hoists, ASME B30.21 & EN 13157 require that these tools offer a minimum safety to the operator. For this reason, they must be built according to the same guidelines, the only difference being the specifications resulting from their mechanisms:

- Mechanical strength requirements are exactly the same as lever chain hoist:
  The device must be designed to withstand all stresses imposed under normal operating conditions while handling loads within the rated load.
  - EN 13157 says that they must be designed to be operated within an ambient temperature range of - 10°C to + 50°C, and also designed to withstand 1500 cycles with 110% of the rated capacity with no failure, replacement of parts, and no resting time, except for lubrication.
  - They must be designed with a minimum safety factor of 4:1
  - ASME B30.21 also says that visible warnings of severe overload by permanent deformation while operating the hoist should be designed to show obvious deformation before other load suspension parts fail.
- Braking system and load control:
  As mentioned above, these systems are not fitted with friction brakes. Thus the braking is provided by the dog of the ratchet that must operate automatically when the operator cease acting the lever and whether the motion is lifting or lowering.
  - The braking device must also allow a regular and controlled descent, whatever the position of the load, and the failure of a spring must not lead to the failure of the brake.
  - Free spooling must be possible only when the lever hoist is loaded. EN 13157 requires that the brake system automatically applies when the load is greater than 30 kg for capacities up to 1 000 kg and greater than 3% of the rated load above 1 000 kg. The brake system must be designed not to allow the load to descend more than 300 mm before acting, and it must not be possible to declutch or disengage the chain wheel, the drive shaft, and other components.
- Operating efforts:
  As mentioned previously these devices usually have no gears, so the multiplication of the force result from the size of the lever and the ratchet it operated. However, similarly to lever chain hoists, these models should be designed not to require too much effort from the operator and, thus, comply with the requirement of EN 13157 that requires that the operating effort on the lever should not be above 55 daN, and not less than 20 daN. If it is below the minimum required, a protection system against overloading caused by excessive operating effort on the lever must be provided. (Note that 1 daN = 1.02 kgf)
- Protection:
  As for lever chain hoists, the mechanism must be protected, and there should not be sharp ends that can injury the operator.
- Drum:
  ASME B30.21 does not provide specific information regarding the drum. This point is more covered by EN 13157 that request the following:
  - For lever hoists with wire rope, the D/d ratio for the drum must be at least equal to 10.
  - The pitch circle diameter of the sheave groove (D) must be at least 12 times the nominal diameter of the wire rope (d).
  - The angle of the sheave groove for wire rope must be between 45 ° and 55 °.
  - The radius of the sheave groove for wire rope must be between d/2 + 5 % and d/2 + 10 %.
  - The depth of the sheave groove for wire rope must be at least 1,5 times the nominal diameter of the rope.
  - The ratio of the belt sheave and the drum diameter to the rated webbing thickness must not be less than 15 ($D/s \geq 15$, where "s" is the thickness of the webbing) .
  - The groove of the sheave for fibre rope must be rounded, with a radius at least equal to half of the fibre rope diameter.
  - A rope guide system must be fitted to ensure that the rope stays in the sheave's groove, whatever the conditions.
  - The projection of the drum flanges, when the maximum design length of rope or webbing has been fully wound onto the drum, must be at least 1,5 times the rope diameter or webbing thickness.
- Wire ropes and synthetic fiber ropes:
  Note that ASME B30.21 groups the two types of ropes where EN 13157 separates them.
  - ASME B30.21 does not provide specific requirements regarding standards, and says that they must be selected by a competent person. At the opposite, EN 13157 says that wire ropes must conform to EN 12385-1, and EN 12385-4. EN 13157 also requires that the minimum breaking strength must be at least equal to 3 for wire ropes, and equal to 7 for synthetic fibre ropes.

- Wire ropes supplied in single lengths with splices or connections only at the ends. Regarding rope end terminations, EN 13157 says that they should withstand at least 85 % of the minimum breaking force of the rope. Wire rope grips are forbidden for this purpose, and only the following systems can be used:
    - Asymmetric wedge socket (EN 13411-6),
    - Symmetric wedge socket (EN 13411-7) for ropes up to 8 mm diameter,
    - Metal and resin socketing (EN 13411-4)
    - Ferruled secured eyes using thimbles (EN 13411-3 & EN 13411-1)
- In addition, ASME B30.21 says that the rope ends must be attached to the hoist, so disengagement is impossible. Also, at least two wraps on the drum must remain when the rope is fully extended. Regarding this point, EN 13157 adds that the rope anchor on the drum must withstand at least 2,5 times the rope's nominal forces and not be kinked. The friction coefficient must be taken into account. For wire ropes, it should not be more than 0.1.

- Webbing:
  The anchoring of webbing to the drum must be done similarly to ropes. Also, the coefficient of utilization for load-bearing webbing must be at least 7
  A system should prevent the webbing from being wound onto the drum in the wrong direction.
  ASME B30.21 says that a means shall be provided to equalize the tension on all parts if a load is supported by more than one part of web strap.
- Hooks
  Hooks are of similar models as those of lever chain hoist. Thus, they must comply with recognized standards, and be fitted with safety latches to prevent unintentional detachment. Again, refer to the dedicated chapter about hooks in this document.
  EN 13157 requires top hook must be capable of swivelling. ASME B30.21 add that swivelling hooks should rotate freely.
- Marking:
  Similarly to lever chain hoists, the marking must provide at least:
    - The name and address of the manufacturer, the model, serial number, & year of manufacture.
    - The safe working load, direction of movement, and if applicable, the direction of winding of the rope.
    - Safety requirements regarding the correct use of the tool

1.2.3 - Lever hoists designed to work underwater

Lever hoists have been used within maritime environments and underwater for a long time. However, most models are not initially designed for operations in such surroundings, which results that they can be affected by the corrosion of their internal parts, and the decomposition of the braking disks that are not designed for prolonged exposure to water.
It must be noted that these problems are mostly reported with chain hoists. This is mainly due to the complexity of their mechanisms that involve multiple gears, bearings, springs, snap rings, breaking disks, pins, etc., not initially treated for such exposure. It is also due to the fact that these devices are more used than other types of lever hoists. That has resulted in multiple failures that gave rise to incidents involving load falling while divers were working to install them.
For these reasons, in addition to specific operational precautions, explained in the following sections, regarding the maintenance of such devices when used underwater, it has become evident that specific lever hoists for underwater applications had to be studied.
Two main strategies have been proposed by the manufacturers regarding lever chain hoists:

- Protect the mechanism of the lever chain hoist in a sealed housing so its sensitive parts are not exposed to water. This system has the disavantage that water intrusion may happen if the tool is used at deeper depths than the one it is designed for.
- Treat all the components of the lever chain hoist against corrosion, install friction disks that are designed for prolonged exposure to water, and use water resistant lubricants. This procedure removes the limitation in depth. However, the lever hoist’s mechanism can be exposed to the intrusion of mud and sand, which may happen if the tool is left on the sea bottom or used in muddy water.

These lever hoists are submitted to the same tests as standard lever hoists not designed for underwater operations regarding their regular use, such as lifting and pulling (if designed for being used horizontally).
However, during the certification phases, manufacturers are required to test their lever hoists according to ASTM B117 “Standard practice for operating salt spray (fog) apparatus”. As suggested by the title, the purpose of this standard is to provide a controlled corrosive environment that is used to produce relative corrosion resistance information for specimens of metals and coated metals exposed in a given test chamber.
The fog chamber consists of a specific room, a salt solution reservoir, a supply of suitably conditioned compressed air, one or more atomising nozzles, specimen supports, provision for heating the chamber, and necessary means of control. The standard describes the preparation of the test specimens, salted solutions, air supply pressure (from 0.83 bar to 1.24 bar), and temperature (from 46 to 49°C). The competent person in charge of the device's certification decides the exposure time so that he can obtain the desired corrosive surrounding, which is expected to be close to the conditions the specimen will be exposed to. After this test, the device is considered suitable for use in a salty environment.
Additional tests include exposure at depth for extended periods to ensure the equipment can withstand a minimum time under such conditions. These tests are usually performed by classification bodies that deliver the certificate and the maximum duration of exposure of the device to underwater conditions.

1.3 - Operational practices

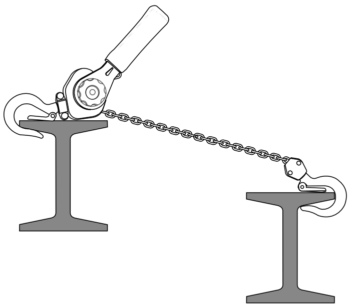
This section describes only lever hoists specific practices. Therefore, this section does not describe general operational practices applicable to all lifting operations. These rigging practices depend on whether the lever hoist is a lever operated chain hoist or a lever operated wire rope hoist. It also depends on the surrounding, as diving and ROV teams use them in marine environments and underwater, which implies saltwater and sometimes mud intrusion within the mechanisms.

1.3.1 - Lever operated chain hoists

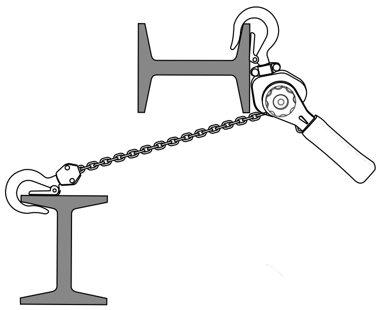
The operational procedures of these lever hoists may depend on whether they can be used horizontally.
It must be noted that most classical lever chain hoists are not designed to be used horizontally. In this case, the chain tends to jam and may block the system. That was a well-known problem of divers using them for tasks like flange matching, where it is common to use such devices horizontally to approach the flanges gradually. However, apart from these specific operations where such lever chain hoists were not used in the recommended position, because of the absence of more adapted tools, using lever hoists for horizontal and angled operations is not recommended if the device is not designed for this purpose.
It must be noted that many new models designed for underwater operations can work horizontally, as their designers have taken into account the fact that divers often need to use them in such positions and reinforced the roller guides so that jamming is not possible and that the tool can be used in any orientation.
To summarize, if the lifting operations involve using such tools angled or horizontally, ensure that the manufacturer of your device has designed it for this purpose.

Another critical point is that these devices are designed to be connected to proper connectors and slings, with the latches closed and secured. Also, these tools are designed to work in line. Using them to work sideways can damage the hooks, the housing, and sometimes the mechanism. Also, the chain is not intended to be used as a sling. Thus, choking loads with the chain may also damage it and the hook.
The drawings below show examples of incorrect practices encountered on worksites:

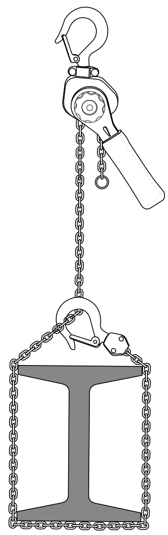
- Example #1 shows hooks that are incorrectly connected, with the latches not closed and the system not working in line. That may result in damage to the hooks and the housing.
- Example #2 also shows incorrectly connected hooks, with the latches not closed and the system not working in line. In addition, the chain has an improper angle and works against its guides. That results in difficult or impossible pulling and damage to the chain, the guides, the sheave, and the housing.
- Example #3 shows the chain of the lever hoist used as a sling and choked around a beam with sharp edges. That may result in damage to the chain and the hook.



Example #1

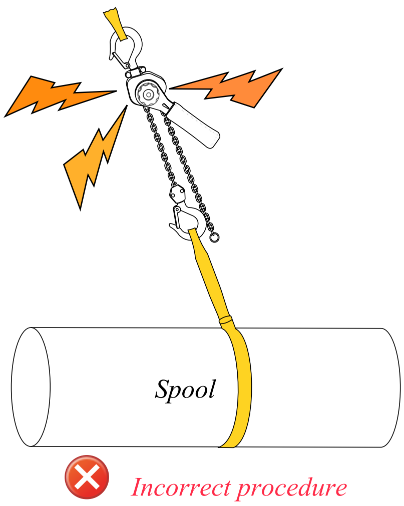


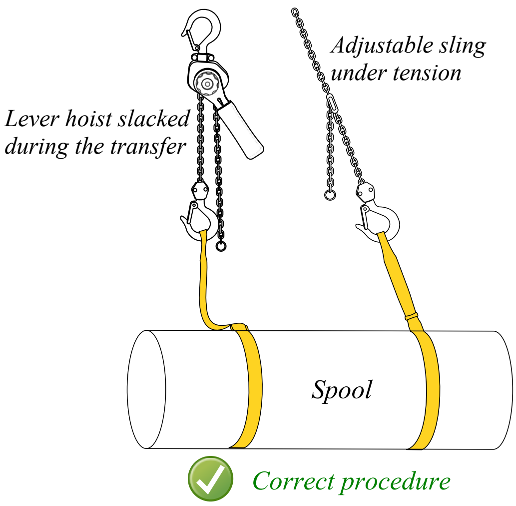
Example #2



Example #3

Some teams often use lever hoists as adjustable slings to ensure that large pieces, such as connecting spools, are transferred flat. Such practices are dangerous as, according to EN 13157, the lever hoists are designed with a safety factor of 4:1 which is too weak to withstand the dynamic forces created during the transfer, and the manufacturers strictly recommend not using them for this purpose. Adjustable slings can be used to replace them advantageously.





Lever chain hoists must be used as they are designed:

- The lever is designed for an effort of the operator not above 55 daN and not less than 20 daN. This effort is sufficient to lift the maximum load the lever hoist is designed for. For this reason, it must not be extended and be operated by only one person. An extension would multiply the operator's force, resulting in the temptation to use the tool for loads it is not designed for. The maximum capacity of the equipment must never be exceeded.
- Linked to above, some lever hoists are also designed for minimum weights below which they should not be used (remember the rule of "not less than 20 daN"). For this reason, clarifications should be obtained from the manufacturer regarding this point. In addition, consider it not advisable to use a device designed for 5 tonnes to lift a weight of 100 kg. The range of the working load limits of the devices sold by the manufacturer, so its range of lever hoists (for example, 1 t, 2 t, 3 t, 5 t …) is also an indicator.
- Lever hoists are usually not designed for personnel transfer.
- A load must not be shared between several lever hoists unless approved engineering calculation requests it.

ASME B30.21 says that the supporting structure or anchoring means must be able to support the load imposed by the hoist. It is also recommended to add an adjustable static rigging as a backup when the tool is used in conditions where its failure can result in injuries or damages.

ASME B30.21 & HST 3 recommend not to leave a loaded hoist unattended at the end of a work shift or for extended periods during the work shift.

Lever chain hoists must not be left on the sea floor where sand and mud can enter and damage them. This point is valid for all types, including the models designed to work underwater.

In the answers to questions at the end of ASME B30.21, it is said that a brand new lever hoist should be load tested before being put into service.

1.3.2 - Lever operated wire rope hoists and lever operated rope or webbing hoists

The problem with selecting these devices is similar to lever chain hoists for opposite reasons: Some lever wire rope hoists (synthetic rope or webbing hoists) models are not designed for lifting tasks and are often sold under the name "Ratchet puller". However, some manufacturers use this terminology instead of "Lever hoist" for equipment also designed to lift, which is often confusing, as the device description on their catalogs is sometimes unclear. For this reason, before starting lifting operations, it is advisable to ensure that the model available can be used for the intended task.

These lever hoists are also designed to work aligned with the load. Thus the requirements regarding hooks' connection and the load line angle are the same as those of lever chain hoists. However, the models with frames made of plied steel (as in the photo) are more sensitive to deformation than those made of moulted or welded steel or the housings of lever chain hoists. A lever wire rope hoist, with a deformed frame should be removed from service.

As mentioned before, synthetic ropes and webbing can be damaged by sharp objects, so precautions have to be implemented to preserve them.

The precautions regarding the length of the handle, that must not be modified, and operated by only one person are the same.

The load line must be of the model recommended by the manufacturer. As for chain lever hoists, manufacturers recommend not using them as slings.

It is also recommended not to use these lever hoists as adjustable slings to ensure that large pieces, such as connecting spools, are transferred flat. The procedure of substitution described for lever chain hoists applies to lever wire rope hoists.

Similarly to lever chain hoists, the supporting structure or anchoring means must be able to support the load imposed by the hoist.

Despite they have simpler mechanisms than lever chain hoists, these devices must not be left on the sea floor where sand and mud can enter and damage them.

They should be load tested before being put into service.

1.3.3 - Operational considerations

It must be noted that lever hoists usually have limited load line length. Lever chain hoists are generally limited to 3 m, and lever wire ropes can be used up to 6 m if used with single reeving, which divides their lifting/pulling performance by two. Thus, we can consider them suitable for short-distance lifting or pulling. Nevertheless, Jaw or drum winches should be preferred for long-distance lifting or pulling.

Some diving contractor organizations say that their affiliates complained that lever hoists designed for underwater activities had presented signs of failure. Although these tools are perfectible due to the fact that this generation of lever hoists has been created recently, they should be preferred to "classical" models for underwater operations as they are reinforced against the effects of corrosion and overloads. Also, most are studied to work in any orientation, which is an advantage. However, they should not be considered magical tools, and their utilization and maintenance procedures should be identical to classical units.

Despite their simpler mechanisms, lever rope & saddle hoists are underestimated by diving and ROV teams. Even though they are not as smoother as lever chain hoists for lifting and lowering tasks, they are more efficient for horizontal and angled pulling tasks as they do not have problems with jammed chains. Also, their mechanism accepts to work in rough conditions and can be easily cleaned and checked underwater as most parts are visible from the external. Their only problem is their limitation to two tonnes for most models and three tonnes for the most efficient ones.

Lever hoists with drive chains perform smoother lifting and lowering than those using welded chains. However, as mentioned previously, these chains require regular lubrification, so these devices should not be used at sea and underwater.

Select quality tools is also essential for marine and underwater operations. In addition to the risks of an accident linked to failures, unreliable tools may result in loss of time and, thus, money. For example, consider the daily cost of a dynamic positioning vessel and how ridiculous it would be to be stuck by a tool 10000 times cheaper.

Linked to above, it is advisable to have several new lever hoists in the store.

Standardizing the models used to ensure that the personnel is familiar with them is also advisable. Using the same models avoids losing time explaining how they work to the team. That also has the advantage of minimizing the number of spare parts stored for maintenance.

1.4 - Maintenance

The maintenance of lever hoists depends on the frequency of use and the conditions of use. ASME B30.21 provides guidelines regarding this point on which many manufacturers have built their recommendations. However, these guidelines apply to lever hoists not used underwater. Considering that underwater works are performed in an environment aggressive for mechanical parts, it will be necessary to reinforce the frequency of inspection and preventive maintenance of the devices submitted to such working conditions.

1.4.1 - Competent personnel

The maintenance of lever hoists involves troubleshooting, periodic inspections, preventive maintenance, and commissioning procedures before returning the device to service. It is therefore essential that the technician in charge has the technical level for these tasks. ASME provides the following examples of source of training material:

- Information outlined in the manual provided with the equipment. Note that this documentation is mandatory.
- Information from trade associations
- Government training resources such as labour and educational ministries
- Organized labour groups
- Courses, seminars, and literature offered by manufacturers of lever hoists, consultants, trade schools, continuing education schools, and employers.
- Requirements and recommendations found in national consensus standards.

Note that a technician competent for diving or ROV systems has normally the required level for such inspections and maintenance tasks.

1.4.2 - Troubleshooting

Troubleshooting consist of detecting the source of a breakdown and solving the problem. It also consists of logging the problem and reporting it adequately to ensure that solutions will be found to prevent it happening again.
Note that too many interventions may indicate design problems or maintenance problems.
The table below takes into account common problems reported by manufacturers.

Problem	*Common cause*	*Lever hoist affected*
Lever inefficient (not clicking)	· *Pawl partially or not engaging in the ratchet disc due to lack of lubrification, dirt, or foreign object.* · *Pawl spring damaged (to be replaced).* · *Selector switch spring loose or damaged (to be tightened or replaced).*	*All types*
Load slipping during the lowering phase	· *Braking system dirty or corroded (to be cleaned and lubricated).* · *Breaking disk damaged or worn (to be replaced).*	*Lever chain hoists*
Load not lowering	· *Brake caught, corroded, or damaged. (Brake system to be reset, lubricated, or changed.*	*Lever chain hoists*
Hand wheel not moving	· *Disk hub damaged (to be replaced)*	*Lever chain hoists*
Chain free willing impossible	· *Brake caught or damaged (Reset the brake of replace the damaged parts)*	*Lever chain hoists*
Drum rotation difficult	· *Drum axle corroded or damaged, or foreign objects and dirt between the drum and the frame (Clean, lubricate, and replace the damaged part)*	*Hoists using wires ropes, synthetic ropes, and webbing*
The cable cannot be fully recovered	· *Cable damaged, foreign object in the drum, cable not suitably wended.*	*Hoists using wires ropes, synthetic ropes, and webbing*

Note: Manufacturers say that disk brakes caught can be can be reset by selecting the function "down" and pushing hard the lever.

1.4.3 - Preventive inspection and maintenance

It is recommended to organize a preventive maintenance based on:

- The recommendations from standardization bodies
- The recommendations outlined in the hoist manufacturer's manual.
- The recommendations from specialists.
- Reports regarding defect or weaknesses of the equipment
- Safety flashes

ASME B30.21 classifies the inspections to be organized as follows:

- Initial inspection:
  It is the examination to be performed before committing to service new, altered, or modified hoists.
- Pre-operation Inspection:
  It is performed before the first use of each shift with records not required. It consist of visually examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - The hooks, including the latches.
  - The damage and correct reeving of the load line.
  - The over-travel restraint attachment.
  - Whether deformations, cracks, and other damages are visible on the body and lever.
- Frequent Inspection:
  They are visual inspections not required to be documented, that should be scheduled as follows:
  - Normal service: monthly
  - Heavy service: weekly to monthly
  - Severe service: daily to week

  They consist of examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - The hooks, including the latches.
  - The load line:
    - The chain, if equipped with, must be function tested under load, and closely inspected for damages, wear, and elongation.
    - The wire rope, if equipped with must be verified for external damages, corrosion, evidence of heat damages, reduction of diameter.
    - Synthetic ropes and webbing should be inspected for melting or charring, acid or caustic burns, weld spatter, broken stitching (webbing), cuts or tears, damaged eyes or fittings, abrasive wear, knots, discolouration, brittle fibres, and hard or stiff areas.
  - The over-travel restraint attachment.
  - Whether deformations, cracks, and other damages are visible on the body and lever.
- Periodic Inspection:
  It is a documented visual inspection. It can be indicated by a coded mark on the device, and should be organized as follows:
  - Normal service - yearly:
    Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
  - Heavy service - semiannually:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
  - Severe service - quarterly:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The following elements should be inspected:
  - Evidence of loose bolts, nuts, or rivets
  - Evidence of worn, corroded, cracked, or distorted parts such as load blocks, suspension housing, levers, chain attachments, clevises, yokes, suspension bolts, shafts, gears, bearings, pins, rollers, and locking and clamping devices.
  - Evidence of damage to hook retaining nuts or collars, and pins and welds or rivets used to secure the retaining members.
  - Evidence of damage or excessive wear of load sprockets or idler sprockets
  - Evidence of worn, glazed, or oil contaminated friction disks; worn pawls, cams, or ratchets; corroded, stretched, or broken pawl springs in brake mechanism.
  - The presence of the required labels and marks.

- ◦ End connections of load chain, including over-travel restraints, rope, or web strap.
- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

1.4.4 - Additional precautions for lever hoist used underwater

During diving operations, the water enters into the components of the lever hoist and gradually washes out the lubricants. As a result, unless the device is specifically designed for underwater operation, its efficiency will be progressively diminished as the effects of de-lubrification and corrosion will occur.
For these reasons, lever hoists not specifically designed for underwater operations should not be immersed for more than one week - 1 week ½, and a turnover must be organized using additional devices. Note that similar turnovers will have to be arranged with lever hoists designed for underwater operation, but on a more extended basis, as manufacturers claim that their products can be immersed for more than three weeks.
When the "standard" immersed lever hoist is back on deck, it must be rinsed with fresh water (not using HP jets) and immediately dismantled for a throughout cleaning and inspection. The reason is that the salted water is present in sensitive internal parts such as bearings, gears, springs, washers, circlips, etc., that are not treated against corrosion (see the schemes in point 1.2). In the presence of air, the conditions for accelerated corrosion are fulfilled to result in the device being out of order and, thus, dangerous within only a few days.
Note that the water quickly invades the sensitive parts of the tool. Therefore, the rule should be that immersed hoists must be thoroughly cleaned, decontaminated, and inspected, whatever the duration of immersion.

A particular focus is to be made on components that may look in perfect condition and, in fact, may not be:

- Bearings are made of assemblies of small rollers, needles, or balls in a sealed cage (see the photo) and may look in perfect condition from the external. However, this seal is not designed to withstand pressure, resulting in water often penetrating the cage when the tool is exposed to underwater pressure. For this reason, bearings have to be removed, cleaned, dried, and examined before being reinstalled with a proper lubricant. If that is impossible or damages are noticed, they must be replaced.

- Another sensitive point to focus on is the friction discs of the braking system of lever chain hoists. Incidents resulting in dropping loads have been attributed to the materials composing these discs, which are also used for vehicle braking systems, being contaminated by the salt water and therefore decomposing. It must be noted that many of these reported incidents happened during the period these parts were made of compressed asbestos, which is now strictly forbidden due to the fact this material is considered to promote cancer. New materials based on mixes of metal, resins, carbon fibres, and other components that are more resistant to water intrusion than compressed asbestos are now used in replacement. However, these materials have not been initially designed for prolonged exposure to water. For this reason, these essential parts must be closely examined and replaced if there is suspicion of decomposition.

- Springs, particularly pawl springs, are often made of carbon steel not treated against corrosion. They are thin and can break easily if corroded. In addition, depending on their quality, they can lose flexibility and not suitably engage the pawl into the ratchet, which may result in an accident. For these reasons, they must be closely examined, tested, and changed if necessary. The rule should be that when the lever hoist is reassembled, all the springs in place should be like brand new.

Note that all the replacement parts must conform to the originals.

When the internal parts of the lever hoist have been rinsed and fully dried, they must be adequately lubricated using hydrophobic lubricants of at least similar properties to those used by the manufacturer for normal use at the surface. That should be done in collaboration with the manufacturer, and/or a specialist in lubricants.
Note that many manufacturers of lever hoists not designed for underwater operations lubricate their products with motor grease, which is sufficient for surface works but not adapted for underwater operations for the following reasons:

- When such greases are immersed, water mix with their components, and they quickly become white colour, stiff, and sticky. Thus their adhesive, lubricant, and anti corrosion properties are lost, and motion parts are no longer protected.
- In addition, if the tool is left on a sandy or muddy seabed, sand or mud can enter the housing, mix with the grease and create a highly abrasive compound that quickly destroys the internal parts of the hoist.

For these reasons, standard motor greases must be replaced by lubricants suitable for immersion.

Consider that because the lever hoist has been dismantled, it must be load tested before being returned to operations, as recommended by ASME standards. This procedure applies for all lever hoist (used underwater or not) and is explained in the next point.
If after being considered good to service, the lever hoist is not used, it must be inspected according the the "ASME rules for devices not in regular service".

Maintenance procedures of lever hoists designed to work underwater:

Maintenance procedures of lever hoists designed to work underwater:
The frequency of detailed inspections should be indicated by the manufacturer in the maintenance manual of the device. Without precise indications, the maintenance of these tools should be organized as for "standard" lever hoists. Also, some contractors' organizations report that some devices are not corrosion-resistant as the manufacturer's brochure lets it suppose. For this reason, inspecting them as "standard" lever hoists at the beginning they are in service and gradually validating what is said in the brochure is advisable.

About the use of diesel:
Some people think that the procedures described above regarding the cleaning and treatment against corrosion of lever hoists used underwater are too time-consuming, so that it is more advantageous to replace them by plunging the lever hoist in a bucket filled with diesel to repeal water and lubricate its internal parts. These practices are dangerous and must be strictly banished for the following reasons:

- Even in the open air, having a bucket filled with diesel, thus, a noticeable volume of fuel, is a vector for an uncontrolled fire and thus against all safety practices regarding firefighting.
- Diesel is a fuel used in thermal engines specifically designed to ignite it by compression. Even though it has more lubricant properties than benzene, it remains a fuel, and it has the capacity to dissolve motor oils and greases. Thus, it has poor lubricant properties compared to motor oils and quickly evaporates. As a result, the components are no more protected by an adhesive oil film.
- As with most fuels, diesel contaminates or dissolves plastics and rubbers not designed to withstand their corrosive effects, which is the case for most plastic and rubber components used to build lever hoists.
- Diesel fuel does not have a high capacity for repelling water. Thus, plunging the tool into the diesel will not remove the water from parts such as bearings.
- Diesel fuel makes the surface of tools that have been plunged in it slippery, which is against the principles of safety that consider that an instrument must have an optimal grip. Also, it contaminates the gloves and, by cascade effects, the hands of the divers handling these tools.
- To summarize what is said above, diesel fuel is not efficiently removing water and is eliminating lubricants. Thus, it leaves the lever hoist's internal parts unprotected, in addition to the gripping problems indicated above. As a result, instead of lowering the effects of corrosion, this procedure speeds them up, making tools that, in addition, have not been inspected in detail, extremely dangerous for those using them.

1.4.5 - Lever hoist testing

ASME B30.21 says that the hoist manufacturer must test all new hoists with a load test of at least 125% of the rated load.
ASME B30.21 also says that all altered or repaired hoists or hoists placed in service that have not been used within the preceding 12 months must be tested by, or under the direction of, a designated person to ensure compliance with the manufacturing standards. These tests can be static or dynamic, and a written report should be issued and classified on file.

A. A qualified person must approve the anchorages or suspensions for the tests before starting the operation.
B. The functions of the hoist must be checked with the hoist suspended in the unloaded state, taking into account that some hoists may require a nominal load or pull on the load hook to test the lowering motion. Then, a load of at least 100 lb (46 kg) times the number of load-supporting parts of the chain, rope, or web strap is applied to the hoist to check the load control.
C. A qualified person must determine the need to load test the hoist.
D. The test must not be less than 100% of the rated load of the hoist or more than 125% of the rated load of the hoist unless otherwise recommended by the hoist manufacturer or a qualified person.
E. The replacement of chain, rope, or web strap is specifically excluded from the load test. However, an operational test of the hoist should be made in accordance with step “B” before placing the hoist back in service.

1.4.6 - Elements to take into consideration

The maintenance of lever hoists used underwater requires organization and commitment to ensure that no failure will happen during the operations. Some standard practices can help the technicians avoid losing too much time when implementing the maintenance procedures and avoid having devices not in service due to missing spare parts:

- Many companies have put in place standardization policies to minimize the number of spare parts in the store and ensure that the operators and the technicians preparing these tools are thoroughly familiar with them. On the other hand, that makes the process of selection crucial.
- The selection of the models should be done by the people who use and maintain them on-site.
- Models with simple mechanisms, so easy to repair should be preferred.
- It must be ensured that the manufacturer can supply the complete spare parts set and that these parts will be available for a long time. It must be considered that manufacturers often modifying their products may cease producing spares of those of the previous generation. Thus, manufacturers selling devices with unchanged designs and provided with large stores of spare parts should be preferred.
- Incident and maintenance reports regarding models' weaknesses have to be considered.
- Even though devices sold at low prices can be attractive, that should not be the 1st criterion for selecting tools used in an unfavorable environment. The price should be considered for selecting two pieces of equipment of the same quality and ease of use and repair. In this case, also consider the price of spare parts, as some

manufacturers try to make extra margins on them.

- The store should always be provided with more than the necessary spare parts. The maintenance reports should be considered for this purpose. However an exceptional break down may happen and should be considered.
- Extra lever hoists should be stored in case of tool loss, not reparable damages or underestimation regarding the number to use.

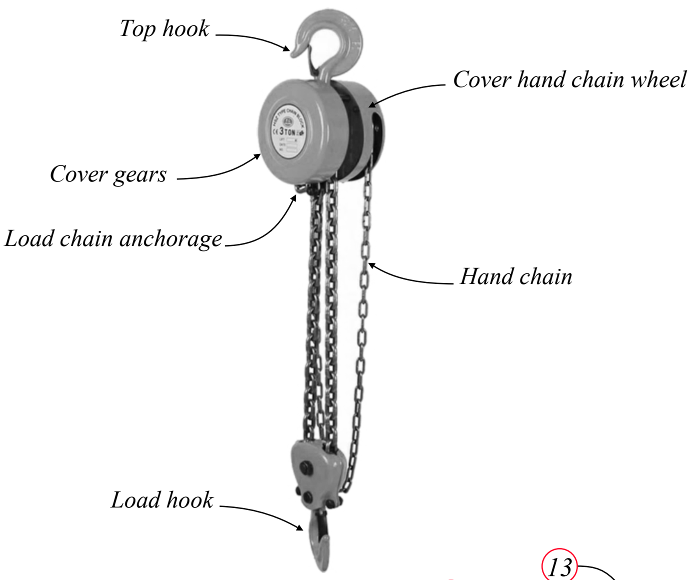
2 - Hand chain hoists

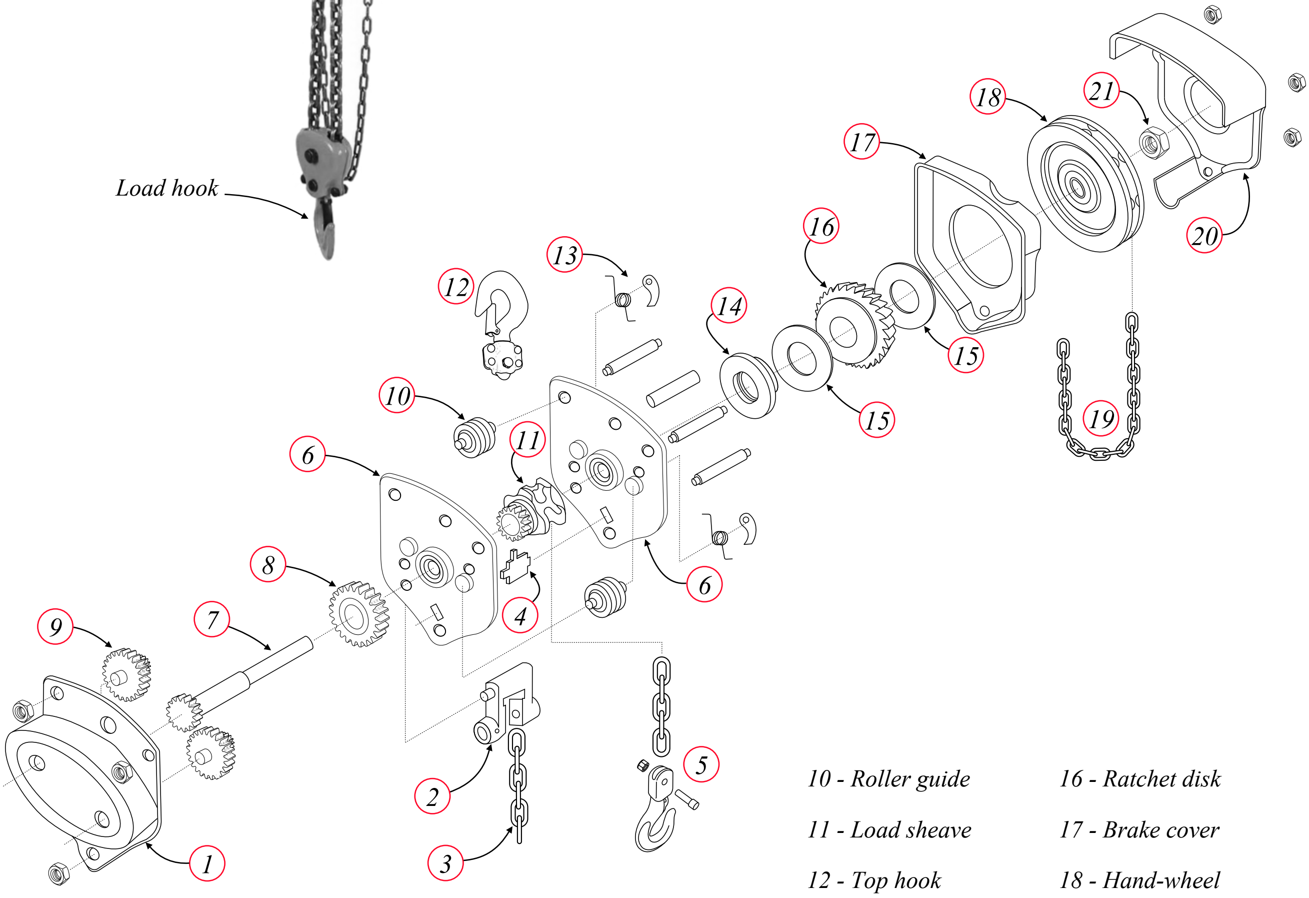
2.1 - General description

Chain hoists are devices designed for lifting and lowering loads from 500 kg to 100 tonnes using human effort. Their mechanisms are similar to those of lever chain hoists using welded chains, except the energy deployed by the operator is transmitted through a chain instead of a lever: Pulling the hand chain to the right raises the load, and pulling it to the opposite direction lowers the load. They are usually built according to the standards EN 13157 “Hand powered cranes”, also regulating lever hoists, ASME B30.16, ”Overhead underhung and stationary hoists”, ASME HST-2 “Performance standard for hand chain manually operated chain hoists”, and the Indian standard IS 3832 “Hand-operated chain pulley block”. These devices are designed for lifting only, and divers often use them with A-frames for matching spool flanges or similar underwater operations. They are also often used for organizing static riggings to which loads are transferred from cranes and then safely lowered in places not accessible to cranes. They are also used for many lifting operations in workshops. Opposite to lever chain hoists, their hand chain allows the operator to operate them from the soil, thus, close to the load he lifts or lowers.

2.2 - Design and construction requirements

As suggested above, the mechanisms of chain hoists consist of the load sheave (see # 11 below) and gears (see #9) activated by the “hand wheel” (see #18), driven by the operator using the “hand chain” (see #19) and multiplying his force. A ratchet and braking disks (see # 14, 15, 16) assembly is in place to automatically secure the load.





1 - Housing cover
2 - Anchor chain
3 - Chain
4 - Stripper
5 - Bottom hook
6 - Side plates
7 - Driving shaft
8 - Splined gear
9 - Gear
10 - Roller guide
11 - Load sheave
12 - Top hook
13 - Spring + pawl
14 - Brake seat
15 - Brake disk
16 - Ratchet disk
17 - Brake cover
18 - Hand-wheel
19 - Hand-chain
20 - Cover
21 - Castle nut

ASME B30.16 & EN 13157 give the following construction requirements that are similar to those of lever chain hoists:

- Mechanical strength:
  The device must be designed to withstand all stresses imposed under normal operating conditions while handling loads within the rated load.
  - EN 13157 requires that they can be operated within an ambient temperature range of - 10°C to + 50°C and have a safety factor of 4:1. In addition, the lever hoist should be designed to withstand 1 500 cycles with 110% of the rated capacity with no failure, replacement of parts, and no resting time, except for lubrication.
  - Linked to the above, ASME HST-2 requires that chain hoists can withstand 5000 operating cycles.
  - ASME B30.16 says that visible warnings of severe overload by permanent deformation while operating the hoist should be designed to show obvious deformation before other load suspension parts fail.
  - ASME B30.16 also says that load suspension parts of hand-chain-operated hoists must be designed so that the static stress calculated for the rated load does not exceed 25% of the minimum tensile strength.
- Braking system:
  The hoist must be equipped with a mechanism allowing a full control of the load.
  - EN 13157 requires that the hand chain hoists have an automatic braking function that operates when the operating force ceases, whether the motion is lifting or lowering. The braking device must allow for a regular descent automatically controlled whatever the position of the load. In addition, EN 13157 says that the fracture of a spring must not lead to a failure of the braking system.
  - ASME adds that under normal operating conditions with rated load and test conditions with test loads up to 125% of rated load, the braking system must limit the speed of load during lowering to a maximum speed of 120% of the lowering speed for the load being handled, have the thermal capacity for the frequency of operation, have provision for adjustments where necessary to compensate for wear.
- Operating efforts:
  The lever hoist should be designed not to require too much effort from the operator. For this reason, EN 13157 requires that the operating effort on the lever should be less than 55 daN at the end of the lever. However, the system must be designed for a minimum effort, not less than 20 daN. If it is the case, a protection system against overloading caused by excessive operating effort on the lever must be provided. (1 daN = 1.02 kgf).
- Protection:
  The gears of the lever hoist are to be protected. It is usually done by closed housings. EN 13157 also says that there should not be sharp ends that can injury the operator.
- Hand chain and chain wheel:
  EN 13157 says that a chain guide must be provided to prevent the hand and load chains from jumping off the chain wheels. In addition, ASME B30.16 says that the hand chain shape and pitch fit the hand chain wheel without binding or jamming and should withstand a force of three times the pull required to lift the rated load without permanent distortion.
- Loading chains:
  EN 13157 requires to refer to EN 818-7, "Fine tolerance short link chains (grade T)", and ISO 606, "Short pitch transmission precision roller chains and chain wheels". In addition, ASME B30.16 requires that the chains provided by the manufacturers are proof tested with a load at least equivalent to l ½ times the hoist's rated load divided by the number of chain parts supporting the load.
  Both standards say that the chain must be restrained not to run out of the sheave entirely. According to ASME B30.16, the restraint must withstand a lowering hand chain force equivalent to twice the pull required to lift the rated load or, with a rated load on the hoist, a hand chain force equal to the power needed to raise the rated load. According to EN 13157, the end stop should withstand 2,5 times the static chain tensile force at rated capacity.
- Hooks
  Hooks must comply with recognized standards and, thus, be fitted with safety latches to prevent unintentional detachment. Regarding this point, refer to the dedicated chapter about hooks in this document.
  EN 13157 requires top hook must be capable of swivelling. ASME B30.21 add that swivelling hooks should rotate freely.
- Marking
  The hoist must be marked with at least the following information
  The name and address of the manufacturer, the model, serial number, & year of manufacture.
  The safe working load, direction of movement, and if applicable, the direction of winding of the rope.
  Basic safety requirements regarding the correct use of the tool

2.3 - Hand chain hoists designed to work underwater

Like lever hoists, hand chain hoists have been used within maritime environments and underwater for a long time and suffer the same problems of corrosion of their internal parts due to the complexity of their mechanisms that involve multiple gears, bearings, springs, snap rings, breaking disks, pins, etc., not initially treated for such exposure, and the decomposition of the braking disks that are not designed for prolonged exposure to water. That may results in multiple failures that may result in incidents involving load falling while divers were working to install them.
For these reasons, in addition to specific operational precautions, explained in the following sections, regarding the maintenance of such devices when used underwater, it has become evident that specific lever hoists for underwater

applications had to be studied.
Two main strategies have been proposed by the manufacturers regarding lever chain hoists:

- Protect the mechanism of the hand chain hoist in a sealed housing so its sensitive parts are not exposed to water. This system has the inconvenience that water intrusion may happen if the tool is used at deeper depths than the one it is designed for.
- Treat all the components of the lever chain hoist against corrosion, install friction disks that are designed for prolonged exposure to water, and use water resistant lubricants. This procedure removes the limitation in depth. However, the lever hoist's mechanism can be exposed to the intrusion of mud and sand, which may happen if the tool is left on the sea bottom or used in muddy water.

These hand chain hoists are submitted to the same tests as standard hoists not designed for underwater operations regarding their regular use. However, during the certification phases, manufacturers are required to test their lever hoists according to ASTM B117 "Standard practice for operating salt spray (fog) apparatus". As suggested by the title, the purpose of this standard is to provide a controlled corrosive environment that is used to produce relative corrosion resistance information for specimens of metals and coated metals exposed in a given test chamber.
The fog chamber consists of a specific room, a salt solution reservoir, a supply of suitably conditioned compressed air, one or more atomising nozzles, specimen supports, provision for heating the chamber, and necessary means of control.
The standard describes the preparation of the test specimens, salted solutions, air supply pressure (from 0.83 bar to 1.24 bar), and temperature (from 46 to 49°C). The competent person in charge of the device's certification decides the exposure time so that he can obtain the desired corrosive surrounding, which is expected to be close to the conditions the specimen will be exposed to. After this test, the device is considered suitable for use in a salty environment.
Other tests include exposure at depth for extended periods to ensure the equipment can withstand at least several weeks of exposure. These tests are usually performed by classification societies that deliver the certificate and the maximum duration of exposure of the device to underwater conditions.

2.4 - Operational practices

This section describes only lever hoists specific practices. Therefore, this section does not describe general operational practices applicable to all lifting operations. These rigging practices depend on whether the lever hoist is a lever operated chain hoist or a lever operated wire rope hoist. It also depends on the surrounding, as diving and ROV teams use them in marine environments and underwater, which implies saltwater and sometimes mud intrusion within the mechanisms.
In addition to the normal safe use criteria, special precautions should be taken as follows:

- Only a block suspended by a hook or equivalent fitting should be used. Also, a brand new lever hoist should be load tested before being put into service.
- The suspension point must be suitable for the line of force and of adequate strength. Remember that ASME recommends at least 125% of the WLL.
- The block must be free to align between the top suspension and the bottom hook.
- The hand chain lever hoist must be at the required angle(s).
- The hand chain lever hoist is designed to lift vertically, without side pull, except when specifically authorized by a qualified person
- The maximum force on the block must be calculated by someone competent for the purpose taking account of the angle(s) and must not exceed the WLL.
- The operator must ensure that multiple-part chains are not twisting around each other when the lift is made. Also, he must lift the load a few inches to check the hoist operation, and verify that the load is secured, balanced, and positioned on the hook and in the sling or lifting device.
- Suspended load must not be left unattended unless provisions have been made to provide auxiliary supporting means under the suspended load, or guards or barriers are used on the floor to prevent people from entering the area affected by the suspended load. It is also recommended to add an adjustable static rigging as a backup when the tool is used in conditions where its failure can result in injuries or damages.
- Hand chain hoists must not be left on the sea floor where sand and mud can enter and damage them. This point is valid for all types, including the models designed to work underwater.

Hand chain hoists must be used as they are designed:

- The hand chain is designed for an effort of the operator not above 55 daN and not less than 20 daN. For this reason, it must be operated by only one person. Also, the maximum capacity of the equipment must never be exceeded. Also, some hand chain hoists are designed for minimum weights below which they should not be used (remember the rule of "not less than 20 daN"). For this reason, clarifications should be obtained from the manufacturer regarding this point. In addition, consider it not advisable to use a device designed to lift 5 tonnes to lift a weight of 100 kg. The range of the working load limits of the devices sold by the manufacturer (for example, 1 t, 2 t, 3 t, 5 t …) is also an indicator.
- Some teams use hand chain hoists as adjustable slings to ensure that large pieces, such as connecting spools, are transferred flat. Such practices are dangerous as, according to EN 13157 and ASME B30.16, these hoists are designed to work vertically, even though their design is similar to Lever hoists. Also, they have a safety factor of 4:1 which is too weak to withstand the dynamic forces created during the transfer, and the manufacturers strictly recommend not using them for this purpose. Adjustable slings can be used to replace them advantageously.
- Hand chain hoists are usually not designed for personnel transfer.

- A load must not be shared between several hoists unless approved engineering calculation requests it.

2.5 - Maintenance

The maintenance of hand chain hoists depends on the frequency of use and the conditions of use. ASME B30.16 provides guidelines regarding this point on which many manufacturers have built their recommendations. However, these guidelines apply to chain hoists not used underwater. Considering that underwater works are performed in an environment aggressive for mechanical parts, it will be necessary to reinforce the frequency of inspection and preventive maintenance of the devices submitted to such working conditions.

2.5.1 - Competent personnel

The maintenance of chain hoists involves troubleshooting, periodic inspections, preventive maintenance, and commissioning procedures before returning the device to service. It is therefore essential that the technician in charge has the technical level for these tasks. ASME provides the following examples of source of training material:

- Information outlined in the manual provided with the equipment. Note that this documentation is mandatory.
- Information from trade associations
- Government training resources such as labour and educational ministries
- Organized labour groups
- Courses, seminars, and literature offered by manufacturers of lever hoists, consultants, trade schools, continuing education schools, and employers.
- Requirements and recommendations found in national consensus standards.
- Note that a technician competent for diving or ROV systems has normally the required level for such inspections and maintenance tasks.

2.5.2 - Troubleshooting

Troubleshooting consist of detecting the source of a breakdown and solving the problem. It also consists of logging the problem and reporting it adequately to ensure that solutions will be found to prevent it happening again.
Note that too many interventions may indicate design problems or maintenance problems.

The table below takes into account common problems reported by manufacturers.

Problem	*Common cause*
Hoist not moving	· *Hand chain wheel jammed, worn, or damaged.* · *Gears and/or bearings damaged.*
Hand chain slipping over the wheel.	· *Chain wheel damaged or worn cogs.*
Load difficult to lift	· *Load too heavy.* · *Some models are equipped with overload protection and may have it triggered following lifting a too heavy load (The chain wheel must be opened and the protection reset).* · *Load sheave jammed (Check for foreign objects, dirt, or excessive worn).* · *Ratchet assembly damaged or corroded.* · *Gears and/or bearings or corroded*
Load difficult to lower	· *Load chain stuck due to obstruction, damage, or wear.* · *Brake or ratchet assembly damaged or obstructed*
Load falling or lowering	· *The load is beyond the capacity of the hoist.* · *Brake and/or ratchet assembly worn, corroded, or damaged.* · *Brake discs dirty or corroded.*
Load chain jumping or noisy	· *Chain dirty, corroded, and/or insufficiently lubricated.* · *Chain twisted.* · *Load chain damaged or worn.*

2.5.3 - Preventive inspection and maintenance

As mentioned for other lifting tools, it is recommended to organize a preventive maintenance based on:

- The recommendations from standardization bodies
- The recommendations outlined in the hoist manufacturer's manual.
- The recommendations from specialists.
- Reports regarding defect or weaknesses of the equipment
- Safety flashes

ASME classifies the inspections to be organized as follows:

- Initial inspection:

It is the examination to be performed before committing to service new, altered, or modified hoists.

- Pre-operation Inspection:
  It is performed before the first use of each shift with records not required. It consist of visually examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - The hooks, including the latches.
  - The damage and correct reeving of the load line.
  - The over-travel restraint attachment.
  - Whether deformations, cracks, and other damages are visible.
- Frequent Inspection:
  They are visual inspections not required to be documented, that should be scheduled as follows:
  - Normal service: monthly
  - Heavy service: weekly to monthly
  - Severe service: daily to week

  They consist of examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.
  - The hooks, including the latches.
  - The chain must be function tested under load, and closely inspected for damages, wear, and elongation.
  - The over-travel restraint attachment.
  - Whether deformations, cracks, and other damages are visible.
- Periodic Inspection:
  It is a documented visual inspection. It can be indicated by a coded mark on the device, and should be organized as follows:
  - Normal service - yearly:
    Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
  - Heavy service - semiannually:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
  - Severe service - quarterly:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The following elements should be inspected:
  - Evidence of loose bolts, nuts, or rivets
  - Evidence of worn, corroded, cracked, or distorted parts such as load blocks, suspension housing, chain attachments, clevises, yokes, suspension bolts, shafts, gears, bearings, pins, rollers, and locking and clamping devices.
  - Evidence of damage to hook retaining nuts or collars, and pins and welds or rivets used to secure the retaining members.
  - Evidence of damage or excessive wear of load sprockets or idler sprockets
  - Evidence of worn, glazed, or oil contaminated friction disks; worn pawls, cams, or ratchets; corroded, stretched, or broken pawl springs in brake mechanism.
  - The presence of the required labels and marks.
  - End connections of load chain, including over-travel restraints, rope, or web strap.
- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

2.5.4 - Additional precautions for chain hoists used underwater

These precautions are exactly the same as those of lever hoists remembered below:

During diving operations, the water enters into the components of the chain hoist and gradually washes out the lubricants. As a result, unless the device is specifically designed for underwater operation, its efficiency will be progressively diminished as the effects of de-lubrification and corrosion will occur.
For these reasons, chain hoists not specifically designed for underwater operations should not be immersed for more than one week - 1 week ½, and a turnover must be organized using additional devices. Note that similar turnovers will have to be arranged with chain hoists designed for underwater operation, but on a more extended basis, as manufacturers claim that their products can be immersed for more than three weeks.
When the “standard” immersed chain hoist is back on deck, it must be rinsed with fresh water (not using HP jets) and immediately dismantled for a throughout cleaning and inspection. The reason is that the salty water is present in

sensitive internal parts such as bearings, gears, springs, washers, circlips, etc., that are not treated against corrosion (see the schemes in point 2.2). In the presence of air, the conditions for accelerated corrosion are fulfilled to result in the device being out of order and, thus, dangerous within only a few days.
Note that the water quickly invades the sensitive parts of the tool. Therefore, the rule should be that immersed hoists must be thoroughly cleaned, decontaminated, and inspected, whatever the duration of immersion

A particular focus is to be made on components that may look in perfect condition and, in fact, may not be:

- Bearings are made of assemblies of small balls, rolls, or nails in a sealed cage (see the photo) and may look in perfect condition from the external. However, this seal is not designed to withstand hydrostatic pressure, resulting in water often penetrating the cage when the tool is is used at depth For this reason, bearings have to be removed, cleaned, dried, and examined before being reinstalled with a proper lubricant. If that is impossible or damages are noticed, they must be replaced.

- Another sensitive point to focus on is the friction discs of the braking system of chain hoists. Incidents resulting in dropping loads have been attributed to the materials composing these discs, which are also used for vehicle braking systems, being contaminated by the salt water and therefore decomposing. It must be noted that many of these reported incidents happened during the period these parts were made of compressed asbestos, which is now strictly forbidden due to the fact this material is considered to promote cancer. New materials based on mixes of metal, resins, carbon fibres, and other components that are more resistant to water intrusion than compressed asbestos are now used in replacement. However, these materials have not been initially designed for prolonged exposure to water. For this reason, these essential parts must be closely examined and replaced if there is suspicion of decomposition.

- Springs, particularly pawl springs, are often made of carbon steel not treated against corrosion. They are thin and can break easily if corroded. In addition, depending on their quality, they can lose flexibility and not suitably engage the pawl into the ratchet, which may result in an accident. For these reasons, they must be closely examined, tested, and changed if necessary. The rule should be that when the chain hoist is reassembled, all the springs in place should be like brand new.

Note that all the replacement parts must conform to the originals.

When the internal parts of the chain hoist have been rinsed and filly dried, they must be adequately lubricated using hydrophobic lubricants of at least similar properties to those used by the manufacturer for normal use at the surface. That should be done in collaboration with the manufacturer, and/or a specialist in lubricants.
Note that many manufacturers of chain hoists not designed for underwater operations lubricate their products with motor grease, which is sufficient for surface work but not adapted for underwater operations for the following reasons:

- When such greases are immersed, water mix with their components, and they quickly become white colour, stiff, and sticky. Thus their adhesive, lubricant, and anti corrosion properties are lost, and motion parts are no longer protected.
- In addition, if the tool is left on a sandy or muddy seabed, sand or mud can enter the housing, mix with the grease and create a highly abrasive compound that quickly destroys the internal parts of the hoist.

For these reasons, standard motor greases must be replaced by lubricants suitable for immersion.

Consider that because the chain hoist has been dismantled, it must be load tested before being returned to operations, as recommended by ASME standards. This procedure applies for all hoists (used underwater or not) and is explained in the next point.
If after being considered good to service, the chain hoist is not used, it must be inspected according the the “ASME rules for devices not in regular service” or a similar process.

Maintenance procedures of chain hoists designed to work underwater:
The frequency of detailed inspections should be indicated by the manufacturer in the maintenance manual of the device. Without precise indications, the maintenance of these tools should be organized as for "standard" chain hoists. Also, some contractors' organizations report that some devices are not corrosion-resistant as the manufacturer's brochure lets it suppose. For this reason, inspecting them as "standard" chain hoists at the beginning they are in service and gradually validating what is said in the brochure is advisable.

About the use of diesel:
Some people think that the procedures described above regarding the cleaning and treatment against corrosion of chain hoists used underwater are too time-consuming, so that it is more advantageous to replace them by plunging the chain hoist in a bucket filled with diesel to repeal water and lubricate its internal parts. These practices are dangerous and must be strictly banished for the following reasons:

- Even in the open air, having a bucket filled with diesel, thus, a noticeable volume of fuel, is a vector for an uncontrolled fire and thus against all safety practices regarding firefighting.
- Diesel is a fuel used in thermal engines specifically designed to ignite it by compression. Even though it has more lubricant properties than benzene, it remains a fuel, and it has the capacity to dissolve motor oils and greases. Thus, it has poor lubricant properties compared to motor oils and quickly evaporates. As a result, the components are no more protected by an adhesive oil film.

- As with most fuels, diesel contaminates or dissolves plastics and rubbers not designed to withstand their corrosive effects, which is the case for most plastic and rubber components used to build chain hoists.
- Diesel fuel does not have a high capacity for repelling water. Thus, plunging the tool into the diesel will not remove the water from parts such as bearings.
- Diesel fuel makes the surface of tools that have been plunged in it slippery, which is against the principles of safety that consider that an instrument must have an optimal grip. Also, it contaminates the gloves and, by cascade effects, the hands of the divers handling these tools.

To summarize what is said above, diesel fuel is not efficiently removing water and is eliminating lubricants. Thus, it leaves the lever hoist's internal parts unprotected, in addition to the gripping problems indicated above. As a result, instead of lowering the effects of corrosion, this procedure speeds them up, making tools that, in addition, have not been inspected in detail, extremely dangerous for those using them.

2.5.5 - Change the chains

The load and hand chains of chain hoists can be changed. That can be done to adapt the tool to the working conditions or when the chain is worn. Manufacturers provide load chains fro 1.5 m to 12 m. Hand chains can also be adapted to the distance from which the chain host is operated by adding a length or shortening it.

- The new load chain should be of the same type of the chain selected by the manufacturer. Note that if the chain in place is too short, it cannot be lengthen to the desired distance with another chain, but must be replaced by a new chain of the desired length. IF the chain is worn and thus, need to be replaced, it may be necessary to replace the load sheave as well. For this reason, a close inspection of this spare part is to be performed. Note that many people change is by precaution at the same time of the chain.
- Manufacturers authorize that the hand chain is opened to be shortened or lengthen with another piece of chain of the same model. As an example, JET (https://jettools.com/), a well known manufacturer indicates the following procedure:
    - The link to cut is inserted lengthwise into a vise with the side opposite the weld lying completely below the surface of the vise's jaw (about 1/3 of a link) to prevent damaging it.
    - Then the link is cut at the weld using a hacksaw, and the link is repositioned vertically in the wise with the level of the cut above the wise's jaw.
    - The link is then twisted to opened it using an adjustable wrench.
    - The same operation is done with another link. It is selected in function the chain is shortened or lengthen.
    - When the chain is shortened or lengthen, the links are closed using the opposite procedure.

2.5.6 - Chain hoist testing

ASME B30.16 says that the hoist manufacturer must test all new hoists with a load test of at least 125% of the rated load.

ASME B30.16 also says that all altered or repaired hoists or hoists placed in service that have not been used within the preceding 12 months must be tested by, or under the direction of, a designated person to ensure compliance with the manufacturing standards. These tests can be static or dynamic, and a written report should be issued and classified on file.

A. A qualified person must approve the anchorages or suspensions for the tests before starting the operation.
B. The functions of the hoist must be checked with the hoist suspended in the unloaded state, taking into account that some hoists may require a nominal load or pull on the load hook to test the lowering motion.
C. A qualified person must determine the need to load test the hoist.
D. The test must not be less than 100% of the rated load of the hoist or more than 125% of the rated load of the hoist unless otherwise recommended by the hoist manufacturer or a qualified person.
E. The replacement of the chain is excluded from the load test. However, an operational test of the hoist should be made in accordance with step "B" before placing the hoist back in service.

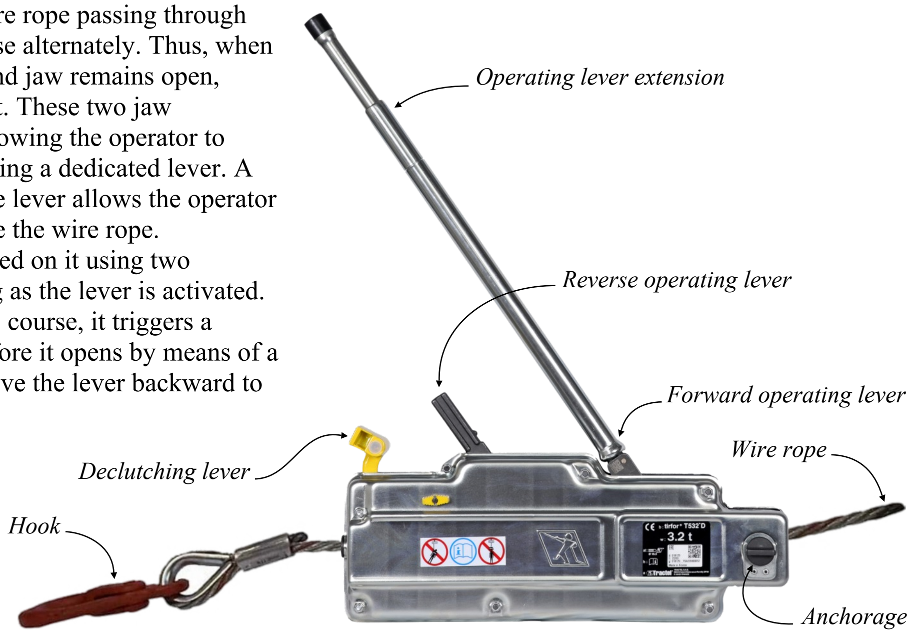
3 - Jaw winches

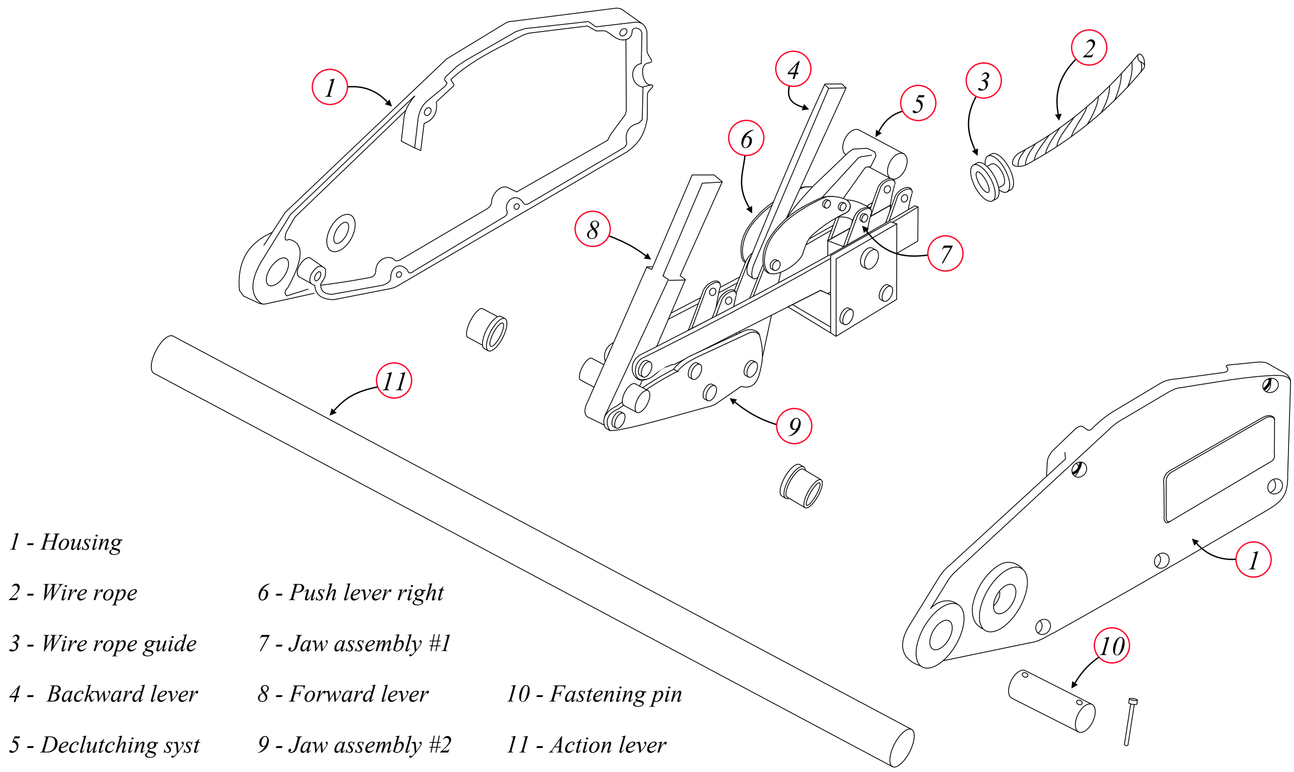
3.1 - General description

“Jaw winches”, also called “Tirfors”, “cable grip hoists”, or “cable grip pullers”, are devices designed for pulling, lifting, lowering, and holding loads using a wire rope where the rope is gripped and moved by jaws using human effort on a lever or levers. Their construction and recommendations of use are described by the ASME B30.21 and EN 13157 standards. However, ASME B30.21 refers to wire rope lever hoists requirements without making a noticeable difference between the two tools, while EN 13157 provides more specific requirements regarding such devices.

Their work principle consists of a wire rope passing through two clamping jaws that open and close alternately. Thus, when one jaw assembly is closed, the second jaw remains open, allowing the cable to move through it. These two jaw assemblies are mounted on pivots allowing the operator to move them forward and backward using a dedicated lever. A removable extension connected to the lever allows the operator to deploy the requested force to move the wire rope.
The jaw moving the wire rope is closed on it using two eccentrics and remains closed as long as the lever is activated. When the jaw arrives at the end of its course, it triggers a command that closes the 2nd jaw before it opens by means of a spring. The operator just needs to move the lever backward to restart the pulling operation.

Note:
The model in the picture is a Tractel - Tirfor T 500 Series
“Tirfor” is a brand of Tractel
https://www.tractel.com/





3.2 - Design requirements

3.2.1 - Mechanical strength and securing of the load

The requirements for jaw winches mechanical strength are similar to those of wire rope lever hoists.

- EN 13157 says that Jaw winches should have a safety coefficient of at least 4:1 and should be able to withstand 400 continuous cycles at full capacity without failure and need for replacing parts. Also, they must be fitted with a device which limits the lifting force to not more than 2 times the rated capacity. The wire ropes used should have a safety coefficient of at least 5:1, and should also be capable of withstanding at least 400 operational cycles. Some models can use fibre ropes. In this case, their safety coefficient should be at least 7:1. Also, wire ropes should be supplied in single lengths with splices or connections only at the ends. Note that EN 13157 requires that rope terminations conform with EN 13411 "Terminations for steel wire ropes".

- ASME B30.21 says that the device must be designed to withstand the stresses imposed under normal operating conditions. Also, the load suspension parts must be designed so that the calculated static stress for the rated load should not exceed 25% of the minimum ultimate tensile strength. In addition, the device must be designed to give a visible warning of severe overload by showing permanent deformation before the failure of other load suspension parts.
- EN 13157 also says that jaw winches, and their components, should be capable of operating within an ambient temperature range of - 10°C to + 50°C unless another temperature range is agreed between the manufacturer and the purchaser.
- EN 13157 emits stringent requirements regarding the capacity of jaw winches to secure and control the load:
    - As mentioned in the general description, jaw winches must be designed so that one jaw block is gripping the rope during lifting and lowering. Also, the wire rope clamping mechanism must be designed to ensure minimum variation in the tightening coefficient with the wear of the jaws or rope. As a result, the clamping system must be able to hold a load equal to at least 1.1 times the rated load despite a reduction of 10 % of the nominal wire rope diameter caused by wear.
    - An automatic braking system must be provided to control the load during the lifting and lowering. It should allow a controlled descent, whatever the position of the load. As mentioned above, this braking function is ensured if one jaw assembly is gripping the rope throughout the pulling, lifting, or lowering sequence. However, once the action on one of the levers has stopped, both jaw assemblies should automatically close like two independent brakes. If one of the two jaw assemblies fails, the alternating motion should cease, and the second jaw assembly should hold the rated capacity. Also, as with all other hoist systems, EN 13157 says that the fracture of a spring must not lead to a failure of the braking system. The manufacturer can fulfill this requirement with a single guided spring or several springs. The guided pressure springs should have a distance between the coils of less than or equal to the wire diameter.
    - In addition, a system must be provided to prevent the load from falling due to a human mistake. For this reason, the disengagement of the jaws should only be possible when there is no or a low load. Thus, a system that prevents the declutching lever from opening the jaws simultaneously as long as the system is under tension must be provided.
- Hooks and anchorage should be fitted with safety latches or locking devices to prevent unintentional detachment. They should be manufactured according to a recognized standard, and EN 13157 requires that they are designed not to have permanent deformation at a static load of 2 times the rated capacity. Also, EN 13157 allows the hook to bend at four times the rated capacity, provided that it continues to hold the load safely.

3.2.2 - Ease of use and protection of the mechanism

- En 13157 requires that the maximum force the operator applies on the lever to lift the rated capacity must not exceed 55 daN, which is usually obtained with the help of a removable extension. This extension should be designed to be secured against unintentional disconnection.
  Note that the mechanical advantage achieved by the association of the gear and the lever should not allow lifting a load exceeding 2.5 times the rated capacity when 100 daN force is applied to the lever.
- As with all hoist systems, jaw winches must be designed such that their accessible parts have no sharp edges, no sharp angles, and no rough surfaces likely to cause injury.
  Also, the jaws and their actuating mechanism should be guarded to prevent accidental ingress.

3.2.3 - About jaw winches used underwater

Jaw winches have been used within maritime environments and underwater for a long time. Similarly, to other hoists and pullers not designed to resist such an environment, they can be affected by the corrosion of their internal parts, which results in their mechanisms not responding adequately, even though they are more straightforward than those of lever hoists and chain hoists. Thus, water usually replaces the original lubricant and triggers the corrosion of bearings, springs, snap rings, pins, etc. In addition, mud and matter in suspension or adhering to the rope can enter the mechanism and nest into the abovementioned elements.
There is currently no model of a Jaw winch specifically designed for underwater applications. For this reason, these tools' maintenance process should be the same as lever hoists, not initially created for underwater work.

3.3 - Operational practices

Similar to other hand lifting and pulling tools described in this chapter, this section describes only jaw winch specific practices. Therefore, this section does not describe general operational practices applicable to all lifting operations, but only those that are specific to jaw winches.

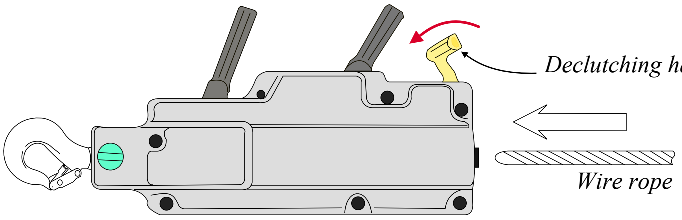
3.3.1 - Increasing the capacity of jaw winches

The capacity of the jaw winch can be considerably increased without affecting the effort provided by the operator by using multiple sheave blocks. In such devices are used, the diameter of their pulleys should be equal to at least 18 times the diameter of the wire rope. In addition, rigging arrangement which requires the calculation of the forces applied should be checked by a competent engineer with special attention to the appropriate strength of fixed point used.

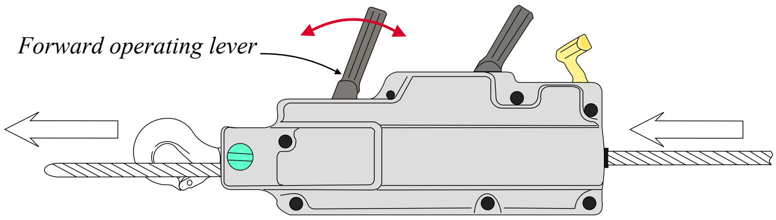
3.3.2 - Installing the wire rope

Installing wire ropes in jaw winches is not tricky. However, it is often a source of problems for many people not trained to do it. For divers underwater, that results in a loss of time that may compromise the operations planned for a dive. For this reason, it is essential to ensure that divers can do it easily on deck and underwater. Pre-installing the wire rope is a wise procedure allowing to save time many operators apply. However, having divers able to adjust the device quickly and solve installation problems will save precious time. The classical procedure for activating such tools is as follows:

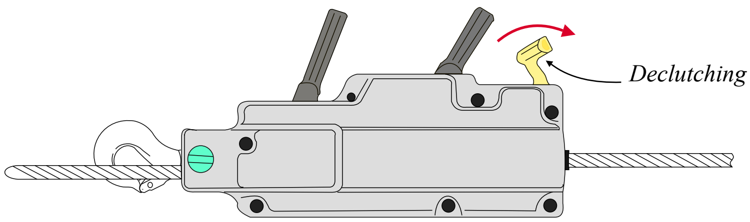
- As for handling any type of wire rope it is recommended to protect the hands by using thick work gloves.
- If the wire rope is to be anchored to a high anchor point, the wire rope should be anchored before fitting the wire rope in the machine.
- The wire rope should be uncoiled in a straight line to prevent loops or kinks.
- The internal mechanism should be released, so that both jaw assemblies are open. This is usually done by activating the declutching system.
- Insert the wire rope through the rope guide at the end opposite to the anchor point (hook or anchor pin).



- The wire rope should be pushed through the machine, helping it by operating the forward operating lever if necessary.



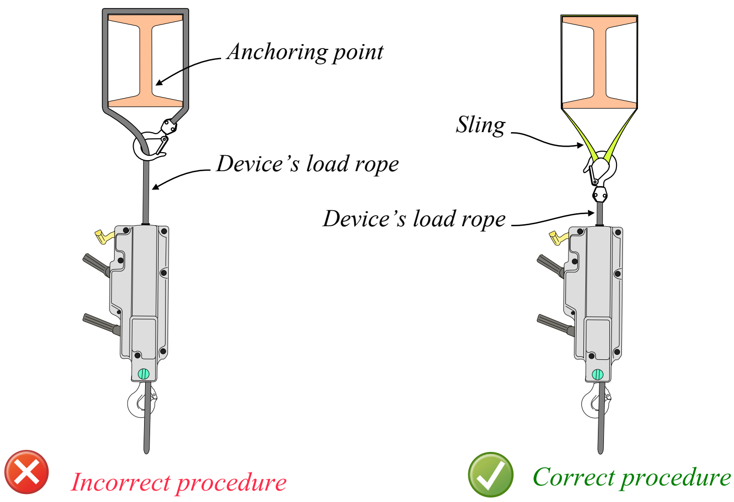
- When the wire rope appears through the anchor point, the operator pulls the slack wire rope through the device to the point required.
  Then, he engages the jaws by releasing the declutching mechanism so that the jaws assemblies can close and open normally.



3.3.3 - Anchoring the device

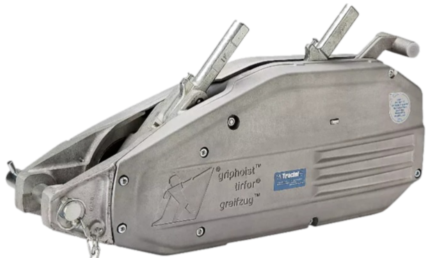
The user must always ensure before operation that the anchor point(s) for the machine and wire-rope are of sufficient strength to hold the load.

- It is recommended to anchor the jaw winch to a fixed point or the load using an appropriate capacity sling.
- As for other hoists and pulling devices, using the machine's load rope as a sling by passing it around the load or the anchoring point is forbidden.



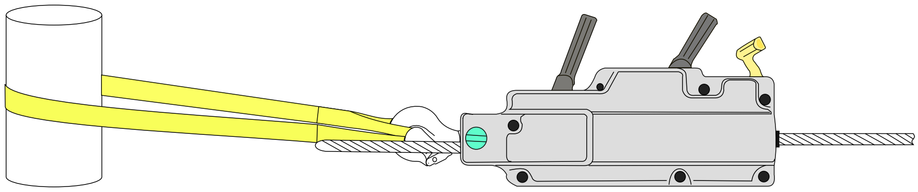
- When anchoring the jaw winch, the safety latch of the anchor hook should be closed. This advice for the machine anchor hook also applies to the hook fitted to the wire rope.
  Some jaw winches are anchored by means of a removable anchor pin fitted across the two ends of the side cases and locked in position by a spring clip. This anchor pin allows for connecting a hook or a sling. It is the case of the Tirfor model TU 32 below. Some other jaw winches are provided with an anchor hook mounted on a pivot . It is the case of the Tirfor model TU 16 below.

Tirfor model TU 16 - https://www.tractel.com/

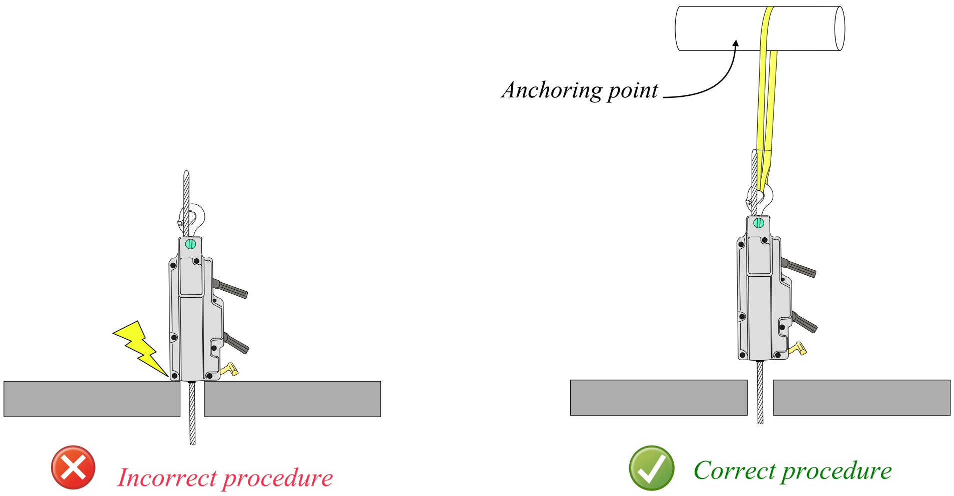


Tirfor model TU 32 - https://www.tractel.com/

- The operator must ensure that there are no obstructions near the Jaw winch that could prevent the wire rope from moving out the jaw winch freely. Thus, there must be a minimum distance is to be between the jaw winch and the anchoring point. Therefore, a sling of an appropriate capacity is recommended between the anchor point and the jaw winch.



- In addition, when organizing lifting or pulling operations through a hole, it is highly not recommended to use the body of the jaw winch as a fulcrum point as it is not strong enough for this. Instead, the jaw winch must always be fastened to an anchoring point through the anchor hook or pin.



3.3.4 - Standard precautions when using jaw winches

Jaw winch manufacturers, notably "Tractel", provide the following recommendations for using jaw winches:

- Jaw winches must not be used for lifting people.
- Jaw winches must not be used beyond their maximum working load.
- Jaw winches must not be used for applications other than those for which they are intended.
- The rope release mechanism must never be operated whilst the machine is under load.
- Never obstruct the operating levers or the rope release lever.
- Never operate the forward and reverse operating levers at the same time.
- Never subject the controls to sharp knocks.
- Never attempt to reverse the rope completely through the machine whilst under load.
- Do not operate the Jaw winch when the rope ferrule gets to within 10 cm of the machine. Otherwise the ferrule is likely to foul the casing and push the rope guide inside the machine.

3.3.5 - Precautions when using jaw winches underwater

In addition to the corrosion problems, jaw winches can be affected by debris, mud, and sand entering their casing, which may destroy their mechanisms. For these reasons, divers should avoid leaving jaw winches on the sea floor, particularly sandy or muddy bottoms.

3.4 - Maintenance

The maintenance of jaw winches is based on the same principle and procedures as other hoists and pulling systems and, thus, depends on the frequency and conditions of use. As a result, many procedures are exactly the same, as the only differences depend on the mechanisms. As for other hoists and pullers, the guidelines provided by the manufacturers apply to devices not used underwater. Considering that underwater operations are performed in an environment aggressive for mechanical parts, it will be necessary to reinforce the frequency of inspection and preventive maintenance of the devices submitted to such working conditions.

3.4.1 - Competent personnel

The maintenance of jaw winches involves troubleshooting, periodic inspections, preventive maintenance, and commissioning procedures before returning the device to service. It is therefore essential that the technician in charge has the technical level for these tasks. ASME provides the following examples of source of training material:

- Information outlined in the manual provided with the equipment. Note that this documentation is mandatory.
- Information from trade associations
- Government training resources such as labour and educational ministries
- Organized labour groups
- Courses, seminars, and literature offered by manufacturers of lever hoists, consultants, trade schools, continuing education schools, and employers.
- Requirements and recommendations found in national consensus standards.
- Note that a technician competent for diving or ROV systems has normally the required level for such inspections and maintenance tasks.

3.4.2 - Troubleshooting

Troubleshooting consist of detecting the source of a breakdown and solving the problem. It also consists of logging the problem and reporting it adequately to ensure that solutions will be found to prevent it happening again.
Note that too many interventions may indicate design problems or maintenance problems.

The table below takes into account common problems reported by Tractel .

Problem	*Common cause*
Operating lever moving freely and not operating the mechanism	• *The winch has been overloaded, and the shear pins are sheared. Replacing the shear pins usually solves the problem.*
Pumping	• *This problem is due to a lack of lubrication and results in the jaw assembly gripping the rope becoming locked onto it, preventing the other jaw assembly from taking over the load. Manufacturers say that such a problem, which does not trigger a dangerous condition, can be solved by thoroughly lubricating the device.*
Jerkiness	• *This is also a symptom of lack of lubrication.*
Blockage	• *It usually happens when a damaged section of wire rope is stuck within the jaws. Pumping backward sometimes allows for disengaging the damaged part. However, the operation with the jaw winch affected cannot continue. That results that the load is to be transferred to another device to be able to disconnect the tool and change the damaged wire rope. The jaw winch may have to be opened to remove the stuck wire rope if it cannot be pulled backward. Such an operation is to be performed by a competent person.*

3.4.3 - Preventive inspection and maintenance

As for the hoists and pullers previously described it is recommended to organize a preventive maintenance based on:

- The recommendations from standardization bodies
- The recommendations outlined in the hoist manufacturer’s manual.
- The recommendations from specialists.
- Reports regarding defect or weaknesses of the equipment
- Safety flashes

ASME B30.21 classifies the inspections to be organized as follows:

- Initial inspection:
  It is the examination to be performed before committing to service new, altered, or modified hoists.
- Pre-operation Inspection:
  It is performed before the first use of each shift with records not required. It consist of visually examining the following:
  - The operating mechanisms function test, proper adjustment, and unusual sounds.

   - The hooks, including the latches.
   - The condition of the load line.
   - Whether deformations, cracks, and other damages are visible on the body and lever.
- Frequent Inspection:
  They are visual inspections not required to be documented, that should be scheduled as follows:
   - Normal service: monthly
   - Heavy service: weekly to monthly
   - Severe service: daily to week

  They consist of examining the following:
   - The operating mechanisms function test, proper adjustment, and unusual sounds.
   - The hooks, including the latches.
   - The wire rope must be verified for external damages, corrosion, evidence of heat damages, reduction of diameter.
   - Whether deformations, cracks, and other damages are visible on the body and lever.
- Periodic Inspection:
  It is a documented visual inspection. It can be indicated by a coded mark on the device, and should be organized as follows:
   - Normal service - yearly:
     Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
   - Heavy service - semiannually:
     As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
   - Severe service - quarterly:
     As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The following elements should be inspected:
   - Evidence of loose bolts, nuts, or rivets
   - Evidence of worn, corroded, cracked, or distorted parts such as suspension housing, levers, bearings, pins, jaw assemblies, and locking and clamping devices.
   - Evidence of damage to hook retaining nuts or collars, and pins and welds or rivets used to secure the retaining members.
   - The presence of the required labels and marks.
- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

3.4.4 - Cleaning and inspection

The following guidelines are those provided by Tractel (https://www.tractel.com/) and other manufacturers for devices used for normal operations at the surface, so not involving immersion.
Note that Tractel says that grease or oil containing graphite additives or molybdenum disulphide should not be used to lubricate jaw winches.

- Cleaning the jaw winch should be performed as follows:
   - Tractel says that the device should be soaked in a bath of proprietary cleansing fluid but not acetone and derivatives or ethylene trichloride and derivatives. In addition, and as explained for other hoists and pulling devices, diesel must not be used. Note that many fluids are sold that are designed for this purpose.
   - The jaw winch should then be vigorously shaken and turned upside down to loosen foreign matters and allow the dirt to come out through the openings for the operating levers.
   - When the cleaning is completed, the technician allows the mechanism to drain and become dry.
   - When confirmed dry, the device should be lubricated using oil *(type SAE 90 120)*. This is done through the openings for the operating levers and specific lubrication holes for some models. The technician should operates the operating levers to allow the lubricant to penetrate all parts of the mechanism.
   - According to Tractel, excess lubrication cannot cause the wire rope to slip.
   - A visual inspection should be carried out, and devices where the side cases show signs of dents or damage, or of which the hook is damaged, should not be used and be returned to an approved repairer.

3.4.5 - Additional precautions for jaw winches used underwater

The procedures above show that jaw winches are usually more robust than lever hoists and chain hoists. This is due to their mechanisms that are quite more simple, and involve a reduced number of pieces that can be affected by corrosion.

However, similarly to the mentioned devices water entering into the mechanism gradually washes out the lubricants. As a result, its efficiency will be progressively diminished as the effects of de-lubrification and corrosion will occur.
For these reasons, Jaw winches should not be immersed for more than one week - 1 week ½, and a turnover must be organized using additional devices.
When the immersed lever hoist is back on deck, it must be rinsed with fresh water (not using HP jets) and immediately dismantled for a throughout cleaning and inspection. The reason is that the salt water is present in sensitive internal parts such as bearings, articulations, springs, washers, circlips, etc., that are not treated against corrosion (see the schemes). In the presence of air, the conditions for accelerated corrosion are fulfilled to result in the device being out of order and, thus, dangerous within only a few days. As it is not proven that the cleansing agent mentioned in the previous point will be efficient in removing salt water from enclosed parts, this procedure should be preferred to the manufacturer's one, initially designed for devices that are not immersed.

Note that the water quickly invades the sensitive parts of the tool. Therefore, the rule should be that immersed jaw winches must be thoroughly cleaned, decontaminated, and inspected, whatever the duration of immersion.

When the internal parts of the jaw winch have been rinsed and fully dried, they must be adequately lubricated using hydrophobic lubricants of at least similar properties to those used by the manufacturer for normal use at the surface. That should be done in collaboration with the manufacturer, and/or a specialist in lubricants.
Note that manufacturers of jaw winches usually lubricate their products with motor oil, which removes the problem posed by motor grease. In case motor grease is used, it should be removed for a more adequate lubricant as explained for lever hoists and chain hoists.

Wire ropes should also be rinsed and dried. They should be closely inspected for corrosion, wear, and damage. Note that they are usually galvanized and should be changed when this protection has disappeared, or a loss of flexibility is noted.

Consider that because the jaw winch has been dismantled, it must be load tested before being returned to operations, as recommended by ASME standards. This procedure applies for all jaw winch (used underwater or not) and is explained in the next point.
If after being considered good to service, the jaw winch is not used, it must be inspected according the the "ASME rules for devices not in regular service".

3.4.6 - Jaw winch testing

ASME B30.21 says that the hoist manufacturer must test all new hoists with a load test of at least 125% of the rated load.

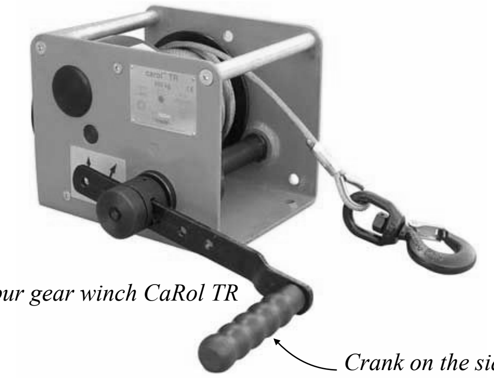
ASME B30.21 also says that all altered or repaired hoists or hoists placed in service that have not been used within the preceding 12 months must be tested by, or under the direction of, a designated person to ensure compliance with the manufacturing standards. These tests can be static or dynamic, and a written report should be issued and classified on file.

A. A qualified person must approve the anchorages or suspensions for the tests before starting the operation.
B. The functions of the hoist must be checked with the hoist suspended in the unloaded state, taking into account that some hoists may require a nominal load or pull on the load hook to test the lowering motion. Then, a load of at least 100 lb (46 kg) times the number of load-supporting parts of the chain, rope, or web strap is applied to the hoist to check the load control.
C. A qualified person must determine the need to load test the hoist.
D. The test must not be less than 100% of the rated load of the hoist or more than 125% of the rated load of the hoist unless otherwise recommended by the hoist manufacturer or a qualified person.
E. The replacement of the wire rope is excluded from the load test. However, an operational test of the hoist should be made in accordance with step "B" before placing the hoist back in service.

4 - Manual drum winches

4.1 - General description

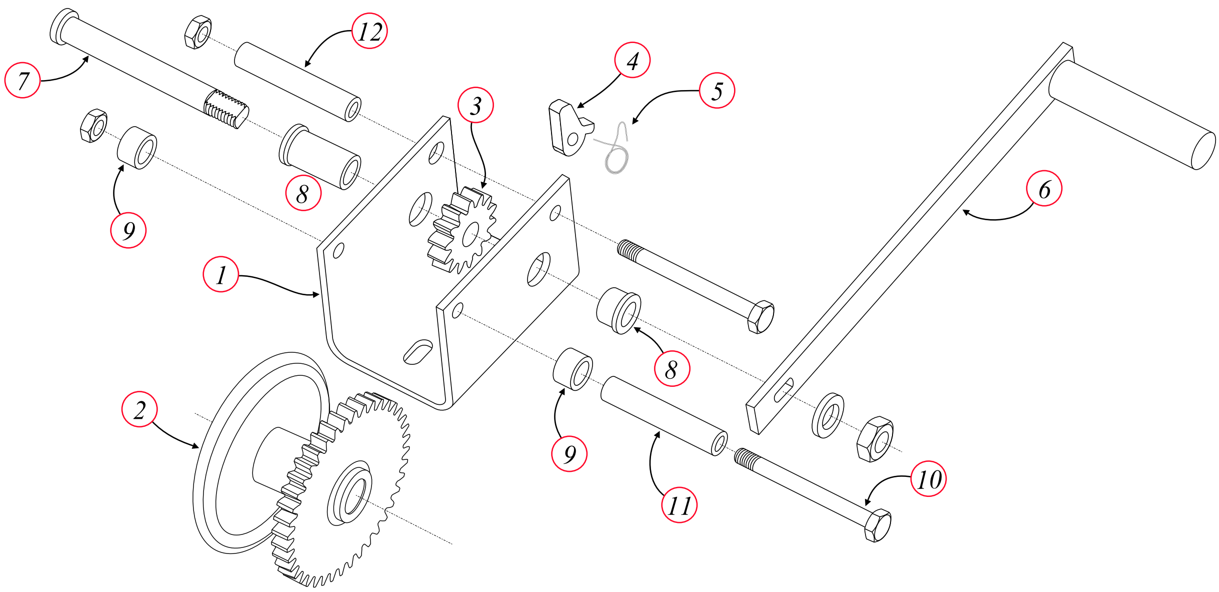
“Manual drum winches”, also called “hand drum winches”, are devices designed for lifting, lowering and pulling loads connected to a rope or webbing wound onto a drum using a handle activated by human effort.
Manual drum winches are often used on davits, “A” frames and on all sorts of static installations. Their advantage is that many models are rated “man riding”, which is not the case of jaw winches and the hoists previously described. For this reason, they are present in bells and diver recovery davits. They are not often used underwater where the jaw winches are preferred because their better polyvalence, and are covered by the standards EN 13157 and ASME B30.7.
Manual drum winches are of two types: “Spur gear winches” and “Worm gear winches”. The difference is that as indicated by their name, worm gear winches are activated by an endless screw and do not have ratchets and pawls. They can be visually differentiated by the fact that the crank of gear winches are on the side and parallel to the gears’ shafts. Opposite, worm gear winches have their crank oriented at 90 degrees to the gear shaft, thus usually at the back or the top of the winch instead of the side. That can be seen on the photos below of the “CaRol TR & TS series” designed by Tractel, which proposes the two options to its clients (https://www.tractel.com/).



Spur gear winch CaRol TR

Worm gear winch CaRol TS

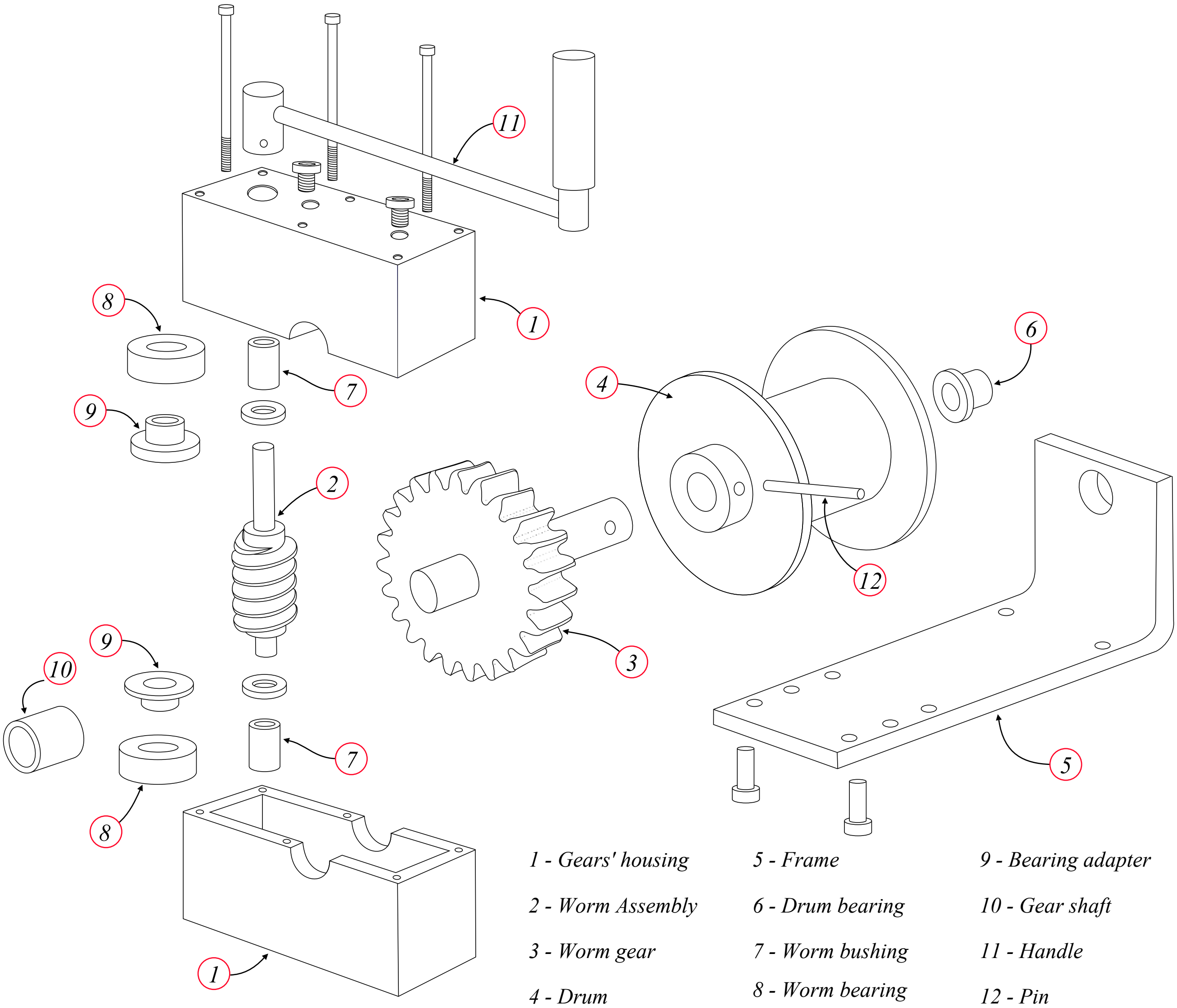
About spur gear winches:
The mechanism of spur gear winches consists of an assembly of gears arranged in cascade (see #3 & #2 below) that provide the multiplication of the force applied through a crank, usually mounted on one side of the apparatus. A pawl (see #4) secures the load when the crank is not activated, and manual and automatic brakes are added on potent units.
The drum and the mechanism are often protected from shocks in the housing that also has the function of a frame. However, a protector is provided on large models.
These types of hand powered winches were used for handling heavy loads during the 19th and the 1st part of the 20th century. However, they have been gradually replaced by powered models using the same mechanisms to which motors have been fitted. As a result, hand-powered models are limited to reduced loads today, with the most potent models apparently limited to 30 tonnes.



1 - Housing / frame	*4 - Ratchet pawl*	*7 - Handle shaft*	*10 - Shaft drum bolt*
2 - Drum + gear	*5 - Spring*	*8 - Bearing handle*	*11 - Spacer - shaft*
3 - Gear	*6 - Handle assembly*	*9 - Bearing drum*	*12 - Spacer*

About worm gear winches:
Worm gear transmissions consist of a spiraled shaft that drives a toothed wheel. They offer high reduction, good reliability, and a built-in braking mechanism associated with their design, as the gear cannot move if the worm does not

rotate (see #2 & #3 below), so ratchets are unnecessary with such transmission systems. However, it is said that they transmit less energy than spur gear solutions and provide a slower winching speed. Worm transmissions are often composed of a worm made of steel and gears made of copper alloys. The reason is that this solution allows for lower friction forces than steel-to-steel. Note that these mechanisms are usually in a housing filled with oil.



1 - Gears' housing
2 - Worm Assembly
3 - Worm gear
4 - Drum
5 - Frame
6 - Drum bearing
7 - Worm bushing
8 - Worm bearing
9 - Bearing adapter
10 - Gear shaft
11 - Handle
12 - Pin

4.2 - Design requirements

4.2.1 - Mechanical strength and safety design

The mechanical strength and safety design requirements are similar to those of the previously described hoists.

- EN 13157 says that this category of winches should have a minimum safety coefficient of 4:1. Their drum should be able to withstand 1500 continuous cycles at full capacity without failure and parts replacement, and they should be designed to at least operate at temperatures from - 10°C to + 50°C.
- As with every powered winch, manual drum winches should have a braking system that automatically operates when the operating force ceases. ASME B30.7 says that this braking system must be able to hold at least 125% of the rated load and should be adjustable to compensate for wear. On small units used to transfer reduced loads, such as those drawn above, this function is often fulfilled by the ratchet assembly or worm gears. However, similarly to powered units used for cranes and davits, an additional brake is provided on units designed for heavy loads. This additional brake is also mandatory for units dedicated to personnel transfer. Regarding this point, ASME B30.7 adds that winches holding loads while unattended must be equipped with a mechanical holding device other than a brake, such as a pawl.
  EN 13157 says that the braking system should allow for controlled descent, whatever the position of the load. Also, the brake system should automatically apply when the load on the lifting medium is greater than 30 kg for capacities up to 1000 kg and greater than 3% of the rated load above 1000 kg. In addition, the load should not descend more than 300 mm before the brake acts to stop it from falling. Note that brake pads should not contain asbestos, as this material is considered to trigger cancers.
  As mentioned previously for other hoist systems, EN 13157 also says that the fracture of a spring should not lead to a failure of the braking system. The guideline recommends that single-guided pressure springs or several springs be used to fulfill this requirement. In addition, many manufacturers design the pawl to automatically close by gravity if its spring breaks.

- Declutching or disengaging the drive shaft or other components should not be possible as long as the system is under load. Also, the crank or operating wheel (used with potent units) should also be secured against unintentional disconnection.
  EN 13157 adds that cranks and operating wheels should have a return travel distance not exceeding 150 mm and that the pawl or another load-retaining device should engage after a movement of not more than 150 mm.
- Like wire ropes used with powered winches and cranes, the ropes used on manual winches should conform to the requirements previously provided in the dedicated chapter and should be designed as follows:
  - They should be supplied in single lengths with splices or connections only at the ends. These connections can be sockets or ferrules. Wire ropes minimum breaking strength should equal 3. This coefficient should be at least 7 for synthetic fiber ropes and webbings.
  - They should be anchored on the drum without being kinked and withstand not less than 2.5 times the nominal forces. For wire ropes, the coefficient of friction for calculations should not be greater than 0.1. Also, the D/d ratio for the drum should be at least equal to 10. *(D/d ratio= Ratio of the pitch circle diameter of the first rope or webbing layer on the drum or sheave to the rope's diameter or the webbing's thickness.)*. The belt sheave and drum diameter ratio to the rated webbing thickness should not be less than 15 (D/s > 15), where “s” is the thickness of the webbing.
  - A minimum of two windings should always remain on the drum and should be marked. Also, the distance of the end of drum flanges beyond the final wound layer of rope or webbing should be at least 1.5 times the rope diameter or the webbing thickness when the maximum length of rope or webbing has been fully wound onto the drum. However, remember that this distance is 2.5 times instead of 1.5 for winches installed on diver launch and recovery systems.
  - The design of the drum should be such that the rope or webbing cannot be wound in the wrong direction. EN 13157 says that these two requirements can be fulfilled if no braking function is provided when the rope or webbing is installed in the wrong direction.
- Hooks should be fitted with safety latches or locking devices to prevent unintentional detachment. They should be manufactured according to a recognized standard, and EN 13157 requires that they are designed not to have permanent deformation at a static load of 2 times the rated capacity. Also, EN 13157 allows the hook to bend at four times the rated capacity, provided that it continues to hold the load safely.

4.2.2 - Ease of use and protection of the mechanism

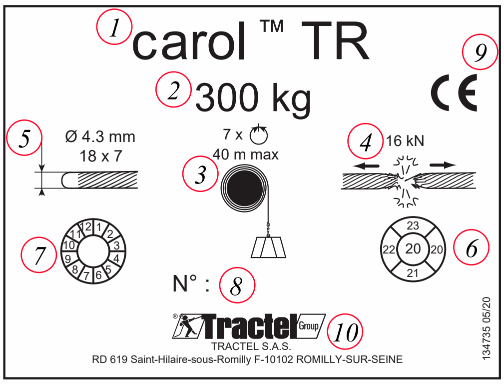
Unlike the hoists systems previously described, manual drum winches are designed to be permanently fixed to a support which can be an “-frame”, a davit, the side of the diving bell, the deck, etc. Thus these tools cannot be considered portable and are usually devoted to pre-determined tasks.

- As with all hoist systems, manual drum winches must be designed such that their accessible parts have no sharp edges, no sharp angles, and no rough surfaces likely to cause injury, and their actuating mechanism should be guarded to prevent accidental ingress. Note that the elements to consider are those that could be accessible when the apparatus is mounted on its support. Many small winches have frames with square shapes that are usually no more accessible to the operator when installed on their support. However, an additional support, such as a connection plate, may be needed if the planned support is not large enough. In this case, the installer of the winch should consider this point and ensure that this support and the winch's housing do not become a potential source of injuries.
- EN 13157 says that manual drum winches must be designed such that the the effort made by the operator does not exceed 25 daN on the crank or the operating wheel.

4.2.3 - Labelling

Drum winches should be provided with a visible labelling providing the information listed below. Note that a winch without appropriate labelling should not be used.

1. Model
2. Working load limit
3. Number of winding layers and maximum length of the wire rope
4. Tensile strength of wire rope
5. Ø and structure of wire rope
6. Production year
7. Production month
8. Serial No. (Traceability code)
9. Norms applied
10. Logo + name + address manufacturer



4.2.4 - Manufacturer’s certificate

After all testing and examination, the manufacturer should issue a certificate which should include at least the following information:

- The manufacturer's name and address, symbol or mark
- Model
- Working load limit
- Tensile strength of wire rope
- Serial No. + Traceability code)
- Date of production
- Ø and structure of wire rope
- The number of the Standards *(EN 13157 + additional standards , or equivalent standards)*
- Test references
- Identity of the person authorized to sign the certificate on behalf of the manufacturer and date of signature.

4.2.5 - About manual drum winches used underwater

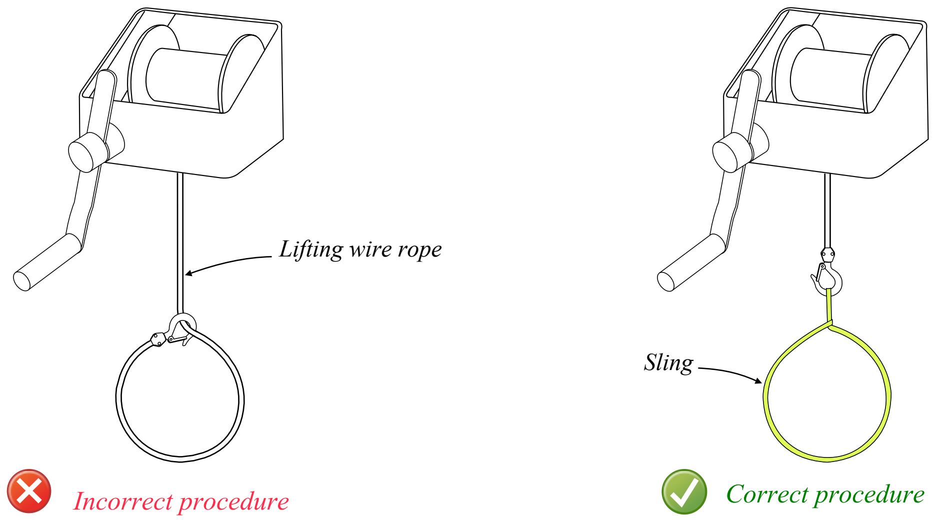
Manual drum winches have been used on boats for a long time. They are, in fact, the 1st models implemented in this industry. For this reason, even though the models made of carbon steel can be affected by corrosion if they are not regularly maintained, they are sufficiently robust and protected to work for a long time on deck. Also, many small units are made of stainless steel and are initially designed for such an environment. Such units usually have straightforward mechanisms and can be used underwater. However, note that units using worm gears have a part of their mechanism in an oil housing not designed to withstand underwater pressure and, thus, cannot be immersed.
It often happens that small manual drum winches not initially designed for the maritime environment are used. These models are as sensitive to corrosion as other hoists previously described and should be maintained similarly.

4.3 - Operational practices

Similar to other hand lifting and pulling tools described in this chapter, this section describes only manual drum winches specific practices. Therefore, this section does not describe general operational practices applicable to all lifting operations, but only those that are specific to these devices.

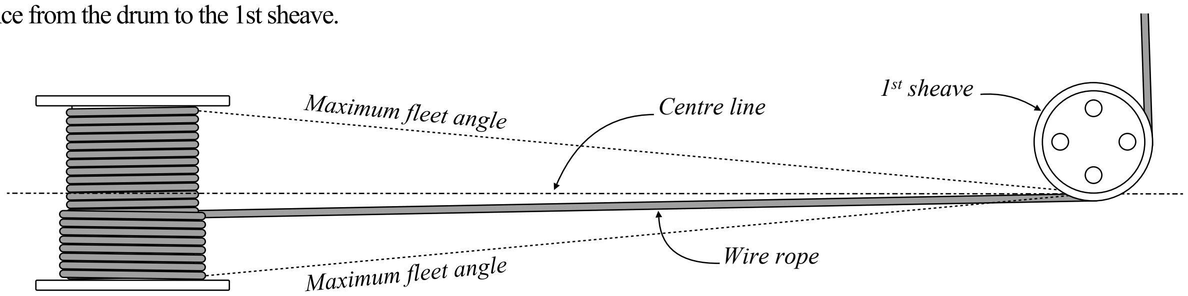
4.3.1 - Rigging the load

The load must be rigged using the hook of the wire rope, equipped with its safety latch. It should be rigged using a sling of appropriate capacity, dimensions, and type for the object to be handled. It is strictly prohibited to use the wire rope as a sling by running it around an object with the hook fastened to the wire rope.



4.3.2 - Fleet angle

"Feet angle", previously explained in the chapter "Wire ropes", is the largest angle of the rope between the first sheave and the drum flange relative to the centre line of the drum. This angle depends on the distance of the sides of the drum to the centre line and the distance from the drum to the 1st sheave.



It must be taken into account while using snatch blocks to lift or pulling objects. As already said, excessive fleet angles can result in

considerable abrasive damage to both sheave flanges and rope and considerably reduce the life of the rope and the equipment. Also, Excessively high fleet angles can return the rope across the drum prematurely, creating gaps between rope wraps close to the drum flanges and increasing the pressure on the rope at the cross-over positions. As a result, structural damage to the wire rope such as a "birdcage" or "core protrusion" may be visible. As the fleet angle increases, so does the problem.
In summary, a maximum fleet angle improperly calculated may result in damages that may be confused with those linked to the rope's quality or design.
The values for the maximum fleet angles vary slightly from one organization to another. EN 12385-3 says that the angle should be no greater than 2° for rotation-resistant ropes and no greater than 4° for single-layer ropes.
EN 12385-3 also says that when spooling onto a drum, the fleet angle is generally recommended to be limited between 0,5° and 2,5°. If the angle is too small, so less than 0,5°, the rope tends to pile up at the flange of the drum and fails to return across the drum in the opposite direction. In this situation, the problem may be alleviated by increasing the fleet angle by introducing a sheave or spooling mechanism. Also, even where the drum is provided with helical grooving, large fleet angles inevitably result in localised areas of mechanical damage as the wires "pluck" against each other. This is often referred to as "rope interference", which can be reduced by selecting a Lang lay rope, if the reeving allows, or a compacted strand rope.

4.4 - Maintenance

The maintenance of manual drum winches is based on the same principle and procedures as other hoists and pulling systems and, thus, depends on the frequency and conditions of use. As a result, many procedures are exactly the same, as the only differences depend on the mechanisms. As for other hoists, the guidelines provided by the manufacturers apply to devices not used underwater. Manual drum winches are currently not often used underwater. However, considering that some models are designed to resist salt water egress, the possibility to use systems with straightforward mechanism should be taken into account.

4.4.1 - Competent personnel

The maintenance of manual drum winches involves troubleshooting, periodic inspections, preventive maintenance, and commissioning procedures before returning the device to service. It is therefore essential that the technician in charge has the technical level for these tasks. ASME provides the following examples of source of training material:

- Information outlined in the manual provided with the equipment. Note that this documentation is mandatory.
- Information from trade associations
- Government training resources such as labour and educational ministries
- Organized labour groups
- Courses, seminars, and literature offered by manufacturers of lever hoists, consultants, trade schools, continuing education schools, and employers.
- Requirements and recommendations found in national consensus standards.
- Note that a technician competent for diving or ROV systems has normally the required level for such inspections and maintenance tasks.

4.4.2 - Troubleshooting

Troubleshooting consist of detecting the source of a breakdown and solving the problem. It also consists of logging the problem and reporting it adequately to ensure that solutions will be found to prevent it happening again.
Note that too many interventions may indicate design problems or maintenance problems.
The table below takes into account common problems reported by manufacturers

Problem	***Common cause***
Load coming down when the crank is turned in the "up" direction, and vice-versa.	*· Wire rope stuck in the drum or wire rope coiled in the wrong direction*
Cable blocked	*· Load snagged*
No ratchet sound (Spur gear winches)	*· Ratchet broken or seized on the rotation shaft*
Brake system not operating	*· Brake system seized or broken*
Effort on crank is abnormally high	*· Gear system seizure or drum seized on rotation shaft*
Load not moving	*· Gear/drum link pin seized in its housing, or gear/drum link pin spring is damaged*
Control crank not locking	*· Return spring broken or pin seized*

4.4.3 - Preventive inspection and maintenance

As for the hoists and pullers previously described it is recommended to organize a preventive maintenance based on:

- The recommendations from standardization bodies
- The recommendations outlined in the hoist manufacturer's manual.
- The recommendations from specialists.
- Reports regarding defect or weaknesses of the equipment
- Safety flashes

ASME classifies the inspections to be organized as follows:

- Initial inspection:
  It is the examination to be performed before committing to service new, altered, or modified hoists.
- Pre-operation Inspection:
  It is performed before the first use of each shift with records not required. It consist of visually examining the following:
  - The operating mechanisms function test, proper adjustment, unusual sounds, and drum rotation.
  - The hooks, including the latches.
  - The damage and correct reeving of the load line.
  - The limiting devices and all other aids
  - Whether deformations, cracks, and other damages are visible.
- Frequent Inspection:
  They are visual inspections not required to be documented, that should be scheduled as follows:
  - Normal service: monthly
  - Heavy service: weekly to monthly
  - Severe service: daily to week

  They consist of examining the following:
  - The operating mechanisms function test, proper adjustment, unusual sounds, and drum rotation.
  - The hooks, including the latches.
  - The load line:
    - The wire rope, if equipped with, must be verified for external damages, corrosion, evidence of heat damages, reduction of diameter.
    - Synthetic ropes and webbing should be inspected for melting or charring, acid or caustic burns, weld spatter, broken stitching (webbing), cuts or tears, damaged eyes or fittings, abrasive wear, knots, discolouration, brittle fibres, and hard or stiff areas.
  - The limiting devices and all other aids.
  - Whether deformations, cracks, and other damages are visible.
- Periodic Inspection:
  It is a documented visual inspection. It can be indicated by a coded mark on the device, and should be organized as follows:
  - Normal service - yearly:
    Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
  - Heavy service - semiannually:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
  - Severe service - quarterly:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The following elements should be inspected:
  - Evidence of loose bolts, nuts, or rivets
  - Evidence of worn, corroded, cracked, or distorted parts such as shafts, gears, bearings, pins, rollers, and locking and clamping devices.
  - Evidence of damage to hook retaining nuts or collars, and pins and welds or rivets used to secure the retaining members.
  - Evidence of damage or excessive wear of load sprockets or idler sprockets
  - Evidence of worn pawls, cams, or ratchets corroded, stretched, or broken pawl springs in brake mechanism.
  - The presence of the required labels and marks.
  - End connections of the load rope, or web strap.
- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

2.5.4 - Additional precautions for manual drum winches used underwater

These precautions are similar to those of hoists previously mentioned:

During diving operations, the water enters the winch's components and gradually washes out the lubricants.
As a result, its efficiency will be progressively diminished as the effects of de-lubrification and corrosion will occur.
As mentioned before, some models of manual drum winches are designed for use at sea and made of stainless steel. However, even though their bearings are waterproof on deck, they are not designed to resist the hydrostatic pressure at depth, and their rollers are usually not made with corrosion-resistant materials. As a result, the salt water can invade and corrode them, in addition to being the source of seizure and accelerated wear. In addition, the salt water will mix with the grease usually used to lubricate them, which will become white colour, stiff, and sticky. Thus its adhesive, lubricant, and anti-corrosion properties will be lost, and motioned parts are no longer protected.
Of course that will be worst with winches not initially designed for operations at sea. For these reasons, and because the manual drum winches are not specifically designed for underwater operations, they should not be immersed for more than one week - 1 week ½, and a turnover must be organized using additional devices.
When the immersed winch is back on deck, it must be rinsed with fresh water (not using HP jets) and immediately dismantled for a throughout cleaning and inspection.
When the internal parts of the winch have been rinsed and fully dried, they must be adequately lubricated using hydrophobic lubricants of at least similar properties to those used by the manufacturer for normal use at the surface. That should be done in collaboration with the manufacturer, and/or a specialist in lubricants.
Referring to what is said above, motor greases should not be used, and be replaced by the specific oils or greases mentioned above.
Also, as previously explained for other hoist systems, diesel should never be used for cleaning or lubricating the device.

Consider that because the winch has been dismantled, it must be load tested before being returned to operations, as recommended by ASME standards. This procedure applies for all hoists (used underwater or not) and is explained in the next point.
If after being considered good to service, the chain hoist is not used, it should be inspected according the the “ASME rules for devices not in regular service”.

2.5.5 - Manual drum winch testing

ASME B30.7 also says that all altered or repaired winches or winches placed in service that have not been used within the preceding 12 months must be tested by, or under the direction of, a designated person to ensure compliance with the manufacturing standards. These tests can be static or dynamic, and a written report should be issued and classified on file.

A. A qualified person must approve the anchorages or suspensions for the tests before starting the operation.
B. The functions of the hoist must be checked with the hoist suspended in the unloaded state, taking into account that some hoists may require a nominal load or pull on the load hook to test the lowering motion.
C. A qualified person must determine the need to load test the hoist.
D. The test must not be less than 100% of the rated load of the hoist or more than 125% of the rated load of the hoist unless otherwise recommended by the hoist manufacturer or a qualified person.

The replacement of the chain is excluded from the load test. However, an operational test of the winch should be made in accordance with step “B” before placing the hoist back in service.

5 - Deflection pulleys and pulley blocks

5.1 - General description

“Deflection pulleys” consist of a sheave freely rotating on an axle to be used with drum winches and jaw winches to change the direction of a rope. They can also be used to multiplicate the force of the winch. In this case, they are provided with a bottom anchorage called “becket” at the opposite end of the hook, which is not figured in the drawing below. Also, note that the hook figured in the drawing is replaced by a shackle on some models.
“Pulley blocs” usually consist of assemblies of two or three sheaves grouped on the same block. Nevertheless, more than three sheaves can be assembled for specific units. They are used to multiplicate the hand power of a person or the force of a winch. They can also be used to modify the direction of the force applied. These systems of multiplication of force have been used since antiquity. Pulleys are covered by the European standard EN 13157 and the ASME standard B30.26.

1 - Anchoring hook

2 - Sheave

3 - Side plate

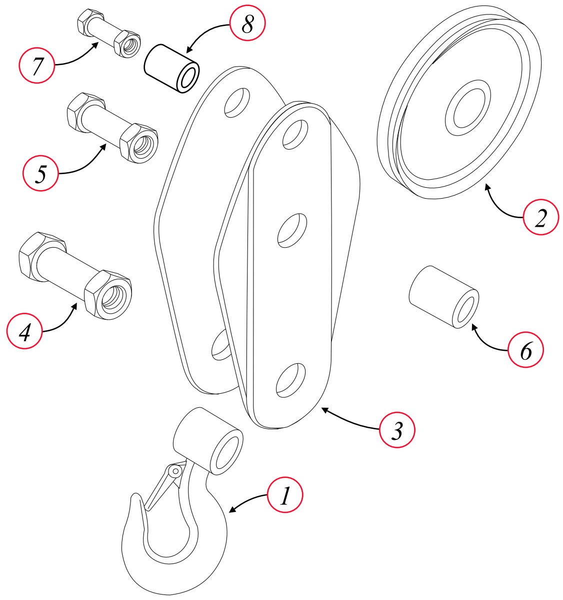
4 - Hook axle

5 - Axle sheave

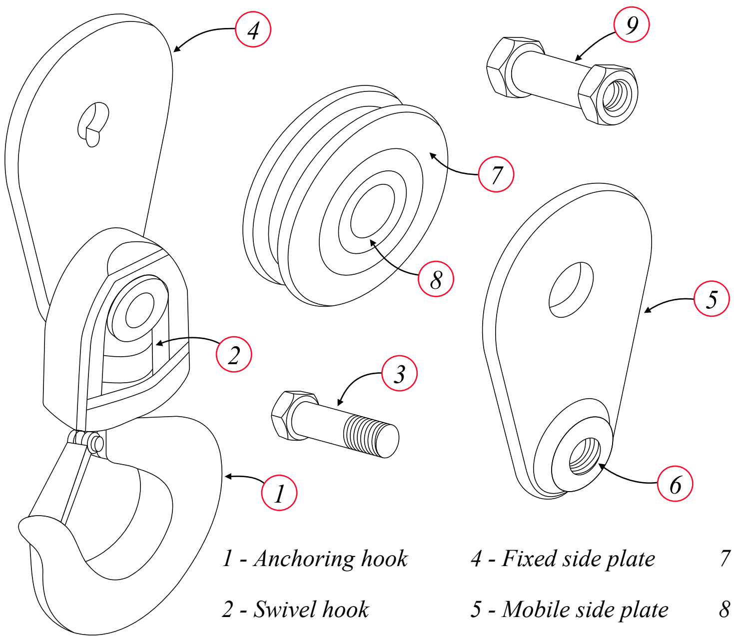
6 - Sheave bearing

7 - Block bolt

8 - Block spacer



Opening sheaves, also called "snatch blocks", consist of deflection pulleys designed so that one side plate can be opened, allowing the operator to install the rope or remove it without disconnecting the pulley from its support. This design also allows installing them on lines already deployed. For this reason, they are commonly used to correct inadequate directions and install temporary lines on the deck and in the water.

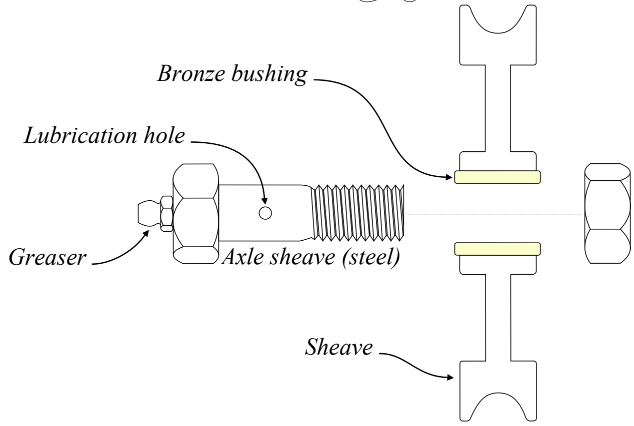


1 - Anchoring hook	*4 - Fixed side plate*	*7 - Sheave*
2 - Swivel hook	*5 - Mobile side plate*	*8 - Sheave bearing*
3 - Hook axle	*6 - Welded nut*	*9 - Axle sheave*

Similarly to classical deflection pulleys, many models of snatch blocks are provided with a shackle or a connecting ring in place of the hook. This arrangement is also usually mounted on a swivel.
Also, the axles of many pulleys’ sheaves rotate on bronze bushings instead of bearings for the following reasons:

- It is already mentioned in the description of winches using worm gears that bronze gears assembled with a steel worm result in less friction than steel to steel. Using bronze is also common for connecting rod bearing shells of the majority of engines, proving the efficiency of such a solution.

- Pulleys designed with bronze bushings give the following advantages:
  - Resistance to contamination and corrosive environments
  - Resistance to shock stress and vibrations
  - Easy maintenance and lubrication.
  - Measurable wear not resulting in immediate failure.

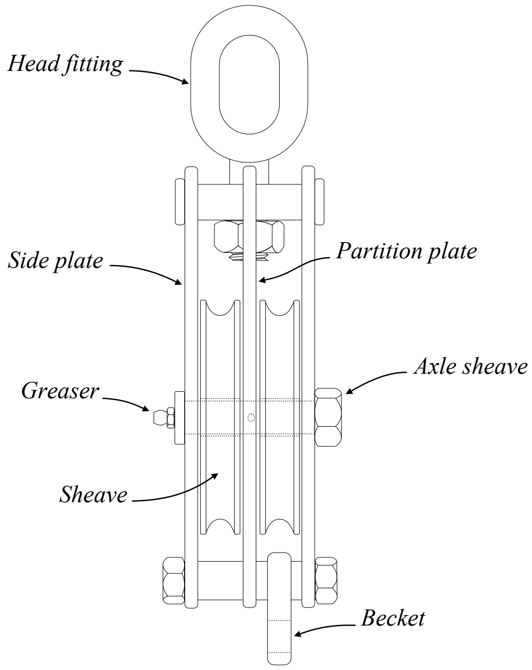


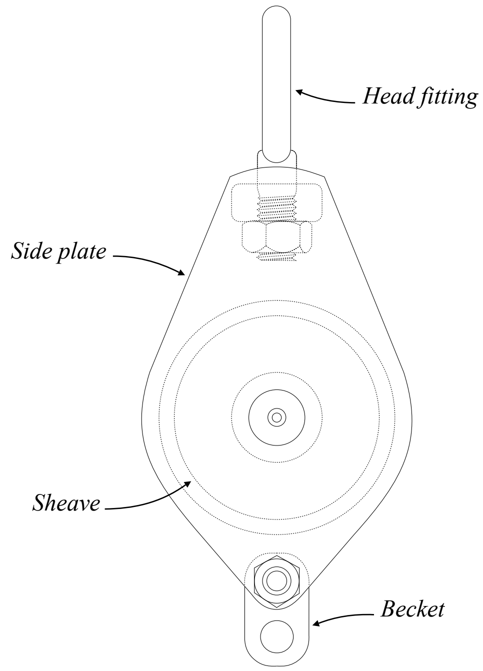
5.2 - Design requirements

5.2.1 - Mechanical strength and security

Pulleys are simple tools with fewer moving parts than hoists and winches. However, they must be designed according to established standards to ensure they will not break during the operations. It must be noted that many registered lifting accidents are linked to the use of inappropriate pulleys.

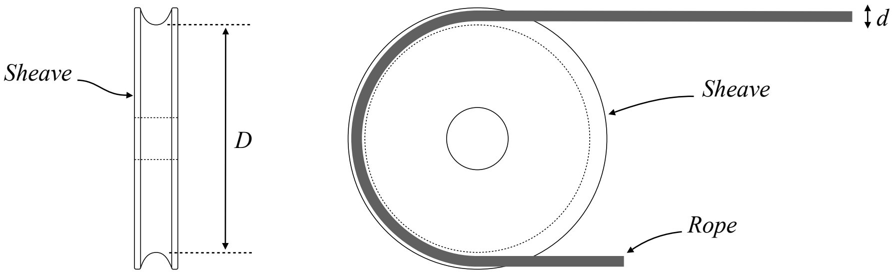
- EN 13157 and ASME B30.26 require that pulley blocks and sheaves elements have a safety coefficient of at least 4. EN 13157 also says that they should be designed to work at an ambient temperature range of -10°C to + 50°C unless another temperature range is agreed. Regarding this point, note that ASME requires temperatures between -18 °C and + 66°C.
- ASME B30.26 says that the pulley block must have sufficient ductility to deform permanently before losing the ability to support the load at the temperatures specified for use. In addition, EN 13157 says that the load hooks should be manufactured according to a recognized standard or not show permanent deformation at a static load of 2 times the rated capacity. It is accepted that it bends at a static load of 4 times its rated capacity. However, it must continue to hold the load safely. Note that these requirements apply to the beckets when pulleys are equipped with.
- The shell or side plates can be made of metal, wood, or synthetic materials. The sheaves can be made of metal or synthetic materials, and the load bearings should be made of metal only.
- The sheave should be designed not to damage the rope:
  - The pulley blocks and sheaves must be fitted with a rope guide system that ensures that the rope stays in the groove of the sheave in case of slack rope. That is usually fulfilled by minimizing the space between the side plates and the edge of the sheave so that the rope automatically sits in the sheave's groove. Partition plates are also added with multiple sheave blocks, so each sheave is separated from the others.





  - The pitch circle diameter to the centre line of the rope (D) should be at least 12 times the nominal diameter of the rope (d).
  - The groove angle should be between 45 ° and 55 °.
  - The radius of the groove should be between d/2 + 5 % and d/2 + 10 %.

- The depth of the groove should be at least 1.5 times the nominal diameter of the rope.
- The groove of the sheave for fibre rope should be radiused. The radius must be at least equal to half of the fibre rope diameter.



5.2.2 - Labelling and certificate

The labelling of the deflection pulleys and pulley blocks must conform to what is applied to all lifting devices. It should be visible on the side of the pulley:

- Working load limit
- Production date
- Serial No. (Traceability code)
- Production month.
- Ø of wire rope agreed
- Norms applied
- Logo + name + address manufacturer

The certificate should indicate the references indicated above plus:

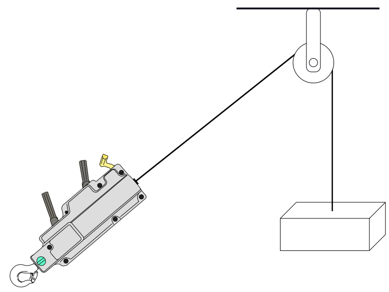
- The tests performed
- The identity of the person authorized to sign the certificate on behalf of the manufacturer and date of signature.

5.3 - Operational practices

5.3.1 - Applications

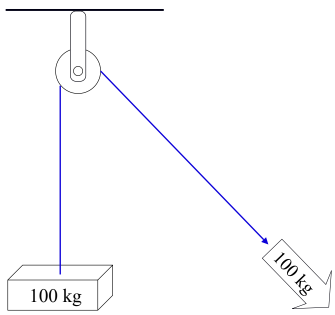
A single line sheave block can be used to change a load line direction.:

For example, in the figure aside, the Jaw winch is installed to prevent the operator from being in the direct vicinity of the load. The same principle can be applied to pull loads or adapt to the worksite configuration.

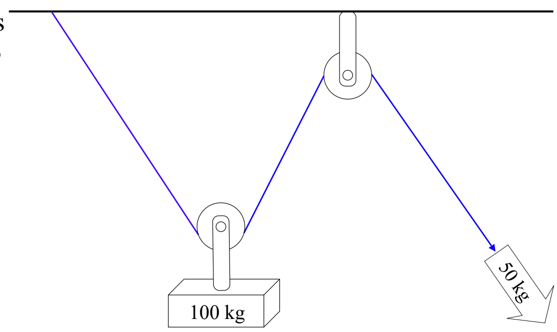


A multiple part block gives the mechanical advantage to divide the necessary force to lift (or move) a load:

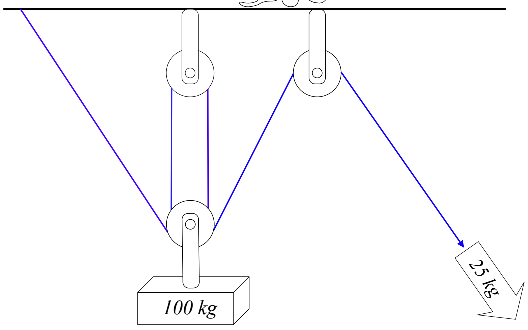
For example, if a 100 Kg block is suspended using a single line sheave, the only change is the direction of the force applied to lift the weight. If the operator wants to raise the 100 kg, he has to apply a force sufficient to lift a mass of 100 kg.



If a 2nd pulley is added so that the weight is suspended by two pulleys rather than one, the weight is split equally between the two pulleys, so each one holds 50% of the mass. That means a force sufficient to lift 50 kg only is enough to lift the 100 kg load.



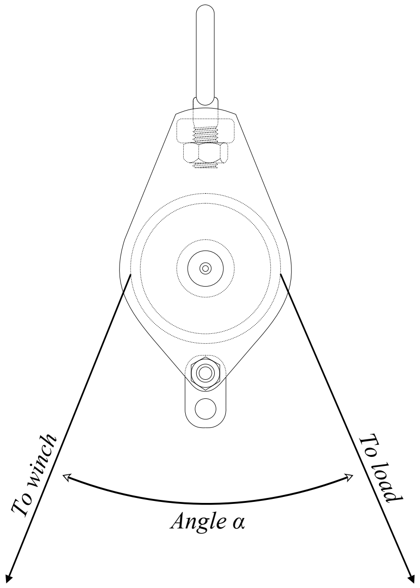
If the weight is split again by adding a block with two sheaves to the two pulleys used in the previous example, the operator needs to apply a force of 25 Kg instead of 50 kg in the previous example.



Note:
To raise the load, the winch has to pull the distance planned multiplied by the number of parts of lines.
The advantage of a multiple part block is reduced by the friction of the sheaves.

5.3.2 - Pre installation

The load applied to the block must be calculated:
The maximum Working Load Limit (WLL) written on the side of the block is the maximum load that should be exerted on the block. This total load value F varies with the "angle α" between the incoming and departing lines to the block. The table below indicates the factor to be multiplied by the line pull to obtain the total load on the block.
The value obtained must be strictly lower to the working load limit (WLL) of the block and the resistance of the anchorage point where the block is fitted.



Angle α	*Load factor block*	*Angle α*	*Load factor block*
0°	*Winch WLL x 2*	*90°*	*Winch WLL x 1.41*
10°	*Winch WLL x 1.99*	*100°*	*Winch WLL x 1.29*
15°	*Winch WLL x 1.98*	*110°*	*Winch WLL x 1.15*
20°	*Winch WLL x 1.97*	*120°*	*Winch WLL x 1.00*
30°	*Winch WLL x 1.93*	*130°*	*Winch WLL x 0.84*
40°	*Winch WLL x 1.87*	*135°*	*Winch WLL x 0.76*
45°	*Winch WLL x 1.84*	*140°*	*Winch WLL x 0.68*
50°	*Winch WLL x 1.81*	*150°*	*Winch WLL x 0.52*
60°	*Winch WLL x 1.73*	*160°*	*Winch WLL x 0.35*
70°	*Winch WLL x 1.64*	*170°*	*Winch WLL x 0.17*
80°	*Winch WLL x 1.53*	*180°*	*Winch WLL x 0.00*

Remark:
In case of a 3 legs block assembly, add to the above calculated effort the load applied on the becket.
Example: If α = 0% F= 2 X winch WLL + Becket loading.
Bending a rope reduces its strength and repeated bending of a wire rope causes "fatigue". The Table below shows the loss of strength linked to the D/d ratio:

D/d	*Strength efficiency*	*D/d*	*Strength efficiency*	*D/d*	*Strength efficiency*
40	*0.95*	*16*	*0.89*	*6*	*0.79*
30	*0.93*	*14*	*0.88*	*4*	*0.75*
25	*0.92*	*12*	*0.87*	*2*	*0.65*
20	*0.91*	*10*	*0.86*	*1*	*0.5*
18	*0.9*	*8*	*0.83*		

5.3.3 - Underwater use

Pulleys designed with bronze bushings can be used underwater without damage.
Note that pulley blocks initially designed for sail boats are designed to resist corrosion, and can be advantageously used with synthetic ropes.
Considering the extended range of pulleys designed with bronze bushings, there is no reason for using models with ball, roller, or needle bearings underwater.

5.3.4 - Pre use checks

Investigation through safety flashes published by professional organizations shows that many incidents have happened due to miscalculations in selecting the block, which is why the abovementioned pre-installation procedures must be considered. However, many incidents have also occurred due to carelessness regarding the connecting point and pulley block condition:

- Inspecting the connecting point and ensuring the connecting sling's strength and condition is essential. They must, at least, withstand the efforts applied to the pulley. Thus, the elements previously discussed regarding the manufacturing of the hook should apply.
- Even though pulley blocks are usually robust, they are often submitted to harsh conditions and may be damaged. For this reason, similarly to hoists and slings, they must be thoroughly verified before each lifting. The ASME "preventive inspections" guidelines, discussed in the section "Maintenance" below, should be followed.

5.4 - Maintenance

5.4.1 - Preventive inspection and maintenance

As mentioned for other lifting tools, it is recommended to organize a preventive maintenance based on:

- The recommendations from standardization bodies
- The recommendations outlined by the manufacturer.
- The recommendations from specialists.
- Reports regarding defect or weaknesses of the equipment
- Safety flashes

ASME classifies the inspections to be organized for pulley blocks as follows:

- Initial inspection:
  It is the examination to be performed before committing to service new, altered, or modified devices.
- Frequent Inspection:
  They are visual inspections, not required to be documented, that should be performed by the operators each shift before the rigging block is used. However, rigging hardware may be in semi-permanent and inaccessible locations, making such inspections not feasible. For such cases, ASME recommends examining them according to the ”periodic inspection” procedures.

  Frequent inspections consist of examining whether the following defects are present:
  - Missing or illegible identification.
  - Misalignment or wobble in sheaves.
  - Excessive sheave groove corrugation or wear.
  - Loose or missing nuts, bolts, cotter pins, snap rings, other fasteners, and retaining devices
  - Indications of heat damage, including weld spatter or arc strikes
  - Excessive pitting or corrosion
  - Bent, cracked, twisted, distorted, stretched, elongated, or broken load-bearing components.
  - Excessive wear, nicks, or gouges
  - A 10% reduction of the original or catalogs dimensions at any point.
  - Excessive damage to load-bearing threads.
  - Evidence of unauthorized welding or modifications.
  - Hooks and shackles excessively worn or damaged. Note that they should be inspected and eventually discarded according to the criteria indicated in the chapters describing them.
  - Other conditions, including visible damage, causing doubt as to the continued use of the rigging block.
  - Important note:
    It is essential to ensure that sheave rotates freely: A sheave that does not rotate results in additional efforts to lift or pull the load, in addition to excessive wear and not visible damage to the rope.

  Note that the pulley block should be removed from service if one of the elements mentioned above is not satisfactory.
- Periodic Inspection:
  It is a documented visual inspection performed by a specialist who determines whether the pulley block is safe or hazardous. It can be indicated by a coded mark on the device, and should be organized as follows:
  - Normal service - yearly:
    Visual inspection by a designated person making records of conditions to provide the basis for a continuing evaluation.
  - Heavy service - semiannually:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.
  - Severe service - quarterly:
    As above unless conditions as determined by a qualified person indicate that disassembly should be done to permit detailed inspection.

  The elements listed in “frequent inspection” above should be closely inspected. Note that the specialist removes the pulley block from service if one of the elements mentioned in the above list is unsatisfactory. However, consider that a pulley removed from service can be repaired and returned to service after being inspected again.

- Devices not in regular service:
  A device not used for a period of 1 month or more and less than 1 year should be inspected according to the requirements of frequent inspections (see above).
  A device not used for a period of 1 year or more should be inspected according to the requirements of periodic inspections (see above)

5.4.2 - Repairs and Modifications

ASME says that repairs, alterations, or modifications must be as specified by the rigging block manufacturer or a qualified person. Note that these specifications should follow the requirements of the selected manufacturing standard.

- The replacement parts, such as pins, hooks, and sheaves, must meet or exceed the original equipment manufacturer's specifications. Note that this point should be documented.
- It is not indicated whether static and dynamic load tests are to be performed. However, we can consider that it should be done, particularly if hanging elements have been changed. In this case, the ASME procedures for hoist devices should be applied (100% to 125 % of the work Load Limit).

5.4.3 - Immersion Policy

Pulleys are usually robust and usually resist immersion without problems. However, a single immersion policy should be implemented to avoid their deterioration. For this reason, pulleys should have a specified maximum immersion time limit equivalent to hoists, so less than two weeks. They should not be submerged again until inspected, serviced, and tested by a suitably qualified person.
This inspection should consist of dismantling them and verifying the condition of the sheave's axle, bushes, and suspension parts.
Note that standard motor grease should not be used to lubricate them as it will become sticky and will quickly lose its lubricant properties. For this reason, it should be replaced by a water repellant grease before the initial immersion. That can be easily done if the pulley is provided with greasers. When doing it, the operator should ensure the the "old" grease is pushed pout by the new one.
Pulley sheaves rotating on ball, roller, or needle bearings, must be opened, and these bearings must be thoroughly cleaned and lubricated as for those used in hoists.

Page left blank intentionally

E - Lifting slings, ropes and sailor knots, and cargo nets

1 - Textile slings

1.1 - Norms and standards applied

Many norms are applied for the fabrication of webbing slings, and it is important to be sure of what norm has been used and have knowledge of these norms.

The standards indicated in this chapter are the European Standards EN 1492- 1 “flat woven webbing slings” & EN 1492-2 “Round slings” , which specify the requirements related to safety, including methods of rating and testing of webbing slings, with or without fittings, made of polyamide, polyester and polypropylene man-made fibre webbing in the width range of 25 mm to 450 mm inclusive.

The webbing slings covered by EN 1492 are intended for general purpose lifting operations, i.e. when used for lifting objects, materials or goods which require no deviations from the requirements, safety factors or working load limits specified. Lifting operations not covered by this standard would include the lifting of persons, potentially dangerous materials such as molten metal and acids, glass sheets, fissile materials, nuclear reactors and where special conditions apply.

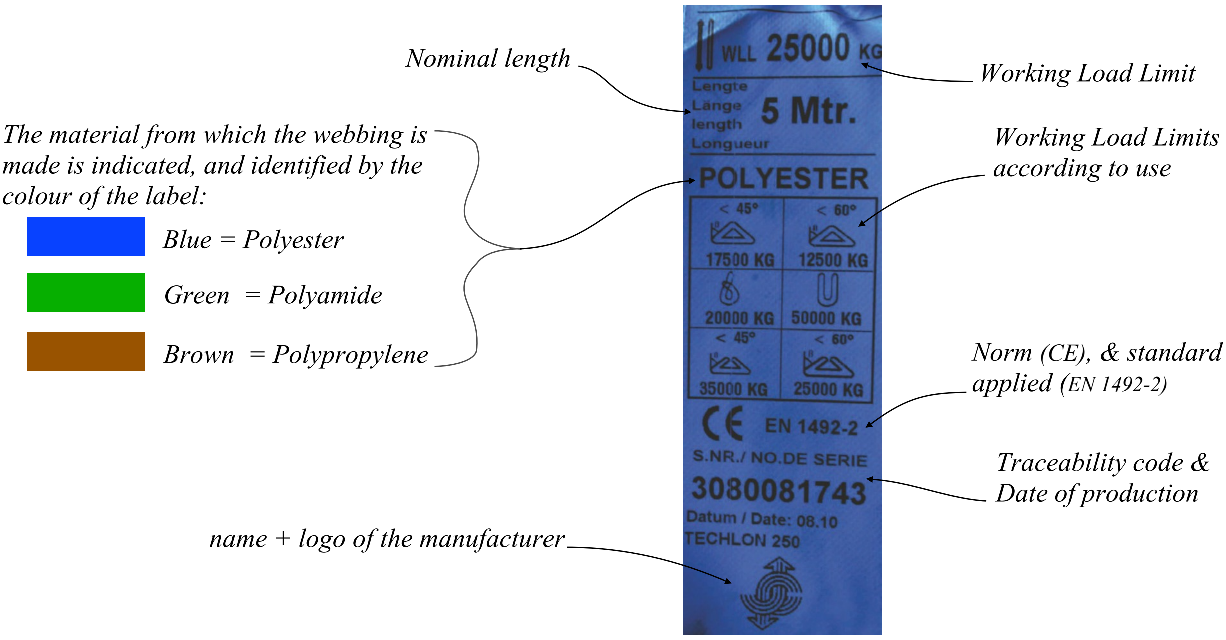
Webbing slings conforming to this European Standard are suitable for use and storage in the following temperature ranges:

- polyester and polyamide: 40 °C to 100 °C;
- Polypropylene: 40 °C to 80 °C.

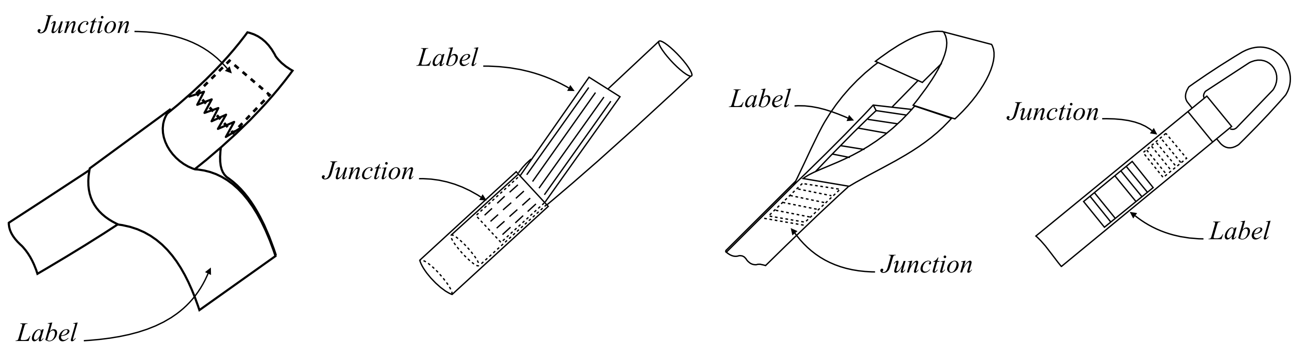
1.2 - Identification

1.2.1 - Label

Textile slings must have a visible durable identification label showing at least the following information:



The label must be installed at one end of the sling or at the junction of the rounded and endless flat slings



The following requirements must apply to 2 leg, 3 leg or 4 leg sling assemblies:

- The marking must be on a readily identifiable form of durable label which must be attached to the master link to differentiate from other sling types.
- The marking of the sling assembly must include the maximum angle of use of any leg to the vertical.
- The label on each leg shall not show the WLL.

1.2.2 - Colour coding

The manufacturers are using specific colours to identify the maximum WLL of the slings:

Colour		*Working Load Limits*	*Colour*		*Working Load Limits*
Violet		*1000 kg (1 tonne)*	*Brown*		*6000 kg (6 tonnes)*
Green		*2000 kg (2 tonnes)*	*Blue*		*8000 kg (8 tonnes)*
Yellow		*3000 kg (3 tonnes)*	*Orange*		*10000 kg (10 tonnes)*
Grey		*4000 kg (4 tonnes)*	*Orange*		*> 10000 kg (> 10 tonnes)*
Red		*5000 kg (5 tonnes)*			

Note: Many countries have adopted similar norms to the European norms, but with a different colour coding. To avoid mistakes, the norms used for the fabrication of the slings must be carefully assessed during the selection.

1.3 - Fabrication requirements *(European standard En 1492)*

1.3.1 - Materials

The webbing shall be woven wholly from industrial yarns and certified by the manufacturer as being fast to light and heat-stabilized with a tenacity of not less than 60 cN/tex, from one of the following materials:

- Polyamide (PA), high tenacity mutli-filament
- Polyester (PES), high tenacity mutli-filament;
- Polypropylene (PP), high tenacity mutli-filament.

NOTE 1: The definitions for these are given in ISO 2076. The content of the constituent materials may be determined in accordance with ISO 1833.

NOTE 2: Attention is drawn to the different resistance of man-made fibres to chemicals, which are summarized in Point 1.4.2.

1.3.2 - Fabrication requirements for Flat slings

Weaving

- All yarns should be of identical parent material (see 1.2.1).
- Whether it is conventional or shuttle-less woven, the webbing should be woven with multiple piles, uniformly woven and the edges such that when one of the yarns breaks during weaving the ends cannot be pulled from the webbing causing it to unpick.
- The method of weaving should be such that the width of the finished sling changes by no more than -10 % for widths less than or equal to 100 mm, and -12 %for widths over 100 mm, when a sample is tested in accordance with annex A.

Width

- The width of the woven webbing should not be less than 25 mm and shall not exceed 450 mm, and when measured with a steel tape or rule graduated in increments of 1 mm, should have the following tolerances:
  - ±10 %for nominal widths less than or equal to 100 mm;
  - ±8 %for nominal widths greater than 100 mm.

Webbing thickness and sling thickness

- For single layer flat woven webbing slings, the load-bearing element of the sling should have a minimum thickness of 2 mm exclusive of any finishes or cast-on features. For multi-layer slings, the webbing used to provide each layer of the load-bearing element of the sling should have a minimum thickness of 1.2 mm.
- The thickness, S1, should be measured in accordance with ISO 5084.

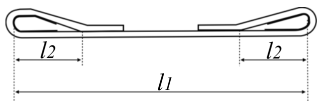
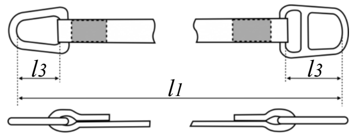
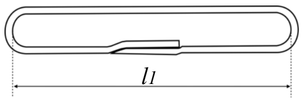
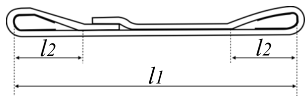
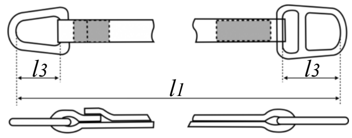
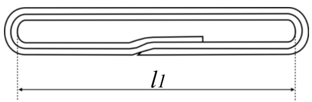
Finishing and other treatments

- The webbing forming the sewn webbing component should be coloured. The sewn webbing component should be treated to produce a closed surface.
- NOTE: These treatments inhibit abrasion and the ingress of abrasive materials and may be applied to the webbing and/or the sewn webbing component and/or the yarn.

- NOTE: Where the webbing has been impregnated to prevent thread slippage, further treatment is not necessary, in which case the ends may be over-sewn.

Sling types and designation: The letter gives the type and number, how many layers have been weaved, e.g. A2.

- Type A: Endless flat woven webbing slings, should be made from 1 or 2 webbing layers.
- Type B: Single flat woven webbing slings with soft eyes, should be made from 1, 2, 3 or 4 layers.
- Type C: Single flat woven webbing slings with metal fittings, should be made from 1, 2, 3 or 4 layers.
- type Cr: Reevable fittings, should be made from 1, 2, 3 or 4 layers.

Form	***A - endless***	***B - Single sling with reinforced eyes***	***C - Single sling with fittings*** ***Cr Single sling with reevable fittings***
Load bearing webbing parts			
Single load bearing parts		*B1 - Single layer sling with reinforced eyes* 	*C1 - Single layer sling with fittings* 
Two load bearing parts	*A2 - Single layer sling* 	*B2 - Two layer sling with reinforced eyes* 	*C2 - Two layer sling with fittings* 
Four load bearing parts	*A4 - Two layer sling* 		

Effective working length (EWL)

- The effective working length (EWL), of a flat woven webbing sling must not differ from the nominal length by more than 3 % of the nominal length when laid flat and measured with a steel tape or rule graduated in increments of 1 mm.

Sewing of slings

- All seams should be made from thread of identical parent material (see 1.2.1) as the webbing and should be made with a locking stitch machine.
- Stitches should not touch or affect the edges of the webbing except those which secure the eye durability reinforcement.
- NOTE: The use of a different colour thread to that of the rest of the sling will facilitate inspection during the manufacturer's verification and in-service inspections by the user.
- The stitches of the seam should traverse the parts of the webbing to be sewn together, and the stitching should lay flat and not have loops above the surface of the webbing.
- The ends of cut webbing should be treated in such a way (e.g. fused by heating) as to prevent unravelling. Treatment of cut ends by heating shall not damage adjacent stitching, and heat-treated ends shall not be over-sewn.

Reinforcement of soft eyes

- Soft eyes should be reinforced to protect the inner surface of the eye against damage during lifting and at the point of choking in a choked lift.
- NOTE Examples of suitable reinforcing material are a sleeve or piece of webbing or leather or other durable material.

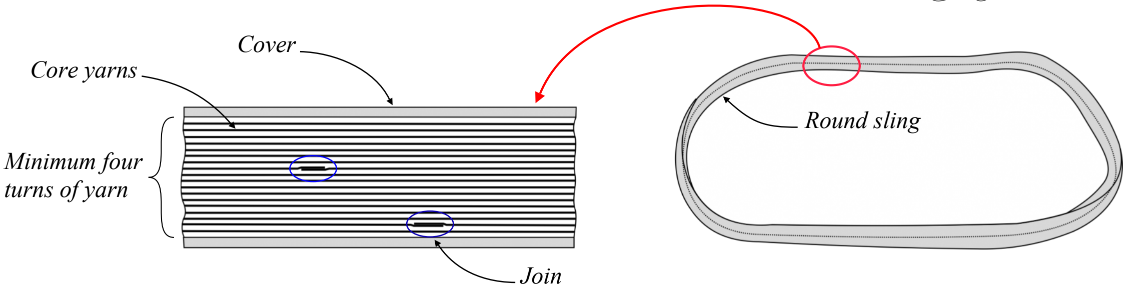
Failure force

The minimum failure force for the sewn webbing component should be such that it will sustain a force equivalent to 7 times the Working Load Limit.

1.3.3 - Fabrication requirements for round slings

Core

- The core should be formed from one or more yarns of identical parent material (see 1.2.1) wound together with a minimum of 11 turns, and joined to form an endless hank. It should be uniformly wound to ensure even distribution of the load.
- Any additional joins in the yarns should be separated by at least four turns of the yarn and should be compensated for by an extra turn per join (see picture next page).



Cover

- The cover should be of webbing woven from identical parent material (see 1.2.1) as the core, and made with the ends overlapped and sewn.
- The edges of the woven cover material should be finished in such a way that they cannot unravel.
- If the cover is welded, care shall be taken to ensure that the welding does not affect the core. The woven material of the cover should be treated to produce a closed surface.

Sewing

- The thread of all seams should be made of identical parent material as the cover and core, and the seam shall be made with a locking stitch machine.
- NOTE The use of a different colour thread to that of the cover will facilitate inspection during the manufacturer's verification and in-service inspections by the user.

Effective working length (EWL)

- The effective working length (EWL) of a round sling must not differ from the nominal length by more than 2 % of the nominal length when laid flat and pulled taut by hand tension and measured with a steel tape or rule graduated in increments of 1 mm.

Failure force

- The minimum failure force for the round-sling core in straight pull should be such that it should sustain a force equivalent to 7 times the Work Load Limit.

1.3.4 - Manufacturer's certificate

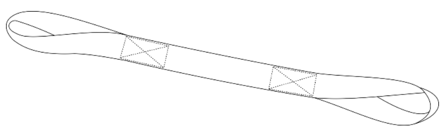
After all testing and examination, the manufacturer should issue to the purchaser, for each batch of slings delivered, a certificate which should include at least the following information:

- The manufacturer's name and address, symbol or mark;
- Working Load Limit of the sling, and for multi-leg sling assemblies the range of angles to the vertical;
- Type, including eye, fitting, number of legs, nominal length and width;
- For flat slings, the expression "Flat woven webbing sling"or "Flat woven sling assembly";
- For round slings, the expression "round sling" or "round sling assembly material" of the webbing;
- Material used;
- Grade of fitting;
- If fitted, details of reinforcements and protection against damage from edges and/or abrasion;
- The number of this European Standard (EN 1492-1 or EN 1492-2);
- Test references;
- Traceability code;
- Identity of the person authorized to sign the certificate on behalf of the manufacturer and date of signature.

1.4 - Common models

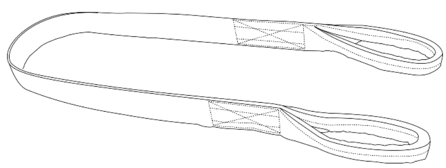
1.4.1 - Flat eye slings

Designed for vertical or basket hitches.



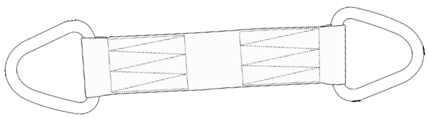
1.4.2 - Reversed eye slings

Designed for choker hitches or where proper alignment of the load is needed. The eyes being in the same plane as the webbing.



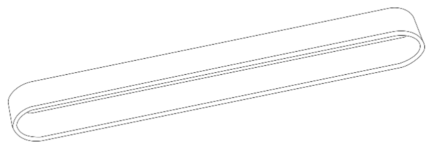
1.4.3 - Metal Dee

Same application but with metal dees. These dees can be plain on both ends or in choker form.



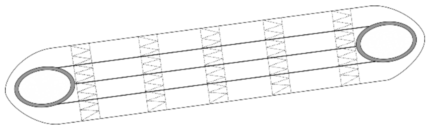
1.4.4 - Flat Loop slings

Most suitable for bulky and awkward loads where stability and easy contour are most important factors.



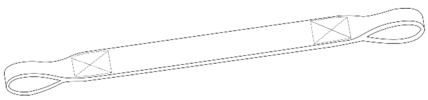
1.4.5 - Wide load loop slings

An extension of the sling. The use of the wide load pad gives greatest possible bearing surface for delicate loads.



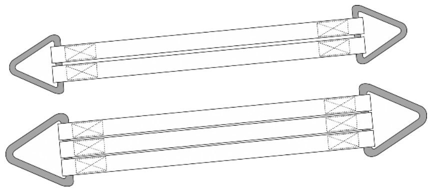
1.4.6 - Reduced eye slings

For use with small hooks.

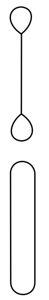
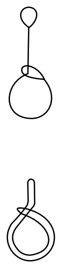
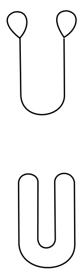
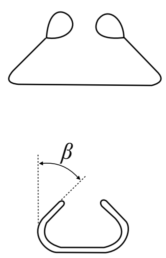
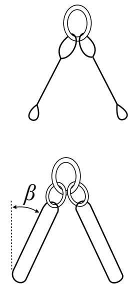
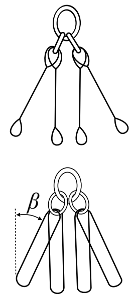


1.4.7 - Parallel construction slings

They are used for very heavy cargoes. They are normally constructed from webbing laid side by side. Separate eyes are formed in each of the load bearing webbings and these normally incorporate metal end fittings. Such slings are normally made for use in basket hitch only and may vary in width from 300 mm to more than 1200 mm.



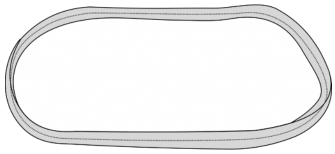
1.4.8 - Working load limits and colour codes flat webbing slings *(Source EN 1492-1)*

WLL of sewn webbing component	Colour of sewn webbing components		Working load limits in tonnes								
			Straight lift	Choked lift	Basket hitch			Two leg sling		Three & four leg slings	
											
					Parallel	β = 0 to 45°	β = 45° to 60°	β = 0 to 45°	β = 45° to 60°	β = 0 to 45°	β = 45° to 60°
			M = 1	M = 08	M = 2	M = 1.4	M = 1	M = 1.4	M = 1	M - 2.1	M = 1.5
1 tonnes	Violet		1	0.8	2	1.4	1	1.4	1	2.1	1.5
2 tonnes	Green		2	1.6	4	2.8	2	2.8	2	4.2	3
3 tonnes	Yellow		3	2.4	6	4.2	3	4.2	3	6.3	4.5
4 tonnes	Grey		4	3.2	8	5.6	4	5.6	4	8.4	6
5 tonnes	Red		5	4	10	7	5	7	5	10.5	7.5
6 tonnes	Brown		6	4.8	12	8.4	6	8.4	6	12.6	9
8 tonnes	Blue		8	6.4	16	11.2	8	11.2	8	16.8	12
10 tonnes	Orange		10	8	20	14	10	14	10	21	15
Over 10 tonnes	Orange										

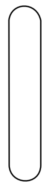
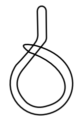
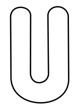
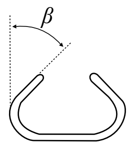
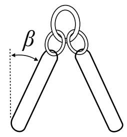
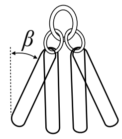
M = Mode factor for symmetrical loading handling tolerance for slings or parts of slings indicated as vertical - 6°

1.4.9 - Round-slings

Similarly to "flat loop" slings, they are multipurpose slings most suitable for bulky and awkward loads where stability and easy contour are the most critical factors. As explained before, their construction is different from flat slings.



1.4.10 - Working load limits and colour codes Round webbing slings *(Source EN 1492-2)*

WLL of sewn webbing component	*Colour of sewn webbing components*	*Working load limits in tonnes*								
		Straight lift	*Choked lift*	*Basket hitch*			*Two leg sling*		*Three & four leg slings*	
										
				Parallel	*β = 0 to 45°*	*β = 45° to 60°*	*β = 0 to 45°*	*β = 45° to 60°*	*β = 0 to 45°*	*β = 45° to 60°*
		M = 1	*M = 08*	*M = 2*	*M = 1.4*	*M = 1*	*M = 1.4*	*M = 1*	*M - 2.1*	*M = 1.5*
1 tonnes	*Violet*	1	0.8	2	1.4	1	1.4	1	2.1	1.5
2 tonnes	*Green*	2	1.6	4	2.8	2	2.8	2	4.2	3
3 tonnes	*Yellow*	3	2.4	6	4.2	3	4.2	3	6.3	4.5
4 tonnes	*Grey*	4	3.2	8	5.6	4	5.6	4	8.4	6
5 tonnes	*Red*	5	4	10	7	5	7	5	10.5	7.5
6 tonnes	*Brown*	6	4.8	12	8.4	6	8.4	6	12.6	9
8 tonnes	*Blue*	8	6.4	16	11.2	8	11.2	8	16.8	12
10 tonnes	*Orange*	10	8	20	14	10	14	10	21	15
Over 10 tonnes	*Orange*									
M = Mode factor for symmetrical loading handling tolerance for slings or parts of slings indicated as vertical - 6°										

1.5 - Inspection of textile slings in service (Source EN 1492)

1.5.1 - Before first use

The sling corresponds precisely on that specified on the order;

The manufacturer's certificate is on hand;

The identification and Working Load Limit marked on the sling correspond with the information on the certificate.

1.5.2 - When in use

The sling should be inspected to ensure that the identification and specification are correct.

Frequent checks should be made for defects or damage, including damage concealed by soiling, which might affect the continued safe use of the sling. These checks should extend to any fittings and lifting accessories used in association with the sling.

If any doubt exists as to the fitness for use, or if any of the required markings have been lost or become illegible, the sling should be removed from service for examination by a competent person.

The following are examples of defects or damage likely to affect the fitness of slings for continued safe use:

- Surface chafe: In normal use, some chafing will occur to the surface fibres. This is normal and has little effect. However, the effects are variable and as the process continues, some loss of strength should be expected. Any substantial chafe, particularly localized, should be viewed critically. Local abrasion, as distinct from general wear, can be caused by sharp edges whilst the sling is under tension, and can cause serious loss of strength.
- Cuts: Cross or longitudinal cuts, cuts or chafe damage to selvedges, cuts to stitching or eyes.
- Heat or friction damage: This is indicated by the fibres taking on a glazed appearance and in extreme cases, fusion of the fibres can occur.
- Damaged or deformed fittings.

  Chemical attack: Chemical attack results in local weakening and softening of the material. This is indicated by flaking of the surface which may be plucked or rubbed off.
    - Polyester (PES) is resistant to most mineral acids but is damaged by alkalis.
    - Polyamides (PA) are virtually immune to the effect of alkalis; however, they are attacked by acids.

- Polypropylene (PP) is little affected by acids or alkalis and is suitable for applications where the highest resistance to chemicals other than solvents is required.

Damages caused by various chemicals to textile slings

Chemical	*Polyester*	*Polypropylene*	*Polyamide*
Acetic Acid (80%)	Negligible	Negligible	Negligible
Acetone	Limited	Negligible	Negligible
Ammonia sol (25%)	Considerable	Negligible	Negligible
Benzene	Negligible	Limited	Negligible
Brine (saturated)	Negligible	Negligible	Limited
Carbon dioxide	Negligible	Negligible	Negligible
Carbon tetrachloride	Negligible	Negligible	No damage
Castor oil	Negligible	Negligible	No damage
Glycerin	Negligible	Negligible	No damage
Hydrochloric acid	Limited	Negligible	Limited
Hydrofluoric acid	Negligible	Negligible	Negligible
Hydrogen Peroxide (10%)	Destructive	Destructive	Negligible
Lactic acid (20%)	Negligible	Negligible	No damage
Lanolin	Negligible	Negligible	Negligible
Meat juices	Negligible	Negligible	No damage
Methanol	Negligible	Negligible	Limited
Motor oil	Negligible	Negligible	Negligible
Nitric acid (50%)	Limited	Considerable	Destructive
Phosphoric acid (50%)	Considerable	Negligible	Limited
Sodium Hydroxide (50%)	Destructive	Negligible	No damage
Sulphuric acid (50%)	Limited	Negligible	Negligible
Sulphur dioxide	Limited	Negligible	No damage
Tallow	Negligible	Negligible	Negligible
Toluene	Negligible	Negligible	Negligible
Turpentine	Negligible	Considerable	No damage
White spirit	Negligible	Considerable	No damage
Xylene	Negligible	Considerable	No damage

1.6 - Selection and use of textile slings *(Source EN 1492)*

1.6.1 - Prepare the lift

Consideration should be given to the required working load limit given on the label, taking into account the nature, size, shape and weight of the load, together with the intended method of use, and working environment

The selected sling should be both strong enough and of the correct length for the mode of use.

In the case of multi-leg slings, the maximum angle to the vertical should not be exceeded.

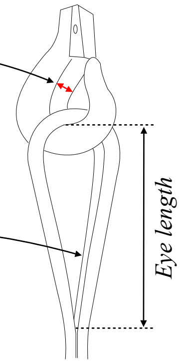
If more than one sling is used to lift a load, these slings should be identical.

The material from which the webbing is made should not be affected adversely by the environment or the load.

Consideration should also be given to ancillary fittings and lifting devices which should be compatible with the sling(s).

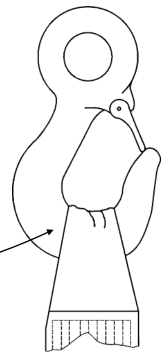
The termination of the sling should also be considered i.e. whether fittings or soft eyes are required.

When using slings with soft eyes, the minimum eye length for a sling for use with a hook should be not less than 3.5 times the maximum thickness of the hook and in any event the angle formed in the eye of the sling must not exceed 20°.



When connecting a sling with soft eyes to a lifting appliance, the part of the lifting appliance which bears on the sling should be essentially straight, unless the bearing width of the sling is not more than 75 mm in which case the radius of curvature of the lifting appliance attachment should be at least 0.75 times the bearing width of the sling.

Wide webbings may be affected by the radius of the inside of the hook as a result of the curvature of the hook preventing uniform loading across the width of the webbing.



This figure illustrates the problem of accommodating webbing on a hook of radius less than 0.75 times the bearing width of the sling

Slings should be placed on the load such that the loading is uniform across their width.

The slings should be correctly positioned and attached to the load in safe manner. <u>They should never be knotted or twisted.</u>

Stitching should never be placed over hooks or other lifting devices: the stitching should always be placed in the standing part of the sling.

Damage to labels should be prevented by keeping them away from the load, the hook, and the angle of choke.

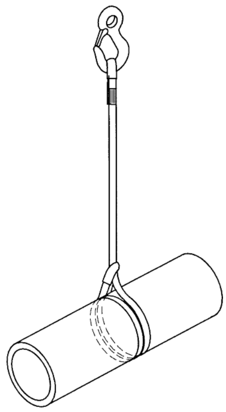
In the case of multi-leg slings, the Working Load Limit values have been determined on the basis that the loading of the sling assembly is symmetrical. This means that when a load is lifted the sling legs are symmetrically disposed in plan and subtended at the same angle to the vertical.
In the case of 3 leg slings, if the legs are not symmetrically disposed in plan the greatest tension is in the leg where the sum of the plan angles to the adjacent legs is greatest. The same effect occurs in 4 leg slings except that the rigidity of the load should also be taken into account.

Slings should be protected from edges, friction and abrasion, whether from the load or the lifting appliance. Where reinforcements and protection against damage from edges and/or abrasion is supplied as part of the sling, this should be correctly positioned. It may be necessary to supplement this with additional protection.

The load should be secured by the sling(s) in such a manner that it cannot topple or fall out of the sling(s) during the lift. Sling(s) should be arranged so that the point of lift is directly above the centre of gravity and the load is balanced and stable. Movement of the sling over the lifting point is possible if the centre of gravity of the load is not below the lifting point.

When using basket hitch, the load should be secure since there is no gripping action as with choke hitch and the sling can roll through the lifting point. For slings which are used in pairs, the use of a spreader is recommended so that the sling legs hang as vertically as possible and to ensure that the load is equally divided between the legs.

When a sling is used in choke hitch, it should be positioned so as to allow the natural (120°) angle to form and avoid heat being generated by friction. A sling should never be forced into position nor an attempt made to tighten the bite. The correct method of securing a load in a double choke hitch is illustrated on the side. A double choke hitch provides greater security and helps to prevent the load sliding through the sling.



1.6.2 - During the lifting operation

Care should be taken to ensure the safety of personnel during the lift. Persons in the danger area should be warned that the operation is to take place and, if necessary, evacuated from the immediate area.

Hands and other parts of the body should be kept away from the sling to prevent injury as the slack is taken up.

A trial lift should be made. The slack should be taken up until the sling is taut. The load should be raised slightly and a check made that it is secure and assumes the position intended. This is especially important with basket or other loose hitches where friction retains the load.

If the load tends to tilt, it should be lowered and attachments re-positioned. The trial lift should be repeated until the stability of the load is ensured.

Care should be taken when making the lift to ensure that the load is controlled, i.e. to prevent accidental rotation or collision with other objects.

Snatch or shock loading should be avoided as this will increase the forces acting on the sling. A load in the sling or the sling itself should not be dragged over the ground or rough surfaces.

The load should be lowered in an equally controlled manner as when lifted.

Trapping the sling when lowering the load should be avoided. The load should not rest on the sling, if this could cause damage and pulling the sling from beneath the load when the load is resting on it should not be attempted.

1.6.3 - After the lift

On completion of the lifting operation the sling should be returned to proper storage.

When not in use, slings should be stored in clean, dry and well ventilated conditions, at ambient temperature, and on a rack, away from any heat sources, contact with chemicals, fumes, corrodible surfaces, direct sunlight or other sources of ultra-violet radiation.

Prior to placing in storage, slings should be inspected for any damage which may have occurred during use. Slings should never be returned damaged to storage.

Where lifting slings have come into contact with acids and/or alkalis, dilution with water or neutralization with suitable media is recommended prior to storage. Depending on the material of the lifting sling and on the chemicals, *(See point 1.5.2)* it may be necessary in some cases to request from the supplier additional recommendations on the cleaning procedure to be followed after the sling has been used in the presence of chemicals.

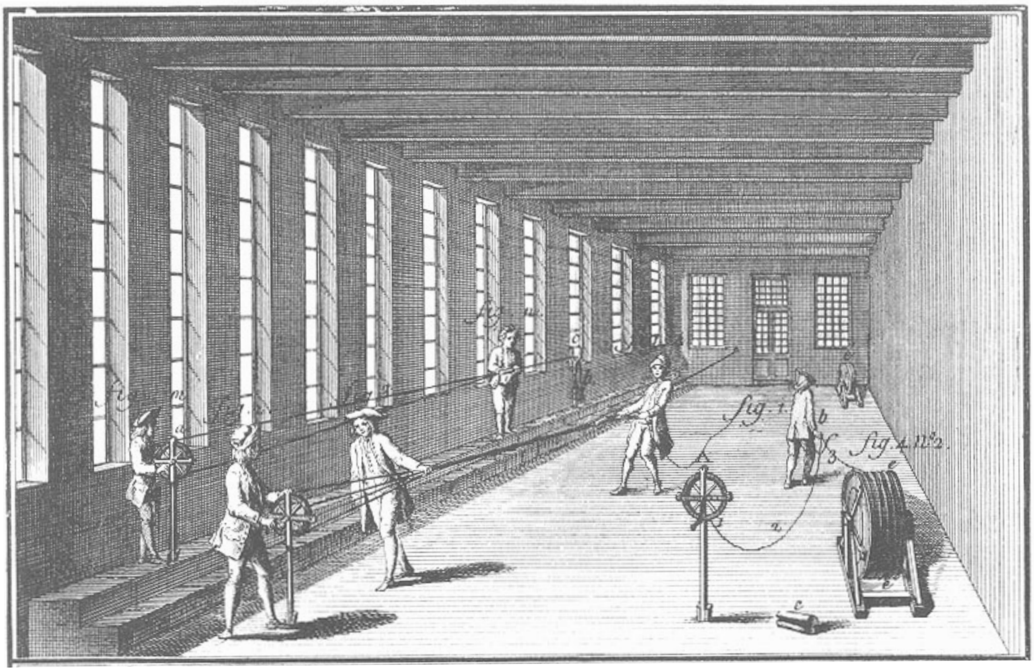
Solutions of acids or alkalis which are harmless can become sufficiently concentrated by evaporation and cause damage. Contaminated slings should be taken out of service at once, soaked in cold water, dried naturally and referred to a competent person for examination.

Slings with grade 8 *(Steel quality)* fittings and multi-leg slings with grade 8 master links should not be used in acidic conditions. Contact with acids or acidic fumes causes hydrogen embrittlement to grade 8 materials. If exposure to chemicals is likely, the manufacturer or supplier should be consulted.

2 - Rope slings

2.1 - History and considerations

Despite they are banished from use by some companies, rope slings are covered by standards and can be used for lifting purposes, provided that they are built according to the recommendations of theses standards.
Ropes are made from several parallel load-bearing elements twisted together to allow the assembly to operate as a cohesive whole. They are the oldest system of slings whose construction principle has been improved for ages. Remains of ropes suggest that their fabrication and use started during the prehistoric period.
Ropes were initially made by hand using natural materials, and their fabrication process improved throughout the ages to become industrialized, with specific plants created for this purpose, such as in the picture below from the encyclopaedia Diderot - d'Alembert, published in France between 1751 and 1777.



Based on the above, we can consider that rope fabrication is based on a considerable transmission of experience. Also, since the sixties, the introduction of composite materials, such as polyamide, polyester, and polypropylene, has made them more solid and durable. In addition, it must be noted that wire ropes are built according to the same fabrication principle. Ropes are commonly used to fasten and tow ships of all sizes, and considering all the above, there is no reason not to use rope sling for lifting operations.

2.2 - Norms and standards applied

This document is based on the European Standard EN 1492-4, which specifies the requirements related to safety, including methods of rating and testing single, two, three, four leg, and endless slings, with or without fittings, made of:

- Sisal, hemp, and manila, natural fibre ropes
- Polyamide, polyester and polypropylene, construction man-made fibre ropes having a reference number in the range of 16 to 48 inclusive.

The fibre rope slings covered by EN 1492-4 are intended for general purpose lifting operations, they are used for lifting objects, materials or goods which require no deviations from the requirements, safety factors or working load limits specified. Lifting operations not covered by this standard would include the lifting of persons, potentially dangerous materials such as molten metal and acids, glass sheets, fissile materials, nuclear reactors and where special conditions apply.

Fibre rope slings conforming to the European Standard EN 1492-4 should be suitable for use and storage in the following temperature ranges:

- polyester and polyamide -40°C to 100°C,
- manila, sisal, hemp and polypropylene -40°C to 80°C.

2.3 - Fabrication materials *(European standard En 1492- 4)*

The definitions of the fibres used are given in ISO 2076:1999 "Textiles - Man-made fibres - Generic names", and ISO 6938:1984 "Textiles - Natural fibres Generic names and definitions". The constituent materials may be determined in accordance with ISO 1833:1977 "Textiles - Binary fibre mixtures - Quantitative chemical analysis".

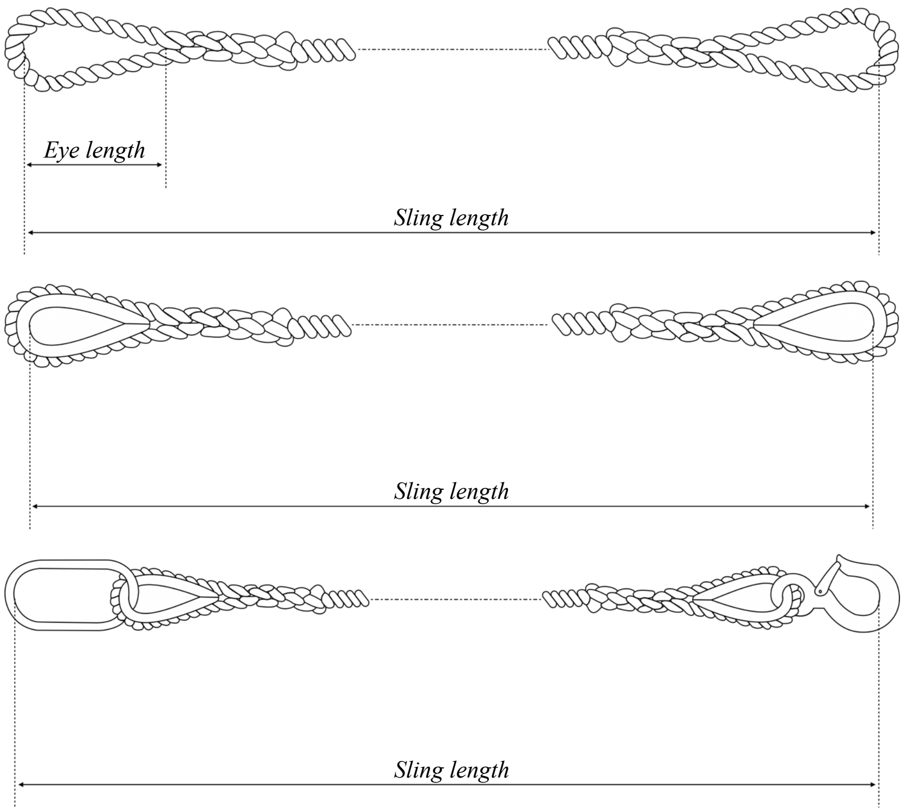
The fibre rope from which the sling is manufactured should be from one of the materials and to the specification given in the table on the next page

Type of fibre rope	*European Specification*	*ISO Specification*	*Comments*
Hemp	*EN 1261*	*ISO 1968:1973 ropes*	*Specification / Guidance*
Manila	*EN 698*	*ISO 1181:1990 Ropes*	*Specification*
Sisal	*EN 698*	*ISO 1181:1990 Ropes*	*Specification*
Polyamide	*EN 696*	*ISO 1140:1990 Ropes*	*Specification*
Polyester	*EN 697*	*ISO 1141:1990 Ropes*	*Specification*
Polypropylene	*EN 699*	*ISO 1346:1990 Ropes*	*Specification*
Polyethylene	—	*ISO 1969:1990 Ropes*	*Specification*

2.4 - Type of rope slings *(European standard En 1492- 4)*

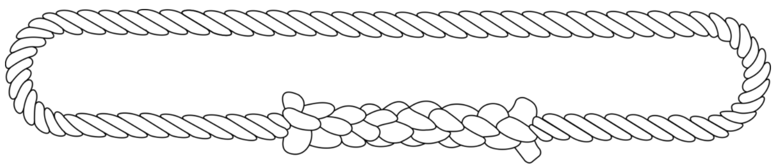
2.4.1 - Single leg sling

A single leg sling should be formed from a single piece of rope and shall have eyes, with or without thimbles and fittings, spliced at each end. The figure below shows three typical examples of single leg slings.



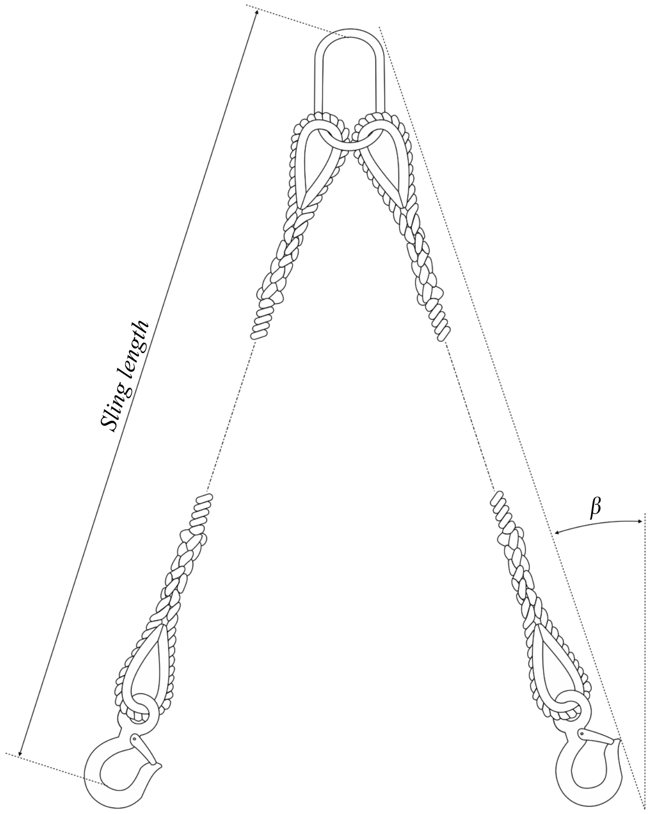
2.4.2 - Endless sling

An endless sling should be formed from a single piece of rope and shall have the ends joined together by a single splice (see below)



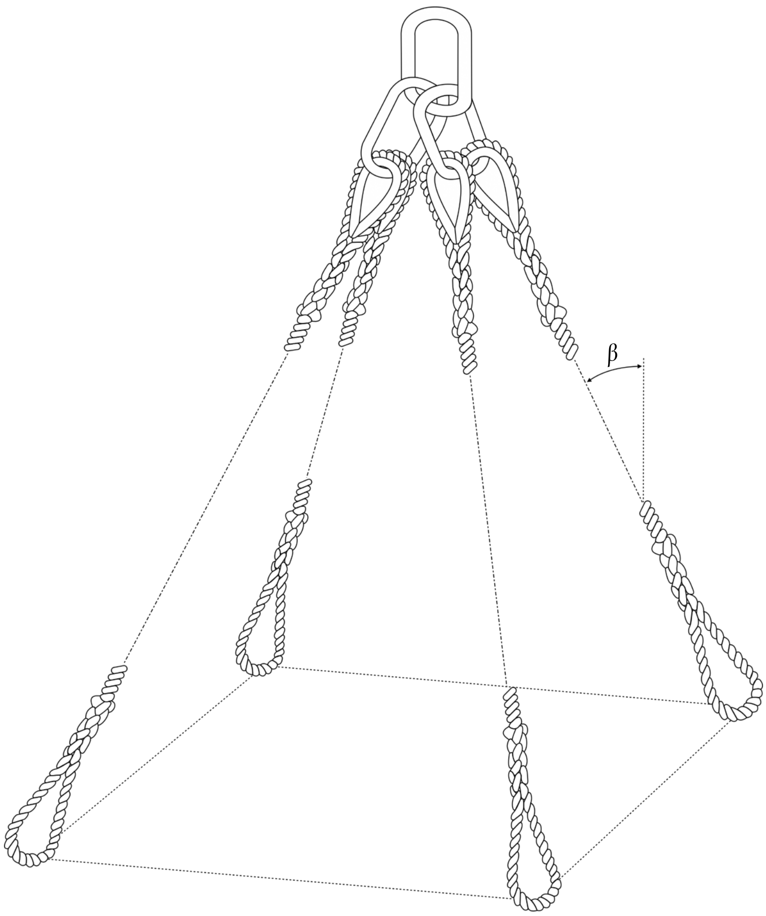
2.4.3 - Two leg sling

A two leg sling should comprise two identical sling legs, with or without thimbles and terminal fittings; the eye of one end of each leg should be made around a master link. The figure below shows a typical two leg sling.



2.4.4 - Three and four leg slings

A four leg sling should comprise four identical sling legs, with or without thimbles and terminal fittings, the eye of one end of each leg should be made around an intermediate link so that two legs are attached to each intermediate link. The intermediate links should be attached to a master link. Three leg slings should be produced in the same way, but two legs should be attached to one intermediate link and one leg to the other. See below shows a typical four leg sling.



2.5 - Sling constructions *(European standard En 1492- 4)*

Splicing should be the only method used for joining or producing eyes.

Endless slings should have only a single splice.

Other sling legs should be spliced at each end to produce an eye and no other splices should be permitted

Multi-leg slings should be constructed so that all corresponding items are identical in respect of rope construction, size, material and fittings.

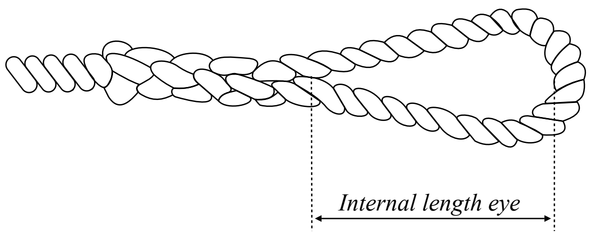
2.5.1 - Eyes

Soft eyes

The minimum internal length, l_2, of a soft eye *(see figure below)* measured with a steel tape or rule graduated in increments of 1 mm when closed by hand should l not be less than the appropriate value given in table below.

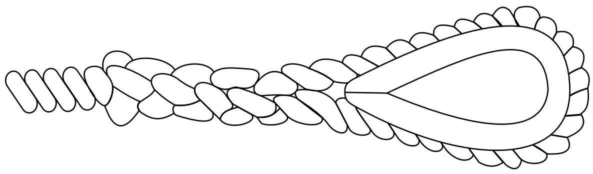
Note:
The reference number is the number quoted in documentation which specifies the mass/metre, breaking force and other parameters of the fibre rope. The reference number corresponds to the approximate diameter in millimetres; minimum breaking force in daN, in EN 696, 697, 698, 699 and 1261

Reference number rope	*Min. Internal length soft eye*
16	150
18	155
20	160
24	170
28	185
32	195
36	210
40	220
44	232
48	245



Thimbled or hard eyes

The thimbles used to form thimbled, or (hard) eyes should comply with EN 13411-1 and have a corrosion resistant finish. The use of thimbled (hard) eyes is recommended when fittings form part of the fibre rope sling. The fitting of heart shaped thimbles will prevent the sling being used in choke hitch. In such cases, either a soft eye or thimbles of a shape and size suitable for reeving may be used.



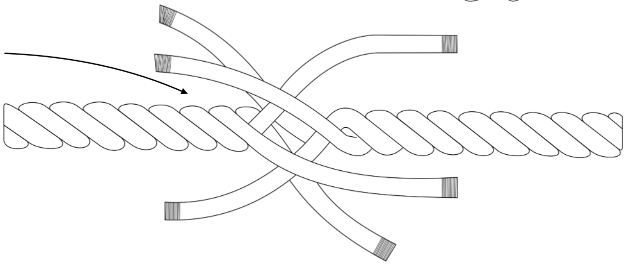
2.5.2 - Splicing (European standard En 1492- 4)

All splicing must be carried out by a trained and competent splicer.

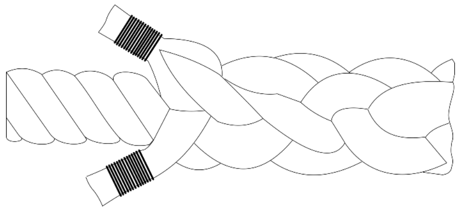
2.5.2.1 - Short splices

Where 3 and 4 strand laid ropes are spliced by short splices, the splice should comply with the following requirements:

- All the tucks of the splice should be against the lay of the rope.
- For polyamide, polyester multifilament ropes, and polypropylene monofilament ropes, five full tucks should be made; alternatively four full tucks with all of the yarns in the strands should be made, followed by a further tuck with not more than half of the material cut out of each strand and a final tuck with not less than a quarter of the original strand material.
- For polypropylene fibrillated film, staple ropes, and for natural fibre ropes, not less than four full tucks should be made, each with all of the yarns in the strands.
- After completion of splicing, the protruding strands, or parts of strands, should be cut at a distance of not less than one nominal rope diameter from the standing part of rope.
- As an alternative, for polypropylene fibrillated film, staple fibre ropes, and for natural fibre ropes, one fewer full tuck is permissible; in which case, the length of the protruding strands after completion of the splicing should not be less than three times the nominal diameter of the rope.
- In the case of endless slings, the splicing requirements given above should apply to each side of the marrying point of the rope *(see the picture at the top of the next page).*



- Where the protruding parts of the strands are contained, e.g. by binding, gluing, tapering etc, to improve the appearance of the finished splice, such finishing shall not affect the performance of the splice.
- In the case of full strands an alternative method of finishing the splice, known as dogging is permissible. The emergent strands are separated into identical proportions and then bound (seized) one half of the emergent strand to the adjacent half of the next emergent strand and so on around the rope *(see the scheme)*. Tapered splices should not be subject to dogging.



2.5.2.2 - Alternative splicing methods

The method of splicing known as the “Liverpool splice” where the tucks are made with the lay of the rope shall not be used.

Long splicing of endless rope slings is permissible but, where used, the length of the splice should not be less than 100 times the rope diameter and the working load limit of the sling shall not be greater than 60% of the value given in tables or as calculated in accordance with 2.7.1.

In the case of 8 strand plaited ropes, the rope manufacturer’s written splicing procedures should be obtained and strictly followed.

2.5.2.3 - Length between splices

For single leg slings and the individual legs of multi-leg slings, there must be a minimum length of rope between the emergence of the final tucks of the splice of 20 times the nominal diameter of the rope.

2.5.2.4 - Effective working length (EWL)

The effective working length of a fibre rope sling should not differ from the nominal length by more than 3%, when laid flat under hand tension and measured with a steel tape or rule graduated in increments of 1 mm.

The length of each leg of a multi-leg sling should not differ from the lengths of the other legs by more than 2.5%.

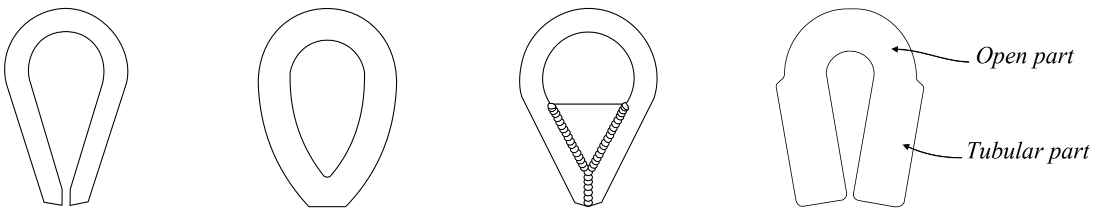
2.5.3 - Fittings

The fittings can be hooks, connecting rings, shackles or other connecting means. They should conform to the appropriate part or parts of the standard EN 1677 “Components for slings.

The seating of a fitting in contact with the rope should be so finished that:

- There should be no damage to the area of the rope in contact with the fitting;
- The fitting should sustain the load rated for the sling.
- The fitting dimensions should be such that the included angle between the two parts of the rope at the splice should not exceed 30°.
- If the part of the fitting with which the rope is in contact has a profile of engagement less than the nominal diameter of the rope, a thimble should be placed in the eye.
- Welded fittings should be placed so that the welds remain visible when the sling is in use.

Thimbles are recommended for all applications when fittings form part of the fibre rope sling, as they offer protection from contact damage and assist in maintaining the shape of the eye.
Many models of rope thimble exist that can be selected according to the conditions the sling will be used. They can be made of nylon, galvanized steel, or stainless steel. Note that steel is usually preferred for lifting slings. Also, they can be designed such that they have an open end or a closed end. The closed-end units provide additional protection to the splice when the sling is slacked. The metallic closed ends units used with slings can be cast or welded. Another type of rope thimble is the tubular one that partially encloses the rope and, thus, prevents the thimble from escaping.



2.5.4 - Calculation of working load limit (WLL)

The working Load limit should be calculated as follow:

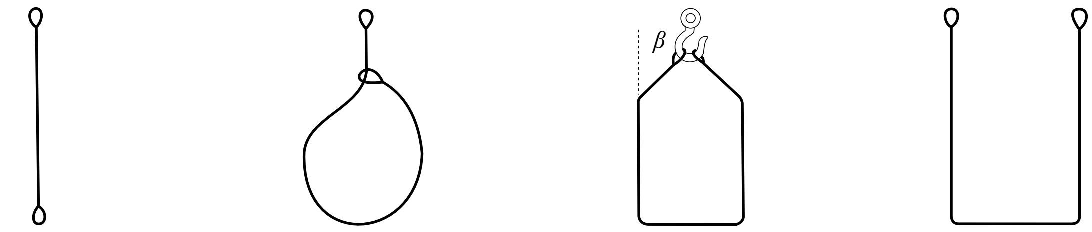
$$\left(\frac{90\%\text{ of specified breaking force of fibre rope}}{\text{Coefficient of utilization } (7)}\right)\text{ Mode factor } \textit{(see below)}$$

Where:

- The breaking force is expressed in Kilo Newton (KN)
- The coefficient of utilization is 7
- The mode factor is indicated next page *(Noted "M")*

2.5.5 - Modes of assembly for single, multi-leg and endless fibre rope slings

2.5.5.1 - Single strop



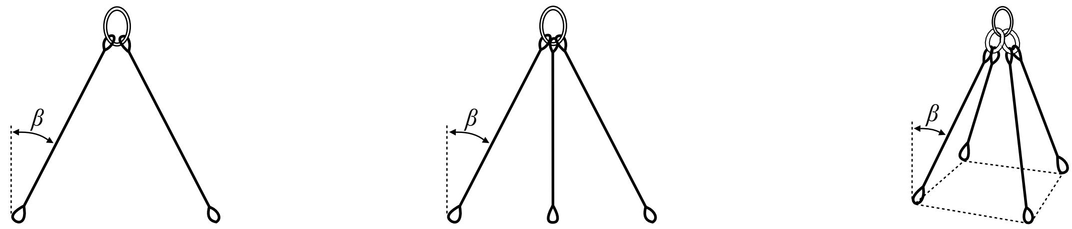
Straight pull
Mode factor = 1

Choke hitch
Mode factor = 0.8

Basket hitch
Mode factor = 1.4
With β = 0 to 45°

Basket hitch parallel
Mode factor = 2

2.5.5.2 - Multiple legs rope slings

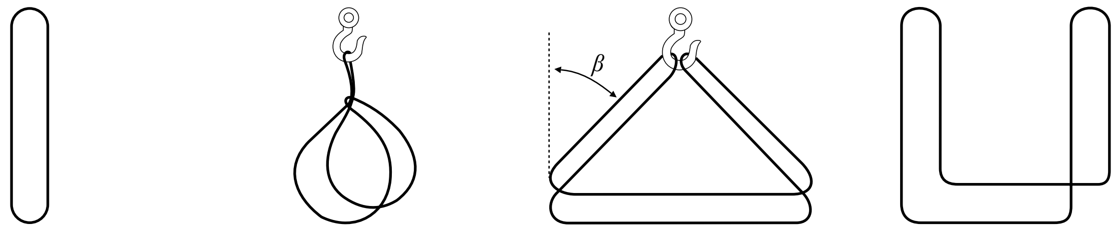


Two legs rope sling
Mode factor = 1.4
with β = 0 to 45°

Three legs rope sling
Mode factor = 2.1
with β = 0 to 45°

Four legs rope sling
Mode factor = 2.1
w β = 0 to 45°

2.5.5.3 - Endless sling



Straight pull
Mode factor = 2

Choke hitch
Mode factor = 1.6

Basket hitch
Mode factor = 2.8
With β = 0 to 45°

Basket hitch parallel
Mode factor = 4

2.6 - Verification after construction

2.6.1 - General

All testing and examination should be carried out using a tensile test machine conforming to the requirements of class 1 of EN ISO 7500-1, and where applicable, a steel tape or rule graduated in increments of 1 mm.

During load tests, the force should be applied to the test pieces so that the elongation of the specimen takes place at a maximum rate of 110 mm/min per 1000 mm length of the specimen.

The test piece should not be pre-loaded prior to testing, unless all of the slings of that type are subject to identical pre-loading;, in which case, they shall not be pre-loaded to more than two times the WLL.

WARNING: During load testing procedures, considerable energy is stored in the rope under tension. If the sample breaks, this energy will be suddenly released. Suitable precautions should therefore be taken to protect the safety of persons in the danger zone.

2.6.2 - Qualification of personnel

All testing and examination should be carried out by a competent person.

2.6.3 - Type test to verify sling legs *(for information)*

For the purposes of type test verification, ropes are grouped in the following range of rope sizes:

- 16 mm to 24 mm;
- greater than 24 mm to 32 mm;
- greater than 32 mm.

Testing should take place for each type of rope (including change of source of material), size range and splicing method to be used in the manufacture of slings. Two test pieces should be produced by each splicer. The rope size selected should be representative of the middle of the relevant group, or in the case of ropes larger than 32 mm, in the middle of the range of ropes for which the splicer will be splicing eyes.

Each test piece should be made with a soft eye at each end and the distance between the tails of the splices shall be at least 15 times the nominal rope diameter so that four splices are presented for testing.

The test piece should be mounted, straight and without twist, between the pins or bollards of the test machine. The diameter of the pins or bollards shall be such that an included angle between 20° and 30° is subtended by the loop of the splice. The specimen should be subjected to a force equivalent to not less than 7 times the Working Load Limit of the specimen.

Type test verification, in accordance with this clause, should be repeated if a period of three years has elapsed since the last sample, including manufacturing test samples, was submitted for testing by the splicer.

The results of the tests, i.e. whether the specimens were accepted or rejected, must be recorded for the purposes of the manufacturer's record. If one or more of the samples does not sustain a force equivalent to 7 times the Working Load Limit, slings of this type shall be deemed not to comply with this standard.

2.6.4 - Type test to verify the interaction of endless slings with fittings *(For information)*

A representative endless sling, of the type intended for use with fittings, should be made with test fittings representing the smallest profile of engagement of the range of fittings that will be used in production.

The specimen should be mounted, straight and without twist, between the pins or bollards of the test machine.

The contact radius of the pin or bollard should be such that it supports the representative fitting over sufficient area so as to prevent the fitting from distorting or twisting whilst under test. The specimen should be submitted to a force equivalent to 5 times the Working Load Limit of the endless sling.

The test piece should have passed the test if the breaking force of the sample is equal to, or greater than, the equivalent of 5 times the Working Load Limit.

The results of the test, i.e. whether or not the specimen was accepted or rejected, should be recorded for the purposes of the manufacturer's record. If the sample does not sustain a force equivalent to 5 times the Working Load Limit, slings of this type shall be deemed not to comply with this standard.

2.7 - Marking & Manufacturer certificate

2.7.1 - General

The marking of the sling shall include the following:

- The working load limit in straight lift in the case of single leg or endless slings, or for multi-leg slings having an angle â of 0 to 45°;
- The material of the rope, e.g. manila, polyester etc;
- The reference number of the rope and grade of fittings;
- The nominal length in m;
- The manufacturer's name, symbol, trade mark or other unambiguous identification;
- The traceability code;
- The number and Part of this European Standard.

The marking shall be in a type size of not less than 1.5 mm in height.

2.7.2 - Labelling

The information above shall be marked on a label attached to the sling as follows:

- On single legs with soft eyes, in one eye adjoining the splice or on the standing part of rope at the end of the splice;
- On single legs with thimbles, on the standing part of rope at the end of the splice;
- On multi-leg slings, on a durable label (e.g. a round tag) attached to the master link or on one leg of the sling;
- On endless slings, at the end of the splice.

One suitable method for applying the marking is to inscribe the details onto a plastic sleeve threaded on the rope and shrunk to it, with a clear plastic sleeve shrunk over the marked sleeve to protect it from soiling.

The material from which the sling is made shall be identified by the colour of the label itself on which the information is marked. The following colours shall be used:

- Polyamide = Green
- Polyester = Blue
- Polypropylene = Brown
- Manila/sisal/hemp = White

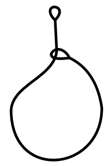
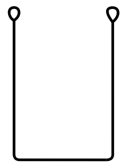
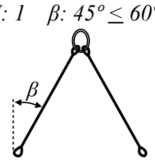
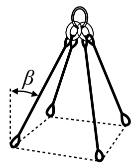
2.7.3 - Manufacturer's certificate

- After all testing and examination, the manufacturer should issue to the purchaser, for each batch of slings delivered, a certificate which should include at least the following information:
  - The manufacturer's name, address, symbol or mark.
  - Working Load Limit of the sling.
  - For multi-leg sling assemblies the angle to the vertical.
  - Type, including eye, fitting, number of legs and nominal length.
  - Nominal diameter or reference number of rope.
  - The rope material and type of construction.
  - Grade of fittings.
  - The number of this European Standard, e.g. EN 1492-4.
  - Traceability code.
  - Identity of the person authorized to sign the certificate on behalf of the manufacturer and date of signature.

2.8 - Rope slings Working Load Limits

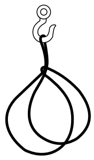
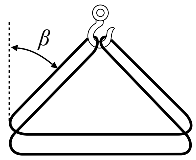
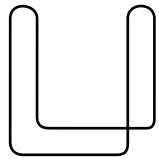
The following tables from the "annex B of EN 1492- 4" give the "informative" working load limits for different configurations and types of material for fibre rope slings indicated in the standard EN 1492-4. The Working Load Limit's shown have been calculated in accordance to the requirements indicated point 2.7.

2.8.1 - Working load limits for fibre rope slings made of polyamide ropes according to EN 696, Form A (3-strand hawser laid) and Form L (8-strand plaited) constructions for single slings

Ref: Number of rope EN 696		*Working load limits*				
		Straight lift	*Chocked lift*	*Basket hitch parallel*	*Basket hitch 2 legs*	*3 or 4 leg sling*
					*M: 1 β: 45° ≤ 60°* 	
Form A ***Mm***	***Form L*** ***Mm***	***M = 1*** ***t***	***M = 0.8*** ***t***	***M = 2, Parallel*** ***t***	***M = 1.4*** ***β = 0° ≤ 45°*** ***t***	***M = 2.1*** ***β = 0° ≤ 45°*** ***T***
16	***16***	*0.68*	*0.54*	*1.35*	*0.95*	*1.4*
18	*–*	*0.85*	*0.68*	*1.7*	*1.2*	*1.8*
20	***20***	*1.1*	*0.88*	*2.2*	*1.5*	*2.3*
22	*–*	*1.3*	*1*	*2.6*	*1.8*	*2.7*
24	***24***	*1.5*	*1.2*	*3*	*2.1*	*3.2*
26	*–*	*1.8*	*1.4*	*3.6*	*2.5*	*3.8*
28	***28***	*2.1*	*1.7*	*4.2*	*2.9*	*4.4*
30	*–*	*2.3*	*1.8*	*4.6*	*3.2*	*4.9*
32	***32***	*2.6*	*2.1*	*5.2*	*3.6*	*5.5*
36	***36***	*3.2*	*2.6*	*6.4*	*4.5*	*6.7*
40	***40***	*3.8*	*3*	*7.6*	*5.3*	*8*
44	***44***	*4.5*	*3.6*	*9*	*6.3*	*9.5*
48	***48***	*5.4*	*4.3*	*10.8*	*7.6*	*11.3*

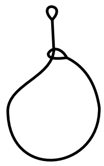
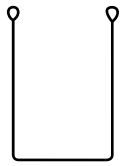
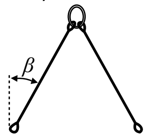
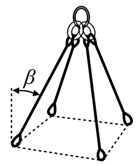
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.2 - Working load limits for fibre rope slings made of polyamide ropes according to EN 696, Form A (3-strand hawser laid) and Form L (8-strand plaited) constructions for endless slings

Ref: Number of rope EN 696		*Working load limits (WLL)*			
		Straight lift	*Chocked lift*	*Basket hitch*	*Basket hitch parallel*
					
Form A Mm	*Form L* Mm	*M = 2* t	*M = 1.6* t	*M = 2.8* β = 0º ≤ 45° t	*M = 4* T
16	**16**	1.35	1.1	1.9	2.7
18	–	1.7	1.35	2.4	3.4
20	**20**	2.2	1.75	3	4.4
22	–	2.6	2	3.6	5.2
24	**24**	3	2.4	4.2	6
26	–	3.6	2.8	5	7.2
28	**28**	4.2	3.4	5.8	8.4
30	–	4.6	3.6	6.4	9.2
32	**32**	5.2	4.2	7.2	10.4
36	**36**	6.4	5.2	9	12.8
40	**40**	7.6	6	10.6	15.2
44	**44**	9	7.2	12.6	18
48	**48**	10.8	8.6	15.2	21.6

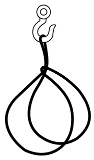
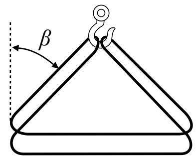
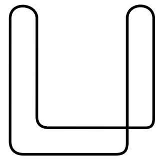
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.3 - Working load limits for fibre rope slings made of polyester ropes according to EN 697, Form A (3-strand hawser laid) and Form L (8-strand plaited) constructions for single slings

Ref: Number of rope EN 697		*Working load limits*				
		Straight lift	*Chocked lift*	*Basket hitch parallel*	*Basket hitch 2 legs*	*3 or 4 leg sling*
					*M: 1 β: 45° ≤ 60°* 	
Form A Mm	*Form L* Mm	*M = 1* t	*M = 0.8* t	*M = 2, Parallel* t	*M = 1.4* β = 0º ≤ 45° t	*M = 2.1* β = 0º ≤ 45° T
16	**16**	0.52	0.42	1.05	0.73	1.1
18	–	0.65	0.52	1.3	0.91	1.4
20	**20**	0.8	0.64	1.6	1.1	1.7
22	–	1	0.8	2	1.4	2.1
14	**24**	1.2	0.96	2.4	1.7	2.5
26	–	1.4	1.1	2.8	2	2.9
28	**28**	1.5	1.2	3	2.1	3.2
30	–	1.8	1.4	3.6	2.5	3.8
32	**32**	2	1.6	4	2.8	4.2
36	**36**	2.5	2	5	3.5	5.2
40	**40**	3	2.2	6	4.2	6.3
44	**44**	3.7	3	7.4	5	7.7
48	**48**	4.3	3.4	8.6	6	9

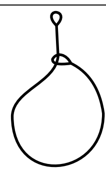
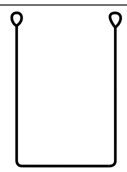
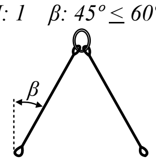
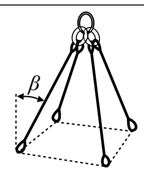
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.4 - Working load limits for fibre rope slings made of polyester ropes according to EN 697, Form A (3-strand hawser laid) and Form L (8-strand plaited) constructions for endless slings

Ref: Number of rope EN 697		*Working load limits (WLL)*			
		Straight lift	***Chocked lift***	***Basket hitch***	***Basket hitch parallel***
					
Form A ***Mm***	***Form L*** ***Mm***	***M = 2*** ***t***	***M = 1.6*** ***t***	***M = 2.8*** ***β = 0º ≤ 45°*** ***t***	***M = 4*** ***T***
16	**16**	*1.05*	*0.84*	*1.45*	*2.1*
18	–	*1.3*	*1*	*1.8*	*2.6*
20	**20**	*1.6*	*1.3*	*2.2*	*3.2*
22	–	*2*	*1.6*	*2.8*	*4*
24	**24**	*2.4*	*1.9*	*3.4*	*4.8*
26	–	*2.8*	*2.2*	*4*	*5.6*
28	**28**	*3*	*2.4*	*4.2*	*6*
30	–	*3.6*	*2.8*	*5*	*7.2*
32	**32**	*4*	*3.2*	*5.6*	*8*
36	**36**	*5*	*4*	*7*	*10*
40	**40**	*6*	*4.8*	*8.4*	*12*
44	**44**	*7.4*	*6*	*10*	*14.8*
48	**48**	*8.6*	*6.8*	*12*	*17.2*

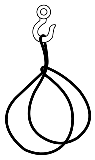
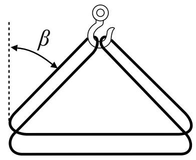
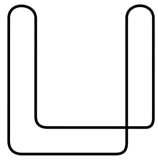
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.5 - Working load limits for fibre rope slings made of polypropylene ropes according to EN 699, Form A (3-strand hawser laid) and Form L (8-strand plaited) constructions for single slings

Ref: Number of rope EN 699		*Working load limits*				
		Straight lift	***Chocked lift***	***Basket hitch parallel***	***Basket hitch 2 legs***	***3 or 4 leg sling***
					*M: 1 β: 45° ≤ 60°* 	
Form A ***Mm***	***Form L*** ***Mm***	***M = 1*** ***t***	***M = 0.8*** ***t***	***M = 2, Parallel*** ***t***	***M = 1.4*** ***β = 0º ≤ 45°*** ***t***	***M = 2.1*** ***β = 0º ≤ 45°*** ***T***
16	**16**	*0.48*	*0.38*	*0.96*	*0.67*	*1*
18	–	*0.6*	*0.48*	*1.2*	*0.85*	*1.3*
20	**20**	*0.75*	*0.6*	*1.5*	*1*	*1.6*
22	–	*0.9*	*0.72*	*1.8*	*1.3*	*1.9*
14	**24**	*1.1*	*0.88*	*2.2*	*1.5*	*2.3*
26	–	*1.2*	*0.96*	*2.4*	*1.7*	*2.5*
28	**28**	*1.4*	*1.1*	*2.8*	*2*	*2.9*
30	–	*1.5*	*1.2*	*3*	*2.1*	*3.2*
32	**32**	*1.7*	*1.4*	*3.4*	*2.4*	*3.6*
36	**36**	*2.2*	*1.8*	*4.4*	*3.1*	*4.6*
40	**40**	*2.6*	*2.1*	*5.2*	*3.6*	*5.5*
44	**44**	*3.2*	*2.6*	*6.4*	*5*	*6.7*
48	**48**	*3.7*	*3*	*7.4*	*5.2*	*7.8*

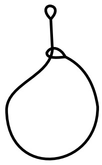
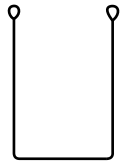
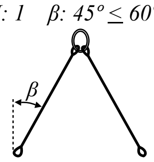
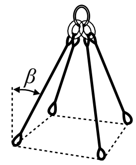
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.6 - Working load limits for fibre rope slings made of polypropylene ropes according to EN 699, Form A (3-strand hawser laid) and Form L (8-strand plaited) constructions for endless slings

Ref: Number of rope EN 699		Working load limits (WLL)			
		Straight lift	Chocked lift	Basket hitch	Basket hitch parallel
					
Form A Mm	Form L Mm	M = 2 t	M = 1.6 t	M = 2.8 β = 0º ≤ 45° t	M = 4 T
16	16	0.96	0.76	1.3	1.9
18	–	1.2	0.96	1.7	2.4
20	20	1.5	1.2	2	3
22	–	1.8	1.4	2.6	3.6
24	24	2.2	1.8	3	4.4
26	–	2.4	1.9	3.4	4.8
28	28	2.8	2.2	4	5.6
30	–	3	2.4	4.2	6
32	32	3.4	2.8	4.8	6.8
36	36	4.4	3.6	6.2	8.8
40	40	5.2	4.2	7.2	10.4
44	44	6.4	5.2	1	12.8
48	48	7.4	6	10.4	14.8

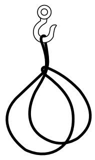
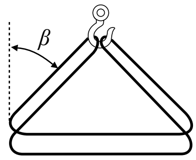
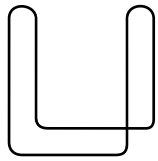
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.7 - Working load limits for slings made of manila ropes according to EN 698, Form A (3-strand hawser laid) construction for single slings

Ref: Number of rope EN 698		Working load limits				
		Straight lift	Chocked lift	Basket hitch parallel	Basket hitch 2 legs	3 or 4 leg sling
					M: 1 β: 45° ≤ 60° 	
Form A Mm	Form L Mm	M = 1 t	M = 0.8 t	M = 2, Parallel t	M = 1.4 β = 0º ≤ 45° t	M = 2.1 β = 0º ≤ 45° T
16	16	0.26	0.2	0.52	0.036	0.55
18	–	0.32	0.25	0.64	0.45	0.67
20	20	0.4	0.32	0.8	0.56	0.84
22	–	0.47	0.38	0.95	0.65	1
14	24	0.58	0.46	1.15	0.81	1.2
26	–	0.68	0.54	1.35	0.95	1.4
28	28	0.78	0.62	1.55	1.1	1.6
30	–	0.88	0.7	1.75	1.2	1.8
32	32	1	0.8	2	1.4	2.1
36	36	1.3	1	2.6	1.8	2.7
40	40	1.5	1.2	3	2.1	3.2
44	44	1.8	1.4	3.6	2.5	3.8
48	48	2.2	18	4.4	3.1	4.6

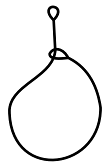
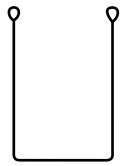
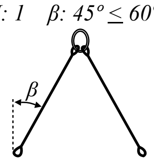
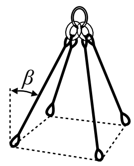
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.8 - Working load limits for slings made of manila ropes according to EN 698, Form A (3-strand hawser laid) construction for endless slings

Ref: Number of rope EN 698		Working load limits (WLL)			
		Straight lift	Chocked lift	Basket hitch	Basket hitch parallel
				 β	
Form A Mm	Form L Mm	M = 2 t	M = 1.6 t	M = 2.8 β = 0º ≤ 45° t	M = 4 T
16	16	0.52	0.4	0.72	1.05
18	–	0.64	0.5	0.9	1.3
20	20	0.8	0.64	1.1	1.6
22	–	0.95	0.76	1.3	1.9
24	24	1.15	0.92	1.6	2.3
26	–	1.35	1.1	1.9	2.7
28	28	1.55	1.25	2.2	3.1
30	–	1.75	1.4	2.4	3.5
32	32	2	1.6	2.8	4
36	36	2.6	2	3.6	5.2
40	40	3	2.4	4.2	6
44	44	3.6	2.8	5	7.2
48	48	4.4	3.6	6.2	8.8

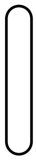
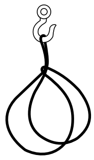
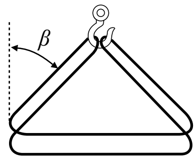
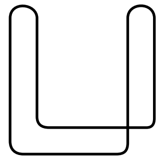
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.9 - Working load limits for slings made of sisal ropes according to EN 698, Form A (3-strand hawser laid) construction for single slings

Ref: Number of rope EN 698		Working load limits				
		Straight lift	Chocked lift	Basket hitch parallel	Basket hitch 2 legs	3 or 4 leg sling
					M: 1 β: 45° ≤ 60°  β	 β
Form A Mm	Form L Mm	M = 1 t	M = 0.8 t	M = 2, Parallel t	M = 1.4 β = 0º ≤ 45° t	M = 2.1 β = 0º ≤ 45° T
16	16	0.22	0.18	0.44	0.3	0.46
18	–	0.27	0.22	0.54	0.38	0.57
20	20	0.36	0.29	0.72	0.5	0.75
22	–	0.43	0.35	0.86	0.6	0.9
14	24	0.52	0.42	1.05	0.73	1.1
26	–	0.6	0.48	1.2	0.85	1.3
28	28	0.68	0.54	1.35	0.95	1.4
30	–	0.78	0.62	1.55	1.1	1.6
32	32	0.88	0.7	1.75	1.2	1.8
36	36	1.1	0.9	2.2	1.5	2.3
40	40	1.4	1.1	2.8	2	2.9
44	44	1.6	1.3	3.2	2.2	3.4
48	48	1.9	1.5	3.8	2.7	4

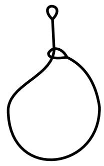
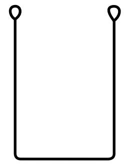
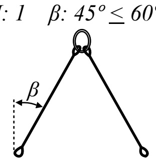
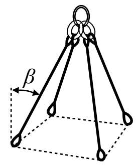
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.10 - Working load limits for slings made of sisal ropes according to EN 698, Form A (3-strand hawser laid) construction for endless slings

Ref: Number of rope EN 698		***Working load limits (WLL)***			
		Straight lift	***Chocked lift***	***Basket hitch***	***Basket hitch parallel***
					
Form A ***Mm***	***Form L*** ***Mm***	***M = 2*** ***t***	***M = 1.6*** ***t***	***M = 2.8*** ***β = 0º ≤ 45°*** ***t***	***M = 4*** ***T***
16	***16***	*0.44*	*0.36*	*0.6*	*0.88*
18	*–*	*0.54*	*0.44*	*0.76*	*1.08*
20	***20***	*0.72*	*0.58*	*1*	*1.45*
22	*–*	*0.86*	*0.7*	*1.2*	*1.75*
24	***24***	*1.05*	*0.84*	*1.45*	*2.1*
26	*–*	*1.2*	*0.96*	*1.7*	*2.4*
28	***28***	*1.35*	*1.1*	*1.9*	*2.7*
30	*–*	*1.55*	*1.25*	*2.2*	*3.1*
32	***32***	*1.75*	*1.4*	*2.4*	*3.5*
36	***36***	*2.2*	*1.8*	*3*	*4.4*
40	***40***	*2.8*	*2.2*	*4*	*5.6*
44	***44***	*3.2*	*2.6*	*4.4*	*6.4*
48	***48***	*3.8*	*3*	*5.4*	*7.6*

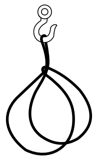
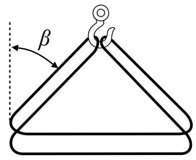
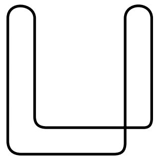
Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.11 - Working load limits for fibre rope slings made of hemp ropes according to EN 1261, Form A (3-strand hawser laid) construction for single slings

Ref: Number of rope EN 1261		***Working load limits***				
		Straight lift	***Chocked lift***	***Basket hitch parallel***	***Basket hitch 2 legs***	***3 or 4 leg sling***
					*M: 1 β: 45° ≤ 60°* 	
Form A ***Mm***	***Form L*** ***Mm***	***M = 1*** ***t***	***M = 0.8*** ***t***	***M = 2, Parallel*** ***t***	***M = 1.4*** ***β = 0º ≤ 45°*** ***t***	***M = 2.1*** ***β = 0º ≤ 45°*** ***T***
16	***16***	*0.25*	*0.2*	*0.5*	*0.35*	*0.52*
18	*–*	*0.3*	*0.24*	*0.6*	*0.42*	*0.63*
20	***20***	*0.35*	*0.28*	*0.7*	*0.5*	*0.73*
22	*–*	*0.43*	*0.35*	*0.86*	*0.6*	*0.9*
14	***24***	*0.5*	*0.4*	*1*	*0.7*	*1.05*
26	*–*	*0.6*	*0.48*	*1.2*	*0.85*	*1.3*
28	***28***	*0.7*	*0.56*	*1.4*	*1*	*1.5*
30	*–*	*0.8*	*0.64*	*1.6*	*1.1*	*1.7*
32	***32***	*0.9*	*0.72*	*1.8*	*1.3*	*1.9*
36	***36***	*1.2*	*0.96*	*2.4*	*1.7*	*2.5*
40	***40***	*1.4*	*1.1*	*2.8*	*2*	*2.9*
44	***44***	*1.6*	*1.3*	*3.2*	*2.2*	*3.4*
48	***48***	*2*	*1.6*	*4*	*2.8*	*4.2*

Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.8.12 - Working load limits for fibre rope slings made of hemp ropes according to EN 1261, Form A (3-strand hawser laid) construction for endless slings

Ref: Number of rope EN 1261		***Working load limits (WLL)***			
		Straight lift	***Chocked lift***	***Basket hitch***	***Basket hitch parallel***
					
Form A ***Mm***	***Form L*** ***Mm***	***M = 2*** ***t***	***M = 1.6*** ***t***	***M = 2.8*** ***β = 0º ≤ 45°*** ***t***	***M = 4*** ***T***
16	***16***	*0.5*	*0.4*	*0.7*	*1*
18	***–***	*0.6*	*0.48*	*0.84*	*1.2*
20	***20***	*0.7*	*0.56*	*1*	*1.4*
22	***–***	*0.86*	*0.7*	*1.2*	*1.75*
24	***24***	*1*	*0.8*	*1.4*	*2*
26	***–***	*1.2*	*0.96*	*1.7*	*2.4*
28	***28***	*1.4*	*1.1*	*2*	*2.8*
30	***–***	*1.6*	*1.3*	*2.2*	*3.2*
32	***32***	*1.8*	*1.45*	*2.6*	*3.6*
36	***36***	*2.4*	*1.9*	*3.4*	*4.8*
40	***40***	*2.8*	*2.2*	*4*	*5.6*
44	***44***	*3.2*	*2.6*	*4.4*	*6.4*
48	***48***	*4*	*3.2*	*5.6*	*8*

Note 1: *Slings having working loads below 1 tonne are usually marked in kilograms (1 tonne = 1000 kilograms).*
Note 2: *This table is for rating purposes only and does not indicate proposed method of use.*
Note 3: *The handling tolerance for fibre rope slings or parts of fibre rope slings indicated as vertical is 7º.*
Note 4: *The WLL for form B (4-strand, should-laid) is 10% less.*
Note 5: *Mode factor M for symmetrical positioning of load.*

2.9 - Inspection of rope slings in service *(Source EN 1492)*

The inspection of rope slings requires the same process as for textile webbing slings

2.9.1 - Before first use

The sling corresponds precisely to that specified on the order;

The manufacturer's certificate is on hand;

The identification and Working Load Limit marked on the sling correspond with the information on the certificate.

2.9.2 - When in use

The sling should be inspected to ensure that the identification and specification are correct. A sling that is unidentified or defective should never be used, but it should be referred to a competent person for examination.

During the period of use, frequent checks should be made for defects or damage, including damage concealed by soiling, which might affect the continued safe use of the sling. These checks should extend to any fittings and lifting accessories used in association with the sling. If any doubt exists as to the fitness for use, or if any of the required markings have been lost or become illegible, the sling should be removed from service for examination by a competent person.

The following are examples of defects or damage likely to affect the fitness of slings for continued safe use:

- General external wear due to abrasion:
  Abrasion causes a breakdown of the filaments and fibres and is readily observed. In ordinary use, some disarrangement or breaking of the fibres is to be expected, and if not excessive, is harmless. Areas of severe abrasion, as distinct from general wear, for example, caused by the passage of the rope sling over a sharp edge whilst under tension, will cause a serious loss of strength. Serious reduction in the section of one strand would warrant rejection.
- Surface chafe, cuts, and mechanical damage:
  The vulnerability of rope slings to wear and mechanical damage increases inversely with cross sectional area. Smaller ropes have all or most of the yarns on the outside of the strand and hence the effect of chafing is more sever. Larger ropes have strands composed of concentric rings of yarn and such chafing has to be proportionally deeper to have the same effect. Cuts, which may be difficult to detect when first inflicted, have a serious effect on the strength of the rope. They may be indicated by local fraying of the yarns or strands.

- Internal wear: Internal wear, caused by repeated loading and flexing of the rope when under tension, is indicated by excessive looseness of the strands or by the presence of fibre dust within the rope. Internal wear is accelerated by the penetration of grit and other sharp particles into the rope.
- Chemical attack: Chemical attack results in local weakening or softening of the rope. This is indicated by flaking of the surface fibres, which may be plucked or rubbed off (as a powder in extreme cases). The resistance of the fibres to chemicals is summarized below :
    - Natural fibres are degraded by acids, alkalis and certain organic solvents.
    - The man-made-fibres from which rope slings are manufactured are similar to those used for the fabrication of textile slings and have selective resistance to chemicals *(See also the list point 1.5.6)*
        - Polyamides are virtually immune to the effects of alkalis; however, they are attacked by mineral acids;
        - Polyester is resistant to mineral acids but is damaged by alkalis;
        - Polypropylene is little affected by acids or alkalis and is suitable where the highest resistance to chemicals other than solvents is required;
- Heat or friction damage: Heat damage of natural fibre ropes is indicated by charring of the fibres, whilst man-made fibres take on a glazed appearance, and in extreme cases, fusion of the fibres occurs. A rope may be severely weakened by heat without observable indications.
- Damages due to improper storage: Fibre rope slings are suitable for use and storage in the following temperature ranges:
    - Manila, sisal, hemp and polypropylene: -40°C to 80°C;
    - Polyester and polyamide: -40°C to 100°C.

  At low temperatures, ice formation will take place if moisture is present. This may act as a cutting agent and an abrasive causing internal damage to the sling. Further, ice will lessen the flexibility of the sling, in extreme cases, rendering it unserviceable for use.
  These ranges vary in a chemical environment, in which case the advice of the manufacturer or supplier should be sought.
  Limited indirect ambient heating, within these ranges, is acceptable for drying.
  The man-made fibres from which the rope is produced are susceptible to degradation if exposed to ultraviolet radiation. Similarly, natural fibres may be subject to drying age embrittlement if exposed to direct sunlight. Fibre rope slings should not be exposed or stored in direct sunlight or sources of ultra-violet radiation.
  Mildew will attack natural fibre rope if it is stored wet and/or in damp conditions and/or stagnant air. The mould will live on the cellulose of the rope and consequently, a loss of strength will occur. Mildew does not attack man-made fibre ropes, although surface contamination may provide a nutrient which permits its growth. This will not affect the strength of man-made fibre ropes and may be removed by washing them in clear water – detergents should not be used. Fibre rope slings which have accidentally become wet in use, e.g. due to rain, should be carefully dried before placing them in store.
- Damaged, cracked, or deformed fittings can be the result of defect, bad lifting, or exposure to acid: Contact with acids or acidic fumes causes hydrogen embrittlement to grade 8 materials. Slings with grade 8 fittings and multi-leg slings with grade 8 master links should not be used in acidic conditions.

2.10 - Selection and use of rope slings *(recommendations EN 1492)*

2.10.1 - Prepare the lift

Consideration should be given to the required Working Load Limit given on the label, taking into account the nature, size, shape and weight of the load, together with the intended method of use, and working environment.

The selected rope sling should be both strong enough and of the correct length for the mode of use.

In the case of multi-leg slings, the maximum angle to the vertical should not be exceeded.

If more than one sling is used to lift a load, the slings should be chosen such that the sling forming each leg is not overloaded and that the load remains balanced and stable.

The material from which the fibre rope sling is made should not be affected adversely by the environment or the load.

Consideration should also be given to ancillary fittings and lifting devices which should be compatible with the sling(s). The termination should also be considered, i.e. whether fittings, hard eyes or soft eyes are required.

The part of the lifting appliance, lifting accessory or load with which the rope engages should not be less than the nominal diameter of the load.

When using slings with soft eyes, care should be taken to ensure that the eye is of sufficient size so that the lifting machine hook to which the eye is fitted, or lifting accessory which may be placed in the eye, does not open the eye so that the included angle between the two parts of the rope is greater than 30°.

Fibre rope slings should not be overloaded: the correct mode factor should be used *(see point 2.7 and WLL tables point 2.10)*. Working Load Limits for some modes of use may be given on the label. In the case of multi-leg slings the maximum angle to the vertical should not be exceeded.

Good slinging practices should be followed: the slinging, lifting, and lower operations should be planned before commencing the lift.

Fibre rope slings should be correctly positioned and attached to the load. They should never be knotted or twisted.

Damage to labels should be prevented by keeping them away from the load, the hook and the angle of choke.

In the case of multi-leg slings, the WLL values have been determined on the basis that the loading of the sling assembly is symmetrical. This means that when a load is lifted the sling legs are symmetrically disposed in plan and subtended at the same angle to the vertical.

In the case of 3 leg slings, if the legs are not symmetrically disposed in plan the greatest tension is in the leg where the sum of the plan angles to the adjacent legs is greatest. The same effect occurs in 4 leg slings, except that the rigidity of the load should also be taken into account.

NOTE With a rigid load the majority of the weight may be taken by only three, or even two, of the legs, with the remaining legs only serving to balance the load.

Slings should be protected from edges, friction and abrasion, whether from the load or the lifting appliance, by the use of protective sleeves, suitable packing and/or corner pieces.

The load should be secured by the sling(s) in such a manner that it cannot topple or fall out of the sling(s) during the lift. The sling(s) should be arranged so that the point of lift is directly above the centre of gravity of the load and the load is balanced and stable. Movement of the sling over the lifting point is possible if the centre of gravity of the load is not below the lifting point.

When using a basket hitch, the load should be secure since there is no gripping action. The choke hitch and sling can roll through the lifting point. For slings used in pairs, the use of a spreader is recommended so that the sling legs hang as vertically as possible and to ensure that the load is equally divided between the legs.

When a sling is used in a choke hitch, it should be positioned so as to allow the natural (120°) angle to form and avoid heat being generated by friction. A sling should never be forced into position nor should any attempt be made to tighten the bite.

2.10.2 - During the lift

Care should be taken to ensure the safety of personnel during the lift. Persons in the danger area should be warned that the operation is to take place, and if necessary, be evacuated from the immediate area.

Hands and other parts of the body should be kept away from the sling to prevent injury as the slack is taken up.

A trial lift should be made. The slack should be taken up until the sling is taut. The load should be raised slightly and a check should be made to verify that it is secure and that it assumes the position intended. This is especially important with basket or other loose hitches where friction retains the load.

If the load tends to tilt, it should be lowered and attachments re-positioned. The trial lift should be repeated until the stability of the load is ensured.

Care should be taken when making the lift to ensure that the load is controlled, i.e. to prevent accidental rotation or collision with other objects.

Snatch or shock loading should be avoided as this will increase the forces acting on the sling. A load in the sling or the sling itself should not be dragged over the ground or rough surfaces.

The load should be lowered in an equally controlled manner as when lifted.

Trapping the sling when lowering the load should be avoided. The load should not rest on the sling, if this could cause damage, and pulling the sling from beneath the load when the load is resting on it should not be attempted.

2.10.3 - After the lift

On completion of the lifting operation the sling should be returned to proper storage.

When not in use, slings should be stored in clean, dry, and well ventilated conditions, at ambient temperature, and on a rack, away from any heat sources, contact with chemicals, fumes, corrodible surfaces, direct sunlight or other sources of ultra-violet radiation.

Slings which have become wet in use, or as a result of cleaning, should be hung up and allowed to dry naturally.

Prior to placing in storage, slings should be inspected for any damage which may have occurred during use. Slings should never be returned damaged to storage.

Where lifting slings have come into contact with acids and/or alkalis, dilution with water or neutralization with suitable media is recommended prior to storage.

Solutions of acids or alkalis which are harmless can become sufficiently concentrated by evaporation and cause damage. Contaminated slings should be taken out of service at once, soaked in cold water, dried naturally and referred to a competent person for examination.
Depending on the material of the lifting sling and the chemicals, *(See point 1.5.2)* it may be necessary in some cases to request from the supplier additional recommendations on the cleaning procedure to be followed after the sling has been used in the presence of chemicals.

Examination periods should be determined by a competent person, taking into account the application, environment, frequency of use and similar matters, but in any event, slings should be visually examined at least annually by a competent person to establish their fitness for continued use. Records of such examinations should be maintained.

Damaged slings should be withdrawn from service. Never attempt to carryout repairs to slings yourself.

3 - Wire rope slings

3.1 - Norms and standards applied

This document is based on the European Standard *En 13414* which specifies the construction requirements, calculation of Working Load Limits, verification, certification and marking of steel wire rope slings for general lifting service. It covers single, two, three and four leg slings, with ferrule-secured or spliced eye terminations and spliced, or ferrule-secured endless slings made from 8 mm to 60 mm diameter 6 strand ordinary lay steel wire rope with fibre or steel core, and 8 strand ordinary lay steel wire rope with a steel core conforming to EN 12385-4.

The standard assumes a working coefficient (factor of safety) of five.

This standard does not cover slings for single use, i.e. one trip slings, having a working coefficient lower than 5.

This standard does not cover matched sets of slings with spliced eyes.

This document is not applicable to slings which are manufactured before the date of publication of this document by CEN.

3.2 - Fabrication requirements *(European standard En 13414)*

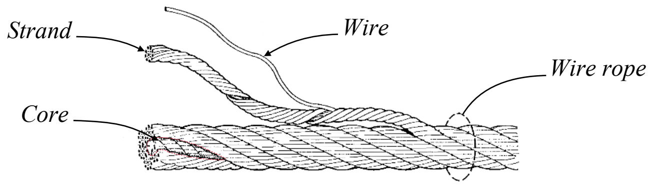
3.2.1 - Wire rope

Wire rope consists of three essential components. These, while few in number, vary in both complexity and configuration , so as to produce ropes for specific purposes or characteristics. Basically, the three components of a standard wire rope design are:

1) Wires that form the strand.

2) The core.

3) The multi-wire strands laid helically around the core.



Wire, for rope, can be made in several materials and types; these include steel, iron, stainless steel, and bronze. The most widely used material is high-carbon steel on which the specification En 13414 is based.

For manufacturing of wire rope slings, the rope grade should be either 1770 or 1960 N/mm².

In multi-leg slings, the rope dimension and grade should be the same for each leg.

The working load limit of the lower terminal fitting(s) should be at least equal to that of the leg(s) to which it is/they are fitted.

Where a terminal fitting is used, the eye termination should always be fitted with a thimble. For 3- and 4-leg slings, a master link with intermediate link should be used.

3.2.2 - Ferrule

The ferrule should be legibly and indelibly marked with the “Ferrule Secured Eye Termination” manufacturer's name, symbol or mark. Notice that for ropes smaller than 8 mm diameter, the marking can be on the package.

The material selected for the ferrule should be non-alloy carbon steel or aluminium.

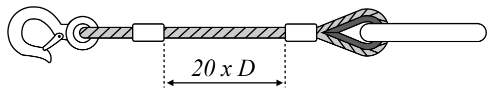
The tube from which ferrules are made should be free from any cracks, folds, and surface defects.

With the exception of steel ferrules for Flemish eyes, ferrules shall be produced to provide a seam-free hollow product.

Approximate dimensions should be:

- Cylindrical ferrules: Straight edges against the wire rope. Externally diameter should be approximately two times the rope diameter. Total length should be approximately 4.5 times the rope diameter
- Cylindrical/conical ferrules: Cone against the wire rope on one end, the other end should be straight. Externally diameter should be approximately two times the rope diameter. Total length should be approximately 5-6 times the rope diameter

The minimum length of plain rope between the inside ends of ferrules terminating a sling leg should be 20 times the nominal rope diameter.



3.2.3 - Spliced eye slings

The minimum length of plain rope between the tails of splices shall be at least 15 times the nominal rope diameter.

Spliced eyes should conform to EN 13411-2.

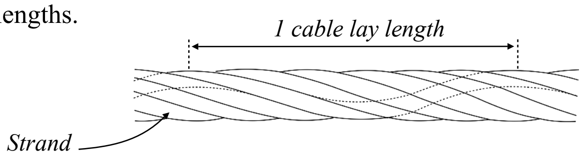
3.2.4 - Hard eyes

Hard eyes should be fitted with thimbles free from any flaws or defects. There should be wide enough to allow insertion of a component of 1.5 times the nominal rope diameter, conforming to EN 13411-1

A small gap at the joint may be tolerated.

3.2.5 - Soft eyes

The peripheral length of a soft eye should be at least four rope lay lengths.
Note: "Lay Length" is the distance, parallel to the axis of the cable, in which a strand makes one complete turn about that axis is knows as the lay length or pitch length.



3.2.6 - Terminal fittings

The Working Load Limit of any master link shall be at least equal to that of the sling.

The Working Load Limit of any intermediate link fitted to a three-leg or four-leg sling shall be at least equal to 1.6 times the Working Load Limit of one of the legs suspended from it.

The working load limit of the lower terminal fitting(s) should be at least equal to that of the leg(s) to which it is/they are fitted.

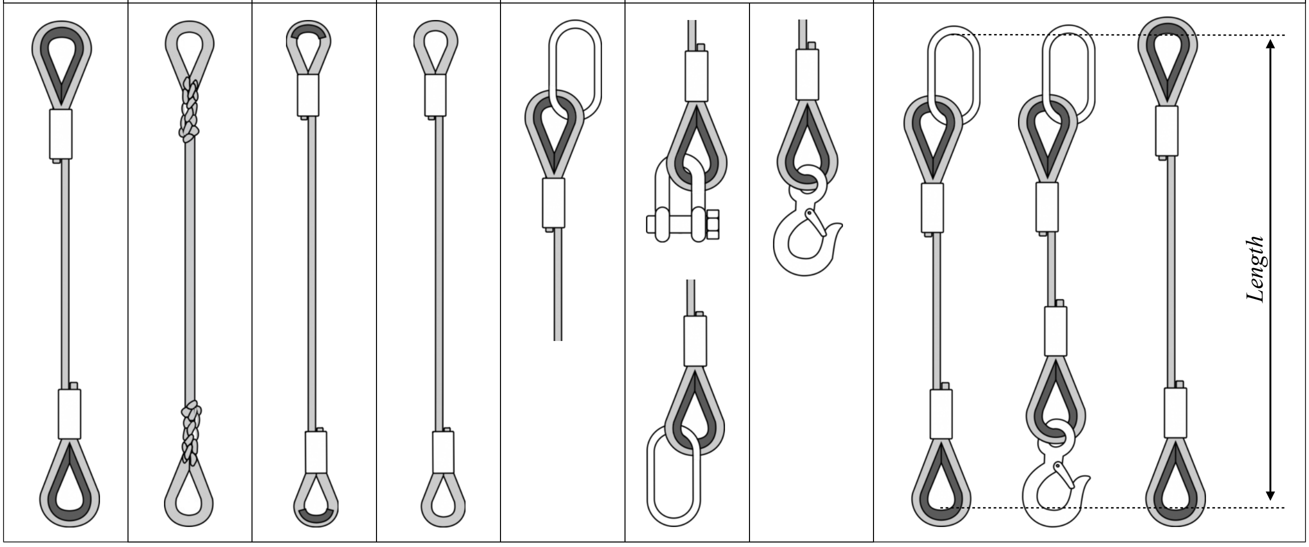
Where forged steel lifting hooks with latch grade 8 forged steel, self-locking hooks grade 8, linksgrade 8, forged steel lifting hooks with latch grade 4, links grade 4 are used, they should conform to EN 1677 parts 2 to 6 respectively.

Where shackles are used they should conform to EN 13889. *(See chapter shackles)*

3.3 - Common models.

3.3.1 - Single legs

Single-leg slings should be one of the types shown in the table below, with or without terminal fittings such as links or hooks. Where a terminal fitting is used, the eye termination should always be fitted with a thimble.

Form end sling leg				*Terminal fitting*			*Nominal length of sling leg (Bearing to bearing)*
Ferrule Secured hard eye	*Hand spliced soft eye*	*Ferule secured soft eye*	*Ferrule secured soft eye*	*At upper end*	*At lower end*		
							

The length should be that measured between the bearing points of the sling.

The working load limit (WLL) of a single leg sling, should be calculated as follows:

$$WLL = \frac{F_{min} \times K_T}{Z_p \times g}$$

Where:

F_{min} *is the minimum breaking force of the rope, in kilonewtons;*
K_T *is a factor which allows for the efficiency of the termination;*
Z_p *is the working coefficient and has the value = 5*
The term working coefficient is also known as the coefficient of utilization.
g is the factor relating mass to force and has the value = 9,806 65.
For ferrule secured terminations K shall be 0,9 and for spliced terminations K_T *shall be 0,8.*

3.3.2 - Ferrule-secured and spliced endless slings

The length of an endless sling should be that measured along its circumference on the centre-line of the rope.

The working load limit (WLL) in tonnes for an endless sling shall be calculated as follows:

$$WLL = \frac{F_{min} \times 2 \times 0.8}{Z_P \times g}$$

Where the elements used for the calculation are the same than above

The rope should be formed into a circle such that the two ends overlap by the amount necessary for splicing.

Each end should be spliced back into the main body of the sling. (The operation must as specified in EN 13411-2)

3.3.3 - Multi-leg sling

The length should be measured between the bearing points of the sling.

The sling should comprise two, three, or four legs of the types specified below. The rope size type and grade for each leg should be the same.

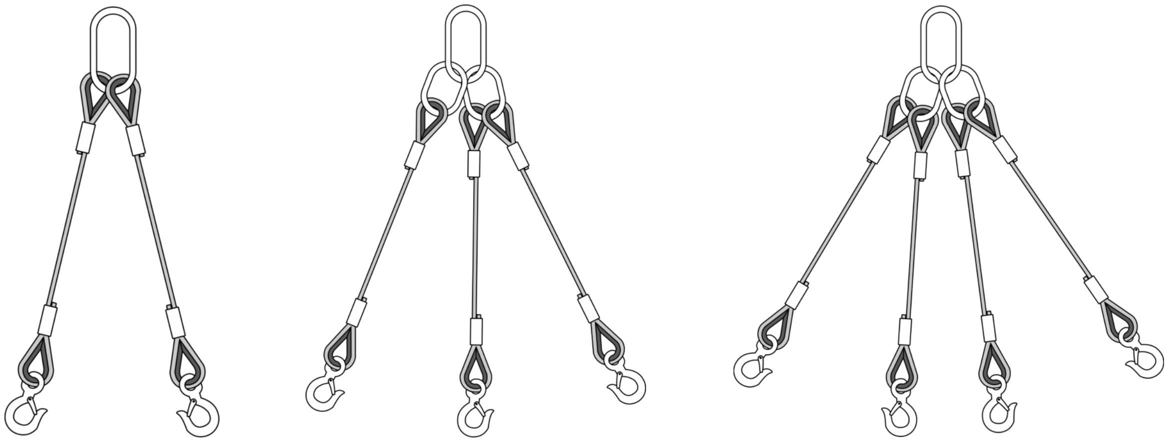
The legs of two-leg slings should be joined at their upper ends by a master link. (see #1)

In a three-leg sling, two of the legs should be joined by a single intermediate master link to the master link, the third leg shall be connected via a second intermediate master link. (see #2)

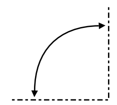
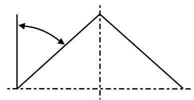
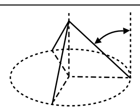
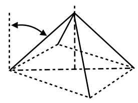
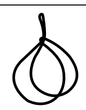
In a four-leg sling, each of the two pairs shall be joined by an intermediate master link to the master link. (see #3)

Upper eyes shall always be fitted with thimbles, and if lower terminal fittings are used, the eyes shall always be fitted with thimbles. Thimbles shall conform to EN 13411-1.

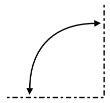
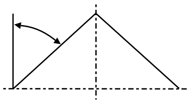
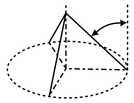
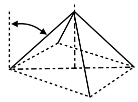
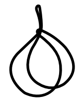
#1 #2 #3



3.3.4 - Working load limits for slings using fibre cored rope of classes 6 x 19 and 6 x 36 in grade 1770 and having ferrule-secured eye terminations a_i

	One leg sling	*Two leg sling*		*Three and four leg sling*		*Endless sling*
Angle to vertical	*0º*	*0º to 45º*	*Over 45º to 60º*	*0º to 45º*	*Over 45º to 60º*	*0º*
						
	Direct	*Direct*	*Direct*	*Direct*	*Direct*	*Choke hitch*
Nominal rope diameter (mm)	*Working load limit (Tonne)*					
8	*0.700*	*0.950*	*0.700*	*1.50*	*1.05*	*1.10*
9	*0.850*	*1.20*	*0.850*	*1.80*	*1.30*	*1.40*
10	*1.05*	*1.50*	*1.05*	*2.25*	*1.60*	*1.70*
11	*1.3*	*1.80*	*1.30*	*2.70*	*1.95*	*2.12*
12	*1.55*	*2.12*	*1.55*	*3.30*	*2.30*	*2.50*
13	*1.80*	*2.50*	*1.80*	*3.85*	*2.70*	*2.90*
14	*2.12*	*3.00*	*2.12*	*4.35*	*3.15*	*3.30*
16	*2.70*	*3.85*	*2.70*	*5.65*	*4.20*	*4.35*
18	*3.40*	*4.80*	*3.40*	*7.20*	*5.20*	*5.65*
20	*4.35*	*6.00*	*4.35*	*9.00*	*6.50*	*6.90*
22	*5.20*	*7.20*	*5.20*	*11.0*	*7.80*	*8.40*
24	*6.30*	*8.80*	*6.30*	*13.5*	*9.40*	*10.0*
26	*7.20*	*10.0*	*7.20*	*15.0*	*11.0*	*11.8*
28	*8.40*	*11.8*	*8.40*	*18.0*	*12.5*	*13.5*
32	*11.0*	*15.0*	*11.0*	*23.5*	*16.5*	*18.0*
36	*14.0*	*19.0*	*14.0*	*29.0*	*21.0*	*22.5*
40	*17.0*	*23.5*	*17.0*	*36.0*	*26.0*	*28.0*
44	*21.0*	*29.0*	*21.0*	*44.0*	*31.5*	*33.5*
48	*25.0*	*35.0*	*25.0*	*52.0*	*37.0*	*40.0*
52	*29.0*	*40.0*	*29.0*	*62.0*	*44.0*	*47.0*
56	*33.5*	*47.0*	*33.5*	*71.0*	*50.0*	*54.0*
60	*39.0*	*54.0*	*39.0*	*81.0*	*58.0*	*63.0*
Leg factor K_1	*1*	*1.4*	*1*	*2.1*	*1.5*	*1.6*

3.3.5 - Working load limits for slings using steel cored rope of classes 6 x 19, 6 x 36 and 8 x3 6 in grade 1770 and having ferrule-secured eye terminations CI

	One leg sling	*Two leg sling*		*Three and four leg sling*		*Endless sling*
Angle to vertical	*0º*	*0º to 45º*	*Over 45º to 60º*	*0º to 45º*	*Over 45º to 60º*	*0º*
						
	Direct	*Direct*	*Direct*	*Direct*	*Direct*	*Choke hitch*
Nominal rope diameter (mm)	*Working load limit (Tonne)*					
8	*0.750*	*1.05*	*0.750*	*1.55*	*1.10*	*1.20*
9	*0.950*	*1.30*	*0.950*	*2.00*	*1.40*	*1.50*
10	*1.15*	*1.60*	*1.15*	*2.40*	*1.70*	*1.85*
11	*1.40*	*2.00*	*1.40*	*3.00*	*2.12*	*2.25*
12	*1.70*	*2.30*	*1.70*	*3.55*	*2.50*	*2.70*
13	*2.00*	*2.80*	*2.00*	*4.15*	*3.00*	*3.15*
14	*2.25*	*3.15*	*2.25*	*4.80*	*3.40*	*3.70*
16	*3.00*	*4.20*	*3.00*	*6.30*	*4.50*	*4.80*
18	*3.70*	*5.20*	*3.70*	*7.80*	*5.65*	*6.00*
20	*4.60*	*6.50*	*4.60*	*9.80*	*6.90*	*7.35*
22	*5.65*	*7.80*	*5.65*	*11.8*	*8.40*	*9.00*
24	*6.70*	*9.40*	*6.70*	*14.0*	*10.0*	*10.6*
26	*7.80*	*11.0*	*7.80*	*16.5*	*11.5*	*12.5*
28	*9.00*	*12.5*	*9.00*	*19.0*	*13.5*	*14.5*
32	*11.8*	*16.5*	*11.8*	*25.0*	*17.5*	*19.0*
36	*15.0*	*21.0*	*15.0*	*31.5*	*22.5*	*23.5*
40	*18.5*	*26.0*	*18.5*	*39.0*	*28.0*	*30.0*
44	*22.5*	*31.5*	*22.5*	*47.0*	*33.5*	*36.0*
48	*26.0*	*37.0*	*26.0*	*55.0*	*40.0*	*42.0*
52	*31.5*	*44.0*	*31.5*	*66.0*	*47.0*	*50.0*
56	*36.0*	*50.0*	*36.0*	*76.0*	*54.0*	*58.0*
60	*42.0*	*58.0*	*42.0*	*88.0*	*63.0*	*67.0*
Leg factor K1	*1*	*1.4*	*1*	*2.1*	*1.5*	*1.6*

NOTE: The Working Load Limits (WLL) given in the tables are based on the assumption that soft eyes of single-leg slings are used over bearing points having diameters not less than twice the nominal diameter of the rope.

3.4 - Marking

Each sling shall be legibly and durably marked with the information listed below. This certificate should be at one end for single leg , near the junction for endless sling, or near the master link for multi-leg sling

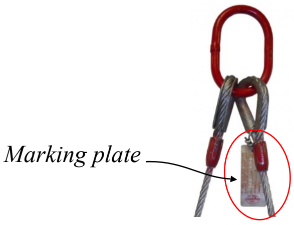
3.4.1 - Single-leg sling (single part or endless)

The sling manufacturer's identifying mark;

Numbers and/or letters identifying the sling with the certificate conforming to point 3.5;

The Working Load Limits;

Any legal marking.



3.4.2 - Multi-leg sling

The sling manufacturer's identifying mark;

Number and/or letters identifying the sling with the certificate conforming to 3.5;

The working load limits and the angles applicable, i.e. the WLL 0° to 45° to vertical and, additionally, the WLL 45° to 60° to the vertical if applicable;

Any legal marking.

3.5 - Certification

A certificate must be supplied with each sling or batch of slings. It should contain the following information:
The name of the manufacturer or supplier and address.
The Standard according to which the sling has been built.
The description of the sling including all component parts.
The Working Load Limit and the appropriate angle(s) to the vertical for multi-leg slings.
The type of sling *(see points 3.3.1; 3.3.2; 3.3.3)*.
The number of legs.
The nominal length in metres *(see points 3.3.1; 3.3.2; 3.3.3)*.
The terminal fittings *(if any)*.
Wire finish *(zinc coated or bright)*.
Type of rope core.
Diameter of rope.
Operating temperatures.
Special hazards *(e.g. chemical, environmental)*.

3.6 - Inspection of wire slings in service

3.6.1 - Before first use

- The sling corresponds precisely to that specified on the order;
- The manufacturer's certificate is to hand;
- The identification and Working Load Limit marked on the sling correspond with the information on the certificate.

3.6.2 - When in use

The sling must be regularly inspected and removed from service if defect such the following are visible:

- Missing or illegible tag.
- Evidence of heat damage or corrosion of rope (internal and external) or attachments.
- Kinking, crushing, bird caging, or any other damage resulting in distortion of the rope structure.

- Wear or other loss of the original diameter of the individual wires. *(British Standard 6570 recommends that a wire rope should be discarded when the diameter of the rope is reduced to 90% of the nominal diameter.)*
- Broken wires. *(The Construction (Lifting Operations) Regulations (UK) requires a rope to be replaced when the number of broken wires reaches 5% of the total number of wires in the rope in 10 x d.)*

Note that thick gloves must be worn when handling the cable slings.
Any suspicious sling should be temporary removed from service for examination by a competent person.

3.7 - Selection and use of wire slings

3.7.1 - Prepare the lifting

Consideration should be given to the required Working Load Limits given on the label, taking into account the nature, size, shape and weight of the load, together with the intended method of use, and working environment

The selected wire sling should be both strong enough and of the correct length for the mode of use.

If more than one sling is used to lift a load, the slings should be chosen such that the sling forming each leg is not overloaded and that the load remains balanced and stable.

Consideration should also be given to ancillary fittings and lifting devices which should be compatible with the sling(s). The termination should also be considered.

Wire rope slings should not be overloaded: The correct mode factor should be used *(see point 3.3 and WLL tables points 3.3.4 & 3.3.5)*. Working Load Limits for some modes of use may be given on the label. In the case of multi-leg slings the maximum angle to the vertical should not be exceeded.

The slings, should be correctly positioned and attached to the load in a safe manner. They should never be knotted or twisted.
Damage to labels should be prevented by keeping them away from the load, the hook, and the angle of choke.

A sling should never be forced into position nor should any attempt be made to tighten the bite.

In the case of multi-leg slings, the WLL values have been determined on the basis that the loading of the sling assembly is symmetrical. This means that when a load is lifted the sling legs are symmetrically disposed in plan and subtended at the same angle to the vertical.

In the case of 3 leg slings, if the legs are not symmetrically disposed in plan the greatest tension is in the leg where the sum of the plan angles to the adjacent legs is greatest. The same effect occurs in 4 leg slings, except that the rigidity of the load should also be taken into account.

Slings should be protected from edges, friction and abrasion, whether from the load or the lifting appliance, by the use of protective sleeves, suitable packing and/or corner pieces.

The sling(s) should be arranged so that the point of lift is directly above the centre of gravity of the load and the load is balanced and stable. Movement of the sling over the lifting point is possible if the centre of gravity of the load is not below the lifting point.

For slings used in pairs, the use of a spreader is recommended so that the sling legs hang as vertically as possible and to ensure that the load is equally divided between the legs.

3.7.2 - During the lift

Care should be taken to ensure the safety of personnel during the lift. Persons in the danger area should be warned that the operation is to take place, and if necessary, evacuated from the immediate area.

Hands and other parts of the body should be kept away from the sling to prevent injury as the slack is taken up.

A trial lift should be made. The slack should be taken up until the sling is taut. The load should be raised slightly and a check made that it is secure and assumes the position intended. This is especially important with basket or other loose hitches where friction retains the load.

If the load tends to tilt, it should be lowered and attachments re-positioned. The trial lift should be repeated until the stability of the load is ensured.

Care should be taken when making the lift to ensure that the load is controlled, I.e. to prevent accidental rotation or collision with other objects.

Snatch or shock loading should be avoided as this will increase the forces acting on the sling.

A load in the sling or the sling itself should not be dragged over the ground or rough surfaces.

The load should be lowered in an equally controlled manner as when lifted.

Trapping the sling when lowering the load should be avoided. The load should not rest on the sling. This could cause damage and pulling the sling from beneath the load when the load is resting on it should not be attempted.

3.7.3 - After the lift

On completion of the lifting operation the sling should be returned to proper storage.

When not in use, slings should be stored in clean, dry and well ventilated conditions, at ambient temperature and on a rack, away from any heat sources, contact with chemicals, fumes, corrodible surfaces.

Slings which have become wet in use, or as a result of cleaning, should be hung up and allowed to dry naturally.

Prior to placing in storage, slings should be inspected for any damage which may have occurred during use. Slings should never be returned damaged to storage. Damaged slings should be withdrawn from service.

Where lifting slings have come into contact with acids or alkalis, dilution with water or neutralization with suitable media is recommended prior to storage. Contact with acids or acidic fumes causes hydrogen embrittlement to grade 8 materials. Slings with grade 8 fittings and multi-leg slings with grade 8 master links should not be used in acidic conditions. Contaminated slings should be taken out of service at once, soaked in cold water, dried naturally and referred to a competent person for examination.

Lubrication: During fabrication, ropes receive lubrication. This in-process treatment provides the finished rope with ample protection for a reasonable time if it is stored under proper conditions. But, when the rope is put into service, the initial lubrication may be less than needed for the full useful life of the rope. Because of this possibility, periodic applications of a suitable rope lubricant are necessary. Before applying lubrication, accumulations of dirt or other abrasive material should be removed from the rope. Cleaning is accomplished with a stiff wire brush and solvent, and compressed air or live steam. Immediately after it is cleaned, the rope should be lubricated. Characteristics of a good wire rope lubricant are as follow:

- It should be free from acids and alkalis.
- It should have sufficient adhesive strength to remain on the ropes.
- It should be of a viscosity capable of penetrating the interstices between wires and strands.
- It should not be soluble in the medium surrounding it under the actual operating conditions.
- It should have a high film strength.
- It should resist oxidation.

Examination periods should be determined by a competent person, taking into account the application, environment, frequency of use, and similar matters. All slings should be visually examined at least annually by a competent person to establish their fitness for continued use. Records of such examinations should be maintained.

4 - Chain slings

4.1 - Norms and standards applied

This document is based on the European Standard EN 1677 & EN 818 , which specify the requirements related to safety of single, two, three, four leg, and endless chain slings:
The chain slings covered by EN 818 are intended for general purpose lifting operations, i.e. when used for lifting objects, materials or goods which require no deviations from the requirements, safety factors or working load limits specified. Lifting operations not covered by this standard would include the lifting of persons, potentially dangerous materials such as molten metal and acids, glass sheets, fissile materials, nuclear reactors and where special conditions apply.

4.2 - Terminologies used

Some particular terminologies are associated with the lifting chains and, a need clarification :

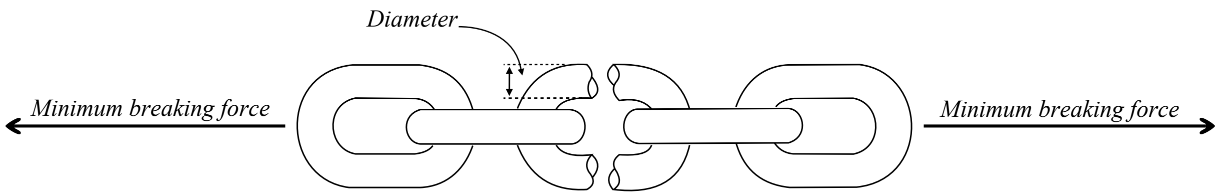
4.2.1 - Minimum breaking force

The "Minimum Breaking Force" is the minimum force at which the chain during manufacture has been found by testing to break when a constantly increasing force is applied in direct tension. Breaking force values are not guarantees that all chain segments will endure these loads. This test is a manufacturer's attribute acceptance test and shall not be used as a criterion for service or design purposes

4.2.2 - Grade *(source NACM)*

The grade refers to the tensile strength of the chain. This is expressed in newtons per square millimetre (a newton is approximately 0.224805 lbs). It is calculated by taking the minimum breaking force load and dividing by two times the nominal cross section area of the link.

- Metric Units
  Grade = 1/10 of the minimum breaking force in newtons divided by two times the nominal cross sectional area in square millimetres. = (Minimum Breaking Force) / (0.005) (π) $(d)^2$
- Imperial Units
  Grade = 0.000689 of the minimum breaking force in lbs. divided by two times the nominal cross sectional area in square inches = (0.000689)(Minimum Breaking Force) / (0.5) (π) $(d)^2$



Round diameter cross sectional area = $\pi d^2 / 4$

NOTE:
The Minimum Breaking Force is expressed in kN (Metric), or lbs (imperial).
d = Chain diameter expressed in mm or in.

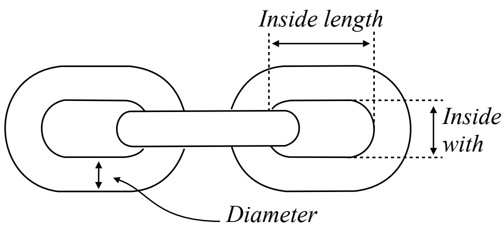
The grade is used to calculate the safe working load of a chain (or other device):
Example for a chain grade 80:

Diameter x Diameter (in mm) x 32 = WLL in Kg
Or, Diameter x Diameter (in mm) x grade (t = 80) x 0.4 = WLL in Kg
For a chain diameter 10mm / grade 80: 10^2 x 32 = 3200 kg

NOTE:
This formula is for information only. Only chains with tags and certificates that conform to what is indicated in this chapter should be used for lifting.

4.2.3 - Nominal size (also called trade or commercial size)

In manufacturing, a “nominal size” is a size "in name only" used for identification.
The nominal size may not match any dimension of the product, but within the domain of that product the nominal size may correspond to a large number of highly standardized dimensions and tolerances.



Nevertheless, on a lot of documents from manufacturers like the example on the next page from the “National Association of Chain Manufacturers” the “Nominal chain size” seems to correspond to the “Material diameter” which is corresponding to the diameter “d” indicated in the drawings point 4.2.2 above and on the side.
However, considering the official definition above, the “nominal size” and the diameter could be different. This reference has to be considered as information only. When selecting a sling, the WLL should be considered.

Nominal chain size		Material diameter		Working load limit (Max.)		Proof test (min)		Minimum breathing force		Inside length (Max.)		Inside with range	
in	*mm*	*in*	*mm*	*lbs*	*kg*	*lbs*	*kN*	*lbs*	*kN*	*in*	*mm*	*in*	*mm*
7/32	5.5	0.227	5.5	2100	970	4200	19	8400	37.4	0.69	17.5	0.281 - 0.325	7.14 - 8.25
9/32	7	0.276	7	3500	1570	7000	31	14000	62.3	0.9	22.9	0.375 - 0.430	9.53 - 10.92
5/16	8	0.315	8	4 500	2000	9000	40	18000	80	1.04	26.4	0.430 - 0.500	10.92 - 12.70
3/8	10	0.394	10	7100	3200	14200	63.1	28400	126.3	1.26	32	0.512 - 0.600	13.00 - 15.20
1/2	13	0.512	13	1200	5400	24000	106.7	48000	213.5	1.64	41.6	0.688 - 0.768	17.48 - 19.50
5/8	16	0.63	16	18100	8200	36200	161	72400	322	2.02	51.2	0.812 - 0.945	20.65 - 24.00
3/4	20	0.787	20	28300	12800	56600	251.7	113200	503.5	2.52	64	0.984 - 1.180	25.00 - 30.00

4.3 - Fabrication requirements *(European standard En 1677)*

4.3.1 - Articulation and movements

The dimensions of the forged steel components should be such as to ensure articulation so that the force imposed is transmitted in the intended direction.

Parts of mechanical joining devices, such as pins and their securing elements, should be so designed and manufactured that, after assembly, no unintended displacement can occur. The effects of wear, corrosion of securing elements or rough usage should be considered.

4.3.2 - Quality of materials

The steel shall be produced by an electric process or by an oxygen blown process.

The steel shall be stabilized against strain age embrittlement, and have an austenitic grain size of 5 or finer when tested in accordance with EN ISO 643:2003 *“Steels -Micrographic determination of the apparent grain size”.* This should be accomplished by ensuring that the steel contains sufficient aluminium (minimum 0.025 %) to permit the manufacture of components stabilized against strain age embrittlement during service.

The steel should contain alloying elements in sufficient quantities so that the finished component possesses adequate ductility in order to work satisfactorily in the temperature range -40 °C to 400 °C.

4.3.3 - Manufacture

Each forged part of a component should be forged hot in one piece. Excess metal from the forging operation should be removed cleanly leaving the surface free from sharp edges. After heat-treatment, furnace scale should be removed.

Edges of machined surfaces shall be rounded to eliminate cutting edges and to ensure attainment of mechanical properties of the component.

Welding should not be used during the manufacture of components unless:

- None of the parts to be welded are load bearing.
- The area affected by the weld is not to be subjected to load under normal operating conditions or under any foreseeable misuse of the component, and the welding is completed before heat treatment.
- Care should be taken during welding to ensure that the mechanical properties of any load bearing parts of the finished component are not affected.
- All welds shall be smoothly finished.

The finished condition of components should include any surface finish. Note: Components are supplied in various surface finishes, e.g. descaled, electroplated, or painted.

Components, including load-bearing pins, if used, should be able to withstand the manufacturing proof force specified in table 4 of EN 1677.

4.3.4 - Marking

Each component should be legibly and indelibly marked in a place where the marking will not be removed by use and in a manner that will not impair the mechanical properties. The marking should include the following information:

- Code number which identifies the Working Load Limit of the chain sling
- The grade number.
- The manufacturer's name, symbol or mark.
- The traceability code.

4.3.5 - Manufacturer's certificate

The certificate should include the following information:

- The name and address of the manufacturer or authorized representative, including the date of issue of the certificate and authentication.
- The number and relevant part of the Standard applied.

- Code number.
- The quantity and description of the component.
- The grade number.
- The Working Load Limits, In tonnes.
- The manufacturing proof force, In kilonewtons.
- Confirmation that the specified minimum breaking force was met or exceeded.
- An identification of the quality system to EN ISO 9002 when In place and operating.

The manufacturer should keep a record, for at least 10 years after the last certificate has been issued, of the material specification, heat treatment, dimensions, test results, quality system in use, and all relevant data concerning the components that have satisfied the type tests, including records of sampling. This record should also include the manufacturing specifications that should apply to subsequent production.

4.4 - Inspection of wire slings in service *(En 818)*

4.4.1 - Before first use

The sling corresponds precisely to that specified on the order.

The manufacturer's certificate is on hand.

The identification and Working Load Limit marked on the sling correspond with the information on the certificate.

Full details of the chain sling are recorded.

4.4.2 - When in use

4.4.2.1 - Examination:

A thorough examination should be carried out by a competent person at intervals not exceeding twelve months. This interval should be less where deemed necessary in the light of service conditions.

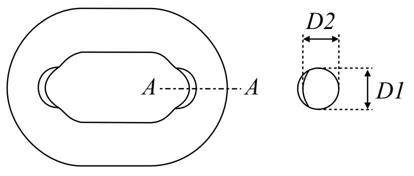
Records of such examinations should be maintained.

Chain slings should be thoroughly cleaned so as to be free from oil, dirt and rust prior to examination. Any cleaning method which does not damage the parent metal is acceptable. Methods to avoid are those using acids, overheating, removal of metal or movement of metal which may cover cracks or surface defects.

Adequate lighting should be provided and the chain sling should be examined throughout its length to detect any evidence of wear, distortion or external damage.

The chain sling should be withdrawn from service and referred to a competent person for thorough examination if any of the following are observed:

- The tag or label identifying the chain sling and its working load limit becomes detached and the necessary information is not marked on the master link itself or by some other means.
- Distortion of the upper or lower terminals.
- Chain stretch: If the chain links are elongated or if there is any lack of free articulation between the links or noticeable difference in the leg length of multi-leg chain slings, the chain may have been stretched
- Wear by contact with other objects usually occurs on the outside of the straight portions of the links where it is easily seen and measured. Wear between adjoining links is hidden.



  - The chain should be slack and adjoining links rotated to expose the inner end of each link.
  - Inter-link wear, as measured by taking the diameter indicated “D1” and one at right angles, “D2” may be tolerated until the mean of these diameters has been reduced to 90% of the nominal diameter “DN”: “D1” + “D2” / 2 ≥ 0.9 “DN”
- Cuts, nicks, gouges, cracks, excessive corrosion, heat discoloration, bent or distorted links or any other defects.
- Signs of opening out of hooks, i.e. any noticeable increase in the throat openings or any other form of distortion in the lower terminal.

4.4.2.2 - Repair:

Any replacement component or part of the chain sling should be in accordance with the appropriate European Standard (or equivalent) for that component or part. With Grade 8 or Grade 4 chain slings, if any chain link within the leg of a chain sling is required to be replaced then the entirety of the chain within that leg should be renewed.
The repair of chain in a welded chain slings should only be carried out by the manufacturer using a resistance butt or flash butt welding process.

Components that are cracked, visibly distorted or twisted, severely corroded or have deposits which cannot be removed should be discarded and replaced.

Minor damage such as nicks and gouges may be removed by careful grinding or filing. The surface should blend smoothly into the adjacent material without abrupt change of section. The complete removal of the damage should not reduce the thickness of the section at that point to less than the manufacturers specified minimum dimensions or by more than 10 % of nominal thickness of the section.

the case of chain slings on which repair work has involved welding, each repaired chain sling should be proof-tested following heat treatment using a force equivalent to twice the Working Load Limits and thoroughly examined before it is returned to use. However, where repair is carried out by inserting a mechanically assembled component, proof-testing is not required provided that the component has already been tested by the manufacturer in accordance with the relevant European Standard (or equivalent).

The accuracy of the tensile test equipment should be of class 2 as given in EN 10002-2.1992 *"Tensile testing of metallic materials. Verification of the force measuring system of the tensile testing machine"*.

4.5 - Selection and use of chain slings (En 818)

4.5.1 - Prepare the lift

It is essential that the mass of the load to be lifted is known. If the mass is not marked, the information should be obtained from the consignment notes, manuals, plans etc. If such information is not available, the mass should be assessed by calculation.

The position of the centre of gravity of the load should be established in relation to the possible points of attachment of the chain sling. To lift the load without it tilting or toppling the following conditions should be met.

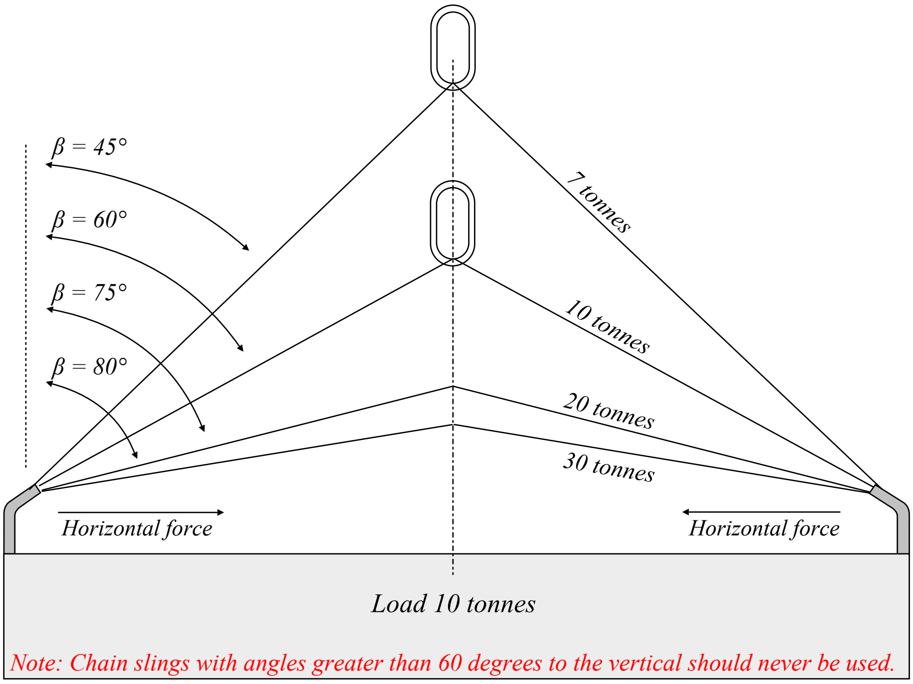
- For single leg and endless chain slings, the attachment point should be vertically above the centre of gravity.
- For two leg chain slings, the attachment points should be either side of and above the centre of gravity.
- For three and four leg chain slings, the attachment points should be distributed in plan around the centre of gravity. It is preferable that the distribution should be equal, and that the attachment points should be above the centre of gravity.

When using two, three, and four-leg chain slings the attachment points and chain sling configuration should be selected to achieve angles between the chain sling legs and the vertical within the range marked on the chain sling. Preferably all angles to the vertical should be equal. Angles to the vertical of less than 15° should be avoided as they present a significantly greater risk of load imbalance.

All multi-leg chain slings exert a horizontal component of force which increases as the angle between the chain sling legs is increased *(see fig 1)*. Where hooks or other fittings are threaded on a loop of chain, (e.g. case chain slings and drum chain slings), the horizontal component of force is much greater, and consequently, the angle of such legs should not exceed 30° to the vertical. Care should always be taken to ensure that the load to be moved is able to resist the horizontal component of force without being damaged.

The hook to which the chain sling is attached should be directly above the centre of gravity.

Fig 1: Example of variation of chain sling leg loading with leg angle for a load of 10 tonnes



- Chains should be without twists or knots.

- The lifting point should be seated well down in a hook, never on the point or wedged in the opening; the hook should be free to incline in any direction so as to avoid bending. For the same reason, the master link should be free to incline in any direction on the hook to which it is fitted.

- The chain may be passed under or through the load to form a choke hitch *(see Fig 2)* or basket hitch *(see Fig 3)*. Where it is necessary, due to the danger of the load tilting, more than one chain sling leg in a basket hitch may be used. This should preferably be done in conjunction with a lifting beam.

When a chain sling is used in a choke hitch, the chain should be allowed to assume its natural angle and should not be hammered down.

Chain sling legs may be attached to the load in several ways.

- Straight leg:
  In this case, lower terminals are connected directly to the attachment points. Selection of hooks and attachment points should be such that the load is carried in the seat of the hook and tip loading of the hook is avoided. In the case of multi-leg chain slings, hook tips should point outwards unless the hooks are specifically designed to be used otherwise.
- Choke hitch:
  In this case, chain sling legs are passed through or under the load and the lower terminal is back hooked or reeved onto the chain *(see Fig 2)*. This method can be used where no suitable attachment points are available, and it has the additional advantage that the chain sling legs tend to bind the load together.
- Basket hitch:
  The chain sling is passed through or under the load as in b). But in this case the lower terminals are connected directly to the master link or to the hook of the lifting machine. Generally, this method requires two or more chain sling legs and should not be used for lifting loads which are not held together. Where the load geometry permits, a single leg chain sling can be used provided that the chain sling passes through the load directly above the centre of gravity of the load. *(See Fig. 3)*
- Wrap and choke or wrap and basket hitch:
  These methods are designed to provide extra security of loose bundles and involve taking an extra loop of chain completely around the load.

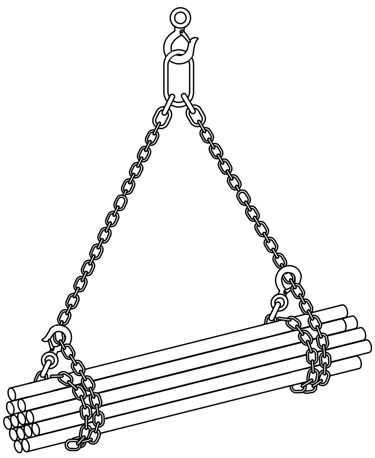


Fig 2: Choke hitches

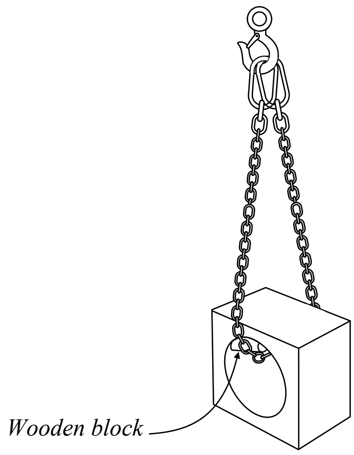
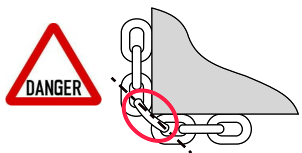


Fig 3: Basket hitches

If two or more chain sling legs are used in a choke hitch or a wrap and choke hitch, care should be taken:

- if it is important to avoid imparting a torque to the load, to align the chokes; or
- if it is important to avoid the load rolling or moving laterally when first lifted, to ensure that (at least) one leg passes either side of the load.

Packing may be required where a chain comes into contact with a load in order to protect either the chain or the load or both, since sharp corners of hard material may bend or damage the chain links, or conversely, the chain may damage the load because of high contact pressure. Packing, such as wooden blocks, may be used to prevent such damage.



In order to prevent dangerous swaying of the load and to position it for loading, a tag line is recommended.

When loads are accelerated or decelerated suddenly, high dynamic forces occur which increase the stresses in the chain. Such situations, which should be avoided, arise from snatch or shock loading, e.g. from not taking up the slack chain before starting to lift or by the impact of arresting falling loads.

WLL values have been determined on the basis that the loading of the chain sling is symmetrical. This means that when the load is lifted the chain sling legs are symmetrically disposed in plan and subtend the same angles to the vertical. *(See fig 4)*

In the case of three leg chain slings, if the legs are not symmetrically disposed in plan the greatest tension will be in the leg where the sum of the plan angles to the adjacent legs is greatest. The same effect will occur in 4 leg chain slings except that the rigidity of the load should also be taken into account. With a rigid load, the majority of the mass may be taken by only three or even two legs with the remaining leg or legs serving only to balance the load *(See fig 5)*.

In the case of two, three and four-leg chain slings, if the legs subtend different angles to the vertical, the greatest tension will be in the leg with the smallest angle to the vertical. In the extreme case, if one leg is vertical, it will carry all the load *(see fig 5)*.

If there is both a lack of symmetry in plan and unequal angles to the vertical the two effects will combine and may either be cumulative or tend to negate each other *(see fig 5)*.

The loading can be assumed to be symmetric if all of the following conditions are satisfied:

- The load is less than 80 % of marked WLL.
- Chain sling leg angles to the vertical are all not less than 15°.
- Chain sling leg angles to the vertical are all within 15° to each other.
- In the case of three- and four-leg chain slings, the plan angles are within 15° of each other.

If all of the above parameters are not satisfied, then the loading should be considered as asymmetric and the lift referred to a competent person to establish the safe rating for the chain sling. Alternatively, in the case of asymmetric loading, the chain sling should be rated at half the marked WLL *(See fig 5)*.

If the load tends to tilt, it should be lowered and the attachments changed. This can be accomplished by re-positioning the attachment points or by using compatible shortening devices in one or more of the legs. Such shortening devices should be used in accordance with the manufacturer's instructions.

Figure 4

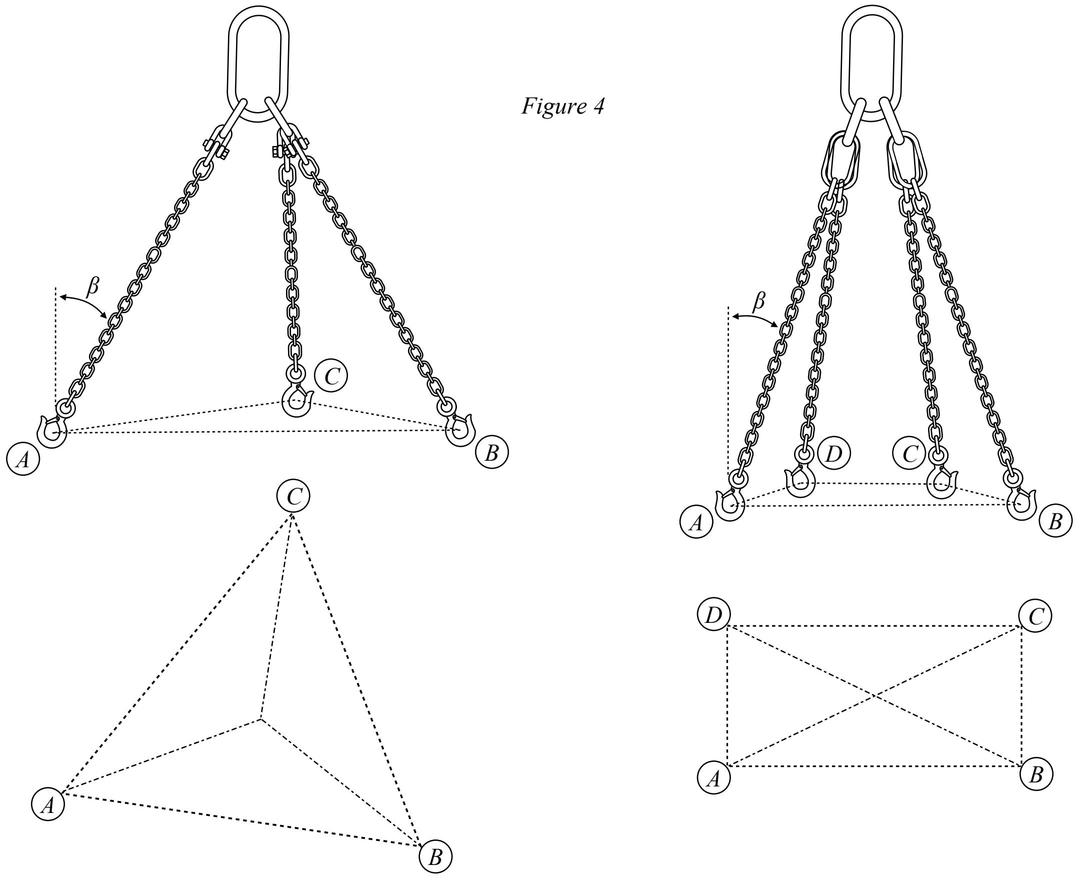
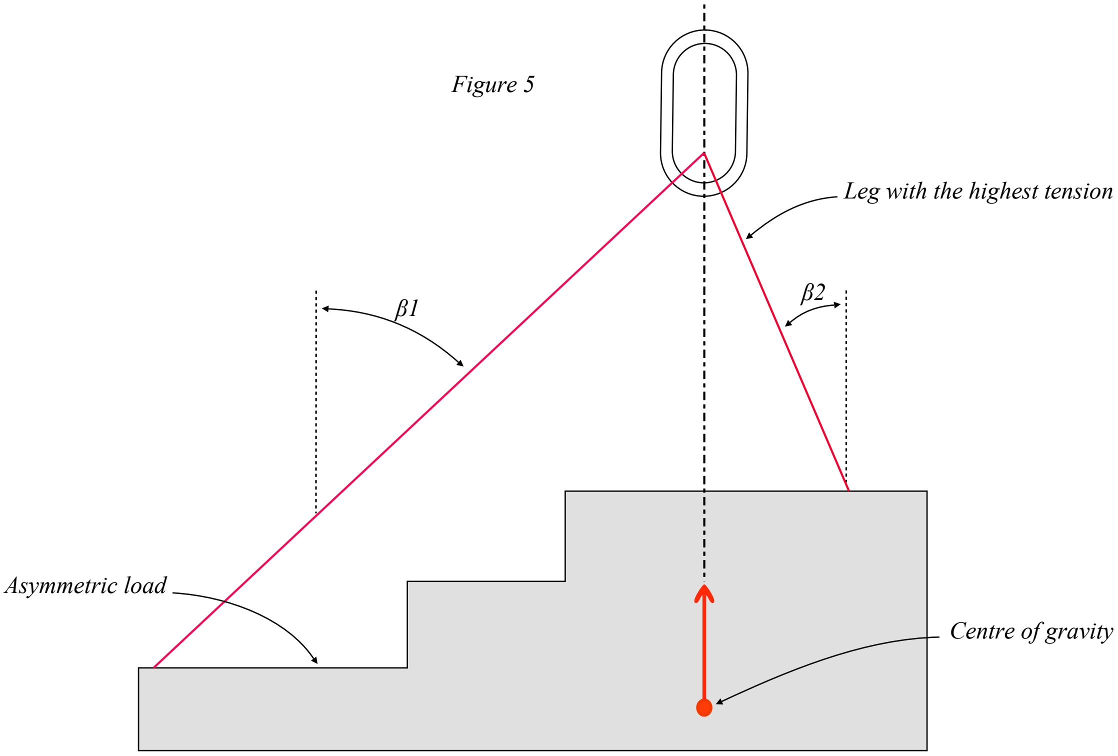


Figure 5



4.5.2 - During the lift

Care should be taken to ensure the safety of personnel during the lift. Persons in the danger area should be warned that the operation is to take place, and if necessary, evacuated from the immediate area.

Hands and other parts of the body should be kept away from the sling to prevent injury as the slack is taken up.

A trial lift should be made. The slack should be taken up until the sling is taut. The load should be raised slightly and a check made that it is secure and assumes the position intended. This is especially important with basket or other loose hitches where friction retains the load.

If the load tends to tilt, it should be lowered and attachments re-positioned. The trial lift should be repeated until the stability of the load is ensured.

Care should be taken when making the lift to ensure that the load is controlled, i.e. to prevent accidental rotation or collision with other objects.

Snatch or shock loading should be avoided as this will increase the forces acting on the sling.

A load in the sling or the sling itself should not be dragged over the ground or rough surfaces.

The load should be lowered in an equally controlled manner as when lifted.

The landing site should be prepared. It should be ensured that the ground or floor is of adequate strength to take the weight taking account of any voids, ducts, pipes etc. which may be damaged or collapse. It should also be ensured that there is adequate access to the site and that it is clear of any unnecessary obstacles and people. It may be necessary to provide timber bearers or similar material to avoid trapping the chain sling or to protect the floor or load or to ensure the stability of the load when landed.

Trapping the sling when lowering the load should be avoided. The load should not rest on the sling. This could cause damage and pulling the sling from beneath the load when the load is resting on it should not be attempted.

When the load is safely landed the chain sling should be removed by hand. The chain sling should not be dragged out with the lifting machine since it may thereby be damaged or it may snag and cause the load to topple over. The load should not be rolled off the chain sling as this may damage the chain sling.

4.5.3 - After the lift

On completion of the lifting operation the sling should be returned to proper storage.

When not in use, slings should be stored in clean, dry, and well ventilated conditions, at ambient temperature and on a rack, away from any heat sources, contact with chemicals, fumes, corrodible surfaces. They should not be left lying on the ground where they may be damaged.

Slings which have become wet in use, or as a result of cleaning, should be hung up and allowed to dry naturally.

Prior to placing in storage, slings should be inspected for any damage which may have occurred during use. Slings should never be returned damaged to storage. Damaged slings should be withdrawn from service.

Where lifting slings have come into contact with acids or alkalis, dilution with water or neutralization with suitable media is recommended prior to storage. Contact with acids or acidic fumes causes hydrogen embrittlement to grade 8 materials. Slings grade 8 , or with grade 8 fittings and multi-leg slings with grade 8 master links should not be used in acidic conditions. Contaminated slings should be taken out of service at once, soaked in cold water, dried naturally and referred to a competent person for examination.

If the chain slings are to be left suspended from a crane hook, the chain sling hooks should be engaged in an upper link to reduce the risk of chain sling legs swinging freely or snagging.

For chain slings delivered painted, The protective paint has to be renewed periodically, or the chain may be painted in another colour for identification purpose. Because the paints designed for metal are using harmful and extremely flammable solvents, this operation has to be performed in a well ventilated area. The chain can be returned to the store only when the paint is fully dry with no noticeable emission of solvents.

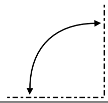
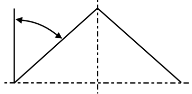
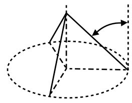
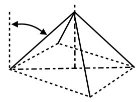
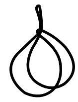
Chain slings without paint or galvanization: Some chain slings can be delivered with oil lubrication as protection against corrosion. As for the wire slings, this protective film has to be renewed periodically, or after exposure in aggressive medium (salt water). The oil to use for this purpose should have similar characteristics than the one used for wire slings:

- It should be free from acids and alkalis.
- It should have sufficient adhesive strength to remain on the chains.
- It should not be soluble in the medium surrounding it under the actual operating conditions.
- It should have a high film strength.
- It should resist oxidation.

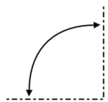
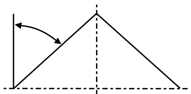
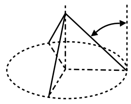
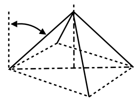
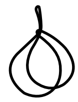
Improper use of diesel: Some teams commonly use diesel to lubricate their lifting chains (and also lever hoists) . If used, this practice must be stopped:

- Diesel is a hydrocarbon designed to run engines and is very volatile and flammable. There is a high risk of fire in the store in addition to the fact that hydrocarbons are health hazards.
- Diesel dissolves the oil protection and has poor adhesive strength, particularly when exposed to seawater. As a result, it will not remain on the chain that is no longer protected.

4.5.4 - Working load limits chain slings grade 8 *(Source EN 818-4)*

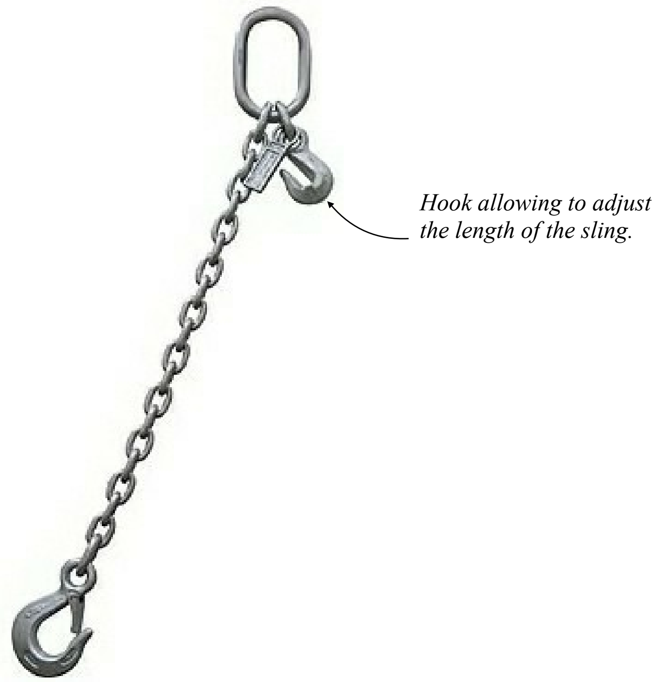
Slings grade 8 WLL	***One leg sling***	***Two leg sling***		***Three and four leg sling***		***Endless sling***
Angle to vertical	***0º***	***0º to 45º***	***Over 45º to 60º***	***0º to 45º***	***Over 45º to 60º***	***0º***
						
	Direct	***Direct***	***Direct***	***Direct***	***Direct***	***Choke hitch***
Nominal size in mm	***Factor 1***	***Factor 1.4***	***Factor 1***	***Factor 2.1***	***Factor 1.5***	***Factor 1.6***
4	***0.5***	***0.71***	***0.5***	***1.06***	***0.75***	***0.8***
5	***0.8***	***1.12***	***0.8***	***1.6***	***1.18***	***1.25***
6	***1.12***	***1.6***	***1.12***	***2.36***	***1.7***	***1.8***
7	***1.5***	***2.12***	***1.5***	***3.15***	***2.24***	***2.5***
8	***2***	***2.8***	***2***	***4.25***	***3***	***3.15***
10	***3.15***	***4.25***	***3.15***	***6.7***	***4.75***	***5***
13	***5.3***	***7.5***	***5.3***	***11.2***	***8***	***8.5***
16	***8***	***11.12***	***8***	***17***	***11.8***	***12.5***
18	***10***	***14***	***10***	***21.2***	***15***	***16***
19	***11.2***	***16***	***11.2***	***23.6***	***17***	***18***
20	***12.5***	***17***	***12.5***	***26.5***	***19***	***20***
22	***15***	***21.2***	***15***	***31.5***	***22.4***	***23.6***
23	***16***	***23.6***	***16***	***35.5***	***25***	***26.5***
25	***20***	***28***	***20***	***40***	***30***	***31.5***
26	***21.2***	***30***	***21.5***	***45***	***31.5***	***33.5***
28	***25***	***33.5***	***25***	***50***	***37.5***	***40***
32	***31.5***	***45***	***31.5***	***67***	***47.5***	***50***
36	***40***	***56***	***40***	***85***	***60***	***63***
40	***50***	***71***	***50***	***106***	***75***	***80***
45	***63***	***90***	***63***	***132***	***95***	***100***

4.5.5 - Working load limits chain slings grade 4 *(Source EN 818-5)*

WLL sling grade 4	***One leg sling***	***Two leg sling***		***Three and four leg sling***		***Endless sling***
Angle to vertical	***0º***	***0º to 45º***	***Over 45º to 60º***	***0º to 45º***	***Over 45º to 60º***	***0º***
						
Nominal size in mm	***Direct***	***Direct***	***Direct***	***Direct***	***Direct***	***Choke hitch***
Leg factor	***1***	***1.4***	***1***	***2.1***	***1.5***	***1.6***
7	***0.75***	***1.06***	***0.75***	***1.6***	***1.12***	***1.25***
8	***1***	***1.4***	***1***	***2.12***	***1.5***	***1.6***
10	***1.6***	***2.24***	***1.6***	***2.36***	***2.36***	***2.5***
13	***2.65***	***3.75***	***2.65***	***5.6***	***4***	***4.2***
16	***4***	***5.6***	***4***	***8.5***	***6***	***6.3***
18	***5***	***7.1***	***5***	***10.6***	***7.5***	***8***
19	***5.6***	***8***	***5.6***	***11.8***	***8.5***	***9***
20	***6.3***	***8.5***	***6.3***	***13.2***	***9.5***	***10***
22	***7.5***	***10.6***	***7.5***	***16***	***11.2***	***11.8***
23	***8***	***11.8***	***8***	***17***	***12.5***	***13.2***
25	***10***	***14***	***10***	***20***	***15***	***16***
26	***10.6***	***15***	***10.6***	***22.4***	***16***	***17***
28	***12.5***	***17***	***12.5***	***25***	***18***	***20***
32	***16***	***22.4***	***16***	***33.5***	***23.6***	***25***
36	***20***	***28***	***20***	***42.5***	***30***	***31.5***
40	***25***	***35.5***	***25***	***37.5***	***37***	***40***
45	***31.5***	***45***	***31.5***	***47.5***	***47.5***	***50***

4.6 - Adjustable chain slings

These slings are not designed explicitly for subsea work. However, many companies continue using lever hoists to adjust their rigging prior to transferring the load, despite the numerous guidelines from standardization bodies and professional organizations indicating that this practice must be forbidden. For this reason, adjustable chain slings should be used when parts of the rigging needs to be adjusted to specific lengths due to the shape and the complexity of the load to transfer, and classical slings do not allow doing it correctly. These slings are built under the same norms as classical chain slings, and their length can be adapted to what is required by inserting the chain links in specific adjustment hooks.



Other adjustable chain sling systems are those that consist of an adjustable master plate that can be slid from one side to another of the sling, such as the "adjust-a-link" system from "LiftAll", a company based in the USA (https://www.lift-all.com/) in the picture underneath *(note that the hooks on the photo should normally be provided with safety latches)*. With these systems, the master control plate can be adjusted on one side or the middle of the double hook chain sling. Also, consider that the sling is passed through the adjusting plate and cannot escape from it.

5 - Ropes and common marine knots

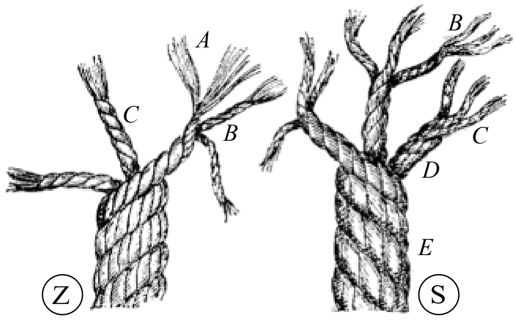
5.1 - Ropes

5.1.1 - Description

The history of ropes is already mentioned in the description of rope slings. As a reminder, they have existed since prehistoric times, and without this invention, sailing, and erecting buildings would not have been possible.
Ropes were used for all lifting operations until wire ropes replaced them on cranes. However, they are still used with pulley blocks and deflection pulleys and are commonly employed to design tag lines.

Ropes are made from several parallel load-bearing elements twisted together to allow the assembly to operate as a cohesive whole.

- In making a rope or line, the fibres *(see A)* are loosely twisted together to form what is technically known as a "yarn" *(see B)*.
- When two or more yarns are twisted together they form a "strand" *(see C)*.
- Three or more strands form a rope *(see D)*
- Three ropes form a cable *(see E)*
- S and Z twist yarn:
  Twist" in spun yarns or ropes is labelled S-twist for left-handed twist, and Z-twist for right-handed twist, due to the respective left and right of the central sections of those two letters.



5.1.2 - References

ISO 9554 “Fibre ropes - General specifications”, which is based on several standards, considers the following construction materials:

- Natural fibres: sisal; manila; hemp; cotton.
- Man-made fibres: polyamide, polyester, polypropylene, polyethylene, mixed polyolefin, polyester/polyolefin dual fibres; high modulus polyethylene, Para-Aramid, Polyarylate, Polybenzobisoxazole.

Type of fibre rope	*Standard*	*Title*
Sisal	*ISO 1181*	*Fibre ropes - Manila and sisal - 3, 4, and 8-strand ropes*
Manila	*ISO 1181*	*Fibre ropes - Manila and sisal - 3, 4, and 8-strand ropes*
Hemp	*EN 1261*	*Fibre ropes for general service - Hemp*
Cotton	*ISO 9554*	*Fibre ropes - General specifications*
Polyamide	*ISO 1140*	*Fibre ropes - Polyamide - 3, 4, 8, and 12 strand ropes*
Polyester	*ISO 1141*	*Fibre ropes - Polyester - 3, 4, 8, and 12 strand ropes*
Polypropylene	*ISO 1346*	*Fibre ropes - Polypropylene split film, monofilament and multifilament (PP2) and polypropylene high-tenacity multifilament (PP3) - 3, 4, 8, and 12 strand ropes*
Polyethylene	*ISO 10325*	*Fibre ropes - High modulus polyethylene - 8 strand braided ropes, 12 strand braided ropes and covered ropes*
Mixed polyolefin	*ISO 10572*	*Mixed polyolefin fibre ropes*
Polyester/polyolefin dual fibres	*ISO 10556*	*Fibre ropes of polyester/polyolefin dual fibres*
High modulus polyethylene	*ISO 10325*	*Fibre ropes - High modulus polyethylene - 8 strand braided ropes, 12 strand braided ropes and covered ropes.*
Aramid	*ISO/DIS 18692-5*	*Fibre ropes for offshore station keeping — Part 5: Aramid*
Polyarylate	*ISO/DIS 18692-4*	*Fibre ropes for offshore station keeping — Part 4: Polyarylate*
Fibre ropes and cordage (all)	*ISO 1968*	*Fibre ropes and cordage - Vocabulary*
Textiles - Synthetic fibres	*ISO 2076*	*Textiles - Man-made fibres - Generic names*
Fibre ropes	*ISO 2307*	*Fibre ropes - Determination of certain physical and mechanical properties*
Natural fibres	*ISO 6938*	*Textiles — Natural fibres — Generic names and definitions*

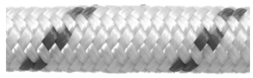
5.1.3 - ISO classification according to construction and structure (ISO 9554)

ISO 9454 considers the following types of constructions:

- Laid ropes:
  Laid ropes are the classical models described in point 5.1.1. Unless specified, 3 strands, 4 strands, 6 stands laid ropes should be Z twist (right-hand lay). Their strands S-twist and their roping yarns Z twist.

- Braided ropes:
  A braided rope consists of a braided (tubular) jacket over the strands.
  The 8-strand plaited ropes must consist of two pairs of S twist strands and two pairs of Z twist strands arranged so that S twist pairs alternate with Z twist pairs.
  The 12-strand braided ropes should consist of six S-twist strands and six Z-twist strands arranged so that S-twist strands alternate (individually or in pairs) with Z-twist strands (individually or in pairs).

- Double-braided ropes:
  A double-braided rope consists of a number of strands that are braided to form a core, around which additional strands are braided to form a sheath. The core lies coaxially within the sheath. The number of strands varies, based upon the size of the rope.



- Covered ropes
  A covered rope consists of a core protected by a non-load bearing cover. A parallel rope construction is a covered rope where the core consists of a number of sub-ropes.

ISO 9454 also provides the following requirements regarding strands, and lay length or braid pitch:

- Stands
  Each strand must consist an equal number of rope yarns to provide the characteristics specified for the relevant product. For ropes of reference number 36 or higher, the number of yarns in each strand may differ by one yarn or ±2,5 % from the intended number of yarns in the strand.
  The ropes and their strands should be continuous, without splices for standard or shorter lengths. To overcome manufacturing limitations, strand interchanges can be used. When present in 12-strand ropes or sub-ropes, they must be staggered along the length of the rope and at a sufficient distance apart. The interrupted and replacement strands are arranged.
- Lay length or braid pitch
  The manufacturer must establish the lay length or the braid pitch of the rope according to its intended use, or based upon the purchaser's acceptance. Note that for a given reference number of rope, the smaller the lay length or braid pitch, the harder the rope will be. That can affect the estimated breaking strength of the rope.
- Finish of the rope:
  There must not be cuts, kinks, or soft spots caused by a change in lay or pitch length, hockles, chafed or damaged sections, or broken, loose, or projecting ends in the rope or the strands. Unspliced rope ends must be cut squarely and then whipped, taped, or heat-sealed.
  When there are strand interchanges in 12-strand ropes or sub-ropes, there must be staggered along the length of the rope and at a sufficient distance apart. Also, interrupted and replacement strands must be arranged in parallel over a determined length and be buried or tucked into the braid to secure them into the braid. They must overlap one another for a sufficient distance to maintain their strength.
- Documentation:
  A document that contains the following should be available.
  - The length of one strand interchange;
  - The minimum distance between two strand interchanges;
  - The total length of the strand interchange;
  - The positions of the strand interchanges from beginning to end in the rope.

  If required, every splice of a strand/part must be permanently marked on the rope to detect a strand interchange slipping apart and distinguish a strand interchange from damage. Note that strand interchanges are allowed only in 12-strand braided ropes.

5.1.4 - ISO recommendations regarding particular treatment of construction materials

ISO provides the following information regarding the construction materials below that should be taken into account by manufacturers. They are also elements that users should know.

- Polyamide and polyester ropes:
  Polyamide and polyester ropes classified "Type 1" are laid ropes that are heat set to ensure their stability. Laid ropes that do not have a heat setting are classified as "Type 2". Ropes without indication regarding their type should be considered ropes without heat setting.
  In addition, manufacturers often add materials to the ropes' fibres to improve their durability against friction. ISO says that in such a case, they should not exceed 2.5% of the total mass of the rope.
- Polypropylene and polyethylene ropes:
  Polypropylene and polyethylene ropes must be protected against ultraviolet damages resulting from the sunlight. The protection must prove to be efficient, provided that the user indicates the foreseen geographical areas.

- High modulus polyethylene ropes (HMPE):
  They are also called “high-performance polyethylene (HPPE)”, “Ultra-high-molecular-weight polyethylene (UHMWPE or UHMW), and “high-performance polyethylene (HPPE)”, are characterized by their long and robust molecules obtained through treatment of the polypropylene. These ropes, which are typically coated, do not absorb water, have a density of 0.95 (floating), a low coefficient of friction, good UV resistance, and are reported to have excellent strength. However, these ropes do not tolerate tight bends due to their long molecules. Similarly to polyamide and polyester ropes those that had a heat setting process are classified “Type 1”. ISO says that heat setting enhances the breaking strength of a high modulus polyethylene rope. However, the overall life time of the rope may be decreased.
- Manila ropes:
  Manila ropes must have an oil lubricant treatment with a product of suitable quality without an offensive odour. The percentage of extractable matter, based on the dry weight of the rope, must not be less than 11.5 % nor more than 16.5 %.
  Mildew and anti-bacterial treatments may be added to extend the performance of the natural fibre when requested by the purchaser.
- Sisal ropes:
  Sisal ropes should have the same oil treatment and percentage of extractable matter as manila ropes. However, it is said that the rope can be free from any oils and sold as un-oiled rope when specified.
  Anti-bacterial treatments may be added to extend the performance of the natural fibre when requested by the purchaser.

5.1.5 - Comparison of average breaking force and other characteristics

The table below compares the maximum strengths of ropes 3 - 4 strands made of the materials the most commonly used in diving and ROV worksites. Its purpose is to give a rough reference of the lifting and pulling capacities of materials to help the team to select the most appropriate rope for the intended task. The breaking forces provided are expressed in kilo newton. Of course, rope manufacturers or resellers must be consulted for more precise data.

Diameter rope *(mm)*	***Sisal*** *(KN)*	***Hemp*** *(KN)*	***Manilla*** *(KN)*	***Polyethylene*** *(KN)*	***Polypropylene*** *(KN)*	***Polyester*** *(KN)*	***Polyamide*** *(KN)*
6	1.71	2.8	2.4	3.92	5	5.85	6.61
8	2.85	4.5	4	6.86	7.61	9.1	10.2
10	3.85	7	5.4	10.7	10.8	12.9	14.4
12	7.56	10.8	10.6	15.1	16.8	22.6	25.2
14	9.83	13.7	13.8	20.5	20.4	28.6	32
16	12.5	18.25	17.6	27.5	24.8	34.8	39.6
18	15.4	22.5	21.6	34	34	49.8	56.8
22	21.9	32.4	30.8	49.8	46	67.7	76.9
24	25.6	39.8	36	59.8	57	88	98.9
26	29.9	46	42	68	64.1	99	112
28	34.2	54.1	48	80.5	71.2	110	126
30	38.4	61.8	54	93	86.1	133	155
32	42.7	70.9	60.1	105	94.1	145	170
36	52.7	85.6	74.1	132	122	188	216
40	64.2	99.8	90.1	160	142	219	255
44	75.4	118	110	192.5	164	254	294
48	88.3	141	120	22.4	208	320	376
Note: *1 Kilo newton = 101.97 kg force = 224.0 pound force*							

The selection of a rope is not only linked to its strength, but also on its various characteristics such as its durability and resistance to various surroundings. The table below provides such a comparison.

	Sisal	*Hemp*	*Manila*	*Polyethylene*	*Polypropylene*	*Polyester*	*Polyamide*
Shock loading	*poor*	*good*	*acceptable*	*poor*	*good*	*acceptable*	*excellent*
Durability	*poor*	*excellent*	*good*	*acceptable*	*good*	*excellent*	*excellent*
Rot resistance	*poor*	*poor*	*poor*	*excellent*	*excellent*	*excellent*	*excellent*
UV resistance	*excellent*	*excellent*	*excellent*	*acceptable*	*poor*	*excellent*	*acceptable*
Acid resistance	*poor*	*poor*	*poor*	*good*	*good*	*excellent*	*poor*
Alkali resistance	*poor*	*poor*	*poor*	*good*	*good*	*poor*	*excellent*
Abrasion resistance	*acceptable*	*good*	*good*	*acceptable*	*poor*	*excellent*	*excellent*
Buoyancy	*Sinks*	*Sinks*	*Sinks*	*Floats (neutral)*	*Floats*	*Sinks*	*Sinks*
Melting point	*N A*	*N A*	*N A*	*about 128°C*	*about 150°C*	*about 245°C*	*About 250°C*

5.1.6 - Rope testing and labelling

- The rope should be tested according to ISO 2307, using a rope sample including a strand interchange in one strand, and must achieve 100% of the specified minimum breaking strength.
- A label should be fixed on the coil and provide the following:
  - The constituent material;
  - The identification of manufacturer and the reference number;
  - The average breaking force;
  - The delivered length;
  - A reference to the relevant product standard.

5.1.7 - Optimize the ropes' lifespan

Ropes' working conditions and the capacity of their components to withstand aging are two factors that influence their lifespan. A suitable selection of their components according to the surrounding they will be employed using the table displayed above allows controlling their aging. However, exaggerated aging can also be controlled by applying precautions to avoid damaging them.

The list below, based on documents published by the US Navy and rope manufacturers, indicates conditions that could cause mechanical damage to ropes and some recommendations to diminish their effects.

- Overloading / Excessive tension:
  Damages linked to overloading primary result from an incorrect selection of the rope regarding the weight of the load, and the forces resulting from the lifting operations. Manufacturers usually provide Work Load Limits (WLL) of the ropes they sold that are calculated by taking into account the static and dynamic forces the rope can withstand. If this information is missing the Minimum Breaking Strength (or force) is to be known to calculate it using the appropriate "Safety Factor". For remembering, the "Safety Factor" serves to determine the maximum load that a lifting device can withstand safely when in use. It is usually ranging from 4 to 7 on lifting equipment in Europe and North America, so that the safe working load can be calculated by dividing the Minimum Breaking Strength by this factor. For safety reasons, use a safety factor of 7 and above.
  Progressively lifting or pulling the load and checking for excessive tension are recommended during the operations. Thus, procedures that may result in uncontrolled dynamic forces and, therefore, shocks must be avoided.
- Surface abrasion:
  These damages consist of tears or wearing of the rope's surface filaments, resulting from its chafing on various supports during normal use. US Navy suggests using fire hoses and heavy canvas wrapping to protect the most exposed parts and installing wood, leather, or rubber rails over the rough surfaces so that the ropes will ride on a smooth surface. That includes removing sharp edges from tying points.
  It is also recommended not to let rope wear become localized in one spot. In addition to the chafing devices mentioned, the line should be reversed or cut off to transfer wear to an unworn area.

- Gritty materials:
  Gritty materials usually consist of hard crystalline sand grains or other aggressive particles that enter and lodge between the rope yarns and strands while the rope is in a relaxed state. these grits will progressively cut the inner fibres of the rope when it will be back in tension. Even though it is not always possible, avoiding exposure to dirty and aggressive environments where sand is present is recommended. It is also recommended to consider that the rope's strength has been affected after exposure to such surroundings. It is also recommended to avoid dragging lines on deck or the worksite floor to avoid catching grits.
- Shearing:
  Shearing is usually caused by crushing or pinching. Such damage often occurs when a kink in the rope binds against the cheeks of a pulley or a crushing resulting from heavy loads set down on the rope or falling on it. The only management procedure is preventative housekeeping.
- Rope kinks and cockles.
  Kinks develop into strand cockles if improperly handled. The proper method for removing kinks is to lay out the rope and rotate the end counter to the direction of the kink. Kinks can be avoided by properly unreeling the rope.
- Bending:
  Bending usually results from excessive loads, too small sheaves, or sheaves that do not rotate freely. It is characterized by internal abrasion between the twisted strands of the rope, and can be detected by the powdery appearance of the stands. In the "US Navy -Naval ship's technical manual", it is said that the rope speed is the primary factor in developing internal stresses under bending conditions and that the drag over each lubricated sheave adds 10 percent to the load being moved. However, this 10% factor increases to 30 percent when a sheave cannot rotate. Implementing recommended coiling and unkinking procedures and properly selecting and inspecting the sheaves can avoid this problem. It is said, the larger the sheave, the longer the rope's life.
- Frozen environment:
  Similarly to sand, ice crystals remaining within the rope yarns and strands will fracture the inner fibres and may result in rope failure when it is returned under tension. It is recommended to allow frozen ropes to thaw thoroughly, drain before use, and store them under covers to prevent ice crystal formation.
- Rust
  Iron rusting promotes the deterioration of ropes. The US Navy says that six days of contact of a natural fibre rope with rusting iron in a salty, wet atmosphere can reduce its strength by 1/3, and 30 days can entirely destroy it. That can also cause a 40 percent loss of a nylon rope breaking strength in only 1 month.

In addition to controlling the conditions that may damage ropes, it is essential to know how they will lose their capabilities with age. Regarding this point, The US Navy gives the following guidelines.

- Aging of natural fibre ropes:
  Natural rope fibres such as manila or sisal consist mainly of cellulose and become yellow or brownish and brittle with time, even under the best storage conditions. This colour change indicates some loss of strength (according to the USN, 1 to 2 percent loss per year of storage), and that the fibres have become stiff and brittle, so they can break when submitted to successive bends. Rope bending strength loss is more significant than rope breaking strength loss because the bending strength decreases five times more rapidly. For these reasons, the age of such ropes must be indicated on the coils. Also, The US Navy recommends not using 5-year-old and above natural fibres ropes for critical operations and employing them for only lashing, fenders, or matting.
- Aging of Synthetic fibre ropes:
  Synthetic fibre ropes also show colour change with aging. For example, when stored in a warm, humid area, white nylon ropes' colour progressively changes to lemon-yellow or pink. Also, they lose their flexibility and become stiff. However, that does not indicate a change in strength, as the initial stiffness will progressively disappear during the tensioning phases, so the ropes will quickly be flexible again with no breaking or bending strength loss.
  Polyester ropes tend to become grey and lose only little strength due to storage and sun exposure.
  However, coloured nylon ropes deteriorate rapidly when exposed to the elements (particularly sunlight), so the US Navy disapproves of their use for outdoor marine operations.
  In addition, unstabilized polyethylene and polypropylene ropes also deteriorate very rapidly when exposed to sunlight on a continuing basis and can easily lose 40 percent of their strength over a 3-month exposure period. For this reason, they should be avoided where prolonged exposure to sunlight is required.

Storage conditions are also to be considered. That can be done using the table regarding their resistance to various surroundings displayed in the previous point.

- Natural fibres ropes can be damaged by chemicals and rot. For these reasons, the best storage for natural fibre ropes is a dry, cool, dark, well-ventilated area, far removed from any source of chemicals or gaseous fumes. Natural fibre ropes stowed on the deck should be hung on reels or pegs and covered with weatherproof materials.
- Depending on the molecules that compose them, synthetic fibre ropes can be affected by sunlight, fluorescent light, and chemicals. For this reason, they are usually packaged on reels and covered with protection to avoid damage during the handling and storage phases. For this reason, damaged reels and protections must be prepared or changed. For logistical reasons, storing ropes in separate rooms is complex and not logical. Thus, except in the case of a too-small space, all ropes should be kept is the same place, which should be a dry, cool, dark, well-ventilated area, far removed from any source of chemicals or gaseous fumes.

5.1.8 - Rope inspection and discard criteria

In addition to eliminating ropes that are no longer suitable for lifting operations, inspections allow for increasing their lifespan. This section is also based on the US Navy and rope manufacturers' recommendations.

- Visible fibre ruptures and powdering between strands indicates that the rope has been overloaded and should be removed from service.
- A powdery appearance between the natural fibre rope strands also indicates internal wear. Depending on the extent, the rope may have to be discarded or used for other tasks than lifting operations.
- Dark red, brown, or black spots between the strands of natural fibre ropes and a sour, musty, or acidic odour indicate that the natural fibre rope is rotting and should be discarded. Note that rot may be transmitted to adjacent ropes, which must be removed from the store, exposed to fresh air, dried, thoughtfully inspected, and treated or discarded
- Cut-out and distorted strand areas result from improper coiling and bending. Such a defect is reported to reduce rope strength by as much as 60 percent, and for this reason, the rope cannot be used further.
- Extensive fibre discolouration and lost of flexibility indicate exposure to chemical substance. The rope should be removed from service if such exposure is suspected. The symptoms for extensive exposure to ultra violets are explained previously. Depending on its composition and exposure time, the rope may have to be discarded.
- Ruptured or brittle fibres, dark red or brown spots, salt incrustation, and swollen areas in natural fibre ropes indicate damage due to chemical substances. Ropes affected by such damages should be discarded.
- Ropes should be inspected for traces of rust and discarded if too affected.
- Fat accumulation affects the ropes' resistance and makes them slippery. They can be cleaned with liquid soap and water (dish soap gives good results without attacking the components of the fibre). Do not use hyperbaric water jets for this purpose.

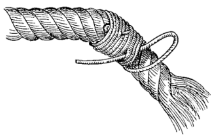
5.2 - Knots

Knowing knots is essential for people working at sea and various diving sites. This section uses illustrations and descriptions from the Alpheus Hyatt Verrill (1871 - 1954) treatise“Knots, splices, and rope work”, which is in public release and can be downloaded on “The Project Gutenberg website (https://www.gutenberg.org/)”

5.2.1 - Simple knots

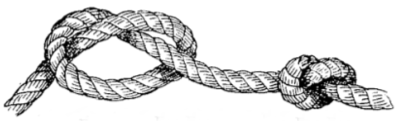
- Whipping *(Fig 1):*
  To whip or seize a rope end, take a piece of twine or string and lay it on the rope one inch or two from the end. Pass the twine several times around the rope, keeping the ends of the twine under the first few turns to hold it in place. Then make a large loop with the free end of the twine, and bring it back to the rope and continue winding for three or four turns around both the rope and the end of the twine. Then finish by drawing the loop tight by pulling on the free end.

Fig. 1



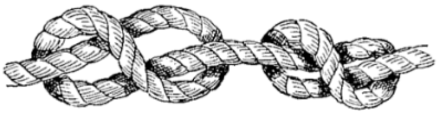
- Overhand kno**t** *(Fig 2)*
  This knot is important as it is frequently used in fastening the ends of yarns and strands in splicing, whipping, and seizing.

Fig. 2



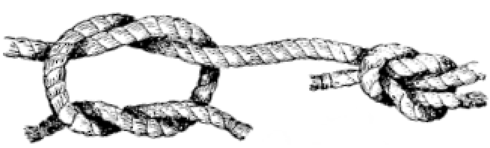
- Figure 8 knot *(Fig 3)*
  The "Figure-Eight Knot" is almost as simple as the overhand.

Fig. 3



- Square knot *(Fig. 4)*
  The square knot is widely used. It is very strong. It never slips or becomes jammed and is readily untied. To make a square knot, take the ends of the rope and pass the left end over and under the right end, then the right over and under the left.

Fig 4

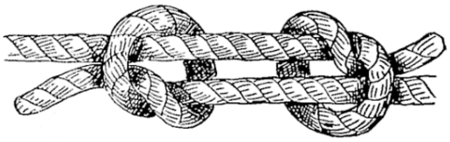


- Open-hand Knot *(Fig. 5)*
  It is considered the better way to join two ropes of unequal diameter. This knot is very quickly and easily made; it never slips or gives but is rather large and clumsy, and if too great a strain is put on the rope, it is more likely to break at the knot than at any other spot.

Fig. 5

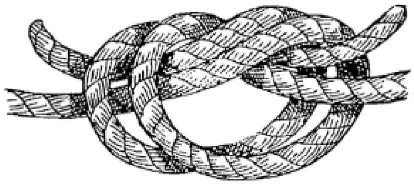
- Fisherman knot *(fig. 6)*
  It is formed by two simple overhand knots slipped over each rope.

Fig. 6



- Ordinary knot *(Fig. 7)*
  It is made by forming a simple knot and then interlacing the other rope or "following around". This knot is very strong, will not slip, is easy to make, and does not strain the fibres of the rope. Moreover, ropes joined with this knot will pay out, or hang, in a straight line.

Fig. 7

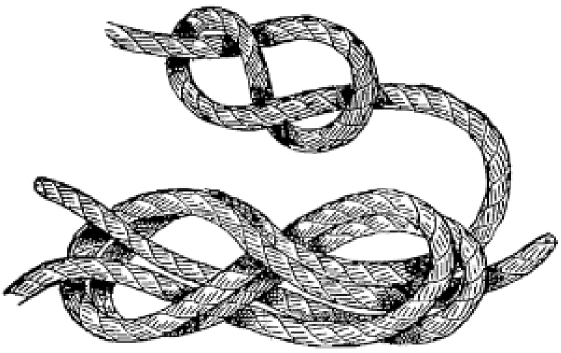


- Weaver’s knot *(Fig. 8)*
  It is useful in joining small lines.

Fig. 8

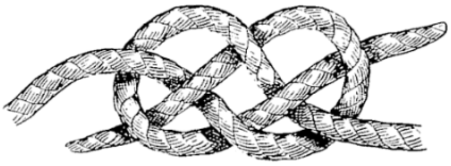
- Double figure 8 knot *(Fig. 9)*
  It is made by forming a regular figure eight and then "following round" with the other rope. It is then drawn taut, and the ends seized to the standing part if desired

Fig. 9



- Carrick bend *(fig. 10)*
  It is used to join two heavy or stiff ropes or hawsers. To make this knot, form a bight by laying the end of a rope on top of and across the standing part. Next, take the end of the other rope and pass it through this bight, first down, then up, over the cross, and down through the bight again, so that it comes out on the opposite side from the other end, thus bringing one end on top and the other below. If the lines are very stiff or heavy, the knot may be secured by seizing the ends to the standing parts.

Fig. 10

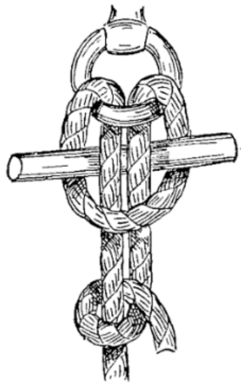


5.2.2 - Ties and hitches

The knots used in making a rope fast to a stationary or solid object are known as "hitches" or "ties".

- Lark's Head *(Fig. 11)*
  It is useful in fastening a boat or other object where it may be necessary to release it quickly. To make this tie, pass a bight of your rope through the ring, or other object, to which you are making fast and then pass a marline-spike, a billet of wood, or any similar object through the sides of the bight and under or behind the standing part.

Fig. 11

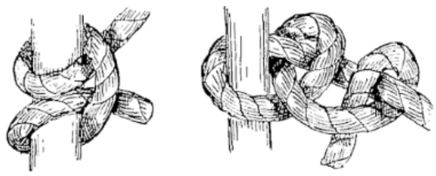


- Slippery Hitch *(fig. 12)*
  Almost as quickly made and unfastened as the lark head.

Fig. 12

- Half hitches *(fig. 13)*
  Two half-hitches, either around a post or timber or around the standing part of the rope, make a quickly tied fastening. To make these, pass the end around the post, ring, or another object, then over and around the standing part between the post and itself, then under and around the standing part and between its loop and the first one formed.

Fig. 13

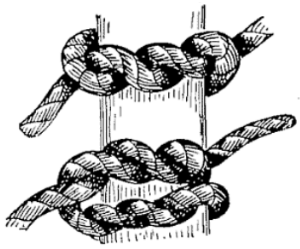


- Clove hitch *(fig. 14)*
  To make this knot, pass the end of the rope around the spar or timber, then over itself, over and around the spar, and pass the end under itself and between rope and spar, as shown in the illustration.

Fig. 14

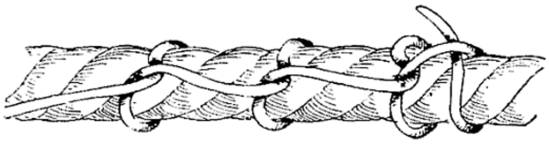
- Twist knots *(fig. 15)*
  They are not knots at all but merely twists.

Fig. 15



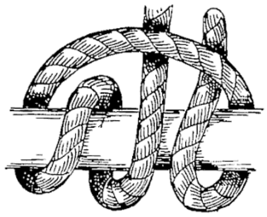
- Chain Hitch *(Fig. 16)*
  Chain hitch is a method of fastening a line to a timber, or large rope, where one has a rope of sufficient length and is used frequently to help haul in a large rope or for similar purposes.

Fig. 16



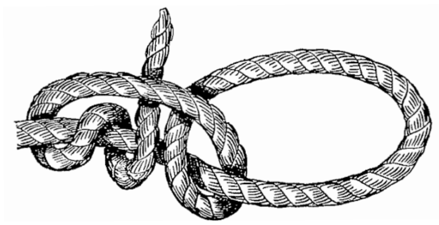
- Magnus hitch *(Fig. 17)*
  This knot is used for holding spears.

Fig. 17



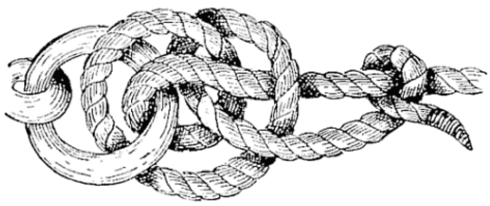
- Midshipman's hitch *(Fig. 18)*
  It is made by taking a half-hitch around the standing part and a round turn twice around above it.

Fig 18



- Fisherman's hitch *(Fig. 19)*
  It is particularly useful in making fast large hawsers; with the end of a rope take two turns around a spar or through a ring; take a half-hitch around the standing part and under all the turns; then a half-hitch around the standing part only and if desired seize the end to standing part.

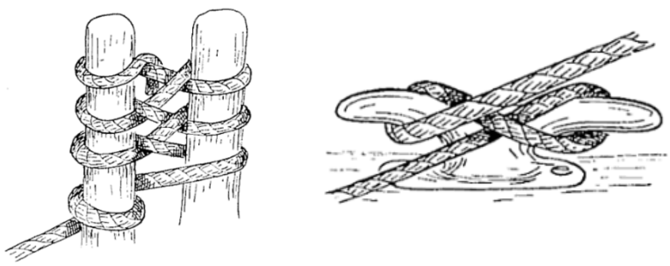
Fig. 19



5.2.3 - Loops and mooring knots

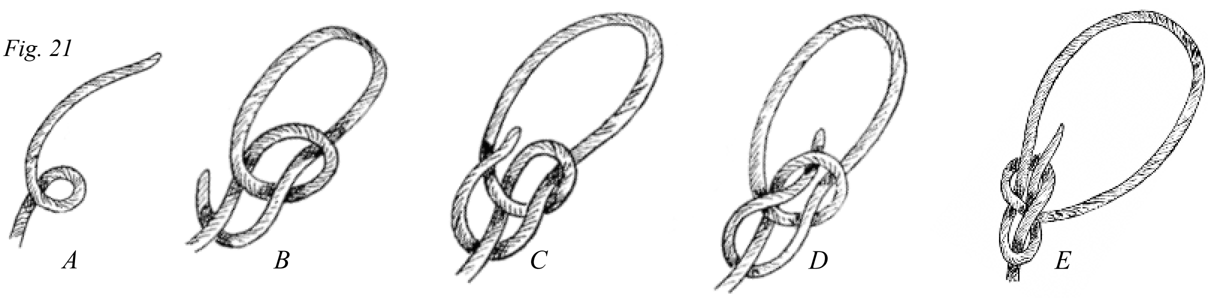
- Cleat and wharf ties *(Fig. 20)*
  It is a few turns under and over and around a cleat.

Fig. 20



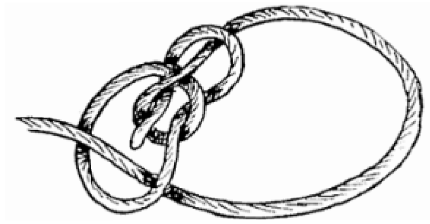
- Bow line *(Fig. 21)*
  In *A,* the rope is shown with a bight or cuckold's neck formed with the end over the standing part. Pass *A* back through the bight, under, then over, then under, as shown in *B*, then over and down through the bight, as shown in *C* and *D*, and draw taut, as in *E*.

Fig. 21



- Running Bow-line *(Fig. 22)*
  It is merely a bow-line with the end passed through the loop, thus forming a slip knot.

Fig. 22



5.2.4 - Shortenings

- Chain knot *(Fig. 23)*
  To make this shortening, make a running loop, then draw a bight of the rope through this loop, as shown at B, draw another bight through this, as at C to D, and continue in this way until the rope is shortened to the desired length; the free end should then be fastened by passing a bit of stick through the last loop, F, or by running the free end through the last loop, as at E.

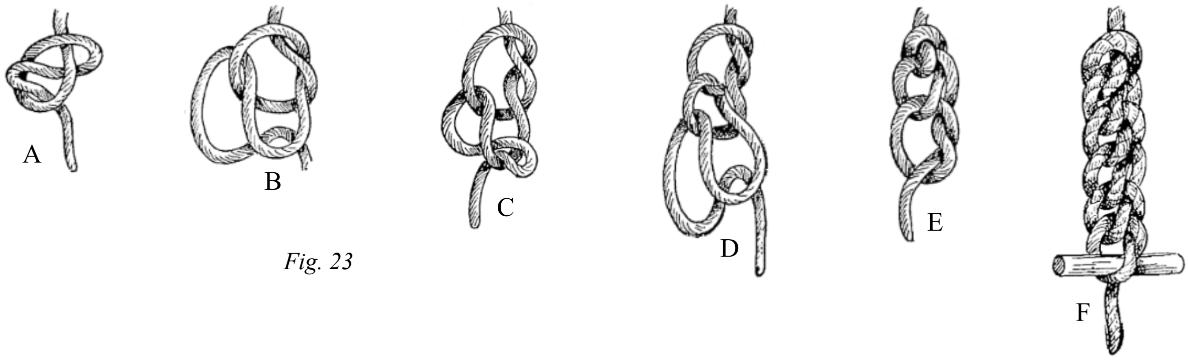
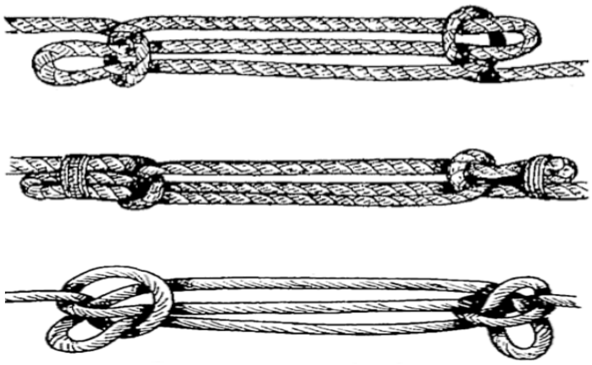


Fig. 23

- Sheepshanks (also called Dogshanks) *(Fig. 24)*
  A simple running knot is first made; a bend is pushed through the loop, which is then drawn taut; the other end of the bend is fastened in a similar manner, and the shortening is complete.

Fig. 24



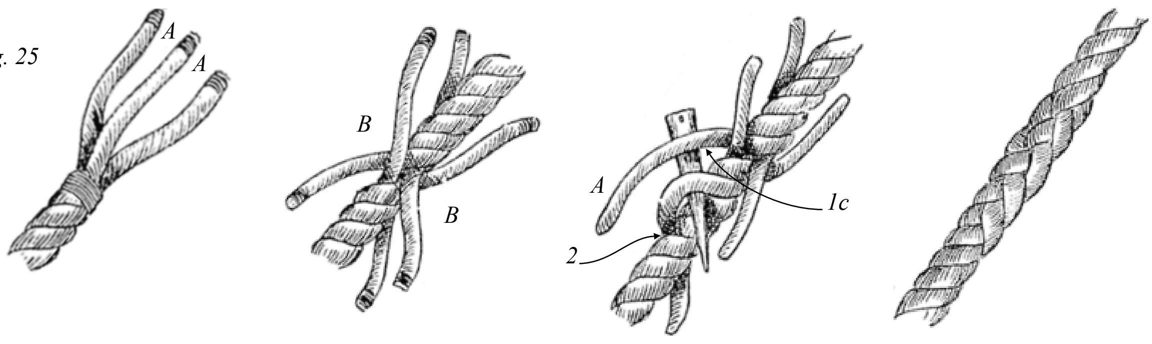
Note: The ends can be seized

Another sheepshank

5.2.5 - Splices

- Short splice *(Fig. 25)*
  Untwist the ends of the rope for a few inches and seize with twine to prevent further unwinding, as shown at A, A; also seize the end of each strand to prevent unraveling and grease or wax the strands until smooth and even. Now place the two ends of the ropes together as shown at B, B.
  Then with a marline spike or a pointed stick, work open the strand 1c, and through this, pass the strand A of the other rope; then open strand 2 and pass the next strand of the other rope through it, and then the same way with the third strand. Next, open up the strands of the other rope below the seizing, and pass the strands of the first rope through as before.

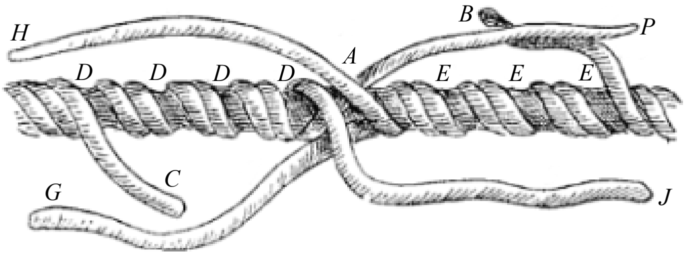
Fig. 25



- Long Splice *(Fig. 26)*

  A well-made long splice cannot be distinguished from the rope itself after a few days' use. To make this splice:
  - Unlay the ends of the rope about four times as much as for the short splice, or from four to five feet.
  - Unlay one strand in each rope for half as much again.
  - Place the middle strands together as at *A*, then the additional strands will appear as at *B* and *C*, and the spiral groove, left unlaid, will appear as at *D* and *E*.
  - Take off the two central strands, *F* and *G*, and lay them into the grooves, *D* and *E*, until they meet *B* and *C*, and be sure and keep them tightly twisted while so doing.
  - Then take strands *H* and *J*, cut out half the yarns in each, make an overhand knot in them, and tuck the ends under the next lays as in a short splice.
  - Do the same with strands *B*, *C* and, *F*, *G*; dividing, knotting, and sticking the divided strands in the same way.
  - Finally, stretch the rope tight, pull and pound and roll the splice until smooth and round, and trim off all loose ends close to the rope.

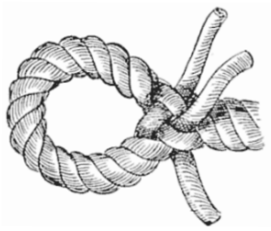
Fig. 26



- Eye Splice *(Fig. 27)*

  It is made in the same manner as the short splice, but instead of splicing the two ends together, the end of the rope is unlaid and then bent around and spliced into its strands of the standing part, as shown in the illustration.

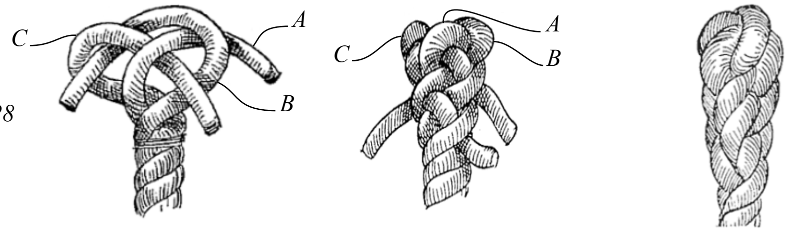
Fig. 27



- Single Crown *(Fig. 28)*

  This single crown is a basis for other more complicated knots and for ending up the rope. To form this knot:
  - Unlay the strands of a new, flexible rope for six to eight inches and whip the ends of each strand, as well as the standing part, to prevent further untwisting.
  - Hold the rope in your left hand and fold one strand over and away from you.
  - Then fold the next strand over *A*, and then, while holding these in place with thumb and finger, pass the strand *C* over strand *B*, and through the bight of *A* as shown in the illustration.
  - Now pull all ends tight and work the bights up smooth and snug. Cut off ends, and the knot is complete.
  - To end up a rope with a crown, it is merely necessary to leave the projecting ends long and then, by bringing them down, tuck them under the strands of the standing part.

Fig. 28



- Double crown *(Fig. 29)*

  Double crown knots are made exactly like the single crown or wall but instead of trimming off or tucking the ends, they are carried around a second time following the lay of the first.

Fig. 29

6 - Cargo lifting nets

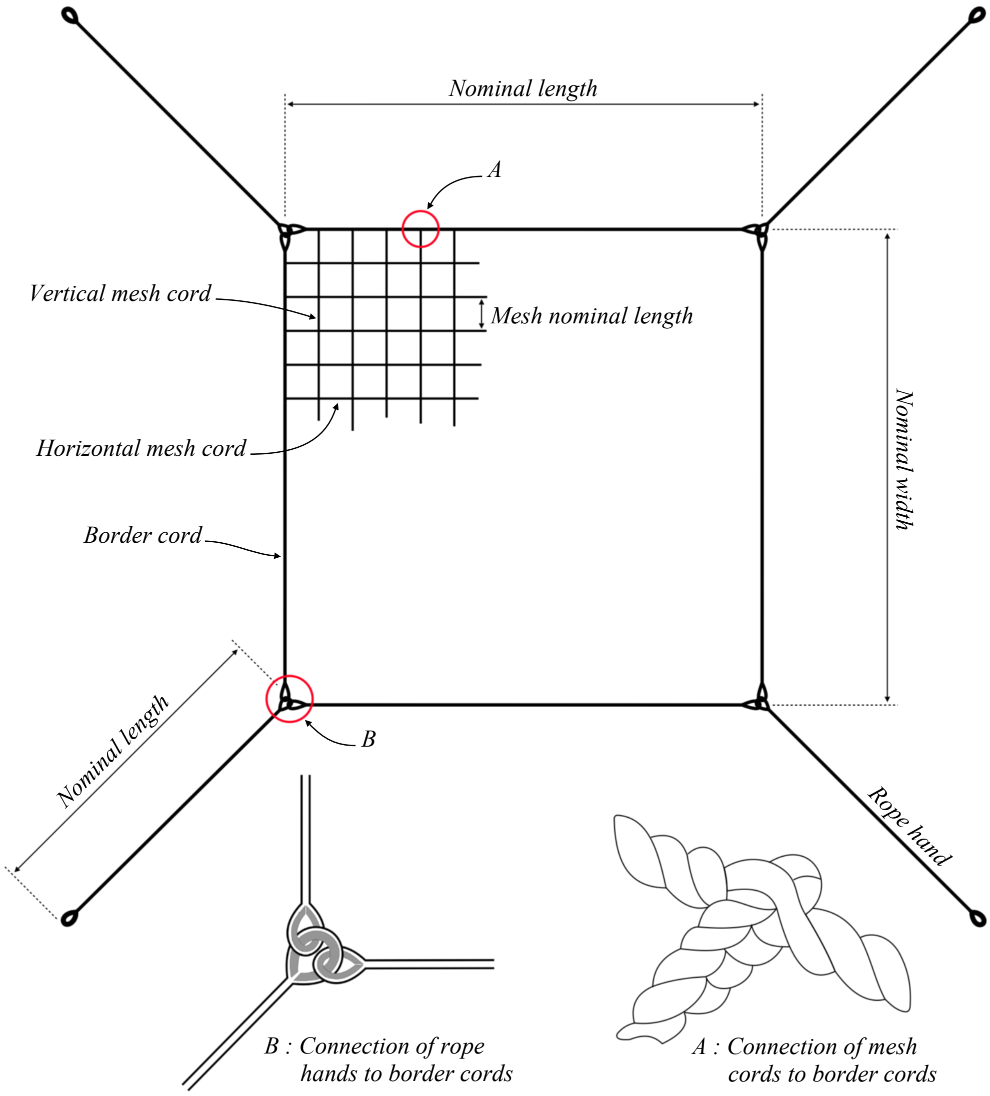
6.1 - Purpose and technical references

Cargo lifting nets are based on the principle of hauled fishing nets. They are used for a very long time to transfer small objects using only one crane movement, thus avoiding multiple transfers of loads whose volume and weights are neglectable. They are also used to lift various heavy and voluminous loads not provided with lifting points.
They can be built with flat webbing or ropes which materials are those described previously for slings and ropes. Rope cargo lifting nets remain the most employed on offshore sites. European and ISO standards currently do not provide specific norms for fabricating lifting cargo nets. For this reason, many manufacturers build them according to standards for slings manufacturing and the standard EN 1263-1, “Temporary works equipment - Safety nets”, which is not specific to lifting nets. However, the Indian Standards have published the document IS 11521, “Specification for cargo handling nets”, which prescribes the requirements of cargo handling nets made from polyamide and polypropylene ropes, and can be considered more suitable for this article.

6.2 - Description and construction requirements

Lifting cargo nets are usually square and should be composed of the following elements:

- The “mesh cords” are the ropes constituting the mesh of the net. The "mesh length", or "mesh side", is the distance between two sequential knots or joints measured from centre to centre when the cord between these joints is fully extended.
- The “border cords” are the surrounding ropes to which the “mesh cords” are fitted (see detail “A” in the scheme below). They determine the overall dimensions of the net.
- The “hand ropes” are the ropes by which the lifting cargo net is connected to the crane attached to the corners of the net , so the extremities of the “border ropes” (see detail “B” in the scheme below).
- Note: The word “Nominal” indicates that the dimensions of the net’s components are measured when they are without tension and are laid on a flat surface.

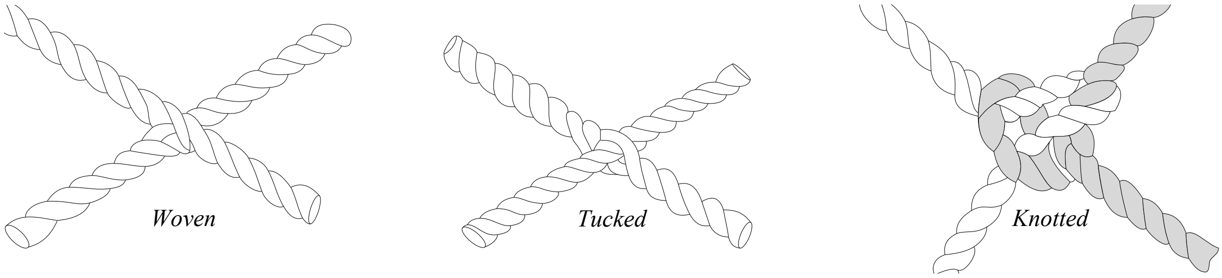


The materials for constructing cargo nets should comply with the standards used for slings and ropes construction. Regarding this point, IS 11521 recommends that cargo lifting nets are made with polyamide ropes conforming to IS 4572 or polypropylene ropes conforming to IS 5175. The minimum safety factors suggested by the Indian standards, and also recommended by OSHA, are 9:1 for polypropylene and 6:1 for polyamide.
IS 4572 says that the safe working load of the net can be calculated with the following formula:

V = Number of vertical mesh cords
H = Number of horizontal mesh cords

$$\frac{(0.67\,(V + H))\ (\text{specified breaking load of the mesh ropes})}{4\ (\text{basic safety factor of the ropes})}$$

IS 4275 recommends the cargo lifting nets be designed with equal vertical and horizontal mesh lengths that must not exceed 30 cm. The mesh ropes interconnections can be woven, tucked, or knotted (see below). Also, the border cords should have a diameter at least 33 percent greater than the mesh ropes.



IS 4572 says that the safe working load for nets manufactured using the formula and parameters above should be 50 percent of the calculated result.
Only one material should be used for manufacturing the cargo lifting net. In other words, IS 5472 says that the cargo lifting net must be manufactured in such a way that the mesh cords, border cords, and hand ropes come from one lot and one rope manufacturer only, respectively. Thus, the load elongation characteristics of all mesh cords, border cords, and hand ropes should be the same, and the stress concentration on the cords should be matched.
IS 4572 provides the table below regarding cargo lifting nets' main design and construction requirements using polyamide and polypropylene ropes. Other designs can be used at the convenience of the buyer and the seller. However, such designs and constructions must conform to the requirements above.

Nominal size of net (m)	*Nominal size of mesh (mm)*	*Nominal length of hands (m)*	*No of mesh cords*		*Diameter of rope*		*Safe working load of net woven type (kN)*
			Vertical (mm)	*Horizontal (mm)*	*Mesh cords*	*Border cords & hand ropes*	
3 x 3	*125 x 125*	*1.5*	*23*	*23*	*12*	*16*	*25.48*
3.6 x 3.6	*125 x 125*	*1.8*	*27*	*27*	*12*	*16*	*29.4*
3 x 3	*225 x 225*	*1.5*	*12*	*12*	*20*	*28*	*35.28*
3.6 x 3.6	*225 x 225*	*1.8*	*15*	*15*	*20*	*28*	*44.1*
3.6 x 3.6	*200 x 200*	*1.8*	*17*	*17*	*20*	*28*	*49.98*

Note #1: Nominal sizes and lengths have 10% tolerance
Note #2: 1 kilo newton (kN) = 101.97 kg force = 224.0 pound force
Note #3: The cargo net must be proof-loaded to 125% of its specified safe working load. As an example, the proof load of a cargo net with a safe working load of 2548 kN is 31.85 kN.

6.3 - Certification process and marking

The certification process consists of the control of the dimensions and strength of one specimen.

- The control of the dimensions consists of measuring the overall size of the net, and the size of components (meshes, border cords, hand ropes).
- Breaking strength tests of the mesh cords, border cords, and hand ropes are performed on samples of the same size and from the lots used to fabricate the net. In case of doubt, to rope manufacturer should be consulted.
- A load test of 25% in excess of the safe working load is performed using sand bags spread uniformly.
- After the load test, the net is checked for fractures or splice slippages.

A cargo lifting net should have at least two labels that give the following information on their border cords.

- The nominal size of the net;
- The nominal mesh size;
- The diameters of mesh cords, border cords, and hand ropes;
- The safe working load (written in capital letters);
- The manufacturer's name and trademark.
- The reference standards

6.4 - Inspection and maintenance

Cargo nets are liable to wear and mechanical damage and can be weakened by various chemical agents, exposure to heat, the effect of icing, and UV from the sunlight. The damages reasons and effects are the same as those detailed for ropes in the chapter "Ropes and common marine knots". Among these various damages, note that those resulting from overloading due to uncontrolled loading and crushing of ropes' fibres due to rough landings and shocks to the vessel's hulls during transfers are common.

The inspection of the cargo lifting basket should be done by examining the small sections of the net, the cordage being turned to reveal all sides before continuing.
At the same time, the cordage should, where practicable, be opened up to allow for internal examination. The elements for discarding the cargo lifting net are those of slings and ropes.

Page left blank intentionally

F - Lifting bags

Lift bags are devices made of a flexible thermoplastic envelope that can be used to lift and move objects from 25 kg to 50 tonnes underwater using the principle of Archimedes' law. They are commonly classified into two categories:

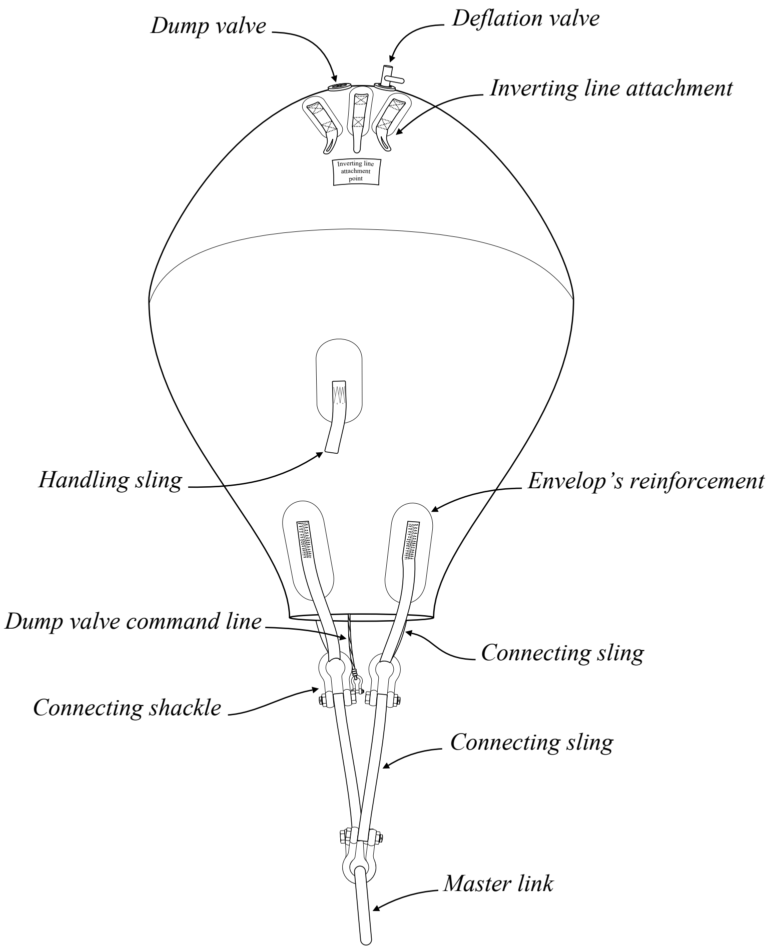
- Open ended lift bags
- Closed lift bags

Even though they are based on the same principle, open ended and closed lift bags are not designed for the same usage. Thus they are complementary tools that may be used together or separately.
There is no specific standard for lifting bags used underwater, and manufacturers do not communicate much regarding the standards they use. However, the envelopes should be tested according to ISO 37 *"Rubber, Vulcanized or Thermoplastic - Determination of tensile stress-strain properties"* and ISO 188 *"Rubber, Vulcanized or Thermoplastic - Accelerated ageing and heat resistance tests"*, or a similar standard.
Note that a category of closed lift bags is designed to be filled with water and is used to lift various vehicles. However, these devices are to be classified as jacks and are not discussed in this handbook.

1 - Open ended lift bags

1.1 - General description

Open lift bags, also known as parachutes, are similar in shape to hot air balloons and use the same physical principle to lift objects underwater. As their bottom is open, the air in excess can escape through it, which guarantees that they cannot be filled with more air than the volume they are designed for.



As suggested, the thermoplastic envelopes they are made with are usually assembled by heat. Reinforcements are added at the points submitted to intensive efforts. Also, they are provided with the following elements:

1. A dump valve must be provided to protect the lift bag envelope when the lift bag has excess air. It must be designed to open automatically and to be triggered manually by the diver. It should be designed according to EN ISO 4126-1 standard or a similar one. It is usually designed to open at a minimum pressure slightly above but not less than 0.1 bar and must be adequately sized to allow a sufficient flow.
   It consists of a valve maintained closed by a spring that gradually opens if the internal pressure exceeds the closing pressure it provides. A command line allows the diver to open it fully. This command line must be sufficiently long to be near the diver and slightly weighted to avoid getting tangled or being kept inside the lift bag. Note that the automatic and manual valves can be separated.

2. A deflation valve must be provided to allow for a complete deflation of the lift bag. It consists of a quarter-turn valve adequately dimensioned. It should be kept open when the lift bag is returned to the surface to avoid having air trapped in it that may expand during the ascent. Some also use this valve to inflate the lift bag.
3. One or several attachment points should be provided at the top of the lift bag to connect the inverting line. The inverting line is, in turn, connected to the piece to be lifted. The function of the inverting line is to maintain the lift bag attached by its top so that it will immediately turn upside down and fully deflate if the lift rigging fails so that it prevents the lift bag from ascending uncontrolled. Note that this line must be strong enough to withstand the force resulting from the volume of the lift bag + the acceleration. Thus, it is wise to over-size the inverting line. This line must be calculated as short as possible. However, it must not conflict with the full deployment of the lift bag. When several connecting points are provided, they must be all connected to the inverting line, so that if one fails, the others will keep the lift bag attached.
4. One or several handling points may be provided on the side of big units. They often consist of a short buckled sling and must not be used for other functions than handling the lift bag.
5. The connecting rigging is usually composed of textiles slings that conform to the requirements indicated in chapter “E”, in addition to shackles, and sometimes a master link that conforms to the requirements indicated in chapter “C”. The connecting points of the slings are embedded in the envelope. Their number and organization depend on the size of the lift bag and the design selected by the manufacturer. For example, they can be connected two by two in shackles that bind to other connecting slings that group in a master link or be directly connected to the master link or a shackle used for this purpose. Type X pin shackles should be used for such applications. Note that some manufacturers use the connecting slings to reinforce the lift bag’s envelope. In this case, their number is multiplied by at least 2, so they can be vented around the envelope without too much space in between and are assembled to a crown at the top of it.

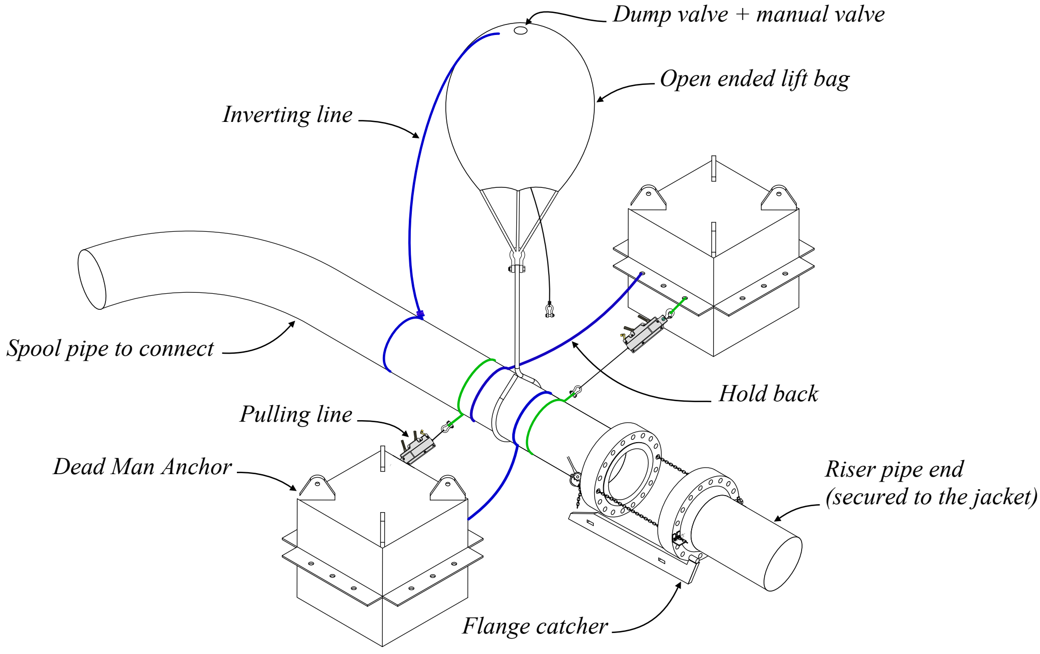
1.2 - Main use

Open lift bags can be used for various applications, such as lightening heavy objects, lifting loads, transferring objects, re-floating objects and boats, and being static rigging support. Thus, these tools allow for an infinity of procedures.

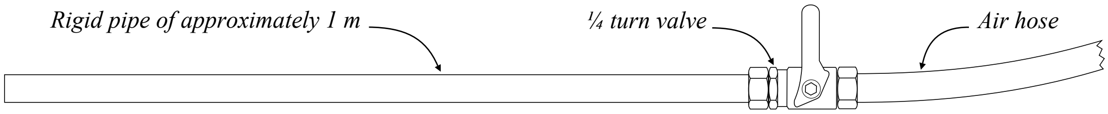
1.2.1 - Lighten heavy objects

These methods consist of lightening part or all of an object to be able to move it with a reduced traction force. Such a procedure is, for example, commonly used when connecting spools' flanges using flange catchers and lever chain hoists. In this case, having the spool with a nearly neutral buoyancy is advantageous as it allows the diver to slide it over flange catchers with reduced effort. Nevertheless, as the connecting flange must rest on the flange catchers, the procedure consists of lightening the spool but avoiding creating an object with a positive buoyancy.
Several precautions must be in place when implementing such procedures, as there is the risk of having the extremity or the totality of the piece coming up to the surface if they are badly organized:

- The number of lift bags involved should be calculated to limit the risk of an uncontrolled ascent and avoid unbalancing the piece.
- Sufficiently heavy Dead Man Anchors should be provided to secure the piece against uncontrolled ascent.
- Hold back lines, dimensioned to withstand a sudden ascent of the piece that may result from loss of control of the lift bag, should be connected to the Dead Man Anchors. When pulling lines with portable winches are used to adjust the load, they must not be used as hold back lines as the winches are not designed for that.
- The inverting line should be connected to the piece, and the dump line should be positioned near the diver.

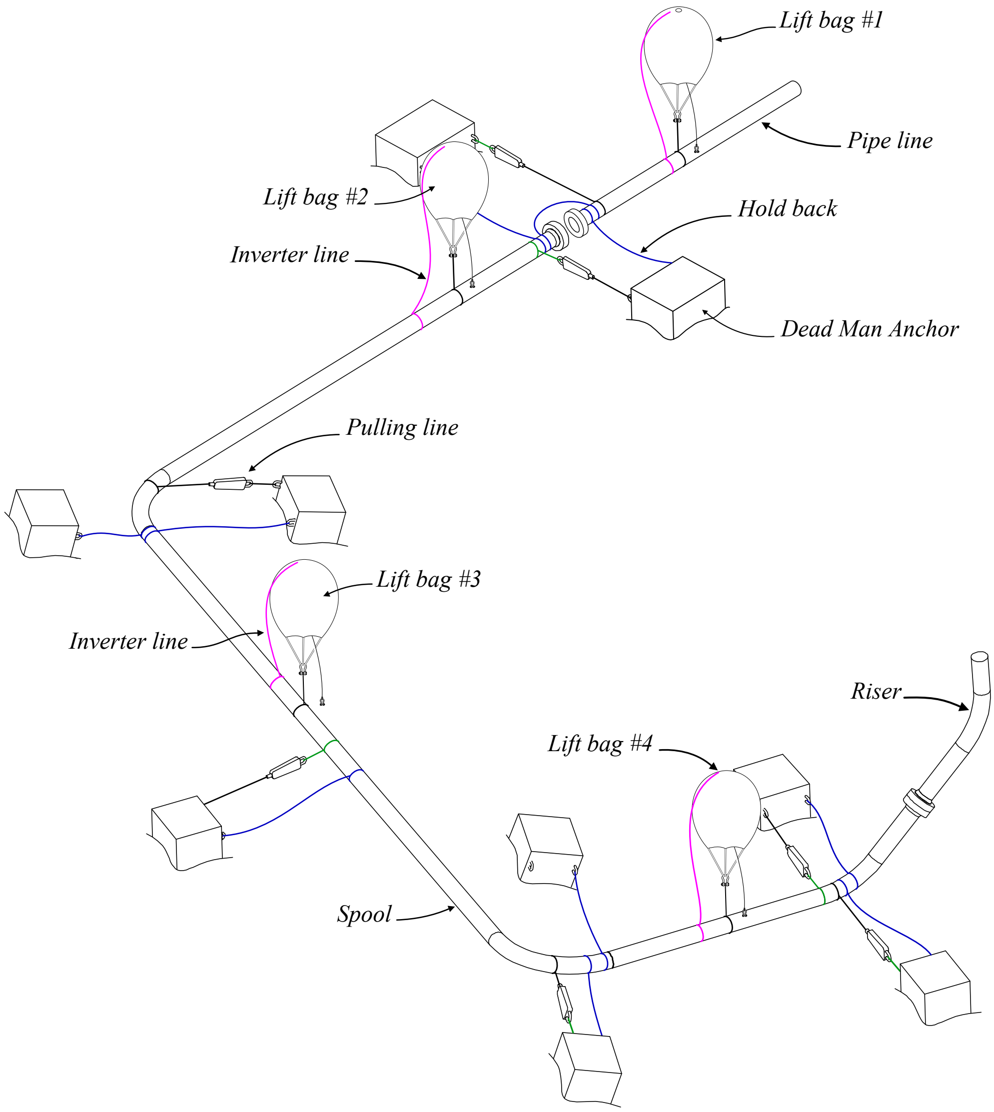


Inflating lift bags must be done progressively, starting by deploying them with a limited quantity of air so that they do not provide significant traction. This allows the diver to verify whether the safety elements mentioned previously are in place and whether the dump valve is not leaking. A specific air supply line ended by a ball valve and an approximately 1 m rigid pipe section is commonly used for this purpose and deployed from the surface *(see the drawing below)*. The rigid section is inserted through the open end of the lift bag to inflate it. Important point: As long as the lift bag is inflated, the diver and his umbilical must never be over or below it.



The quarter turn deflation valve can sometimes be used, notably when several lift bags are inflated simultaneously. In this case, a supply hose will be connected to each lift bag, and a manifold will be used to distribute the air evenly.
The safety elements must be periodically controlled during the inflation process. The reasons are that the inverting line and the hold back line may conflict with the deployment of the envelope and that valves may suddenly leak. Remember that leaking valves will result in an unstable load, thus, a load impossible to control and install.

- When this procedure involves assembling long spools or other voluminous pieces with complex shapes, several lift bags may have to be suitably installed to, as mentioned before, avoid unbalancing. Such calculations are sometimes complex and may require engineering support. Also, the inflation procedure must be organized to maintain the piece horizontal and under control. It generally consists of gradually inflating the lifting bags in short controlled sequences distributed over all of the lifting bags. It is more adequate to terminate the inflation sequences by the area where the divers operate, so by the lift bags #1 & #2 in the scheme below. It must be noted that in addition to creating unbalancing, fully inflating lift bags at one time may result in an uncontrolled ascent and is, thus, to be banished. Note that small lift bags are usually easier to control than big ones. Thus, it is often advantageous to use several small lift bags rather than only a few large units.



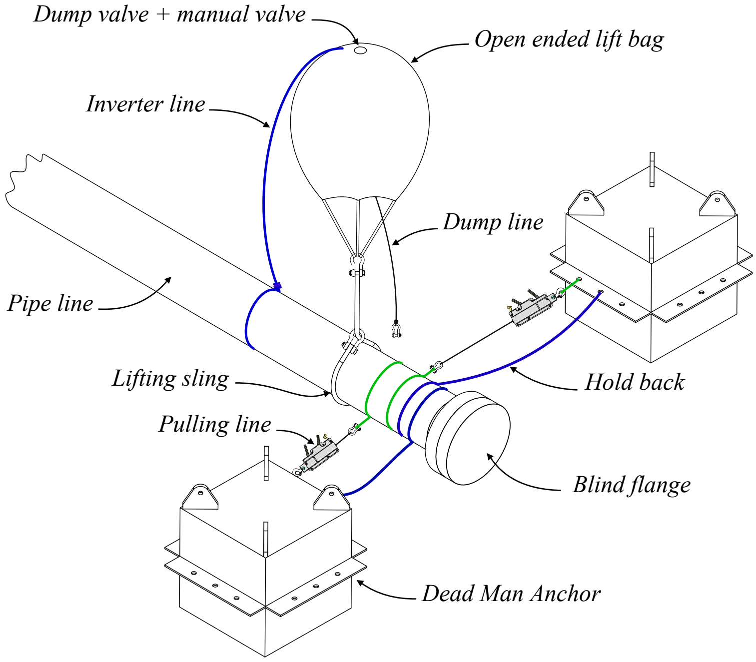
- Deflating the lift bags should start progressively to allow for the piece to sit smoothly on the seabed or in the structure it is installed. When the diver is sure that the piece rests on the seabed or in the structure he can fully deflate the lift bags by opening the ¼ turn deflation valve. The rigging must be removed as long as the lift bag is not fully deflated. The reason is that residual air pockets may be present and result in an uncontrolled ascent. When the lift bag is fully deflated, so laid on the floor, and easy to handle, the diver can remove the lifting slings from the object and then the hold back line. The inverting line should be removed last. Two solutions can be used for recovering the parachute to the surface:

- The diver can fold it and store it in the tools' basket. In this case, he must ensure that no air is trapped within the folds to avoid having small air pockets expand during the ascent. He can use the inverting line to pack it firmly.
- The diver can connect the connecting point of the inverting line to the crane or another lifting device to return it to the surface unfolded. In this case, he ensures that the deflation valve is secured open. The handling points must not be used for this purpose as the lift bag must always have the deflation valve oriented to the top, and the connecting point of the inverting line can easily withstand traction to the surface, which may not be the case for the handling points.

1.2.2 - Lift objects to adjust them

These procedures are a variation of the previous. The difference is that the object, or a part of it, is lifted with the lift bag under control before making it neutral when in position. It is, for example, a common practice for levelling pipeline extremities prior to installing a spool piece.

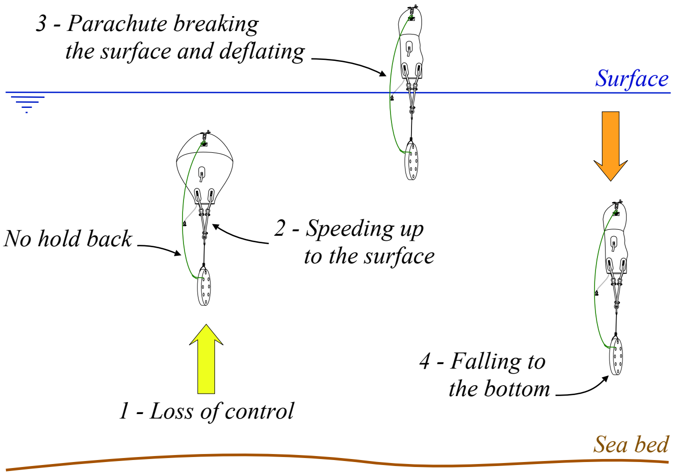
- The rigging and procedure are the same, except for the short period the parachute lifts the object. For this reason, the diver must pre-adjust the hold back and the pulling lines accordingly. In the example below, grout bags or other supports must be ready to be inserted under the pipe.
- It is essential to install sufficient Dead Man Anchors or use existing static points to ensure that the diver does not lose control of the object during the operation. Note that engineering calculations may have to be done when the lift involves several lifting bags.
- When the piece is adjusted, the lift bag is deflated and removed as indicated in the previous point.



1.2.3 - Move objects

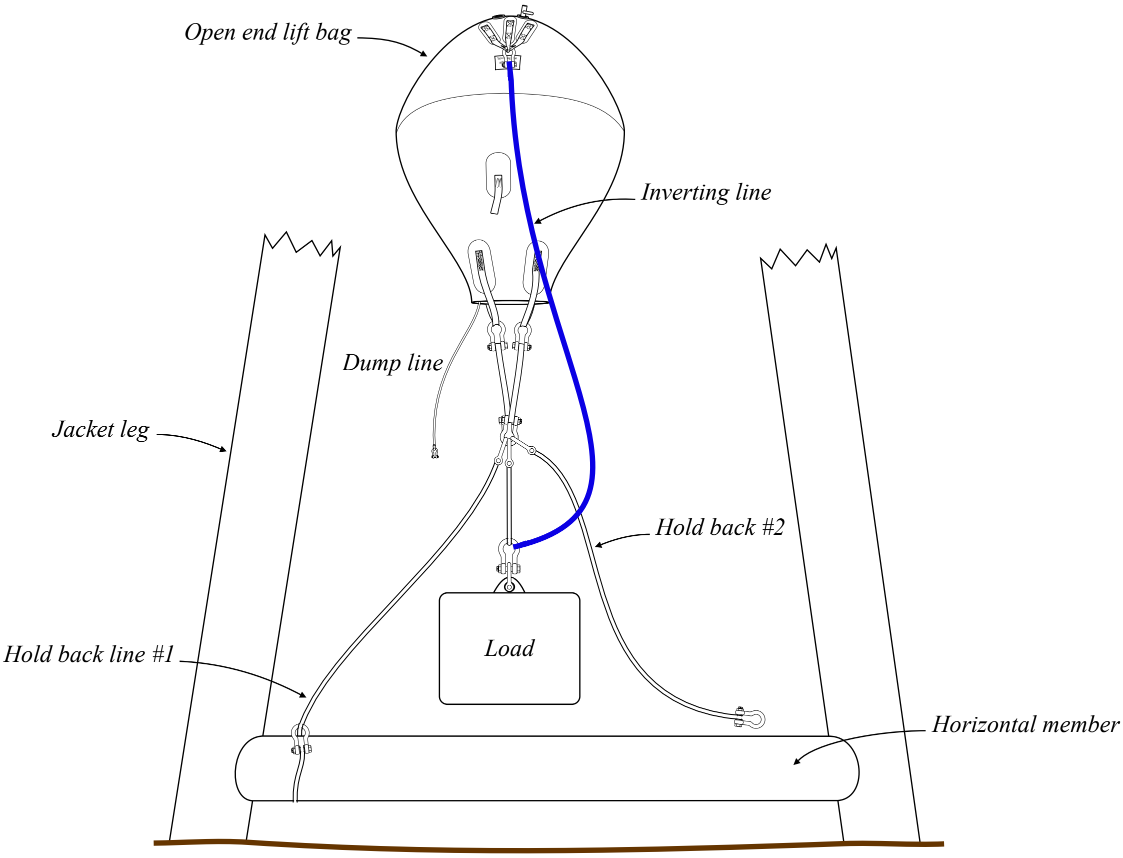
These procedures are deviations from the previous ones to move an object from one point to another. That can be done on short and long distances.

In the early times of the diving industry, it was common to do it without using hold back lines, so only by controlling the object's buoyancy.
Diving organizations have banished such procedures that gave rise to numerous accidents, as in case of loss of control, the absence of hold backs resulted in the parachute and its load ascending to the surface at a speed sufficient to break the surface, which had the effect of deflating the lift bag and having the burden falling to the diver. There was also the risk of dragging the diver with the load to the surface, resulting in all accidents from an uncontrolled ascent, such as pneumothorax, decompression accident, etc.
Another problem was, of course the underwater current pushing away the lift bag and its load.

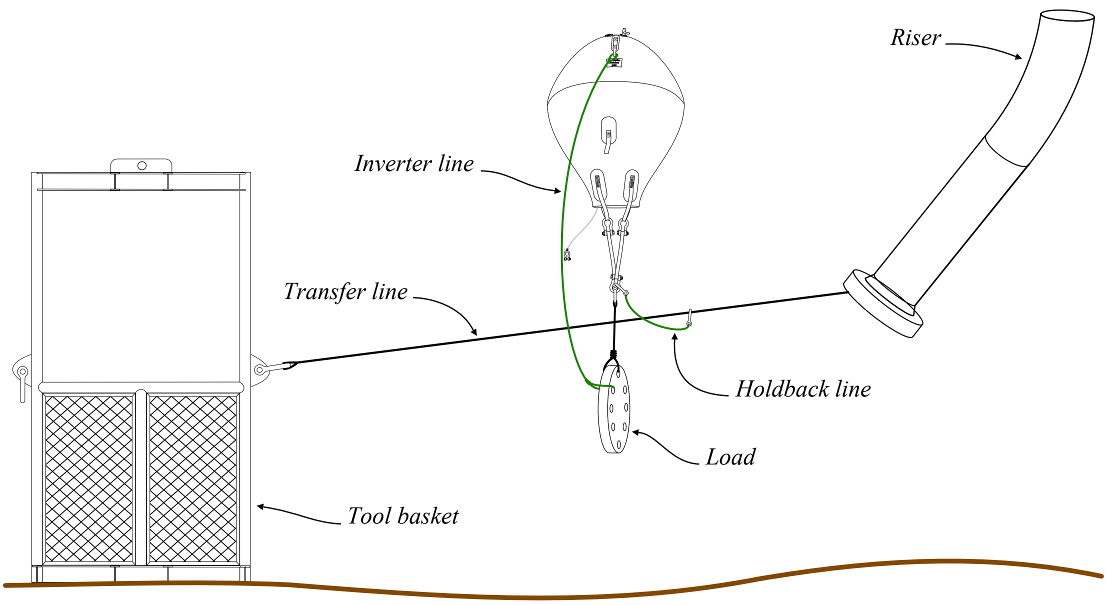


For the above reasons, hold back and inverting lines must be in place when displacing a load horizontally. The procedure for inflating, deflating, and removing the rigging are those previously described. However, the following precautions must be implemented.

- The distance of the hold back must be calculated to minimize the ascent to a few metres in case of loss of control, and it must be connected to a sufficiently heavy and solid point to secure the load and the lift bag. Two procedures can be used when a certain distance is to be done at depth:
  - It is acceptable to use two hold back lines. In this case, the load is moved a few meters. Then, the lift bag is partially deflated to land the load, the 2nd hold back is connected to the next holding point when the object to transfer is landed, the 1st hold back is disconnected, and the progression can continue. Of course, the lift bag must never be left partially inflated without a hold back connected. This procedure is commonly used when the load is transferred a few metres. However, it may be long to implement over long distances.



  - Another procedure involves establishing a transfer line to which a running shackle connects the holdback. This procedure is often used to transfer objects from a tools' basket to the job site. In this case, the hold back is reduced to a minimum, and the transfer line must be tensioned to limit the ascent in case of loss of control and allows the running shackle to slide easily. Note that the two points between which the transfer line is installed must be static. Thus, using this procedure in mid-water from a basket deployed from a vessel is unacceptable. The reason is that vessel movements, even anchored, are unpredictable and may result in the transfer line breaking or exaggeratedly slacking.

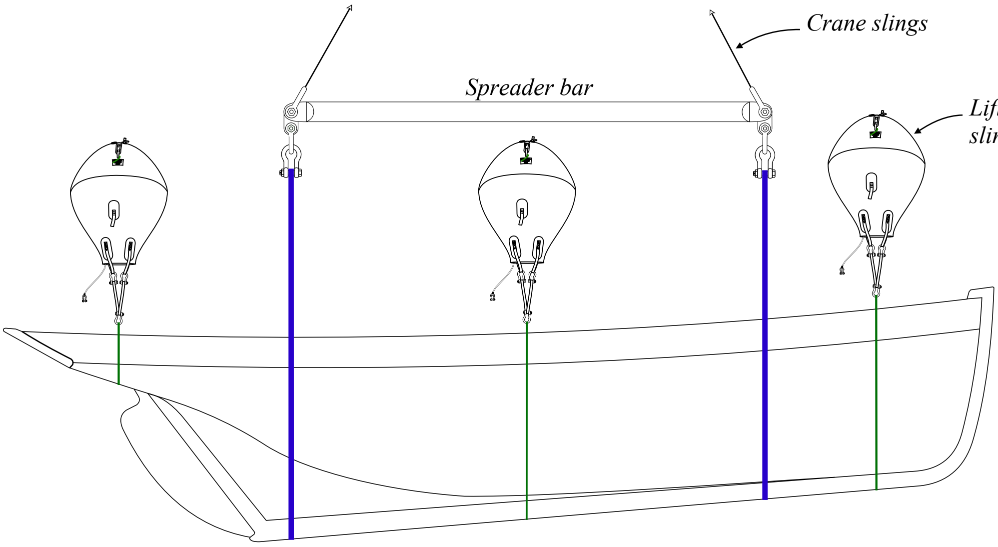


- When transferring objects to inside a structure, it is essential to ensure that the load and the parachute have sufficient room to enter it. It is also necessary to ensure that the envelope of the lift bag will not be damaged by sharp objects.
- The diver must ensure its lines are not tangled or jammed when inflating and moving the lifting bag. He must also ensure that he is never above the lifting bag and below the load: Being above exposes him to a sudden ascent or a reversal of parachute and being below exposes him to a sudden drop of the load.

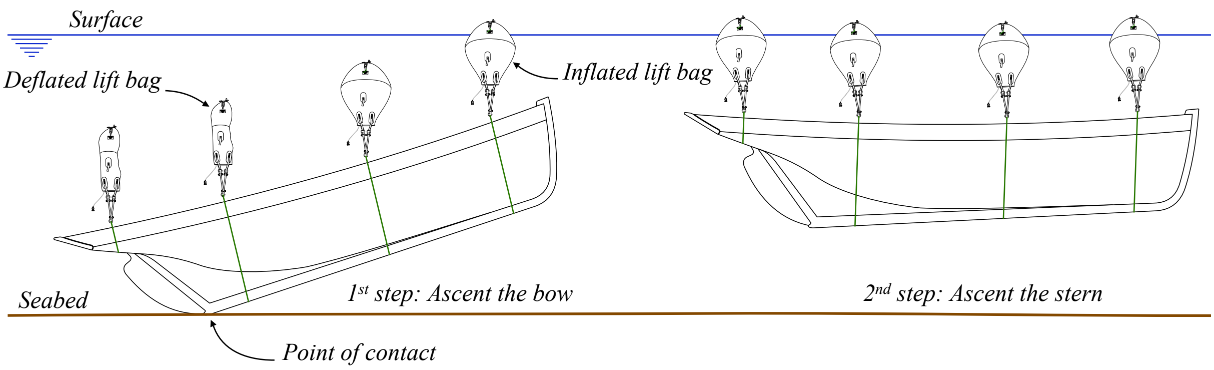
1.2.4 - Re-floating objects and boats and towing them

Re-floating objects consist of sending back to surface sunk objects and boats. Such procedures are often complex, requiring engineering studies and well-trained personnel.
Sending objects to the surface using lift bags must be done with caution for the reasons explained in the previous point: Ascending an object without control will result in it speeding up, the lift bags breaking the surface and deflating, and the object sinking again. Note that the US Navy salvage manual confirms this point. If, by chance, the object does not drop after breaking the surface, consider that its erratic ascent makes it challenging to predict where it will break the surface and whether the surface support of the salvors is safe. Two known methods are commonly implemented to avoid incidents using open-end lift bags. However, many derivations can be applied:

- The 1st method consists of using lift bags to lighten the object and ascent it to the surface using a crane or, depending on the object's size or the wreck, a heavy lift barge. When re floating a vessel, the parachutes must be rigged in pairs on opposite sides with a single line. Such a procedure does not create more safety problems than previously described for installation procedures, as the upthrust provided by the lift bags is insufficient to bring the object to the surface. Additional lift bags may be inflated when the object arrives at the surface, and whether it is transferred to the vessel's deck, a pontoon, or towed toward the shore depends on its size. The process of inflation is similar to those described previously and the rigging must be the same.



- The 2nd method consists of using lift bags to ascend the wreck to the surface without a crane's help. It requires more experience and precautions and can only be used for shallow wrecks. The method consists of gradually sending one end of the wreck to the surface with a maximum angle of 20°, so the part resting on the bottom is used as a pivot point, stabilizing the ascent. The 2nd part is raised to the surface when the 1st part is secured and stabilized between pontoons or with other means. This procedure is also described in the US Navy salvage manual with closed lift bags. It usually requires using dedicated hoses and a gas distribution manifold.



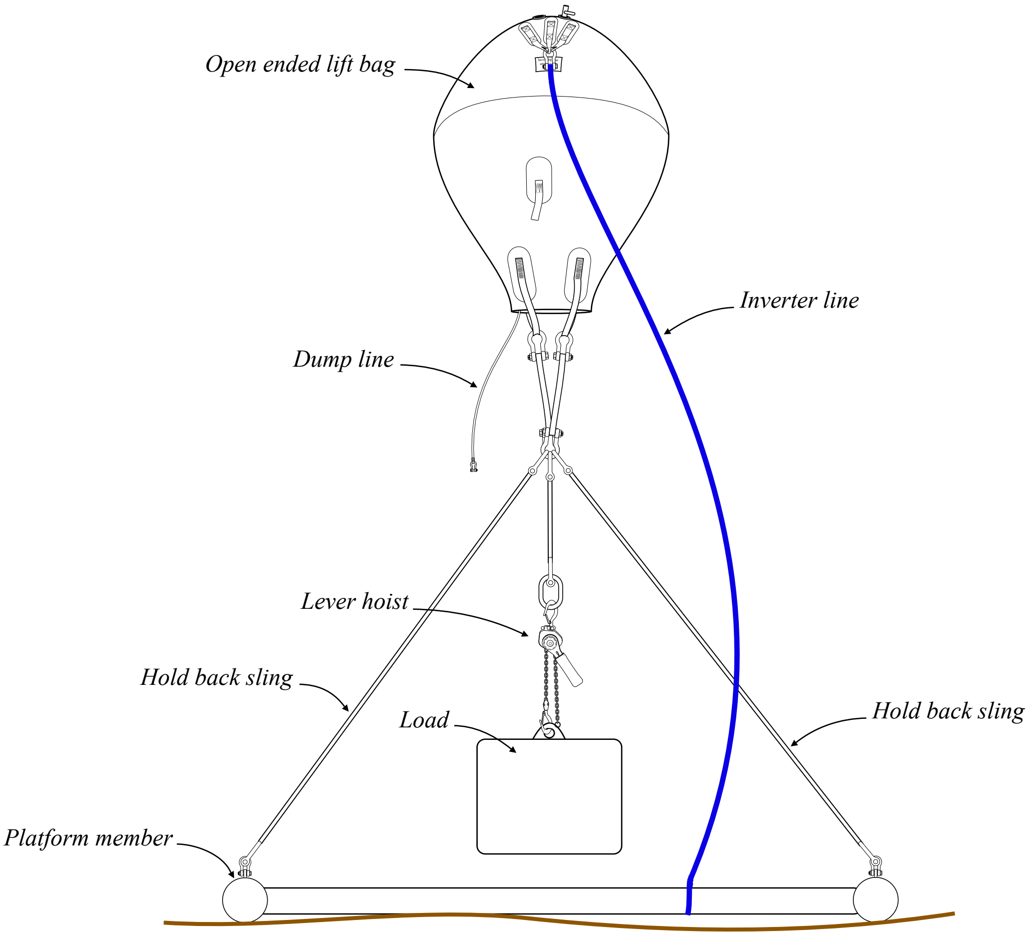
- A derivation of the procedure above is to install a part of the lift bags closer to the surface. Then move the wreck to a shallower bottom to beach it and redo the operation described above.
- Another procedure is also to deploy a part of the lifting bags on the surface when the tide is low and wait for the high tide, which will slowly lift the wreck. The wreck is then moved to a shallower bottom and beached again. Then the lifting bags are adjusted again at low tide to repeat the same process until the wreckage is close enough to the surface to retrieve it directly. It must be noted that this process can be done with open-end lifting bags but

- is more often practiced with pontoons or closed bags to recover large wrecks.

Lift bags are often used to maintain an object or a wreck at the surface and tow it. It must be taken into account that, opposite to the belief of many teams, the US Navy says that parachute-type bags are preferable for a tow because they are more stable than enclosed-type bags that distort under tow.

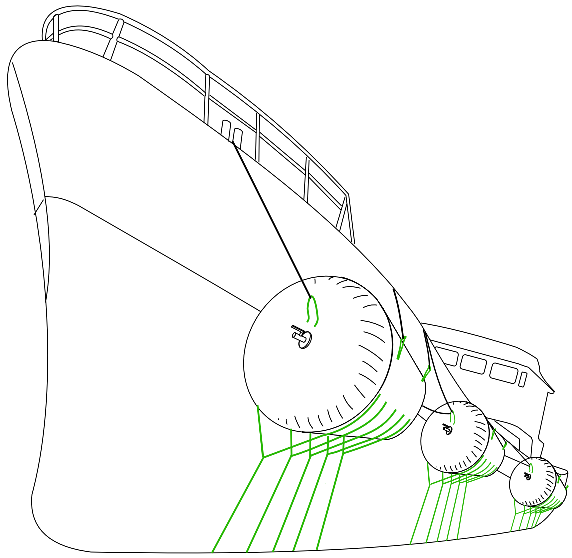
1.2.6 - Static rigging support

This procedure consists of using a fully inflated lift bag to rig a lever or chain hoist and using these devices to adjust an object. It can be employed in the absence of hanging points. With this procedure, the slings securing the lift bag are used as hold back lines. They must be connected on solid points that can resist the lift bag's upthrust, such as the structure's members or similar. The inverting line should also be secured to one of these points. The procedure for inflating and deflating the lift bag is the one previously described.



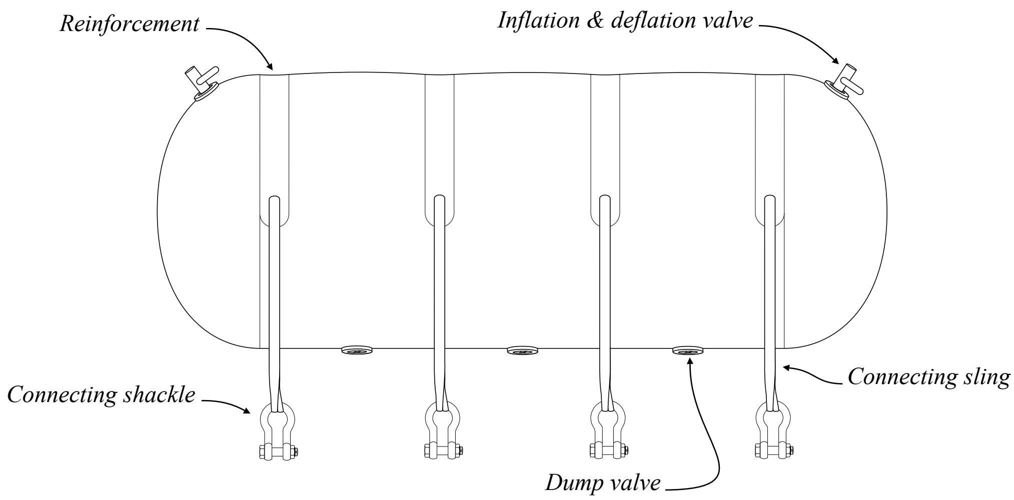
2 - Closed lift bags

2.1 - General description



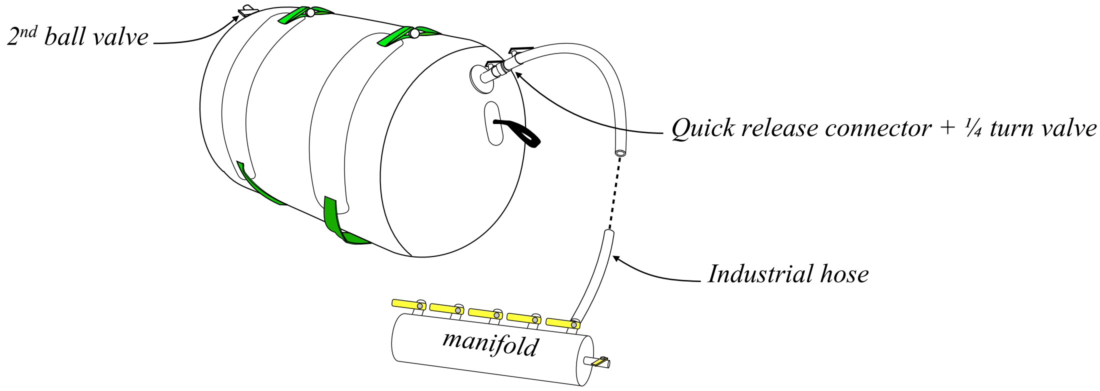
Closed lift bags can be used for buoyancy support and ship salvage operations.
They are an effective alternative to parachute-type lift bags in situations where an insufficient depth of water precludes the deployment of such lifting bags above the object to be raised. In such cases, closed lift bags can be secured close to the load or shackled to straps passed underneath it to reduce its draught when manoeuvring it in limited depth.
Closed air lift bags prevent air loss when the assembly is at the surface. It is why they are used to move objects at the surface or hang them. Nevertheless, as indicated before, the US Navy salvage manual says that closed-type bags distort during towing and that parachute-type bags are preferable for such operations.

The most common shape of closed lift bags is cylindrical. Nevertheless depending on their function, other shapes such as balloon, pillow, or water drop are proposed.
Their lifting capacities vary from 50 kg to 50 tonnes and over.



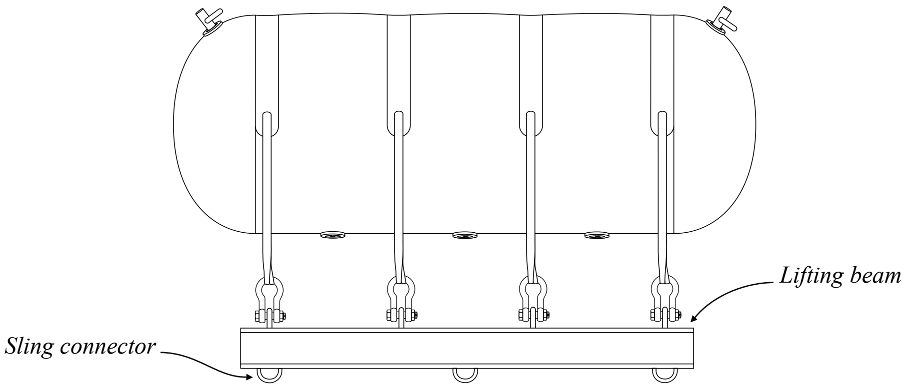
As the open end lift bags, they are made of thermoplastic envelopes that are usually assembled by heat. Reinforcements are added in the most solicited parts. They are also fitted with the following elements:

- An inflation/deflation valve must be provided at each end of the lift bag. Like open end lift bags, they consist of quarter-turn valves adequately dimensioned. They are designed to be connected to industrial air hoses and can be used to inflate or deflate the lift bag using an appropriate manifold.
  The inflation can be controlled by the diver or better from the surface. A lot of enclosed lift bag have a 2nd ball valve that can be used to control the deflation. If connected to a hose that conforms to the hose described previously this 2nd ball valve can allow controlling the deflation from the surface. Note that such arrangement must be studied by engineers and risk accessed.



- Dump valves must be provided to protect the envelope when the lift bag has excess air. They must be designed to open automatically. Like those used with open end lift bags, they should be designed according to EN ISO 4126-1 standard or a similar one and intended to open at a minimum pressure slightly above but not less than 0.1 bar. They consist of a valve maintained closed by a spring that gradually opens if the internal pressure exceeds the closing pressure it provides. These elements are critical for such models of lift bags as there is no open end to allow air to escape during the ascent. For this reason, they must be adequately sized to allow for a sufficient flow in an emergency, taking into account that one of them may be out of order. It must be considered that insufficient dump valves may result in the envelope exploding. These valves are more commonly installed at the bottom of the bag because this positioning allows for expelling water that may have entered it.

- Handling points are usually provided at the extremities and sometimes the sides. They are not designed to hold a load. However, some manufacturers reinforce them so they can be used to secure the lift bag horizontally. Whether this option is available or not should be asked to the manufacturer if it is not notified in the attached documentation.
- Like parachutes, the connecting rigging is usually composed of textiles slings that conform to the requirements indicated in chapter "E", in addition to shackles, and sometimes a master link that conforms to the requirements indicated in chapter "C". The slings are usually wrapped around the top of the envelope and embedded into protections, so they are always kept in position. They fall vertically at the 90º and 270º of the envelope, considering 0º at its top. Their number and organization depend on the size of the lift bag and the design selected by the manufacturer. Type X pin shackles should be used for connecting it to the lifting slings.
- It is a standard procedure to use a specific lifting beam when the closed lift bag is used for lifting a single load. When such a tool is used, all the shackles from the closed lift bag are to be connected to the bar so the force from the lift bag is distributed evenly. Aluminium lifting beams are sometimes used and are preferable, as they have the advantage of being lighter than steel ones.

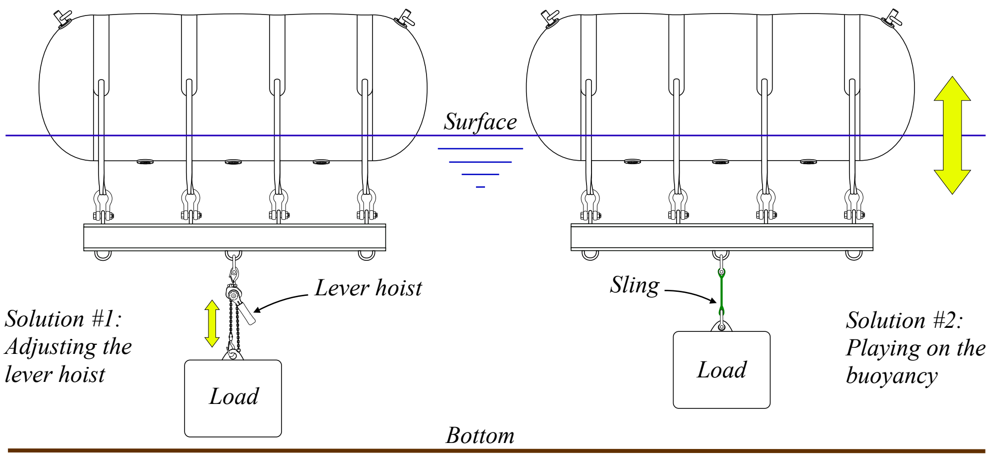


2.2 - Common practices

As the general description says, closed bags are often used to lift and move objects close to the surface and refloat objects and vessels.

2.2.1 - Moving object close to the surface

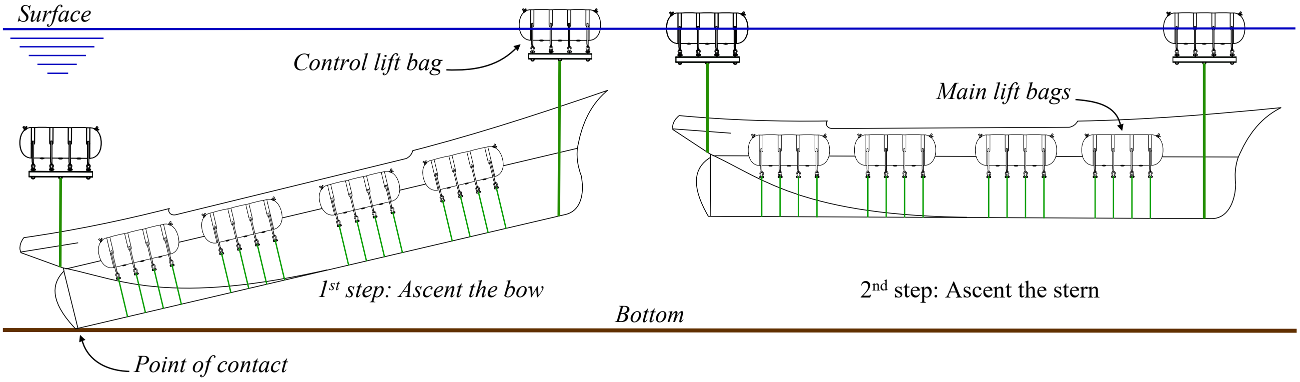
These procedures are to be used in calm waters only. It consists in lifting or lowering an object using a chain hoist or a lever hoist connected to a closed lift bag, or raising an object playing on the buoyancy of the lift bag, so deflating and inflating it. Such a procedure allows, for example, to transfer objects to or from the middle of a pond or a dock with only a crane on the jetty.



2.2.2 - Re-floating large objects of wrecked vessels

Some organization do not recommend using closed lift bags to recover large object and wrecks to the surface. Such procedures are, however use by many salvors to recover shallow wrecks. It is a similar procedure as the method that consists of gradually sending one end of the wreck to the surface with a maximum angle of 20°, so the part resting on the bottom is used as a pivot point, stabilizing the ascent. The 2nd part is raised to the surface when the 1st part is secured and stabilized between pontoons or with other means.

The wreck is then moved to a shallower bottom where it is beached. The control lift bags are readjusted and the same process as before is started again until the main lift bags arrive to the surface.



The following recommendations should be considered:

- The lift bags should not be prepared in areas where they are likely to foul, snag, or tear on sharp objects, pier pilings, or damaged or torn plating. Also, it is recommended to minimise the elements to install in the water.
-
- Because they are fully closed, there is no inverter line on such lift bags. Thus, they are secured by their lifting slings and the attachment points that should all be connected.
- US Navy says these lift bags should not be rigged into enclosed, flooded spaces except when no choice exists. Also, they should be secured to remain horizontal. If they deviate from the flat, air will migrate to one end, causing deformation and loss of efficiency. As previously mentioned, long units should be rigged with a lifting beam to distribute the load evenly.
- The ascent rate should be closely monitored and slow. It is the reason the “control lift bags” should be installed close to the surface. It is preferable to add one stop or two instead of taking the risk of an uncontrolled ascent, which may result in the same problems as described with open lift bags if breaking the surface, resulting in the wreck sinking again.

3 - About suction and maintenance

3.1 - About suction

Some sea beds create a suction that varies with the soil characteristics and the time the object has rested on the bottom. That increases the force required to lift the load, as the total lifting force includes the underwater weight of the object plus the weight of the seabed material being lifted.
These forces are complex to calculate accurately due to many variables and unknowns. Also, if a sufficient pulling force is applied to break the suction force + the weight of the object, the load may rise suddenly and become out of control. For this reason, it is not a wise idea to apply such force, particularly with lift bags, and several precautions have to be implemented to prevent such an incident from happening.
Whatever the project, a study of the seabed should be undertaken to ensure its nature and whether it is stiff enough or likely to create a suction. From this study, precautions will have to be undertaken if necessary. However, the rule is never to use additional lift bags to break the suction.

- If the soil can create suction and a piece is to be installed, it may be judicious to create rest points to store the piece to install. These rest points can be sand or grout bags, trestles with large skids, etc.
- If the project involves recovering an object or a wreck from a seabed that creates a suction, excavation may have to be undertaken using water jets or air blown to reduce this suction to a minimum or eliminate it.

3.2 - Maintenance

Lifting bags do not involve mechanical parts except their valves. For this reason, the cause of a problem can come from a damaged valve or envelope. As a result, the maintenance also focuses on these two elements:

- The area where the lift bag is handled must be clear of objects that might cause damage.
- The lift bag must be washed with fresh water when it is back on deck. Also, manufacturers recommend cleaning them with warm soapy water after each use. They should then be rinsed and dried.
- Before storing them, they should be closely inspected for cuts, damaged connection points, damaged slings, or damaged valves.
- Manufacturers recommend storing them flat and deflated in a room protected from extreme weather conditions, aggressive vapours, and rodents at a storage temperature between -5 ° C and +20 ° C and a degree of hygrometry between 40 and 70%. They also should be protected from sunlight or intense artificial light.
- Lift bags should be visually examined every six months and load tested yearly. Regarding this point, IMCA D 18 says that the load test can be replaced by a detailed visual inspection of the canopy, lifting accessories, structure, and the canopy's inflation test.

Page left blank intentionally

Part #2 - Organize Diving and ROV lifting operations

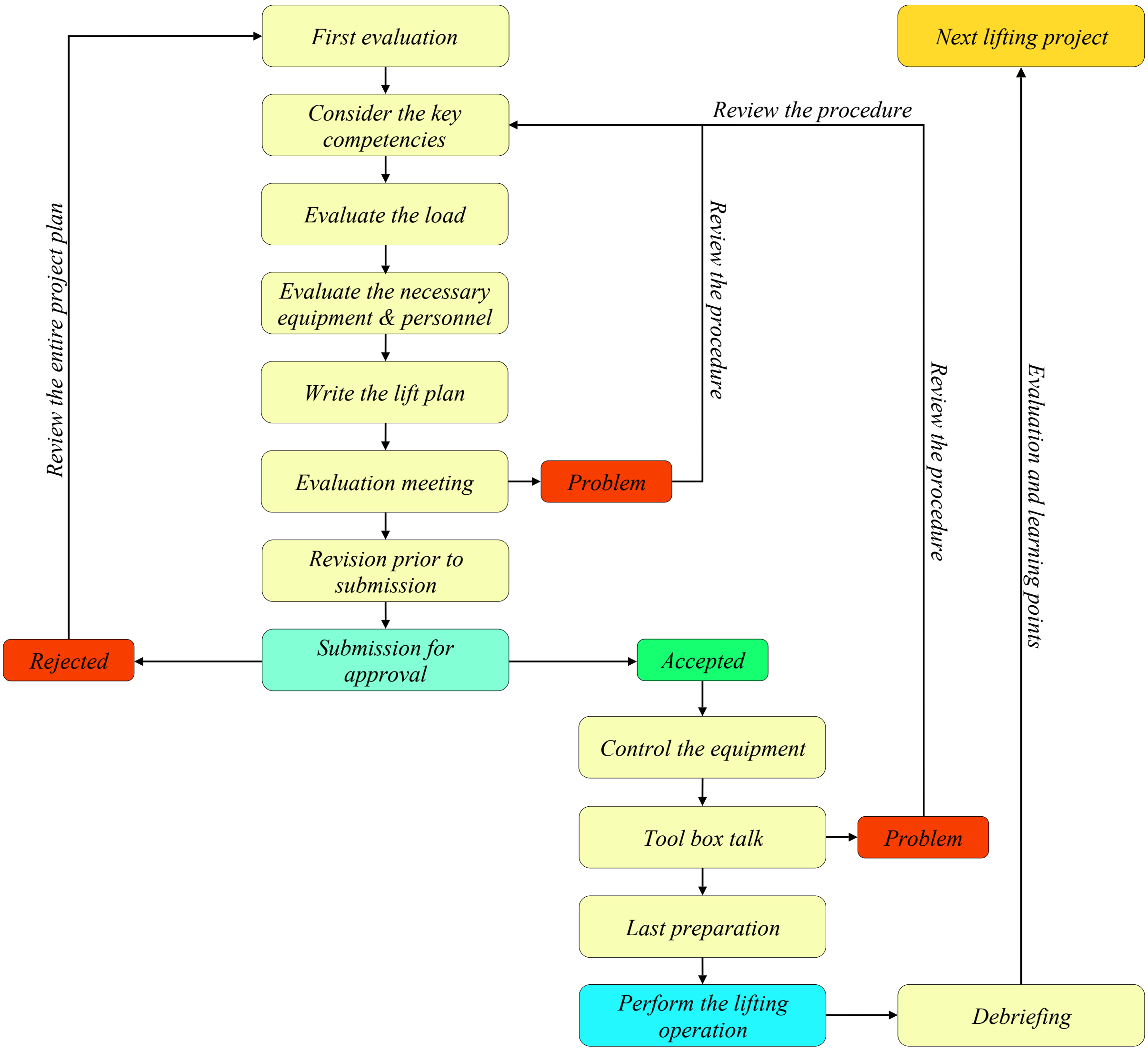
Table of contents

Page left blank intentionally

A - About this part

As mentioned in the introduction, The safety and success of a lifting operation depend on whether the various elements for controlling such activity are in place. For this reason, this part focus on the method for implementing the following steps. It is obvious that such implementation requires knowledge of the elements mentioned in the part #1 of this handbook.

1. Evaluate the task
2. Consider the key competencies necessary for the operation (competent persons & engineers).
3. Evaluate the load
4. Evaluate the necessary equipment and evaluate the necessary complementary personnel.
5. Write the lift plan.
6. Carry on an evaluation meeting.
7. Review the lift plan according to the risk assessment findings.
8. Submit the lift plan for approval.
9. Control the the lifting equipment and ensure that the team is ready to operate
10. Carry on a toolbox talk. In case of a problem is detected, the procedure is reviewed.
11. Last preparation (Rigging installation, lifting device inspection, pre dive checks, etc.)
12. Perform the lifting operation
13. Debriefing



The guidelines provided follow this scheme. Note that example of form is not provided. The reason is that it is to each company to design it according to the operations it undertakes. Specific forms can also be created for particular operations. What is important is to ensure that every element essential for the operation is mentioned .
However elements to analyse the whether conditions and their effects on the vessel and the crane are provided. It is also the case of those for the transfer of personnel at sea and by crane.

Page left blank intentionally

B - Organize the lifting operations

1 - First evaluation of the task

This phase is usually performed by the appointed construction manager or the person nominated to hold his functions. It is the starting point of the lifting project and only a first approach; for this reason, it does not result in the final selection of the equipment and the personnel that will have to be in place, as this aspect is evaluated later during the studies for the lifting procedures. However, it allows categorizing the type of lifting, so assess the profiles of the main competent persons and the level of engineering that would be necessary to organize it. Depending on the evolution of the project preparation, the decisions arising from this 1st approach may have to be reconsidered.
Remember that the construction manager is the contractor's representative at the work site and is generally appointed on large projects. He has overall responsibility for the project execution, and his duties and tasks include:

- Ensuring that activities are carried out in accordance with the requirements in the diving project plan and the applicable laws and regulations.
- Ensuring that personnel is competent, qualified, and familiar with the work procedures, safety precautions to be taken, applicable laws and regulations, and guidelines from selected competent bodies.
- Being the primary point of contact with the client representative. Note that he may or may not have a diving background. If the offshore manager has no diving experience, a diving superintendent must be appointed to assist him.

For the reasons listed above, this person should have competencies in management and leadership and be familiar with the management and working procedures of the company he represents. As mentioned previously, it is usual that on small projects, the construction manager's function is held by the diving superintendent, or in case of lifting not in the water, the vessel master or a person nominated by the company.

1.1 - Categorization

Most organizations categorize lifting operations into "non-routine" and "routine" lifts. However, non-routine lifts are often sub-classified into "simple lifts" and "complex lifts" (also called critical lifts).

1.1.1 - Non-routine lifts

"Non-routine" lifting operations represent the majority of lifting operations, as every lifting operation performed for the first time is to be considered "non-routine" even though it is a straightforward operation. Thus, non-routine operations can be very simple or complex, so these operations are often classified as "simple non-routine lifts" and "complex non-routine lifts".

Simple non-routine lifts can be defined as follows:

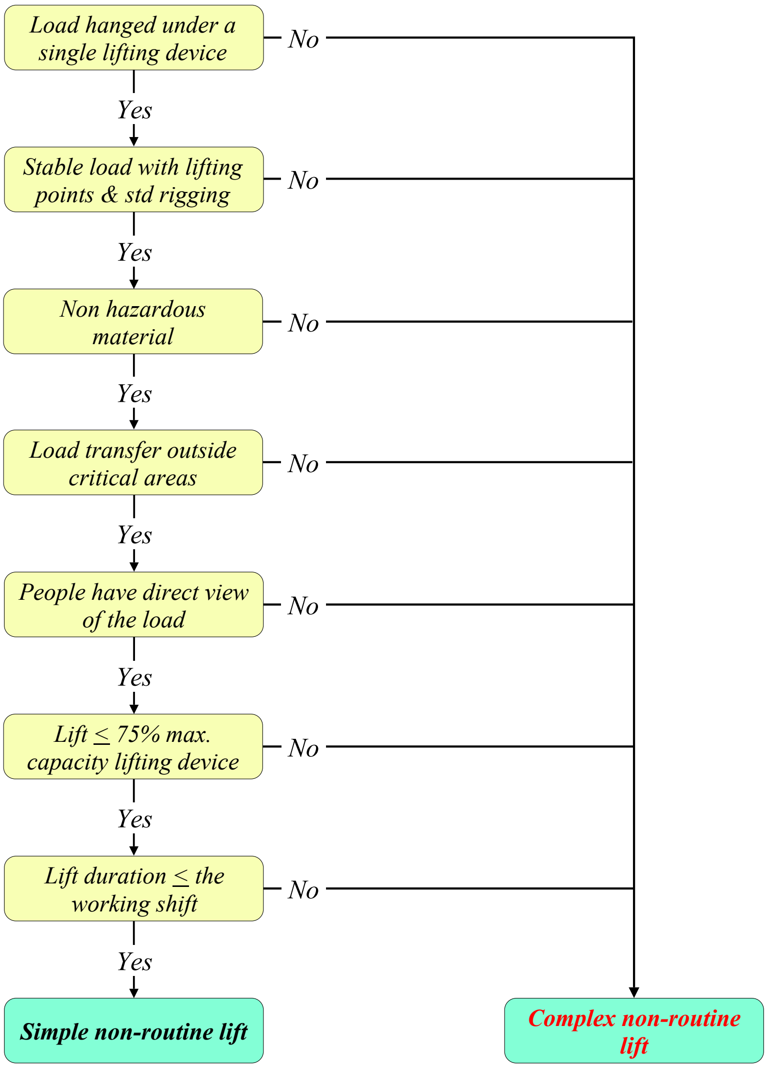
- They consist of a load directly hanged to a crane or a hoist positioned above it, so that only one lifting item is used.
- The load to transfer is known, stable, and with adequate lifting points. As a result, standard rigging arrangements can be used.
- The people performing the operation have a direct view of the load.
- The load transfer is performed outside critical and sensitive areas.
- The engineering involved is not complex except for a voluminous and heavy load. Regarding this point, note that OSHA 1926.751 classify a lift that exceeds 75 percent of the rated capacity of the crane as a "critical lift" ("complex lift" in this handbook). Remember, OSHA means "Occupational Safety and Health Administration" (USA). Based on this standard, we can consider that simple lifts should be limited to 75% of the maximum rated capacity of every type of lifting gear.
- The duration of the operation is no more than the duration of the working shift.
- It is common to re-use reviewed previously used lifting plans and risk assessments for such operations.

Complex non-routine lifts can be defined as follows:

- They involve the transfer of loads that can be of complex shapes and be heavy and very voluminous so that their centre of gravity may be complicated to find, and specific lifting gears and rigging or multiple lifting gears may have to be used. For these reasons, safely handling such loads may require complex engineering studies. As mentioned above, based on OSHA standard 1926.751, a lift that exceeds 75% of the rated capacity of the lifting device is critical, so a complex lifting in this manual. That also includes the transfer of hazardous materials.
- They may also involve a load transfer to a place that is not visible and sometimes of difficult access. Thus, the load is not directly visible to the operators, which requires specific studies and precautions. For this reason, lifting operations that consist of transferring loads from the surface support's deck to underwater worksites are classified as "complex non-routine lifts". It is also the case of operations where the load is transferred in a confined space or in direct proximity to a live production unit, whatever its shape and weight.
- They also consist of operations potentially impacting established schedules, such as those performed in difficult environmental conditions.

Note that the onsite construction manager usually authorizes simple lifting procedures. However, some complex lift plans may have to be prepared by competent persons appointed by the company's management and reviewed and approved by other qualified persons who may be engineering teams external to the company before being submitted to the client's technical authorities. Then, the plan should be reviewed and finalized by the persons in charge of its execution who have the power to reject it.

The chart below, or a similar one, can be used to classify the lifting operation as a simple or a complex non-routine lifting. It is based on the fact that if one element that allows classifying the lifting as a simple lifting is not fulfilled, the lifting is to be considered a complex lifting operation.

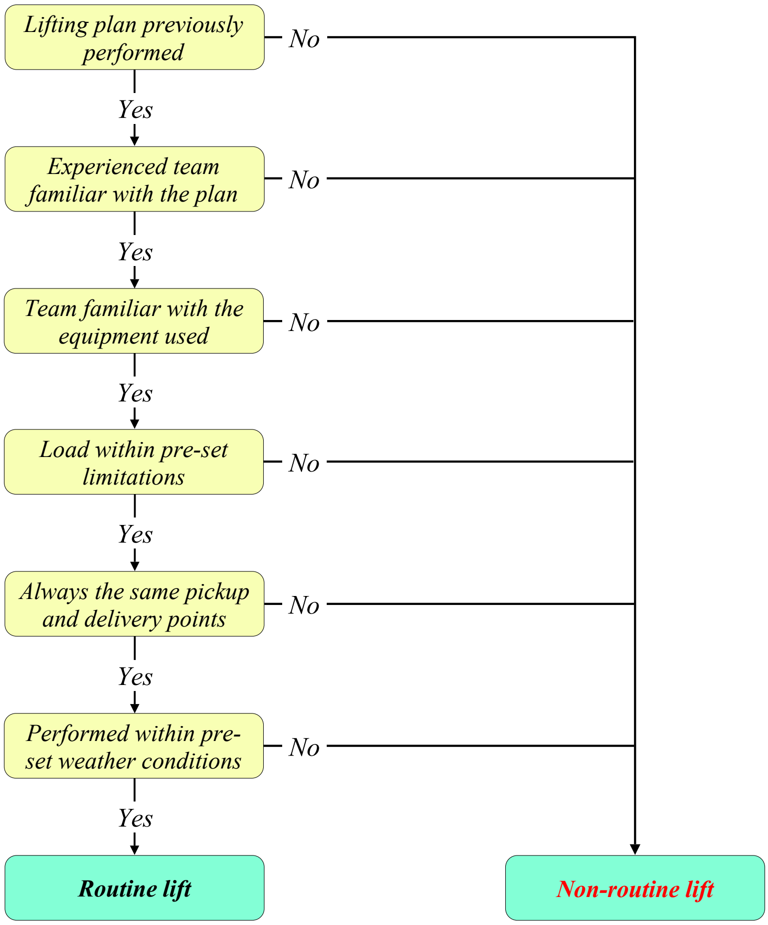


1.1.2 - Routine lifts

Routine lifts consist of repetitive operations covered by a lifting plan that is always the same.
These lifting operations are performed by experienced teams familiar with the task and the equipment employed, and also used to work together.
These operations are also limited to simple lifts, with loads within pre-set weight limitations of known shapes, and which transfer does not require additional engineering calculations. In addition, the pickup and delivery points are always the same, and these operations are always performed within pre-set weather conditions. For example, transferring small equipment and food in offshore containers from a supply vessel to a platform using the platform's crane is usually classified a routine lift.
Routine lifts must not be confused with light weight pieces lifts. As an example, transferring a connecting clamp to the bottom of the sea using a powerful crane is not a routine lift as it does not fill all the conditions described above and, despite the limited weight, requires specific investigations regarding the area where the load is to be transferred, how it will be transferred, and others.
Of course, routine lifting operations should be appropriately supervised and carried out safely, even though the repetitive nature of such operations results in the lifting plan not being required on each occasion the procedure is conducted. It must be taken into account that according to studies from national Health and Safety organizations, most crane accidents happen during a routine lift rather than a non-routine lift. For this reason, as for all lifting operations, the routine lift plan should be properly planned by a competent person and the people who usually use the lifting equipment. This plan should be discussed and reviewed during the pre-lift meeting, which can be the toolbox talk at the beginning of the shift when the operation involves only the lifting team, and a more extensive session for operations involving several crews.
Also, the lifting process should be considered "non-routine" if elements related to the plan have changed. Note that "routine lifts" are the continuation of a "non-routine" lifting operation. In other words, the first "routine lift" performed is

a “non-routine lift”.

A chart, similar to the one used to classify the “non-routine” lifting operations, can be used to classify the lifting as “routine” or “non-routine”. It is also based on the fact that if one element that allows classifying the lifting as a “routine” lifting is not fulfilled, the lifting is considered a “non-routine” lifting operation.



2 - Select the competent persons

When the project construction manager, or the person nominated to hold such responsibilities, who, depending on the project, can be the diving superintendent, the vessel master, or another competent person, has completed his first estimation, depending on the complexity of the lifting, he can nominate the persons in charge, or request the project manager to provide skilled people.

2.1 - Lifting manager

The “lifting manager” is the competent person appointed to lead the lifting operation. He has practical skills, theoretical knowledge, and the ability to carry out risk assessments, produce and assess lift plans, conduct pre-lift meetings, and the supervisory skills and experience required to organize the planned lifting operation. Thus, he is responsible for the following:

- Verifying the previous categorization of the lift, and modifying it if necessary.
- Carrying on risk assessments.
- Writing the lift plan and undertaking technical reviews.
- Selecting the appropriate equipment.
- Selecting the relevant personnel.
- Requesting the support of a technical authority if additional technical skills or advices are necessary.
- Presenting the procedure to the company management and the client.
- Reviewing the procedure according to the comments made by the company management, the technical authority and the client, and ensuring they are approved.
- Organizing the pre-job toolbox talk.
- Supervising the last pre-job preparation.
- Supervising the operations.
- Organizing the post-job debrief.

2.2 - Project’s technical authority (also called “engineering support team”)

Engineering support may be necessary to establish, approve, and assess conformance to complex lifting processes' technical, safety, and certification requirements. This essential support is usually defined by the "lifting manager". On many dive support vessels, the engineering support on site is often provided by the onboard project engineers. However, most projects requesting engineering support are prepared onshore prior to launching the operations. Depending on the project's complexity, the engineering support is provided by structural or senior engineers, naval architects, lifting and rigging supervisors, and other competencies if necessary.
The "engineering support team" usually helps the "lifting manager" to:

- Undertake technical evaluations.
- Select the appropriate equipment.
- Write the lift plan.
- Review the lifting procedures and technical calculations according to the comments made by the company management, the third-party technical authority, and the client.
- Make the lift plan approved.

2.3 - Third party technical authority

The third-party technical authority is an entity external to the company responsible for establishing, approving, and assessing conformance to technical, safety, and certification requirements and policies for the planned lifting processes. Thus, a person or a team who is competent to provide impartial judgments of the scheduled operational plan based on a documented technical review.
The use of a third-party engineering evaluation is usually imposed by clients on large projects as part of their “quality assurance process” *("quality assurance" is a systematic process of making sure that a product/service fulfils given requirements*). Also, note that many companies commonly use such services for the same reasons. Note that the client may impose a third party approved by his technical department.
Similarly to the company engineering support, the competencies involved include engineers, naval architects, lifting and rigging supervisors, and other competencies if necessary.
Note that the third-party technical authority only discusses technical matters: It is not in charge of the projects and managing changes that may arise from its advice.

2.4 - Lifting supervisor

The lifting supervisor is in charge of actively supervising the lifting operation on site, and is nominated by the “lifting manager”.

This position is commonly held in the yard by the foreman, the shift supervisor, or a person appointed to this function. It is the same for operations performed on the vessel's deck or the jetty. However, it is recommended that the diving supervisor or the ROV supervisor is appointed to this function for underwater lifting. In this case, the diving or ROV supervisor is seconded by the deck foreman, or a nominated person, for the phases of the operation to be performed on the deck. The handover of responsibility happens when the load breaks the surface of the water and vice versa. Note that the lifting supervisor should be the diving supervisor for operations involving divers and ROVs.
The lifting supervisor is in charge for:

- Coordinating and controlling the implementation of the lifting process. He is the only person who can launch the lifting operation.
- Reviewing the lifting plan and ensuring that the necessary controls are planned. Also, that the lifting equipment is appropriate, suitably inspected, and ready for operation.
- Ensuring the load integrity and stability, and that the rigging conforms to the lifting plan.
- Ensuring that the people involved in the task are competent, aware of their function, and know the process planned for the operation. Also, managing the integration of new and young personnel.
- Ensuring that clear communications are in place. That includes proper main and backup systems with dedicated channels not affected by others. It also consists of ensuring that no language barrier will affect the operation.
- Manage the simultaneous operations that may affect or be affected by the lifting operation.
- Organizing or carrying on the toolbox talks with the crews involved in or affected by the lifting process.
- Ensures that the lifting process follows the lifting plan, and stop the operations if a technical problem or variations of the conditions that may cause a deviation from the lifting plan.
- Carrying the debriefing with the lifting team and discussing its conclusions with the lifting manager.

2.5 - To clarify this point

We can see that the number of people in charge of lifting operations and their technical levels vary according to the complexity of the planned project. Thus, it often happens that functions that require highly qualified persons for large projects are held by less skilled people for small operations that do not require such a high level of expertise. We can conclude that instead of considering the title given to the people holding these positions, which often vary from one organization to another, it is more essential to ensure that a logical chain of command is in place and that the roles and responsibilities of persons in charge of the lifting operation are clearly defined. For example:

- Case of a minimal diving team limited to 1 shift operating by daylight from a small vessel where small pieces less than 75% of the lifting gear capacity are transferred:
  The diving supervisor is in charge of the lifting operations underwater, and the master is in charge of the other lifting operations. Thus, the diving supervisor holds the official functions of offshore construction manager, diving superintendent, lifting manager, and lifting supervisor for the lifting operations performed underwater, and the vessel master holds the same functions for the lifting operations that are not carried underwater, except that the deck foreman usually operates as lifting supervisor.
- Case of 24 hours diving operations from a small vessel where small pieces less than 75% of the lifting gear capacity are transferred:
  It is usual that the underwater lifting procedures are under the responsibility of the diving superintendent and that the other lifting operations are under the responsibility of the master. Thus, for each underwater lifting, the diving superintendent, who is in charge of the diving operations, is usually appointed to act as offshore construction manager, diving superintendent, and lifting manager. The diving supervisors act as lifting supervisors in addition to their diving supervisor duties. The vessel master usually holds the same functions as the diving superintendent for the lifting operations that are not carried underwater, with the deck foremen acting as lifting supervisors on deck.
- Case of a large project where 24-hour diving and ROV operations are carried out from a large vessel and where loads less than 75% of the lifting gear capacity are transferred:
  In this case, an offshore construction manager is appointed who may also act as lifting manager. The diving supervisors are appointed to operate as lifting supervisors in addition to their regular duties for the operations underwater, and the deck foremen are appointed to act as lifting supervisors for the operations not carried out underwater.
- Case of a large project where 24-hour diving and ROV operations are carried out from a large vessel and where "complex non-routine" lifts with loads above 75% of the lifting gear capacity are transferred:
  In this case, the offshore construction manager or management appoints a "lifting manager". An engineering support team is also appointed to help the "lifting manager", in addition to a third party technical authority, whose function is to provide external advice regarding the procedures and equipment selected. The diving supervisors are appointed to operate as lifting supervisors in addition to their regular duties for the operations underwater, and the deck foremen are appointed to act as lifting supervisors for the operations not carried out underwater.

Many other solutions can be organized, depending on the sizes and requirements of projects.

3 - Evaluate the load

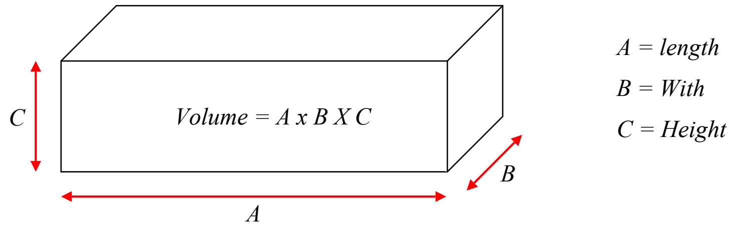
The evaluation of the load consists of calculating its volume, mass, weight in the water, and stability.
This operation is not complicated when the piece to evaluate has simple shapes and is constituted of only one material. However, it may be challenging when the piece is an assembly of elements constituted of several materials of various densities and complex shapes, which is the reason trained engineers may be required.
From this calculation, it is possible to evaluate the centre of gravity of the piece, and, thus, the proper rigging and lifting gear, which depending on the piece's complexity, may also require the advice of specialists.
Note that many complex pieces have pre-installed lifting points and a plate indicating their weight.

3.1 - Evaluate the volume

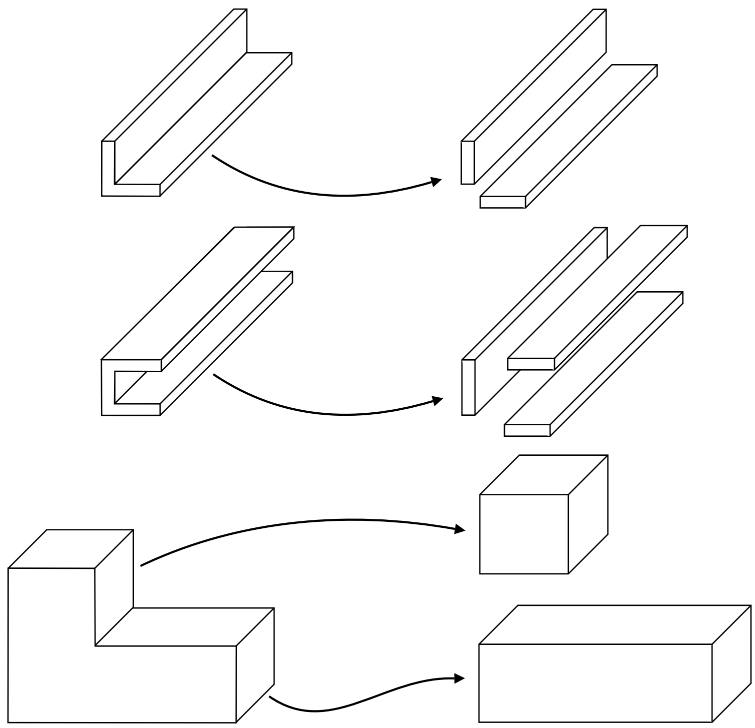
Evaluating the volume of a load allows for calculating its mass and Archimedes thrust.
As suggested previously calculating the volume of assemblies made of several pieces of complex shapes require long processes that are the fact of engineers. However, it is possible to calculate on site the volume of pieces of simple shapes.

3.1.1 - Rectangular and square objects

The formula to calculate the volume of rectangular and square objects is: Length x Width x Height



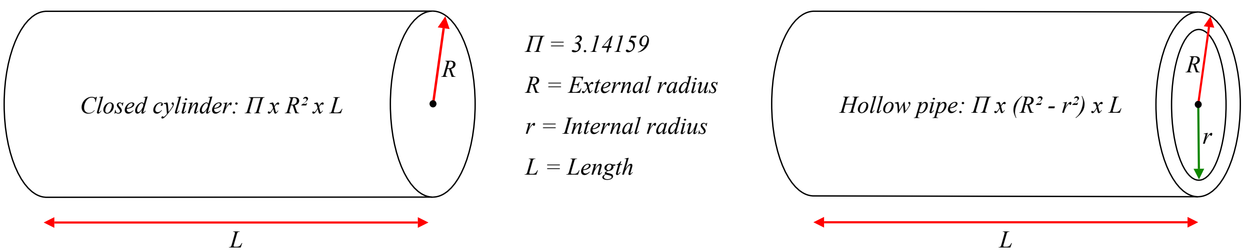
Note that volumes of more complex objects that are an assembly of several rectangles or squares can be easily calculated. For example L or U profiles consist of the following:



3.1.2 - Cylinders and pipes

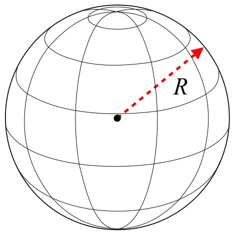
The formula to calculate the volume of a closed cylinder is: $\Pi \times R^2 \times L$

The formula to calculate the volume of a hollow pipe is: $\Pi \times (R^2 - r^2) \times L$



3.1.3 - Sphere

The formula to calculate the volume of a sphere is: 4/3 x Π x R³

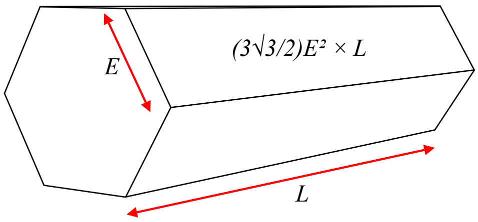


Π = 3.14159

R = Radius

3.1.4 - Hexagonal bar

The formula to calculate the volume of a hexagonal bar is: (3√3/2) x (edge length)² x Length



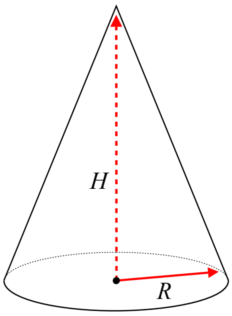
E = Edge

L = Length

3.1.5 - Cones and square base pyramids *(often used with the guides designed for the connections of large assemblies)*

The formula to calculate the volume of a cone is: 1/3 x Π x R² x Height

The formula to calculate the volume of a pyramid with a square base is: 1/3 x side x side x height

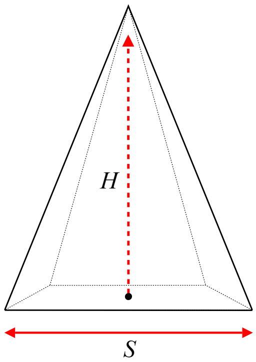


Π = 3.14159

R = Radius

H = Height

S = Side



3.2 - Evaluate the mass

The mass of an object can be determined by multiplying its density by its volume. Thus, mass = Density × volume
Density is a measure of mass per unit of volume.
Note that the unit of mass in the International System of Units (SI), also called the metric system, is the kilogram.
However, the mass of heavy objects is often expressed in metric tons.
Using the imperial system, the calculation is usually done in pounds and cubic feet or imperial ton and cubic feet.
The table below gives average densities of various materials commonly found on diving/ROV job-sites.

Material	*Density (Kg/m³)*		*Material*	*Density (Kg/m³)*
Cast iron	*7150*		*Concrete*	*2400*
Steel	*7770 - 8010*		*Cement*	*2723 - 3044*
Stainless steel	*8010*		*Sand*	*1920*
Aluminium	*2700*		*Gravel*	*1520 - 1680*
Copper	*8250*		*Pine wood*	*352 - 593*
Brass	*8410 - 8730*		*Oak wood*	*770*
Bronze	*8600 - 8810*		*Lignum vitae wood*	*1170 - 1330*
Lead	*11400*		*Rubber*	*1105 - 1185*

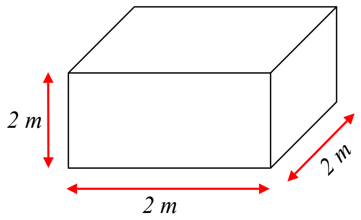
3.3 - Evaluate the effects of the Archimedes principle

Archimedes principle says that when an object is immersed in a liquid the apparent loss of weight of an object is equal to the weight of the liquid displaced. Thus, the upthrust = volume of water displaced x density of water.

Note that:

- The density of freshwater is approximately 1.00 kg/l, or 1000 kg/m³, or 62.5 lbs/ft³.
- The density of seawater is 1.03 kg/l, or 1030 kg/m³, or 64.38 lbs/ft³.

To obtain the “apparent weight” of an object in a liquid, subtract the upthrust from the weight in air.
Example with a “Dead Man Anchor (DMA)” made of concrete with dimensions of 2 m x 2 m x 1 m, deployed in the sea:

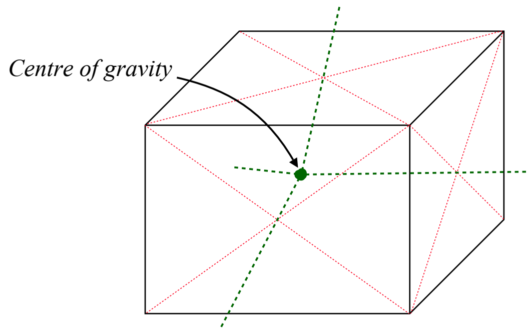


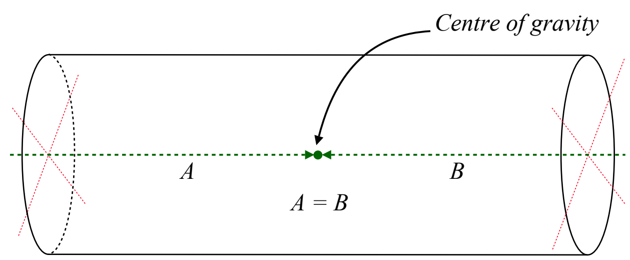
- *Volume: 2 m x 2 m x 1 m = 4 m³*
- *Density of concrete: 2400 kg/m³*
- *Weight in air: 4 x 2400 = 9600 kg*
- *Upthrust: 4 x 1030 = 4120 kg*
- *Weight in the sea: 9600 - 4120 = 5480 kg*

3.4 - Ensure of the stability of the load

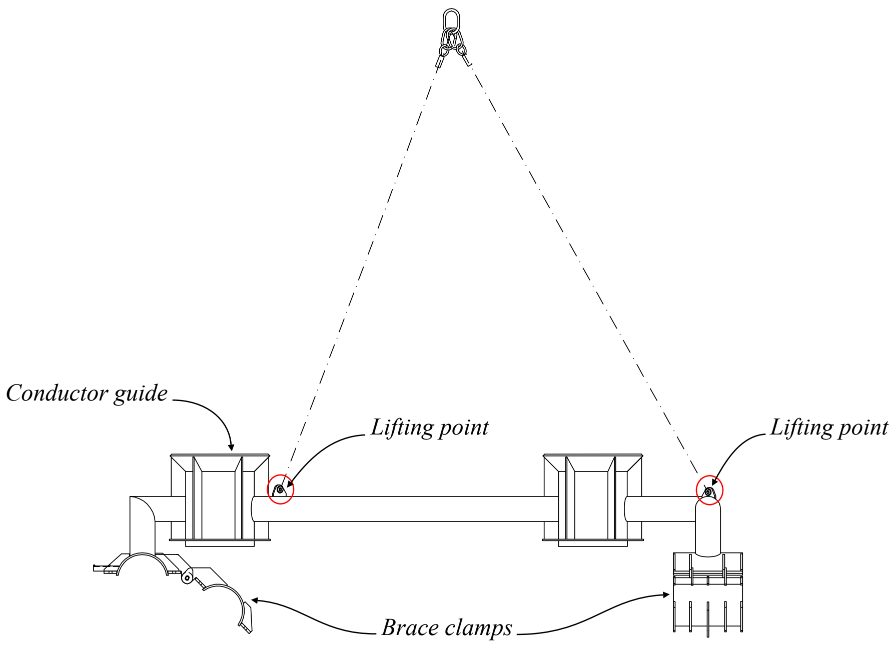
A load is considered stable when it is perfectly balanced or distributed around its centre of gravity, which is the point at which the whole weight of an object is acting vertically. As a result, a load suspended at its centre of gravity, can be turned in any direction with only little effort. However, if a load is lifted to the side of its centre of gravity, it tilts at an angle, and if a load is lifted below its centre of gravity, the weight of the load is above the lifting point, and it tips over. That explain why the lifting points are to be above the point of gravity.

The centre of gravity of objects with simple shapes can be easily found. As an example the centre of gravity of a symmetric rectangular load is the internal meeting point of the crossing lines from the centre of each rectangular face. Or, the centre of gravity of a pipe is the middle of its centre line.





Complex pieces should have their lifting points calculated by engineers, pre-installed at suitable places, and indicated in the lifting plan. It should also be the case for most manufactured heavy and voluminous parts that cannot be moved manually. Also the stability of the load is to be assessed before starting the lifting operation. Thus before any transfer.



4 - Evaluate the adequate equipment and personnel

When the categorization of the lifting and the characteristics of the load to transfer are established, the persons in charge of the operation can select the appropriate lifting equipment and accessories whose specifications fit for the purpose.
This phase is one of the most critical as the characteristics of the lifting device to be used may also influence the selection of the surface support and, of course, the number and qualification of personnel necessary to complete the project safely and efficiently. Thus, an unsuitable lifting device may result in dangerous working conditions and an unsuccessful lifting operation. For this reason, evaluation phases have to be implemented throughout the writing and engineering process of the lifting plan.

4.1 - Selection of the equipment

The selection of lifting equipment is usually performed using a risk assessment where the impact of technical solutions on the safety of the personnel involved is continuously evaluated.

4.1.1 - Lifting capacity

One of the most critical factors in planning a lifting operation is to ensure that lifting equipment selected for the job has sufficient lifting capacity and reach to handle the intended load. The following points, but not limited to, should be considered:

- The weight to be lifted and whether one lifting device or several are necessary
- The load's travel distance from its pickup to the delivery point.
- Whether a load transfer from a lifting device to another one is to be done
- Whether the lifting equipment is of adequate strength for the load and provides an appropriate safety factor against failure.
- The strength and integrity of the load attachments and other lifting accessories.
- Whether procedures are in place to address the hazards about the strength of the equipment.
- In case a mobile lifting device is used, whether it can access to the worksite.
- Whether the environmental conditions or the vessel on which it is installed may impact the lifting capacities of the equipment selected. For example, crawler cranes installed on barges often cannot work at their full capacity for stability reasons and because they are not initially designed to withstand the dynamic amplification factors of marine cranes. A dynamic amplification factor is the multiplication value of the static weight that the lifting system can withstand during dynamic conditions. It is always greater than 1.0.

4.1.2 - Lifting equipment stability

The combination of several forces and unsuitable conditions may affect the lifting device's stability and compromise the operation's safety. These factors differ, depending on whether the lifting is performed: from a vessel to a platform or vice versa, from a ship to the bottom of the sea, from a jetty to a boat or vice versa, from a jetty to the water or vice versa in case of in port and inland works, in the yard to transfer the load to trucks, etc. For this reason, it is essential to consider where the lifting process is planned and plan for adequate control measures.
Note that, depending on its mass, the size of the vessel where the lifting device is installed, and the height and position of the crane tip in relation to the centre of gravity of this vessel, a load transferred at a certain distance from the centre of gravity of the boat can affect the motion, trim, heel, and stability of this one.

- In case a mobile crane is to be used, the base where the lifting device is to be installed must be flat and sufficiently adhesive. In case of a slope or a slippery surface, corrective procedures are to be implemented to ensure the verticality of the lifting device that should not slide unexpectedly. Note that slippery surfaces can be a steel deck or the jetty's paving. For this reason, adequate fastening points should be provided.
- The strength of the soil or the part of the deck under the base of a mobile crane must be sufficient to support the mass of the lifting device plus the load. For this reason, the vessel on which the mobile lifting device is installed must be closely assessed, and if the lifting is performed from a jetty or river bank, the stabilization of the jetty or the bank may have to be considered.
- For the reasons discussed above, it is preferable to use a vessel with an integrated pedestal crane instead of installing a mobile unit on a vessel not initially designed for this purpose.
- If the lifting is performed from a static point (for example, a platform brace), the nature and sturdiness of this static point should be closely investigated.
- If winches are used alone or with an A-frame, their fastening must be closely monitored against possible tearing off. Like the problems of installing mobile cranes, using a boat designed initially with such devices is often preferable.
- The surface support should be sufficiently stable to prevent overturning and an unstable behaviour of the load. That includes:
    - Whether the surface support is anchored or a Dynamic Positioning vessel
    - The maximum wind, wave and swell height and frequency, and current conditions the surface support can withstand without excessive motions (Rolling, pitching, heaving, sway…).

- The maximum operational tilt of the crane and its surface support.
  - Whether stabilization devices such as anti rolling systems, heave compensation and active ballasting, and other counter-balancing weight systems are provided.
  - Whether the load to transfer is stable or not.
  - Whether the wire rope length of the lifting device is sufficiently long.
  - Whether the area where the load transfer is planned has difficult environmental conditions may impact the operation.
- When the load is transferred from a surface support to another floating unit, the effects of the movements of the sea on the stability of the two surface supports are to be considered, as the motions of the two vessels are not synchronized, which may increase the effects of the problems of stability previously described and the transfer's safety. Note that manufacturers such as McGregor provide lifting cranes to compensate for these effects.

4.1.3 - Risks linked to the use of the lifting device

A risk assessment should include an identification of the hazards associated with the equipment use and assess whether they are covered. That consists of considering, but without necessarily being limited to, the following:

- The ergonomics of the system.
- The ease of installation of the lifting device. That includes the ease of access to the job site and the ease of deployment of the system.
- The means of attachment of the load and whether it can be easily connected and disconnected. Also, the protection against an unintentional release of the load.
- The protections for the operator and the riggers on deck (Passive and active protections).
- Whether the equipment is provided with control devices, safety alarms, and backup systems.
- The level of expertise required for using the lifting device.
- Whether specific personal protections are to be planned.
- Whether the lifting device is provided with suitable primary and backup direct communication systems.
- The maintenance and inspection requirements of the lifting gear.
- Whether the equipment is initially designed for the lifting planned, or whether modifications have been made or are planned. Regarding this point, it must be taken into account that any modification of a lifting device must be agreed upon by an official certification body.
- The transportation and installation procedures of the system.
- Whether the equipment has appropriate certificates.

4.1.4 - Risks linked to the use of the equipment on the Jobsite

In addition to the above, the hazards associated with using the selected equipment on the job site should be assessed. It must be considered that a piece of very efficient and safe equipment can become dangerous if inappropriately employed. For this reason, the following elements should be taken into account.

- Whether the lifting is a simple or a complex operation. Remember that in addition to lifts that cannot be classified as "simple" and liftings involving diving & ROV operations, complex lifting operations may consist of “critical” transfers such as the transfer of people, dangerous materials or substances, fragile material, Pieces that require more than 75% capacity of the lifting device, or an operation requiring that more than one lifting device have to be synchronized.
- Whether the load should be manipulated on the seabed or installed in several steps.
- Whether suitable primary and backup communication systems are provided to all involved people.
- The access to the delivery point for the load, and whether it is visible or not by the people operating the lifting device.
- The positioning of the equipment and the delimitation of the areas of operation to prevent risks from uncontrolled movements of the lifting equipment or the fall of the load, which may result in striking other assets or injuring personnel. That includes protecting persons or assets along the path of the load and not lifting loads over people and sensitive areas such as the dive & ROV stations, chemical substances storage, etc. Also, the lifting operations must not compromise the access and egress paths of the work site. Note that suitable barriers should be provided to prevent access to any lifting area.
- Note that the effects of seabed suction and the additional mass from marine growths are to be considered when removing existing subsea structures from the sea, which may result in a more powerful lifting device and more resistant rigging to be provided.
- The management of simultaneous operations that may conflict to avoid colliding with other lifting equipment being used simultaneously or striking, trapping, or crushing persons.

4.2 - Selection of the personnel

The risk assessment of the lifting equipment and the worksite provides elements to evaluate the number of persons who should be involved in the lifting operation and their function. That may result in only divers for a lift involving only lift bags to install a piece previously stored on the seabed, or a large number of people and competencies for transferring a large piece requiring engineering support and a powerful crane. The following competencies should be fulfilled:

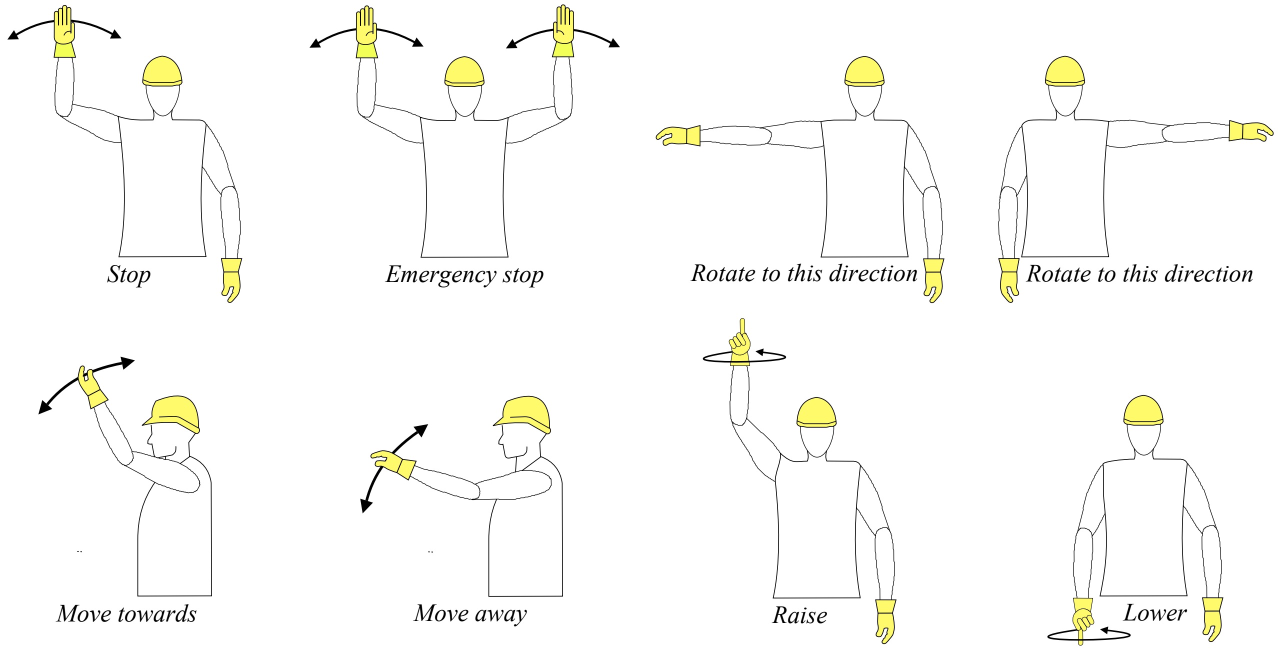
4.2.1 - Lifting Equipment Operator

The appointed operator of the lifting equipment is one of the most important people on the lifting team, as the success of the lifting operation depends on his competencies and wiseness. He must be able to:

- Carrying out the lifting operation in accordance with the lifting plan.
- Ensuring that the load to transfer is within the capacities of the lifting equipment. That includes reading and understanding the load capacity chart of the lifting device he is in charge of.
- Inspecting the lifting equipment, immediately reporting defects to the lifting supervisor, logging the defects in the maintenance records, and ensuring that the anomalies are all solved before using the equipment. That includes checking that the safety devices and communications are functioning correctly.
- Ensuring of the stability of the lifting equipment.
- Taking into account the obstructions and areas forbidden to lift that may disturb the lifting operation.
- Monitoring the environmental conditions that may affect or compromise the safety of the operations, such as thunderstorms, strong winds, heavy waves, etc.
- Carrying out lifting operations only when the lifting supervisor is on site and instructed to start.
- Disengaging from any dangerous manoeuvre and stopping the lifting whenever an unsafe condition occurs.
- Following the instructions of the signalman (Note that for underwater operation, the diving or ROV supervisor acts as signalman). That includes repeating the instructions of the signalman in the communications to confirm that his instruction is understood.
- Stopping any movement in case of doubt or need further clarification.

4.2.2 - Signalman

The name "signalman" comes from the fact that this person should be able to guide the lifting operator using visual hand signals. Radio and wired communications are today used for underwater and deck lifting processes. However, verbal communications must be accompanied by traditional hand signals, which basic ones are as follows. Depending on the complexity of the lifting device, complementary signals, which vary from one company to another, are implemented.



There should be only one appointed signalman per lifting operation. He should be dressed in such a way that he can be distinctively identified. He works under the responsibility of the lifting supervisor and is in charge of:

- Ensuring that the load is properly rigged up prior to to commencing the lifting operation. Note that he should not handle rigging duties simultaneously.
- Ensuring that verbal and visual communications with the lifting supervisor and the lifting device operator are established.
- Starting the operation when instructed by the lifting supervisor.
- Giving correct and clear signals to the lifting equipment operator.
- Ensuring that the communications are maintained with the lifting equipment operator throughout the lift.
- Ensuring that the operation is performed accordance with the lifting plan.
- Ensuring that the load is under control throughout the duration of the operation.
- Ensuring that the areas within the lift are clear of any hazards.
- Following the instructions of the lifting supervisor.

- Stopping the lifting process whenever an unsafe condition occurs.
- Confirming the handover to the lifting supervisor and the lifting device operator if a handover to another signaler is required.

As already mentioned, on many diving projects, the signalman for the lifting operations on deck is the deck foreman, and the diving or ROV supervisor for operations underwater. The handover happens when the load breaks the surface of the sea. Also, remember that the lifting supervisor often acts as a signalman.

4.2.3 - Riggers

In old maritime dictionaries, the name "rigger" described someone who arranged and worked with the ropes that support and control a ship's sails and the mooring ropes and chains. The definition extended later on to describe someone who also works with ropes, chains, and slings of lifting devices.
The appointed riggers work under the direction of the lifting supervisor and the signalman. They are in charge of preparing the lifting slings of the load and other works on deck. During the lifting operation, each rigger involved has a precise function attributed to him by the lifting manager. The riggers are usually assigned to the following tasks:

- Ensuring that slings, webbings, shackles, and other lifting gears used to rig the load are within the planned safe working load (SWL), in good condition, and duly certified. Also, report any lifting rigging and equipment defects to the lifting supervisor.
- Installing the lifting slings and tag lines according to the lifting plan and informing the lifting supervisor that the rigging is in place and conforms with the lifting plan.
- Connecting and disconnecting the lifting slings to the hook of the lifting device when instructed to do so.
- Checking that the load is stable and reporting its condition to the lifting supervisor.
- Controlling the tag lines to ensure load stability and orientation.
- Securing and restricting access to the lifting area.
- Signalling any defect that may affect the lifting operation. As every person involved in the lifting process, the riggers can and must request to stop it if they consider the safety compromised.
- Removing and maintaining the rigging equipment when the lifting operation is completed.

Note that the divers often act as deck riggers during small operations. Also, they should be involved in rigging jobs to prepare the elements to install and disconnect underwater.

4.3 - Ensure the availability of the equipment selected and of the personnel to implement it

Identifying the ideal equipment does not mean that it is available and that the personnel to operate it is also available. Some companies have suitable lifting devices and surface support that fit the requirements identified, and others do not, so they will have to buy or rent them.
For these reasons, it is essential to ensure that the lifting device initially envisaged will be available and its cost as soon as possible. This process does not imply formal commercial arrangements and allows establishing a list of suppliers if the equipment has to be bought or rented. Also, if the company owns the equipment, it allows ensuring it will be available for operation on the requested date, as it may be already booked for other purposes.
For the reasons above, this process has to be done as soon as possible, as the non-availability of the ideal lifting device may result in reconsidering the equipment selection process.
Because the personnel necessary for the lifting operation is linked to the equipment planned to be implemented, the process of finding and selecting people must be performed simultaneously. It may have to be reconsidered if the equipment selection process has to be reviewed.

5 - Writing the lifting plan and ensuring it conforms to the expectations of the client

The Lifting Plan is the set of procedures for the safe and successful lifting operation using the selected lifting devices. It must be accepted by the client representatives, and the permit to work must be established prior to its implementation. With most projects, the acceptance of the lifting plan is done before the project's mobilization.
For these reasons, the team in charge of writing it should take into account the client's requirements which are part of his "quality assurance process" (*"quality assurance" is a systematic process of making sure that a product/service fulfils given requirements*). For this reason, external technical authorities are often requested to advise on large projects involving complex lifting plans.
Also, a final evaluation meeting should be performed before the presentation of the lift plan to the client to ensure that it conforms to the aims of the company management, the client's expectations, and does not conflict with other planned activities for the project. Thus, this presentation and risk assessment should consider the entire project. This usually results in minor or significant corrections to the original plan. This phase is essential as a lift plan jugged "incorrect" by the client representatives will be rejected, resulting in a loss of time and reputation.

5.1 - Writing process

5.1.1 - Justification and engineering calculations

This part of the lifting plan uses the studies previously done for selecting the lifting device and the necessary personnel to operate it and support the operation. Its purpose is to prove that the procedure has been methodologically studied. It must be written such that the readers (technical authorities, client representatives, etc.) understand why the lifting device and procedures have been selected for the task. The following elements, but not limited to them, have to be provided:

- The identification of the lifting plan
  The lifting plan is usually part of a project and, thus, part of an ensemble of task plans that must be referenced and scheduled. For this reason, the following elements should be mentioned:
    - The reference number of the document.
    - The date of issue.
    - The names of the authors, reviewers, and the person in charge.
- The description of the load to transfer
    - Dimensions and weight in the air and the water.
    - Stability in the air and the water, and the position of the lifting points.
    - Whether it requires specific precautions (dangerous materials or substances, fragile material, very heavy pieces, etc.)
- The description of the worksite
    - The exact location of the worksite (inshore or offshore) must be precisely indicated. If at sea, the geodesic position and the distance from the shore and the port facility where the project is prepared. If inland, the roads to access it and the distance from the point of preparation (Yard, etc.)
    - The nearby facilities, particularly those that may impact the lifting process, should be mentioned. That may be pipelines, platforms restricting access, flares, etc.
    - Plan and elevation drawings
    - Weather conditions (Prevalent winds and currents according to periods of the year)
    - Place where the load has to be transferred or retrieved from.
    - The access to the worksite and the lifting point.
    - Whether one or several lifting devices will be necessary to transfer the load
- The description of the lifting device
    - The type of lifting device selected.
    - The distance planned from the place where the load has to be delivered or retrieved
    - The lifting capacity of the equipment. That includes the elements mentioned in point 4.1.1 supported by engineering calculations and the technical specifications from the manufacturer including its load charts. Regarding this point, note that each lifting device has different dynamic amplification factors (DAF).
    - Note that the surface support used must be described in detail with its advantages and inconveniences. That includes the description of its mooring system for barges and four points mooring vessels or of the dynamic positioning system if the ship is equipped with it. That also includes the position of the boat or the mooring plan of the barge.
    - The lifting equipment stability. That includes the elements discussed in point #4,1,2 supported by engineering calculations and the procedures for the reinforcement of the deck, jetty, or bank that may have to be undertaken, in addition, to the fastenings and securing processes. Thus, all calculations proving that the lifting device will not collapse and that the surface support will not have an exaggerated list and will not capsize during the operation.
      When reinforcements of the floor on which the lifting device and fastenings are installed have to be performed, the Non Destructive Techniques (NDT) used to assess their conformity, and the level of the technicians in charge of their implementation are to be mentioned.

  - The certifications of the equipment. Regarding this point, note that the clients generally ensure that the lifting systems used in their fields conform with the national and international rules and their own requirements. As an example, IOGP 376 requests the following:
    - An equipment register must support the equipment maintenance.
    - The lifting devices and equipment must be thoroughly inspected by a "competent person" at least every 12 months, and at least every 6 months for equipment used to lift people, which are the UK- Lifting Operations and Lifting Equipment Regulations (LOLER) rules.
    - The maintenance schedule must be based on the manufacturer's recommendations, operating experience, applicable standards and failure modes. The program must integrate preventative and predictive maintenance techniques. Also, the maintenance schedules must take into account the effects of aging and equipment utilization. The safety critical components and systems must be identified, and arrangements must be implemented to ensure they are adequately maintained. Where third parties provide their lifting equipment, the site manager ensures an auditable system that ensures the equipment's control, integrity, and suitability.
    - The parts of the equipment to be visually examined before use (the operator performs that) should be mentioned.
  - The risks linked to the use of the equipment selected and their mitigation as described in point 4.1.3. This part must be supported by a risk assessment.
  - The risks linked to the use of the selected lifting device on the jobsite as described in point 4.1.4. supported by engineering calculations.
- Rigging design
  The rigging specifications and drawing, should be provided with suitable engineering studies taking into account the specifications of the lifting device, and the particularities of the jobsite. Note that rigging systems such as slings, chains, ropes, and others are described in the next chapters with their limitations and suitable method of use. The lifting design document should provide the following:
  - The rigging drawing, with the type of slings and connectors to be used and the position of the lifting connectors on the load. That includes additional drawings for particular details.
  - The strength calculation of the connecting point of the load. Including the methods for controlling them.
  - The lifting slings calculations. They should consider the rigging geometry, dynamic amplification factors, and effects of slamming that may happen in the splash zone and during adverse weather conditions.
  - The certifications of the rigging, colour code applied, and the recommendation from the manufacturer.
  - The position of the tag lines.
  - The rigging integrity checking procedures.

5.1.2 - Step by step process

This part details the step by step lifting process from the rigging installation to the rigging disconnection while at the delivery point, and the recovery of the lifting device.
It is the document used by the riggers, divers, ROV pilots, and every person involved in the lifting project, and on which the toolbox talk is based. It should comprise the following elements, some of them have been previously employed during the previous steps:

- Job description
  - Job site description (Position, access, distance from the shore, configuration, etc).
  - Description of the lifting device and the surface support.
  - Description of the task (Load to transfer and means of transfer selected, Transfer path planed).
  - Simultaneous operations
  - Previous and following tasks planned.
- Chain of command
  Names and functions of the person involved in the project:
  - Lifting manager, lifting supervisor, signalman.
  - Lifting equipment operator.
  - Riggers.
  - Divers & ROV pilots.
- Description and process of installation of the rigging
  - Rigging drawing where each part of the rigging is identified.
  - List of rigging components to install.
  - Precise procedure and installation requirements.
- Checklist process
  - Checklist and recording of the rigging installed
  - Checklist of the lifting device
  - Checklist of the communications

- Lifting process
  - Connection of the lifting device to the rigging.
  - Lifting above the deck or the seabed.
  - Transfer to the target (planned vertical and horizontal moves).
  - Lowering and adjustments to the target.
  - Disconnection of the load
  - Rigging and lifting device recovery
- Post lifting process
  - Lifting device securing and post job checklist.
  - In case a lifting device of opportunity is used, its decommissioning procedure.
  - Rigging maintenance and storage.

Elements to take into account:

- For any underwater lifting, the behaviour of a dropped load underwater, the effect of the swell on the surface support and by transmission to the load, the behaviour of the load in the splash zone, and the procedures to control them should be considered.
- It often happens that the seasonal weather conditions of the worksite are neglected. That may result in unplanned standby periods impacting the project's profitability and pushing people in charge to take unconsidered risks. For this reason, the most favourable season for the project must be indicated with the percentage of degradation of the weather conditions during the period selected by the client. Arrangements must be planned to prevent inappropriate behaviours during the standby weather periods.
- Linked to the above and the latitude of the worksite, it is essential to consider that the operation may be disturbed by raining, snowing, or icing weather conditions and that some areas are submitted to frequent heavy winds, storms, or strong underwater currents. Also, the position of the surface support and the lifting device may result in operators being disturbed by the sun during dusk or artificial lights during the night.
- An emergency plan must be prepared and included in the procedures. It should provide elements for an effective response to undesirable events and procedures for the worksite evacuation, abandonment ship, alerting the emergency services and the company management, and implementing medical treatments. The training of the workers regarding emergency procedures and the medical support provided must be specified. Note that in the case of a large project, the emergency response plan consists of a document covering the ensemble of the activities planned.
- Again, underwater load transfers should never be considered routine lifts.

5.2 - Final evaluation meeting and reviewing process

5.2.1 - Final evaluation meeting

As already said, prior to presenting the lift plan to the client, it is necessary to ensure that it conforms to his expectations and does not conflict with other planned activities for the project. Also, it is essential to ensure that every safety aspect of the lifting operation is covered. For this reason, depending on the project size, this meeting should involve at least a representative of each position involved in the project. Thus, the functions listed below should be involved.

- The project manager
- The construction manager
- Permit to work coordinator
- The lifting manager
- The document writers
- The technical authority
- The lifting supervisor
- The Signalman
- The deck foreman
- The rigger foreman.

It is evident that these functions are cumulated on small projects, and thus, the evaluation process is often simplified. Of course, this evaluation process is based on risk assessment procedures. Note that this meeting may result in the solutions selected being judged inadequate and, thus, the process to be deeply reviewed. Also, take into account the following:

- It is preferable to limit the number of participants: Several experiences show that too many people result in sessions where the participants are not active or result in a cacophony, leading to disastrous results. Also, remember that the objective of this process is not to dilute or discharge the responsibilities of the persons in charge of the project.
- For the suitability of the discussions, it is advisable to provide the technical elements, and those for the revision of the risk assessment several days before the meeting .
- It is common that client representatives are present on the company's premises during the study phase of the procedure. Depending on their relationship with the team and the company's policy, they may be invited to participate, even though this phase is not the official presentation of the document.

5.2.2 - Reviewing process

The weaknesses of the original plan highlighted during the evaluation meeting must be corrected using the solutions discussed during the evaluation meeting. As suggested above, that can be trivial corrections and reinforcements, or be major modifications which may result in the revision of the entire procedure.
Note that, as long the procedure has not been presented to the client, all these modifications are internal processes, and should not impact the reputation of the company and the relationship with the client.
The lifting and construction managers should ensure that all the points have been covered prior to transmit the document to the client who evaluate it prior to acceptance. Note the following:

- The authors of the document, the reviewers, and the lifting manager should sign the document.
- On small projects and for simple liftings, the description of the lifting process is made on a specific form, supported by the risk assessment, that summarizes the procedures to be performed. Some examples of such forms are provided in the appendix at the end of this handbook. Nevertheless, complex liftings, which is the case for all those made underwater, must be justified as previously indicated.

6 - Approval of the procedure by the client, and implementation

6.1 - Approval of the procedure by the client

Whatever his activity, the client usually does not authorize any operation he has no control over within his premises or during the project he is in charge of. For this reason, any procedure is to be approved by his representatives before its implementation.
The process of approval is similar to the final evaluation previously described. Thus, depending on the project size, the document is usually submitted for the approval of, but not limited to, the following persons.

- The client representatives
- The site manager
- The Health, Safety, and environment manager
- The technical authority
- The third-party technical authority
- Permit to work coordinator

As for the evaluation phase made by the contractor, is evident that these functions are cumulated on small projects, and thus, the evaluation process is often simplified. Also note the following:

- As for the evaluation phase made by the contractor, it is evident that these functions are cumulated on small projects, and thus, the evaluation process is often simplified. Also, note the following:
- Clients often request that their contractors use their permit-to-work system. The client may also ask the contractor to use his forms.
- It often happens that the client asks for clarifications, notably when the lifting is a complex one. For this reason the team must be ready to provide any asked document.

The client representatives and managers can reject the lifting plan if it does not fit their quality assurance system. It is the reason that the final evaluation meeting and reviewing process previously mentioned are essential.

6.2 - Control the lifting equipment

When the project is approved by the client, the team must ensure that the lifting equipment selected is thoroughly inspected. This phase is to be done by a competent person and ensure that:

- Each part lifting rigging part should be provided with its manufacturer tag with relevant information (type, manufacturer, date of fabrication, reference standard, reference number, dates of inspection and expiration) the colour code should be the one applied by the client. Each element to be used must be logged and its position listed according to the rigging plan.
- The floor where the mobile lifting device is reinforced if required and then tested.
- Fixed and mobile lifting devices are inspected according to the requirements for crane, winches and other systems discussed in the next chapters.
- Some installation and inspection works have to be performed at height. In this case, the precautions indicated in the CCO Ltd Diving study #10 "Working at height during the mobilization and the maintenance of diving and ROV systems" should be implemented.

6.3 - Toolbox talk

The lifting supervisor is in charge of the toolbox talk.
Toolbox talks allow the persons in charge of the team to monitor the diving team's health and spirit. Several topics, not only the task to perform during the shift, must be discussed during this meeting. It should comprise the following elements:

- Health / temporary unfitness
  People are responsible for their own safety and the safety of others who may be affected by their actions. It must be remembered that an operation performed by people not in good health, under medical treatment, under stress or excessive fatigue, constitute a hazard for them and the others. That is why any health problem or stress are to be noticed the supervisor. On his side the supervisor must implement the necessary precautions to be sure that every member of his team is in condition to work safely.
  - Any disease, that may compromise the operation should be reported
  - Emotional distress must be reported to the management and the medic. In this case, the person must not be
  - allowed to work without evaluation and green light from the medic.
  - alcohol or drugs problems: The common safety policies have clearly stated the consumption of alcohol and drugs as a breach to the safety rules. People who may be under the influence of these substances must not work and should be evacuated from the worksite. The identification of drugs and management procedures to avoid having people under drug abuse on the worksite is explained in the Diving management study CCO Ltd #3 "Implement a drug and alcohol abuse policy".
- Task plan

To have efficient and positive discussion, the written task plan should be transmitted to the members of the tem at least 1 day before the toolbox talk to let them understand and think about what is planned. The supervisor must remember that people discovering a work procedure will not ask good questions because they have to understand what to do first.

  - The organisation of the team and the function of every team member is clarified during the discussion of the task plan.
  - The risk assessment must be reviewed by the team and additional precautions can be implemented.
  - This is the last stage of the risk assessment. Because the team members may be exposed to potential risks, and they are responsible for their safety, they must have their say. They can request more precautions if they consider the preventive measures insufficient.
  - At the end of the discussion, the persons must be able to explain to the supervisor what they have to do.

- Site rules
  Each work site has particular rules linked to the procedures applied by the client. These particular rules must be explained to the members of the team.
- Safety and on-site life
  The safety directly linked to the task to be performed must be discussed during the discussion of the task plan (and the risk assessment). Nevertheless, it is important to discuss all other aspects of the safety on-site:
  The safety observation cards emitted by the members of the team and the onboard personnel are exposed and discussed.
  - Some safety flashes can be discussed.
  - The safety recommendations from the management and the clients are explained and discussed.
  - Some safety procedures like emergency alarms must be remembered.
  - Diver rescue procedures must be remembered and discussed.
  - Drills must be organised regularly and discussed.
  - Various subjects like living conditions on-site, crew changes, etc., must be discussed.

6.4 - Last checks

These are the classic verifications performed before starting the operation.

- Visual verification of the lifting device
- Verification of the rigging (It is a common practice to deploy a complex rigging to verify it)
- Divers check list
- ROV check list
- Communications
- Conflicting activities under control
- Permit to work & to dive in place

6.5 - Installation, post installation procedures, and debriefing

The installation process should strictly follow the task plan and should be stopped if something differs.
The post-installation procedures should also be followed as indicated in the task plan.
A debriefing should be organized following the post-installation procedure. As for the toolbox talk, the lifting supervisor and the lifting manager are in charge of the debriefing that should discuss the following aspect of the procedure:

- Step by step process
- General safety
- Chain of command
- Technical problems (Lifting device, rigging, etc)
- Schedules and conflicting activities

The conclusions of the debriefing are communicated to the construction and project managers and then to the management of the company.

7 - Evaluate and manage the Weather conditions and currents

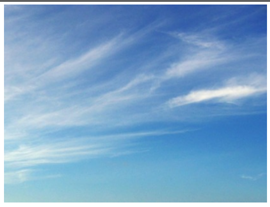
Among reported diving incidents/accidents, a lot were due to adverse environmental conditions not sufficiently anticipated. This is the reason why the supervisor must be sure that everything is under control on this side. For that, a minimum knowledge and good common sense is necessary.

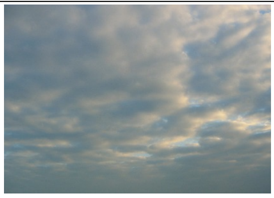
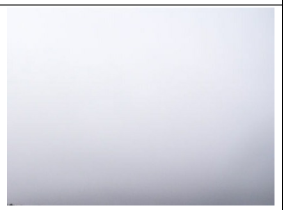
7.1 - Observe and report the weather

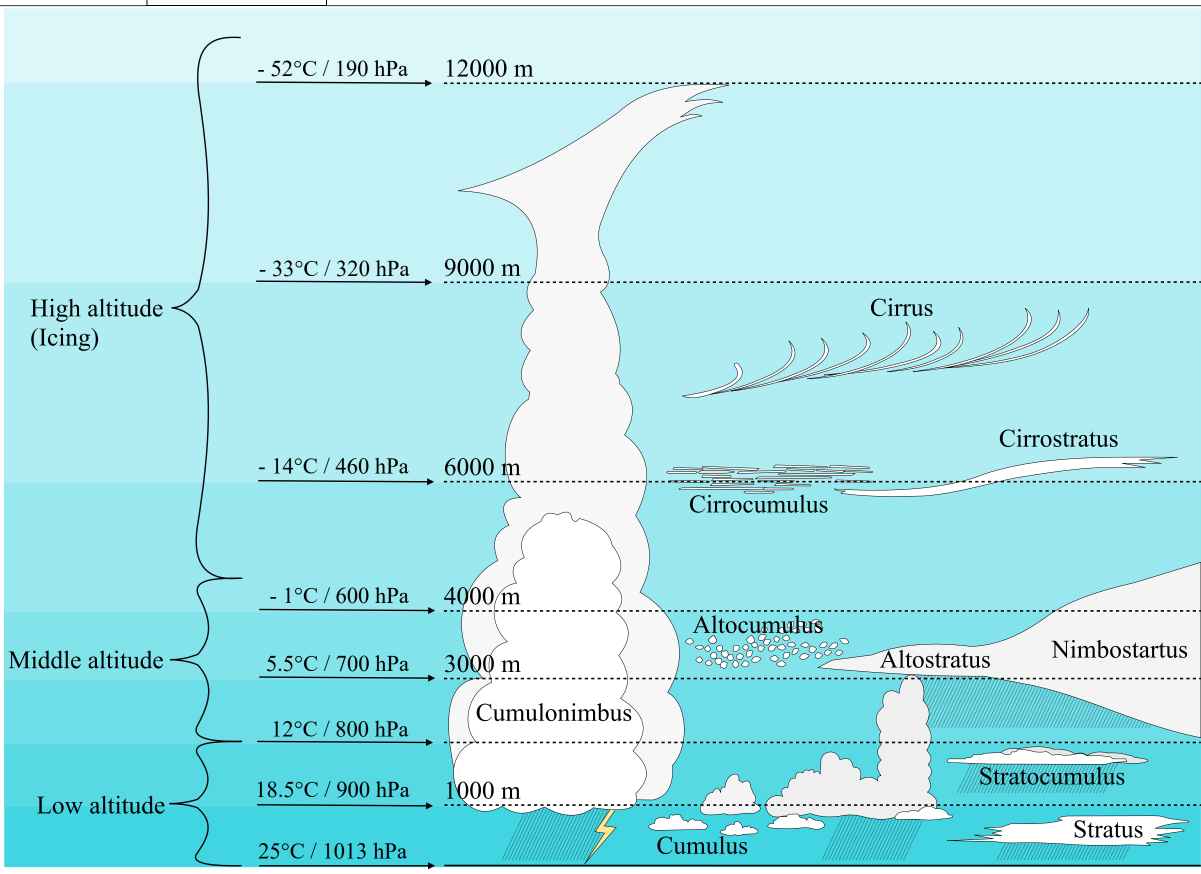
The weather prediction techniques have widely progressed with the development of means of calculation, communications and observation, particularly the space industry. Nevertheless, despite the obvious progress, experience sometimes shows some huge differences with the reality on location. That is why it is important to be able to observe and report clearly what is really happening on site. For that, the means of observation and the classifications developed in the old times are still valid tools.

7.1.1 - Clouds

In addition to the barometer, and the observation of the sea, the “reading” of the clouds is a reliable means of weather prediction.

Altitude	*Name*	*Description*
4000 to 12000 m	Cirrus	Cirrus clouds are formed when water vapor undergoes deposition at high altitudes. Random, isolated cirrus do not have any particular significance, but a large number of cirrus clouds can be a sign of an approaching frontal system or upper air disturbance. When cirrus clouds precede a cold front, squall line or multi-cellular thunderstorm, it is because they have been blown off the top of the cumulonimbus, and the next to arrive are the cumulonimbus clouds. In the tropics, a veil of white cirrus can be seen about 1 and a half days prior the passage of a cyclone. 
4000 to 6000 m	Cirrostratus	As a warm front approaches, cirrus clouds tend to thicken into cirrostratus. When sunlight or moonlight passes through the hexagonal-shaped ice crystals of cirrostratus clouds, the light is dispersed or refracted in such a way that a ring or halo may form. Cirrostratus may thicken and lower into altostratus, stratus, and even nimbostratus. 
3000 to 6000 m	Cirrocumulus	Cirrocumulus clouds are layered clouds which commonly appear in regular, rippling patterns or in rows of clouds with clear areas in between. Like other members of the cumuliform category, they are formed via convective processes. Significant growth of these patches indicates high-altitude instability and can signal the approach of poorer weather. 
2000 to 6000 m	Altocumulus	They are characterized by globular masses or rolls in layers or patches. They are larger and darker than cirrocumulus and smaller than stratocumulus. Altocumulus are commonly found between the warm and cold fronts in a depression, often hidden by lower clouds. Towering altocumulus, frequently signals the development of thunderstorms later in the day, as it shows instability and convection in the middle levels of the troposphere. 
2000 to 4000 m	Altostratus	An altostratus is formed by the lifting of a large mostly, stable air mass that causes invisible water vapour to condense into clouds. It can produce light precipitation. If the precipitation increases in persistence and intensity, the altostratus cloud may thicken into nimbostratus. 
2000 to 4000 m	Nimbostratus	Nimbostratus clouds belong to the Low Cloud group. They are dark grey with a ragged base. Nimbostratus clouds are associated with continuous rain (or snow). Sometimes they cover the whole sky, and you can't see the edges of the cloud. 

Altitude	*Name*	*Description*
2000 to 2400 m	Stratocumulus	They are large dark, rounded clouds, usually in groups, lines, or waves. Larger than the altocumulus, and at a lower altitude. When they produce precipitation, it is only light rain (or snow). However, these clouds are often seen at either the front or tail end of worse weather, so they may indicate storms to come. They are also often seen underneath the cirrostratus and altostratus sheets that often precede a warm front. 
1000 to 3000 m	Cumulus	They are low-level clouds that can have noticeable vertical development and clearly defined edges. They are "cotton-like" in appearance, and generally have flat bases. Cumulus clouds may appear by themselves, in lines, or in clusters. They can be associated with good or bad weather.   Cumulus humilis clouds (photo on the right) are associated with fair weather. Cumulus congestus clouds (Photo on the left) are often precursors of other types of clouds such as cumulonimbus, and usually associated with bad weather. Their tops look like cauliflower heads and mean that light to heavy showers can occur.
Surface to 2000 m	Stratus	These clouds belong to the Low Cloud group which form when a sheet of warm, moist air lifts off the ground and depressurises, or when the ambient air temperature decreases, increasing the relative humidity. They can also form from stratocumulus. They are uniform grey in colour and can cover most or all of the sky, and look like a fog that doesn't reach the ground. They can persist for days in anticyclone conditions. 
1000 to 12000 m	Cumulonimbus	Cumulonimbus clouds belong to the Clouds with Vertical Growth group. They are generally known as thunderstorm clouds. A cumulonimbus cloud can grow up to 12 km high. At this height, high winds will flatten the top of the cloud out into an anvil-like shape. Cumulonimbus clouds are associated with heavy rain, (snow & hail), lightning, and tornadoes. Cumulonimbus progress from overdeveloped cumulus congestus clouds and may further develop as part of a supercell. 



Note: To be more realistic with the tropical areas, the temperatures are calculated for 25 degrees at the surface instead of 15 degrees commonly used for the Standard Atmosphere.

7.1.2 - Beaufort scale

Invented by Admiral Beaufort (1774 - 1857), it is an empirical system of measure based on the observation of the sea state and the wind speed: This system allows to identify the condition of the sea with reduced tools.

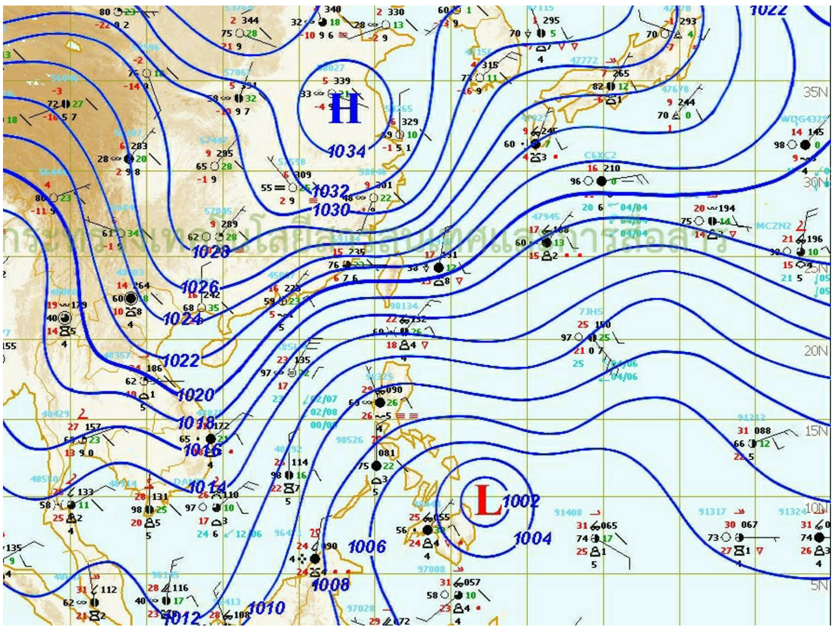
Force (level)	Wind speed (kts)	Waves height	Description	Visual effect
0	0	0	Calm	Sea like a mirror
1	1	0.1	Light air	Ripples with the appearance of scales are formed, but without foam crests
2	4	0.2	Light breeze	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break
3	7	0.6	Gentle breeze	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses
4	11	1	Moderate breeze	Small waves, becoming longer; fairly frequent white horses
5	17	1.8	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed
6	22	3	Strong breeze	Large waves begin to form; the white foam crests are extensive everywhere
7	28	4	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind
8	34	5.5	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam
9	41	7	Strong gale	High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple.
10	46	9	Storm	Very high waves with long overhanging crests; the surface of the sea takes a white appearance; visibility affected
11	56	11	Violent storm	Exceptionally high waves; the sea is completely covered with long white patches of foam; visibility affected
12	64	14 & +	Hurricane	The air is filled with foam and spray; sea completely white with driving spray; visibility seriously affected

7.1.3 - Barometer

A barometer is still used by the forecasters to measure the short term changes. There is a barometer on any boat, and regular records can be helpful to predict the tendency, and also cross check with the indications of the weather maps.

The normal atmospheric pressure at sea level is 760 mm of mercury (also called Torr) which is corresponding to 1013 hecto-Pascal (noted hPa).

- The pressures below 1013 hPa are considered as low. They are indicated on the weather maps by a “L”.
- The pressures Above 1013 hPa are considered high pressure and they are indicated on the map using a “H”.
- Note that some forecasters call the low pressure zones “depression” and the high pressure zone “Anticyclone”. In this case, they are noted using a “D” in place of “L” and an “A” in place of “H”.
- The levels of pressures recorded are indicated on the weather maps using blue or black lines.



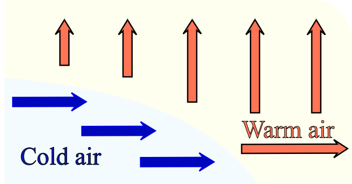
7.2 - Weather system

7.2.1 - Global system

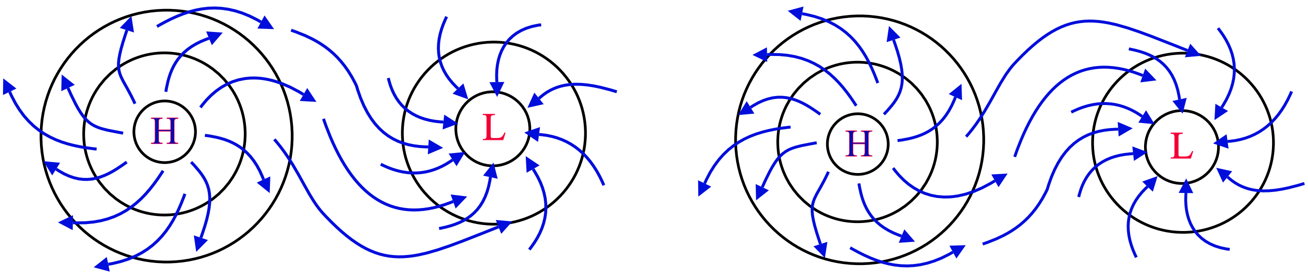
The weather systems are driven by the heat received from the sun at the Earth's surface. Because roughly spherical, with an orientation and a distance from the sun which change during the year, the distribution of heat on earth is not uniform, and varies during the year (it is what we call the seasons). Also, oceans and land absorb heat in different ways. Over oceans, the air temperature remains relatively stable for two reasons: water has a relatively high heat capacity, and because both conduction and convection will equilibrate a hot or cold surface with deeper water. In contrast, dirt, sand, and rocks have lower heat capacities, and they can only transmit heat into the Earth by conduction and not by convection. Therefore, bodies of water stay at a more even temperature, while land temperatures are more variable.

The heat at the surface of land or the sea is transmitted to the atmosphere and creates what is called “air masses”. An air mass is often defined as a widespread body of air that is approximately homogeneous in its horizontal extent, particularly with reference to temperature and moisture distribution; in addition, the vertical temperature and moisture variations are approximately the same over its horizontal extent. The stagnation or long-continued motion of air over a source region permits the vertical temperature and moisture distribution of the air to reach relative equilibrium with the underlying surface: For example, polar air masses are cold and equatorial air masses warm. Air masses over land are usually dry and those above the ocean are moist.

Because the hot air masses are warmer, they expand, and areas of low pressure develop. Meanwhile, the air masses which remain at lower temperatures retain higher pressures. These differences in pressure cause air movements.

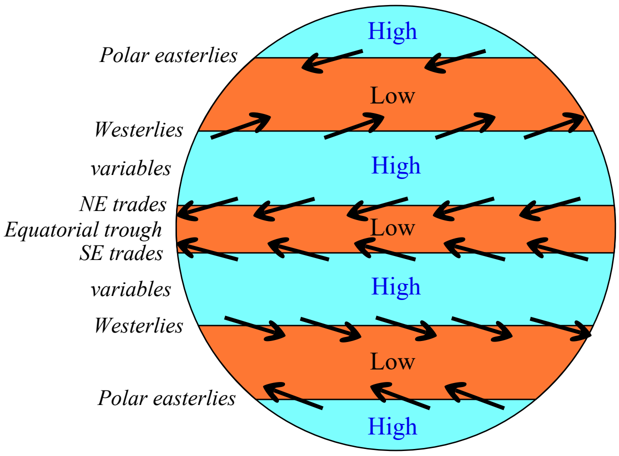


Air naturally flows from high to low pressure; but the “coriolis force” due to the rotation of the Earth, deflect the flow. As a result, in the North Hemisphere, the air from an anticyclone (high pressure) flows clockwise, slightly outwards across the isobars at an angle of about 18°–20°, and blows anticlockwise slightly inwards across the isobars, at an angle of about 10°–20° when approaching a depression. In the South Hemisphere, the circulations are reversed with air diverging in an anticlockwise flow around an anticyclone and converging in a clockwise circulation around a depression. These angles across the isobar are due to the frictions with the environment.



North Hemisphere *South Hemisphere*

Over surfaces free of obstruction, this system should create pressure belts with associated preferential winds, but in reality these belts are disturbed by the land masses. The description of the system is as follows:



- Equatorial trough:

The “Equatorial Trough” or “Doldrums” is a low pressure belt of small gradients. It moves N and S seasonally outside the equatorial latitudes, particularly in the vicinity of large land masses. These areas where the Trade Winds from the two hemispheres converge are marked by lines or zones of massive cumulonimbus clouds and associated heavy downpours, thunderstorms and squalls, and are also named the “Inter-tropical Convergence Zone”. The weather to be expected in the Doldrums is variable light or calm winds alternating with squalls and thunder showers, but there are also stable periods of fine weather. The conditions are generally degraded when the Trade Winds are strong. This zone is often the birthplace of disturbances which can develop and intensify to become violent tropical storms.

- Trade winds:
These winds blow from the sub-tropical oceanic anticyclones (HP) of the N and S Hemispheres towards the "Equatorial Trough". The general direction is NE in the N Hemisphere; SE in the S Hemisphere. They blow persistently over all major oceans of the world, except the North Indian Ocean and the China Seas where the monsoon winds predominate. The zones where they blow follow the migration of the Equatorial trough. Their average speed is between 7 to 16 knots with a maximum strength of 20 knots in the spring. The weather in these zones is generally favourable with clear sky or only small clouds. Mist, fog and impaired visibility can be encountered due to cold ocean currents or dust carried by the wind. The clouds and rain increase towards the "Equatorial Trough" and also near the Westerlies in summer.

- Variables:
"Variable" are the zones covered by the oceanic anticyclones between the "Trade Winds" and the "Westerlies". The winds of these areas are light with fair weather and small amounts of rain.

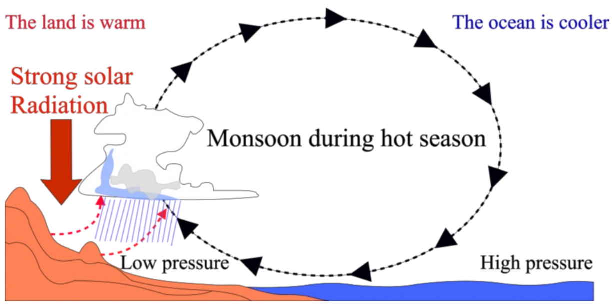
- Westerlies:
They are the areas between 30 and 60 degrees latitude with prevailing winds blowing from the high pressure area in the horse latitude towards the poles from the west to the east. Because there are continual passages of depressions across these zones, the winds vary in direction and strength but they are predominantly from the southwest in the Northern Hemisphere and from the Northwest in the Southern Hemisphere. Gales are frequent, especially in winter, and particularly in the 40° of the South Hemisphere (Roaring Forties). Due to these conditions, the weather changes rapidly and fine weather is seldom prolonged.

- Polar Easterlies:
These prevailing winds are generally from the east. Gales are common in winter often accompanying snow or ice rains . Cloudy sky and fog is frequent in summer. These areas are difficult to access or unreachable by boat due to the amount of ice.

7.2.2- Seasonal system: The monsoon

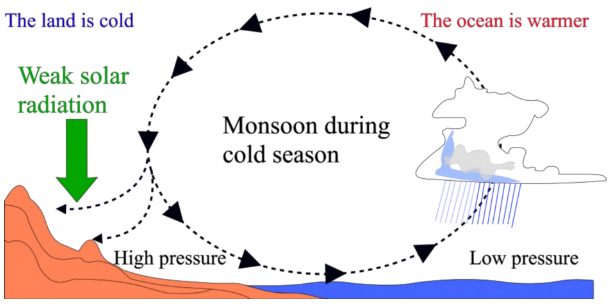
Monsoons are large-scale sea breezes which occur when the temperature on land is significantly warmer or cooler than the temperature of the ocean. "Monsoon" is traditionally defined as a seasonal reversing winds accompanied by corresponding changes in precipitation, and usually refers to the rainy phase, but technically there is also a dry phase.

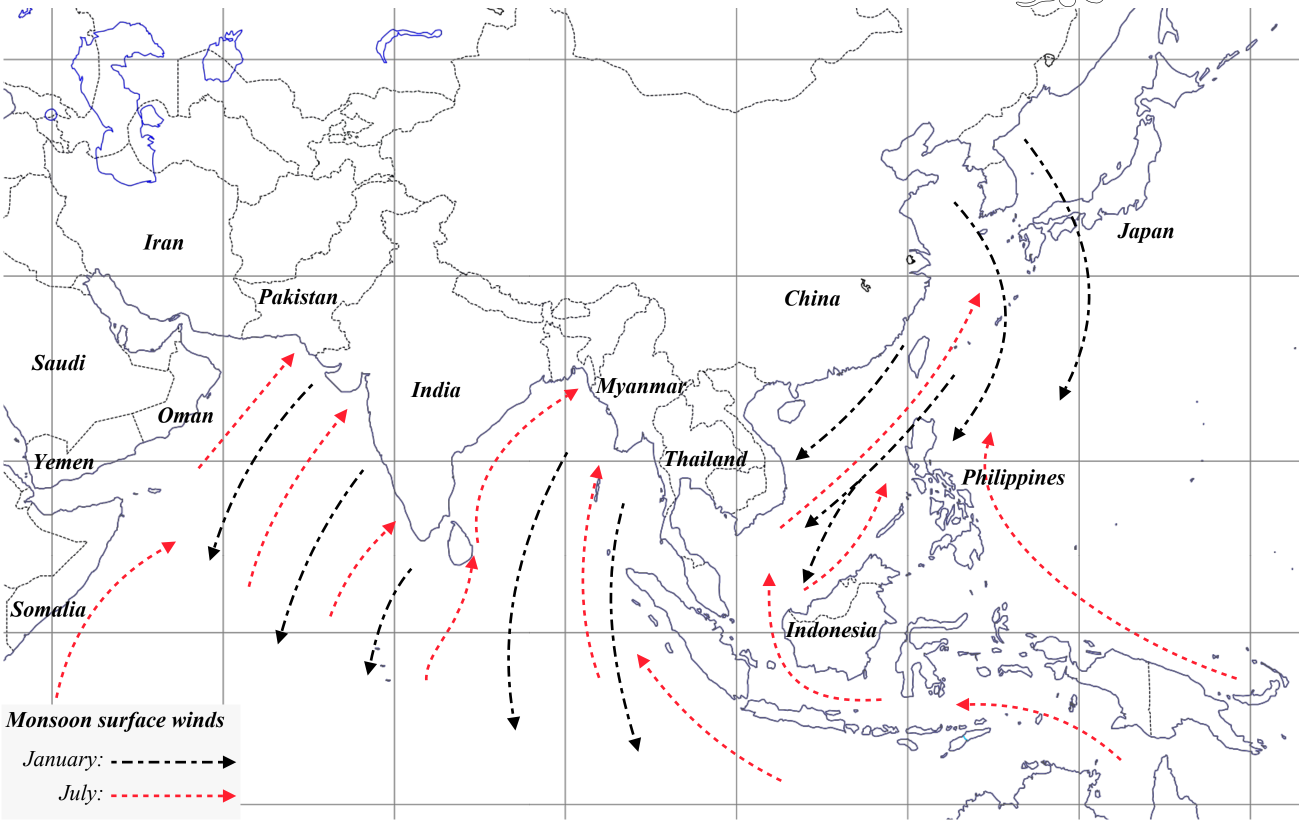
- Hot season:
During the warmer months, the sunlight heats the surfaces of both land and oceans, but land temperatures rise more quickly. As the land's surface becomes warmer, the air above it expands and an area of low pressure develops. Meanwhile, the ocean remains at a lower temperature than the land, and the air above it retains a higher pressure. This difference in pressure causes sea breezes to blow from the ocean to the land, bringing moist air inland. This moist air rises to a higher altitude over land and then it flows back toward the ocean (thus completing the cycle). However, when the air rises, and while it is still over the land, the air cools. This decreases the air's ability to hold water, and this causes precipitation over the land. This is why summer monsoons cause so much rain over land.



As result, in the North, the pressure over Asia falls with lowest pressure near the West Himalayas. The anticlock-wise circulation gives persistent Southwest Monsoon winds from May to September or October over the North Indian Ocean and South China Sea, and South Southwest or South winds over the West Pacific Ocean. Winds are generally fresh to strong and raise considerable seas. Warm humid air gives much cloud and rain on windward coasts and islands.

- Cold season:
In the colder months, the cycle is reversed. The land cools faster than the oceans and the air over the land has higher pressure than air over the ocean. This causes the air over the land to flow to the ocean. When humid air rises over the ocean, it cools, and this causes precipitation.
As result, in the North, an intense anticyclone (high pressure zone) develops over the cold Asian continent and from around October or November to March a persistent North-east Monsoon wind blows over the North Indian Ocean and South China Sea; over the West Pacific Ocean the wind is North Northeast. The winds are generally moderate to fresh but can reach gale force locally as surges of cold air move South and particularly where funneling effects occurs (Taiwan Strait, Palk Strait, for example).



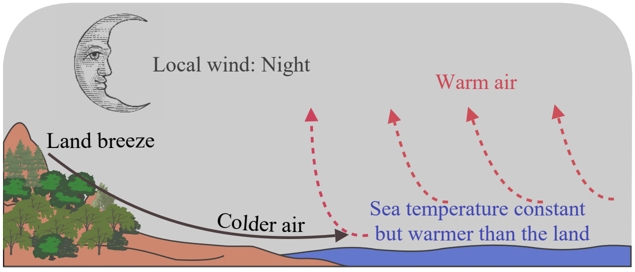


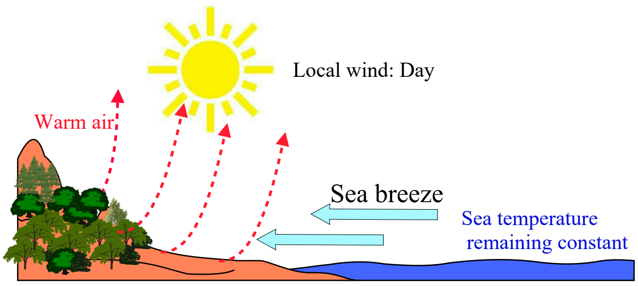
7.2.3 - Local system: Land and sea breeze

The cause of these breezes is the unequal heating and cooling of the land and sea. By day, the sun rapidly raises the temperature of the land surface whereas the sea temperature remains virtually constant. Air in contact with the land expands and rises, and air from the sea flows in to take its place producing an onshore wind known as a “sea breeze”. By night, the land rapidly loses heat by radiation and becomes colder than the adjacent sea; air over the land is chilled and flows out to sea to displace the warmer air over the sea and produces the offshore wind known as a “land breeze”. Sea breezes usually set in during the forenoon and reach maximum strength, about force 4 (occasionally 5 or 6) in mid-afternoon. They die away around sunset. Land breezes set in late in the evening and fade shortly after sunrise; they are usually weaker and less well marked than sea breezes. The following factors favour development of land and sea breezes:

- Clear or partly cloudy skies;
- Calm conditions or light variable winds;
- Desert or dry barren coast as opposed to forests or swamps;
- High ground near the coast.

In windy conditions, the effect of a land or sea breeze may be to modify the prevailing wind by reinforcing, opposing or causing a change in direction.





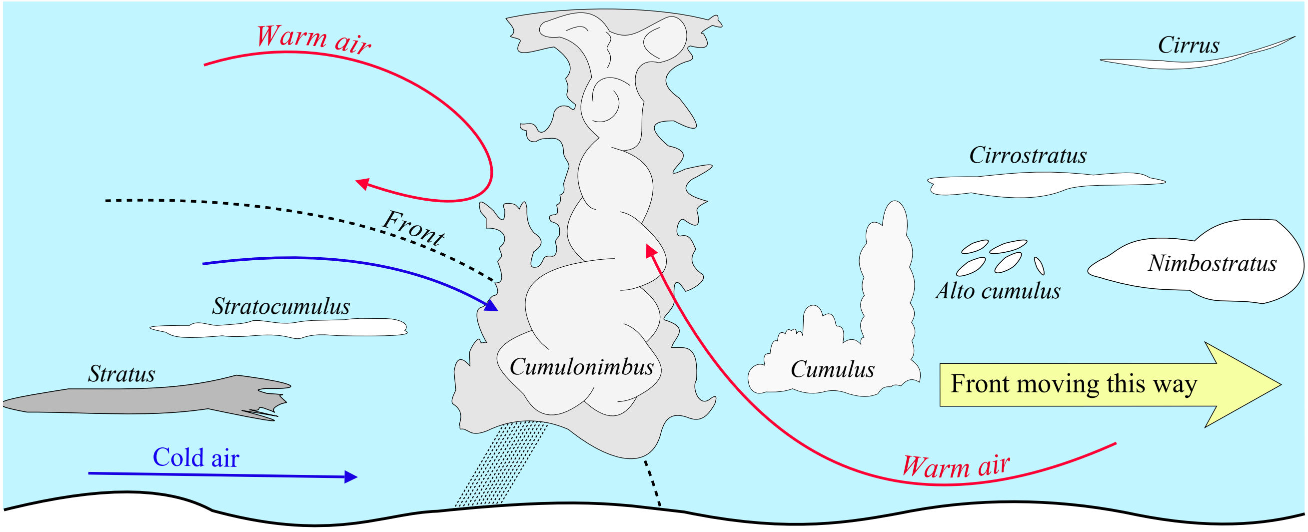
7.3 - Weather perturbations

7.3.1 - Weather front

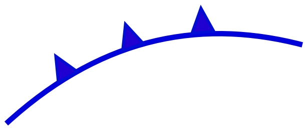
A weather front is a boundary separating two masses of air of different densities, and humidity. It is the principal cause of meteorological phenomena.

- *Cold weather front:*

A cold weather front is due to a cold air mass replacing a warmer air mass. The air behind a cold front is colder and drier than the air in front. Cold fronts generally move from west to east. A cold front approaching is commonly generating strong winds with a sudden drop in temperature and heavy rain. Lifted warm air ahead of the front produces cumulus or cumulonimbus clouds and thunderstorms, often preceded by cirrus, cirrostratus then altostratus and altocumulus. Atmospheric pressure changes from falling to rising at the front. After a cold front moves through an area it may be noticed that the temperature is cooler, the rain has stopped, and the cumulus clouds are replaced by stratus and stratocumulus clouds or clear skies. Because of the greater density of air in their wake, cold fronts and cold occlusions move faster than warm fronts and warm occlusions.

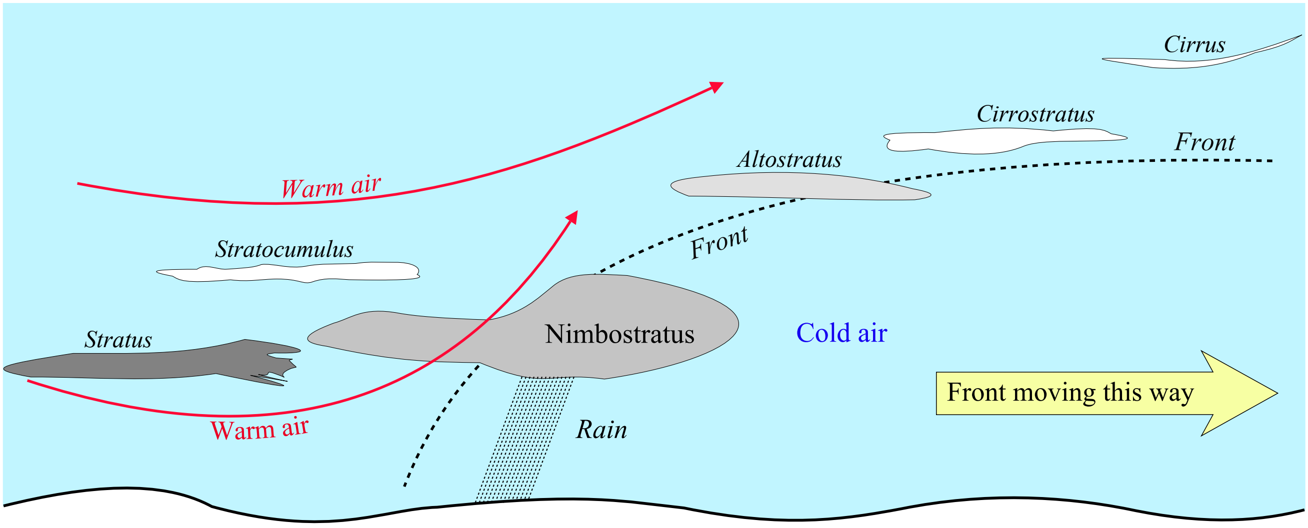


On a weather forecast map, a cold front is represented by a solid line with blue triangles along the front pointing towards the warmer air and in the direction of movement.

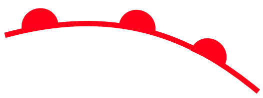


- *Warm front:*

A warm weather front is defined as a warm air mass replacing a cold air mass. Warm fronts usually move from southwest to northeast and the air behind a warm front is warmer and moister than the air ahead of it. When a warm front passes, the air becomes noticeably warmer and more humid than it was before. High clouds like cirrus, cirrostratus, and middle clouds like altostratus are ahead of a warm front. These clouds form in the warm air that is high above the cool air. As the front passes over an area, the clouds become lower and rain and sometimes fog is likely. There can be thunderstorms around the warm front if the air is unstable. The weather usually clears with scattered stratus and stratocumulus. If the warm front is part of a depression, there is often a sheet of altostratus.



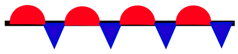
On a weather forecast map, a warm front is represented by a solid line with red semicircles pointing towards the colder air and in the direction of movement.



- *Stationary front:*

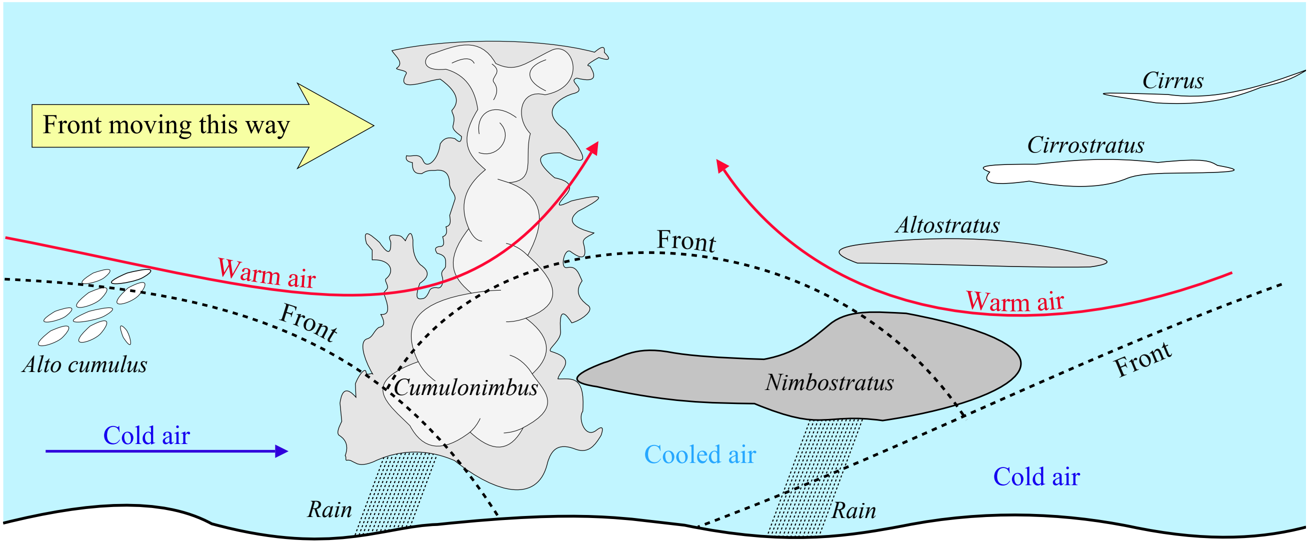
A stationary front forms when a cold front or warm front stops moving. This happens when two masses of air are pushing against each other but neither is powerful enough to move the other. Winds blowing parallel to the front instead of perpendicular can help it stay in place. Stationary fronts may stay put for days. If the wind direction changes the front will start moving again, becoming either a cold or warm front, or the front may break apart.
Because a stationary front marks the boundary between two air masses, there are often differences in air temperature and wind on opposite sides of it. The weather is often cloudy along a stationary front and rain often falls, especially if the front is in an area of low atmospheric pressure. Over time, the density contrast across the frontal boundary vanishes. This is most common over the open oceans. The temperature of the ocean surface is usually the same on both sides of the frontal boundary and modifies the air masses on either side of it to correspond to its own temperature.

On a weather map, a stationary front is shown as alternating red semicircles and blue triangles like in the map on the right. The blue triangles point in one direction and the red semicircles point in the opposite direction.

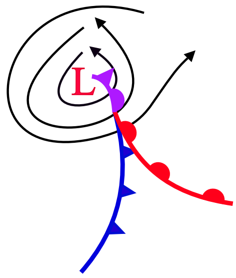


- *Occluded front:*

Sometimes a cold front follows right behind a warm front. A warm air mass pushes into a colder air mass (the warm front) and then another cold air mass pushes into the warm air mass (the cold front). Because cold fronts move faster, the cold front is likely to overtake the warm front. Occluded fronts usually form around areas of low atmospheric pressure.
There is often precipitation along an occluded front from cumulonimbus or nimbostratus clouds with more severe weather than the weather found in a cold front. Wind changes direction as the front passes, and the temperature changes too. The temperature may warm or cool. After the front passes, the sky is usually clearer and the air is drier.



On a weather map, an occluded front looks like a purple line with triangles and semicircles along it pointing in the direction that the front is moving. It ends at a low pressure area shown with a large ‘L’ on the map, and at the other end connects to cold and warm fronts. (See on the right)



7.3.2 - Wind gust & squall

Wind gust is a sudden, brief increase in speed of the wind which reaches at least 16 knots, and the variation in wind speed between the peaks and lulls is at least 9 knots. The duration of a gust is usually less than 20 seconds.
A squall is a sudden, sharp increase in wind speed of 15 knots with a minimum speed of 21 knots which is usually associated with active weather, such as rain showers and thunderstorms.

7.3.3 - Thunderstorm

Thunderstorms are dangerous phenomena which form when very warm, moist air rises into cold air. As this humid air rises, water vapour condenses, forming huge cumulonimbus clouds.

There are two main types of thunderstorms: ordinary and severe.

- Ordinary thunderstorms last about one hour. The precipitation associated with these storms includes rain. With ordinary thunderstorms, cumulonimbus clouds can grow up to 12 kilometers high.
- Severe thunderstorms is a term designating a thunderstorm that has reached a predetermined level of severity. They are generally large, and capable of producing baseball-size hail (25 mm Ø and above), strong winds (at least 93 km/h) , intense rain (> 50 mm / hr, or 75 mm for 3 hrs), flash floods, and tornadoes. Severe thunderstorms can last several hours and can grow 18 kilometers high. These phenomenon can occur from any type of storm cell. However, three common forms of thunderstorms are the most frequently involved in severe weather:
  - “Multicell” thunderstorms, which are clusters of storms that may then evolve into one
  - “Supercell” which are large thunderstorms, also referred to as rotating thunderstorms
  - “Squall lines” are lines of thunderstorms that can form along or ahead of a cold front

- *Thunderstorm formation*

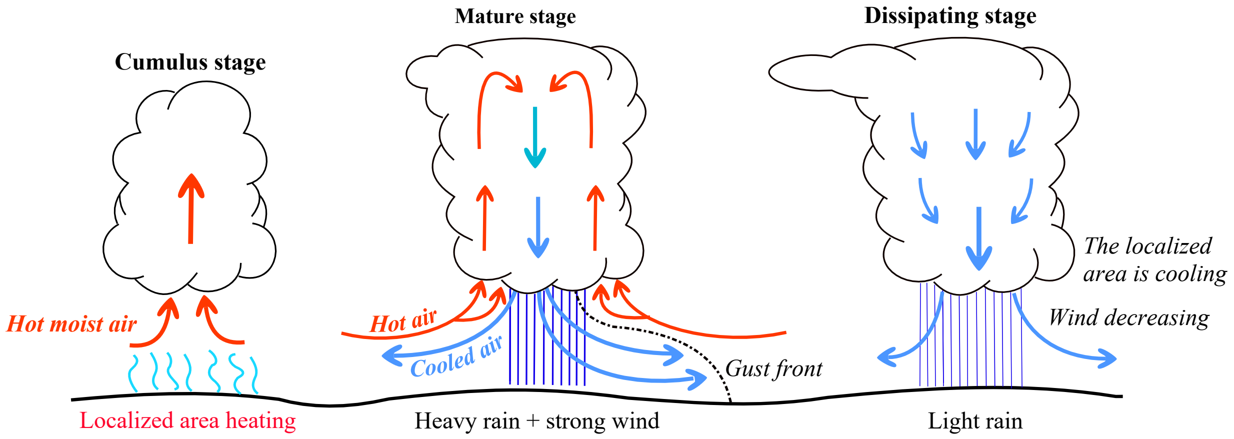
Most thunderstorms develop from a cycle that has three stages: the cumulus stage, mature stage, and dissipating stage.

Cumulus Stage
The sun heats the Earth's surface during the day. The heat on the surface warms the air around it. Since warm air is lighter than cool air, it starts to rise (known as an updraft). If the air is moist, then the warm air condenses into a cumulus

cloud. The cloud will continue to grow as long as warm air below it continues to rise.

Mature Stage:
When the cumulus cloud becomes very large, the water in it becomes large and heavy. Raindrops start to fall through the cloud when the rising air can no longer hold them up. Meanwhile, cool dry air starts to enter the cloud. Because cool air is heavier than warm air, it starts to descend in the cloud (known as a downdraft). The downdraft pulls the heavy water downward, making rain.
This cloud has become a cumulonimbus cloud because it has an updraft, a downdraft, and rain. Thunder and lightning start to occur, as well as heavy rain. The cumulonimbus is now a thunderstorm cell.

Dissipating Stage:
After about 30 minutes, the thunderstorm begins to dissipate. This occurs when the downdrafts in the cloud begins to dominate over the updraft. Since warm moist air can no longer rise, cloud droplets can no longer form. The storm dies out with light rain as the cloud disappears from bottom to top.
The whole process takes about one hour for an ordinary thunderstorm. Supercell thunderstorms are much larger, more powerful, and last for several hours.



Lightning:
Lightning is a giant spark. A single stroke of lightning can heat the air around it to 30,000 degrees Celsius. This extreme heating causes the air to expand at an explosive rate. The expansion creates a shock wave that turns into a booming sound wave known as thunder.

7.3.4 - Tropical cyclones

“Cyclone” is the scientific name referring to hurricane, typhoon, tropical storm, cyclonic storm, and tropical depression. It is a rapidly-rotating storm system characterized by a low-pressure centre, strong winds, and a spiral arrangement of thunderstorms that produce heavy rain. Depending on its location and strength, they are usually characterized by inward spiraling winds that rotate anti-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere of the Earth.
Tropical cyclones typically form over large bodies of relatively warm water. They derive their energy from the evaporation of water from the ocean surface, which ultimately recondenses into clouds and rain when moist air rises and cools to saturation. In fact, the process is similar to thunderstorms.
The first indicator of cyclone development is the appearance of a cluster of thunderstorms over the sea. There are six main requirements to develop a tropical cyclone:

- Sufficiently warm sea surface temperatures
- Atmospheric instability
- High humidity in the lower to middle levels of the troposphere (Troposphere = Surface to 17- 20 km above)
- Enough “Coriolis force” to develop a low pressure centre
- A preexisting low level disturbance
- A low vertical wind shear

With strong cyclones, the Coriolis force initiated by the rotation of Earth causes the resulting low-level winds to spiral anticlockwise in the Northern Hemisphere, and clockwise in the Southern Hemisphere.
The cyclones are classified into 3 main groups based on the intensity:

- *Tropical depression*

It is an organized system of clouds and thunderstorms with a defined, closed surface circulation and maximum sustained winds of less than 34 knots (63 km/h). It has no eye and does not typically have the organization or the spiral shape of more powerful storms. However, it is a low-pressure system, hence the name "depression".

- *Tropical storm*

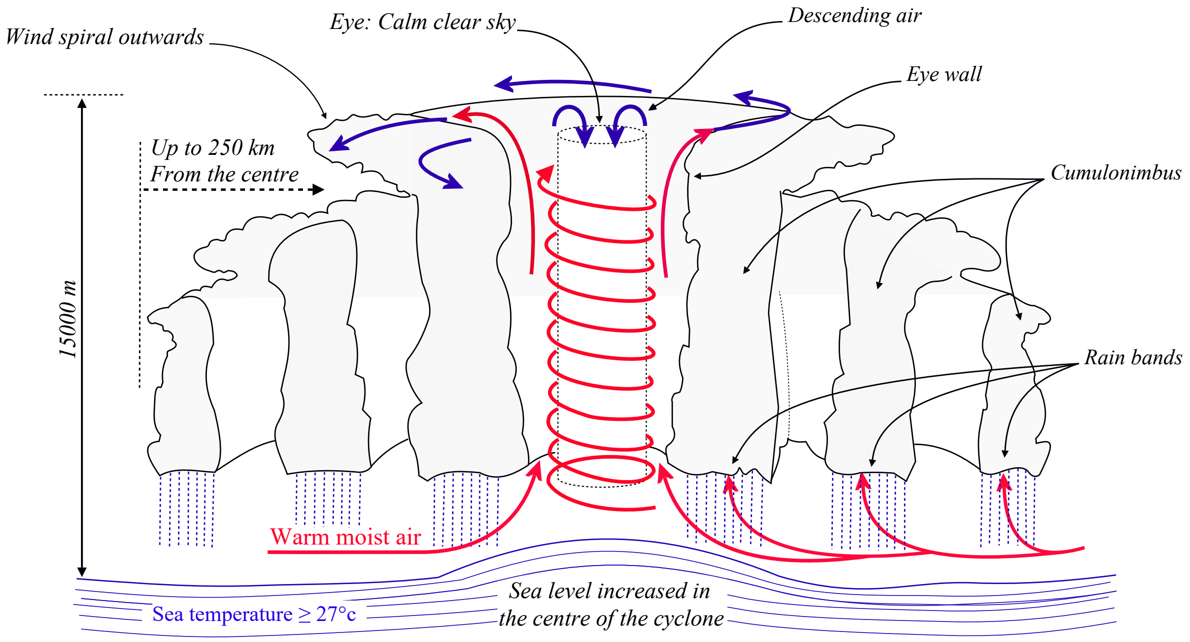
It is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 34 knots (63 km/h) and 64 knots (118 km/h). At this point, the distinctive cyclonic shape starts to develop, although an eye is not usually present.

- *Tropical cyclone or hurricane (also called typhoon):*

Tropical cyclones are typically between 100 and 4000 km in diameter. A cyclone is considered a "hurricane" when the wind speed reaches 119 km/h (64.3 knots). A cyclone of this intensity tends to develop an eye, visible from satellite, which is an area of relative calm and lowest atmospheric pressure at the centre of circulation. Surrounding the eye is the eye-wall, an area about 16 to 80 kilometres wide in which the strongest thunderstorms and winds circulate around the storm's centre. Maximum sustained winds in the strongest tropical cyclones are about 165 knots/h (314 km/h).

A "tropical cyclone" or "hurricane" works like a large heat engine: The fuel is moisture from warm ocean water. The moisture is converted to heat in the thunderstorms that form. Spiral rain bands that surround the tropical cyclone's core help feed the circulation more heat energy. As air nears the centre, it rises rapidly and condenses into clouds and rain. The condensation releases tremendous amounts of heat into the atmosphere. The result is lower surface pressure and strengthening winds.

In this way, the tropical cyclone's engine refuels itself, concentrating its power in a donut-shaped area, called the eye wall, surrounding the centre. The eye wall typically contains the strongest surface winds. Sinking air at the centre clears the tropical cyclone of clouds and forms the "eye." Falling surface pressure can occur only if air mass is removed from the circulation centre. This is accomplished by wind flowing away from the circulation in the upper atmosphere.



Based on wind speeds and damages caused on shore, hurricanes are categorised from 1 to 5 on "Saffir-Simpson" scale. This scale can be used offshore to evaluate the potential damages to a boat and a dive system.

Category 1: Winds 119-153 km/hr. Storm surge generally 1.2-1.5 m (4-5 feet) above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs, and some coastal road flooding and minor pier damage

Category 2: Winds 154-177 km/hr. Storm surge generally 1.8-2.4 m (6-8 feet) above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees, with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center.

Category 3: Winds 178-209 km/h. Storm surge generally 2.7-3.6 m (9-12 ft) above normal. Some structural damage to small residences and utility buildings, with a minor amount of curtain wall (non-load-bearing exterior wall) failures. Damage to shrubbery and trees, with foliage blown off trees, and large trees blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the centre of the hurricane. Flooding near the coast destroys smaller structures, with larger structures damaged by battering from floating debris.

Category 4: Winds 210-249 km/hr (131-155 mph). Storm surge generally 3.9-5.5 m (13-18 feet) above normal. More extensive curtain wall failures, with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the centre of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 feet above sea level may be flooded

Category 5: Winds greater than 249 km/hr (155 mph). Storm surge generally greater than 5.5 m (18 feet) above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures, with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the centre of the hurricane. Major damage to lower floors of all structures located less than 4.5 m (15 feet) above sea level and within 460 m (500 yards) of the shoreline.

- *Precursor signs offshore:*

British Admiralty says: The following signs may be evidence of a storm in the locality; the first of these observations is a very reliable indication of the proximity of a storm within 20° or so of the equator. It should be borne in mind, however, that very little warning of the approach of an intense storm of small diameter may be expected.

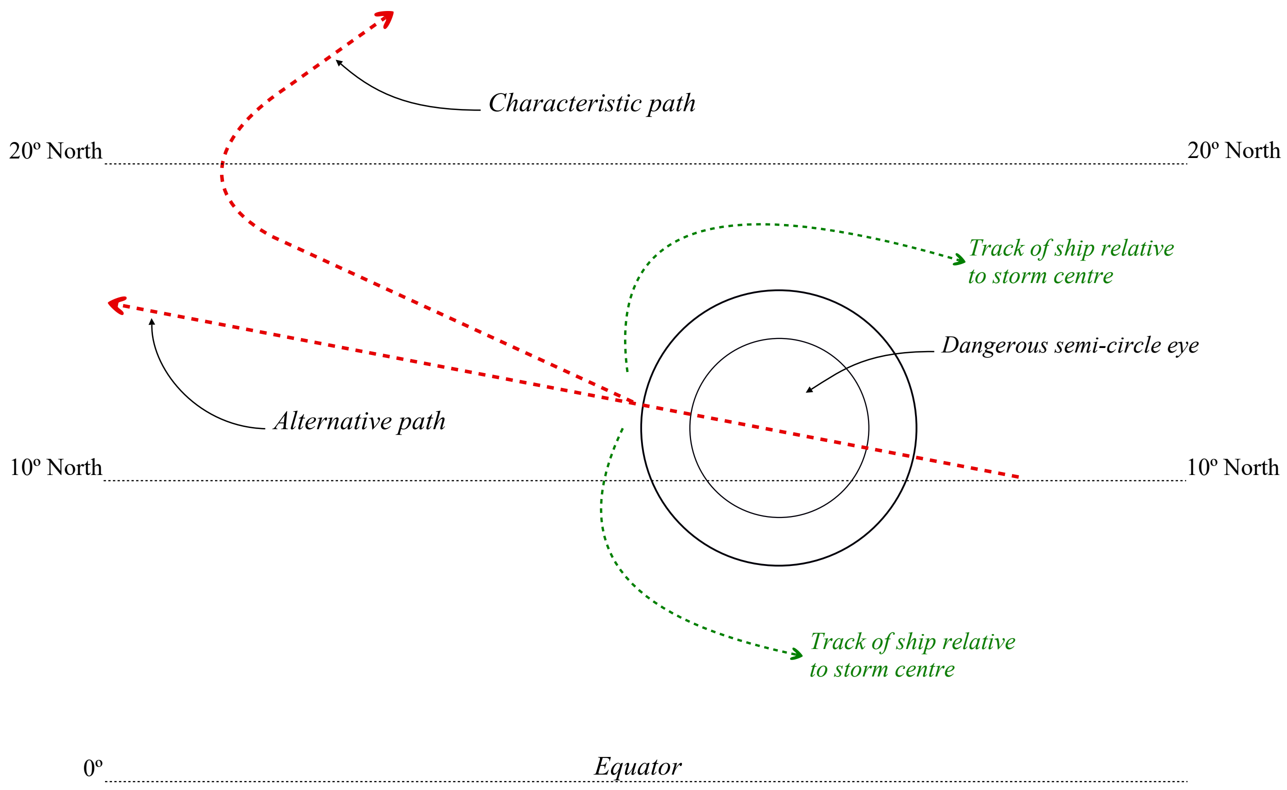
- If a corrected barometer reading is 3 hpa or more below the mean for the time of year, as shown in the climatic atlas or appropriate volume of *Admiralty Sailing Directions*, suspicion should be aroused and action taken to meet any development. The barometer reading must be corrected not only for height, latitude, temperature and index error (if mercurial) but also for diurnal variation which is given in climatic atlases or appropriate volumes of *Admiralty Sailing Directions*. If the corrected reading is 5 hPa or more below normal it is time to consider avoiding action for there can be little doubt that a tropical storm is in the vicinity. Because of the importance of pressure readings, it is wise to take hourly barometric readings in areas affected by tropical storms;
- An appreciable change in the direction or strength of the wind;
- A long low swell is sometimes evident, proceeding from the approximate bearing of the centre of the storm. This indication may be apparent before the barometer begins to fall;
- Extensive cirrus clouds followed, as the storm approaches, by altostratus and then broken cumulus or scud.
- Radar may give warning of a storm within about 100 miles. By the time the exact position of the storm is given by radar, the ship is likely to be already experiencing high seas and strong to gale force winds. It may be in time, however, to enable the ship to avoid the eye and its vicinity where the worst conditions exist.

- *Path of the storm:*

British admiralty also says: To decide the best course of action if a storm is suspected in the vicinity, the following knowledge is necessary:

  - The bearing of the centre of the storm.
  - The path of the storm.

- If an observer faces the wind, the centre of the storm will be from 100° to 125° on his right hand side in the N hemisphere when the storm is about 200 miles away, when the barometer has fallen about 5 hPa and the wind has increased to about force 6. As a rule, the nearer he/she is to the centre the more nearly does the angle approach 90°. The path of the storm may be approximately determined by taking two such bearings separated by an interval of 2–3 hours, allowance being made for the movement of the ship during the interval. It can generally be assumed that the storm is not traveling towards the equator and, if in a lower latitude than 20°, its path is most unlikely to have an E component. On the rare occasions when the storm is following an unusual path it is likely to be moving slowly.
- The diagram below shows typical paths of tropical storms and illustrates the terms dangerous and navigable semicircle. The former lies on the side of the path towards the usual direction of recurvature, the right hand semicircle in the N and the left hand semicircle in the S Hemisphere. The advance quadrant of the dangerous semicircle is known as the dangerous quadrant as this quadrant lies ahead of the centre. The navigable semicircle is that which lies on the other side of the path. A ship situated within this semicircle will tend to be blown away from the storm centre and recurvature of the storm will increase her distance from the centre.



In the North Hemisphere (See previous page)

a) If the wind is backing, the ship will be in the dangerous semi circle. The ship should proceed with all available speed with the wind 10 degrees - 45 degrees depending on speed on the port bow. As the wind backs the ship should alter course to port thereby tracing a course relative to the storm as shown in the diagram on the previous page

b) If the wind remains steady in direction or nearly steady so that the vessel should be in the path of the storm or very nearly in its path. She should bring the wind well on to the port quarter and proceed with all available speed. When well within the navigable semicircle act as at (c) below.

c) If the is wind backing the ship is in the navigable semicircle. The ship should bring the wind on the starboard quarter and proceed with all available speed turning to port as the wind backs to follow a track as shown in the diagram.

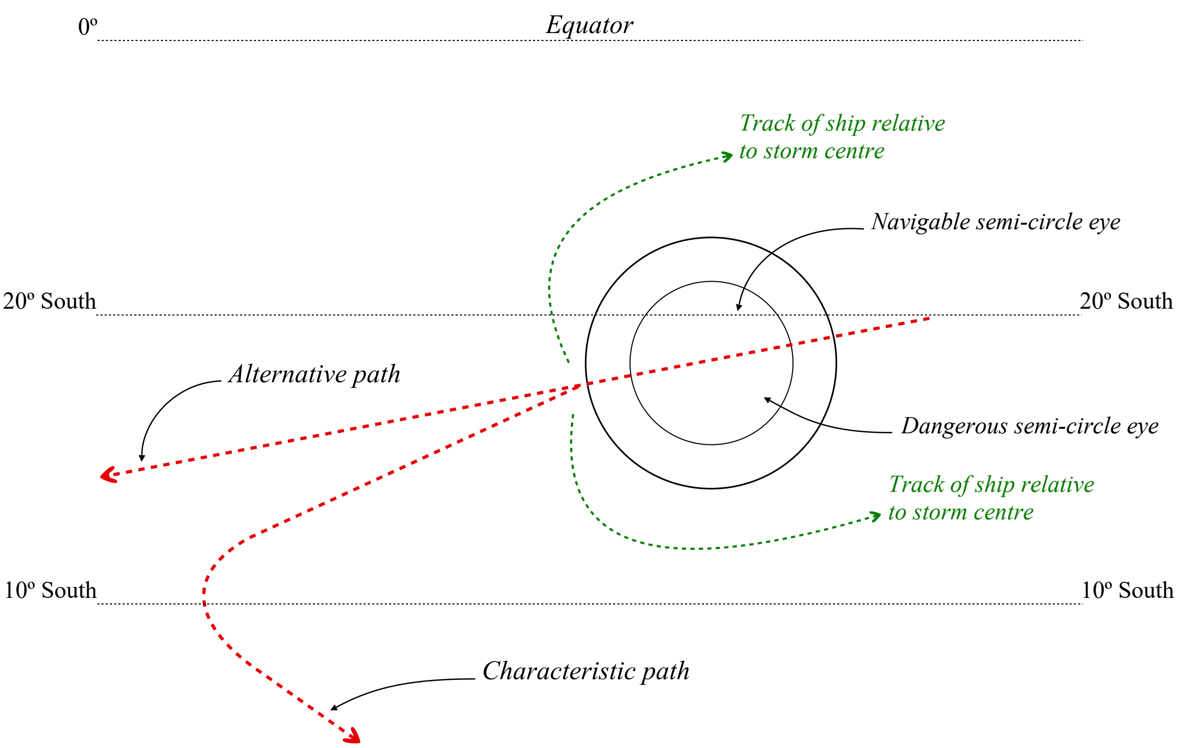
In the South Hemisphere (see below)

a) If the wind backing, the ship must be in the dangerous semicircle. The ship should proceed with all available speed with the wind 10 degrees – 45 degrees, depending on speed, on the port bow. As the wind backs, the ship should alter course to port thereby tracing a course relative to the storm as shown in diagram below.

b) If the wind remains steady in direction, or nearly steady, so that the vessel should be in the path of the storm or very nearly in its path, she should bring the wind well on to the port quarter and proceed with all available speed. When well within the navigable semicircle act as at (*c*) below.

c) If the wind veers, the ship is in the navigable semicircle. The ship should bring the wind on to the port quarter and proceed with all available speed turning to starboard as the wind veers to follow a track as shown in the diagram.

If there is insufficient room to run when in the navigable semicircle and it is not practicable to seek shelter, the ship should heave-to with the wind on her starboard bow in the N hemisphere or on her port bow in the S hemisphere.



- *In the harbour:*

British admiralty also says that when a tropical storm approaches it is preferable to put to sea if this can be done in time to avoid the worst of the storm. A tropical storm in a harbour or anchorage is an unpleasant and hazardous experience especially if there are other ships. Even if berthed alongside or if special moorings are used, a ship may be far from secure.

As an example of what is said above, it is common to find ships that were alongside jetties or moored in a harbor pushed ashore or sunk after a hurricane reached their location.

- *Weakening the cyclones:*

Cyclones and Hurricanes diminish rather quickly when moving over cooler water that can't supply warm moist tropical air, or over land, again cutting off the source of warm, moist air.

The cyclones can also collapse if they are moving into an area where strong winds high in the atmosphere disperse latent heat, reducing the warm temperatures aloft and raising the surface pressure.

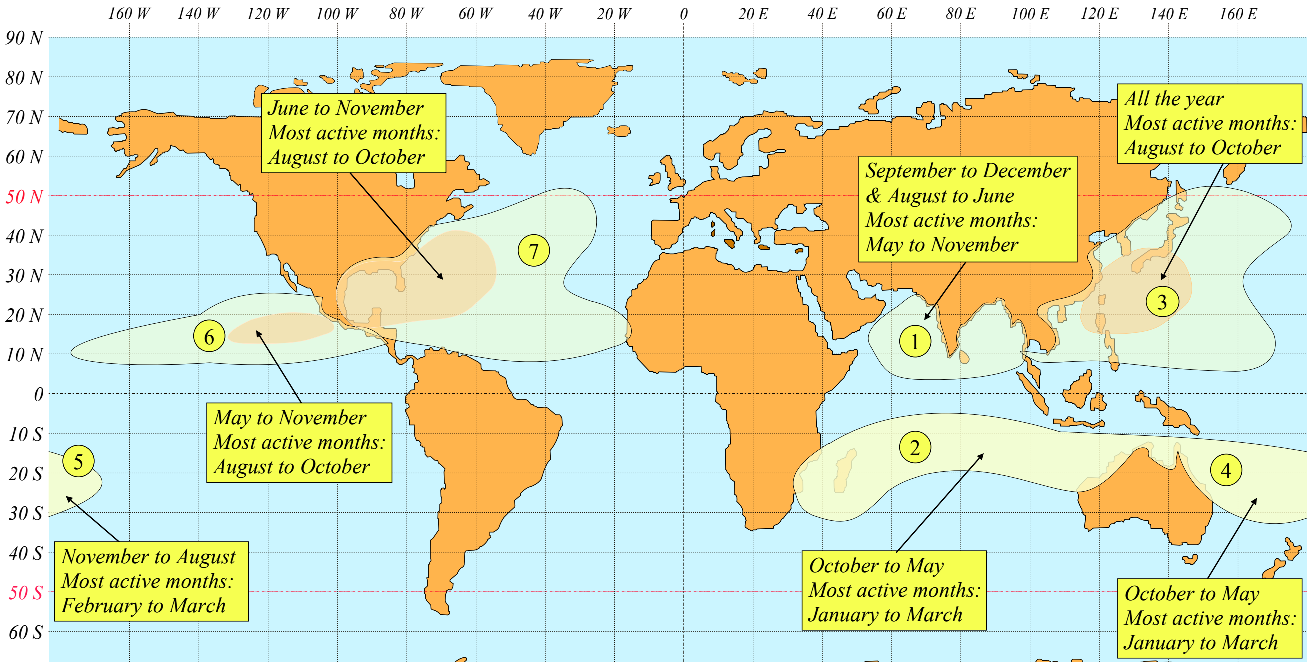
- *Main zones where cyclones are likely to happen:*

A cyclone may develop where all the conditions listed previously can be met.

Areas where Cyclones have favourable conditions to develop are in the Inter-Tropical Convergence Zone. As explained in point 6.2.1, the trade winds from the two hemispheres converge in these zones where cumulonimbus clouds associated with heavy downpours, thunderstorms and squalls are frequently encountered.
There are no cyclones at the equator. For example, there are almost no cyclones in French Guyana, Singapore, or even near the Indian Ocean coast of Africa such as Somalia, Kenya, the northern Tanzania or Zanzibar.
Also, the necessarily warm seas explains why tropical storms are not found in South Atlantic ocean that is under the influence of cold ocean currents. For the same reason, there are no cyclones near the coasts of Chile and Peru, because the "upwelling" phenomenon replaces the warm surface waters of the ocean by wind-driven cold waters from the South Pole and from the very deep depths of the pacific ocean.

In the Northern hemisphere, the summer period is between June and September. However cyclones can develop from June to November.
In the Southern hemisphere, the summer is between December and March, but the cyclonic season extends from November to April or May.

The map and the table below show the main areas where cyclones have been recorded and their average frequency.



Areas where cyclones are likely to be encountered

Areas of high cyclonic frequencies *(> 20/year)*

Number	Situation	Cyclonic period(s)	Most active period(s)	Number of tropical storms / year	Number of hurricanes / year
1	North of Indian Ocean	September to December & August to June	May and November	5	2
2	Southwest of Indian Ocean	October to May	January to March	10	6
3	Northwest of Pacific Ocean	All year	August to October	24	16
4	Southeast Australia	October to May	January to March	6	8
5	South Pacific	November to August	February to March	8	8
6	Northeast and Central Pacific	May to November	August to October	16	8
7	North Atlantic	June to November	August to October	15	7

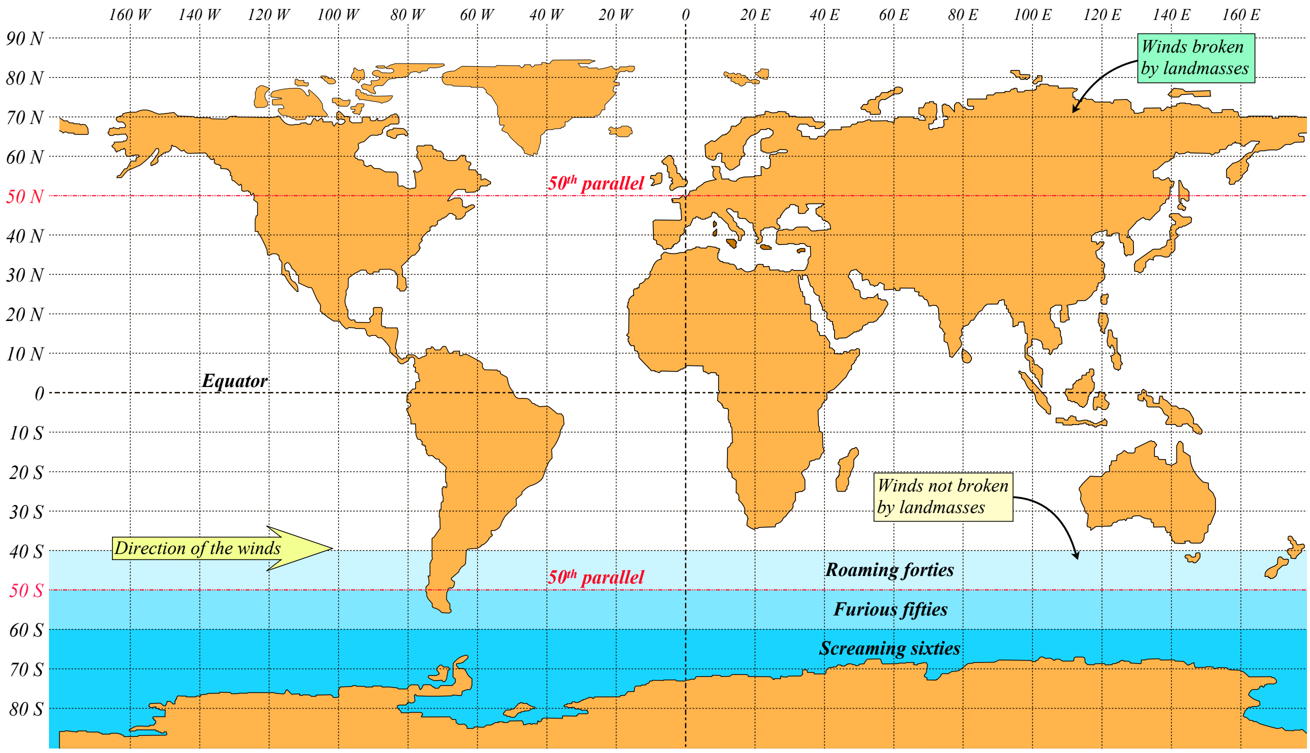
7.3.5 - Polar vortices and their effects

Polar vortices are persistent, large-scale cyclones, circling the North and South poles. The bases of the polar vortices are located in the middle and upper troposphere and extend into the stratosphere. They surround areas of high atmospheric

pressure that are around the poles.
The cold temperatures in the polar regions cause air masses to descend and create high-pressure zones. These air masses of polar origin meet and clash with those of tropical or subtropical origin in convergence zones as the extremely cold and dry air masses do not mix with the warmer moist maritime air masses. Storms with high wind speeds routinely form in these high-temperature gradient regions. The higher the temperature gradient is, the higher the wind speeds will develop. Generally it happens in areas around the 50th parallels of latitude.
Polar vortices are strong in winter and weaken in summer due to their dependence upon the temperature differential between the equator and the poles. The air in a polar vortex circulates counter-clockwise in the Northern hemisphere, and clockwise in the Southern hemisphere.

Polar vortices have an influence on Westerlies that increase in strength when the polar vortices are strong. In the south hemisphere, they are at the origin of the “Roaring Forties”, “Furious Fifties”' and “Screaming Sixties”.
The “Roaring Forties” are strong westerly winds found between the latitudes of 40 and 50 degrees. These almost continuous winds are powerful as they are not broken by landmasses except for the extremity of the South American continent and New Zealand.
The “Furious Fifties” that are between the latitudes of 50 and 60 degrees and the “Screaming Sixties” that are below 60 degrees latitude are subject to incessant storms and hurricanes with waves that can be over 15 m in height. Icebergs are common in these latitudes.

It must be noticed that some offshore facilities are situated in such areas where the working conditions are much difficult and hazardous.



7.4 - Effects of the wind on the crane

High winds can affect the safety of the crane by swinging the load, reducing the crane's stability. They also may induce stresses over the equipment's structural integrity, which can cause an overloading situation, possibly causing boom failure and mobile cranes tipping over, resulting in personnel injuries or fatalities.
Crane specialists say that it must be kept in mind that the higher the crane lifts the load, the more the effects of the wind speed are likely to be. The table below from the “Construction Plant Hire Association (https://www.cpa.uk.net)”, provides increasing factors in areas without obstructions.

Height	*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*	*100*	*110*	*120*	*130*	*140*	*150*
Wind speed multiplier	*1*	*1.1*	*1.17*	*1.22*	*1.26*	*1.29*	*1.32*	*1.35*	*1.37*	*1.39*	*1.41*	*1.43*	*1.44*	*1.46*	*1.47*

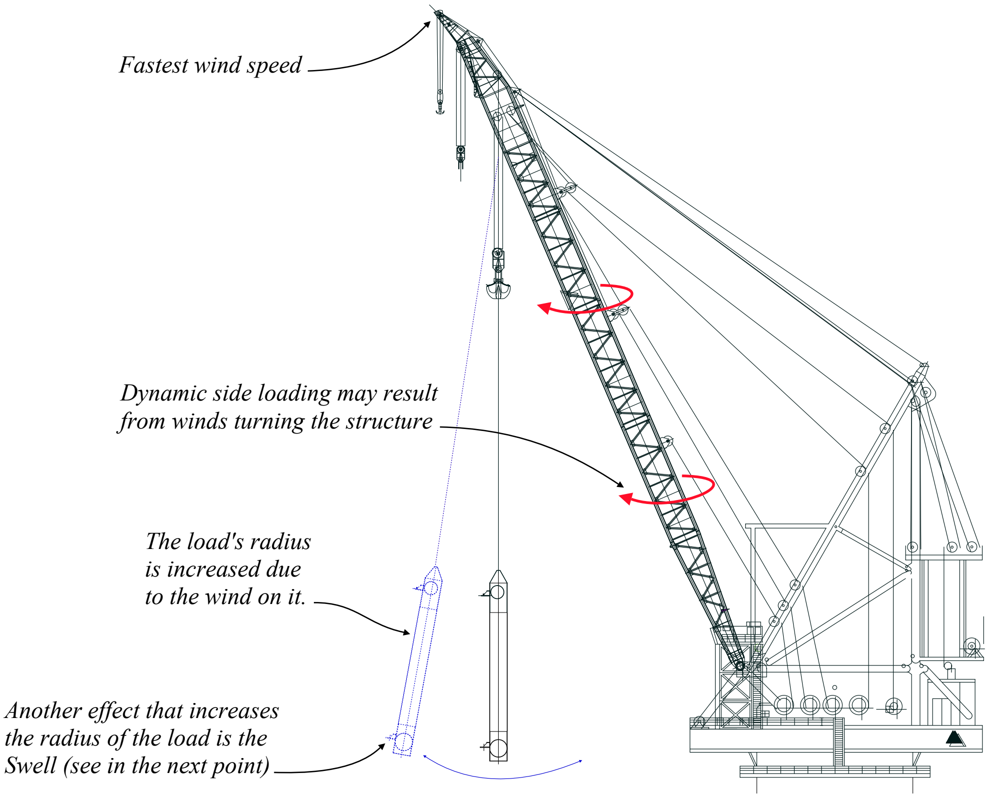
To control the load and lower it to the desired place, the operator must adjust the load taking into account the effects of the wind resulting in load drift, load spin, and swinging of the boom. The effect of the wind on the load will depend on its weight, surface exposed, wind speed, and dynamic pressure. The surface is the face of the object exposed to the wind. However, the larger surface is usually taken into account to calculate the surface exposed (SE*). Also, the shape of the load influences its coefficient of resistance, which is used to specifies how great the obstruction to the air flow the body presents. The surface exposed to the wind is therefore the produce of the surface by the coefficient of resistance.

The following coefficient are considered:

Shape	*Cubic or rectangular*	*Cylindrical*	*Ball*	*Wind power plant rotor*
Coefficient of resistance	*1.1 to 2*	*0.6 to 1*	*0.3 to 0.4*	*± 1.6*

The dynamic pressure (DP*) results from air density (1.25 kg/m³) multiplied by the square wind speed (V²) and per 0.5. Or: 1.25 x 0.5 x V². Note that The wind speed is usually given in metres per second and is usually measured at the highest point of the crane. Metres per second can be easily converted in knots per hour by converting it to m per hour and dividing this value by 1852 (1 mile = 1852 m).
Therefore the "wind load" is the result of the surface exposed multiplied by the dynamic pressure. So: SE* x DP*

Also, how the crane is affected depends on the wind's direction. For example, lateral winds are reported to produce more disturbing effects than those flowing from the back of the crane. Note that gusts with winds suddenly changing direction are dangerous and often result in the crane's stability or its boom integrity being compromised. In addition, turbulences created by the boom may create additional constraints even though the wind speed does not vary.
The crane manufacturers provide specification sheets and load charts to provides information on the acceptable wind tolerances. It should be always consulted especially when conducting an important lift.
Regarding complex lifts, most manufacturers and safety organizations guidelines say that critical lifts, so close to the maximum capacity of the crane, should not be attempted during any high wind conditions. Also, the crane should be secured with its boom lowered to its rest support in case of storms or hurricane.

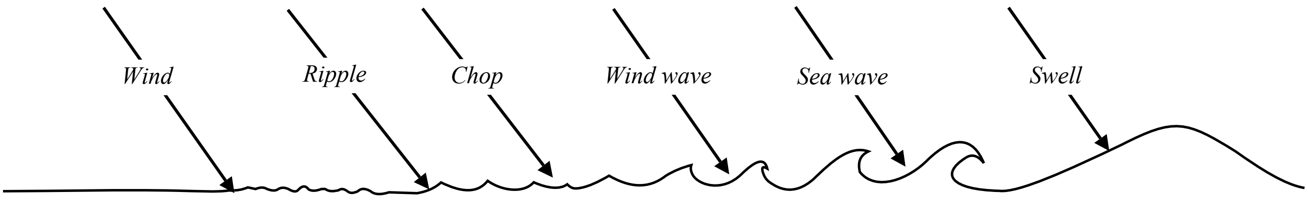


7.5 - Waves and swell

7.5.1 - Waves

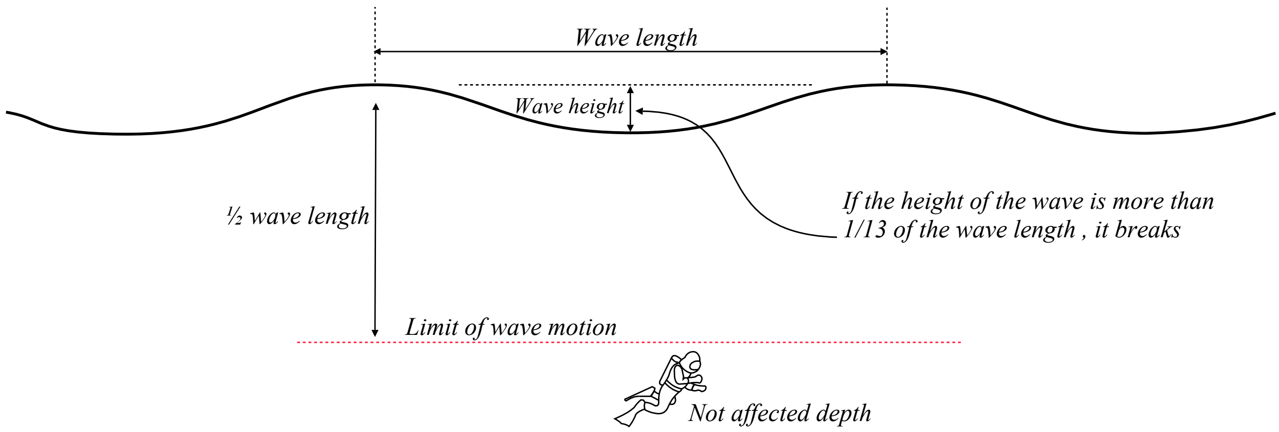
Almost all waves at sea are caused by wind, though some may be caused by other forces of nature such as volcanic explosions, earthquakes or even icebergs calving. The area where waves are formed by wind is known as the generating area, and "sea waves" is the name given to the waves formed in it.

The height of the sea waves depends on how long the wind has been blowing, the fetch, the currents and the wind strength. The Beaufort Wind Scale gives a guide to probable wave heights in the open sea, remote from land, when the wind has been blowing for some time.



Wave generation

The dimensions of a wave are its height, from crest to trough, its wavelength, the distance between crests and the depth to which its movement can be felt. Wavelength is always much greater than height, and if the ratio of height to wavelength becomes greater than about 1:13 the wave breaks. If the wave moves into shallow water, it will slow down, but the wave height increases rapidly. It will start to break when the water depth is equal to about half its wavelength.



The distance that the waves will travel depends on their wavelength. Long wavelengths travel furthest, and it is common to experience a long wavelength swell generated by a wind many miles away.
Under normal conditions, the wave pattern is a combination of one or more wave trains. A local wind, for example, may generate waves on top of a remotely produced swell. The interference between the wave trains can produce considerable variation in wave height.

7.5.2 - Swell

Swell is the wave motion caused by a meteorological disturbance, which persists after the disturbance has died down or moved away.
Swell often travels for considerable distances out of its generating area, maintaining a constant direction as long as it remains in deep water. As the swell travels away from its generating area, its height decreases though its length and speed remain constant, giving rise to the long low regular undulations so characteristic of swell.
The measurement of swell is no easy task. Two or even three swells from different generating areas, are often present and these may be partially obscured by the sea waves also present. For this reason a confused swell is often reported.

Sea state

code	Description	Height in metres
0	Calm - glassy	0
1	Calm - rippled	0.1
2	Smooth wavelets	0.1 - 0.5
3	Slight	0.5 - 1.25
4	Moderate	1.25 - 2.5
5	Rough	2.5 - 4
6	Very rough	4 - 6
7	High	6 - 9
8	Very high	9 - 14
9	Phenomenal	over 14

Swell waves

Swell length

Description	Metres
Short	0 - 100
Average	100 - 200
Long	Over 200

Swell height

Description	Metres
Low	0 - 2
Moderate	2 - 4
Heavy	Over 4

7.5.3 - Rogue waves

Rogue waves also called “extreme storm waves”, are waves which height can be up to 26 m, and perhaps above, and quickly break after their formation. They are very unpredictable and come unexpectedly from directions other than those of prevailing winds and waves. Such waves are responsible for the sinking of several vessels, which some of them were more than 250 m long. When the rogue wave has collapsed, the sea returns to its previous condition.

Because these waves are rare, scientists continue to investigate how and when they form. However, two theories have been emitted:

1. Some scientists think that such waves may result from the addition of different waves that travel at different speeds and have their peaks occasionally overlapping, producing an exceptional mass of water that erects as a wall up to the heights indicated before for several minutes.
2. Another theory is that waves may interact with one another, transferring energy between them. These interactions may result in a similar effect as above.

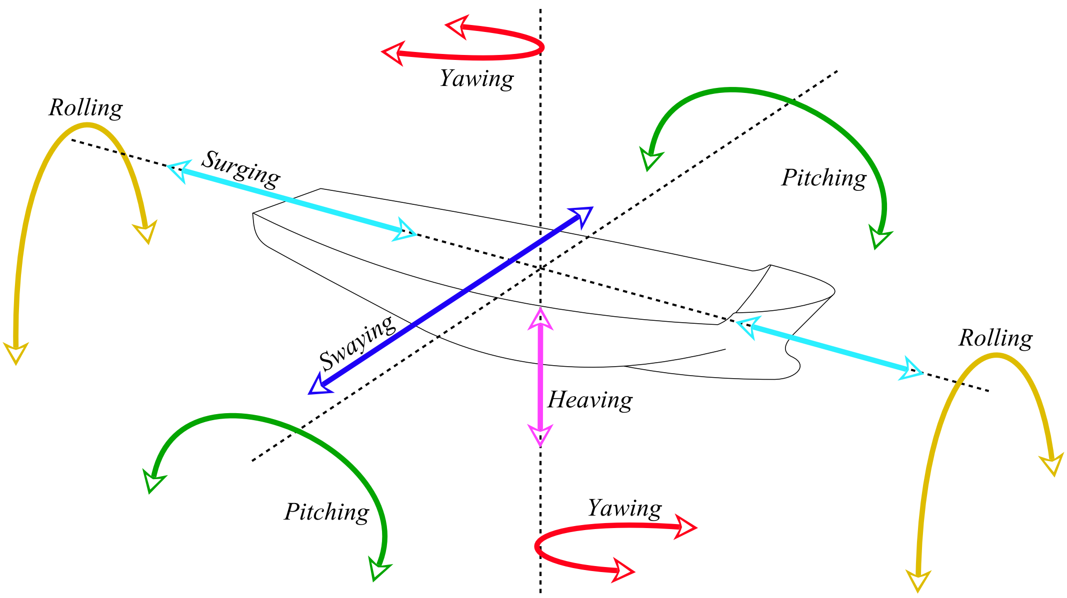
7.6 - Effects of waves and swell

7.6.1 - Effects on the vessel

The weather conditions are likely to exert a combination of forces upon a ship and its cargo over a prolonged period. Such forces may arise from pitching, rolling, heaving, surging, yawing or swaying or a combination of any two or more.
The acceleration values depend on the shapes of the vessel, its beam, the position of the centre of gravity and centre of buoyancy and similar parameters which determine the behavior of ships at sea.

The ship’s movement may be divided into three types of linear motion and three types of rotational motion.

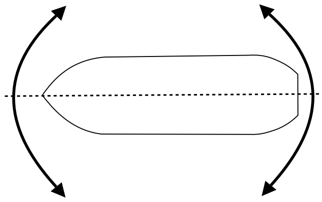
Linear motion	Rotational motion
Surging is motion along the longitudinal axis.	Rolling is motion around the longitudinal axis.
Swaying is motion along the transverse axis.	Pitching is motion around the transverse axis.
Heaving is motion along the vertical axis.	Yawing is motion around the vertical axis.



7.6.1.1 - Rotational motions:

Yawing:

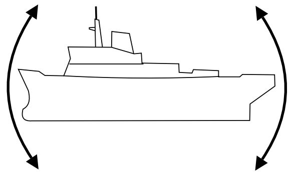
Yawing involves rotation of the ship around its vertical axis. This occurs due to the impossibility of steering a ship on an absolutely straight course. Depending upon sea conditions and rudder deflection, the ship will swing around its projected course. Yawing normally does not happen on a moored barge or 4 point mooring. It has direct effect on a DP vessel heading, but normally, this movement is controlled by the system. Because under control, this movement normally does not affect the diving operation. It also has no effect on the systems installed on deck during the cruising periods.



Pitching:

The ship is lifted at the bow and lowered at the stern and vice versa. Pitching angles vary with the length of the vessel. In relatively long vessels, they are usually less than 5°, but it can be considerably more on small units.

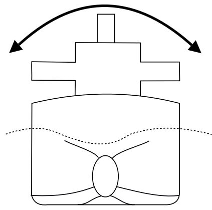
When diving from the stern, which is often the case from supply vessels, these movements create hazardous situations due to the rapid oscillation up and down of the basket/bell, the waves breaking on decks, and the uncontrolled movements during the launching and recovering. In addition the constrains applied to the launch and recovery system can quickly affect its condition.



Rolling:

Rolling involves side-to-side movement of the vessel. The rolling period is defined as the time taken for a full rolling oscillation from the horizontal to the left, back to horizontal then to the right and then back to horizontal. Rolling angle is measured relative to the horizontal. Just in moderate seas, even very large vessels roll to an angle of 10°. In bad weather, angles of 30° are not unusual. Even the largest ships must be expected to roll to such angles. Stabilizers and other anti-heeling systems may help to damp ship movements. However, not all systems are usable or sufficiently effective in bad weather.

A diving operation undertaken from the side of a vessel affected by rolling is very hazardous. Due to the uncontrolled movements, there is a risk of hitting the hull with the baskets/bell during the launching and recovering. The rolling can also create up and down oscillations, initiating shocks and vibrations which can affect the resistance of the whole launch and recovery system in the same manner as the "pitching" effect . Like for the majority of movements applied to the boat, the sea fastenings of the materials stored on deck will be submitted to strong efforts.

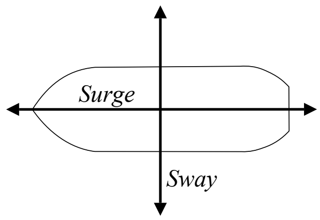


7.6.1.2 - Linear motions:

Surging and swaying:

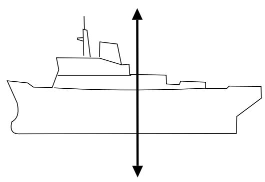
The sea's motion pushes the ship forward and backward and side to side. These movements may occur in all possible axis, not merely, for example, horizontally. If a vessel's fore-body is on one side of a wave crest and the after-body is on the other side, the hull may be subjected to considerable torsion forces.

The diving operations undertaken in these conditions are hazardous with the basket/bell banging the hull during the recovering and launching and over-fatigue of the launch and recovery system. On deck, the materials not sufficiently secured can start to move and create additional danger to the personnel.



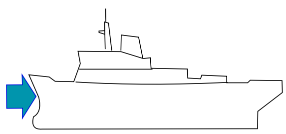
Heaving:

Heaving involves upward and downward acceleration of a ship along its vertical axis. In very long swells, the vessel moves slowly upwards and downwards and is not affected, but the buoyancy varies a lot if the ship is moving through wave crests and troughs with rapid oscillations. Such constant up and down movements have an effect on the materials stored on deck. During the diving operations, they can create hazards due to the basket /bell coming up and down all the time (ears equilibration & possible injuries when coming in and out and hazardous recovery).



Slamming:

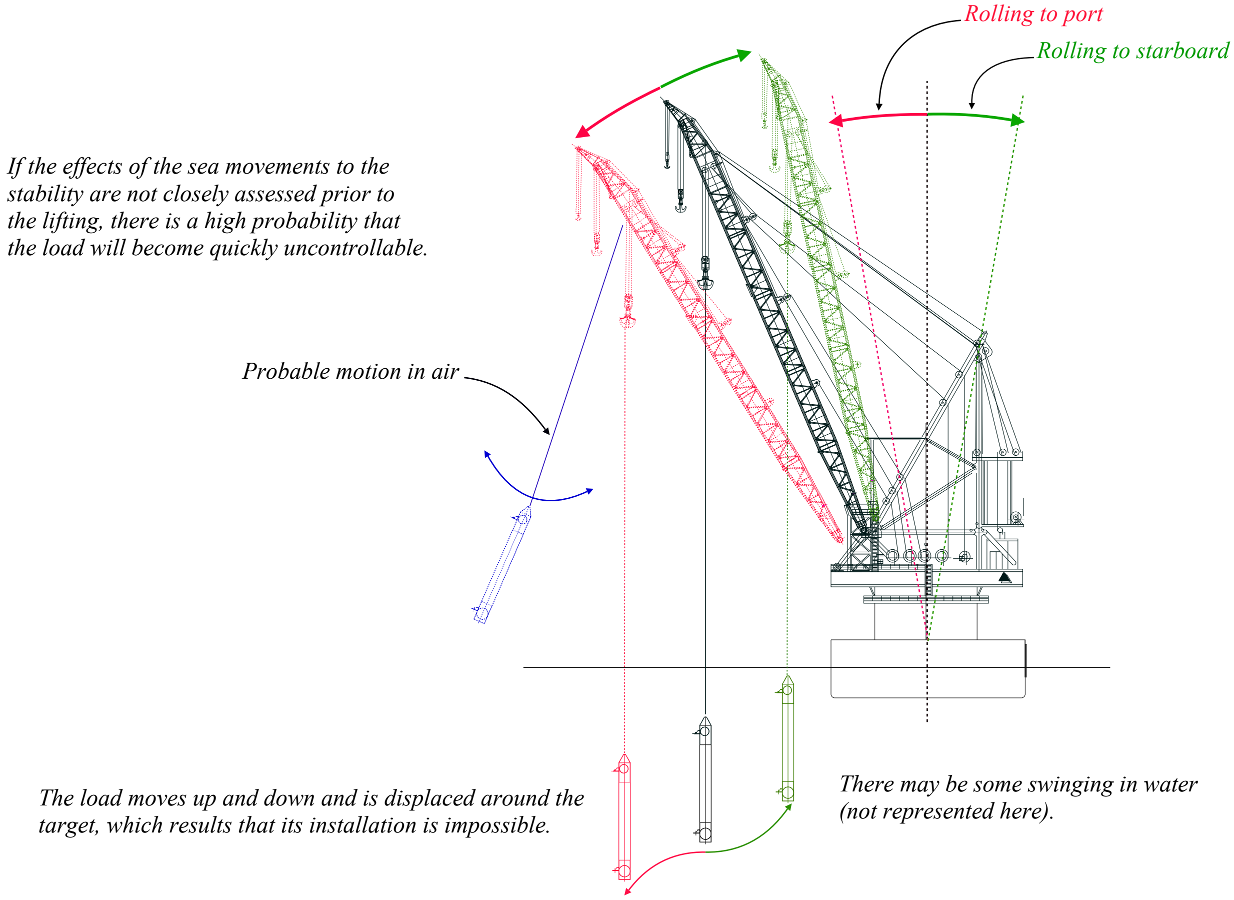
Slamming is not a motion, but the term is used to describe the hydrodynamic impacts which a ship encounters due to the up and down motion of the hull, entry into wave crests and the consequent abrupt immersion of the ship into the sea. This impact creates vibration and stresses to the whole ship and the materials stored in it. Due to their square shapes, barges are very vulnerable to these effects



7.6.2 - Effects on crane operations and systems to control them

7.6.2.1 - Effect on crane operations

In the case of lifting operations by bad sea, the motion of the vessel will be amplified by the boom of the crane, which is often very high. That may result in a load that starts swinging and moving up and down and becomes uncontrollable if the crane and the vessel are not equipped with systems to control these movements.

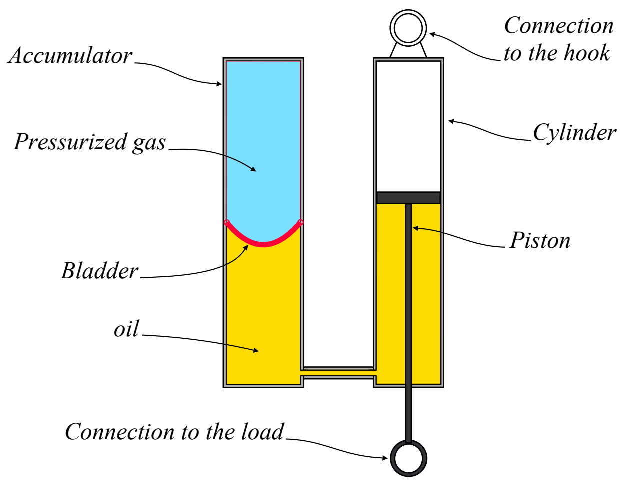


Rolling and pitching effects can be moderated by adjusting the heading of the surface support. However, that can be difficult with anchored vessels due to the constraints resulting from the pre-established anchor positions. Dynamic Positioning vessels offer more possibilities of adjustment, except when they are obliged to work alongside a facility, which is often the case. Also, even though the effects of rolling and pitching can be moderated by adjusting the heading of the vessel, motions such as heaving cannot be under control using such a method. For this reason, modern units are equipped with heave compensation and roll reduction systems.

7.6.2.2 - Heave compensation:

Heave Compensation systems are designed to compensate for the vertical vessel movement caused by waves, so the relative distance between the load and seabed or the other vessel is kept constant.
Heave compensation can be divided into two main categories: passive heave compensation (PHC) and active heave compensation (AHC).

Passive Heave Compensation (PHC) requires no input energy to operate. Its principle of work is to accumulate kinetic energy during the vessel movement and then to use this energy to compensate for the change of position between the vessel and the load. Similarly to a shock absorber, it is a reactive device that attempts to isolate the weight from the vessel heave using a compressed gas cushion (usually nitrogen), as shown in the scheme on the side, where the accumulator is charged with pressurized gas set to hold the load at a steady-state on one side of a bladder that separates the gas from the hydraulic oil, which is at the same pressure as the gas and holds the load by pushing on the piston in the cylinder. Note that some systems use a spring in place of the compressed gas.
Passive Heave Compensators are connected between the hook of the crane and the load.

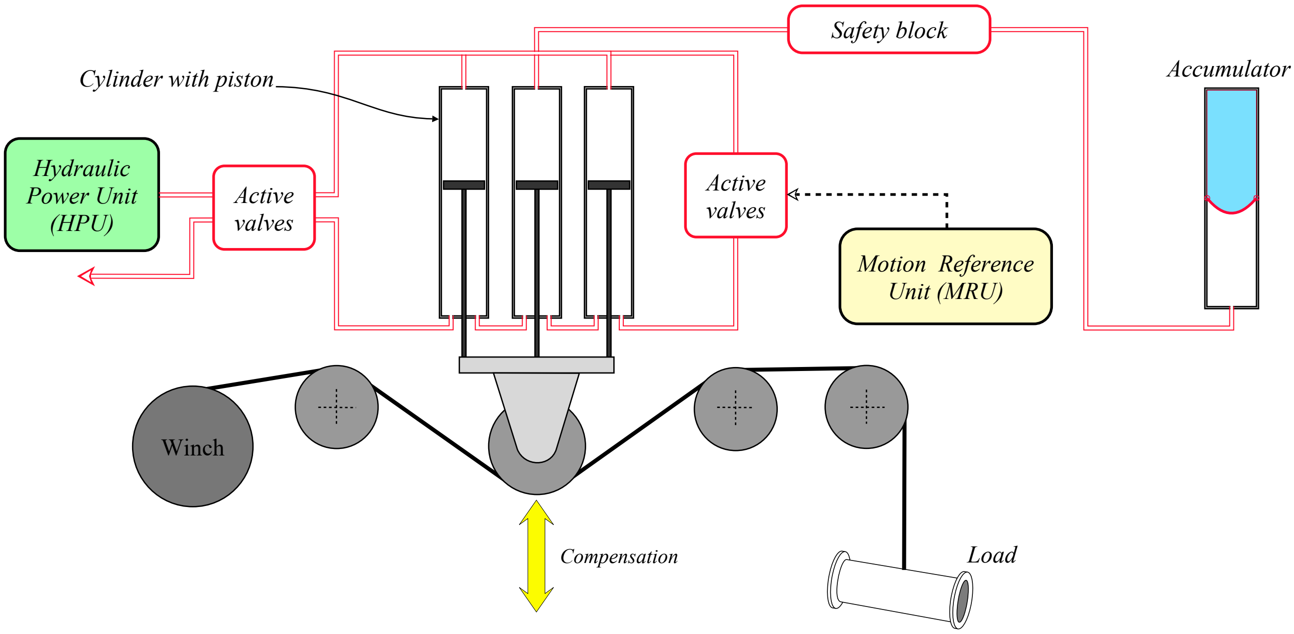


Passive Heave Compensators are often used with lattice boom cranes. Their advantages are that there is no power consumption, they are easy to operate and maintain, and they are relatively cheap.
Their disadvantages are that they require adjustment for the actual load that must have a high resistance to movements, and that they provide a limited range of motion.

Passive Heave Compensation has a limited efficiency, and for this reason, most modern vessels are equipped with Active

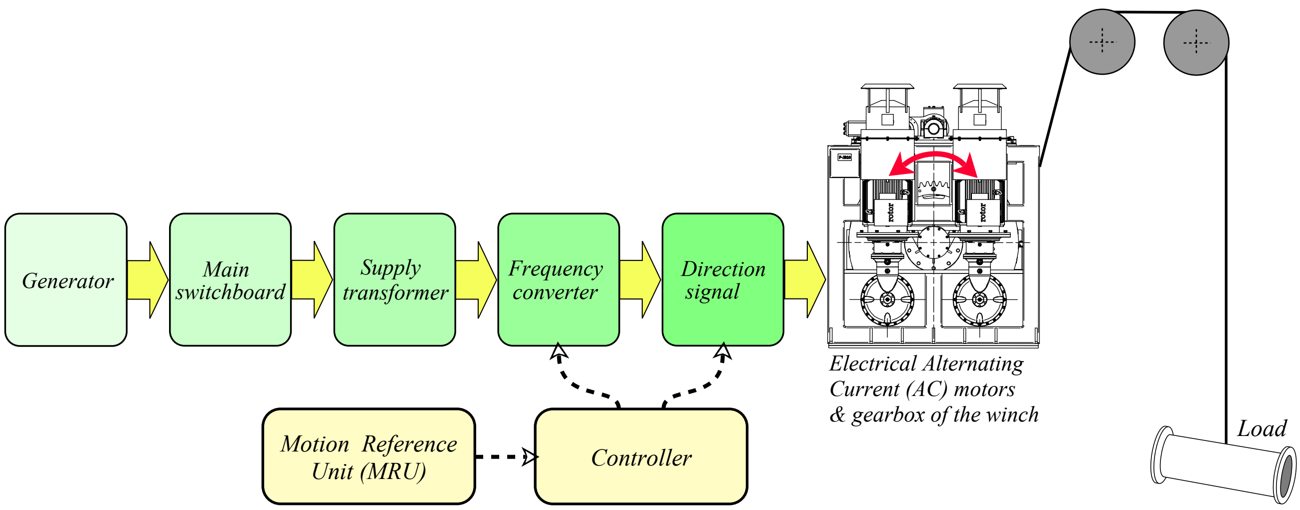
Heave Compensation (AHC) systems.
Active Heave Compensation (AHC) systems utilize a Motion Reference Unit (MRU), which is an inertial measurement unit with multi-axis motion sensors that actively measures all the movements of the vessel. Based on the data collected, a computer calculates the necessary counter motion of the system and controls it in real time. As a result, the length of the cable is permanently adjusted to counteract the vertical movements of the vessel, and there is no variation of the distance of the load from the bottom; thus, its depth is kept constant.
The systems that adjust the length of the cable can be based on hydraulic cylinders, and also rotary hydraulic motors or electric motors that directly move the winch.

Hydraulic cylinder systems are based on pistons that extend and retract according to the direction of the fluid coming from the Hydraulic Power Unit (HPU) through a series of electronically piloted control valves that direct this fluid according to the orders from the Motion Reference Unit (MRU). The cylinders are working independently from the winch, which is usually inactive. They can be installed vertically or horizontally. The function of the accumulator is to maintain a constant pressure in the system.



Rotary hydraulic systems are based on the same principle as hydraulic cylinders. The difference is that the cylinders are replaced by the motor of the winch that acts in one direction or its opposite in function of the direction of the fluid sent from the HPU through the electronically piloted control valves.

Electrically driven heave compensation systems are often used due to their high efficiency as well as the fact that they can be easily fed by the generators of the last generation diesel-electric vessels. Also, it is said that they are more silent than other hydraulic systems. In addition, they do not need an oil reservoir and Hydraulic Power Unit (HPU), which may save some space and attract contractors who do not want to deal with oil replacement and potential leaks.
The advantage of electricity is also that it can act directly to the motor and allows the same torque at a slow speed as that at rapid speed. However, the electricity produced by the generators must be adjusted to the needs of the electric motor of the winch. The scheme below shows an example of a chain of conversion of the electrical current produced by the generator and where the Motion Reference Unit (MRU) intervenes to allow heave compensation.



Definitions:

- *An electric switchboard is a device that directs electricity from one or more sources of supply to several smaller regions of usage. It is an assembly of one or more panels, each of which contains switches that allow electricity* *to be redirected.*

- *A transformer is a device used to change the voltage of an alternating current in one circuit to a different voltage in a second circuit. Transformers consist of a frame-like iron core that has a wire wound around each end. As a current enters the transformer through one of the coils, the magnetic field it produces causes the other coil to pick up the current. If there are more turns on the second coil than on the first coil, the outgoing current will have a higher voltage than the incoming current. This is called a step-up transformer. If there are fewer turns on the second coil than on the first, the outgoing current will have a lower voltage. This is called a step-down transformer.*
- *A frequency converter is a device that converts alternating current (AC) of one frequency to alternating currents of other frequencies. As the speed of an AC motor is dependent on the frequency of the AC power supply changing this frequency allows changing the motor speed. As a result, the rotational speed of the motor can be adjusted using this means instead of using a gearbox, which allows saving energy.*

Active Heave Compensation solves most of the problems that cannot be solved by Passive Heave Compensation, so the distance of the load from the seabed is accurately monitored and stable. That allows increasing the weather window of lifting operations. The major inconveniences of such systems are that they have an elevated demand for power, and the rope wear of cranes equipped with such devices is higher than with classical cranes. Also, they are often complicated, and so are more exposed to breakdowns than passive systems and must be maintained by specialized personnel.

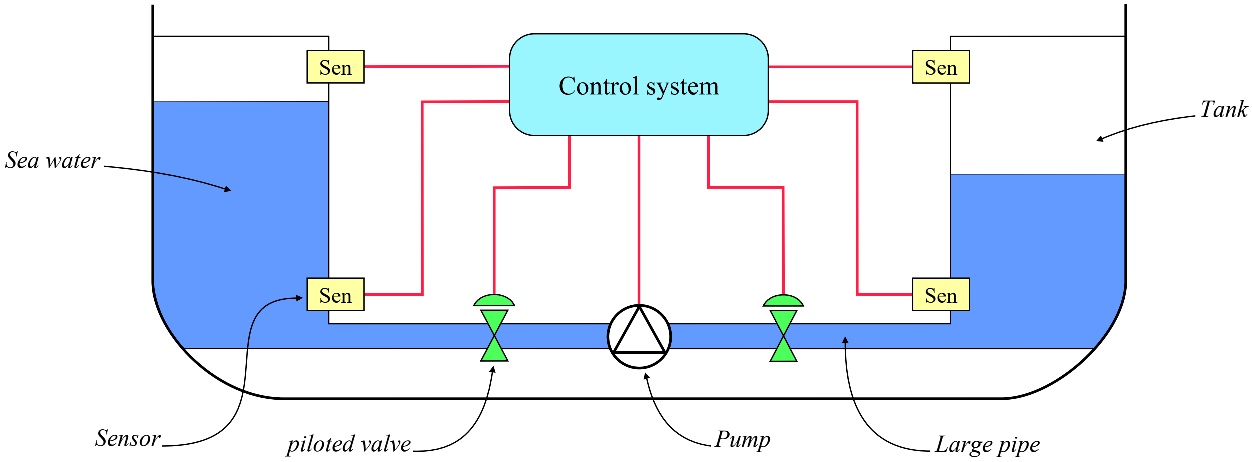
Roll and Pitch compensation:
Active Heave Compensation allows controlling the load vertically on the target but does not control the other movements of the vessel. However, some crane manufacturers have engineered a hydraulically actuated two-directional motion compensation system employing high-speed hydraulic cylinders at the base of the crane.
With the active heave compensation and the two-axis motion compensation system tied into the ship's motion reference unit (a gyro), the system allows full three-axis (x, y, and z) compensation.

7.6.2.3 - Ship stabilization systems:

Boats designed for crane operations with heavy loads may have their stability compromised by the cumulated effect of the waves and the weight deployed overboard. Also, heavy and voluminous cargo that may be on deck and unfavourable weather conditions may influence the behaviour of the boat, making her uncomfortable and affecting her safety. For this reason, several systems of stabilization are in place:

- Bilge keels which are plates projecting from the turn of the bilge and extending over the middle half to two-thirds of the ship's length are in place. They create turbulence dampening the motion of the ship and causing a reduction in rolling amplitude. However, they are effective only when the ship is sailing.
- Ballast tanks, which are compartments filled with sea water, are used to provide stability. Also, the water in the ballasts can be pumped out to temporarily reduce the draft of the vessel when required to enter in shallow waters or to maintain the vessel afloat in the case of flooded compartments.
  Note that according to chapter II / rule 8 - "Construction, structure and stability" of SOLAS (International Convention for the Safety of Life at Sea), ballast systems that can be operated during adverse conditions are mandatory with new vessels.
- Anti heeling tanks / anti rolling tanks which can be used as classical ballast tanks are provided to compensate the movements of the cranes. The anti-heeling system automatically detects the angle of the ship and compensates it, which allows the vessels to have continues loading and unloading cargo operation without stopping in between for tilt correction.
  The system consists of ballast tanks which are internally connected to each other by means of pipelines, automatic valves and control systems. When the ship tilts to any of the sides, the heeling sensor sends the signal for a change of ships angle with respect to the ship's upright position to the master control panel. The change of angle is compensated by auto transferring the water from one side to the other side of the ship, maintaining the

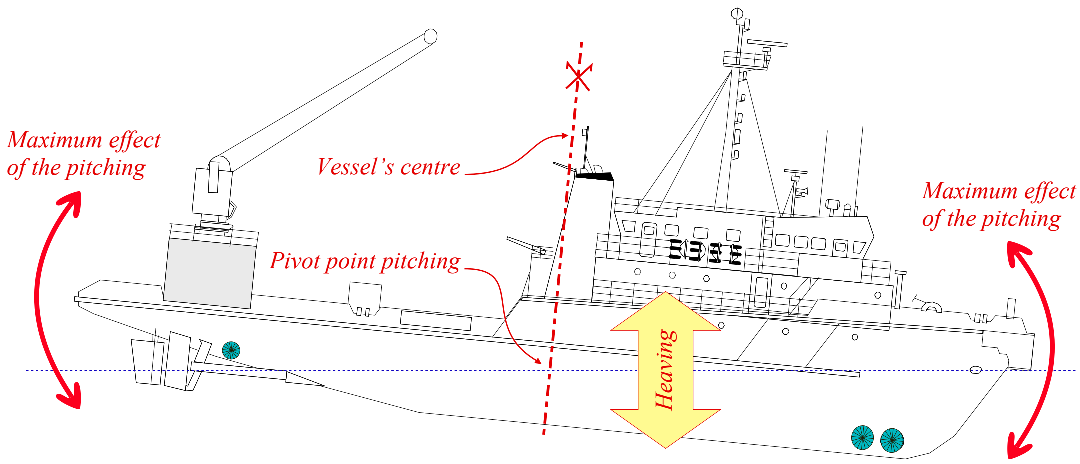
vessel in upright position. The anti heeling system can be used as anti rolling system while the vessel is underway. Similar pumps as those used for ballasting tanks are used to fill and empty these tanks.



7.6.3 - Effects on surface supplied diving operations and the measures to control them

7.6.3.1 - Effect on diving operations:

During unfavorable weather conditions, the effects of the movements of the vessel on a basket or a wet bell are similar to those on a load hanged to a crane. Thus, the basket or bell moves up and down and bumps the hull during the launching and recovery, depending on their amplitude. As a result, the launching and recovery can be dangerous for the divers and the personnel operating the system, who can be seriously wounded or ejected to the sea. In addition, the in-water decompression is not performed in optimal conditions, which may result in a decompression illness. Note that in case the deployment of the diver is done from a ladder by such unfavorable weather conditions, the diver can be thrown away by the waves, injured by the up and down movements of the ladder, and not be able to grab it. Also, the movements of the deployment device are amplified if the position of the Launch And Recovery System (LARS) is at the very stern of the vessel, which is frequently the case with diving operations from units tied to platforms.



Another effect is that the elements incorrectly fastened may be torn off from their initial position and become uncontrolled objects acting like battering rams, resulting in injuries or fatalities of the personnel and equipment damages.

7.6.3.2 - Means of control:

It must be considered that diving operations from unstable surface support are hazardous and must not be launched. For this reason, the sea condition should be risk assessed, taking into consideration the stability of the surface support used, the exposure of the dive station to the weather, and the available means for the rescue of the divers.
The ship stabilization systems described previously are efficient means of control of the rolling. The use of heave compensation systems similar to those used by cranes is technically possible. Unfortunately, surface-supplied diving systems are usually not provided with such devices, even though they are commonly used with saturation systems. The main reasons are their costs, complexity, and the space necessary to install them. However, several other solutions allow to partially compensate for the problems described above:

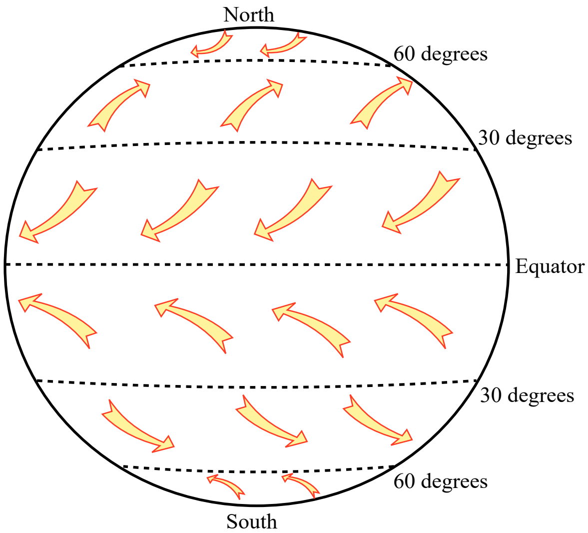
- It is preferable to install the diving launch and recovery station and the crane as close as possible as to the pivot point of the vessel which is not affected by the pitching (see the scheme above).
- A suitable heading of the vessel allows diminishing the rolling and pitching effects. Thus, the ship's position has to be studied during the project preparation. Also, dynamic Positioning vessels can easily modify their orientation, except when working alongside facilities.
- The components of the dive station and tools must be fastened. These fastenings must be calculated and verified.
- Surface decompression procedures must be ready to replace in-water decompression at all times.

7.7 - Ocean currents

The main cause of surface currents in the open ocean is the direct action of the wind on the sea surface and a close correlation accordingly exists between their directions and those of the prevailing winds. It is said that the speed of a wind generated current is usually about 3% of the wind speed. Winds of high constancy blowing over extensive areas of ocean will naturally have a greater effect in producing a current than will variable or local winds. Thus, the Northeast and Southeast Trade Winds of the two hemispheres are the main spring of the mid-latitude surface current circulation.

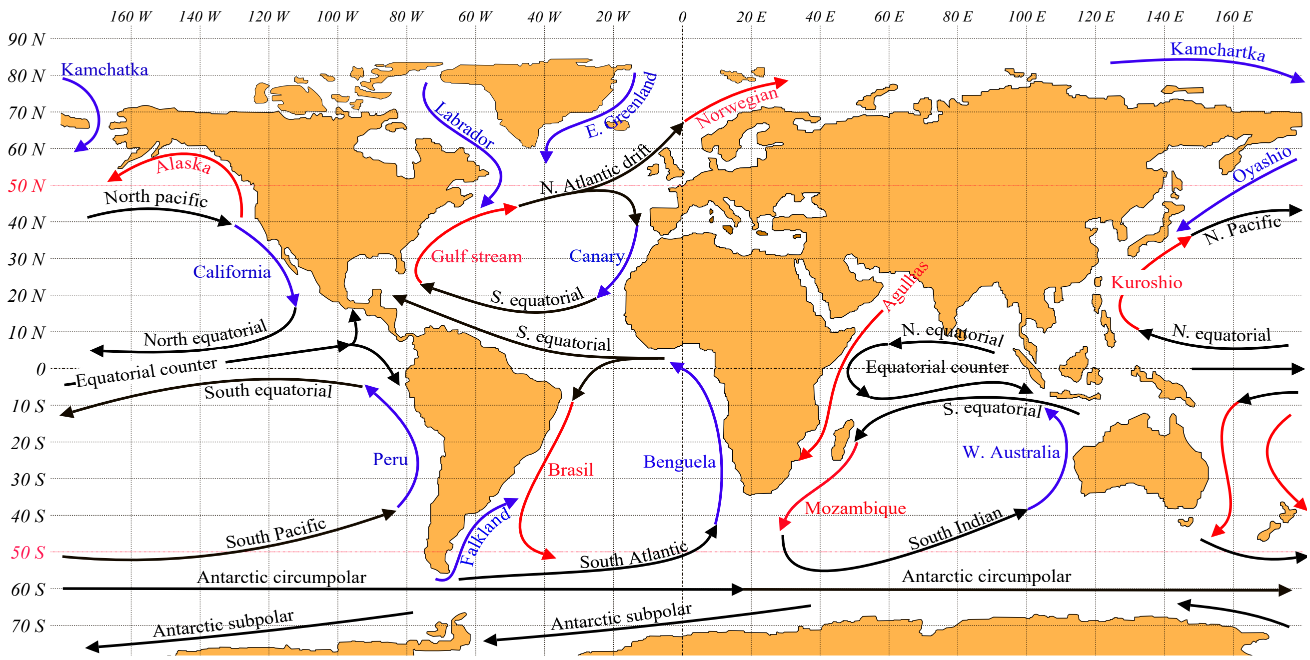
In the Atlantic and Pacific Oceans, the two Trade Winds drive an immense body of water “W” over a width of some 50° of latitude, broken only by the narrow belt of the E-going Equatorial Counter-current, which is found a few degrees N of the equator in both of these oceans. A similar transport of water to the “W” occurs in the South Indian Ocean driven by the action of the Southeast Trade Wind.

The Trade Winds in both hemispheres are balanced in the higher latitudes by wide belts of variable “W” winds. These produce corresponding belts of predominantly E-going sets in the temperate latitudes of each hemisphere. With these E-going and W-going sets constituting the N and S limbs, there thus arises great continuous circulations of water in each of the major oceans. These cells are centred in about 30°N and S, and extend from about the 10th to at least the 50th parallel in both hemispheres. The direction of the current circulation is clockwise in the N Hemisphere and anti-clockwise in the S Hemisphere.



There are also regions of current circulation outside the main gyres, due to various causes, but associated with them or dependent upon them. As an example, part of the North Atlantic Current branches from the main system and flows N of Scotland and N along the coast of Norway. Branching again, part flows past Svalbard into the Arctic Ocean and part enters the Barents Sea.
In the main monsoon regions, the North part of the Indian Ocean, the China Seas and Eastern Archipelago, the current reverses seasonally, flowing in accordance with the monsoon blowing at the time.
The South Atlantic, South Indian and South Pacific Oceans are all open to the Southern Ocean, and the Southern Ocean Current, encircling the globe in an East direction, supplements the South part of the main circulation of each of these three oceans.

Main oceanic currents:



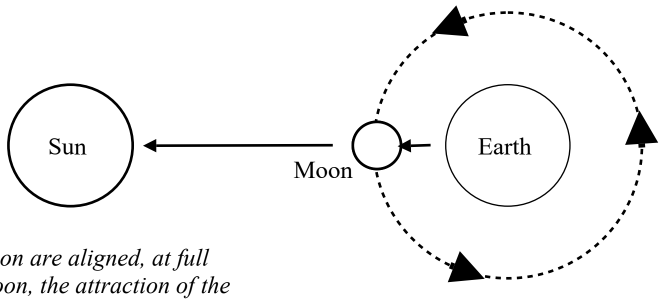
In general, oceanic currents which set continuously E or W acquire temperatures appropriate to the latitude concerned. Currents which set N or S over long distances, however, transport water from higher to lower latitudes, or vice versa. The Gulf Stream, for example, transports water from the Gulf of Mexico to the central part of the North Atlantic Ocean where it gives rise to temperatures well above the latitudinal average. The map on the bottom of the previous page shows the main warm (in red) and cold (in blue) North or South currents, and also the main East or West currents (in black).

7.8 - Tides

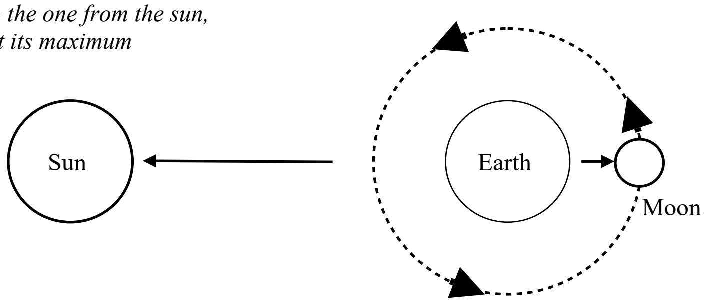
Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the Moon and the Sun and the rotation of the Earth.

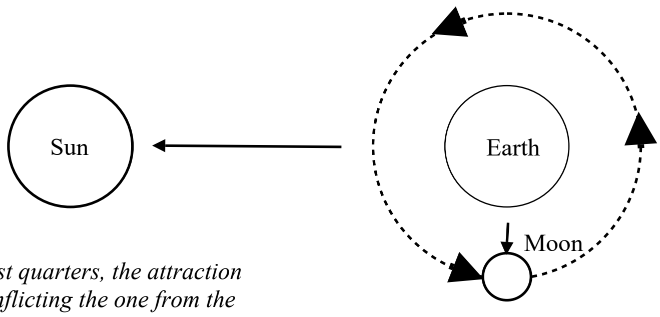
The tidal forces affect the entire earth, but the movement of the solid earth is only centimeters. The atmosphere is much more fluid and compressible, so its surface moves kilometers, in the sense of the contour level of a particular low pressure in the outer atmosphere. Because it is a fluid, the water is also more sensitive to attraction than solid materials and can move up and down several meters, depending of the period of the year.

The peak amplitudes are reached around the spring and autumn equinoxes along the Atlantic coast, or around the summer and winter solstices in some parts of Asia.

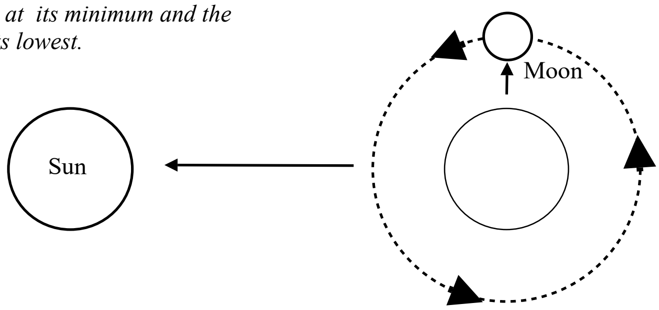


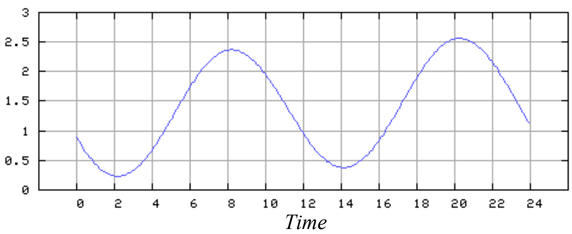
When sun and moon are aligned, at full moon and new moon, the attraction of the moon is adding to the one from the sun, and the effect is at its maximum





At the first and last quarters, the attraction of the moon is conflicting the one from the sun. The effects is at its minimum and the tidal range is at its lowest.

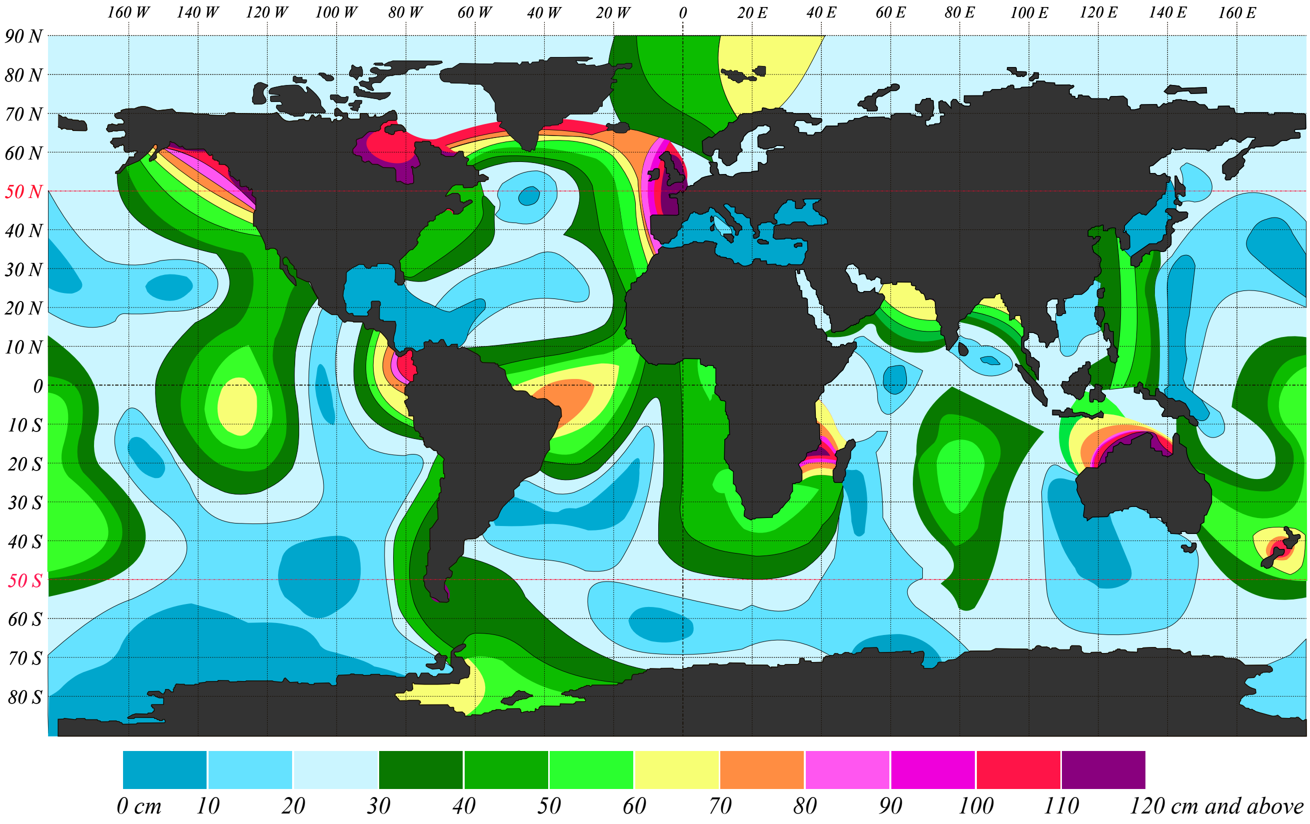




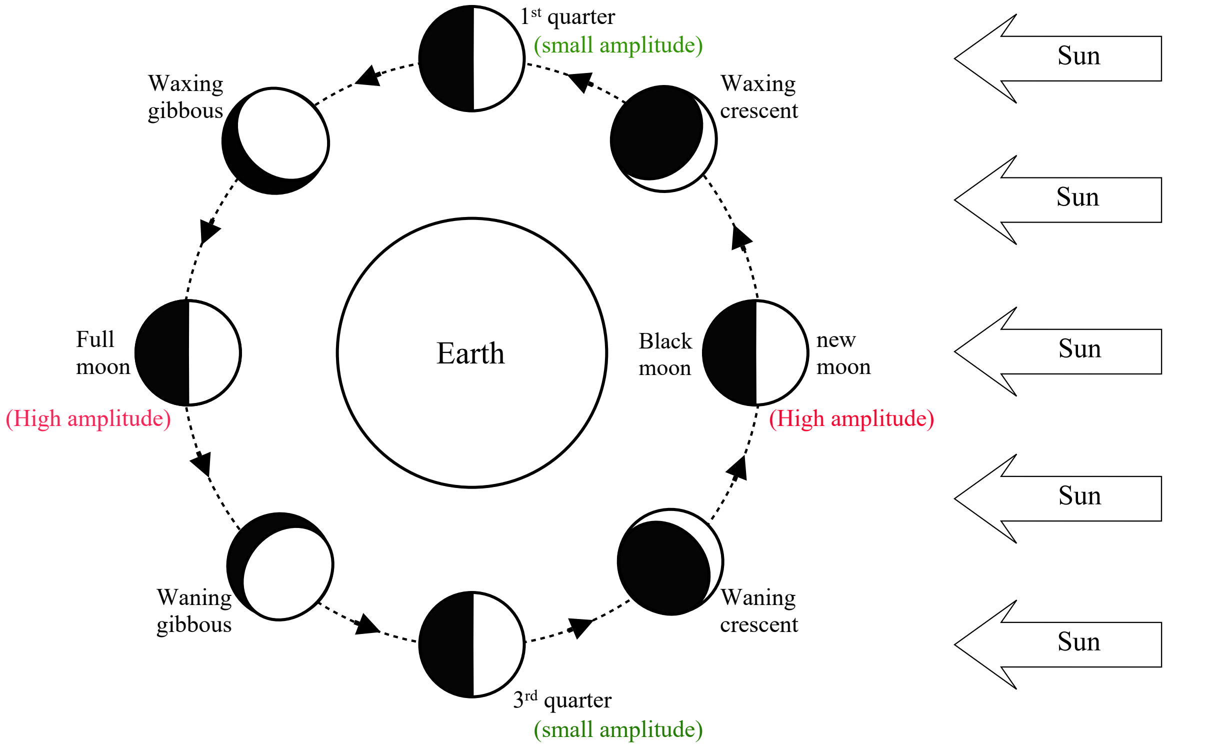
Tides are commonly semi-diurnal (two tidal cycles each day), or diurnal (one tidal cycle per day).
The tidal range is the difference in height between low tide and high tide. It depends on the phase of the moon and the shape of the coastline, so that some bays may have different tidal ranges than the open sea. The times and heights of tides are given in tide tables and can be affected considerably by strong winds.

Hyperlink Table of contents

The map below shows the world tidal amplitudes expressed in centimetres.



The amplitudes of the tides are given on tables, but they can also be evaluated according to the position of the moon :



Tides produce oscillating currents known as tidal streams:
The moment that the tidal current ceases is called "slack water or slack tide". The tide then reverses direction and is said 'to be turning". "Slack water" usually occurs near "high water" and "low water". But, there are locations where the moments of slack tide differ significantly from those of high and low water.

The amplitude of the tide has a direct effect on the speed and the power of the tidal stream: The bigger the range, the faster the tidal stream. Tidal streams can also increase in speed around headlands and in narrow channels. In some estuaries, the tidal streams can cumulate with the current from the river. These currents are often associated with poor visibility caused by sediment carried by the river. Some tide currents can be as fast as 10 knots.
In addition, due to the interferences initiated by the conditions at the location, the currents may run in different directions at different depths. This possible effect is common and has to be anticipated before launching the dive. Major ocean currents may superimpose on these currents, increasing or decreasing the speed and producing turbulence.

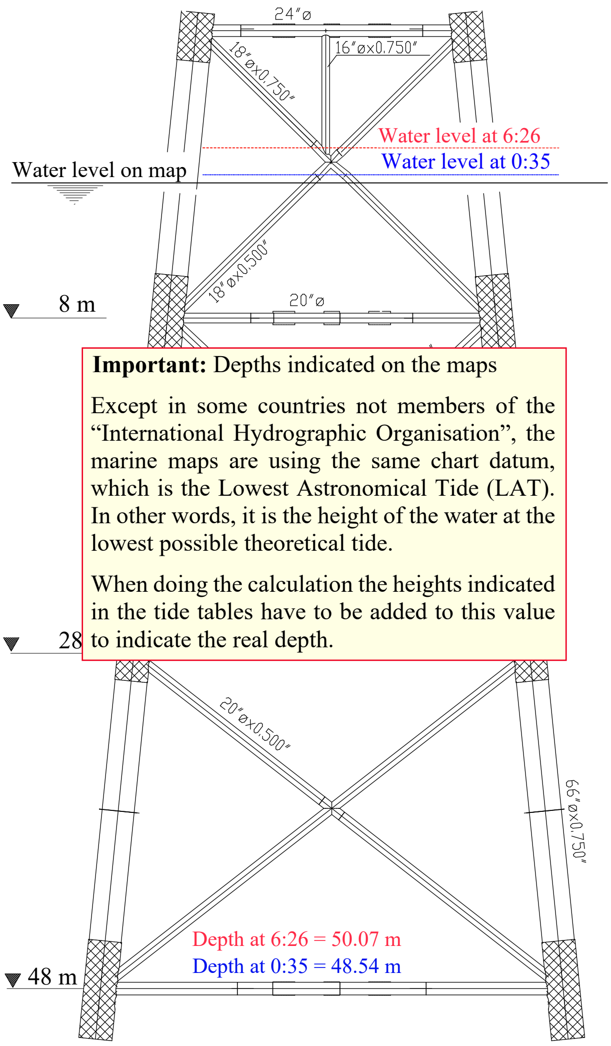
There is “high water” every 12:25 hrs. On average, the tide rises for 6 hours and 12 minutes. This is “the rising, or flood tide”. At the top of the flood, the level remains constant for a short period at “high water slack”. The “falling or ebb tide” then runs for about 6 hours 12 minutes until low water slack. Then the cycle begins again. In some areas, flood and ebb tides may run for considerably less than six hours.
The twelve’s rule is used to calculate the amount of rise or falling. This rule is based on: The range divided by 12 and the duration divided by 6.

Hours	Twelfth of Range
Hour 1	1/12 of range
Hour 2	2/12 of range
Hour 3	3/12 of range
Hour 4	3/12 of range
Hour 5	2/12 of range
Hour 6	1/12 of range

Example: Check the real depth of a platform member indicated at 48 m on the elevation.

The tide table of the day is indicating:

Statement	Time	Height
Low water	0:35	0.4 m
High water	6:26	2.07 m
Low water	12:11	0.45 m
High water	18:30	2.71 m



Important: Depths indicated on the maps

Except in some countries not members of the “International Hydrographic Organisation”, the marine maps are using the same chart datum, which is the Lowest Astronomical Tide (LAT). In other words, it is the height of the water at the lowest possible theoretical tide.

When doing the calculation the heights indicated in the tide tables have to be added to this value to indicate the real depth.

1) Flood tide between 0:35 and 6:28

At 0:35, the depth of the brace will be 48 + 0.4 = 48.4 m

At 6:28, the depth of the brace will be 48 + 2.07 = 50.07 m

The range is 50.07 - 48.4 = 1.67 m

1/12 = 1.67 / 12 = 0.139 m (0.14)
2/12 = 0.139 x 2 = 0.278 m (0.28)
3/12 = 0.139 x 3 = 0.417 m (0.42)

Time	hr	1/12	Height
1:34	1st	1/12	48.4 + 0/139 = 48.54 m
2.32	2nd	2/12	48.539 + 0.278 = 48.81 m
3.31	3rd	3/12	48.81 + 0.417 = 49.23 m
4:29	4th	3/12	49.234 + 0.417 = 49.65 m
5:28	5th	2/12	49.651 + 0.278 = 49.93 m
6:26	6th	1/12	49.929 + 0.139 = 50.07 m

2) Ebb tide between 6:28 and 12:11

At 6:26 the depth of the brace will be 48 + 2.07 = 50.07 m

At 12:11 the depth of the brace will be 48 + 0.44 = 48.45 m

The range is 50.07 - 48.45 = 1.62 m

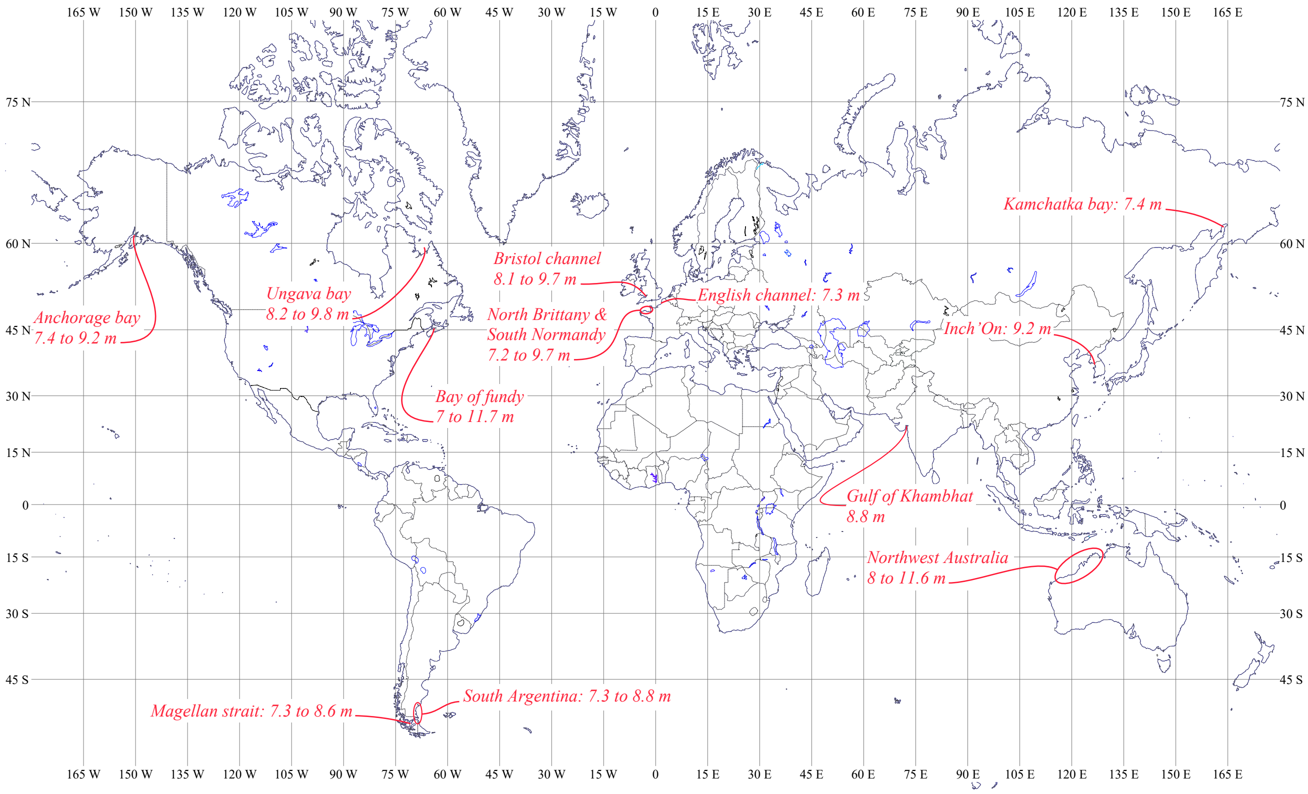
1/12 = 1.62 / 12 = 0.135 m
2/12 = 0.135 x 2 = 0.27 m
3/12 = 0.135 x 3 = 0.405 m (0.42)

Time	hr	1/12	Height
7:24	1st	1/12	50:07 - 0.135 = 49.93 m
8:21	2nd	2/12	49.935 - 0.27 = 49.66 m
9:18	3rd	3/12	49.665 - 0.405 = 49.26 m
10:15	4th	3/12	49.26 - 0.405 = 48.85 m
11:13	5th	2/12	48.855 - 0.27 = 48.58 m
12:11	6th	1/12	48.785 - 0.135 = 48.45 m

Hyperlink Table of contents

Areas with extreme ranges of tides:
There are a lot of places in the world that have extreme tides such as those indicated in the list below that shows some of the areas where tide ranges are 7 metres and above. These data, that are based on records from the US National Oceanic and Atmosphere Administration (NOAA) and other organizations, do not indicate the exceptional tides.

Location	***Range (metres)***	***Location***	***Range (metres)***
Bay of Fundy - Canada	7 to 11.7 m	South Argentina coast	7.3 to 8.8 m
Northwest Australian coast	8 to 11.6 m	Gulf of Khambhat - India	8.8 m
Ungava bay - Canada	8.2 to 9,8 m	North Brittany and South Normandy coasts - France	7.2 to 9.7 m
Bristol channel - United kingdom	8.1 to 9.7 m	Magellan strait	7.3 to 8.6
Anchorage bay - Alaska - USA	7.4 to 9.2 m	Kamchatka bay Russia (East Siberian coast)	7.4
Inch'On - Korea	9.2 m	English channel, (Cayeux [Fr] & Dover [UK])	7.3 m



There is a belief that says that extreme tides happen in areas above the North and South 45th parallels, which is incorrect, and as it is proved by the map above. Instead, extreme tidal ranges are created by the configurations of the continents and the surrounding coastlines, the prevailing winds, the currents, and other interactions, as indicated in the previous pages. For example, NOAA says that favorable conditions for high ranges of tides in the high latitudes of the northern hemisphere result from the fact that North American, European, and Asian continents are close in these latitudes. Also, a lot of areas where such tidal effects are recorded are bays or locations at the proximity of straits.

High and low tides in Saint Malo - North Brittany - France

7.9 - Effects of underwater currents on divers' performance and safety

As described previously the underwater currents can have several origins which can conflict or cumulate.

- The seasons have direct effect on the power of tidal currents and the ocean currents.
- The weather perturbations can create fast surface currents, most often from surface to 10 m, but sometimes much deeper. These currents can persist for days following the perturbation. Some surface currents can also establish due to bad weather situated far out in the ocean.
- In some estuaries, the rivers are sometimes conflicting with the tides, creating "tidal bore" effects. Tidal bore is due to the incoming tide forming a wave of water that travels above the river. This effect is quite dangerous because these waves are established very suddenly. Most often, there is not a tidal bore, and the river is merely flowing underneath the rising salt water.
- In case of conflicting currents, it is common to have several currents crossing by layers at different depth. It is also frequent to have cold currents establishing through masses of warm water.

All these elements make the predictions of underwater currents difficult.

IMCA D 067 "The effects of underwater currents on divers' performance and safety", that supersedes AODC 47 says:

The effects of currents on divers varies with the individual, the work being done, the diver's position in the water and the diving method used. Currents produce forces which affect not only divers' bodies but also their umbilicals, together with any hoses and cables from the surface to equipment and tools the divers may have at the working depth. Currents can also have an adverse effect on diver deployment devices, for example cages, bells and/or bell umbilicals.

As an increasing amount of energy is devoted to combating the effects of current, as well as carrying out productive operations, it follows that the greater the speed of the current, the shorter will be the period during which the diver will be effective before the onset of significant fatigue.

A diver operating from a bell or wet bell is better able to operate in currents than a surface orientated diver since his umbilical is shorter, is deployed in the horizontal plane, and therefore, attracts much less resistance to water movement. Thus, a diver operating down or upstream from a bell has to contend with the effect of the current on his person only and not on his umbilical.

The force exerted on a diver and his equipment by the current is proportional to the water velocity squared. If the velocity doubles, the force increases four times. The table below shows approximate drag forces exerted on the "average" diver in both a vertical and horizontal position.

Current speed (knots)	*Force on the diver standing facing the current (Max. Profile)*		*Force on the diver horizontal facing the current (min. Profile)*	
	lbs	*Kg force*	*lbs*	*Kg force*
0.5	*6*	*3*	*1*	*0.5*
1	*23*	*10*	*4*	*2*
1.5	*52*	*23*	*9*	*4*
2	*92*	*41*	*15*	*7*
2.5	*144*	*65*	*24*	*11*
3	*207*	*94*	*36*	*16*
3.5	*282*	*128*	*47*	*21*
4	*369*	*167*	*61*	*28*
4.5	*467*	*212*	*78*	*35*
5	*567*	*260*	*96*	*44*

Note: 1 kg force = 9.80 newton (measured at Paris) - 1 pound force = 4.45 newton (measured at London)

The possibility to organize an efficient and safe dive when currents are present depends on factors such as:

A) The physical condition of the diver and his experience with strong currents.
B) Whether the standby diver can be deployed to rescue the diver in the event of an emergency.
C) Whether the work is to be performed in mid-water or on the seabed, and requires strong efforts or not.
D) The means of deployment used (bell or a basket), the umbilical deployed's length, buoyancy, and orientation.
E) The influence of the current on the implementation and the recovery of the equipment to be used.
F) The means of prediction and monitoring that are available to control the underwater current changes.
G) The current's strength and evolution, and if other currents are present at depths above or below.
H) Whether swim-lines, down-lines, means of attachment, and/or an underwater tender are available.
I) Whether the diver can be sheltered by underwater structures or the configuration of the seabed.

Based on the elements above, IMCA has reviewed the previous limitations of AODC 47 for diving operations that may be possible at various current speeds and reduced the exposure of divers to such conditions as displayed below:

	0.0 to 0.7 knots	*0.7 to 1.0 knots*	*1.0 to 1.2 knots*	*1.2 to 1.5 knots*	*1.5 knots and over*
Surface supply in mid water	Normal work	Light work	Special precaution	No diving	No diving
Surface supply on bottom	Normal work	Normal work	Special precaution	No diving	No diving
Bell or wet bell in mid water	Normal work	Light work	Special precaution	No diving	No diving
Bell or wet bell on the bottom	Normal work	Normal work	Special precaution	No diving	No diving

Normal work	*No restrictions*
Light work	*Dives limited to works not requiring strong efforts.*
Special precaution	*Diving in these currents should not be considered a routine operation:* ◦ *Based on the elements indicated previously, the diving supervisor should consult with the divers involved and other people about the feasibility of such an operation.* ◦ *A risk assessment should be performed to ensure that suitable control measures are in place.* ◦ *The team must also consider whether the standby diver can be safely deployed to rescue the diver in the event of an emergency.*
No diving	*Diving operations are normally forbidden beyond 1.2 knots*

The new IMCA limitation of the normal conditions to 1 knot merely follows the limits set up by the industry as a lot of clients have published this maximum limit in their working rules for a very long time.
It is also the rule to ensure that means of prediction *(see in point 5.7 "tides")* and monitoring of the current are in place.

Note that the diving supervisor responsible for the operation is the only person who can order the start of a dive. However, the client representative, the diving superintendent, and the master of the vessel can ask him to abort it if they consider the conditions unsuitable.

7.10 - Water turbidity

7.10.1 - Remembering about the visible light in water

Light is an electromagnetic wave oscillation varying in length between 380 and 750 million (manometers). It is apparently white, but through a prism, the white is decomposed into six colours: red, orange, yellow, green, blue and purple. Each of such colours has a wavelength that is specific.

Colour	Min and Max wavelength
Purple	400 - 430 million
Blue	430 - 490 million
Green	490 - 560 million
Yellow	560 - 590 million
Orange	590 - 620 million
Red	620 - 700 million

It is considered that the "hot" colours are those whose wavelength is longer than its 560: yellow, red and orange. Those whose wavelength is shorter are cool colours: blue, green, purple.
The speed of light is 300,000 km/ second. It is the speed at which it enters into the atmosphere and it is not significantly slowed down when it reaches the surface of the sea except during cloudy days.

7.10.1.1 - Reflection of the light:

When sunlight reaches the surface of the sea, depending on the angle of incidence, there is a partial reflection back to the atmosphere of a part of the light rays, with the result of a loss of light.
The wider the angle incidence (when the angle of the sun is close to the horizontal of the sea surface), the more reflected rays, therefore, the amount of light that enters the water is small. When the sun is high in the sky, the angle of incidence is smaller (the incident ray will be near the vertical) and, therefore, the loss of light is lower. One can easily deduce that the best time to have underwater natural light are the hours between 11:00 and 15:00 because the sun is at the zenith, and the loss of light by reflection is reduced.

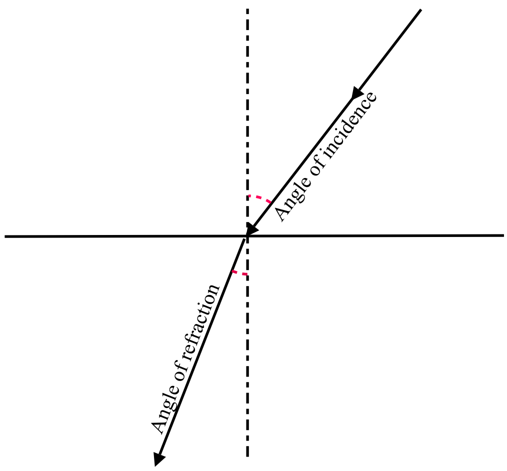
The figures below indicate the loss of light with a clear sky. If the sky is overcast, the light lost in the clouds is about 6% whatever the position of the sun.

Angle of incidence	% of light reflected (lost)
0º	0.02
10º	2.1 %
20º	2.1 %
30º	2.1 %
40º	2.5 %
50º	3.4 %
60º	6 %
70º	13.4 %
80º	38.4 %
90º	100 %

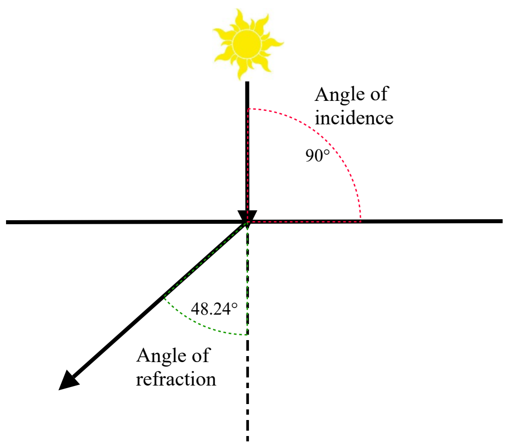
7.10.1.2 - Refraction of the light:

The refraction is the change in direction of a wave due to a change in its transmission medium. The refraction is a constant, and is not really influenced by the weather conditions. For remembering only:

- Refraction law: Sin of the angle of incidence / Sin of the angle of refraction = Constant
- In air: Sin of the angle of incidence / Sin of the angle of refraction = 1 (index of refraction of air)
- In fresh water: Sin of the angle of incidence / Sin of the angle of refraction = 1.33 (index of refraction of fresh water)
- In salt water: Sin of the angle of incidence / Sin of the angle of refraction = 1.34 (index of refraction of salt water)



- Example with an angle of incidence of 90 degrees with sea water:
  - In salt water: Sin of the angle of incidence / Sin of the angle of refraction = 1.34
  - Sin 90° / sin of the angle of refraction
  - Sin 90° = 1 so 1/1.34 = 0.746 = 48.24 degrees



- Effects:
  - 1.333 (index of refraction fresh water) = 4/3
  - An object in the water is seen 1/3 bigger: A fish which appear 1.2 m is in fact 0.8 m long
  - An object appears closer 1/4: an object at 4 m seems to be a 3 m (which often create problems to grab them…)

7.10.2 - Other causes of loss of the light

Other causes of the extinction of light at sea are due to absorption and diffusion in water.

- Absorption
  The water absorbs an amount of light that is proportional to the thickness of the liquid column crossed and the number of particles suspended in it. The first cause is constant, but the second cause varies according to the size, the type and amount of solution.
- Diffuse reflection
  Diffuse reflection is the scattering of light in all directions. There are 2 main causes. The water that normally reflects the light, and the suspended particles composed of mineral salts, sediments, and also varieties of plankton. Because of their irregular shapes, these particles deviate the trajectory of the light, and when crossed by it, they refract it in every direction. This light is then reflected to the particles that were not initially crossed by the initial light, with the same effect. The intensity of the light and the contrast are affected. The well known effect is foggy pictures on the video.
  Because the absorption and diffusion increase with depth, there is a decrease in light intensity which is related to the depth and also a phenomenon of modification of the colours:

Depth	*% of sun light*
0 m	100 %
1 m	40 %
5 m	25 %
10 m	14 %
20 m	7 %
30 m	3 %
40 m	1.5 %
50 m	0.7 %
60 m	0.25 %
90 m	0.17 %

Depth	*Effect on colours*
5 m	Red not visible
15 m	Orange not visible
30 m	Yellow not visible
35 m	Blue and green are the most visible
55 m	Purple and indigo are the most visible

The absorption and diffuse reflection are more intense in the vicinity of the coasts and river mouths than open sea due to a greater number of particles in suspension and the direct influence of heavy rains on the rivers and of the bad weather to the shallow sea floors.

That creates situations where the diver is constrained to work in reduced visibility or in the darkness, which creates additional risk, because the hazards are difficult to identify in these conditions. Also, some untrained divers can become anxious in these conditions.

7.11 - Effects of temperatures and lightning strikes on cranes

7.11.1 - Effects of temperatures

Environmental temperatures can affect cranes and winches, and also the generators that power them:

- Too hot temperatures may affect engines which can overheat or break. The problem is usually solved by installing appropriate heat exchangers.
- Viscosity is the measure of oil's resistance to flow. Based on the fact that low-viscosity fluids tend to flow more easily and quickly than high-viscosity fluids, engineers usually design hydraulic systems for a particular range of viscosities. Thus, it is a critical element for the transfer of hydraulic power. As a result, too-hot temperatures decrease the effectiveness of hydraulic systems because the oil's viscosity is reduced, and thus the pressure delivered by the pump falls. On the contrary, if the environmental temperature is too cold, a crane's hydraulic system can slow down due to too high thickening of the hydraulic oil, resulting in a reduced flow speed.
- Hot temperatures also affect the operator, who can suffer from dehydration and heat exhaustion if air conditioning is not installed to cool the cabin. Cold stress can also affect the operator if the cabin is not appropriately heated. That may result in disorientation, numbness, frostbite, or hypothermia.
- Extreme cold can favour snow and ice accumulation on the crane, resulting in extra load, particularly on the boom.

- Extreme cold can also reduce the crane's structural strength. For this reason, specialists say that the load should be reduced by 25% at temperatures near -20 Cº and 40 % at temperatures near -30 Cº. Cranes designed to work in extreme cold conditions should be provided with lifting load charts taking into account these effects.

7.11.2 - Effects of lightning strikes

Offshore cranes are the highest element of a vessel at work when deployed, and it is also the case for many onshore and inland projects. As a result, they are the preferred lightning targets during storms, which may result in the following:

- Destruction of the crane's electrical systems, causing a loss of power and affecting the safety systems.
- The Load Moment Indicator (LMI), a device installed on lattice cranes, mobile cranes, or tower cranes to warn the crane operator when the load lifted exceeding the crane capacity can be damaged.
- "Two blocking" happens when the uppermost hoist line component touches the upper block, boom tip, or a similar part. As a result, the tension of the line increases, which results in the following:
    - The wire rope breaking, and consequently, the load falling.
    - Damage to the sheaves.
    - Structural damages to the boom

  To prevent such events, most safety organizations' standards make installing a device called the "Anti-Two blocking", which consists of sensors alerting the crane operator, mandatory. This system can be damaged, resulting in the incidents listed above happening.
- Cranes can conduct the electrical charge from the lightning to the floor. As a result, people on the crane or in direct proximity can be injured or killed.

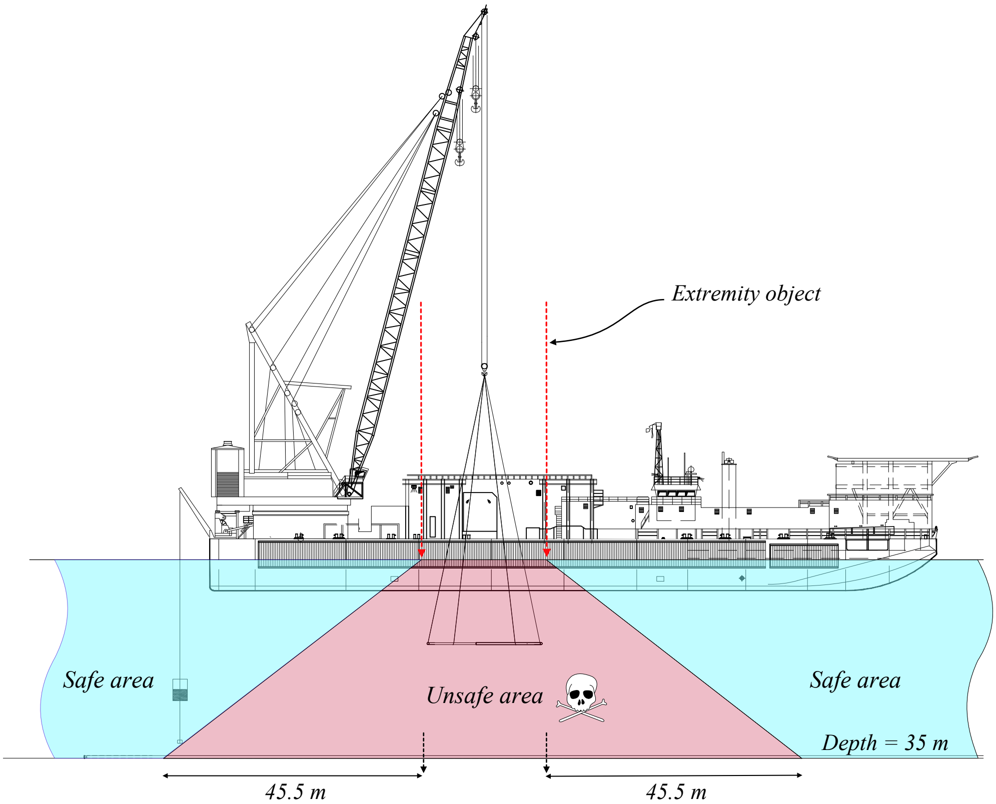
As previously said, the crane should be secured with its boom lowered to its rest support in case of a storm.
Also, as for diving operations, the weather must be monitored during the lifting process. Note that storms can be detected by radar and also visually sufficiently early to stop the operations.
In case of a more sudden squall than usual and there is no time to lower the crane, the load should be lowered to the floor, and the crane operator and people in its proximity should take shelter sufficiently away from the crane.
As lightning strikes are unpredictable and can happen when the storm rain is several miles away. Crane specialists recommend waiting for a clear sky or waiting at least 30 - 60 minutes after the last sound of thunder.
If the crane has been exposed, a thorough inspection should be performed.
Note that a lightning arrester rod and a proper low-resistant grounding system should be installed on the crane. Also, more efficient systems are sold.

8 - Falling object prevention

Many teams and companies think that the bell is sufficiently robust to protect the divers from falling objects and that they are in a safe place if they are recalled under it, either on the clump weight or in the standoff frame, during load transfers. Opposite to this belief, a bell is extremely fragile, and a falling object may easily damage it and make the recovery of the divers impossible, if the diving system is provided with only one bell.

It must be remembered that the bell is equipped with numerous items that are essential for the divers' survival and are very vulnerable to shocks. They are protected from damage by the protection frame during the launching and the recovery of the bell. However, this protection system is not designed to protect the bell from weighty falling objects. For example, a pipeline section of which half its overall length was found vertically sunk in the mud during a seabed cleaning operation in Indonesia. If this object had hit a bell with this angle, this bell's integrity could have been seriously compromised.
For this reason, the bell and the divers should never be under a load and within an area where it may fall. Thus, the object to transfer should be lowered to the bottom before the bell, or the deployment area must be sufficiently far away, so the bell and the divers will not be affected in case the load is dropped.
Several calculation methods to keep the bell and the divers away from falling objects have been published, which some of them are based on probabilistic databases. Among these procedures, two guidelines are commonly used by teams to calculate safe distances: The IMCA guideline D 007 *"Overboard scaffolding operations and their effect on diving safety"*, and the recommended practice DNV-GL-RP-F107 *"Risk assessment of pipeline protection"*.

IMCA D 007 says that diving operations must not be conducted directly underneath activities such as scaffolding or overboard movement of tubes or any other construction work. This guideline also says that between scaffolding activities and diving operations, a minimum horizontal distance should be applied of 1.3 times the depth at which the diver is working. Note that this calculation is based on an approximate evaluation resulting from working experiences instead of specific calculations. However, this procedure has proved its efficiency since 1996, and IMCA still recommends it. Note that it has often been used to calculate distances from voluminous objects than in the absence of other evaluation means.

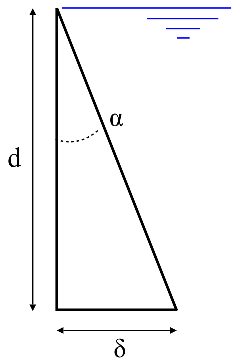


DNV-GL-RP-F107 is a document based on scientific studies regarding sinking objects' trajectories that provides a methodology for assessing the risks and required protection from dropped crane loads and ship impact to risers and pipeline systems within the safety zone of installations.
This guideline, which says that an object excursion in water is extremely dependent on its shape and weight and that the fall pattern of a pipe is dependent on the entry angle into the sea, concludes that an object falling area can be calculated using the following equation:

$$p(x) = \frac{1}{\sqrt{2\pi}\delta} e^{-\frac{1}{2}(\frac{x}{\delta})^2}$$

where:

- P(x) = probability of a sinking object hitting the sea bottom at a distance x from the vertical line the drop point.
- x = horizontal distance at the sea bottom (in metres)
- δ = lateral deviation (in metres). Note that " δ " means "delta" in the Greek alphabet.



d = Depth

δ (delta) = Distance of deviation, which is the tangent of the angle

α (alpha) = Angle in degrees

DNV-GL provides seven categories of angular deviations based on the weight and the shape of the objects commonly transferred, and are indicated in the table below, which can be used to predict an object's falling area.

Cat.	***Description***	***Weight in air (tonnes)***	***Angular deviation (Degrees)***	***Typical objects***
1	Flat/long shaped	< 2	15	Drill collar/casing, scaffolding
2		2 - 8	9	Drill collar/casing
3		> 8	5	Drill riser, crane boom
4	Box/round shaped	< 2	10	Container (food, spare parts) , basket, crane block
5		2 - 8	5	Container (spare parts , basket), crane test block
6		> 8	3	Container (equipment) , basket
7	Box/round shaped	> > 8	2	Massive objects as BOP, pipe reel, etc.

The object's falling area can be calculated through a specific software based on the formula provided on the previous page or by calculating the tangents of the angular deviations indicated above that are displayed in the table below. Thus, the δ (delta) of the angular deviations DNV-GL can be found by multiplying the relevant tangent value by the depth.

Angle (Degrees)	***Tangent (Deviation for 1 m depth)***	***Angle (Degrees)***	***Tangent (Deviation for 1 m depth)***	***Angle (Degrees)***	***Tangent (Deviation for 1 m depth)***	***Angle (Degrees)***	***Tangent (Deviation for 1 m depth)***
1º	0.0174	5º	0.0875	9º	0.1584	13º	0.2309
2º	0.0349	6º	0.1051	10º	0.1763	14º	0.2493
3º	0.0524	7º	0.1228	11º	0.1944	15º	0.2679
4º	0.0699	8º	0.1405	12º	0.2125	16º	0.2867

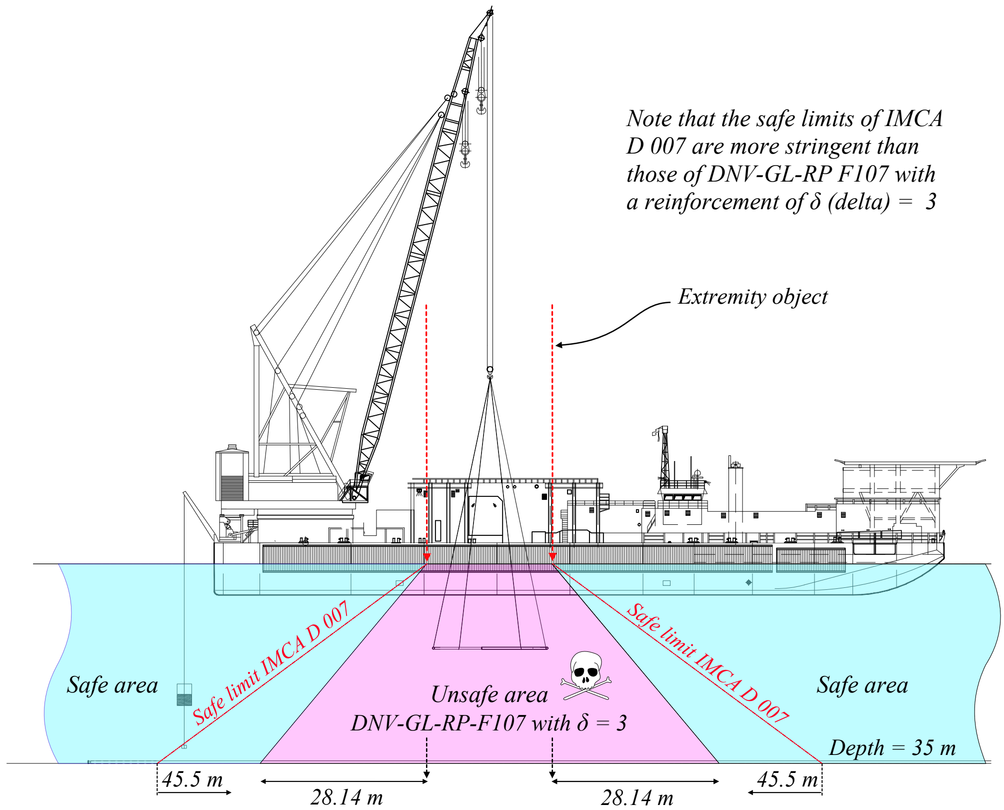
Note that IMCA D 060 "Guidelines for lifting operations", says that these angular deviations are based on a standard deviation of 1, which gives 68% impact probability, and that an accepted practice is to apply 3 standard deviations to ensure that 99.7% of objects fall within the drop cone diameter to obtain a conservative approach.
This procedure consists of multiplying the δ (delta) of the angular deviations DNV-GL (standard deviation of 1) by 1.96 or 2.58 to obtain 95% and 99% probabilities of impact.
IMCA D 060 provides an example of such a reinforcement for a depth of 90 m, which gives the following results:

Cat.	***Description***	***Weight in air (tonnes)***	***Angular deviation***	***Distance δ = 1 (68% probabilities)***	***Distance δ = 1.96 (95% probabilities)***	***Distance δ = 2.58 (99% probabilities)***
1	Flat/long shaped	< 2	15	24	47	62.2
2		2 - 8	9	14	28	36.7
3		> 8	5	8	15	20.2
4	Box/round shaped	< 2	10	16	31	40.9
5		2 - 8	5	8	15	20.2
6		> 8	3	5	9	12.1
7	Box/round shaped	> > 8	2	3	6	8.1

As already said, the safe distances δ (delta) = 1 can be obtained by multiplying the relevant tangent by the depth; for example, an angular deviation of 15 degrees = 0.2679 x 90 m = 24.11 m, and an angular deviation of 9 degrees = 0.1584 x 90 m = 14.26 m, etc.

Because the purpose of the calculation is protecting divers, it can be considered suitable to calculate a probability of impact using the less favourable angular deviation category, so category #1 of the DNV-GL classification, and to take into account the recommendations from IMCA D 060, to reinforce the deviations provided by the original δ (delta) by multiplying it by 3 to obtain a conservative calculation that can be used in many situations. The reason for using a δ (delta) reinforcement that is more stringent than the 2.58 recommended in IMCA D 060 is that IMCA says that a δ (delta) reinforcement of 2.58 provides a 99% probability that the load falls within the predicted falling area. Thus, a δ (delta) of 2.58 does not guarantee at 100% that a falling load will be within the safety limit required for divers.
Note that most safety organizations say that the safe distance should be calculated considering the maximum possible dispersion angle for each type of object that may fall through the water. For this reason, it not ridiculous and safer to apply a safety factor of 3 instead of 2.58 to ensure that no falling object hits the divers and the bell. The table below is an example of such calculations.

Depth	***Deviation δ = 1***	***Deviation δ = 3***	**Depth**	***Deviation δ = 1***	***Deviation δ = 3***	**Depth**	***Deviation δ = 1***	***Deviation δ = 3***
10	2.68	8.04	130	34.83	104.49	250	66.99	200.97
20	5.36	16.08	140	37.51	112.53	260	69.67	209.01
30	8.04	24.12	150	40.19	120.57	270	72.35	217.05
40	10.72	32.16	160	42.87	128.61	280	75.03	225.09
50	13.4	40.20	170	45.55	136.65	290	77.71	233.13
60	16.08	48.24	180	48.23	144.69	300	80.38	241.14
70	18.76	56.28	190	50.91	152.73	310	83.06	249.18
80	21.44	64.32	200	53.59	160.77	320	85.74	257.22
90	24.12	72.36	210	56.27	168.81	330	88.42	265.26
100	26.79	80.37	220	58.95	176.85	340	91.1	273.30
110	29.47	88.41	230	61.63	184.89	350	93.78	281.34
120	32.15	96.45	240	64.31	192.93	360	96.46	289.38



Regarding the application of the model in deep waters, DNV-GL says the spreading of long/flat objects will increase down to approximately 180 metres depth, and does not significantly increase further down.
Note also that in deep waters, the spreading of objects on the seabed does not necessarily follow the normal distribution (Katteiand and Oygarden, 1995).

DNV-GL-RP-F107 also says the following regarding currents:
The effect of currents becomes more pronounced in deep water. The time for an object to reach the seabed will increase as the depth increases. This means that any current can increase the excursion. At 1000 metres depth, the excursion has been found to increase 10-25 metres for an average
current velocity of 0.25 m/s and up to 200 metres for a current of 1.0 m/s (Katteiand and Oygarden, 1995).
The effect of currents may be included if one dominant current direction can be identified. This can be applicable for rig operations over shorter periods, such as during drilling, completion and intervention on subsea wells. However, for a dropped object assessment on a fixed platform, seasonal changes in current directions can be difficult to incorporate.
Note also that the current may change direction through the column for large water depths. If applicable, this should be accounted for.
The effects of current should be considered when establishing a "safe distance" away from lifting activities.

The table below compares values of DNV-GL-RP-F107 with safe distances δ (delta) x 3 with those of IMCA D 007.

Depth	***DNV-GL δ = 3***	***IMCA D 007***	***Depth***	***DNV-GL δ = 3***	***IMCA D 007***	***Depth***	***DNV-GL δ = 3***	***IMCA D 007***
10	8.04	13.0	130	104.49	169.0	250	200.97	325.0
20	16.08	26.0	140	112.53	182.0	260	209.01	338.0
30	24.12	39.0	150	120.57	195.0	270	217.05	351.0
40	32.16	52.0	160	128.61	208.0	280	225.09	364.0
50	40.2	65.0	170	136.65	221.0	290	233.13	377.0
60	48.24	78.0	180	144.69	234.0	300	241.14	390.0
70	56.28	91.0	190	152.73	247.0	310	249.18	403.0
80	64.32	104.0	200	160.77	260.0	320	257.22	416.0
90	72.36	117.0	210	168.81	273.0	330	265.26	429.0
100	80.37	130.0	220	176.85	286.0	340	273.3	442.0
110	88.41	143.0	230	184.89	299.0	350	281.34	455.0
120	96.45	156.0	240	192.93	312.0	360	289.38	468.0

Important notes:
In case several load transfers have to be performed that cannot be at a distance that is guaranteed 100% safe for the divers, the bell (and the clump weigh) must be recovered to a safe depth and then lowered again to the worksite when the load is close to the bottom. Such procedure obliges several deployments and recoveries of the divers and the bell. However, it guarantees that the divers are always safe. Also, note that today's technology allows not exposing the divers, as ROVs can be used to monitor the descent of the load and pre-position it near the final installation place. Thus, a relevant organization of the operations can avoid unnecessarily exposing divers to potential dangers.
Another important point is to ensure that no unplanned operation will be carried on during the dives. That is usually prevented by implementing a permit to work system and announcements when launching the dive.

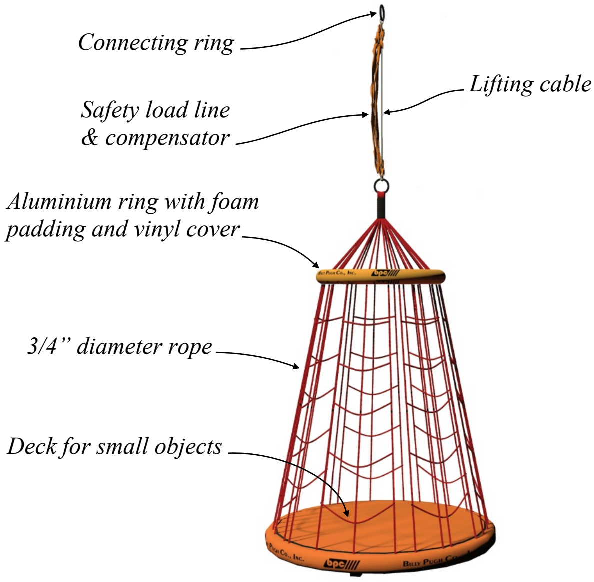
9 - Personnel transfer at sea using baskets and cranes

9.1 - Basket models

Subject to local regulations, company and client procedures, basket transfers by personnel basket to or from vessels or offshore structures can be undertaken using a number of different devices. Three main types of devices are commonly used for personnel transfer at sea: Flexible baskets, rigid baskets, and transfer capsules

9.1.1 - Flexible baskets

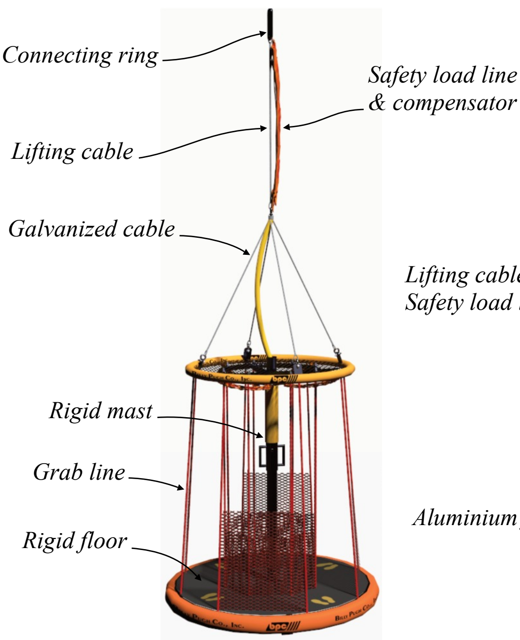
They are the oldest personnel transfer basket design in which personnel is transferred in a standing position while holding onto the outside of the lifted structure. Their advantage is that they are foldable and so easy to store, which results in they are often preferred on small vessels where the space is limited. Their disadvantages are that passengers, standing on its periphery, are not protected from shocks, that they do not provide buoyancy, and that they collapse if they are not kept deployed by the crane, which, thus, cannot be entirely slacked.
The model on the side is an 800 series designed by Billy Pugh, one of the oldest brands (https://www.billypugh.com/).
Depending on the model, these baskets can carry from 4 (model 870) to 12 people (model 871-12). The centre of the basket is commonly used to transfer the small belongings of the people.
Note that some clients and countries have banished the use of flexible baskets.



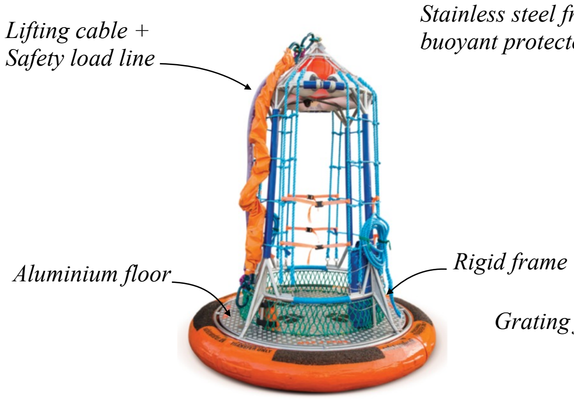
9.1.2 - Rigid baskets

They are rigid framed baskets, sometimes provided with buoyancy rings and fenders, inside which the transferred personnel stand. They have been created to solve some of the problems highlighted above.
They offer protection against lateral shocks, but not vertical ones, and are also equipped to carry small personal belongings. Depending on the model, these baskets can transfer from four to 12 passengers.
Several manufacturers sell products corresponding to this basket's category, such as:

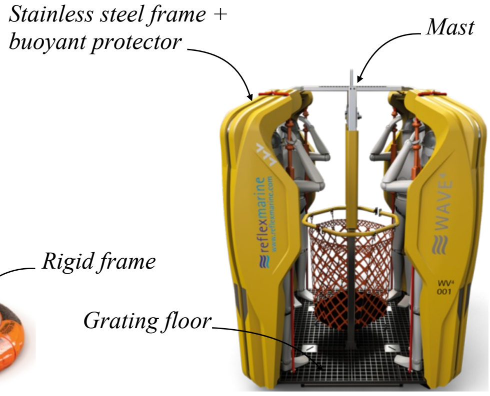
- Billy Pugh (https://www.billypugh.com/products/x-904-transfer-device/),
- SafeTransfer (https://safetransfer-basket.com/products/),
- Reflex Marine (https://www.reflexmarine.com/).



Billy Pugh - x-904 basket



SafeTransfer - Offshore basket



Reflex Marine - Wave 4

9.1.3 - Transfer capsules

They consist of a rigid framed device with buoyancy devices, in which the personnel transferred is sat and strapped in bucket seats. These seats are provided with a shock absorber to compensate for the effects of a hard landing.

The capsule's buoyancy is such that if the device falls into the water, the occupants have the upper part of their body outside the water, and the device does not capsize. Depending on the model. the capacity of these personnel transfer capsules varies from 2 to 10 passengers. Note that such devices are the only ones accepted for personnel transfer at sea by some companies and in some countries.
Among the personnel transfer basket manufacturers, two are well known for providing such equipment:

- Reflex marine (https://www.reflexmarine.com/) designed a transfer capsule series called "Frog" that has been used on offshore sites since 1992. The production of these models stopped in mid-2014, as they were replaced by the new "Frog XT" series, which significantly improved the initial design with better seats and harnesses, better seat shock absorbers, and better protection from contacts and shocks with structures.
- SafeTransfer (https://safetransfer-basket.com/products/) sells an evolution of its offshore personnel transfer basket equipped with seats and additional buoyancy devices. As the model above, it complies with NORSOK requirements.

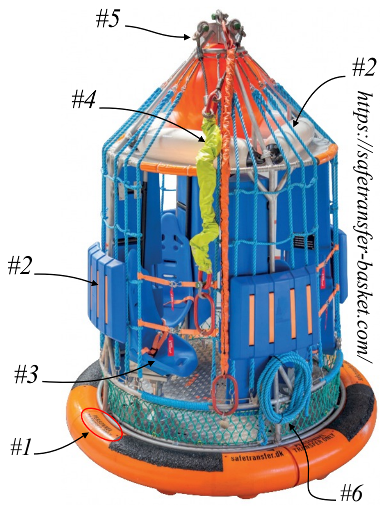
Reflex marine - Frog

Reflex marine - Frog XT

SafeTransfer - Basket NORSOK

9.1.4 - Requirements for personnel transfer baskets

The following conditions must be in place for using the personnel transfer basket:



- The basket must be certified (every year & 5 years) and meet the vessel's country laws and classification requirements. The fact that it should never be used as a work platform should be mentioned on it *(See #1 in the photo)*.
- Its maximum Safe Work Load (SWL), empty weight, maximum weight, and passenger capacity should be written on it. These should be based on documented studies and testing processes approved by a recognized certification body. These certifications include the rigging associated with it, such as hooks, master links, slings, ropes, and shackles.
- A safety line and a compensator should be installed. The role of this safety line is to keep the basket attached in case of a rupture of the main line. The function of the compensator is to amortize the shock arising from the break of the main lifting cable.
- Some standards (ex., NORSOK) and client policies require that the basket is designed for floating and not capsizing in the water *(See #2)*, that the passengers are secured on seats provided with shock absorbers *(See #3)*, , protected for lateral shocks, and that the safety and compensator line *(See #4)* is to be attached on separate lifting points *(see #5)*.
- Tag lines should be connected at opposite sides of the lower parts of the basket *(see #6)*. They must be of sufficiently large diameter (18 to 20 mm) not to cut the hands and long enough to allow comfortable handling by the riggers. However, too-long tag lines can be caught by structures, which is why they are usually limited to 3 - 4 m and made of materials not too light, so they keep nearly vertical in windy conditions. Note that polyester ropes are often preferred to polypropylene for this reason. Their extremity must be seized (knots or back-splices should not be used as they may get snagged).

9.2 - About personnel transfer cranes

The following conditions must be in place regarding cranes used for personnel transfer basket:

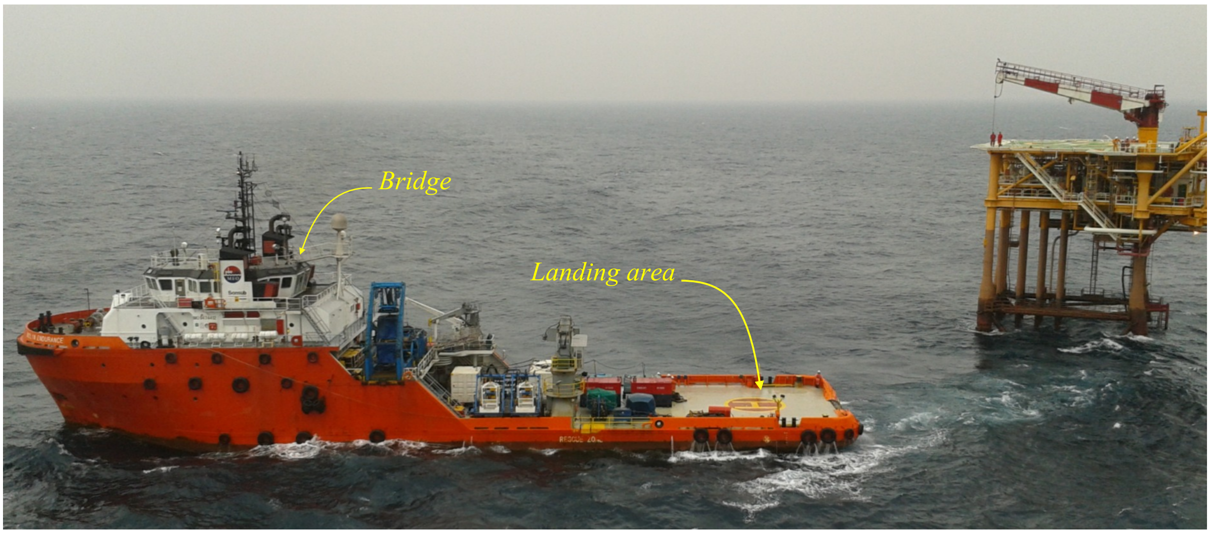
- The crane must be certified for man riding operations and meet, at a minimum, the vessel's country laws and classification requirements.
- The Oil Companies International Marine Forum (OCIMF) says that cranes to be used for personnel transfer should be located at the mid-body of the vessel and that cranes on the stern, such as stores cranes, should not be used for personnel transfers because the risks associated with manoeuvring a ship under any overhang. In addition to this rule, the landing place should be visible, sufficiently broad, and stable. Note that the ship should be positioned to protect the lifting or the landing area from the effects of the weather.

- The maximum Safe Work Load (SWL) should be written on the crane. It should be based on documented studies and testing processes approved by a recognized certification body. Also, the table indicating the maximum safe working load according to its distance from the crane's trunk should be provided. Regarding this point, OSHA 1926.1431(d) that the Safe Working Load (SWL) of the crane should be reduced to 50% of the normal SWL when transferring personnel, and the safety factor of the wire should be at least 10:1.
- Similarly to the winches used for the deployment of diving baskets and bells, the crane's winches must be equipped with manual brakes capable of holding the rated SWLs, in addition to a system that regulates the lowering rate of speed of the hoist mechanism, and independent brakes that are automatically activated when:
    - The controls are in the neutral position.
    - The emergency stop has been activated.
    - There is a power failure.
- OSHA 1926.1431(d) requests that articulating cranes are equipped with a properly functioning automatic overload protection device. Also, equipment with telescoping booms must be equipped with a device to indicate the boom's extended length clearly to the operator, or must have measuring marks on the boom.
- Hooks used in the connection between the hoist line and the basket must be of a type that can be closed and locked, eliminating the throat opening. The lifting assembly of the basket should be of sufficient length to ensure the crane hook remains clear of people.
- Shackles used in place of hooks must be of the alloy anchor type, with a bolt, nut and retaining pin.
- Rigging hardware (including wire rope, shackles, rings, master links, and other rigging hardware) and hooks must be capable of supporting, without failure, at least five times the maximum intended load applied or transmitted to that component. Where rotation resistant rope is used, the slings must be capable of supporting without failure at least ten times the maximum intended load.
- OSHA 1926.1426 also says that free fall of the load line hoist is prohibited, and that the use of equipment in which the boom hoist mechanism can free fall is also prohibited.

9.3 - Vessel characteristics

Different vessels equipped with a crane classified for personnel transfer are used offshore. Also, supply boats not equipped with a crane are usually employed to perform crew changes. These vessels can be fastened along an anchored ship, such as a lay barge or a four points mooring vessel, or be maintained at direct proximity using the dynamic positioning system. A vessel performing personnel transfer should be designed as follows:

- Be sufficiently stable not to be too much affected by the weather conditions. Large vessels equipped with anti heeling tanks/anti rolling tanks are preferable.
- The units equipped with a crane should have it installed close to mid ship, as mentioned above.
- The dynamic positioning system should be at least DP2. The reason is that as for diving operations, every activity exposing human lives performed from a DP vessel must by performed with a unit equipped with two automatic fully redundant systems providing, in case of loss of one, a smooth transfer of the other, and sufficient warning to safely recover people.
- The landing area should be marked on a not slippery part of the deck, free from obstructions, broad enough to correct minor vessel moves, and with exit routes marked. This landing area should be visible from the bridge.



9.4 - Elements for the implementation

9.4.1 - Evaluate whether the operation can be undertaken

It must be taken into account that some companies do not consider this method of transfer suitable and have banished it. However, instead of such a stringent policy that may handicap the teams working at sea, most companies and health and

safety organizations limit their use to situations where other means of transfer cannot be used. In other words, using personnel basket transfers at sea is considered inappropriate when safer transfer methods are available. However, crane transfer is commonly used for crew changes, personnel transfers to other field facilities using dedicated small vessels, and emergency and medical evacuations.
Based on the abovementioned limitations, such an operation should be classified as risky and complex. For this reason, before starting such operations, the following factors should be taken into consideration, but without limiting to:

- Whether other methods can be used. Depending on the vessel and the location, these alternative means of transfer can be a helicopter, pilot ladder, heave compensated gangway, swing ropes (note that some companies forbid swing ropes), accommodation ladder, classical boat landing, V-shaped boat landing, etc.
- Whether the transfer is urgent or can be delayed.
- The capacity of the vessels to keep their position during the transfer, and the impact of the sea condition and the possibility of unexpected movements and loss of position should be considered.
- Whether the crane to be used is certified for man-riding operations, its capacity, and whether this capacity meet the one of the lifting basket and the number of persons it can carry.
- There should be guidelines stating when the weather exceeds the suitable conditions, and the operation should cease or not take place. These parameters depend on the vessel's behaviour at sea and the crane design. Note that the loading table provided with the crane should indicate the maximum lifting capacity according to the distance of the load from the pedestal, the wind speed, and the waves. As indicated in point 9.2, these parameters should be reduced to 50%. The maximum limits may also depend on the client policy: for example, EN-13852-1 limitations of a maximum wind speed of 20 knots, waves not above 2 m height, temperatures between -20ºC & + 60ºC, and operations strictly limited to daylight are commonly imposed. Note that the person authorizing the transfer on board the vessel is the master. Also, the evolution of the weather conditions should be monitored.
- It is necessary to ensure that the height of the basket plus the lifting sling connected to the hook has a minimum clearance (> 1 metre) above obstacles. The transfer by crane should not occur if this clearance is insufficient.
- The planned route of the basket, taking into account the differences in freeboard between the vessels or the offshore structures. Also, whether the crane operator and the signalman have a suitable visibility of the pick-up, transfer and landing area.
- The competency of the crane operator, signalman, and riggers for man-riding operations.
- It should be highlighted that personnel transfer by basket may involve the potential of injury or fatalities as a result of impacts, drowning, pinching, crushing, falling from height, and others. A document from the “Marine Transfer Forum” provides the following frequencies of incidents:

Place of occurrence		***Phase of the process***		***Types of incidents***	
Fixed installations	*13%*	*Picking up the basket*	*46%*	*Collisions and impacts*	*56%*
Mid transfer	*7%*	*Mid transfer*	*21%*	*Falling from the basket*	*29%*
Vessels' decks	*68%*	*Landing the basket*	*30%*	*Trips and entanglement*	*9%*
Unknown	*12%*	*Unknown*	*3%*	*Basket falling at sea*	*6%*

  Vertical impacts usually occur when the basket lands on an unstable vessel or result from a loss of control from the crane operator.
  Lateral impacts result from uncontrolled swigging resulting in a collision with the vessel or the fixed structure. The authors of this document say that such incidents are often due to misalignment between the crane hook and the basket during a pick-up, causing the basket to swing uncontrollably. Also, the challenges are increased when using flexible baskets (which can collapse), as the crane operator needs to maintain tension in the net during heave cycles.
  Falls often follow a collision with a part of the vessel or an unexpected movement of the crane. They are mainly associated with flexible baskets.
  Note that cranes and vessels equipped with motion compensation systems can minimize the hazards listed above. Also a trial without passengers should be made before starting the operations.
- It is not recommended to perform such operations at night due to the lack of visibility. For this reason, many companies forbid them. However, they may have to be performed for emergency reasons. In such cases, the crane boom should be fitted with adequate lighting to illuminate the crane hook and the basket, the take-off and landing areas should be illuminated to a level of at least 20 lux, and the basket should be fitted with a strobe light. These lights should not disturb the signalman or the crane operator.
- Some companies allow crane transfer with vessels underway. However, this adds hazards to those listed above. For this reason, many companies banish this practice we consider unsuitable for our activities.

9.4.2 - Passenger briefing and personal protections

The passengers should be physically able to make the transfer by crane, confirm they agree to it, and be briefed on the following topics prior to being transferred:

- Depending on the basket, crane, and vessel to and from where the transfer is undertaken, the potential hazards and safety features listed in the sections above.

- The entry and exit procedures to and from the lift-up and landing areas.
- Passenger positioning instructions specific to the basket type:
  - Boarding the basket only when instructed to do so.
  - Being evenly distributed around the basket to stabilize it.
  - Grabbing the the net or hand holds with both hands at all times.
  - Following the instructions of the signalman or the assigned rigger.
  - While transferred standing, keep the knees bent during lifting and landing to absorb any sudden impacts.
  - In a seated position, fasten the seat belt and ensure that the legs follow the vertical movement of the seat.
  - Being ready to quickly exit the basket when it is close to the deck in case the vessel rises on a wave.
- The personal protective equipment required, which should comprise:
  - A safety helmet.
  - Safety shoes.
  - A coverall or a clothes offering a similar protection.
  - Gloves
  - A personal flotation device with reflective tapes, a whistle, and a light. Regarding this point, instruction should be provided on the best way for entering water from heights while wearing such a device.
  - A harness that can be quickly dressed and equipped with a lanyard with a quick connector should be provided for transfers using a basket from which there is a possibility of falling.
  - A survival suit should be provided in cold areas.
- Luggage policy
  - Backpacks or side bags must not be worn.
  - Not carrying objects that may drop.
  - Small bags containing essential devices such as computers can be secured in the lodgments designed for this purpose.
  - Heavy luggage is to be transferred separately in a specific basket.
- Emergency procedures
  - Behaviour when the basket is kept at height due to a breakdown:
    There is nothing the passengers can do except not panic and wait for the backup system to be activated.
  - Behaviour in case of excessive swinging and impacts:
    There is also nothing the passengers can do except not move, grab the basket firmly, and wait for the crane operator to regain control.
  - Behaviour in case of a vertical impact while landing:
    Be always ready to amortize an abrupt shock when landing (see above). In case a person is injured, the riggers must be trained to evacuate the casualty safely, so it is generally recommended to leave the area as soon as possible to avoid disturbing them. Passengers who are 1st aiders can then help the riggers and the emergency response team when the casualty is in a safe place.
  - Behaviour if the basket falls in the water:
    The proper action depends on the basket used. Rigid baskets not equipped with sufficient buoyancy devices sink, so the passengers must exit them as soon as possible. Please take into account that a flexible basket may collapse on its passengers. Capsules and some rigid baskets are designed to float and preserve their passengers who stay in them.

9.4.3 - Emergency Response plan

The Emergency Response Plan of the vessel, facility, and project should take into account incidents that may arise while transferring people by crane:

- Procedures to regain control of the basket in case of exaggerated swinging should be indicated.
- Procedures in case of a breakdown of the lifting device should be in place. They are usually based on a Failure Mode Effect Analysis (FMEA) and consist of activating the backup devices.
- The rescue boat, with appropriately trained personnel, should be ready for immediate deployment in case of a falling at sea. In addition, Life-buoys with heaving lines should be available for immediate use.
- The onboard emergency response team should be ready to intervene. That includes the onboard doctor and the remote medical support. That also includes training the riggers to quickly evacuate an injured person from the landing area.
- Other methods to evacuate injured personnel to a shore-based medical facility should be considered in the emergency response plan.

9.4.4 - Last preparation

Before starting the transfer the lifting supervisor should ensure of the following:

- The crane should be visually inspected and function tested (these inspections and tests are similar to those performed for every lifting).

- The basket and the connecting rigging should be closely inspected.
- The permit to work should be in place, and the team and the personnel to transfer has been briefed.
- The communications between the signalman, the crane operator, the bridge of the vessel where the people are to be transferred, and the bridge of the ship or the facility from which the lift-up is performed should be in place and tested.
- The vessels should be in position, ready for transferring people. There should be a minimum offset between the boats (usually 10 m) or the ship and the facility. Also, as mentioned previously, there should be enough distance between the hook and obstructions to allow the basket and its rigging to pass with a minimum clearance (1 m).
- The landing and lift-up areas should conform with what is said in point 9.3.
- Precautions should be implemented to ensure that the passengers are kept in a safe place and access the lifting device only when it is ready:
  - There should be a designated passenger waiting area.
  - Precautions should be in place to prevent unauthorised access to the waiting, and lifting/landing areas.
  - The team should ensure that the passengers wear appropriate personal protections. Note that passengers not in condition to be transferred should not be kept in the waiting area.
  - It is recommended that inexperienced people should be accompanied by experienced persons.
  - On large projects with many people to transfer, a system of registration and call is in place. It is more familial in small units where the lifting team knows every crew member.
  - Buoyancy devices and harnesses should be distributed before accessing the basket.
  - The passengers move to the lifting area on the instruction of the person assigned to this function (Usually the lifting supervisor or the signaler).
- The team should ensure that the maximum capacity of the basket is not exceeded
  - Passengers and their personal effects, such as computers, tablets, and confidential documents, should be weighed and distributed appropriately for the good stability of the basket.
  - As mentioned, the luggage must be transferred separately in a specific basket.
- The green light to launch the operation is given by the bridge. The lifting supervisor should not undertake the procedures as long as this green light is not given.

9.4.5 - Landing and post transfer procedures

The passengers should wait for the instruction of the person in charge to leave the basket after its landing. Depending on the company's procedures and the site configuration, they should go into the designated waiting area. They leave this area when the person in charge instructs them.

The lifting supervisor should inform the bridge when the operation is completed. Also, the crane operator and the riggers should:

- Disconnect the basket, and store it in its dedicated place.
- Secure the crane in the rest position and stop it.
- Visually inspect the crane, fill out the logbook, and request technical intervention if needed.
- Closely inspect the basket and its lifting rigging.
- Protect the basket and its rigging from weather conditions.

The permit to work is closed when the basket and the crane are secured.

Bibliography

ASME B29.24: “Roller load chains for overhead hoists”.

ASME B30.16: “Overhead Underhung and Stationary Hoists - Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings”.

ASME B30.20: “Below-the-Hook Lifting Devices”

ASME B30.21: “Lever Hoists: Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings”

ASME B30.26: “Rigging Hardware”

ASME B30.30: “Ropes: Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings”

ASME B30.7: “Winches”

ASME HST-2: “Performance standard for hand chain manually operated chain hoists”

ASTM A1023/A1023M-21: “Standard Specification For Carbon Steel Wire Ropes For General Purposes”

ASTM A153/A153M: “Hot Dip Zinc Galvanised Coating on Fasteners”

ASTM A-220, 60004: “Standard Specification for Pearlitic Malleable Iron”

ASTM A-27: “Standard Specification for Steel Castings, Carbon, for General Application”

ASTM A563: Standard Specification for Carbon and Alloy Steel Nuts

ASTM B117: “Standard practice for operating salt spray (fog) apparatus”

ASTM B-695: “Mechanical Zinc Plated Fasteners”

EN 10083: “Steels for heat treatment, alloy steels and free-cutting steels “

EN 10244-2: “Steel wire and wire products. Non-ferrous metallic coatings on steel wire Zinc or zinc alloy coatings”

EN 10264-1: “Steel wire and wire products. Steel wire for ropes General requirements”

EN 12329: “Corrosion protection of metals - Electrodeposited coatings of zinc with supplementary treatment on iron or steel”

EN 12385-1: “Steel wire ropes. Safety General requirements”

EN 12385-2: “Steel wire ropes. Safety Definitions, designation and classification”

EN 12385-3: “Steel wire ropes. Safety Information for use and maintenance”

EN 12385-4: “Steel wire ropes. Safety Stranded ropes for general lifting applications”

EN 1261: “Fibre ropes for general service - Hemp”

EN 1263-1: “Temporary works equipment. Safety nets Safety requirements, test methods”

EN 1300: “Secure storage units”

EN 13000: “Cranes. Mobile cranes”

EN 13001: “Crane safety. General design Load actions”

EN 13155: “Cranes - Safety - Non-fixed load lifting attachments”

EN 13157: ”Cranes - Safety - Hand powered cranes”

EN 13411-1: “Terminations for steel wire ropes. Safety. Thimbles for steel wire rope slings”

EN 13411-2: “Terminations for steel wire ropes. Safety Splicing of eyes for wire rope slings”

EN 13411-3: “Terminations for steel wire ropes - Safety - Part 3: Ferrules and ferrule-securing”

EN 13411-4: “Terminations for steel wire ropes. Safety Swage terminals and swaging”

EN 13411-5: “Terminations for steel wire ropes. Safety U-bolt wire rope grips”

EN 13411-6: “Terminations for steel wire ropes. Safety Asymmetric wedge socket”

EN 13411-7: “Terminations for steel wire ropes - Safety - Part 7: Symmetric wedge socket”

EN 13414: “Steel wire rope slings. Safety. Slings for general lifting service”

EN 13414-1: “Steel wire rope slings. Safety Slings for general lifting service”

EN 13414-2: “Steel wire rope slings. Safety. Specification for information for use and maintenance to be provided by the manufacturer”

EN 13414-3: “Steel wire rope slings. Safety. Grommets and cable-laid slings”

EN 13852-1: “General-purpose offshore cranes”

EN 13853: “Swap bodies for combined transport - Stackable swap bodies type C 745-S16 - Dimensions, design requirements and testing”

EN 13889:20W: “forged steel shackles for general lifting purpose”

EN 14492: “Cranes - Power driven winches and hoists - Part 2: Power driven hoists”

EN 14492-2: “Cranes - Power driven winches and hoists - Part 2: Power driven hoists”

EN 1492-1: “ Textile slings. Safety Flat woven webbing slings made of man-made fibres for general purpose use”

EN 1492-2: “Textile slings. Safety Round slings made of man-made fibres for general purpose use”

EN 1492-4: “Textile slings. Safety Lifting slings for general service made from natural and man-made fibre ropes”

EN 1562: “Founding. Malleable cast irons”

EN 1563: “Founding. Spheroidal graphite cast irons”

EN 1677: “Components for slings - Safety - Part 1: Forged steel components, Grade 8”

EN 20286: “ISO system of limits and fits - Part 1: Bases of tolerances, deviations and fits”

EN 20898-2: “Mechanical properties of fasteners - Part 2: Nuts with specified proof load values - Coarse thread

EN 696: “Fibre Ropes for General Service”

EN 697: “Fibre ropes for general service - Polyester”

EN 698: “Fibre ropes for general service - Manila and sisal”

EN 699: “Fibre ropes for general service - Polypropylene”

EN 818-1: “Short link chain for lifting purposes. Safety General conditions of acceptance”

EN 818-2: “Short link chain for lifting purposes. Safety Medium tolerance chain for chain slings. Grade 8”

EN 818-3: “Short link chain for lifting purposes. Safety Medium tolerance chain for chain slings. Grade 4”

EN 818-4: “Short link chain for lifting purposes. Safety Chain slings - Grade 8”

EN 818-5: “Short link chain for lifting purposes. Safety Chain slings - Grade 4”

EN 818-6: “Short link chain for lifting purposes. Safety Chain slings. Specification for information for use and maintenance to be provided by the manufacturer”

EN 818-7: “Short link chain for lifting purposes. Safety Fine tolerance hoist chain, Grade T (Types T, DAT and DT)”

IS 11521: “Specification for cargo handling nets”

ISO 13628-1: “Petroleum and natural gas industries - Design and operation of subsea production systems - Part 1: General requirements and recommendations”

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

ISO 16625: "Cranes and hoists — Selection of wire ropes, drums and sheaves"

ISO 16857: "Ships and marine technology — Loose gear of lifting appliances on ships — Shackles"

ISO 17558: "Steel wire ropes — Socketing procedures — Molten metal and resin socketing"

ISO 1833:“Textiles - Binary fibre mixtures - Quantitative chemical analysis”

ISO 1833-12: "Textiles — Quantitative chemical analysis — Part 12: Mixtures of acrylic, certain modacrylics, certain chlorofibres, certain elastane fibres with certain other fibres (method using dimethylformamide)"

ISO 188 “Rubber, Vulcanized or Thermoplastic - Accelerated ageing and heat resistance tests”

ISO 2076: "Textiles — Man-made fibres — Generic names"

ISO 2076: “Textiles - Man-made fibres - Generic names”

ISO 2307: "Fibre ropes — Determination of certain physical and mechanical properties"

ISO 2398: “Rubber hoses, textile-reinforced for compressed air. specification”

ISO 2408: " Steel wire ropes — Requirements"

ISO 37 “Rubber, Vulcanized or Thermoplastic - Determination of tensile stress-strain properties”

ISO 4042: "Fasteners - electroplated coatings"

ISO 4126-1: "Safety devices for protection against excessive pressure — Part 1: Safety valves"

ISO 4309: "Cranes — Wire ropes — Care and maintenance, inspection and discard"

ISO 5084: "Textiles — Determination of thickness of textiles and textile products"

ISO 606: "Short-pitch transmission precision roller and bush chains, attachments and associated chain sprockets"

ISO 643: “Steels -Micrographic determination of the apparent grain size”

ISO 6938: “Textiles - Natural fibres Generic names and definitions”

ISO 7500-1: Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system"

ISO 898-1: "Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread"

ISO 9002: "Quality management systems — Guidelines for the application of ISO 9001"

ISO 9454: "Soft soldering fluxes — Classification and requirements — Part 1: Classification, labelling and packaging"

ISO 9554: “Fibre ropes - General specifications”

OSHA 1926.1431: "Hoisting personnel"

OSHA 1926.1413: "Cranes and Derricks in Construction"

OSHA 1926.751: "Steel Erection"

OSHA 1926.1431(d): "Cranes and Derricks in Construction"

UK Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)

Cargo work for maritime operations (Author: David J. House)

Container Quay Crane Structural Response under Trolley Traveling (Authors: Xiong Hu , Kai Dong , Pei Zheng , Zhiwei Sun , and Sen Mu)

MEDEA: “Conversion of marine cranes in offshore cranes”

US Navy S0300-BV-CAT-020: “Emergency ship salvage catalog”

Dynamic Analysis of Full-Circle Swinging Hoisting Operation of a Large Revolving Offshore Crane Vessel under Different Wave Directions (Dapeng Zhang, Bowen Zhao, Keqiang Zhu ,and Haoyu Jiang)

Mechanical characteristics analysis of horizontal lifting of subsea pipeline with different burial depths (Dapeng Zhang, Bowen Zhao, and Keqiang Zhu 3

Finite Element Analysis and Reinforcement of Steel Crane Beam under Eccentric Track Loading (Chunting Lu, Zheng Yang, Pengfei Li, Xiangwei Zhang, Jie Huang, and Ling Wang

Heave Reduction of Payload through Crane Control based on Deep Reinforcement Learning using Dual Offshore Cranes (Jun-Hyeok Bae, Ju-Hwan Cha, Sol Ha

Maritime Coast guard agency MGN 618: Guidance for the control and operation of lifting gear

Installation of offshore wind turbines: A technical review (Author: Zhiyu Jiang)

Tips for crane operation in extreme weather conditions (Steve Verboom / American crane and transport)

Step change in safety: Lifting and mechanical handling

Maritime & coastguard agency: Code of Safe Working Practices for Merchant Seamen

DNV-GL: Part 5 Ship types Chapter 10 Vessels for special operations

Safe transfer: Offshore personnel basket sit down

Marine transfer forum: Offshore personnel transfer by crane

OCIMF: Transfer of personnel by crane between vessels

Brookhaven National laboratory: Basic rigging workbook

London Offshore Consultants: Marine lifting

Noble Denton: Guidelines for marine lifting operations