Guidelines and recommendations for ship design on work deck installation and operations for scientific equipment

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1. Introduction

The fast expansion of oceanography in recent years, probably begun with fisheries research vessels and later with multipurpose vessels, has focused attention on the design of modern and efficient Research Vessels (RVs) capable to optimally deploy sophisticated instruments and to collect a wide range of in-situ data.

Many fisheries research vessels have been built, from the early 1950s onwards. The first ships could perform some trawls and also incorporated acoustic instruments such as direct samplers, CTD, plankton nets, etc. Some of these ships were refitted over the years as a result of increasing interest in the study of marine biology, physical oceanography and geo-sciences. Stern A-frames replaced the whip. In some cases the spare decks and ramps were removed to facilitate the deployment of new equipment astern; this gradually incorporated electronics. This development was consolidated with the passage of time, leading to multipurpose vessels. Oceanographic vessels are becoming more versatile today. Achieving versatility in a 90-metre ship is relatively easy as its available deck space and laboratories are large enough to deploy any type of equipment. But having a good multi-purpose vessel 50 metres in length or less is more difficult, with space constraints, limits on the maximum load for winches and cables, and on the dimensions for multibeam transducers etc. The design of such vessels therefore needs to be analysed thoroughly.

Depending on the area where the ship is to work, bathymetric, meteorological, and logistical features, as well as the scientific objectives of the researchers, will determine the performance of the vessel. There is a difference between work on the continental shelf at depths of 200-300 metres and work in the open sea, off the slope, in areas where the shelf is minimal and depths can reach 2000 or 3000 m. Winches, cables, echosounders and instrumentation will have different features: winches influence the required power of the vessel, echo sounders the keel structures where they settle. Deep-water multibeam echosounders have transducers with physical dimensions that can be a major factor in the design of a ship's keel. The maximum working depth in the specifications therefore has the most influence on the shape, power, and ultimately the vessel performance.

Another aspect is habitability. Depending on labour regulations for seamen in the country concerned, there may be as many crews on a medium-size vessel as on a larger ship. Another factor is the sailing regime: for oceangoing RVs, with cruises lasting 10 to 40 days, a crew of 12-14 is common. It follows that the number of crew cabins in a medium-size vessel is very similar to that on a larger vessel. However, the size does determine the number of science cabins. This in turn affects the amount of laboratory space and space on deck.

This report aims to provide guidelines and recommendations on work deck installation for Regional Research Vessels (RRVs) devoted to carry out oceanographic and/or fisheries research missions on the continental shelf and in the open ocean in specific geographic regions.

Making recommendations is not easy because the recipient of these recommendations has objectives to meet that have sometimes not even crossed the minds of those issuing the recommendations. There is no such thing as a standard Regional Vessel. However, it is possible to find common ground for existing ships. These existing common points embody solutions in design, construction and operation that showcase sources of inspiration for the designers of future RRVs.

In this context, the present analysis initially attempts to list and describe in a non-exhaustive way instruments and vehicles which can be deployed from a RRV. As a contribution of the EUROFLEETS2 project towards standardization of sampling procedures and interoperability of equipment and gears within European research fleets, the study then provides guidance on the choice of gears and the sequence of actions required for their safe deployment and recovery on board. Deck operations and deployment of sampling equipment are indeed tasks that require the participation of all the teams on board. Researchers define the scientific objectives; technical personnel adapt sampling equipment and operational conditions to these objectives; the deckhands and the boatswain deploy the equipment safely; engineers on board oversee the operation of the rigs and gear; and last but not least, the mate and officers steer the ship. All of them are essential and necessary to get the sample on deck. In view of this, when designing a RV, all these groups must be involved on work deck design.

Finally, general work deck arrangement and facilities are presented, aiming to ensure flexibility over the work deck despite its limitation in space and to make the ship as multipurpose as possible.

2. Some preliminary definitions

2.1. Maximum sampling depth

Maximum sampling depth will affect winch specifications, cable lengths, and multi-beam and other echo-sounders installed on the hull. For the equipment installed on the work deck and winch deck, the weight of the winch and cable will affect the structure and Safe Working Load (SWL) of frames, cranes and other gear installed. The assumption is that if the ship is designed for deep sea sampling, shallow sampling will also be possible but the dimensions of the gear will result in less space on deck, more loads and structure on deck, and more maintenance. This is because if a ship never works at deep sea, the design can allow for less equipment being needed. However, future changes to equipment could be limited due to layout and construction practices.

A maximum depth of 3000 m is proposed for these guidelines for RRV. In most oceans, this depth is not attained on abyssal plains but is on covering slopes. For towing equipment, 3000 m is also a good length for cables.

2.2. Research Vessel and scientific disciplines

Science is likely to be conducted in increasingly remote and environmentally challenging areas, i.e. with the ability to operate with minimal interruptions from the natural elements. However, the following areas of functionality are becoming increasingly important in modern research ship design.

During the second half of the twentieth century, developed countries began to build fisheries research vessels to study fish stocks and populations. Since then, commercial fishing vessels – usually stern trawlers – were used for this purpose. Later, other disciplines, such as marine biology or physical oceanography, supplemented the main objectives of fisheries research with integrated studies of the environment and its influence on fish stocks. These vessels were designed as conventional fisheries vessels with some laboratories and accommodation for scientific and technical staff attached, in line with academic objectives and standards. By the close of the twentieth century, some RVs were designed for other main objectives including marine geology, seismics, etc. which needed other deck arrangements. Fisheries vessels have a very 'closed' work deck with ramp and breakwater, winches, net drums, and whip and fixed frames. Later, RVs were designed for sampling not only fish but also phyto- and zooplankton, water, and sediments in general. These vessels deployed Niskin bottles and bongo nets from aside the ship.

Two types of RVs can therefore be considered: fisheries RVs and multi-purpose RVs. Other concepts of specialized RVs, such as seismic and drilling ships, were developed as well but they have not been considered in this document because they are rarely to be found in the format of a Regional RV.

2.2.1. Multi Purpose RV

Oceanographic research vessels carry out research into the physical, geosciences, chemical and biological characteristics of water, the atmosphere and climate, and to these ends carry equipment for collecting water samples from a range of depths, including the deep seas, as well as equipment for the hydrographic sounding of the seabed, along with numerous other environmental sensors. These vessels often also carry unmanned underwater vehicles. Since the requirements of both oceanographic and hydrographic research are very different from those of fisheries research, these vessels often fulfil dual roles.

Thus, limitations of remote sensing mean that ships remain the primary method of conducting oceanographic research, both through direct observation as well as through the deployment of autonomous vehicles and installations. At the same time, research vessels are likely to be required to support increasingly complex, multidisciplinary, multi-investigator research; this will drive many aspects of design, including power plant and propulsion, laboratory and work deck layout, over-the-side handling, launch and recovery, and equipment changeover. Because technology changes rapidly and ship lifespans are long, present and future research ship design will need to be highly adaptable as needs change.

Moreover, the safe handling of increasingly large and more complex platforms and instruments over the side in high sea states (up to sea state 6) means that handling arrangements are critical. The installation of heave compensation, to isolate deployed packages from ship motion, is also becoming increasingly common, in the form of CTD winches. In addition, autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) require specific deployment and recovery procedures and equipment. The main purpose of this document is to give some guidelines about all these points.

2.2.2. Fisheries RV

Fisheries Research Vessels (FRVs) are usually stern trawlers with an aside frame or frames for deploying equipment. The stern of these vessels is equipped with a ramp for deploying and recovering the net and with a grantee or frame aside for deployment of bongo plankton nets and CTD or equivalent.

A FRV requires platforms which are capable of towing different types of fishing nets, collecting plankton or water samples from a range of depths, and carrying acoustic fish-finding equipment. Fisheries research vessels are often designed and built along the same lines as a large fishing vessel, but with space given over to laboratories and equipment storage, as opposed to storage of the catch.

Moreover, nowadays, FRVs are increasingly multipurpose vessels which can also carry out other oceanographic research. The work deck, laboratories and all scientific spaces are designed with flexibility in mind.

2.3. Definition of a Regional Research Vessel (RRV)

Regional RVs operate on the continental shelf and in the open ocean in specific geographic regions. They are designed to optimize unique regional conditions, such as the capability to work in shallower areas such as estuaries and bays, or under seasonally harsh weather conditions.

Several categories of RVs can be considered depending on their performances: Global, Ocean, Regional, Coastal and Local. A definition of RVs from the Regional class was described in the EUROFLEETS2 Deliverable D2.1 ([6]) and presented in the ERVO 2014 meeting in Barcelona (Spain) ([7]): RRVs should sail a maximum of 2000 nautical miles from a base, have a length between perpendicular comprised between 30 metres and 65 metres, and have a capacity of science berths (including scientists and non-permanent technicians) of more than 10.

This document is focused on this type of RV as regards recommendations on work deck installation and does not apply to larger or smaller vessels.

2.4. Decks

2.4.1. *Aft working deck*

The research vessel's aft work deck is an exposed deck (weather deck). Most handling operations are carried out on this deck. Research vessel work decks are designed with flexibility in mind, with deck areas uncluttered by fittings and as open as possible to enable fitting of a wide variety of equipment. New research vessels facilitate the fitting of equipment and storage and laboratory containers on deck by means of a matrix of deck sockets. Ideally, research vessels should be designed with low freeboard to facilitate deployment and recovery of over-the-side equipment, but in rough seas this leads to these decks becoming submerged regularly, limiting working conditions, while modern damage stability requirements are leading to higher freeboards. Once again, the design has to be a compromise.

2.4.2. *Winch deck*

When possible in the general arrangement of research vessels, fishery and oceanographic winches are fixed on a deck lower than the work deck. In such cases, this deck is known as the Winch Deck. The aim of this is to clear the work deck to have more flexibility. Nevertheless, this set-up includes managing specific sheaves for deck outsets linked to the A-frame or telescopic boom used for handling.

3. Equipment and vehicles deployed from a RRV

3.1. Conductivity, Temperature and Depth Equipment (CTD)

3.1.1. *CTD and Rosette*

CTD (Conductivity, Temperature and Depth) equipment is perhaps the most popular tool in oceanographic cruises. Knowing seawater conductivity and temperature allows seawater salinity and density to be calculated; on that basis, other variables such as the velocity of sound can be calculated along a depth profile. Consequently CTD is used not only in physical oceanography but also in marine biology and geosciences.
CTDs are widely used in physical oceanography, and are also commonly used in marine research in biology and earth science. CTDs are usually integrated in carousels containing Niskin bottles: this allows physical water sampling at selected depths.

Fig. 3.1.1.a - CTD-Rosette on board RV Sarmiento de Gamboa (Photo: UTM)

To control these two instruments, a cable with an internal conductor is needed to transmit commands and receive digital data from the equipment. As a result, the winch to deploy this equipment requires a slip ring to transmit electrical signals and power from the cable through the winch drum to the laboratory or control room.
Some CTDs (self-contained) can store the data in the internal memory of the instrument, and can thus operate without a coax cable. In this case a traction cable is sufficient. The rosette can be programmed to close bottles at specified depths, or a manual command can be used to take water samples. Several types of sensor in addition to temperature, conductivity & depth, such as fluorescence, oxygen, pH, transmittance, etc. can be installed on CTDs. In order to prevent the instrument package hitting the ocean floor, an altimeter is needed for safety purposes.

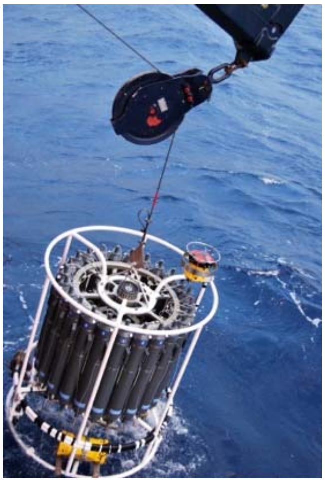


Fig. 3.1.1.b - CTD-Rosette deployment (Photo UTM)

Fig. 3.1.1.c - CTD Rosette deployed astern. R/V García del Cid. (Photo UTM)

3.1.2. Undulating CTD

This is a conventional CTD installed in a tow vehicle, allowing the instrument to be navigated up and down in the water column while the ship is sailing. There are two ways to make the vehicle go up and down. The first is simply to pull and haul down the cable alternately. For the second, the vehicle is equipped with two side fins with a variable angle of attack. These are programmable, and/or under command of the operator. A hydraulic pump powered by a propeller is actuated to move the flaps. This type of equipment is used for longer sampling periods, as it takes time to stabilize the undulating path. Once this is configured, it can be used for several days.

For the first method, one of the available winches on board can be used, for example the one also used for side scan sonar or electronic plankton nets. In the second case a specific winch is used. These winches have a single layer of cable and the cable has fairings reducing drag and making it sink more easily. The winch drum diameter is large enough to hold 2000 m of wire in a single layer.

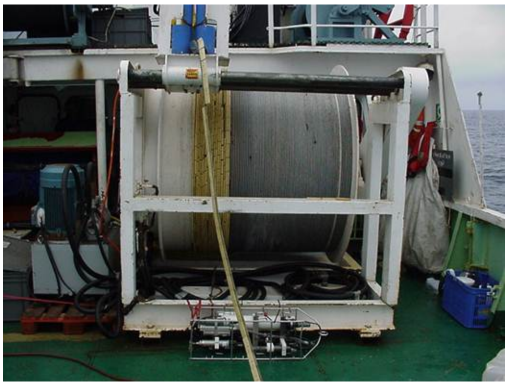


Fig. 3.1.2.a - SeaSoar winch (Photo UTM)

3.1.3. MVP

The Moving Vessel Profiler™ (MVP) is a multi-purpose instrument for collecting both shallow and deep water data sets. The main function of the MVP is to acquire accurate data collection when the ship is moving. This equipment is an alternative to CTD in specific cases.

The system ([10]) includes a computer-controlled smart winch and deployment system that allows a free fall fish to be deployed while the vessel is underway. The system is completely autonomous and can be controlled by computer without the need for personnel on deck. The system was originally adapted to collect Sound Velocity (SV) data for shallow water (100 m) hydrographic operations. The data was used to calibrate multibeam sonar data for the Canadian Hydrographic Service.

The Free Fall Fish designed for use with the MVP system can carry a variety of sensor packages. Each fish is specifically designed to work with a MVP system to obtain that system's maximum operating depth. The Free Fall Fish is available in single- and multi-sensor models. Sensors that have been used with the MVP system to date include Sound Velocity, CTD, Laser Optical Particle Counter (LOPC) and fluorimeter.

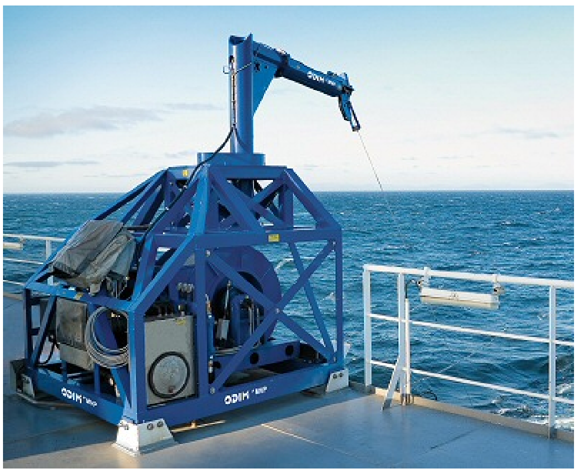


Fig. 3.1.3.a - Example of MVP300 (Photo RollsRoyce)

3.1.4. CTD deployment

CTD Winch

A CTD winch can be either electrical or hydraulic, and should be equipped with a slip ring. Its safe working load depends on the maximum operational depth of the CTD. The weight of a CTD-Rosette may be up to one tonne, however the weight of the cable must also be considered.

Deployment is recommended amidships, on the starboard side (the “clean” side of an oceanographic vessel) to avoid pitch effects and a long distance between the spooler and the snatch block and frame. The lowering speed of equipment depends on winch specifications, sea state conditions and total weight. Usually, this never exceeds 60 metres per minute.

Cable

CTD cable may be steel cable with one or more conductors, or a coax cable. Because transmission of data is usually by means of FSK, a coax cable can be used. Its external diameter should be 11 mm or 14 mm. Nowadays, dyneema cables are used for CTD deployment, especially for clean CTD operations.

Gear required

CTD can be operated by a side A frame, a boom or a davit, depending on the vessel design and the size of the CTD Rosette system. The use of a wave compensator is recommended. Moreover, the safe working load depends on the maximum depth to be reached by the CTD. Indeed, the weight of a CTD-Rosette may be as much as one tonne, however the weight of cable, especially in the case of a steel cable, needs to be considered.

3.1.5. Operation and ship conditions

A CTD is operated when the ship is on station (see §4.1.1). It is raised over the deck with block and frame in the vertical. Usually a deckhand is there to prevent swinging of the rosette or instrument package. Some frames (scissor frames) prevent or damp swinging.

When deploying a CTD or a CTD-Rosette system, as with other deployments, care should be taken with the speed of lowering. The cable must be taut at all times; speed can be increased once there is enough cable in the water. If done too quickly, cables run the risk of being lowered faster than the equipment. Sometimes the weight of the structure may be increased by adding lead weights.

3.1.6. Space necessary on board

The space necessary on board is highly dependent on the type/size of CTD. These operations should be wet operations. Space for the CTD is required on the work deck.
The best solution, where possible, is to place the CTD in the wet laboratory before collecting samples. The laboratory will be used to analyse the sample or to save/package it if necessary prior to further analysis.

Fig 3.1.6.a - Astern deployment of CTD-Rosette.
RV García del Cid. CSIC. (Photo UTM)

3.2. Plankton nets

Plankton nets are used for collecting planktonic organisms of any size, in good condition. Plankton nets may be towed or lowered vertically with the ship on station. To fish plankton, different mesh sizes are needed as appropriate for the different plankton sizes. In addition, organisms' behaviour (swimming) will determine the fishing strategy: vertical sampling or oblique sampling (towing).
Several plankton nets have been developed in the past, ranging from Hensen to Clarke-Bumpus, Nansenm, WP2, Bongo, etc. There are also other systems such as the Continuous Plankton Recorder, able to sample phytoplankton in particular, and towed at high speed. (http://www.briangwilliams.us/marine-ecology/plankton.html).

3.2.1. Bongo net

Bongo nets are generally used for icthyoplankton (fish larvae) collection. This type of net is used in fisheries research in particular, but nowadays may also be used in general marine biology cruises, together with other plankton nets.
Bongo nets have a double ring (steel or plastic) to avoid turbulence in the mouth of the net. They are towed with a 20 kg v-fin acting as a depressor. The mesh size of each of the two nets may differ. The cod-ends are usually cylindrical plastic buckets with a window, covered with a net, for water evacuation. Bongo nets have a long funnel shape, the length of which depends on two factors:

- area of the mouth
- mesh size.

Normal net length is 2.5 m. Two flowmeters are attached to the mouth to estimate filtered water volume.

Fig. 3.2.1.a Bongo net (Photo I. Palomera)

Fig. 3.2.1.b Flowmeters in the mouth of the net (Photo I. Palomera)

Bongo nets are used for the following:

- Ichthyoplankton and zooplankton production
- Oblique and vertical towing applications
- Spatially correlated plankton studies

A standard Bongo net ([11]) will be deployed over the side of the ship collecting plankton on its way up vertically from depths of up to 300 m. As the ship is pitching and rolling in the sea, at one moment the drag and the speed of the net may dramatically increase, while at the next the wire may slacken and the speed of the net slow down.

To compensate for the ship's movements, the Bongo net has a spring mechanism. When the ship heaves upwards, the inertia and increased drag of the net causes more wire to come off the drum, thus maintaining the net's upward velocity somewhere close to the steady state. As the ship moves down, the spring takes in wire and again maintains the upward motion of the net. The motion compensation unit not only maintains a more or less steady speed of the net and considerably reduces stress on the wire; moreover, it catches plankton in much better conditions than in the absence of such a unit.

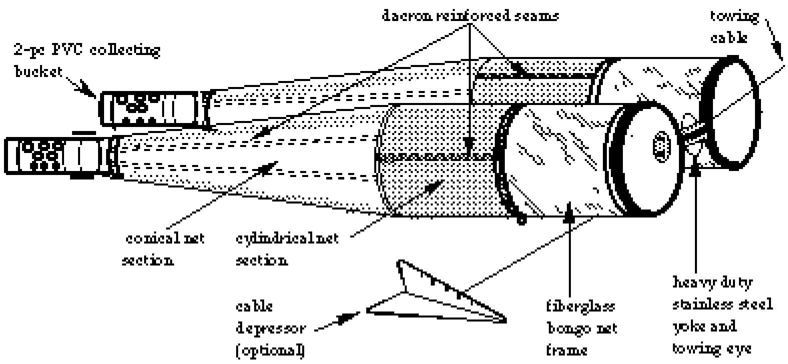


Fig. 3.2.1.a - A bongo net

3.2.2. WP2

The WP2 net is based on a design by UNESCO Working Party 2. The WP2 Closing Net is a vertical plankton net with a messenger for operating the closing mechanism. The ring (mouth) is about 60 cm in diameter and has a length of approx. 2.5 m. The bucket is weighted, to stretch the bag as it descends. This bucket has a window with mesh for water drainage and sample collection. During the ascent, the net can be closed at the desired depth, closing the bag below the ring. This is achieved by sending the messenger via the cable, activating a trigger and releasing the ring as a fixed rope closes out the bag. A flowmeter can be used to estimate filtered water volume. Currently, depth sensors are also used to determine the maximum depth of the net.

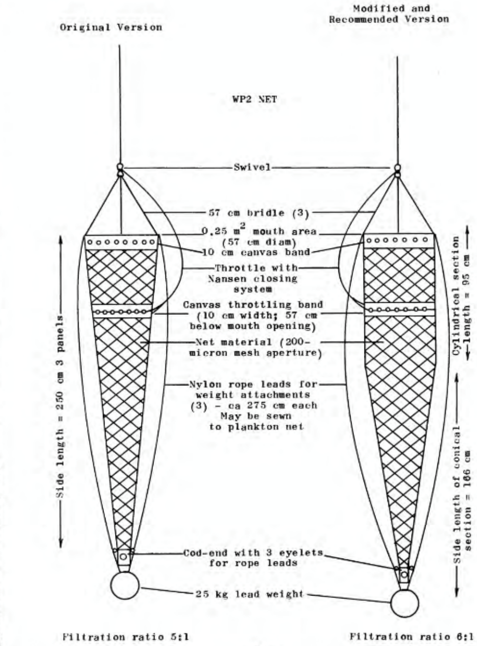


Fig. 3.2.2.a- WP2 net diagram from REPORTS OF WORKING GROUP 13 ON ZOOPLANKTON SAMPLING METHODS. UNESCO. Source: International Council for Science (ICSU) SCOR

3.2.3. Phytoplankton nets

Phytoplankton consist of plant forms and seawater and freshwater algae. In view of algae sizes, phytoplankton nets are very fine (from 350 µm to 50 µm mesh size). The plankton net is funnel-shaped, and towed through the water. The net concentrates the plankton-rich water that passes through it.

A phytoplankton net is very simple ([11]). A metal ring holds a cone-like tube of mesh net with an opening at the end, where a plastic bucket or bottle captures the organisms. The ring, which maintains the mouth open, is tied with three strands of string that are used to pull it. The particles in the seawater which do not pass through the net will be concentrated and trapped within the bottle.

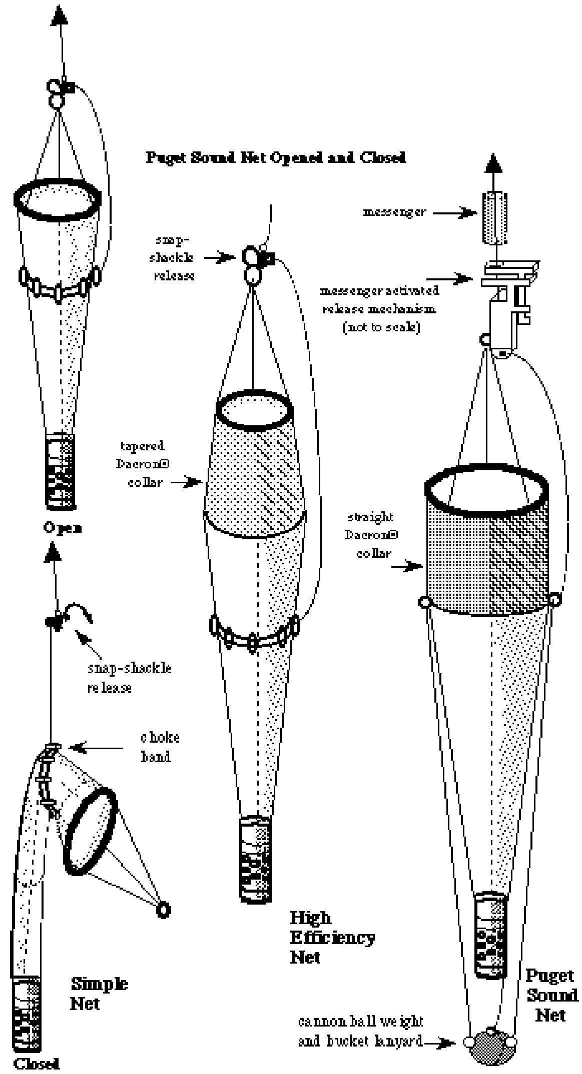


Fig. 3.2.3.a - A phytoplankton net

3.2.4. IKMT and RMT

There are several plankton nets dedicated to macroplankton and nekton, organisms with a size of between 1 mm and 1 cm, including some small fishes like mictophids and crustaceans (euphausiids). Two examples of such nets are IKMT and RMT, usually deployed astern but that may also be deployed aside depending on frame performance, available cable (IKMT nets have a maximum load at high speed (5 knots) of approximately 1.5 tonnes) and ship steering.
A CTD could be added to this type of net if conductor cable is used. A RMT may be controlled by electrical connection or acoustically.

3.2.4.1. IKMT

IKMT (Isaac-Kid Midwater Trawl) is a net with a metal wing acting as a depressor and pulled by steel cables. Its mouth may be from 3 m^2 to 9 m^2; the cod end usually is a plastic bucket about 20 cm diameter and 60 cm in length, alternatively a net cod end may be used. Because it does not have a structural frame or similar, its shape is like a fishing net and deployment is very similar, launching the cod end first ([19 20]).

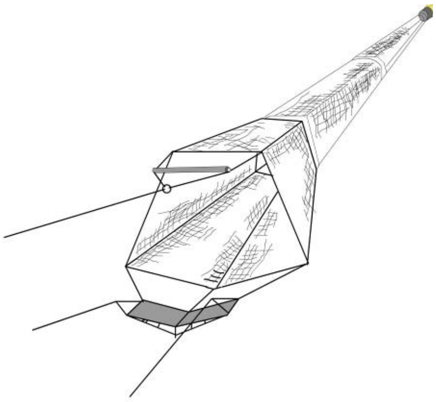



Fig 3.2.4.a - IKMT drawing and picture. Length: 950 cm, mouth area: 3 m2. (Photo: UTM)

This kind of net could be use for collecting microplastics, which are small pieces of plastic less than <5mm. They come from the breakdown of larger plastic items or from direct input as small plastic pellets, scrubbers in cosmetics, plastic powders which are used for air blasting ships hulls. Microplastic fibres can also come from the breakdown of ropes in the marine environment, or from washing synthetic clothing and fibres are not removed at sewage treatment works ([30]).

3.2.4.2. RMT

RMT, from Rectangular Midwater Trawl, is an opening and closing net system with a mouth area of 1 m2 (mesh size 0.33 mm) or 8 m2 (mesh size 4.5 mm). Originally, there was a mechanical system for net closing, but today this can be activated by an acoustic signal or by means of an electromechanical cable ([21]).

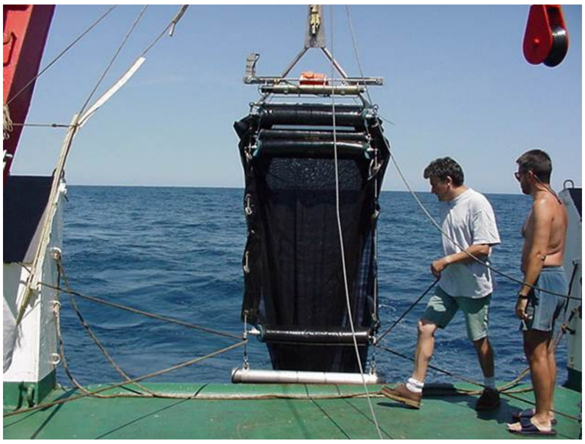


Fig.3.2.4.b - 1 m^2 RMT with mechanical release, controlled with electromechanical cable or acoustically. (Photo UTM)

3.2.5. Deployment of plankton nets

Deployment should be carried out amidships or to starboard (the clean side of oceanographic vessels) to avoid pitch effects and tangling between plankton nets and other nets. The lowering speed for equipment depends on winch specifications, sea state conditions and the type of plankton net.

Winch

Plankton net winches can be electrical or hydraulic. Their safe working load depends on the maximum depth to be reached but is usually around 1 tonne. The maximum cable length also depends on the type of net, but a few hundred metres is always enough for this kind of equipment. Nevertheless, the winch should have the capacity to shoot it very slowly, and have a measure of warp tension and speed. In the case of IKMT and RMT, a trawl winch may be used.

Cable

The cable may be a simple cable, e.g. steel cable, with a diameter as required for the safe working load. Usually, if used only for plankton nets, the diameter can be as small as 6 or 8 mm. Nowadays, dyneema cables are also used, especially for clean measurements.

Gear needed

Plankton nets may be operated by a side "A" frame, a boom, a stern gantry or an stern A-frame, depending on vessel design and other equipment used in the same campaign. Moreover, the safe working load will depend on the maximum depth at which plankton nets are to be used.

3.2.6. Operation and ship conditions

Plankton nets can be towed or lowered on station. In the case of towing, such as for bongo nets, the ship should turn to starboard (if starboard is the deployment side) so that the net does not fish in the ship's wake. Many fish larvae live in the uppermost part of the water column, and propeller turbulence disrupts the sample. Turning slightly to starboard also prevents the cable from touching the hull or passing beneath it, which is dangerous for both the propeller and the bongo net.
Haul speed is approximately 2 to 3 knots. Cable unwinding can range from 10 metres per minute to 20 metres per minute, similarly for winding when loaded. Maximum depth depends on the objective; for ichthyoplankton this is typically around 300 m.

For vertical hauling, the ship must be stopped (on station) and ideally propeller off. The net is lowered to the desired depth (usually using cable length as a depth indicator) and pulled up again at a rate of 10 m per minute.

In the case of IKMT and RMT, towed astern, the operation is similar to dredging: with the ship at 1.5 to 2 knots, the cod end is launched first and the net is hoisted with the winch and frame moving it astern, then lowered slowly into the water. For recovery, the ship must reduce speed slightly and, with the frame all out, pull the cable until the net mouth and depressors are out of the water and approximating a vertical position. The frame is then retracted and the net and cod end recovered.

3.2.7. Space necessary on board

Relatively little space is required to use plankton nets. The operations involved are wet operations. A space on the work deck is necessary to place the net and collect samples. A wet laboratory is then used to analyse samples, preferably near the work deck.

3.3. Electronic Plankton nets

A new development relating to plankton nets and the evolution of electronics is the "electronic plankton net". These devices are developed with a number of aims in mind:

- Having multiple samples for different depths (depth stratified sampling) or other conditions
- Establishing the environmental conditions of the sample, such as salinity, temperature, fluorescence, oxygen, etc.

To achieve this, signals must be received from or sent by the ship to the device. Some nets may be operated on a "self-contained" basis, i.e. programmed and functioning with no conductor cable, but it is generally more beneficial to operate the net in real time, closing and opening the consecutive nets as desired, taking decisions on the basis of information from the equipment, e.g. temperature/salinity, depth etc., or from ship echo sounders, for instance. Depending on the size of the target (plankton organisms may vary in size from micrometres to centimetres) the “ideal” multisampling method varies. One of the objectives is to have samples not contaminated by the previous sample. This is achieved using multi-nets: a set of several nets, which open only once the previous net has closed. This is the case for the second and third examples showed here: MOCNESS and MultiNet (HydroBios). If the size of the targets is relatively small (mesoplankton) then another system is used. Inspired by the Continuous Plankton Recorder, the LHPR uses two layers of gauze, rolled together and preserving the sample between the layers.

<table>
<tr><td>megaloplankton</td><td>> 20 mm</td><td></td></tr>
<tr><td>micronekton</td><td>20 - 200 mm</td><td rowspan="3">net plankton</td></tr>
<tr><td>macroplankton</td><td>2 - 20 mm</td></tr>
<tr><td>mesoplankton</td><td>200 µm- 2 µm</td></tr>
<tr><td>microplankton</td><td>20 - 200 µm</td><td rowspan="3">water bottle plankton</td></tr>
<tr><td>nanoplankton</td><td>2 - 20 µm</td></tr>
<tr><td>ultrananoplankton</td><td>< 2 µm</td></tr>
</table>

Table 3.3 Plankton size. From: Makoto Omori and Tsutomu Ikeda. Methods in marine zooplankton ecology. (New York: Wiley, c1984.)

Some of these plankton nets may be deployed towed (oblique haul) or “on station” (vertical haul)

3.3.1. LHPR

As noted previously, the Longhurst Hardy Plankton Recorder (LHPR) (&é) collects plankton samples using two mesh layers which are rolled together and trap the organisms, which are collected by a plankton net. This system is very useful for high resolution studies in the water column and can be used as a continuous plankton sampler. The LHPR is 2.5 m in length and 76 cm in diameter with a conical nose on the front, 20 cm or 40 cm in diameter.

Fig. 3.3.1.a LHPR on board. (Photo UTM)

Fig. 3.3.1.b Deploying the LHPR. (Photo UTM)

Fig. 3.3.1.c The LHPR in the water. (Photo UTM)

3.3.2. <u>MOCNESS</u>

MOCNESS (Multiple Opening and Closing Net ([13 22])), with an Environmental Sensing System) is a multi-net system with several (6 to 20) nets that are opened and closed remotely. Environmental sensors are attached to the net; these provide depth, temperature, conductivity (salinity) (CTD), fluorescence, oxygen and light readings in real time.

A research vessel tows MOCNESS at a crawl - 2 to 3 knots with a 45º frame angle and at depths of up to 6000 m. The size of the net ranges from 0.25 m^2 to 20 m^2. The mesh size may be geared to phytoplankton (64 um) up to 3 mm for macrozooplankton and micronekton organisms. Anything larger than the mesh size gets swept into the back of the net and collected in a sampling container called a cod end.

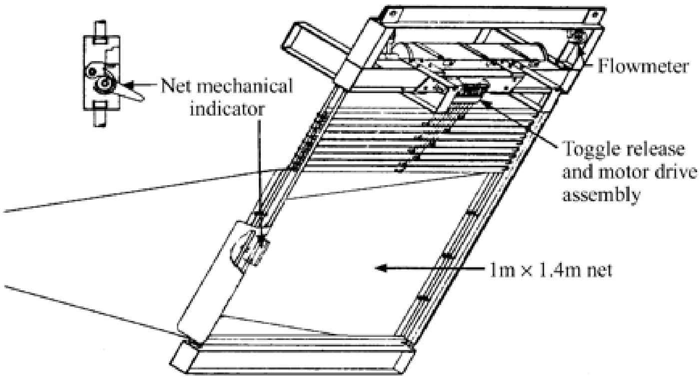


Fig. 3.3.2.a - Drawing of a MOCNESS (Wiebe et al., 1976)

3.3.3. <u>MULTINET</u>

The improved MultiNet generation of the Multiple Plankton Sampler([13]) claims to be the world's leading sampling system for horizontal, oblique and vertical collections in successive water layers. The HydroBios MultiNet can be used in 4 sizes (apertures): mini (0.125 m^2), midi (0.25 m^2), maxi (0.5 m^2) and mammoth (1 m^2) and 5 or 9 nets are used. The net bags are opened and closed by means of levers, triggered by a deck unit through a single or multiple connector cable.

A wide selection of mesh sizes for the net bags is available to meet the requirements of all standard and non-standard applications. For common uses, mesh sizes from 55 to 780 microns are applicable. The current depth of the device is monitored continuously using a depth sensor. Two electronic flowmeters (one inside the net mouth and one outside) are integrated in the equipment. The MultiNet can be used for vertical and oblique hauls. A depressor is used in oblique-horizontal hauls.

Fig.3.3.3.a - MultiNet deployment astern.
(Photo UTM)

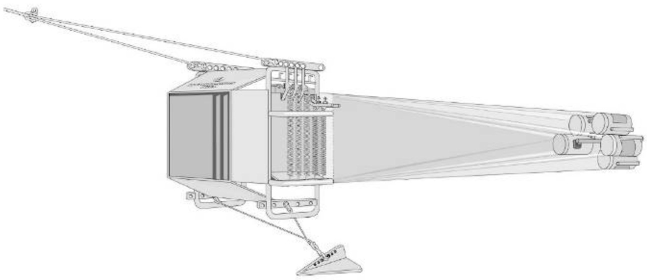


Fig. 3.3.3.b - Multinet (13)

3.3.4. Deployment of plankton nets

Deployment should be carried out amidships and to starboard (the clean side of oceanographic vessels) to avoid pitch effects and tangling between plankton nets and other nets. The lowering speed for equipment depends on winch specifications, sea state conditions and the type of plankton net.

Winch

Plankton net winches can be electrical or hydraulic. Their safe working load depends on the maximum depth to be reached but is usually around 1 tonne. The maximum cable length also depends on the type of net, but a few hundred metres is always enough for this kind of equipment. Nevertheless, the winch should have the capacity to shoot it very slowly, and have a measure of warp tension and speed.

Cable

The best solution is to have a conducting cable available on board with at least one conductor, with a diameter as required for the safe working load. Usually, if used only for plankton nets, the diameter can be as small as 6 or 8 mm. Nowadays, dyneema cables are also used, especially for clean measurements.

If a conducting cable is not available on board, the required sampling depth can be pre-programmed using a PC. The activation of the net bags is then carried out automatically according to the pre-selected depth intervals. All measuring data are stored inside the internal data memory during the operation and can be read by a PC once the net is back on board.

Gear needed

Plankton nets may be operated by a side “A” frame, a boom, a stern gantry or an stern A-frame, depending on vessel design and other equipment used in the same campaign. Moreover, the safe working load will depend on the maximum depth at which plankton nets are to be used.

3.3.5. Operation and ship conditions

Plankton nets work by being towed behind almost any research vessel, as long as they have a winch, the proper kind of data-conducting cable, and enough engine power to pull the plankton net through the water. The net must be towed slowly (at less than 3 knots). The slow speed means that some of the larger zooplankton can actually out-swim the net and escape.

In its initial position, the net is brought to water with all net bags closed and the water flowing freely through the frame. The instrument can be lowered with high speed to the greatest desired depth. There, the first net bag is opened by push-button control from the deck command unit. At the end of the horizontal collection, after passing the intended depth interval in the case of vertical operation, the first net bag is closed by a second command.

The second net is opened simultaneously. This procedure is repeated for the remaining net bags; the deck command unit indicates the number of the currently active net bags.

3.3.6. Space necessary on board

Relatively little space is required to use plankton nets. The operations involved are wet operations. A space on the work deck is necessary to place the net and collect samples. A wet laboratory is then used to analyse samples, preferably near the work deck.

3.4. Trawls

3.4.1. Bottom trawls (3)

A bottom trawl involves using a cone-shaped net that is towed (by one or two boats) along the bottom. The aim of this kind of trawl is to catch bottom and demersal species. The net consists of a body ending in a cod end, which retains the catch. Normally the net has two lateral wings extending forward from the opening. The mouth of the trawl is framed by headline and groundrope. It is designed and rigged to catch species living on or near the bottom. Bottom contact with the gear is needed for successful operations. Three categories of bottom trawls can be distinguished based on how their horizontal opening is maintained: beam trawls, bottom otter trawls, and bottom pair trawls.

- Beam trawls are commonly designed without wings; in these trawls the horizontal opening of the net is provided by a beam, made of wood or metal, which is up to 12 m long. The vertical opening is provided by two hoop-like trawls, mostly made from steel. No hydrodynamic forces are needed to keep a beam trawl open.
- An otter trawl consists of a cone-shaped body, normally made from two or four panels, ending aft in a cod end and with lateral wings extending forward from the opening.
- A bottom pair trawl consists of a cone-shaped body, normally made of two or four (or sometimes more) panels, closed by a cod end and with lateral wings extending forward from the opening.

The groundrope, equipped with rubber discs, bobbins, spacers etc., protects the trawl from damage. On very rough bottoms, special rock hopper gear is used. Beam trawls are designed and equipped differently.

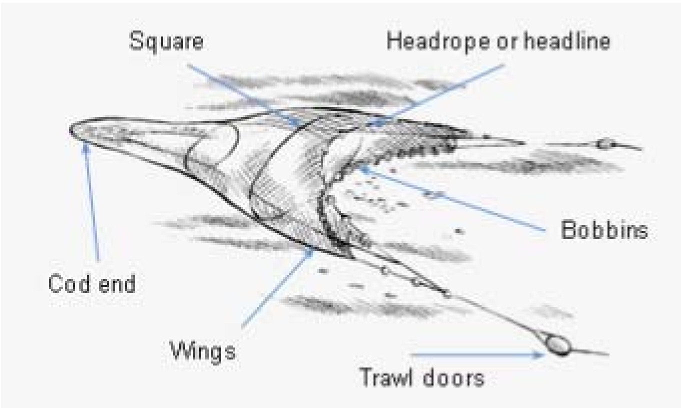


Fig. 3.4.1.a - Bottom trawl (3)

3.4.2. Pelagic trawls

A midwater trawl (15) consists of a cone shaped body, normally made of four panels, ending in a cod end with lateral wings extending forward from the opening. It is usually much larger than a bottom trawl and designed and rigged to fish in midwater, including in surface water. The front parts are sometimes made with very large meshes or ropes, which herd the targeted fish inwards so that they can be overtaken by smaller meshes in the aft trawl sections. The horizontal opening is maintained either by otter boards or by towing the net by two boats (pair trawling). Floats on the headline and weights on the ground line often maintain the vertical opening. Modern large midwater trawls, however, are rigged in such a way that floats are not required, relying on downward forces from weights to maintain the vertical opening during fishing.

A sonar is useful tool to detect fish concentration ahead of the trawler, so the trawl path and trawl depth can be adjusted accordingly. The fishing depth and the trawl are usually controlled by means of a netsounder (*netsonde*) or depth recorder.

Midwater trawling is carried out mainly at sea, on the continental shelf, but can be carried out in deeper waters; in most cases it is a single species fishery. The target species can be demersal fish, but usually the target species are pelagic species such as mackerel, herring, tuna, pilchard, and sea bass.

Electronic equipment such as sonar, net and catch monitors has greatly improved the precision of this method of fishing. Normal towing speed is in the region of 3.75 knots, but may be increased to as high as 5 knots when fishing for mackerel. Pelagic gear is also used for a number of seasonal fisheries such as that for hake in the Clyde and North Channel, the sea bass fishery in the English Channel, certain cod and haddock fisheries in the Irish Sea, and various targeted North Sea fisheries.

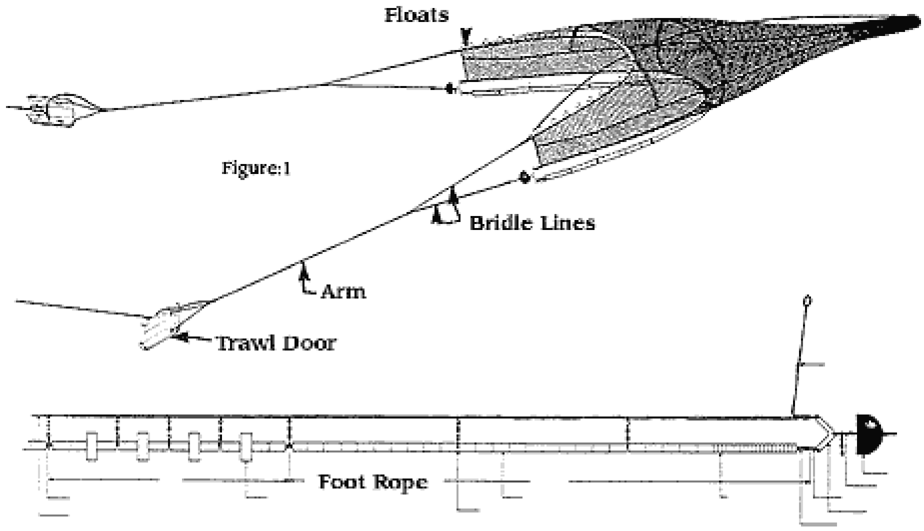


Fig. 3.4.2.a - Pelagic Trawl

3.4.3. Other trawls

There are many kinds of trawls. Space does not permit all the kinds to be detailed; this paragraph focuses on the most-used type: boat seines ([3]).

Boat seines consist basically of a conical netting body, two relatively long wings and a bag. An important component for the capture efficiency of boat seines is the long ropes extending from the wings, which are used to encircle a large area. Many seine nets are very similar in design to trawl nets. Frequently, however, the wings are longer than on trawls. The groundrope is usually a fairly heavy rope weighted with lead rings or hanging lead ropes. The seine ropes are made from synthetic fibre ropes with a lead core or from a combination of ropes.

In medium and large sized vessels, special rope hauling (a small but fast winch) and coiling machinery is installed on deck. The long ropes are often coiled in bins (on or below the deck) but on modern Seiners these are stored on large hydraulic reels.

Seine netting as originally developed, included setting of an anchored dahn (marker) buoy from where a first dragline was set, followed by one for the wing, the bag net, the second wing and finally the second dragline when the boat comes back to the anchored buoy. The whole gear encircles a large area in a more or less triangular pattern. The net is retrieved by the anchored boat: this is done by hauling the two drag lines simultaneously with the help of the winches, first relatively slowly, then increasing to a larger hauling speed when the net is nearly closed. The use of an anchor is often referred to as Danish Seining. Fish inside the ropes are frightened into the forward moving path of the seine net, where they are subsequently overtaken by the net and captured. Another boat seine technique is similar, but does not use an anchor. Instead the boat is kept stationary during haul-back using the propeller. This technique is often referred to as Scottish Seining or Fly dragging.

The catching area depends on the length of the ropes; catching depth is shallower than 50 m in lakes and as much as 500 m in marine waters. The technique is most efficient on a flat and smooth bottom, where long ropes (2,500 m) can be used. Boat seines are also used in rougher grounds, but with shorter ropes. In some areas, boat seines are used to catch schooling fish from the bottom.

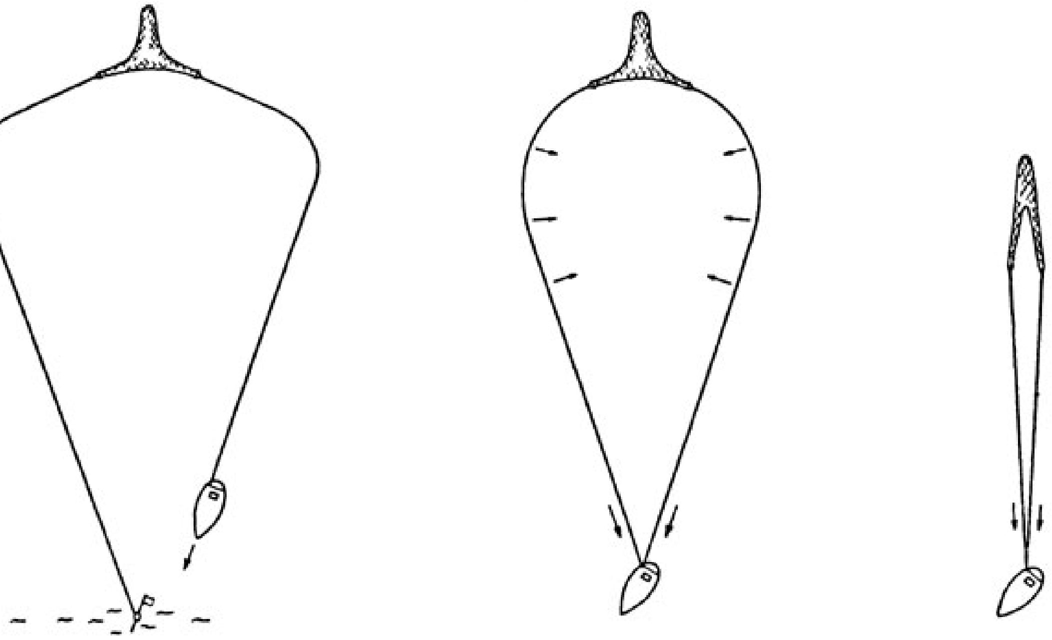


Fig. 3.4.3.a - Boat seines

3.4.4. Deployment of trawls

Bottom trawlers range in size from small, undecked boats powered by outboard engines up to large vessels with up to 8,000 HP engines and a size of up to 3,000 GT.

Winch

Trawl winches can be electrical or hydraulic. Their safe working load depends on the maximum depth to be reached and the type of fishery. The maximum cable length also depends on the type of trawls.

Trawl winches are installed on deck (mobile or fixed), control the trawling warps and store them when not in use. Gilson winches and lifting tackle support the handling on deck. Net drums are common tools for handling trawls on board vessels.

Cable

Trawl warps are made of galvanized steel or stainless steel. For surface pelagic fishing, steel dyneema ropes may be used. The diameter depends on the required safe working load, the depth at which the fishery is taking place and the kind of trawls.

Gear needed

Trawls are operated by the A frame with the use of lateral wrap pulleys, depending on vessel design and other equipment used in the same campaign. To bring the trawl on board, a stern ramp or trawl round at the stern is required.

3.4.5. Operation and ship conditions

Trawls are towed at speeds ranging from 1 to 7 knots (0.5-3.5 m/s), frequently between 3 and 5 knots. Duration of a tow mainly depends on the expected density of fish (whether the fish is aggregated or not), the shape of the bottom and the slope in the fishing area, from a few (10-15 minutes) up to 10-12 hours, commonly 3-5 hours.

Trawl nets may be towed by one or two boats.

3.4.6. Space necessary on board

Many stages of trawling operations are carried out on the work deck. They require large areas in several respects:

- spreading trawls before trawling or for repair
- emptying out the trawl, directly on the deck or in a specific box or tank; this may be equipped with a specific conveyor fixed on deck
- sorting fish directly on the deck, with boxes, or with a conveyor in a laboratory or fully-equipped container. This specific container may be fixed on deck near the fish tank.

Moreover, trawl drums also require space on deck. Drum dimensions depend on the type of trawl chosen.

Space for storing fish is also needed. Space for a cooling and/or freezing fish container or insulated fish hold for freezing is thus necessary. The dimensions of these spaces depends on the aims of scientific operations.

3.5. Sledges

3.5.1. Neuston sledges

A Neuston sledge is used to collect plankton and fish larvae right at the surface. It has the form and function of a sledge, as it slides on its two runners either side of the net through the surface layer of the sea. As it rides right at the surface, it can only be used in very calm conditions and has to be deployed at the side of the ship. The aim is to get the sledge as far out from the side of the ship as possible to get an undisturbed sample ([12]).

Fig. 3.5.1.a - Neuston sledges (12)

3.5.2. Benthic sledges

A benthic sledge consists of a rectangular steel frame with a mesh net (often more than one) attached to it. Towed along the ocean floor, its weight scrapes into the benthos, collecting any organisms on the surface or in the first few centimetres of sediment. It also collects the organisms in the water column just above the benthos. A video camera is often attached to the net. Benthic sledges are good for collecting relatively mobile (but not fast swimming) benthic organisms, but it can cause injury to delicate organisms. Sledges differ from benthic trawls in that the sledges are meant to collect some organisms that live in surface layers of the sediment, whereas trawls are designed primarily to sample from upwards of the sediment-water interface.

Fig. 3.5.2.a - Benthic sledge (12)

3.5.3. Deployment of sledges

The sledge can be deployed easily from regional vessels.

Winch

Winches can be electrical or hydraulic. Their safe working load depends on the maximum depth to be achieved and the type of sledge. The maximum cable length also depends on the type of sledge.

Winches are installed on deck (mobile or fixed). They should have the capacity to shoot the cable very slowly, and have a measure of warp tension and speed.

Cable

The cable may be a simple cable, e.g. steel cable, with a diameter as required for the safe working load. Usually, for sledges, the diameter can be as small as 6 or 8 mm. Nowadays, dyneema cables are also used

Gear needed

Sledges may be operated by a side "A" frame, a boom, or a stern gantry, depending on vessel design and other equipment used in the same campaign. Moreover, the safe working load will depend on the maximum depth at which the sledge is to be deployed.

3.5.4. Operation and ship conditions

To prevent the sledge from spinning as it drops to the sea bed and to keep the towing wire under tension as it is paid out, the vessel steams slowly ahead into the wind at about 2 to 3 knots. Speed is then reduced depending of the kind of sledge in use.

Towing speed is best controlled by towing into the wind and tide so that the vessel is developing more thrust and has more steerage way. A warp length/water depth ratio of two to three is used depending on surface conditions, with more warps required to counteract the vessel's motion in a heavy swell.

Since there is a significant risk of losing the sledge when towing on rough or previously unsurveyed grounds, there are two security features:

- Attached to the rear of the sledge is enough 10 mm rope to reach the surface with a buoy. If the towing cable snaps, the sledge may be recovered using this rope.
- Fixing a pinger on the sledge which can be tracked by the vessel's equipment. If the recovery rope is also lost in an accident, the vessel can grapple at the position given by the pinger.

In common with other unpowered towed vehicles, sledges lack manoeuvrability.

3.5.5. Space necessary on board

Sledges do not require much space. The operations involved are wet operations. A space on the work deck is necessary to place the sledge and collect samples. A wet laboratory is then used to analyse the sample, preferably near the deck space used.

3.6. Landers / Video sledges

3.6.1. Video sledges

Many kinds of video sledge exists and the science for which they can be used for is quite varied. For benthic biologists, it is an ideal sea bed survey tool. Creatures in the deep ocean are generally insensitive to light, and a video sledge drifting silently above them captures everything that is living on the sea bed. Colour pictures capture the subtle changes in sediment caused by creatures' tracks, as well as making positive identification simpler. Still photographs are statistically random, and can be used to estimate the populations of the lifeforms observed. They always are equipped with a powerful flash, and will capture colour images at a greater altitude than video. It has also been found that video will capture otherwise well-camouflaged creatures that can only be seen when they move, or when their shadow moves as the sledge passes overhead. Except in very shallow water, every living thing observed on the sea floor is some form of animal: plants can only exist where there is sunlight.

For geologists and sedimentologists, video sledges offer the opportunity to observe the undisturbed sea floor. The type of sediment – sand or mud, varied or homogeneous – can be observed directly. The thickness of sediment on boulders or stones can be observed, allowing their placement to be dated, and decide whether they have rolled there downslope from a volcano or been dropped by a passing iceberg. The surface layers of sediment are often lost in other operations, such as coring and dredging, so these images supplement direct sampling.

Video sledges use a specific digital camera that photographs the seafloor as the sledge is towed above the ocean bottom behind an oceanographic research vessel. A regular underwater camera would not work in such an extreme environment, where it must take pictures in total darkness, crushing pressure, and freezing temperatures.

Fig. 3.6.1.a- Example of video sledge, TOAD from NOAA (Photo NOAA)

Fig. 3.6.1.b - Example of video sledge from Shark Marine Technologies

3.6.2. Deployment of landers

Sledges can be deployed easily from both large and small vessels. To prevent the sledge from spinning as it drops to the sea bed and to keep the towing wire under tension as it is paid out, the vessel steams slowly ahead into the wind at about 2 to 3 knots. Speed is then reduced to around one knot for detailed examination of the sea bed, and slightly faster, 1.5 knots, for wider coverage of an area. At a slower speed, 0.5-1 knots, observation is easier and most objects on the sea bed can be identified.
Towing speed is best controlled by towing into the wind and tide so that the vessel is developing more thrust and has more steerage way. A warp length/water depth ratio of two to three is used depending on surface conditions, with more warps required to counteract the vessel's motion in a heavy swell. In common with all unpowered towed vehicles, this sledge lacks manoeuvrability, and the inability to stop and examine interesting objects in detail is a handicap. This can be partially overcome by mounting the cameras and lights on a steerable platform on the sledge, but with some loss of robustness. A more complex approach involves carrying a small self-powered vehicle on a short umbilical to inspect interesting areas more closely.

Winch

Winches can be electrical or hydraulic. Their safe working load depends on the maximum depth to be achieved and the type of sledge. The maximum cable length also depends on the type of sledge. Winches are installed on deck (mobile or fixed). They should have the capacity to shoot the cable very slowly, and have a measure of warp tension and speed.

Cable

The type of cable is highly dependent on the instruments installed with the camera on the sledge, such as CTD, pinger, etc. The usual cable is a TV cable combining a coax cable and several copper conductors. Usually, its diameter is around 14 mm. It may be steel armoured cable, or more often nowadays, cable with Kevlar armour and a polyurethane jacket.

Gear needed

Sledges may be operated by a side “A” frame, a boom, or a stern gantry, depending on vessel design and other equipment used in the same campaign. Moreover, the safe working load will depend on the maximum depth at which the sledge is to be deployed.

3.6.3. Operation and ship conditions

The camera system is towed several metres (ranging from a few metres to thousands of metres) behind the ship at speeds of 1/4 to 1 knot. Each tow lasts several hours. It can operate night or day.

When there is a CTD, it provides the depth measurement as well as scientific data. The winch operator controls the altitude directly by hauling in and paying out wire. According to the type of sledge, the optimum height from the sea bed depends on visibility, and the safe height depends on the topography and the sea state, but between 3 to 5 m is typical. Beyond 10 m there is insufficient illumination for the colour cameras; and less than 3 m requires a flat sea floor and a flat sea. The sledge is directly coupled to the ship, and moves up and down in the water as the ship is moved up and down by the swell. The vehicle is drifted, rather than towed, at about 0.5 to 1 knots ideally. Slower speeds allow for overlapping still pictures, faster speeds allow for greater video coverage.

3.6.4. Spaces necessary on board

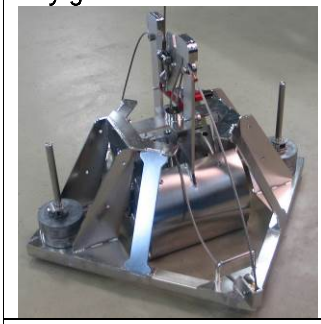
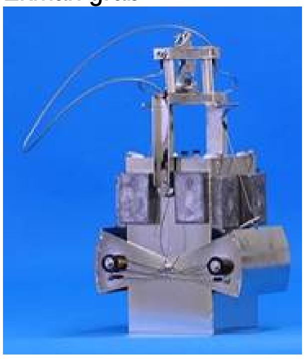
Video sledges do not require much space. The operations should be wet operations. A space on the work deck is necessary to place the sledge and collect samples. A wet laboratory to analyse the sample, preferably near, the deck space used, is then required. A dry laboratory is also needed to pilot the sledge and/or to control the video.

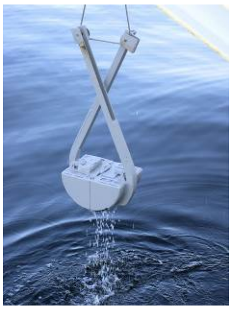
3.7. Grabs

3.7.1. Overview

Marine sediments are made up of varying mixtures of geological and biological material that have accumulated over long time periods. The biogeochemical processes which determine the relative mix of materials and rates of accumulation vary greatly. Sediments may settle quietly to the bottom, accumulating in layers which record their order of settling. In other places, biological processes (e.g., burrowing in fauna) may churn up the top few centimetres and completely obliterate the record of deposition. Coastal bottom sediment types range from almost exclusively sands and gravels to very flocculent, highly organic muds. Thus, sampling marine sediments requires a suite of different sampling tools and some knowledge of the controlling processes which determine the mix. Sampling tools vary as widely as the sediments. They include a variety of grab samplers and corers. Simple clam shell type bottom grabs have been used effectively for many decades to sample the top few centimetres of soft sediments. A very common sampler is the Van Veen grab. If a sediment is very flocculent, this sampler will "blow away" some of the surficial material, perhaps losing important information. Grabs also tend to mix the sample, providing a mixed 0-5 cm surface sample. Because of their simplicity of operation and low cost, grab samplers remain an important sediment sampling device.

The main grabs used in oceanographic measurements are listed in the following table ([5]).

	Type of sample	Type of sediment	Typical area sampled	Mechanism	Advantages	Disadvantages
Hamon Grab 	Seabed surface	Coarse (gravel)	0.25 m²	Rectangular frame with bucket on pivoting arm; upon reaching sea floor, bucket scoops the sediment	• Robust • easy to use	• Sediment sample is mixed • Large grab, not easily deployed from small vessel
Day grab 	Seabed surface to a depth of 10 cm	Soft sediments (sands to muds)	0.1 m²	Spring load jaws shut upon reaching seafloor, taking section of seabed	• Deployable from small vessel • Easy to use	Not effective in coarse substrate (large particles prevent closure of buckets)
Ekman grab 	Seabed surface	Muddy sediment	0.04 m²	When the sampler reaches the bottom, a messenger is sent down the line, tripping the overlapping spring-loaded scoops	• Good sample of top part of sediment • Deployable from small vessel	Small sample
Shipek grab 	Seabed surface	Large range of sediment sizes	0.04 m²	Semi-circular bucket activated by springs	• No wash out of sediment during recovery • Deployable from small vessel	Small sample

	Type of sample	Type of sediment	Typical area sampled	Mechanism	Advantages	Disadvantages
Van Veen Grab 	Seabed surface to a depth of 20 cm	Softer sediment	0.1 or 0.2 m²	Closure of two opposing jaws; large arms attached to each bucket give good leverage during closure	• Samples are not excessively disturbed • Deployable from small vessel	• Not recommended for coarse materials as gravel tends to get caught between the jaws • Loss of fine sediment

3.7.2. *Deployment of grabs*

Deployment is recommended from amidships to avoid pitch effects, on the starboard side (the “clean” side of an oceanographic vessel) to avoid sample pollution. The lowering speed of equipment depends on winch specifications and sea state conditions. Typically it is around 1 m/s to 2m/s.

Grab winch

Grab winches may be electrical or hydraulic. Increasingly, for mobile equipment, the winch is electrical since this is easy to install. Drum capacity depends on the targeted maximum depth and the diameter of cable. This maximum depth is related to the vessel’s working areas, in line with its goal schedule.

To define the safe working load of the winch, 2 forces should be considered:

- the weight of the cable at maximum length at sea, especially for steel cable
- the weight of the grab with sediment and additional weights if necessary.

.

Thus, the safe working load of the winch should be defined as the sum of these two loads multiplied by a safe working coefficient; this will depend on the regulations applied on the vessel.

Cable

Cable may be steel or synthetic. The safe working load of the cable is chosen on the basis of the loads defined above. A specific safety coefficient should be applied to the cable depending on the type of cable (steel or synthetic) and on the regulations applied on the vessel (Bureau Veritas, DNV, Lloyds).

Gear needed

Grabs may be operated by a side “A” frame, a boom, or directly with a crane, depending on the vessel design. The choice of the safe working load should be coherent with the definition of the winch capacity. The A-frame, the boom or the crane may be used for other operations, in which case the safe working load will be a compromise between all the needs involved.

3.7.3. *Operation and ship conditions*

The corer is operated when the ship is on station (see §4.1.1).

3.7.4. Space necessary on board

Relatively little space is required to use grabs. Grab operations are very dirty, with a lot of sediment where the grab is put on deck. A space on the work deck is necessary to place the grab and collect samples. A wet laboratory is then used to analyse samples, preferably near the deck space used.

3.8. Coring

For many marine geologists, looking at the sediments lying on the seafloor is not enough. By looking at the layers of sediment below the surface, they can get an idea of the geological history of an area and see what processes have affected the seabed over time. This is particularly important for studying climate change, because sediment layers preserve a record of past climates. Looking at the subsurface geology is also vitally important in the oil and gas industry. Profiles of the subsurface allow identification of geological features which can trap hydrocarbons, or cause them to escape. It can also tell scientists whether the area is likely to hold oil or not.

To look below the seafloor, specialized equipment is required. For a direct view, sediment coring can be used: this removes a cylinder of sediment from the seabed. The sample gives very detailed information on the sediments for a specific point on the seafloor. A broader view of the sub-seafloor can be gained by using seismic profiling (see §3.11). Sediment coring is a common way of getting very detailed information about the layers of sediment below the seafloor. Sites for coring are usually chosen based on results of an earlier sidescan survey, in which target areas have been identified. There are several different types of corer, depending on what sort of sediment is on the seafloor, and what sort of sample needs to be taken (see below).

3.8.1. Gravity coring with or without a piston

Gravity coring involves a long, heavy tube which uses the weight of the coring equipment to push the core barrel into the soft mud at the bottom of the ocean. Weights may be added to the top of the corer and be adjusted to the type of bottom sediment. The goal is to ensure that the core barrel is pushed far enough into the seafloor sediment.

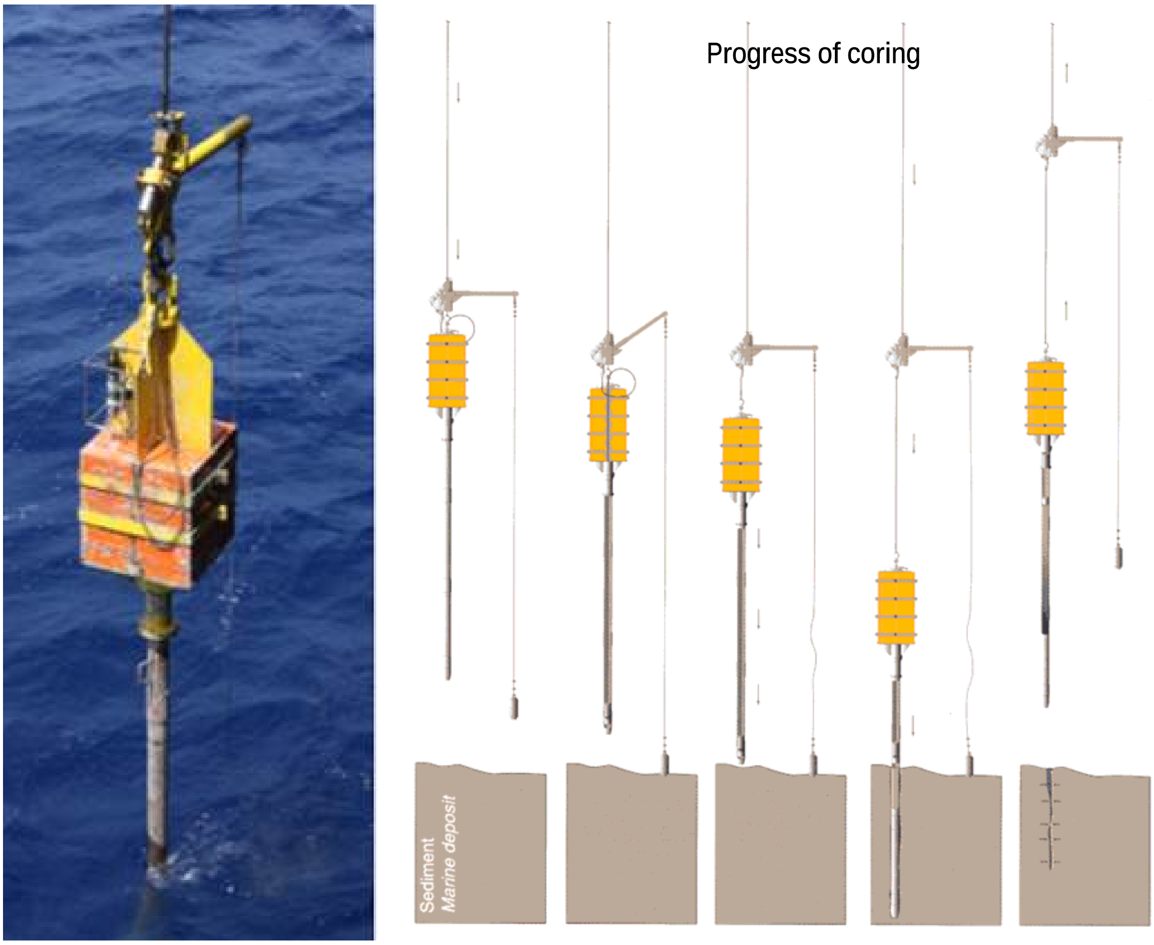


Fig. 3.8.1.a - Corer principle (Ifremer Sources)

The length and diameter of the mud cookies extracted depends on the type of corer used, the free area usable on board and on the capacity of the frame/boom used. Once the corer has been brought back on board the ship, the core is removed. Plastic tubes (rather like drainpipes) are used to line the core barrel and keep the sediment core in one piece when it is removed. Cores are split in half lengthways to reveal the layers of sediment inside.

Piston corers are similar, but include a piston inside the core barrel which provides suction to help pull sediments up into the core barrel. The addition of the internal piston allows the soft sediment to be captured without significant compression or disturbance. This allows researchers to capture the best possible sediment sample.

A coring device comprises a steel cable attaching the equipment to the ship's winch, weights to help drive the corer into the seabed, and a steel tube known as the core barrel, the part of the corer which is pushed into the seafloor.

3.8.2. Multicoring

The multi-corer is a frame with several short tubes around 50 cm in length. This goal of this equipment is to collect samples of mud and small animals living within the first 50 centimetres of the sea bed. The number of tubes depends on type of multi-corer, and is usually comprised between 4 and 16.

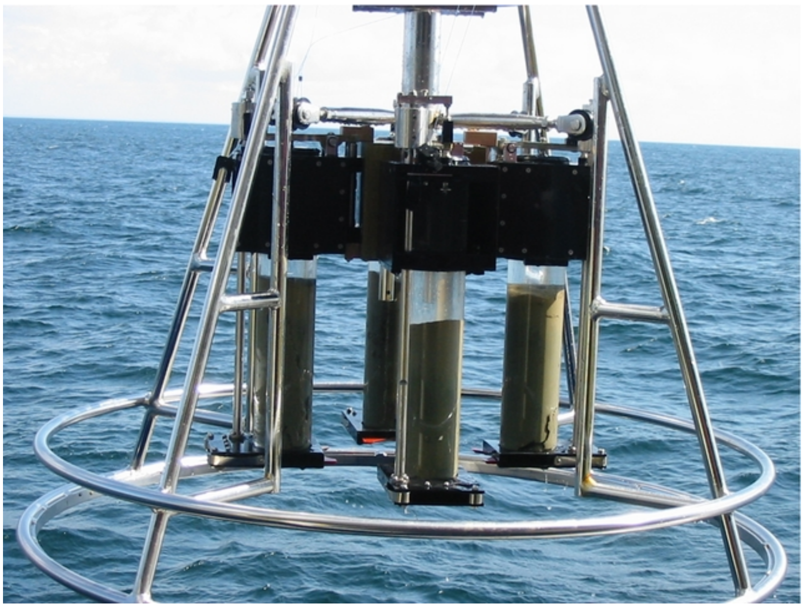


Fig. 3.8.2.a - Multicoring (Photo Ifremer)

3.8.3. Box coring

Box coring uses a sample box which is pushed into the seabed. When it reaches the seabed, a scissor blade closes the base of the box after penetration. This equipment has a limited penetration depth, depending on the box dimensions. It is heavy to deploy but easy to use. It may take a large sample volume, but sediment layering may be lost in this case.

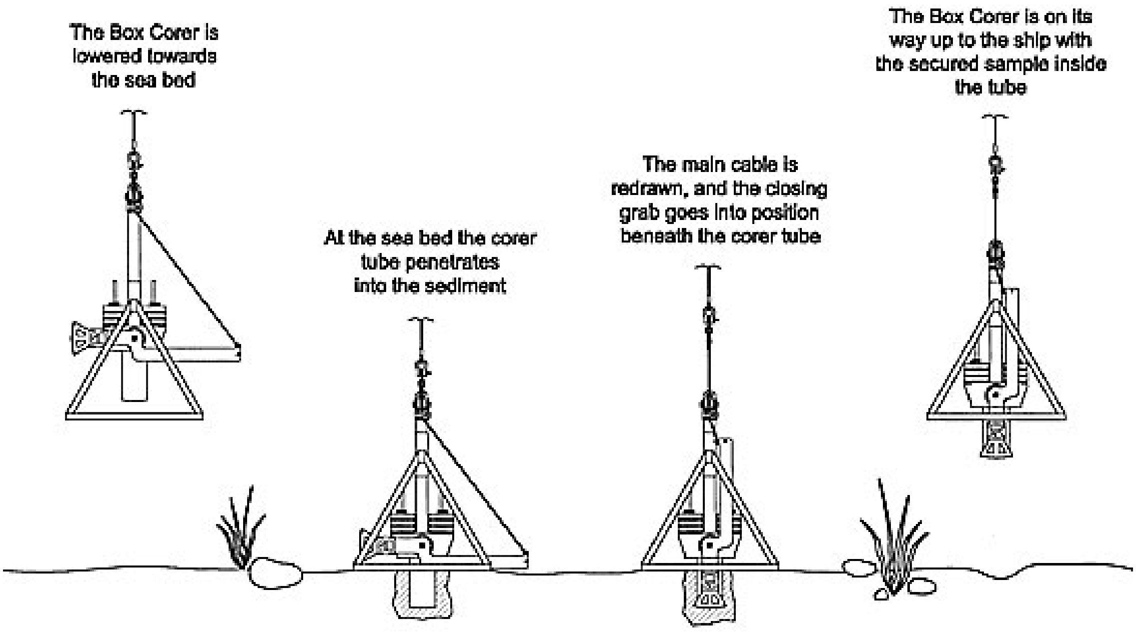


Fig. 3.8.3.a - Boxing Corer

3.8.4. Vibrocoring

Vibrocoring works wherever soil conditions are unsuited to gravity or piston corers, in sands and denser soils. The vibrating mechanism of a vibrocorer, sometimes called the "vibrohead", is a motor operated by hydraulic, pneumatic, mechanical or electrical power from an external source. The attached core tube is driven into sediment by the force of gravity, enhanced by vibration energy. When the insertion is completed, the vibrocorer is turned off, and the tube is withdrawn with the aid of hoist equipment.

In general, the frequency of vibrations is in the range of 3,000 to 11,000 vibrations per minute (VPM), and the amplitude of movement is of the order of a few millimetres (mm). The vibrations cause a thin layer of material to mobilize along the inner and outer tube wall, reducing friction and easing penetration into the substrate. The liquid spaces in the matrix allow sediment grains to be displaced by the vibrating tube. The length of tube is limited to the framework of the corer.

© SEAS Offshore Pty Ltd *(Photo Ifremer)*

Fig.3.8.4.a- Vibrocoring examples

3.8.5. Deployment of corers

Amidships deployment is recommended to avoid pitch effects, to starboard (the clean side of oceanographic vessels) to avoid sample pollution. The lowering speed of equipment depends on winch specifications and sea state conditions. Typically, it is around 1 m/s to 2m/s.

Coring winch

Coring winches may be electrical or hydraulic. Increasingly, for mobile equipment, the winch is electrical since this is easy to install. Drum capacity depends on the targeted maximum depth and cable diameter/material. This maximum depth is related to the vessel's working areas, in line with its goal schedule.

To define the safe working load of the winch, three forces should be considered:

- the weight of the cable at maximum length at sea, especially for steel cable
- the weight of corer with sediment and additional weights if necessary
- the pull force as the corer is removed from the sediment. This value is very difficult to define; it can only be estimated on the basis of experimentation on other vessels. This value depends on sediment types and the type of corer.

Thus, the safe working load of the winch should be defined as the sum of these three loads multiplied by a safe working coefficient; this will depend on the regulations applied on the vessel.

Cable

Cable may be steel or synthetic. Steel cable should be an anti-vibration stainless steel design. The anti-vibration property enables coring with good sample quality and less distortion to be achieved. The safe working load of the cable should be chosen on the basis of the loads defined above. A specific safety coefficient should be applied to the cable depending on the type of cable (steel or synthetic) and on the regulations applied on the vessel (Bureau Veritas, DNV, Lloyds).

In view of safe working limitations and of their light weight at sea, synthetic cables tend to be favoured. Moreover, these cables can increase corer quality due to their mechanical properties. They enable less distortion in the sample, especially for gravity corers. To optimize results, the diameter of dyneema cable should be as large as possible given the winch used (a compromise between winch dimensions and the maximum depth required). The larger the diameter of the cable, the lower the elastic restoring force. As a result, the choice of synthetic cable diameter is more often due to achieving the best corer than definition of a safe working load limit.

Gear needed

Corers may be operated by a side "A" frame, a boom, depending on the vessel design. The choice of the safe working load should be coherent with the definition of the winch capacity. The choice of the safe working load should be coherent with the definition of the winch capacity. The A-frame or boom may be used for other operations, in which case the safe working load will be a compromise between all the needs involved.

3.8.6. Operation and ship conditions

Corers are operated when the ship is on station (see § 4.1.1).

Deployment of corers follows these steps:

- Preparation of corer on board or aside the vessel,
- During preparation, tubes are filled with plastic tube (liner), then connected together until they reach the corer tube length target. For gravity corers, the tube is connected to the weight.
- Corers with or without launch systems are lifted over the outer bulwark if this has not already been done. Gravity corers are then turned vertical
- For gravity corers, the pilot corer is then attached to the corer
- The whole corer is lowered down to the sea bed
- After it has taken a sample, the corer is hauled up
- The corer is pulled on board and samples are extracted, then cut if necessary.

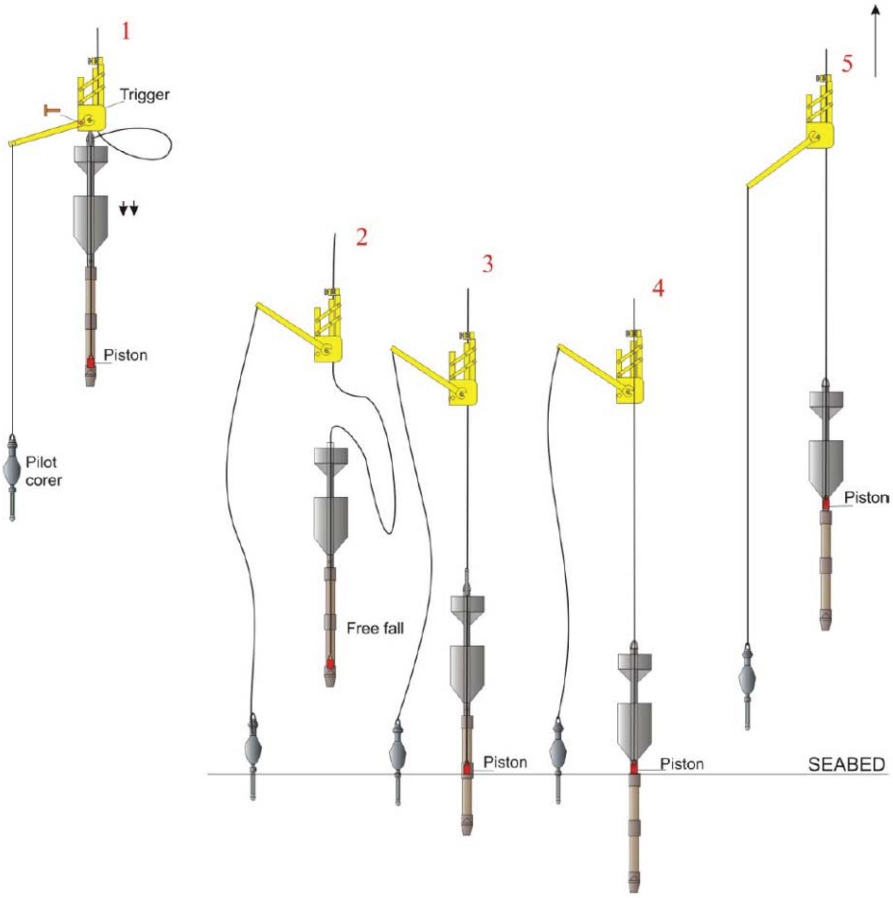


Fig. 3.8.6.a - Coring operation

3.8.7. Space necessary on board

Many steps in coring operations take place on the work deck. Coring operations can be very dirty, with a lot of sediment where the corer is placed and where the liner is extracted. Generally, the liner is extracted and cut into sections on the work deck. This step is very dirty. Then, depending on what the scientific team wants to analyse, the next steps should be carried out in 20' containers or in a wet laboratory.

The biggest difficulty is to find enough space to use a gravity/piston corer. Indeed, on board, the corer is in a horizontal position. To extract the liner, the space needed is longer than the corer tube: up to twice as long depending on on-board practices. To use this kind of equipment, two methods may be envisaged:

- *using a launch system attached outside the bulwark*.
  Corer tubes are put together directly on the launch system. The whole tube is connected to the corer weight on the launch system too.


Fig. 3.8.7.a- A corer on Pelagia (Photo NIOZ)

- *using a combined system with several small booms*.
  Corer tubes are assembled together on the work deck. The whole tube is lifted over the side, and then connected to the corer weight above the sea.

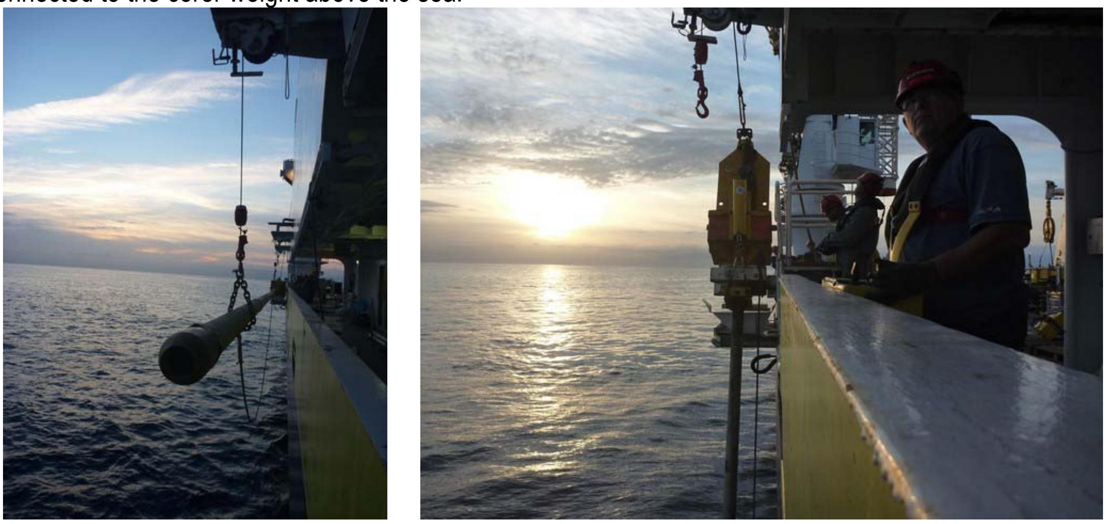


Fig. 3.8.7.b and c - Corer on Pourquoi pas? (Photo Ifremer)

However, this kind of corer needs a long coring alleyway in order to assemble the tube and extract the liner before cutting it.


Fig. 3.8.8.d and e - Corer alleyway on Pourquoi pas? (Photo Ifremer)

3.9. Dredging

3.9.1. Geological dredge

The basic principle of dredging ([16 17 18]) is to have a basket of some kind that gathers samples as it is dragged along the ocean floor. Dredges gather loose rocks sitting on the ocean floor using a technique that has changed little for hundreds of years. They have a chain-link bag with a large metal-jawed opening that scoops the contents into the bag. They are lowered to the seabed on a cable and dragged along the bottom for some distance before being brought to the surface. When the ship moves, the basket is dragged along the seafloor and collects samples.

Scientific sea-floor dredging is currently used in marine geology primarily by the "hard-rock" community interested in the recovery of basement rock samples from the unsedimented deep ocean floor. The technique has generally been eclipsed by ocean drilling for recovery of sedimentary rocks, because of perceived uncertainties in the location of sampling and in the representativeness of recovered material. This contribution reviews dredging equipment currently in use by marine geological institutions and refers to pinger attachments that allow precise information on the behaviour of the dredge to be telemetered back to the ship. It has been asserted that improvements in ship navigation and transponder navigation at the seafloor, when used in conjunction with surface and/or deeply towed sidescan and swathe-mapping surveys, now allow for considerably less uncertainty on the location of dredge sampling. Refined sorting criteria for dredge hauls are now also available. Recent comparisons of regional sample recovery by ocean drilling and by dredge sampling indicate that the dredge hauls can usefully supplement the drilling data in the construction of sedimentary and tectonic histories of seafloor areas.

Geological dredge design has remained very simple, largely because of the logistical constraints of operation in rugged sea floor terrain and the high risk to sophisticated equipment when the primary aim is to break off and recover in situ material for study. Two basic designs have had widespread use:

- rectangular dredges
  These are the most commonly used dredges. The specific aims are to collect large numbers of small cobble-size samples and for the dredge to be able to free itself from a rocky bottom.

Fig. 3.9.1.a - Examples of rectangular dredge (Photo Ifremer)

* Cylinder dredges
  The frame ahead of the collecting bag is an elongated cylinder. Rounded cutting teeth are an integral part of the forward end of the cylinder. Two lugs of round steel rod provide towing attachments, welded to the outside of the cylinder forward of its centre of gravity. A series of drilled holes at the tail end provide securing links for the net collecting bag.

Fig. 3.9.1.b - Examples of cylinder dredges (Photo Ifremer)

The greatest attributes of the cylinder dredge are its simplicity, its strong construction and its reliability. The advantages of the simpler cylinder dredge over less sophisticated versions of the rectangular dredges are:

  - its smaller contact area with the substrate and the relatively large weight applied to this area to engage or scrape rock projections
  - its shape, which ensures that it lands and is kept in an operating position on the sea floor
  - the flexibility of the towing arrangement, which allows it to roll sideways rather than snag on a projection
  - the relatively weak cutting teeth which will bend or break off before tensions build enough to threaten breakage of the ship's cable.

3.9.2. Agassiz or fishering dredge

Basically, a fishering dredge ([16 17 18]) is bottom-towed gear, consisting of a metal frame with a blade or teeth, to dig into the sediment and extract the shelled molluscs, and a mesh bag to collect the catch. There is a great diversity of dredge types, with specific designs used to target different species in particular beds:

* dredges for King scallops
* dredges for Warty venus
* dredges for Queen scallops
* dredges for small bivalves: thick trough shell, palourid
* dredges for Mussels.

Except in the case of scalloping where the dredge designs are widely used, a variety of local design dredges adapted to the target species may be used. The interspecific selectivity of this gear is generally very high and the by-catch rate is low.

A scallop dredge is bottom-towed fishing gear consisting of a metal frame with a toothed bar, with the aim of digging in the sea ground, extracting the scallops and catching them in the mesh bag.


Fig. 3.9.2.a - Example of a fishering dredge (Photo NOAA)

The toothed bar may or may not be used with a deflector. Moreover, the mesh bag may be smooth or rigid with surrounding parallel bars.


Fig. 3.9.2.b - Example of an Agassiz dredge (Photo Ifremer)

3.9.3. Operation and ship conditions

Deployment by the stern A-frame is recommended. The lowering speed of equipment depends on winch specifications and sea state conditions; typically, it is around 1 m/s to 2m/s. The dredge is deployed connected to the vessel's main trawl winch by an anchor chain and weak link. The anchor chain acts as weight to keep the rock dredge on the sea floor during the dredge line transit. The rough terrain causes the frame to bounce around, so the anchor at the front and "bucket" weight at the back keep it grounded. The weak links are a system safety device used to separate the main warp from a trapped rock dredge package.

A strangle wire, wrapped through the chain mail and also connected via a weak link to the main warp, enables the dredge to be recovered in the event of snagging. The strangle wire works by closing the "neck" of the rock dredge net and pulling the dredge net over the steel frame. This tumbling action hopefully frees the rock dredge from its trapped position without spilling the contents. Depending on the ocean depth, the amount of cable deployed to undertake the transit can be up to 2.5 times the ocean depth.

For rock dredges, during transit lines (dredging) where the sea floor topography is known or expected to be extremely broken or rough, a sacrificial pennant wire is attached. It runs for approximately 500 metres between the rock dredge package and the vessel's main trawling cable to prevent damage to the vessel's trawling cable. An acoustic pinger can be secured to the trawling warp/pennant wire 100-300 metres from the rock dredge package. The acoustic pinger can help to indicate that the rock dredge package is on the sea floor by the separation distance of the pinger and the sea floor being less than the length of cable between the pinger and dredge net.

Dredge winch

Dredge winches may be electrical or hydraulic. Drum capacity depends on the targeted maximum depth and the diameter of cable. This maximum depth is related to the vessel's working areas, in line with its goal schedule.

To define the safe working load of the winch, 2 forces should be considered:

- the weight of the cable at maximum length at sea, especially for steel cable
- the weight of dredge with rocks and additional weights if necessary, plus the force required to pull it.

Thus, the safe working load of the winch should be defined as the sum of these two loads multiplied by a safe working coefficient; this will depend on the regulations applied on the vessel.

Cable

Cable may be steel or synthetic. For synthetic cable, an anchor chain and weak link should be used to protect the cable from damage. The anchor chain acts as a weight to keep the rock dredge on the sea floor during the dredge line transit. The rough terrain causes the frame to bounce around, so the anchor at the front and "bucket" weight at the back keep it grounded.

The safe working load of the cable should be chosen on the basis of the loads defined above. A specific safety coefficient should be applied to the cable depending on the type of cable (steel or synthetic) and on the regulations applied on the vessel (Bureau Veritas, DNV, Lloyds).

Gear needed

Dredges should be operated using the stern "A" frame. The choice of the safe working load should be coherent with the definition of the winch capacity. The A-frame may be used for other operations, in which case the safe working load will be a compromise between all the needs involved.

3.9.4. Space necessary on board

Many steps involved in dredging operations are performed on the work deck. Dredging operations are very dirty, resulting in large amounts of sediment or rocks on deck. The deck should not be fragile in the area where the dredge is emptied, since a large number of rocks may fall out.

Fig. 3.9.4.a - Dredge emptying, Pourquoi pas? (Photo Ifremer)

Next, rocks should be cut with a wheel saw in a space which can be cleaned easily. Rock samples are then analysed in a wet laboratory.

3.10. Electronic/acoustic towed equipment

3.10.1. Electronic/acoustic towed sidescan sonar

Sidescan sonars are first and foremost visualization tools, providing acoustic images of the sea bed. They are usually installed on a platform ("fish") towed near the bottom. This configuration allows them to operate with good stability and noise conditions, and at grazing incidence. A sidescan sonar insonifies the bottom with two side antennas and with very narrow horizontal directivity.

The working principle of this seafloor acoustic imaging technique is remarkable in its simplicity: a narrow sound beam is transmitted at grazing incidence and intercepts the bottom along a thin strip, spreading out with distance. Inside this strip, the very short signal transmitted defines the area insonified, of very small dimensions, at any given point in time, as it sweeps over the entire area covered. The echo received over time represents the bottom reflectivity along the swath, and particularly the presence of irregularities or small obstacles. The signal is recorded laterally, hence the name "sidescan sonar". The basic system structure is the same as for single-beam echosounders. Frequencies are usually in the range of hundreds of kHz, with pulse durations as short as possible (typically 0.1 mas or less) ([1]).

Fig. 3.10.1.a - The Klein tow fish, which performs Side-Scan SONAR, being pulled out after a survey. (©Klein Sonar Associates)

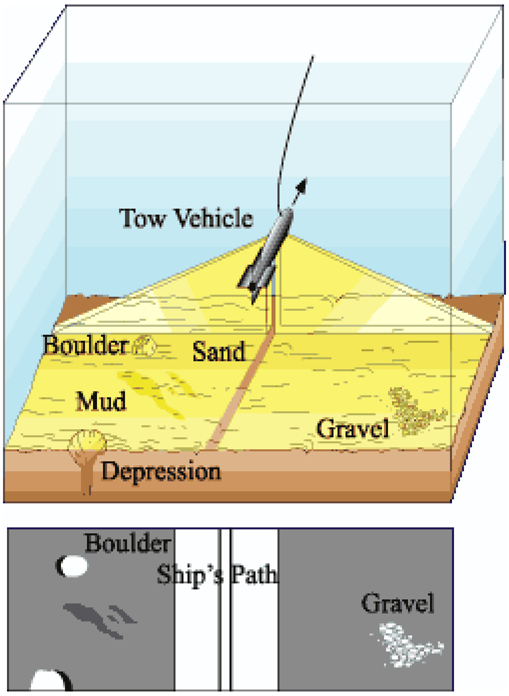


Fig. 3.10.1.b - Diagram showing how a towed SONAR device works as it moves above the surface of the ocean floor.

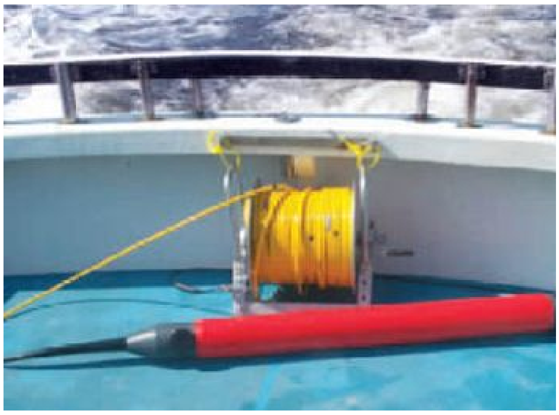
3.10.2. <u>Electronic/acoustic towed magnetometers</u>

Marine magnetometers are generally "fish-type" instruments (so-called because they are sleek and only a few metres in length). They are towed at least two and a half ship-lengths behind the ship, so that the ship's magnetic field does not interfere with magnetic measurements. Marine magnetometers can be scalar, measuring the total strength of the magnetic field; or vector, resolving the magnetic field into the vectors of strength, inclination (the angle at which magnetic field lines intersect the surface of the earth, 0° at the equator and 90° at magnetic poles) and declination (the angle the magnetic field makes with geographic north).

Marine magnetometers contain a chamber filled with a liquid rich in hydrogen atoms, such as kerosene or methanol. Electrons dissolved in the liquid are excited by a radio frequency (RF) power source and pass on their energy to the hydrogen atoms' nuclei (protons), altering their spin states. The transfer of energy from electrons to the protons in the hydrogen atoms is called the "Over Hauser Effect" (after the American physicist Albert Over Hauser who discovered it in the early 1950s) and the magnetometers that use the effect are called "Over Hauser Magnetometers". Once the protons are spinning, the RF power is removed, and the protons spiral back to their original alignment with the total geomagnetic field. The frequency of their spiralling, or "precession," is measured with a coil, and is dependent on a known constant, the "gyromagnetic ratio," and the total geomagnetic field. Thus, if the frequency is measured, and the constant is known, the total geomagnetic field can be calculated ([13]).

Surface-towed magnetometers are towed close to the surface of the ocean and far enough behind the ship so that the ship's magnetization does not interfere with the measurements. Over Hauser magnetometers are vastly more energy efficient than their predecessors, proton precession magnetometers, which relied on excitement of protons by a direct current (DC) source. Over Hauser magnetometers also have faster cycling rates (up to five magnetic measurements taken each second) and higher sensitivities than the older proton precession magnetometers. The power saving improvement is very important, because Over Hauser magnetometers can be mounted on remotely operated vehicles that have limited battery power, thereby improving the spatial coverage of magnetic mapping surveys.

The design of most marine magnetometers makes them lightweight, so they are quite simple to load onto the ship and deploy. Surface-towed magnetometers can cover larger areas and are relatively inexpensive. Surface-towed magnetometers have lower sensitivities than near-bottom magnetometers. Near-bottom magnetometers are more expensive and cover smaller areas than surface-towed magnetometers.



© Dragon Prince Hydro-Survey © courtesy of Marine Magnetics

Fig. 3.10.2.a - Examples of towed magnetometers

3.10.3. Acoustic towed fish

The Acoustic towed fish is a system towed at water depths ranging from 20-30 m to several hundred metres at the side or astern of the ship.

Depending on the type of acoustic towed fish, its acoustic echo-sounder may point in a number of directions:

- sideways, away from the ship, to acoustically explore approximately the top 50 m of the water column. This allows zooplankton density in the surface layers to be identified: normally, they cannot be detected by a ship's built-in echo-sounders, as these are sitting on the bottom of the ship's hull at a water depth of 6 to 8 metres. In addition, they have a so-called "blanking zone" of up to 10 m, where the acoustic noise due to air bubbles is simply too high to obtain any sensible data. This gap of the top 20 to 30 metres, which cannot be sampled by the built-in echo-sounders is filled by the Acoustic towed fish.

Or

- bottomward, away from the ship. The advantage of this mode of towing are that:
  - the upper water layer of the ocean contains air bubbles, induced by wind and waves which attenuate the sound transmission and reception from a hull-mounted transducer. A towed transducer operates below this bubble layer.
  - the transducer is closer to the fish. This gives a better signal to noise ratio, and the resolution of single fish is improved because the width of the sound beam is smaller. For the study of deep water biological resources - below 500 m - a towed transducer is essential.
  - the transducer is not affected by vessel pitch, roll or heave.
  - the noise is lower, as the transducer is a considerable distance below the vessel machinery and propeller.

3.10.4. Deployment of towed equipment

Deployment by the stern A-frame or other gear such as a as crane, gantry or boom is recommended. The deployment speed of the equipment depends on winch specifications and sea state conditions.

Winch

In the majority of deployments, the towed equipment has its own winch. Depending on the kind of towed apparatus, the winch may be manual, electric or hydraulic.
The manual winch is used for lightweight towfish such as magnetometers. In this case, the cable fixing must be suitable for taking up load due to the tensile force.

For heavier towfish, in the majority of cases, the winches are electric. This type of winch may be moved from one vessel to another easily. Drum capacity depends on the targeted maximum depth or distance from the vessel, and on the cable diameter.

To define the safe working load of the winch, 2 forces should be considered:

- the weight of the cable at maximum length at sea, especially for steel cable
- the weight of the towfish

Thus, the safe working load of the winch should be defined as the sum of these two loads multiplied by a safe working coefficient; this will depend on the regulations applied on the vessel.

Cable

The type of cable depends of the type of towed equipment. It may be steel or synthetic cable, and may be equipped with copper connectors or coax depending on the type of towfish. To avoid disturbances due to cable vibrations, fairings should be fixed on cables, especially near the ends.

The safe working load of the cable should be chosen on the basis of the loads defined above. A specific safety coefficient should be applied to the cable depending on the type of cable (steel or synthetic) and on the regulations applied on the vessel (Bureau Veritas, DNV, Lloyds).

Gear needed

Deployment by the stern A-frame or other gear such as a crane, gantry or boom is recommended. The choice of the safe working load should be coherent with the definition of the winch capacity. The A-frame may be used for other operations, in which case the safe working load will be a compromise between all the needs involved.

3.10.5. Operation and ship conditions

Towfish are towed at speeds ranging from 4 to 8 knots, frequently between 4 and 6 knots, several metres (from few metres to thousands of metres) behind the ship. Tow duration depends mainly on the kind of measurements being performed, the shape of the bottom and the slope in the measurement area: it may range from a few minutes (10-15 minutes) to up to 10-12 hours, commonly 6-8 hours. The towfish is directly coupled to the ship, and moves up and down in the water as the ship is moved up and down by the swell. Slower speeds allow for overlapping still measurements.

3.10.6. Space necessary on board

Using towfish does not call for much space. The space necessary comprises:

- A space for placing the fish on board, with a length of about of 1-2 metres and a width of 1 m.
- A space for the winch. Dimensions depend on the type of winch; usually about 1 m^3 is required

A wet laboratory may be useful to check towfish acoustic equipment away from sea spray. Moreover, a dry laboratory is necessary to pilot the towfish winch by controlling its position, especially for side scan sonar.

3.11. Seismic towed electronics/acoustics

There are two principal categories of seismic surveying, two-dimensional (2D) seismic surveys and three-dimensional (3D) seismic surveys. 2D can be described as a fairly basic survey method, although somewhat simplistic in its underlying assumptions. A sub-category of 2D is the site survey where ultra-high resolution data is acquired in the immediate vicinity of an intended well to identify both seabed and shallow subsurface hazards. Ultra-high resolution here means that the survey is intended to provide more detailed information about the seafloor and the conditions of the rock down to a depth of a few hundred metres beneath the seafloor. 3D surveying is a more complex method and involves greater investment and much more sophisticated equipment than 2D surveying.

In 2D operations, a single seismic cable or streamer is towed behind the survey vessel together with a single sound source. The reflections from the subsurface are assumed to lie directly below the sail line that the survey vessel moves along, providing an image in two dimensions (horizontal and vertical) – hence the name '2D'. The processing of the measurements recorded by the streamer sensors is, by the nature of the method, less sophisticated than that employed for 3D surveys. 2D data acquisition lines are typically acquired several kilometres apart on a relatively sparsely spaced grid of lines and usually over a large area. This method is generally used today in frontier exploration areas to produce a general understanding of the area's geological structure before drilling is undertaken.

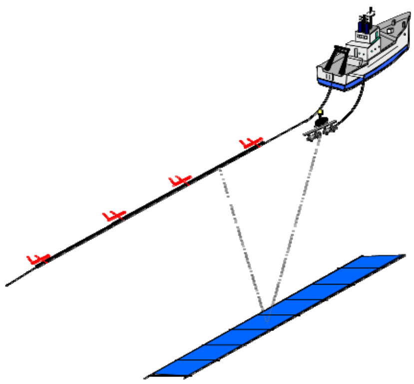


Fig. 3.11.a - 2D surveying. (Drawing Ifremer)

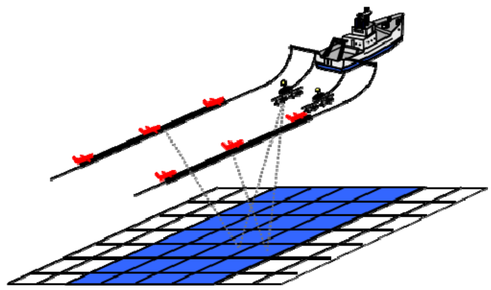


Fig. 3.11.b - 3D surveying. (Drawing Ifremer)

A variety of seismic sources are available for marine applications, including water guns (20-1500 Hz), Airguns (100-1500 Hz), Sparkers (50-4000 Hz), Boomers (300-3000 Hz), and Chirp Systems (500 Hz-12 kHz, 2-7 kHz, 4-24 kHz, 3.5 kHz, and 200 kHz). The greatest resolution of near surface structure is generally obtained from the higher frequency sources such as the Chirp systems, while the lower frequency tend to better characterize structure at depth ([2]).

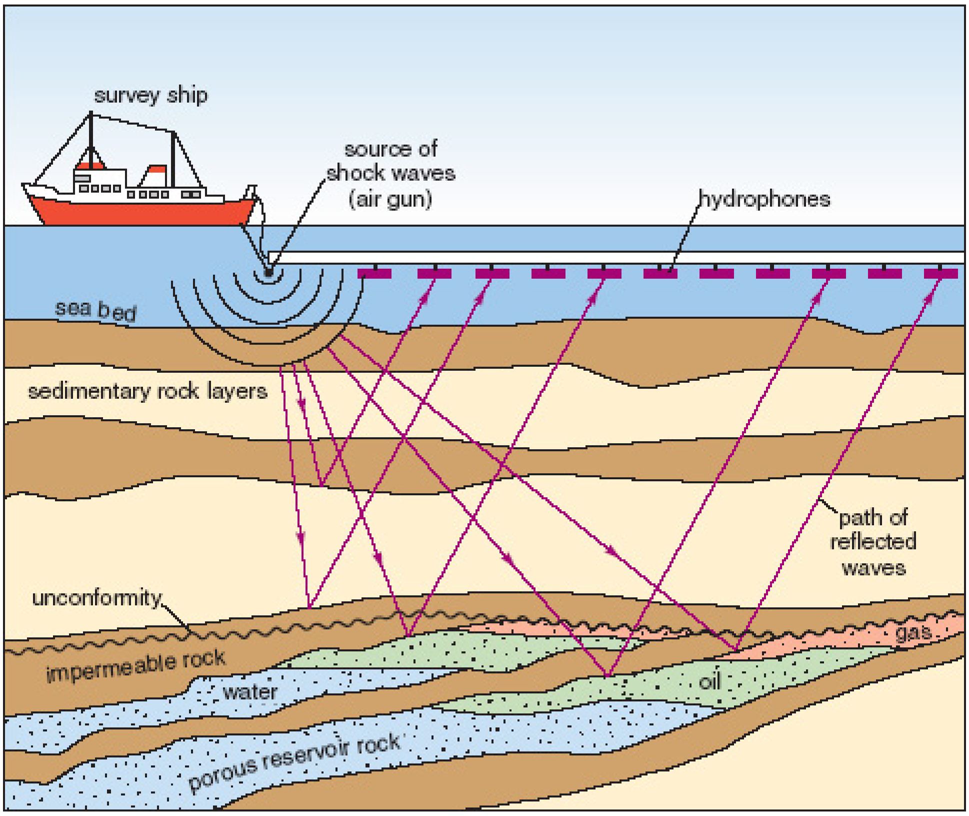


Fig. 3.11.c – Principles of seismic surveying (2)

3.11.1. Streamers

The seismic cable or streamer (2) detects the very low level of reflected energy that travels from the seismic source, through the water layer, down through the earth and back up to the surface, using pressure sensitive devices called hydrophones. These convert the reflected pressure signals into electrical signals, which are digitized and transmitted along the seismic streamer to the recording system on board the vessel where the data are stored onto disk. The streamer itself is made up of five principal components:

- hydrophones, usually spaced almost 1 metre apart, but electrically coupled in groups 12.5 or 25 metres in length
- electronic modules, which digitize and transmit the seismic data
- stress members, steel or Kevlar, that provide the physical strength required, allowing the streamer to be towed in the roughest of weather
- an electrical transmission system, for power to the streamer electronic modules and peripheral devices, and for data telemetry
- the skin of the streamer in which all the above are housed.

The groups in the streamer are combined into sections, each 100-150 metres in length, to allow modular replacement of damaged sections. Each section is terminated with a connector unit, and is filled with electrical isolating foam, with a specific gravity of less than one, to make the overall streamer neutrally buoyant.

Streamer tow depths are a compromise between the requirement to operate these sensitive devices away from the weather and wave noise, which limits the usability of the recorded data, and the ghost notch, which affects the streamer in exactly the same way as the source. The deeper the tow depth is; the greater the immunity to weather noise, but also the narrower the bandwidth of the data. As for most operational parameters, the specific survey objectives will dictate the precise streamer depth required. Typically the range of operating depths varies from 4-5 metres for shallow, high resolution surveys in relatively good weather, to 6 metres in the majority of cases, to 8-10 metres for deeper penetration.

In addition to the internal components, there are different types of external devices which are sometimes attached to the streamer, such as depth control units or birds, magnetic compasses (often integrated within depth control units), and acoustic positioning units. Power for these systems is provided both through the streamer itself, inductively coupled, and by batteries in each external device. In addition, a tailbuoy is connected to the end of each streamer to provide hazard warning of the submerged towed streamer, especially important at night, positional information from a GPS receiver and tension for the tail of the streamer.

Fig. 3.11.1.a – Streamer. (Photo Ifremer)

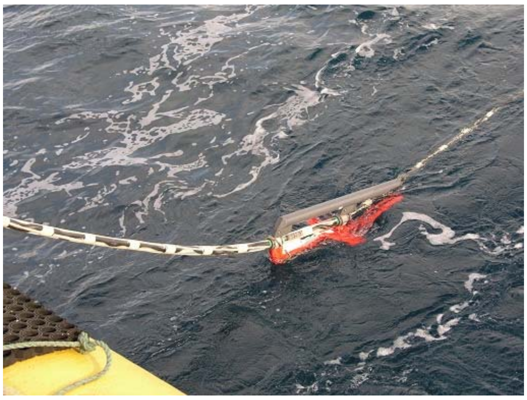


Fig. 3.11.1.b – Bird. (Photo Ifremer)

Fig. 3.11.1.c – Tailbuoy. (Photo Ifremer)

3.11.2. Airguns, sparkers

Airgun arrays (2) used during 2D or 3D surveys are almost always made up of sub-arrays or single strings of multiple airguns. One type of airgun is shown in figure 2.11.2.b. In its ‘charged’ or ‘ready-to-operate’ state, the high pressure air chambers are sealed by a triggering piston and a firing piston, mounted on a common shank forming a shuttle. High pressure air, typically at 2,000 or 2,500 psi, is supplied to the return chamber from the compressor on board the vessel via an air hose and ‘bleeds’ into the main chamber through a small orifice in the shank of the shuttle. The airgun is sealed because the area of the left triggering piston is larger than that of the right firing piston. This results in a net ‘holding’ force. The source is activated by sending an electrical pulse to the solenoid valve which opens, allowing high pressure air to flow to the left side of the triggering piston, into the triggering chamber. This forces the triggering piston to move away from its rest position and as the firing piston, which is physically connected to the triggering piston by the shuttle, follows, the high pressure air in the main chamber is discharged into the surrounding water through the ports. The air from these ports forms a bubble which oscillates, the period and characteristics of the oscillation being dependent on the operating pressure, the depth of operation, the temperature and the volume of air vented into the surrounding water. The shuttle is forced back down to its original position by the high-pressure air in the control chamber, so that once the main chamber is fully charged with high-pressure air, the source can then be activated again. The shuttle opens very rapidly (in only a few milliseconds). This allows the high-pressure air to be discharged very rapidly.

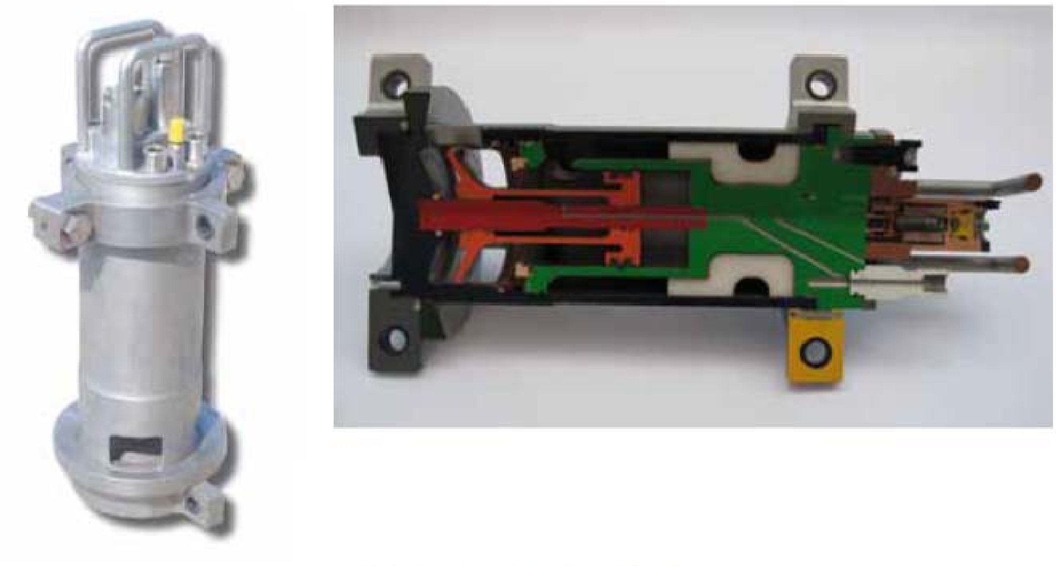


Fig. 3.11.2.a – AirGun. (Photo Sercel)

An airgun array is commonly made up of sub-arrays or 'strings', which are suspended from floatation devices to maintain the specified operating depth. Array dimensions acceptable for regional vessels usually involve lengths of the order of 5 to 15 metres.

Fig. 3.11.2.b - Example of airgun array for high resolution seismic work. (Photo Ifremer)

3.11.3. Deployment of towed seismics

As the survey area is approached, streamers will be deployed astern, attaching depth monitoring and control devices (birds) at regular spacing as they go (typically every 300 metres) and a tailbuoy for positioning if necessary. As sea water temperature and salinity vary by location, considerable care is taken to ensure that the streamers are correctly "ballasted", so as to be neutrally buoyant for the chosen operating depth for the specific survey area. The equipment in the recording room is assumed to be installed, connected and configured for the survey. Then, the compressors will be started and the source arrays prepared. They are deployed after the streamer(s), but can later be recovered and redeployed when necessary. The deployment operation should be conducted in consultation with the helmsman, because adequate steering and speed is required, and with the recording room personnel, in order to continually check streamer integrity.

During acquisition sailings, high voltage is applied to the streamer and so care is required on the work deck. Moreover, the immersed equipment calls for specific sailing rules to be observed: minimum speed, maximum speed, and minimum turning radius depending on streamers and configuration. Failure to observe these rules may affect the production of reliable seismic data and result in damage to the streamer. Moreover, operations may be affected by weather, oceanographic conditions, or adjacent shipping.

Depending on the country of operations and the area-specific environmental controls in place, a visual watch for marine mammals from the vessel may be on-going when the source is activated. On some surveys, dedicated acoustic monitoring methods may additionally be utilized to identify the presence of marine mammals within the vicinity of the source array.

Streamer drums

On oceanographic vessels, towed seismic apparatus is usually mobile equipment, installed in 10' or 20' containers depending on the type of apparatus. Streamer drums are specific winches, designed for streamers. They may be electrical or hydraulic, but are usually electrical. They are enclosed in 10' containers or sometimes 20' containers. The container may weigh as much as 10 tonnes, but the tension stress when the streamer is deployed is around 1 or 2 t maximum. Moreover, the drum speed does not need to be fast, so drum power to provide around 0.6 m/s is enough.

Umbilical winch drums

Depending on the length of umbilicals, some specific drums may be required. As for streamer drums, they are included in the mobile equipment set. They may be electrical or hydraulic, but are usually electrical.

Gear needed

A stern A-frame is required to deploy the tailbuoy and attach the fairlead used for deploying streamers. The needed safe working force is not very high; around 3 t is sufficient. To deploy sources, specific stern gantries may be necessary for deployment with the array at sea. Gantries may be included in the seismic mobile equipment.

3.11.4. Operation and ship conditions

A survey vessel typically operates at a tow speed of between 4.5 and 5.0 knots, 9-10 knots for high-speed seismic surveying. The specific technical acquisition parameters for a given survey can influence productivity. For a survey with a shallow depth of target, the need to record higher frequencies, up to 100 Hertz, necessitates the use of shallow tow depths for the streamer. This increases the effect of wave noise, thus rendering the operation more prone to weather downtime. If the survey objective is deeper, then deeper streamer depths could be used and the productivity of the operation improves.

It is worth noting that due to the action of tides and currents, the seismic streamer does not normally tow directly behind the survey vessel but deviates laterally from the ship track or nominal sail line. Whilst such lateral displacements are not typically crucial to the success of 2D surveys, they are important in 3D. In a typical 2D survey, the 2D lines are shown as a grid.

A 3D survey covers a specific area, generally with known geological targets that have been identified by previous 2D exploration. In 3D surveying, groups of sail lines (or swaths) are acquired with the same orientation, unlike 2D where there is typically a requirement for the lines to be acquired in an orthogonal direction relative to the dominant structural grain. Simplistically, 3D acquisition is the acquisition of many 2D lines closely spaced over the area. The 3D sail line separation is normally in the order of 400 to 800 metres, depending on their cross-line separation. A 3D survey is therefore much more efficient, in that many times more data are generated than for 2D per survey vessel sail line. A small 3D survey size is of the order of 300 square kilometres, or 1,000 sail line kilometres, or 12,000 sub-surface 2D kilometres.

The relative orientation of the survey to the prevailing current and tides has an impact on survey efficiency, since the feathering of the streamers is dictated by these conditions. If the survey is oriented so that the main currents are in the direction of the sail line, changes in these currents and tides will have little impact on the feathering of the streamers. If these currents are across the sail line and they vary, the feathering of the streamers will change correspondingly, causing irregularities in the location of the subsurface data being collected. These irregularities result in data holes or gaps, which need to be 'in-filled', a term used to describe the additional sail lines required during a 3D survey to acquire data for those areas of irregularities in subsurface coverage caused by the feathering of the streamers. In areas with very severe current variation, infill can amount to as much as 40-50% of the total survey area, which has a very dramatic impact on the time taken to complete the survey. Typically infill is between 10 and 20% but increases with increasing streamer length. The presence of shipping in the survey area can restrict vessel operations due to physical access constraints such as proximity to harbours, data acquisition in shipping lane areas such as the English Channel, or due to excessive noise contamination from other vessels.

3.11.5. Space necessary on board

Several spaces needed to perform a seismic survey are described below.

Instrument room

This is where the main seismic instrumentation is located and operated. The position of the instrument room varies from one vessel to another but is usually located centrally, somewhere below the bridge and forward of the back deck. Mobile systems should also should be in a container.

It contains the main seismic instruments for recording seismic data, controlling the seismic streamer(s) and activating the energy source. The electronics associated with the main navigation system are also here with links to satellite, radio systems, compasses and the various positioning control and monitoring systems. There is usually a working area for instrument testing and repair. Computers used for the onboard seismic and positioning data quality checking and processing are also located in this area.

Back deck

Although designs will vary from ship to ship, the back deck is used for storage, deployment and retrieval of the towed seismic equipment. The seismic streamers are stored on large reels and when acquisition is in progress, the streamers are deployed from the back of the vessel and towed directly behind and/or to the sides of the vessel.

For a regional oceanographic vessel, the number of streamers varies between 1 and 2 depending on the type of seismic survey, 2D or 3D. All the wiring from the streamers is fed through watertight connections to the instrument room.

The back deck is also the location for the storage and manoeuvring of airguns, which are supplied with high-pressure air. A marine seismic source is made up of an array of many different sized source elements, linked together with special harnesses, air supply lines and electronic control cables. When not in use, these cables are stored on reels or flake down on the deck. The air feed from compressors to the arrays is monitored from a control panel housed in a small work area where gun repairs can also be done.

The towing equipment is a complex, carefully designed arrangement of specialized equipment that enables the multiple streamers and source arrays to be positioned accurately behind the vessel, and depending on the survey design, allows for different source and streamer separation distances. It can take several hours to deploy or retrieve all the equipment. The tailbuoy with the navigation or positioning in-sea hardware equipment is also stored on the back deck.

Compressor container
This contains the compressor engines and compressors, which supply high pressure air to the source arrays. The compressors are capable of recharging the individual source elements rapidly and repeatedly, which enables the source array to be activated, typically every ten seconds or so during acquisition of data and for periods of up to 12 hours or more, depending on the length of the sail line. Properties of compressors, such as their power and dimensions, depend on the kind of seismic apparatus used. Typically, there may be between two 10' containers and two 20' containers. They need electrical power from the vessel and sea water for cooling.

3.12. AUVs

3.12.1. Different types of AUVs for regional vessels

AUVs are underwater vehicles that operate below the surface without any physical connection with a control station. They are programmed to execute missions and have a small amount of "intelligence" or the ability to make simple decisions. They are used in environmental monitoring (ecosystem assessment, habitat mapping, etc.), geosciences (bathymetry, backscatter, etc.), hydrography (ZEEZ survey, charting, etc.), search and recovery and oil and gas applications, and offer a flexible alternative to traditional surface vessels or ROVs. The technology is now relatively mature and numerous companies propose a wide range of systems.

The term AUV System is used here to define the vehicle in itself and all peripheral equipment such as the control cabin and the workshop cabin. It can also include also the specific launch and recovery system. AUVs range from very small vehicles with limited capabilities to large ones able to dive in deep water and with significant payloads. Typically, AUVs may be grouped into a number of classes:

- Class I: Vehicles less than 1.5 m in length, able to dive in shallow water (100 m) and with a payload limited to small sensors, e.g. for optical imaging and CTD. The mass is typically less than 50 kg

Fig. 3.12.1.a – Remus AUV. (Photo Kongsberg)

- Class II: Vehicles around 3 m long, able to dive up to 500 m, and with the capacity to accommodate sensors such as an MBES. The mass is typically less than 500 kg

Fig. 3.12.1.b – AUV Asterix. (Photo Ifremer)

- **Class III**: Vehicle around 5 m long, able to dive up to 3000 m and with the capacity to accommodate a wide range of equipment: MBES, SBP, spectrometer, etc. The mass is typically 1000 kg, speed is typically 6 knots and autonomy is generally between 10 to 24 hrs at a reasonable speed (3 knots).

  Bigger systems (such as NEREUS, the largest AUV in the world) exist but are generally prototypes designed for a very specific application (often military). They are not considered here.

Fig. 3..12.1.c – NEREUS. (Photo Kongsberg)

3.12.2. Deployment of AUVs ([33])

Autonomous vehicle launching does not generally entail any particular difficulties. Recovery is much more complicated, as there is no physical link between the vehicle and the vessels. The main objective is to avoid the use of rubber dinghies. AUVs can be deployed over the side or stern of the ship using a specific launch and recovery system (LARS) or ship gear (crane, A frame or telescopic boom), adapted if necessary.

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Fig. 3.12.2.a – Deployment examples

For example, manufacturers (KONGSBERG, ODIM, etc.) propose a range of mobile systems: a ramp for a wide range of freeboards or more conventional LARS with a docking head and an articulated A frame, the vehicle being suspended by the nose. This system cannot be considered at the present time as standard, and is generally customized. The ship's handling gear can be also adapted or specifically designed. NOC has developed a specific telescopic boom, the vehicle being deployed over the side of the ship. If no docking head is possible, the use of stabilizing ropes is necessary.

Fig. 3.12.2.b – Deployment example (Photo Kongsberg)

Vehicles are generally designed with lifting handles and handling/towing lines to facilitate handling, and include minimal protrusions and control surfaces to avoid interference. Some systems are also equipped with a line release nose assembly to aid in towing and recovering the vehicle. To recover the lines, most of the systems are equipped with a pop-up system that releases the line that is dragged from the deck of the ship.

Fig. 3.12.2.c – Deployment example (Photo Ifremer)

Ifremer uses a non-conventional launch and recovery system (CALISTE). This consists of a buoyant cage that is deployed at sea and towed a few tens of metres behind the transom. The cage is equipped with a drum. The end of the line is connected to the towing line of the AUV (recovered by a pop-up system). The vehicle is piloted in and docked inside the cage. CALISTE is then recovered.

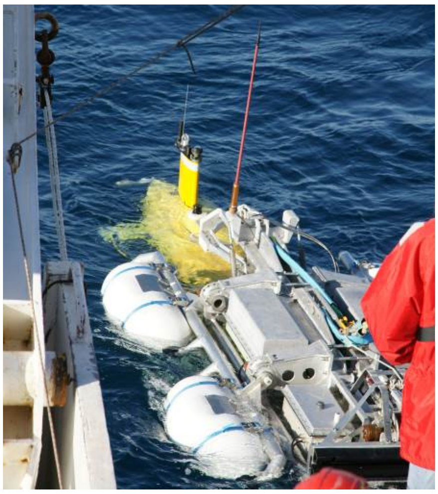


Fig. 3.12.2.d – Deployment examples. (Photo Ifremer)

Gear needed

If a LARS is used astern, the only constraint is that the A-frame clearance must be large enough to accommodate the LARS deployment. If ship gear is used, the most unfavourable case is the use of a cage. The handling system must be able to withstand dynamic loads, including possible snap loads due to the unfavourable drag/in water weight of the cage + vehicle ratio. Therefore, an SWL of at least 5 to 7 tonnes is required.

3.12.3. Operation and ship conditions

Supplies

Appropriate power supply is of prior importance and must be checked carefully.

Fresh water supplies should be provided close to the AUV landing point for the purpose of washing down after use.

Some equipment on an AUV may require seawater, for example the control room air cooling system.

Low pressure air (max. 7 bar) must be available for general purposes.

Air conditioning should be supplied to all inside working areas, e.g. workshop and control containers.

Operational interfaces

A Dynamic Positioning system is preferable for AUV recovery. The system must be able to keep position inside, typically, a 50 m circle for the sea state and wind conditions for which AUV operations can be envisaged, typically 25 knots wind speed at the side and sea state 5.

Positioning and communication

Positioning of the AUV using an SSBL and communication systems (between the AUV and the ship) requires surface transponders that can be installed permanently on the ship or considered as mobile equipment. In this case, the antenna will be deployed from a moon pool or from a specific boom.

3.12.4. *Space necessary on board*

Typical dimensional characteristics of the AUV systems are given below.

Vehicle

- Depth : 3000 msw
- Length : 5000 mm
- Diameter : 800 mm
- Width : 1000 mm
- Mass : 1000 kg

Launch and Recovery System (LARS)

Specific custom designed systems (not standard), for example:

CALISTE

- Length : 3.75 m
- Width : 2.0 m
- Height : 1.60 m
- Mass : 2 t
- Neutral in water

Control room + storage room

- Container: ISO 10' or 20'
- Power: 15 kVA

3.13. ROV

3.13.1. *Types of dedicated ROV for regional vessels*

The term ROV System is used to define the vehicle in itself and all peripheral equipment such as the tether management system (TMS), the control cabin, the workshop cabin, and the umbilical winch. Vehicles that are considered here are neutrally buoyant unmanned vehicles able to move in three dimensions. Trawling systems and towed vehicles do not fall within the scope of this guidance.

ROV range is from small observation class vehicles to systems weighting over 10 tonnes. ROVs may be classified as follows:

- **Class I** eyeball ROVs are small, compact and equipped mainly with camera/lights and sonar. The mass is typically a few tens of kilogrammes. Their objectives are purely observation; they can be equipped with small, lightweight sensors (such as cathodic protection probes, widely used in the oil industry)

- **Class II** Observation ROVs with payload option are fitted with viewing systems (cameras and sonar) and are able to carry out light handling tasks with a basic grabber. The mass is typically a few hundreds of kilogrammes. They are generally equipped with a sample basket

- **Class III** Work Class ROVs are large enough to carry extra sensors and/or two dexterous manipulators. These vehicles are larger and more powerful than Classes I and II and require a significant increase in topside support requirements. The mass is typically a few thousands of kilogrammes.

Nominal oceanographic regional class vessels are not capable of accommodating or operating class III ROV Systems, as their deck space, power supply and handling equipment capacities are not sufficient. This document will therefore focus on Class II ROV Systems.

3.13.2. Method of deployment for ROVs (34)

There are two concepts for vehicle deployment, TMS or live boating:

- The Tether Management System (TMS) protects the vehicle during launching, descent, ascent and recovery. The system manages the tether length once the vehicle is in operation. This can be a top hat system in which the vehicle is latched at the top, or a cage in which the vehicle is protected during descent and ascent. The TMS system becomes compulsory as depth increases (over a few hundred metres). A cage is commonly used for class II vehicles. The TMS and the vessel are connected to each other through a cable (primary cable), as are the ROV and the TMS (secondary cable). A heave compensator reduces heave motions; these can be amplified with depth. Without such a system, cage re-entry can be difficult and reduce the weather window of operation. Moreover, the control of the vehicle is also hampered; this reduces the efficiency of the dive. Heave compensators can be passive (ram tensioners) or active (on the winch), but are not commonly used on small ROV systems.

- The live boating mode, in which the vehicle operates by itself for descend and ascent phases. There are no intermediate systems between the vehicle and the ship. This method is used for shallow water, the vehicle having not enough power to compensate for cable drag.

The vehicle and TMS can be deployed using a launch and recovery system (LARS).The LARS can accommodate the winch, the vehicle and a specific A frame fitted with a docking head. The standard base frame is designed to standard ISO 20ft container dimensions and fitted with corner casts for easier shipment. When space is of prior importance, some of them are smaller and the vehicle is separate. If no LARS is used, the vehicle is deployed using the existing ship gear, a side crane or more generally a stern A frame. The umbilical winch is located directly behind the A-frame or handling system and directs a specific pulley installed on the A frame.

Over-the-side deployment is frequently used, both for launching standalone ROVs from any suitable vessel or as a permanently installed handling system on an ROV support vessel. The weather window is increased as the motions of the ship with respect to the stern decrease. However, on regional vessels, and except if the installation was foreseen on construction, it can be difficult to find a suitable place for the installation (reduced space, existing bulwarks and inappropriate handling gear). It is thus easier to deploy the ROV system astern, using the A-frame or the LARS system.

3.13.3. Space necessary on board

Typical dimensional characteristics of the ROV systems are given below.

Vehicle

- Depth : 2000 msw
- Length : 1500 mm
- Height : 800 mm

- Width : 1000 mm
- Mass : 350 kg
- Payload : 80 kg

Tether Management System (TMS) – cage

- Length : 2 m
- Width : 1.2 m
- Height : 2.5 m
- Mass : 1000 kg

Launch and Recovery System (LARS)

- Length : 6.058 m as standard
- Width : 2.428 m as standard
- SWL (kg): Up to 3,500
- Outreach (m): Up to 3.5 m
- Drum Capacity: 2,200 m x 30 mm; 2,600 m x 25 mm; 3,300m x 20mm
- Mass: 15 t including 2000 m steel cable

The ROV and TMS can be stowed within the frame for security and transportation, providing a single-lift solution for quicker mobilization. The A-Frame can be erected using the system's own rams without the need of any external lifting devices. This simplifies and reduces the cost of mobilization and commissioning to a new location.

Winch (standalone)

- Length : 2.5 m
- Width : 2 m
- Height : 2 m
- Drum Capacity: 2,200 m x 30 mm; 2,600 m x 25 mm; 3,300 m x 20 mm
- Mass: 15 t including 2000m steel cable

Control room + storage room

- Container: ISO 10' or 20'
- Power: 15 kVA

System power requirements

- Input: triple-phase
- 380-480 VAC
- ROV + TMS: 25 kVA
- Tooling: 10 kVA
- LARS (typical): 40 kVA

3.13.4. Operation and ship conditions

Supplies

Appropriate power supply is of prior importance and must be checked carefully.

Fresh water supplies should be provided close to the ROV landing point for the purpose of washing down after use.

Some equipment on an ROV may require seawater cooling, for example the heat exchanger on a hydraulic power unit (HPU) or the control room air cooling system.

Low pressure air (max. 7 bar) must be available for general purposes.

Air conditioning should be supplied to all inside working areas, e.g. workshop and control containers.

Handling gear

If a LARS is used astern, the only constraint is that the A frame clearance must be large enough to accommodate the LARS deployment (over 6 m in height).

If ship gear is used, the most unfavourable case is the use of a cage. The handling system must be able to withstand dynamic loads, including possible snap loads due to the unfavourable ratio drag/in water weight of the cage + vehicle. Therefore, an SWL of at least 5 to 7 tonnes is required.

Operational interfaces

A Dynamic Positioning system is required for ROV operation. The system must be able to keep position inside, typically, a 50 m circle for the sea state and wind conditions for which ROV operations can be envisaged, typically 25 knots wind speed at the side and sea state 5.

Cameras are generally used to provide a remote view of the operational rear sections of the ROV installation. These cameras are generally viewed from the ROV control room, but it should be possible to integrate them into the vessel system so that if necessary, ROV deployment and recovery can be monitored from the vessel bridge or other quarters of the ship.

Communication is an important part of ROV operations. The important issue to consider is the two-way communication between the ROV control room and the bridge.

Positioning

Positioning of the ROV using a SSBL requires a surface transponder that can be installed permanently on the ship or considered as mobile equipment. In this case, the antenna will be deployed from a moon pool or from a specific boom.

3.14. Drifting Buoys

A drifting buoy (or drifter) is an oceanographic device floating at the ocean surface or at a given water depth to investigate ocean currents and other parameters such as temperature and salinity. Drifters move through space and time following fluid parcels, thus they are also called “Lagrangian drifters” after Italian mathematician Lagrange. The operational depth of a drifter is defined by its neutral buoyancy, which means that it stops sinking when its buoyancy force is in equilibrium with its gravitational force ([8]).

3.14.1. Different types of drifting buoys

The modern drifter is a high-tech version of the "message in a bottle". It consists of a surface buoy, connected to a drogue (sea anchor) and equipped with meteorological and/or oceanographic sensing instruments. The buoy contains alkaline batteries, a satellite transmitter to send the data to passing satellites, a thermistor to measure sea surface temperature, a tether strain sensor to verify the presence of the drogue, and sometimes other instruments measuring barometric pressure, wind speed and direction, and salinity.

In 1982 the World Climate research Program (WCRP) declared that a standardized, low-cost, lightweight, easily-deployed drifter should be developed under the Surface Velocity Program (SVP). Competing designs were rigorously evaluated on a number of criteria and in 1992 a uniform design was proposed for the SVP drifter.

This has a spherical surface buoy and a semi-rigid drogue that maintains its shape in high-shear flows. The drogue enables the drifter to follow ocean currents rather than experience the effects of wind at the surface. The nylon cloth drogue used is centred at 15 metres beneath the surface to measure mixed-layer currents in the upper ocean.

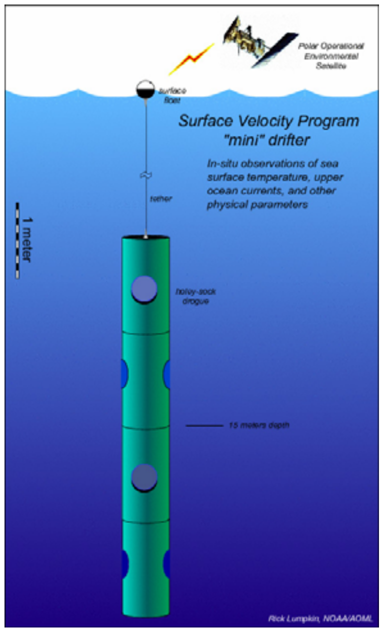


Figure 3.14.1.a - Each SVP drifter weighs 20 kg (44 lbs). Before deployment, the drogue and tether are bound with paper tape, which dissolves in the water, and the tether is sometimes wrapped around a water-soluble cardboard tube to protect it from kinking.

A further development of upper ocean drifters was to add the ability to move through the water column when measuring parameters. Historically the name “drifter” has applied to instruments on the surface and “float” to those in the water column. Floats have the ability to change their own buoyancy and, when they are deployed, they sink to a pre-specified depth. Newer, improved floats like ALACE (Autonomous Lagrangian Circulation Explorer), PALACE (Profiling ALACE), and SOLO (Sounding Oceanographic Lagrangian Observer) led to the ambitious Argo array, which began deployments in 1999 and now includes over 3000 floats. ALACE floats take ocean measurements of temperature when they are floating at depth. PALACE and SOLO floats can measure temperature plus salinity (conductivity) and pressure (depth), and take these measurements as they rise to the surface. For this reason they are sometimes referred to as “floating CTDs” and are totally autonomous after deployment.

3.14.2. Deployment of drifting buoys

Drifters are deployed by throwing them from the stern of a vessel, preferably from the lowest deck and within 10 m of the sea surface. Successful deployments have been made from ships steaming at up to 25 knots. After deployment, if a paper tape is used to bind the drogue with the tether, it may take up to an hour for the paper tape to dissolve and trapped air bubbles to be released, so that the drogue sinks to the target depth (15 m for SVP drifters). Once launched, drifters are totally autonomous and operate on the surface of the deep sea for a period of about one year, transmitting data through satellite devices. Since drifting buoys can survive a free fall from a height of approximately 12/15 metres with no operational degradation, they can also be air-deployed out of dedicated aircraft conducting surveys supporting marine operations.

3.14.3. Winch/Cable/Gear needed

Manual deployments of drifters are highly recommended, as using a crane can increase the risk of buoy damage during deployment.

3.14.4. Operation and ship conditions

Weather is the most critical and unpredictable element affecting these deployments. Flexibility in site locations ensures ease in deployment, thereby allowing ships to avoid hazardous conditions and still carry out the deployment in a minimum time.

3.14.5. Space necessary on board

The space necessary on board relates solely to the actual space occupied by the drifting buoys.

3.15. Moorings

A mooring is composed of a number of devices connected through a wire and anchored on the sea floor. The need to measure ocean currents throughout the water column for extended periods led to the development of oceanographic moorings: they represent the Eulerian way of measuring ocean currents, since a mooring is stationary at a fixed location, in contrast to the Lagrangian way, which measures the motion of an oceanographic drifter.

Today's moorings are used as 'platforms' from which a variety of measurements can be made. These include not only the speed and direction of currents, but also other physical parameters, such as conductivity (salinity), temperature, and sea state, as well as surface meteorology, bio-optical parameters, sedimentation rates, and chemical properties.

3.15.1. Moorings

Moorings typically have three basic components: an anchor, some type of chain or line to which instrumentation can be attached, and flotation devices (glass balls & synthetic foam floats) that keep the line and instrumentation from falling to the seafloor. Shackles and links are typically used to connect mooring components and to secure instruments in line. Most moorings fall into two broad categories: surface and subsurface. Although the two mooring types have similar components, the capabilities of the two are very different.

A surface mooring includes a surface buoy with possible real-time data transmission and possible instrumentation to measure surface meteorology and make measurements in the very upper ocean. The surface mooring, however, is exposed to ocean storms with high wind and wave conditions and therefore must be constructed to withstand the forces associated with the wind and waves. A subsurface (or submerged) mooring, on the other hand, has no possibility for real-time data transmission, is away from surface forces and can be made from smaller, lighter components, which are less expensive and easier to handle. However, it is difficult to make near-surface measurements from a subsurface mooring. Also, submerged moorings need to use an acoustic release or a Timed Release that connects the mooring to an anchor weight on the sea floor. The weight is released by sending a coded acoustic command signal and stays on the ground. Deep-water anchors are typically made from steel and may be as large as 100 kg. A common deep-water anchor consists of a stack of 2-4 railway wheels.

3.15.2. OBS

An ocean-bottom seismometer (OBS) is a seismometer designed to record the earth motion under oceans and lakes due to man-made and natural sources. Sensors at the sea floor are used to observe seismic and acoustic events. An OBS may be equipped with a maximum of a three-component geophone in addition to a hydrophone, and thus it needs a capacity of more than 144 Mbytes. In a typical survey, the instruments can be operational for several days (deployments can exceed 12 months), which requires a data storage capacity of more than 500 Mbytes.

Fig.3.15.1.a - Launching an OBS from the deck of RRS James Cook. (Photo UTM)

3.15.3. Deployment of moorings

Deep-ocean surface and subsurface moorings are typically deployed using an *anchor-last technique*. As the name implies, the anchor is the last component to be deployed. The entire mooring, starting at the top, is put over the side and strung out behind the deployment vessel and towed into position. At the appropriate location, the anchor is dropped. If the current and the wind are from the same direction, the deployment begins by positioning the ship down-current of the desired anchor-drop position. By doing this, the ship can maintain steerage as it slowly steams against the current while the mooring components are deployed and are carried away from and behind the ship by the wind and current. When the wind and current are opposing each other it becomes necessary to alter the deployment plan. In such cases, the important factor is the relative speed of the ship with respect to the water. Depending on the length of the mooring, its complexity, and the wind and current conditions, the start position could be as much as 10 km from the anchor drop position. The goal is to put the mooring line over the side at a rate that is slightly less than the ship's speed through the water and, thus, have the entire mooring stretched out without kinks and loops behind the ship by the time it arrives at the anchor-drop site.

With the ship at the position for starting the deployment sequence, the upper buoyancy of the mooring is lowered into the water. Figure 2.15.3.a illustrates the deployment sequence of a deep-water surface mooring. The mooring components are attached in series and paid out with the assistance of a winch. The ship's speed is typically 50-100 cm/s through the water. Instruments are attached to the mooring at the appropriate locations between premeasured mooring line shots. The last component put in line is the anchor. The ship tows the mooring into position with the anchor still on deck and actually steams past the desired anchor position by a distance equal to approximately 10% of the water depth for a surface mooring and less for a subsurface mooring. Once the ship is beyond the site by the appropriate distance, the anchor is deployed.

Either it is slid into the water by means of a steel-tip plate that is elevated on one end causing the anchor to slide off the plate; or the anchor is placed into the water with the use of a crane and mechanically released from the lowering cable once it is just below the surface. As the anchor falls to the bottom, the mooring is pulled under with it ([8]).

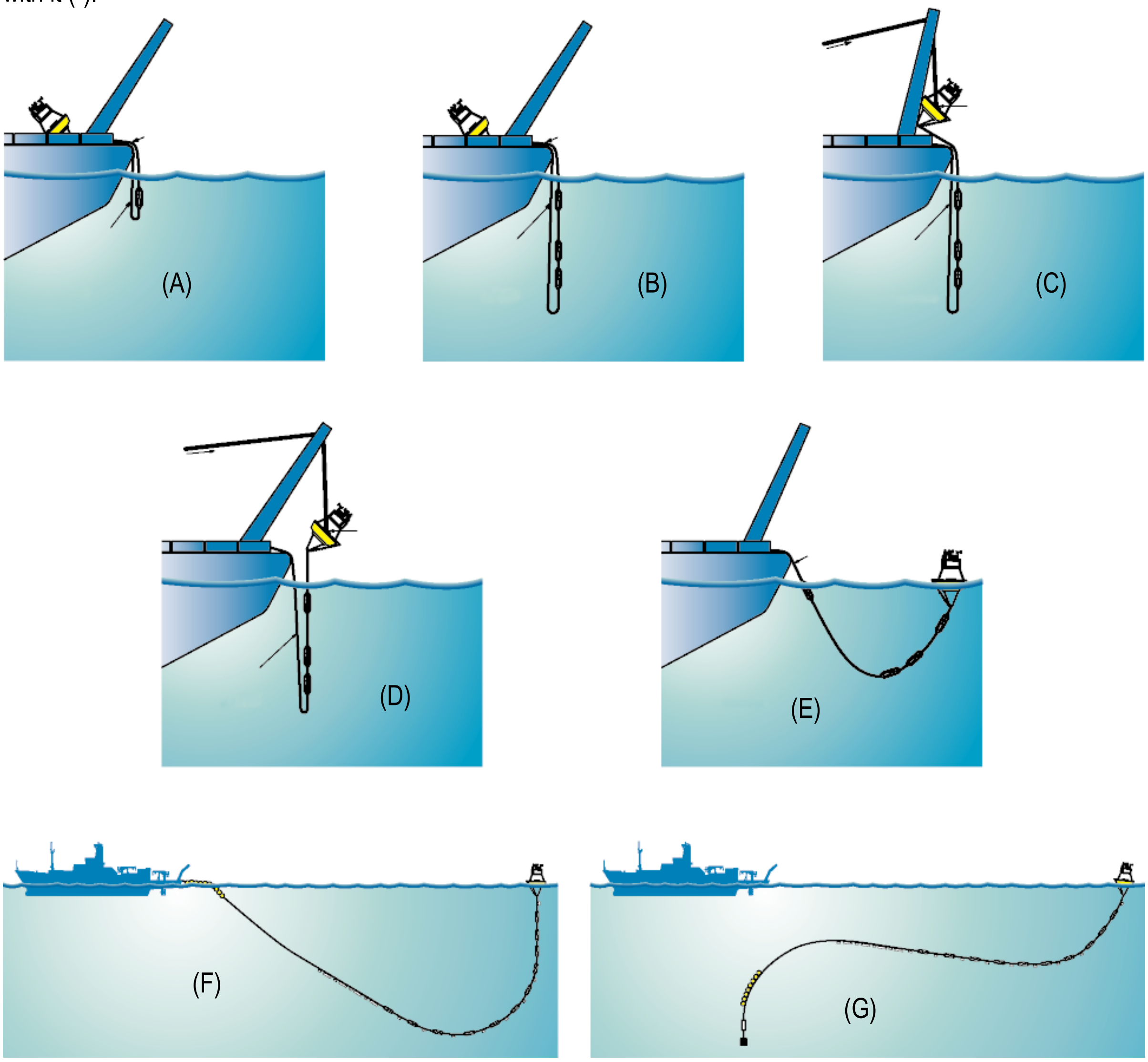


Figure 3.15.3.a - Surface mooring deployment sequence. (A) The first instrument is lowered into the water. (B) Instrumentation in the upper part of the mooring is lowered into the water before deploying the buoy. (C) The upper part of the mooring is attached to the surface buoy. (D) The surface buoy is placed into the water. (E) The ship steams forward slowly as additional mooring line and instrumentation are deployed. (F) The entire mooring is in tow behind the ship as the glass ball buoyancy is deployed. (G) The anchor free-falls to the ocean bottom, pulling the buoy along the surface.

Winch/Cable/Gear needed

The deployment of a sub-surface mooring does not necessarily require the use of a crane if the instruments composing the mooring are not particularly heavy. Surface mooring deployment should be operated by the stern A-frame. The choice of safe working load should be coherent with the definition of the winch capacity and with the type of instruments making up the mooring.

3.15.4. Operation and ship conditions

Operations are carried out using the stern A-frame. The lowering speed for equipment depends on winch specifications and sea state conditions.

3.15.5. Space necessary on board

All the mooring deployment operations are carried out on the work deck, which should contain all the deployed instrumentation, depending on the mooring design.

4. Deck Operations and Deck Gear

4.1. Operations

Operation or manoeuvring is here understood as the sequence of actions with the objective of deploying and recovering equipment into and from the water. The procedure is composed of deck operations and ship manoeuvring. In this section we will classify the second aspect: the attitude of the ship during deployment operations, i.e. ship manoeuvring.

The following scenarios are envisaged for the vessel:

- On station - drifting or with dynamic positioning (DP)
- Trawling or towing gear for fishing or devices for sampling, scanning etc.
- Manoeuvring to anchor mooring lines (with instrumentation) or launching buoys
- ROV and AUV operations will also be considered.

4.1.1. On station

If sampling is required in a particular location, then the vessel must maintain its fixed position, and is on station. This can be easily done under reasonable sea conditions by using dynamic positioning (DP). This is the case for coring operations, CTD profiler, hydrology, and ROV in "work place" mode. Usually this operation is done on the starboard side but could also be done astern if gear and deck conditions do not allow for the starboard side option.

Side operation is always preferable if the ship is stopped because the frame or davit position relative to shipside is more centred. Also, the distance between winch and frame block is short and cables do not slack away when the ship moves. In stern operations with the ship stopped, there is not enough tension in the cable, as there is when towing, and it may slack off with pitch movements; the distance from winch to frame block is long and may produce harmful situations. In starboard side operation it is convenient for the ship to head for the wave, avoiding roll. In the case of stern operations, heave aback is more usual, avoiding pitch movement and cable slack.

DP is basically a system which controls the ship’s attitude by acting on the propellers, thrusters and rudder. This is done by a computer and software which has been set with parameters such as ship dimensions (model), the real time input of ship behaviour (gyro and motion sensors), plus information about wind, current drag and sea state conditions. The system analyses these inputs and controls the propellers and rudder to achieve the selected attitude: on station means a fixed position and heading. Dynamic positioning may either be absolute, with the position locked to a fixed point above the bottom, or relative to a moving object such as an underwater vehicle. The ship may also be positioned at a favourable angle towards wind, waves and current.

Comparison of position-keeping options		
Keeping station manually	Anchoring	Dynamic positioning
Advantages: • No complex systems involving computers • No chance of running off position due to system failures or blackouts. • Manoeuvrability is excellent; it is easy to change position.	Advantages: • No complex systems with thrusters, extra generators or controllers. • No chance of running off position due to system failures or blackouts. • No underwater hazards from thrusters.	Advantages: • Manoeuvrability is excellent; it is easy to change position. • No anchor handling tugs are required. • Not dependent on water depth. • Quick set-up. • Not limited by obstructed seabed.
Disadvantages: • Limited by helmsman fatigue • High fuel costs. • Chance of running off position due to human error	Disadvantages: • Limited manoeuvrability once anchored. • Anchor handling tugs are required. • Less suitable in deep water. • Time to anchor out varies between several hours and several days. • Limited by obstructed seabed (pipelines, seabed).	Disadvantages: • Complex systems with thrusters, extra generators and controllers. • High initial costs of installation. • High fuel costs. • Chance of running off position due to system failures or blackouts. • Underwater hazards from thrusters for divers and ROVs. • Higher maintenance of the mechanical systems. • Generates air bubbles that interfere with acoustic equipment.

Source Wikipedia https://en.wikipedia.org/wiki/Dynamic_positioning

Moreover, if there is no DP on board, the ship will drift due to the effect of wind and waves and the cable will form an angle with the sea surface. Normally, the ship position will be with windward on the starboard side, and the ship will drift leeward, so that the cable does not pass beneath the hull. Depending on the sea state, the ship will use more or less propulsion to maintain position. Because the cable is lowered at an angle, more cable is needed to achieve the desired depth and consequently, more time is also required for the operation.


Fig. 4.1.1.a - Azimuthal bow thruster. (Photo UTM)

4.1.2. Trawling

Trawling is the way gear for fishing or dredging is dragged behind the vessel. Fishing nets etc. may be hauled along the bottom or in mid-water (pelagic) (see §3.4). For trawling, trawl-winches are used, and usually a pair of them is installed on the deck or below-deck. Trawling can also be carried out with one winch in those vessels that are not adapted for fishing. In addition to “commercial-like” fisheries, “experimental” fishing such as deep sea sampling, dredges, etc. must also be considered. In trawling, the speed of the ship is usually between 2 to 5 knots depending on the trawl used. For bottom fishing or dredging 1.5 to 2.5 knots is enough. For pelagic trawling, depending on the target species, the speed may be up to 5 knots.

The operations for trawling depend on whether trawl doors are used. Trawl doors are steel or wooden plates (nowadays they may also be made of carbon fibre or glass fibre) pulled by the cables that dash through the bottom and, due to resistance, open the gear. Pelagic doors are similar, but run in mid-water. If doors are present, the operation is in two steps. First, the net is launched into the water at a low speed of 1.5 to 2 knots. The net is off, and pulling the doors from behind; the winches pay out cable to lower the doors into the water and then, increasing the speed of the ship, run off the cable length needed. During the whole operation, it is convenient for the ship to head for the wave. For recovery, once the doors are secured on the stern, a cable from the net is passed to the net-drum or other winch, pulling the whole net. Trawling may be simple in the case of dredges using a single cable. The dredge is launched into the water using the aft frame, synchronizing the release of the cable with the “all off” movement of the frame. Once in the water, it is hauled down.

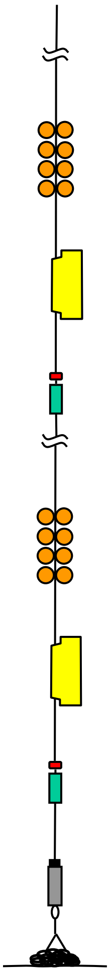
Dredging and bottom trawling may be difficult if the bottom is rough. For dredging, a “fuse” is sometimes useful. This consists in a chain weaker than the cable: if the dredge is snagged in a rocky or muddy bottom, the chain breaks and a second pulling cable, tied to another part of the dredge, can remove the apparatus.

4.1.3. Towing

Towing is a method of pulling something behind the vessel with a cable (synthetic or steel). The vessel may tow a variety of apparatus: sledges (see §3.4), dredges (see §3.9), ROV (see § 3.14), seismic streamers (see § 3.11) and several other items of equipment (see § 3.10).

During towing, vessel speed is a compromise, between 2 to 8 knots depending of the kind of towing, usually around 4-5 kts.

4.1.4. Mooring (buoys and moorings)



Moorings in oceanography are lines of connected instruments with a weight at one end and a float at the other for measuring currents, sediment rating, etc. The mooring is anchored to the seafloor. The weight could be deployed at the bottom or could be in mid-water maintaining the line taut. The buoy may also be deployed at surface or at mid-water. Some moorings are several few kilometres in length, complicating deployment and recovery operations in terms of time and effort.

The conventional operation for deployment involves, firstly, launching the buoy with a ship speed of 1-2 knots while getting off the line, then the line should be stowed in a drum and a brake is needed for deployment, while for recovery a winch is necessary to pull the line in. The ship heads for the mooring location and attempts to arrive at the position with all the line in the water and only the weight on deck.

The weight is launched using the aft frame and released using a release hook when in position.

Recovery is somewhat complicated. Usually, the weight is released from the line using an Acoustic Release. The buoy lifts the whole line to the surface. Using a grapple, the guide line is hooked and lifted using a crane or a capstan. Once the float set is on the deck, the main line must be passed through a block and from there to a winch or capstan.

Usually the operation is done to starboard; the side in question must be to windward to avoid the line passing beneath. Today, using DP and assuming the mooring position is correct, the boat can maintain position some one hundred metres away from the mooring position.

Fig. 4.1.4.a - Buoy ready for deployment on R/V García del Cid. (Photo UTM)

4.1.5. *Vehicles*

4.1.5.1. On station

This mode maintains the vessel in a fixed position (current position), as defined in paragraph 3.1.1. For a vehicle, it is designed for an ROV in “work on site” mode, i.e. when the ROV is taking samples with its arms.

4.1.5.2. Follow the vehicle

This mode may apply to ROV surveys for speeds of within 0 to 2 knots and rock dredges if needed where the vessel has to follow the vehicle to perform the survey. Towing force may reach approx.4-5 tonnes depending on which vehicles are being towed. The ROV is linked by a tether to a depressor or TMS (see § 3.13), itself towed by a support vessel. To ensure a good positioning-feedback in this mode, the distance from the ROV to the depressor must be taken into account, rather than the distance from the ROV to the vessel. Both the position of the ROV and that of the depressor relative to the vessel are given by an acoustic positioning system, either a long base line, or an on-board mounted ultra-short base line. Maximum ROV speed is around 1.5 knots.

4.1.5.3. Vehicle sails alone

This mode is applied with vehicles such as AUVs which are programmed for a specific survey and do not need any link with the vessel during operation. In this case, the vessel can perform other operations during the scheduled survey. When it is necessary to communicate with the vehicle, the vessel can approach the vehicle and a baseline fixed on a pole can be used.

4.2. Ship conditions

“Ship conditions” is understood here as the work deck configurations and the attitudes (steering) to be adopted by the ship during these operations. The deck layout comprises the configuration, location and features of gear such as frames, cranes, booms, winches, footholds, services (like water, power lines, air…), data cable paths, etc.
The attitude (behaviour) comprises the steering of the ship during the manoeuvre, speed and heading, taking into account the sea and wind and the behaviour and capabilities of the gear referred to above.
An operation (manoeuvre) is the result of the combination of several factors:

- Tooling (gear) capabilities
- Ship attitude
- Sea conditions
- Crew performance

In this document a few manoeuvres typical of the whole will be considered. Obviously, it is not possible to preview new equipment operations and, in view of this, the operations described here should be considered as “conventional operations”
These deployment and recovery operations for equipment will be carried out over the side (starboard side preferably) or stern. In addition, some operations can be carried out on the forecastle deck.

As has been defined, the ship attitudes comprise:

- On station: ship drifting or with DP maintaining a fixed position.
- Trawling: dragging some sampling equipment behind following the bottom (or mid-water in case of pelagic trawling)
- Towing: pulling equipment in mid-water
- Moorings: anchoring equipment such as mooring lines and buoys.

<u>Note</u>: The distinction drawn here between trawling and towing is because trawling is when equipment is dragged along the bottom surface. Pelagic trawling, where the equipment is pulled in mid water, is included here in order to have some congruence and link it with bottom trawling.

This document describes a combination of both the gear involved and ship attitude.

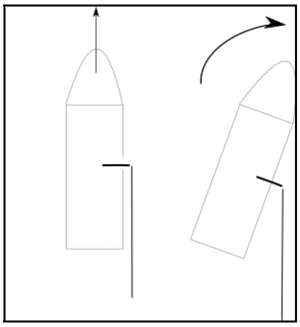


Fig.4.2.a -: Example: turning to starboard to ward off the plankton net

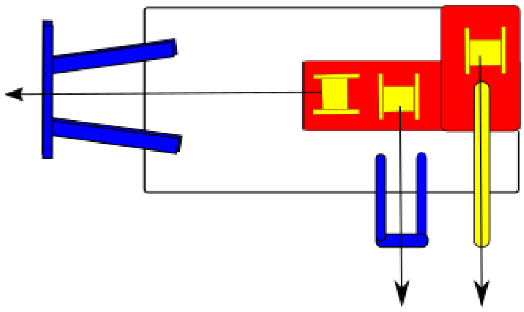
To model these operations, a simple configuration of the work deck of an RRV of 50 m O.L. will be considered. The deck layout, including rigging and superstructures, winch deck, etc. can have different layouts on different RVs. There is no such thing as a standard deck layout.
Some tools needed for operations on deck are described below; others have been described previously in this document.

4.2.1. General arrangement of a ship's work deck

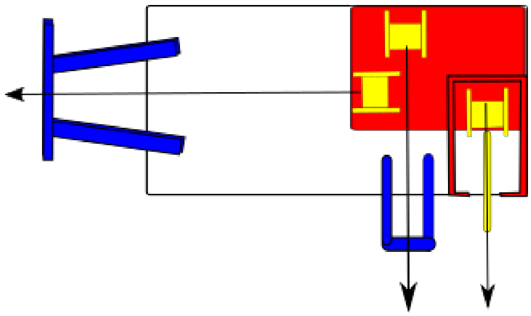
Every RV is different and therefore it is not useful to define a standard work deck, but it is possible to extract from all of them a set of common manoeuvres, and to get a scope of both the constructive and the operative solutions adopted.
Several arrangements can be used in deck design. These depend on general use of the ship (hydrography, fisheries, etc.) and also on shipbuilding tradition.
For simplicity, the different elements that make up the work deck are determined here. On the one hand there are the superstructures such as the hangar, casings, spare decks, etc. Then there are the "tools": gear such as winches, davits and the frames. Thirdly, there are non-mobile elements like the ramps and breakwater for fishing, bulwarks, and others. Lastly, there is the mobile equipment such as seismic structures, containers, labs, ROV LARS, etc.
These are groups are here defined as follows:

A. Superstructures (casings, hangar, spare deck, winch deck, etc.)
B. Winches (with cables, blocks, spoolers, etc.)
C. Frames, davits, booms and cranes
D. Ramps, breakwater, bulwark, tie-downs, etc.
E. Mobile equipment (containers, LARS, seismic, etc.)

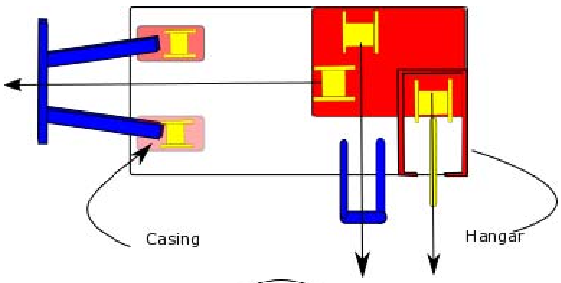
Working on the basis of these elements, as an example, different models can be developed. The diagrams below are deliberate simplifications, designed to suggest some solutions.



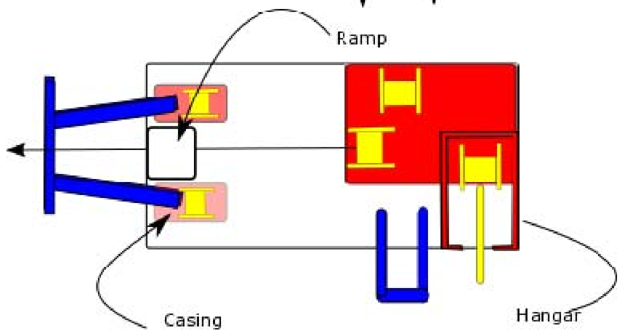
A. Central hangar with side A frame and hydro boom. (Top view).



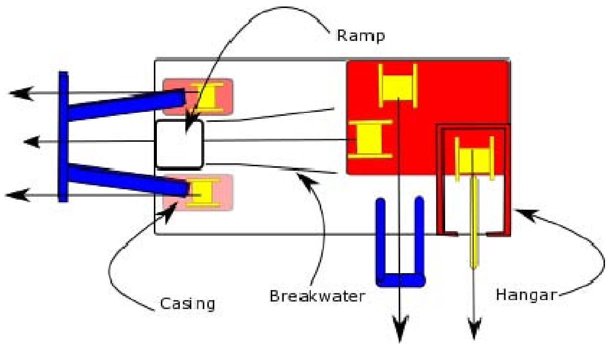
B. Side hangar with telescopic boom and aside A frame



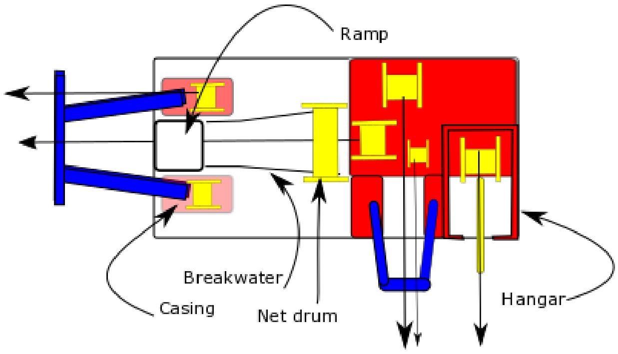
C. Astern casings with trawl winches. Aft A frame over casings



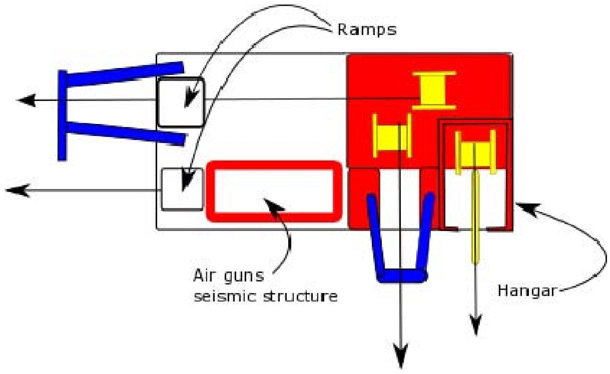
D. Stern ramp



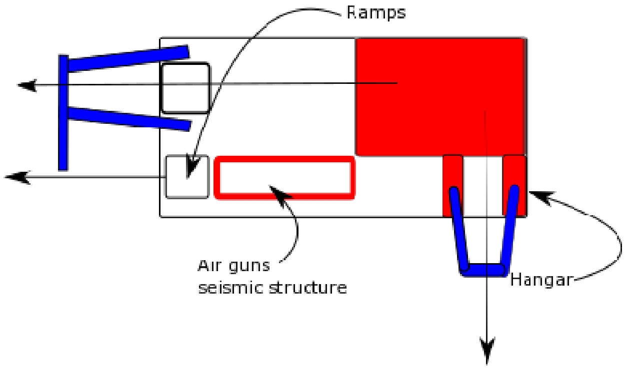
E. Fisheries scenario, with breakwaters.



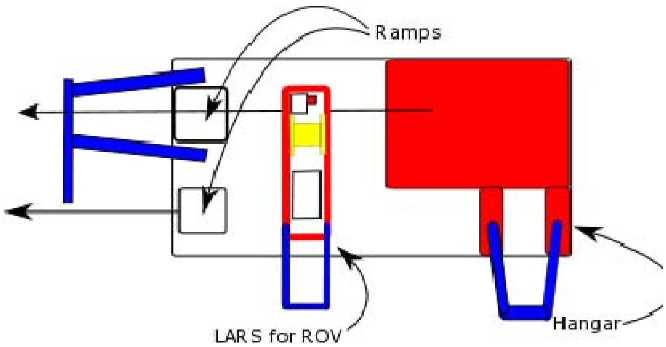
F. With net drum and side "A" frame over winch deck.



G. Asymmetric stern with two ramps, the second for seismic scenarios.



H. The same as G but without aside hangar; aside "A" frame over winch deck.



J. With LARS for ROV deployment aside.

Fig. 4.2.1.a - Examples of different work deck layouts
(Top view. In blue: frames, in red: superstructures, in yellow: winches, in white: ramps)

Clearly, many combinations are possible. However, it is important to note that the work deck can be well-defined (closed) as in *Fig*. *F*, with all the necessary elements for different scenarios fixed on the vessel or, the work deck can be left open, clean, and the items installed as needed, as in *Fig*. *A* or *B*.
Between these two extremes, the work deck can be designed as desired. It is difficult to give recommendations in this regard as these will greatly depend on the actual use of each scenario: if fisheries research will be the main activity, then it is probably a good idea to install a ramp, door fitting elements, breakwaters, whips, trawl winches, net drums, etc. The other activities could be defined but with some limitations for heavy installations and operations.
An open deck could be a good idea if diverse activities and installations are envisaged, along with new equipment deployment and operation. In this case, mobilization and demobilization (mob/demob) and rigging will take time and money. In addition, land facilities are needed to store mobile equipment. Interoperability or compatibility of moveable equipment is one of the advantages of an open deck. Compatibility of deck structures, especially anchorage and container foundations, is an interesting point in this configuration.
Furthermore, there are some scenarios that have the greatest impact in terms of defining deck arrangement. These are fisheries and seismic scenarios and, to a lesser extent, ROV scenarios. Historically, ROVs have arrived on board ships late in the day, and have done so by incorporating movable equipment like LARS and containers. Few Research Vessels have a permanent ROV installation.

As for the seismic scenarios, it all depends on the scale of work intended. The seismic scenario uses compressors, airgun array structures, streamers and umbilical winches. Depending on the power and performance of the equipment, and whether it is multi or mono-channel, the scenario may be rather large and heavy. If the installation is fixed, the limits of the equipment must be defined beforehand. Installing compressors below deck could be a matter to take into account. However, with a frame and winch it is possible to deploy a cluster of 4 airguns and a streamer, for example.

Fig.4.2.1.b - Boom for moving an airgun array aside. (Photo UTM)

Fig. 4.2.1.c. - Airgun array structure. (Photo UTM)

The fishing scenario is usually fairly standard although cable length, (i.e. the maximum working depth for both bottom and pelagic trawls) should be defined. Depending on the type of fishing gear, other tools and rigging will be needed.

Fig.4.2.1.d - Whip on the Celtic Explorer. (Photo UTM)

Stern ramp fishing (bottom and pelagic trawls) requires other operational structures for net recovery, such as door stowing, capstan, whip, fairleader blocks, etc. The support of these elements and their location must be studied, although shipyards usually have extensive experience in these scenarios.
An attempt should be made to combine all scenarios and not to duplicate gear; in other words, it is desirable to analyse operations and determine a minimum number of winches, and try to use the same winch in different scenarios. In some cases, following a previous design is convenient as a starting point. In some fleets such as UNOLS, interoperability of equipment is applied and some standards are defined as minimum capabilities, for instance for winches and cables.

4.2.2. Superstructures on deck

As discussed above, deck superstructures help to distribute gear and therefore manoeuvres. However, these superstructures "close" the deck, restricting its future and new installations. A number of items can be distinguished: casings, spare decks, hangars and the winch deck.

In traditional stern ramp fishing boats, casings (spare decks) housed different elements such as the exhaust, pumps and lockers aft and served as support for cast decks and other decks for cranes, davits, etc. They extend the deck in height. Some fisheries research vessels still maintain these structures around a ramp; they serve as trawl winch housing, and support the doors in the stowed position.

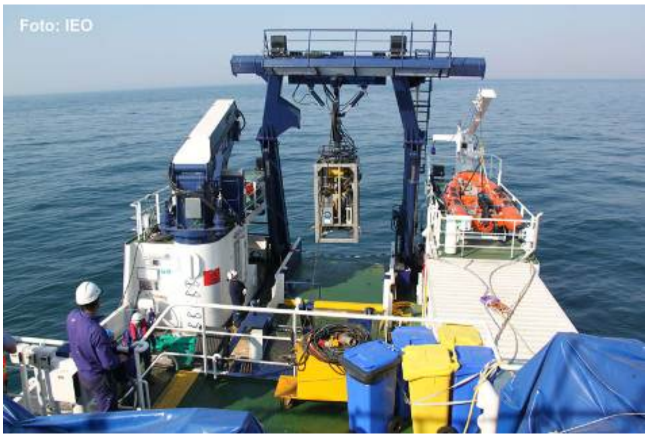


Fig. 4.2.2.a - R/V Ramon Margalef with two casings for trawl winches.
In this case, the frame legs are anchored directly to the main deck. (Photo IEO)

Some RVs mount the aft frame legs over these structures, providing a higher span with the same frame dimensions (see figures below).
In some cases, the casings (spare decks) house mooring elements such as bitts, a crane, or a capstan, moving it from the work deck to facilitate other operations. In addition, a service crane may be installed over these decks.

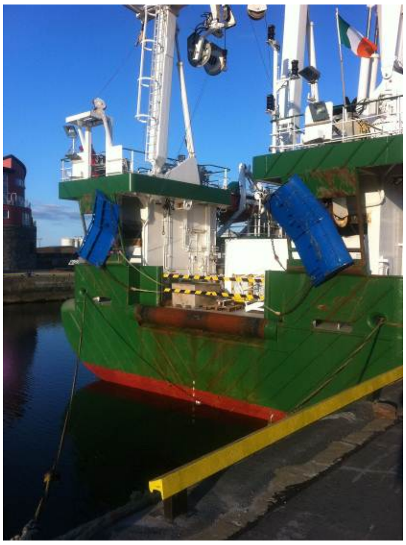


Fig.4.2.2.b - Aft A-frame installed over spare decks on R/V Celtic Explorer.
Note the doors stowed on these structures. (Photo UTM)

Another structure is the hangar. Hangars house equipment and gear for deployment as well as workshops etc. Two types of hangar can be distinguished: centreline hangars and side hangars (CTD hangar).
The first of these follows the centreline lengthwise from the forward work deck to a point in the stern, leaving some distance to the frame.

Fig.4.2.2.c - Centre hangar on RRS James Cook. (hoto NOC-NERC)

This structure usually has two openings, one on the starboard side and the other facing aft. Typically it is used for manoeuvres, CTD runs off to starboard, as a garage for vehicles, etc. though depending on its size it can also be used for stowing containers and other equipment. One advantage of this arrangement is that it can be placed over the upper deck winches needed for these operations and, in the case of working stern winches, closer to these so that the distance between winch and overboard block is not too large. Winches looking to starboard can be in line (two winches to a frame) or in parallel, for two frames, for a hydro-boom and frame, etc.
A hangar must be fitted with gantries for load transfer. SWL has to be defined according to the onboard systems planned for the ship, but will not be lower than 2 tonnes.
The hangar must also be fitted with roll tops to protect it from weather conditions.

Fig.4.2.2.d - View of the work deck of R/V Thomas G. Thompson with centre hangar. (Photo: U. of Washington)

This type of hangar is usually installed in larger ships for the reason stated earlier: avoiding a large distance between the winch and the frame.
The second case is a hangar located to starboard, alongside a side frame or hydro boom. This hangar is mainly used for CTD deployment but also for plankton nets or even a (small) ROV. In large ships, this hangar can reach from side to side and have up to three or four levels. In smaller vessels these can occupy at least half beam. The development of this type of hangar comes from the need and usefulness of covering the CTD operation when performed aside the vessel. Rosette bottle sampling can be done under cover.

Fig.4.2.2.e - Side hangar on R/V Sarmiento de Gamboa. (Photo UTM)

4.2.3. Frames and cranes

4.2.3.1. Side A-frame

Side A-frames are designed to perform a broad range of operations, such as CTD deployment, coring deployment and launch and recovery of special tools and equipment.

Side A-frames generally have lifting capacities ranging from 3 to 10 tonnes, depending on the deployments needed. They are available in electro-hydraulic and electrically-driven versions. These may be delivered as self-contained and self-erecting units for mounting onside of the vessel. The A-frames are available in centre-rigged, side-rigged, knuckle-jib and telescopic versions and may include winches and pendulum dampening scissor frames.

4.2.3.2. Aft A-frame

Like side A-frames, stern A-frames are designed to perform a broad range of operations, such as ROV deployment and launch and recovery of special tools and equipment.

Generally, their lifting capacities are higher than side A-frames, ranging from 5 to 30 tonnes, depending on the deployments needed. They are available in electro-hydraulic and electrically–driven versions. These may be delivered as self-contained and self-erecting units for mounting onside of the vessel. The A-frames are available centre-rigged, side-rigged and may include winches and pendulum dampening scissor frames.

Although other types of frames may be installed depending on the main activity of the vessel, here the aft frame is assumed to be an “A” shape frame. This is the simple frame. The variables to consider are:

- Span (height and width)
- Dynamic SWL
- Static SWL
- Maximum extension (all-off)
- Maximum extension (all-in)
- Maximum and minimum speed.

Other interesting features include the number of attachment points for blocks. Sometimes, different operations with different cables alternate, and having different blocks means it is not necessary to change blocks between cables.
Also it is convenient to have a T-frame where the two horizontal upper legs exceed the span of the “A” of the A-frame. These horizontal legs can house other pulleys or snatch blocks as an aid for side operations or stern-

side (quarter) operations, for example in the case of ramps on both sides, trawling doors on both sides, or for recovery of mooring operations.

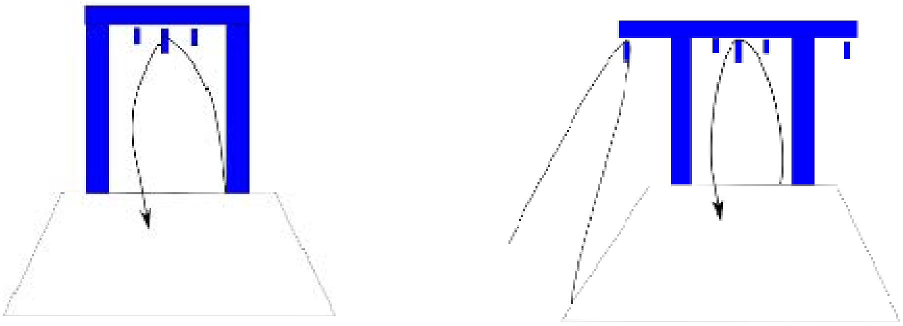


Fig.4.2.3.2.a - A-and T frames

In the case of an A-frame, closed, the cable end (fend) has to pass through the "eye of the needle". With the external supports in the case of T-frame, the cable can be loaded in the snatch block without having in hand the cable end (lend).
As stated before, the frame may be installed on deck in a variety of ways. One is on the same deck; the legs of the frame are installed on the work deck. In some cases, for example vessels with fishing facilities, two casings or spare decks, which protect the trawl winches, are installed on both sides of the aft deck. The legs of the frame are then fixed on these spare decks. This configuration enables easy trawl operation with doors fixed at both sides of the ship stern without interfering with the frame, as well as obtaining a larger frame span without increasing the dimensions of the frame. This arrangement has been installed on NO Thalassa from Ifremer, Celtic Explorer from MI, Ireland and RRS James Cook from NOC (NERC), for example. The spare deck can accommodate docking gear like bitts, winches, hawsers, etc., clearing the work deck.

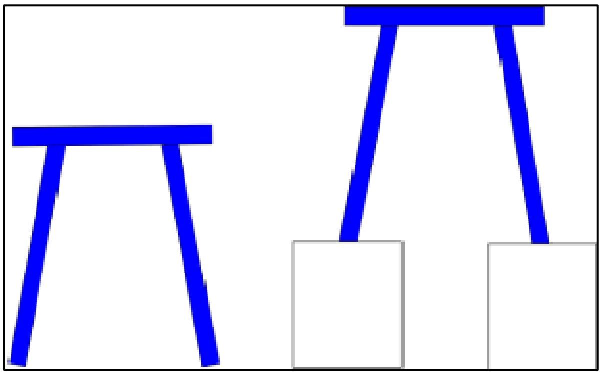


Fig. 4.2.3.2.b - Frame over deck and over casings (spare decks)

Fig. 4.2.3.2.c - R/V Thalassa. (Photo Ifremer)

Fig. 4.2.3.2.d - Alkor (IFM-GEOMAR) aft frame. (Photo UTM)

Fig.4.2.3.2.e - RRS James Cook. NOC. (Photo NERC)

Another solution for fishing with RVs is to install two supports inside the frame, beside the legs, for fixing the trawl doors and overboard trawl blocks. This solution is used on the FS *Alkor* from Geomar.
Some add-ons can be installed on the frame. One is the so-called "travelling block". When launching equipment, the speed of the cable winch and the speed of the frame going out must be synchronized because, as the frame goes out, the total distance increases and then the device or equipment is lifted, rising in the direction of the block. The winch must pay out cable during this operation. During recovery the opposite occurs; the winch must pull cable continuously so as to avoid the apparatus striking the deck.
To avoid this, in some operations, like ROV deployment, an auxiliary winch is installed in one of the legs of the frame. The cable follows the leg of the frame, a block drives the cable along the top bar and a second block drives the cable vertically down. This gear means the equipment suspended is always at the same distance from the block when moving the frame out and in. If a block (snatch block) is installed at the end of this cable, this is very useful for deployments and for changing cables used in the different operations.

Fig. 4.2.3.2.f - Frame winch with fairleader blocks. (Travelling block)

(Photo Ifremer)

Fig. 4.2.3.2.g - RV Simon Stevin Aft frame. (Photo VLIZ)

4.2.3.3. Cranes, davits, and booms

Two kinds of crane are usually used on board oceanographic vessels: cranes with extendable booms or knuckle arms. The safe working load of the crane is defined on the basis of operations that use it at sea and at quay. Thus the Safe Working Load curves over the range of possible working radiuses defined for any given crane, and compared to a plan view of the work deck areas of the ship. Used together, these data can be used to determine the loads that can be lifted at various points on the ship and over the side.

Moreover, the crane should be designed for use at quay or at sea. At sea, dynamic forces due to vessel motions should be considered. Use of the crane at sea is limited primarily by the strength of the slewing or rotating mechanism. The slewing mechanism, although strengthened for use on a moving ship, is not capable of withstanding the potentially extreme side loading dynamic forces that can be caused by towing or pulling loads, or by the roll of the ship. There are no rigid guidelines for the use of the crane in this regard. Limits on crane use at sea are normally set by common sense and by good seamanship practices.

The length of crane arm is chosen on the basis of operations to be carried out with the crane. It may serve as the overboarding point for cables or wire spooled on the trawl winch. In this case, the cable can be led from the trawl winch flag block directly to an over-boarding sheave hung from the crane. Operation in this mode could require a special boom crutch be installed to support the boom and to absorb the forces caused by the working cable; prior arrangements for this equipment are necessary.

Cranes are available in electro-hydraulic and electrically-driven versions. These may be delivered as self-contained and self-erecting units for mounting onside of the vessel. The crane may be self-contained with the electrical controller, hydraulic or electrical power pack and operator station mounted on the crane or its pedestal. The location of the crane is defined by the naval architect to optimize the position depending on the operation called for.

4.2.4. Winches

4.2.4.1. Overview

As has been seen in previous sections, scenarios considered include the ship being on station (with DP or drifting) and towing or trawling (steaming). It follows that winches for these operations must be installed to give service aside and astern.
Cables may be traction cables or conductor cables. The ideal configuration will have both types of winch cable, looking aside and astern. But sometimes there is not enough space for these winches on the winch deck. Other solutions include mobile winches, which can be installed in two or more positions, or a pivoting platform for winch orientation. Special spoolers with fairleader blocks are also an option for driving the cable to the overboard block. But it is recommended to drive the cable directly to the overboard block, if possible, avoiding fairlead blocks: more blocks mean more wear and more complications; the simpler, the better.

Generally, two types of winches can be distinguished: oceanographic winches and trawl winches. Oceanographic winches are those that are used for deploying equipment, excluding fishing gear.
Oceanographic winches are more precise and sophisticated than trawl winches. Speed control and spooling need to be very accurate because coax (electro-mechanical) cables are used.

4.2.4.1. Oceanographic winches

When deploying equipment, winches are always involved, at least to put the equipment in water. All deck gear is necessary for deploying items, but winches are responsible for carrying equipment to the desired depth with all the guarantees. In some cases, a winch cable can deliver power and/or a data signal. They are therefore a fundamental part of oceanographic equipment.
Winch and its cable or rope form an inseparable team that sometimes pass unnoticed. Technology is constantly improving, even as oceanographic instruments are, especially in terms of the handling and performance of the winch. Technologies for manufacturing cables and electric motors, hydraulic control systems, sensors (voltage, speed), remote control, and interfacing with computers, have been incorporated and allow high reliability even in continuous utilization.
On a ship, there are many winches for the ship's own manoeuvers, docking, anchoring, and mooring. Here only oceanographic winches are discussed.
Winches may be electrical or hydraulic (or electro-hydraulic) driven. Decisions must be made when planning renewal of winches on board oceanographic vessels, or on new builds. Electric, electro-hydraulic, and hydraulic drive winches each have advantages and disadvantages. The selection of the winch drive should be based on the expected uses and should be compared to other criteria. All three drive systems (hydraulic, electrical, electro-hydraulic) have been used successfully on board commercial fishing vessels and research vessels. Many newly constructed commercial fishing vessels and research vessels are installing electric drive winches.
Winch specifications start with cable type definition (or wire rope, rope) and the length needed. Winch characteristics (size, load and power) depend on cable length and cable diameter. If the cable must allow data or power transmission with instruments, electromechanical and/or optical cable will be required. The number and size of the conductors must be specified, along with slip ring assemblies for transmission of signals from the rotating drum. If a traction cable (wire rope) is necessary, the material must be properly chosen in line with the safe working load required: galvanized, stainless steel, lubricated, etc. The cable length is also important for the whole load. The weight in water of the entire cable length must be considered when estimating the safe working load of the winch. This load will be greater than the equipment payload itself. Moreover, deck structure should be compliant with the total weight of cable and winch.

Once the cable type and its length have been chosen, the winch can be designed. The minimum bend radius will determine the drum diameter. The cable length will determine the drum width and also the flange (wing) height. The winch must have a level wind system and a grooved shell on the drum to stow the cable correctly. Level wind systems work using a level wind system and a lead screw shaft that moves synchronized with the drum rotation. The groove makes the cable fall properly onto the first layer on the drum so that successive layers are placed separately from the other levels. ([24], [25])

When a decision about winch design or acquisition needs to be taken some key points need to be considered:

- Cable or wire rope: definition
- Type of cable/wire rope: diameter, SWL, number of conductors, etc.
- Length of cable/wire rope
- Payload: maximum weight of devices/equipment to be deployed, more dynamic forces when trawling/towing etc. and cable weight (in-water)
- Maximum speed of winch

With this information / features, the following can be defined:

- Maximum power needed
- Speed range
- Drum (barrel) diameter with the minimum bend radius of the cable
- Flanges (wings): cable diameter and length define the width between flanges and flange diameter
- Spooling: level wind shaft, grooved drum or Lebus shells if a lot of cable has to be spooled
- Slip-ring.
- Traction head: depending on the type of cable, sometimes a traction head is needed to avoid spooling problems, especially with fibre wires.

With the cable or wire rope specifications the drum diameter, drum flange diameter, power and spooler specifications can be defined.

Winch speed limits are defined on the basis of the sea state, the length of cable paid out and the type of equipment lowered.

The safe working load of the winch is defined on the basis of its intended use. Maximum tension occurs at the head sheave. As previously outlined this tension depends on the length of cable paid out, the weight and shape of the payload, the prevailing sea state and the hauling speed. Moreover, limits on deployment depths to avoid high dynamic stresses and on pay-out rates to prevent slack conditions should be considered temporary measures. The alternative is to consider motion compensators which can greatly reduce or suppress the undesirable effects of ship motion.

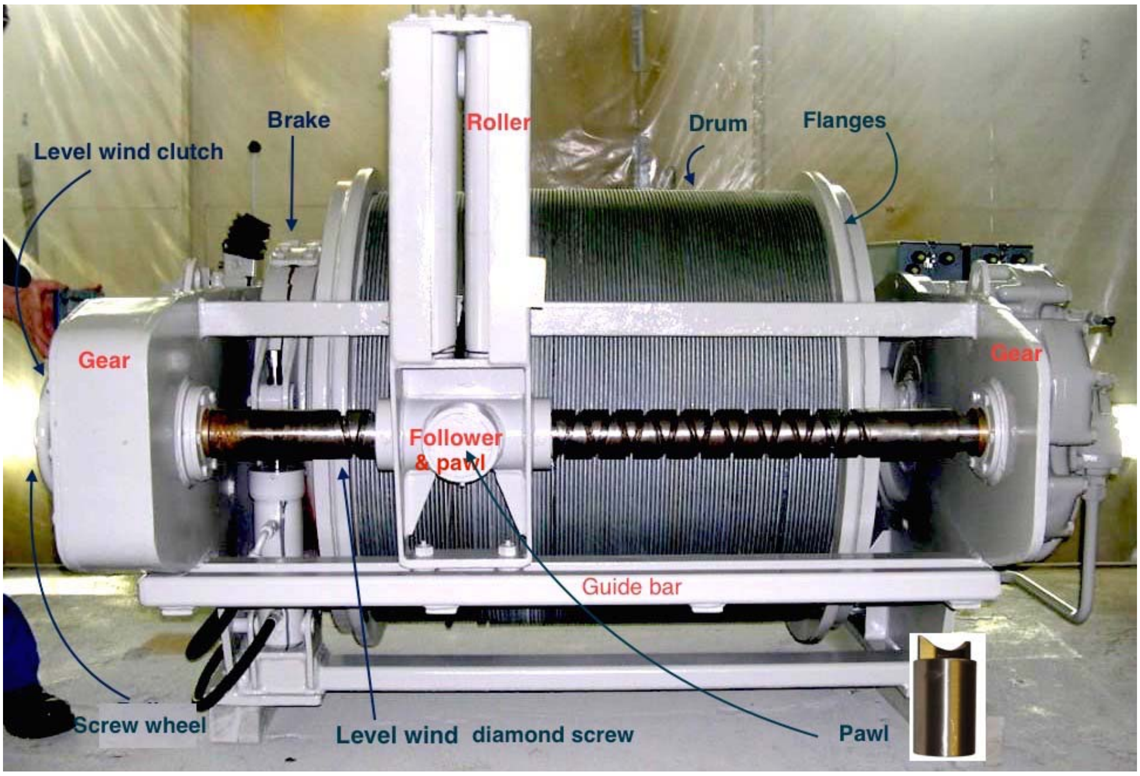


Fig. 4.2.4.1.a - Parts of a hydraulic winch (Rapp-Hydema winch). (Photo UTM)

Drive system

The drive system is important when considering the work deck distribution, piping and cabling, and efficiency. Electric installations for DC motors require cabinets and room for electronics. Hydraulic drives require hydraulic plant, which can be the same for other equipment.

If hydraulic plant is available and very accurate speed control is not required, a hydraulic drive system is suitable. In recent years, low speed high torque hydraulic motors have become available in compact versions which lend themselves well to winch applications and have the advantage of eliminating the gearbox in the drive train. Electronic control in hydraulic pumps allows for a smoothly varying speed control in a closed loop system.

Electric powered winches can be driven from AC or DC sources. Today AC-SCR/DC(1) motors have an electronic control, which allows infinitely variable speed from 2% to 100% of the maximum rated RPM.

The efficiency of electrically driven winches is about 85-90%, compared with hydraulic systems (60%) while providing full torque at any RPM down to zero. This feature allows full rated cable tension control at zero speed.

Spooling (23)

Spooling is important for cable maintenance and operation performance. Smooth stowing of cable must be independent of retrieval speed, line tension and distance from the overboard sheave. Nowadays oceanographic winches have a spooling system both mechanically driven from the drum, and electronically through a separate electric gear motor. To achieve this correct and even spooling, a level wind mechanism and grooved drum are used (Lebus).

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1 An SCR is a Silicon Control Rectifier. This allows variable DC voltage to be obtained from an AC source

Some tension must be applied to cable when stowing it. The shape of cable can be changed with the cable weight of consecutive layers and can also change due to tension. This deformation of the shape can introduce some errors in estimation of cable length stowed and some gaps in Lebus adjustment.

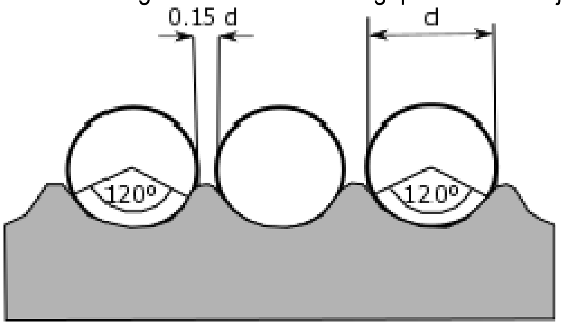


Fig. 4.2.4.1.b - Grooved drum or Lebus.

Source: http://www.jmcprl.net/NTPs/@Datos/ntp_155.htm.

Correct spooling is also important for monitoring cable pay-out length when it is estimated by "cable in the water" and "cable on winch" ratios. It is calculated on the basis of the number of spins per layer and the number of layers completed on the drum compared with the total cable length. This involves calculating the actual radius using the diameter of cable. It is convenient to know the total cable length when stowed the first time. Care must be taken this first time when applying some tension to it; the geometry of the cable section is important for correct stowing.

Knowing what length of cable is in the water is essential when deploying equipment. Different methods exist for estimating cable length. One is using a counter sheave or counter snatch blocks. Another is to count winch spin using several pick-up sensors (induction sensors) placed on winch wings. These allow angular velocity to be estimated and thus, cable length in the water and on the winch. Both methods introduce some errors.

Winch data and Computer control

Winches can be remote controlled from the bridge, a central control point or laboratories, or may be wireless controlled from deck for deployment and recovery. Set up parameters can be introduced into the control PC for calculations depending on cable type, diameter, etc. The monitoring system controls the cable tension load on the winch, cable out, drum speed, pressure and elapsed time. Also, if a heave compensator is installed, input of ship attitude (heave, pitch, roll) is required.

Monitoring of winch data is needed for suitable and safe operation.

Control of cable tension and the amount of cable in the water is necessary to avoid damage to the equipment (payload) or a cable breakage. The applied load can be increased with pitch and roll movements of the ship and thus exceed limits. Tension is also important when dragging along the bottom, with the risk of smearing or hooking. Control of some winches includes monitoring engine torque with a safety feature when a maximum is reached, releasing the drum to prevent cable breakage. It must be borne in mind that with excessive tension the system fails at its weakest point: this must be the cable or a "fuse" (a weak cable installed in the equipment. For example, in the case of a rock dredge, a weaker cable will be installed in the pull gear of the equipment, so it fails at that point in the event of a snag.)

Slip ring

For electrical cables or fibre optics a slip ring is needed for signal transmission while the winch is turning. A slip ring is a device for transmitting power and data signals when the winch is rotating. A stationary contact or brush rubs against a rotating metal ring. Obviously, the number of contacts must match the number of conductors on the cable. One recommendation is to provide enough contacts in the slip ring for future uses and also to install, if possible, the same model of slip ring in all winches, so as to have "spares" in case of malfunction.

Moreover, among oceanographic winches, one initial distinction is that between traction cable winches and conductor cable winches, either coaxial or multiconductor. Secondly, towing winches may be distinguished from "on-station" winches. Lastly, winches may be distinguished by cable type: steel cable, fibre optic cable, fibre rope or cable such as Ultra-high-molecular-weight polyethylene, etc. ([26]).

It is convenient to install winches to work both astern and aside and, if possible, install conductor cable and traction winches to work both astern and aside. One recommendation is for between 4 and 5 oceanographic winches installed:

- CTD winch, aside, coax. cable, approx. 8 or 11 mm diam.
- Plankton winch, aside, traction cable, 6 mm diam.
- Corer winch, aside with option astern, traction cable, 16 mm diam
- Electr. Nets and SSS winch (SSS, elec. Nets, etc), astern, coax cable,14 mm

With this configuration, almost all equipment is covered.
Equipment such as ROVs, undulating CTDs and others need their own winch and cable.

One important issue is a winch with traction cable facing aft. This can be used for operations with dredges, sledges etc. One option, if there are trawl winches, is to use one of them. Another option is to use the corer winch with fairleader block etc. or with a pivoting platform. However, in the case of simultaneous operations using dredges and corer, the latter option will make alternate operations difficult.

The disadvantage of using trawl winches is that they work astern but outside the A-frame with the resulting disadvantages for deployment. While a fairleader is an option, it is difficult to install on trawl winches if these are very near the stern.
Therefore, it is recommended either to have an additional winch (5) or to install mobile winches for these issues. With a foundation based on a container, 10' may be sufficient.

1. CTD winch, aside, coaxial cable, 8 or 11 mm diam.
2. Plankton winch, aside, traction cable, 6 mm diam.
3. Corer winch, aside with option astern, traction cable, 16 mm diam
4. Electronic Plankton Nets, SSS, etc. winch, astern, coaxial cable,14 mm
5. Mobile winch, astern, traction cable 16 mm diam.

Note: measures in mm are approximate

Fig.4.2.4.1.c - Moveable undulating CTD winch on beams on deck (Photo UTM)

4.2.4.2. Trawl winches

Trawl winches have to be robust and efficient systems. With development based on proven design solutions and years of operational data and experience the systems are manufactured to handle the most challenging weather conditions and continuous use over many years. The difference with oceanographic winches is the kind of cables used for trawling. Trawling cables are traction cables made with stainless steel or galvanized steel and sometimes, dyneema cables for pelagic trawls. Because of trawl weight and fishing depth, the diameter of cables is often higher for trawl winches than for oceanographic winches.

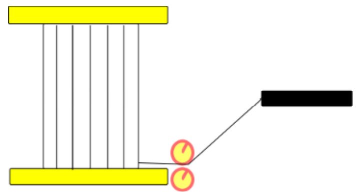


Fig.4.2.4.2.a- Block too close to spooler. Bigger spooling angle.

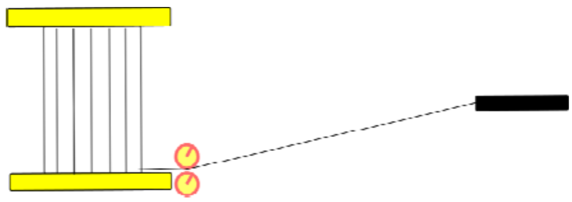


Fig.4.2.4.2.b - Block far from spooler. Smaller spooling angle.

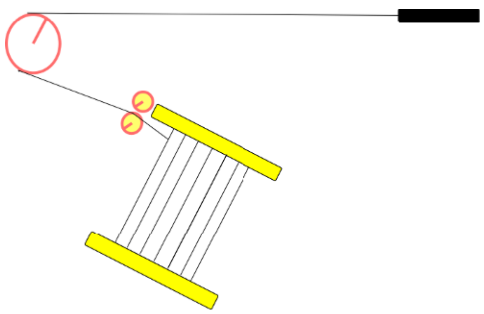
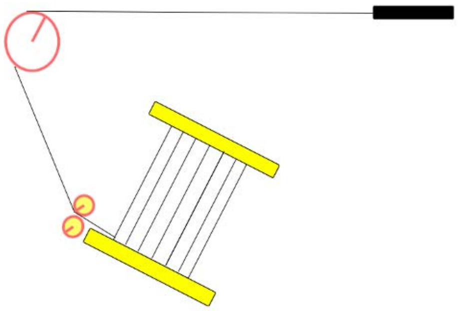


Fig.4.2.4.2.c - Fairlead block (red). No spooling angle on door block (black).



4.2.5. Cables

There are two families of traction cables – steel and synthetic cables.

4.2.5.1. Steel cables

Rope

A rope is made with one or more strands laid around a fibre or steel core. Strands are made with wires helically laid together in a geometric pattern. The number of strands per rope and the number of wires per strand define the wire rope. For instance, a 3x19 wire rope is formed by 3 strands of 19 wires each.

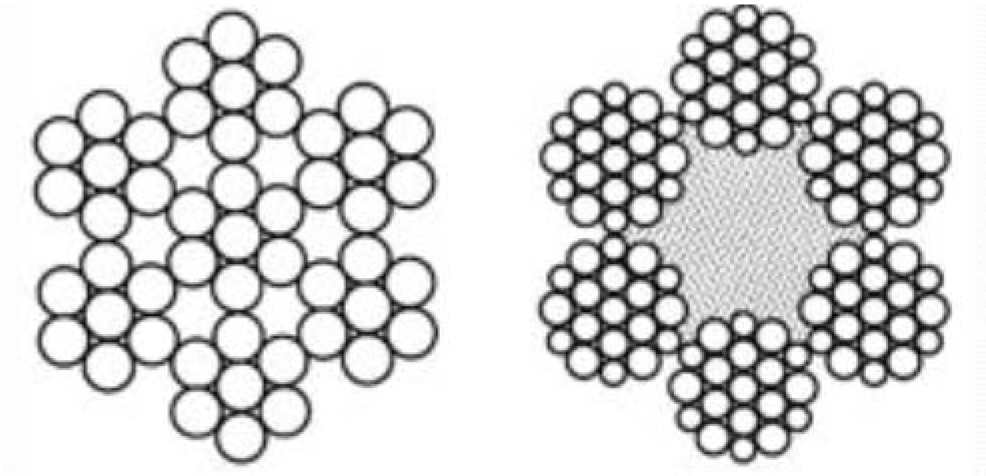


Fig. 4.2.5.1.a – 7 x 7 and 6 x 19 wire rope sections.

The way the strands are organized and the size of wire configure the performance of the wire rope. 6-strand ropes are very common.

Coating or finishing is applied to steel for corrosion protection. Only lubricant is applied to bright wire rope. Another type of protection is galvanization. Galvanic protection can be applied to all wires and strands in the rope (drawn galvanized wire) or only to the finished size wire. Drawn galvanized wires are equal in strength to the equivalent bright wire. Galvanized finished size wires have a strength 10% lower than equivalent bright wire.

Another feature is wire grade. The grade is what determines nominal breaking strength. Standard grades are: Plow steel (PS), Improved Plow Steel (IPS), Extra Improved Plow Steel (EIPS), and Extra Extra Improved Plow Steel (EEIPS). Each is stronger than the previous one.

The helix or spiral of wire and strands in a rope is called the lay.

- Regular lay: when wires in the strands spiral in the opposite direction to the strands in the rope. These ropes are less likely to untwist or kink.
- Lang lay is the opposite. The wires and strands twist in the same direction. These ropes have greater flexibility and abrasion resistance.

The direction in which strands turn around the wire rope can be right or left. Right is when rotation is clockwise and left when counterclockwise. Right is the more common lay.
Lay length is the linear distance a strand extends in making one complete turn around the rope. It is a unit of measurement and, for example, counting the number of broken wires in a lay-length will determine when a wire rope should be replaced.

In preforming or form-set, the wires and strands permanently take the helical shape in the rope. This reduces internal stresses and gives more equal distribution of load on wire and strands. Spooling is more even and passage on blocks is safer and more efficient because broken wires do not protrude (stick). Also, there is more flexibility for bending. Care must be taken, with detection of broken wires during inspections.

Elastic limit. Yield strength is the stress at which a material begins to deform plastically. Prior to the yield point or elastic limit the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible. Elastic limit depends on cable features.

Torque balanced wires resist rotation. Non-torque-balanced ropes unwind when a load is suspended. Any sudden release of load allows the rope to go back to its original form because of the spring-like properties of the rope. This produce hockles (tight loops) and kinks (tight bends).
Torque balanced wire ropes do not kink or form hockles even in case of sudden release of load or slaking. The payload of a torque-balanced wire rope at its elastic limit is 50% greater than a same diameter and equal strength 6-strand. It also has a higher strength to weight ratio.
The elastic limit of torque-balanced wire ropes is 75% of breaking load compared with 50% for 6-strand ropes.
Rope core is also important. Independent wire rope core (IWRC) is recommended. This core is a wire rope itself and acts as support for the strands of the wire rope.
Added to the number of strands, construction and arrangement of strands in the rope will give different properties to the wire rope.
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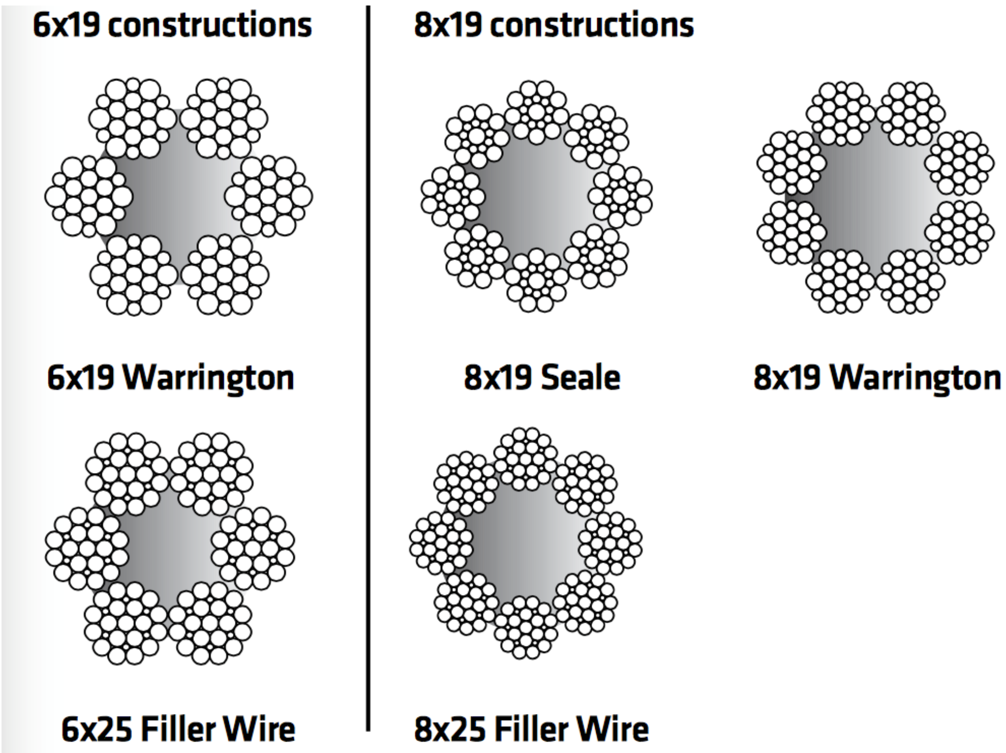


Fig. 4.2.5.1.b - from www.drakaelevator.com. Warrington, Seale and Filler wire types.

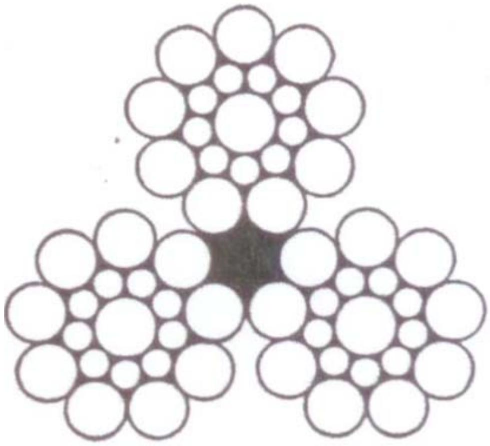


Fig. 4.2.5.1.c - 3/19 SEALE rope.
Note the different diameters for strand wires.

3x19 SEALE is a widely used wire rope for oceanographic traction cables. The strands of this wire rope have the same lay-length (SEALE) and so no crossing is produced.

Breaking load (kg)	Working load (kg)	Type	Torsion (N /mm2)	Diam (mm)	Weight (Kg/m)	Metal. Section (mm2)	Lay
14,000	10,000	3x19 SEALE +1	1770	13	0.585	70.2499	Regular Right lay

Table 4.2.5.1.d - Specifications of general purpose cable for RV García del CID. CSIC

Wire rope handling and installation

Proper installation on a winch is very important for cable life and performance. Wire rope must bend in the way in which it was originally wound. This avoids a reverse bend in the rope. Wire rope must be stowed from the top of the reel onto the top of the drum. Wire rope must be attached on the correct side of the drum.

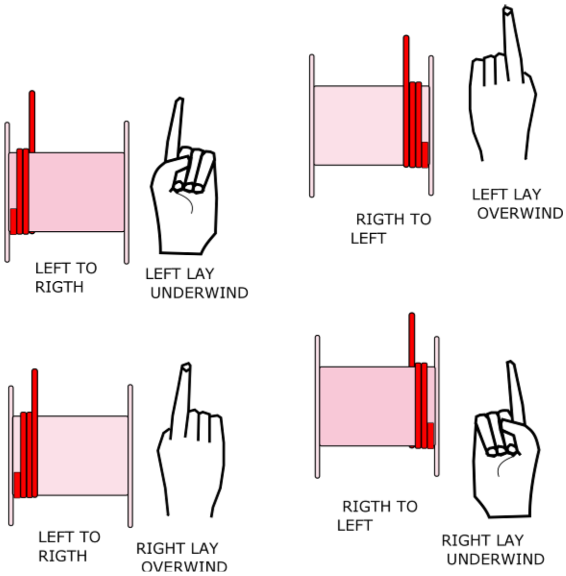


Fig. 4.2.5.1.e - Method for determining how a wire rope must be wound.

Spooling tensions lower than operational loads will produce line failures, crushing and flattening, as well as the “knifing in” effect when the line is pulling down into underlying wraps. It is recommended that the cable is loaded at 45% to 60% of its expected working load. The underlying layers that were not exposed to the working load require pre-tensioning to support the load profile.

Cables

Cables are made with different layers, which develop torque under load conditions. The alternate layers have opposite wire lay directions, producing opposite torques between the different layers. Outer layers develop much greater torque than the inner layers. Adding a third layer can reduce the torque imbalance.
The most common configuration is to have an electrical cable surrounded by steel armour and in some cases a jacket on top. The second is a steel cable on the inside, surrounded by the electrical cables and the outer jacket. The former is more convenient for winch operations. A third and a forth layer of armour can be added but this will increase the cable weight. To reduce cable weight, spaced armour can be used (see figures below)

Cross winding is when the winding direction of the cords in the cable is contrary to the wires. If wires and cords have the same direction, the winding is called Lang.

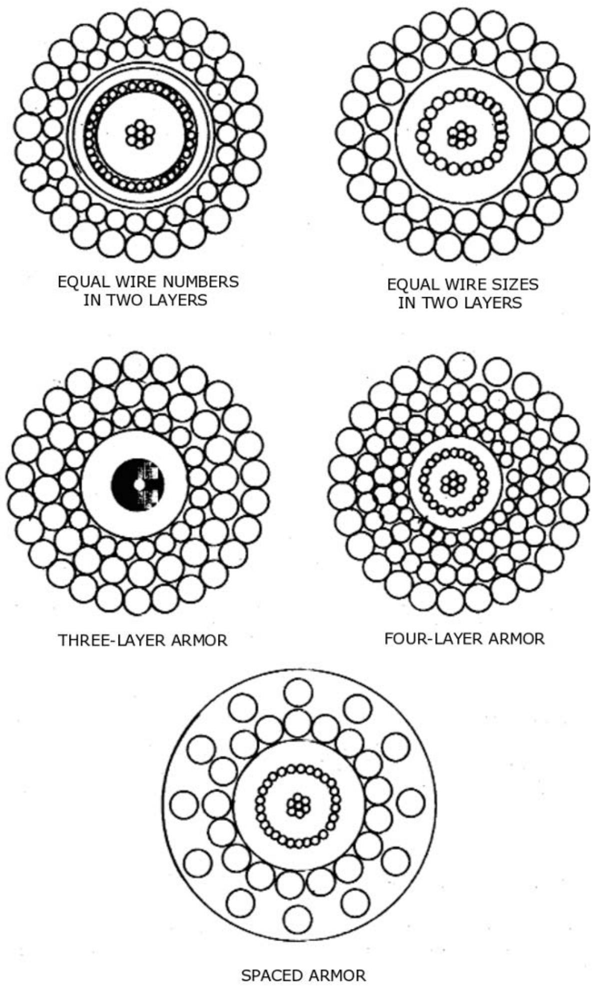


Fig. 4.2.5.1.f - From UNOLS Winch and Wire Handbook (31)

Fig.4.2.5.1.g - Multiconductor tow cable section
(Source: Rochester brand engineered cable solutions)

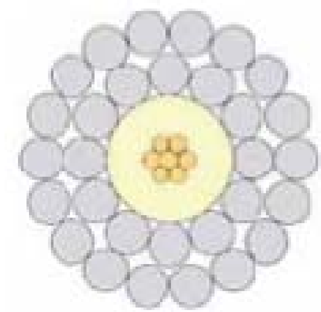


Fig.4.2.5.1.h - Single conductor CTD cable section
(Source: Rochester brand engineered cable solutions)

In oceanography, the most common cable is the non-rotating one. The characteristic of these wire ropes is that the outer layer is twisted in the opposite direction to their inner layers. They may develop a significant drop in breaking strength and an even larger drop in their fatigue life characteristics when used with one end allowed to rotate. 2-layer spin-resistant and rotation resistant ropes will develop only about 55% to 75% of their breaking strength when one end is allowed to rotate freely. This number increases to between 95% to 100% for 3-layer non-rotating ropes. Another important issue is that 2-layer rotation-resistant and 2-layer spin-resistant rope types have been shown to break up from the inside. 3-layer rope constructions (e.g. Python® Lift, Python® Compac 35) have many more outer strands which are much better at distributing the radial pressures onto the reverse lay inner strands. In usual oceanographic operations, 2-layer rotation resistant rope is enough.

Wire ropes are stressed by fluctuating forces, by wear, by corrosion and in rare cases by extreme forces. Rope life is finite.

The choice of cable depends on the operations it is intended to perform. The choice of the diameter should be a compromise between the maximum load to be lifted, the dynamic coefficients used, the design of the winch and the maximum stress to be supported. To optimize cable life, two points are essential and must be in accordance with supplier's recommendations:

- The bending radius
- The working load, including snap loads.

4.2.5.2. Synthetic cables

In recent years, cable technology has made a lot of progress, especially concerning synthetic cables. These new cables combine excellent mechanical properties with low density, especially in sea water where they have a neutral buoyancy, resulting in high performance-on-weight basis. Many kinds of material exists, but the most used is Dyneema fibre.

Dyneema® fibre is a gel-spun, multi-filament fibre produced from ultra-high molecular weight polyethylene (UHMW-PE), with the following main characteristics: high strength and a high modulus (resistance against deformation) in the fibre direction, low density, low elongation at break, and resistance to most chemicals. It has a higher resistance to repeated axial loading than other fibre types. The fibres combine high strength with high fatigue resistance, even if the loading is partly in compression as in repeated bending of rope applications. The water absorption in the fibre is negligible. Despite their high modulus, the fibres are flexible and have a long flexural fatigue life. Because of the low friction coefficient and good abrasion resistance, internal abrasion of ropes is usually negligible.
Dyneema® fibre is used in various outdoor applications under harsh weather conditions. In air, the fibre is stable for many years. No special precautions are necessary during processing or storage apart from rinsing with soft

water after a stage at sea. Another advantage of the synthetic cable is that is very easy to do a termination by hand, only some splice lessons are needed.

Choosing whether to use steel wire or synthetic cables is not easy. One key point is the type of winch. When using fibre rope on a single drum winch, the fibre trends to sink down into lower layers producing spooling problems. Today some manufacturers design fibre ropes with “steel-like” properties, avoiding these problems ([27])

To conclude, the most important advantages of this cable are its high strength and its weight, which, in particular, allows work deeper at sea with the same safe working load of gear. Its most important drawback is its non-resistance to abrasion, involving necessary precautions (for dredging in particular).

4.2.5.3. Electro-optical cables

These cables consist of single or grouped electrical cores and/or fibre optics assembled in the most compact diameter. The definition of the cable depends on the equipment connected to it. Many standard cables are available. Suppliers can also carry out specific drawings. Cable armour could consist of synthetic fibre, strength members, or steel wire. The choice depends on the equipment, winch installation and cost. The benefits of these cables are:

- A combination of power and signal
- Choice of component configurations including singles, pairs or quads
- Choice of optical fibre
- Special thin wall core insulation optimizing cable outer diameters
- Highest strength steel wire while maintaining ductility
- Choice of high modulus fibre strength layers, saving weight on wire armoured variants.

In some cases, fairings can be applied as a solution to the adverse effects of strumming / vibration which can be set up as the cables are towed through the water behind surface vessels.

An example of cables used in R/V Atlantis follows: “The winches hold UNOLS ‘standard’ hydrographic wire, three conductor electro-mechanical cable, trawl wire and deep-tow coaxial and/or fibre optical cable”. “These winches have interchangeable drums that allow changing of cable type without a spooling operation.”
Note the minimum sheave diameter for each depending on cable diameter (size):

	Trawl	Hydro	Conducting	Coaxial
Size	14 mm	6 mm	8 mm	17 mm
Length	9152 m	9152 m	10000 m	9152 m
Construction	3 x 19 galv.	3 x 19 galv.	2 armour galv.	2 armour galv.
Manufacturer	Macwhyte	Macwhyte	Rochester	Rochester
Manuf. ID	9/16" AA	1/4" AA	1592	1241
R.B.S.	14741.7 kg	3061.7 kg	5261.7 kg	>16782.9 kg
Yield	11056.3 kg	2296.5 kg	2268.0 kg	---
2% Yield	12972.7 kg	2676.2 kg	---	---
S.W.L.	6486.3 kg	1338.1 kg	2041.2 kg	9071.8 kg
Wet Wt.	621.4 kg/km	128.8 kg/km	209.6 kg/km	819.6 kg/km
Dry Wt.	732.0 kg/km	148.3 kg/km	259.0 kg/km	1036.9 kg/km
Min. Sheave Dia.	53.34 cm	30.48 cm	30.48 cm	71.12 cm
DC Resistance @ 20 deg	---	---	3 cond., 9.4 ohm/1,000'	---

From R/V Atlantis site: ([28])

Note: Units have been changed from original from *lbs* to *kg* and from *inches* to *cm* and there could be small differences
S.W.L. means Safe Working Load
Yield strength is the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible.

When deploying a CTD, on station, the cable end is free to rotate, and without using a shrivel, the breaking strength is reduced and the inner layer is more stressed than the outer layer.
When towing plankton nets, the cable end is fixed, with no rotation, and the outer layers are more stressed, breaking before inner layers. Torque imbalance can cause cables to form loops, which on reloading, tighten to hockles, with irreversible damage along the length of cable.

When cable has stored some amount of torsional energy, and slack is produced, a loop is generated in the cable. The loop itself will not damage the cable if no tension is applied to the cable again. This situation can arise when the load lands on the seafloor bottom and the cable loses tension. With torsion, a loop will be produced and, when lifted again, increasing tension, a hockle will be generated.
When the load in a cable is reduced suddenly, as in the case of ship pitch and roll situations (see figures below) and slack is produced, the elastic steel armour relaxes and the more flexible and weaker core, made of copper and plastic, retracts more slowly; the extra length will be located and twist. This kinking, called Z-kinking, can produce failures in data communication and electric signals if it is very close or contact with the steel armour.

Fig. 4.2.5.3.a - Z-kinking

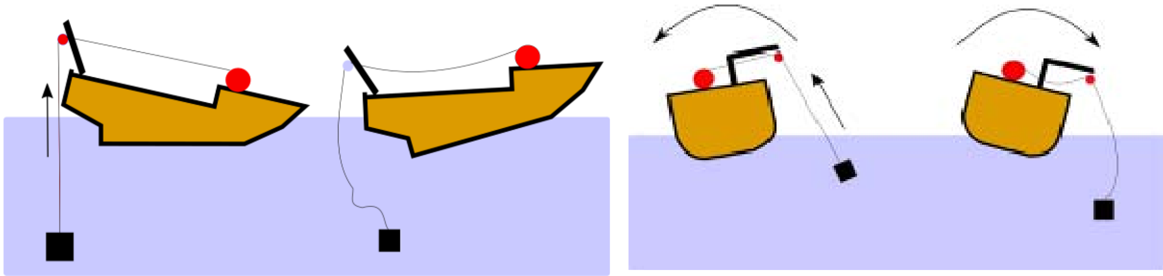


Fig. 4.2.5.3.b - Ship pitch and roll situations with slack.

4.2.6. Moveable configurations

Moveable configurations may be defined with these two specific terms:

- Compatibility, compatible: equipment that can work directly with other devices, apparatus or programs.
- Interoperability is a property of a system, whose interfaces are completely understood, to work with other systems without any restricted access or implementation.

As has been noted, moveable equipment can be adapted to a deck using container foundations and tie-downs. In the case of container foundations, it is convenient to arrange these in two different directions: across and along the ship centreline; it is also useful to install 20' and 10' footprints.
It is recommended to adapt a standard, especially for distances between tie-downs.
Containers used as laboratories can be supplied with standard plugs for power and water lines. In the case of moveable winches, it can also be convenient to install fast plugs for hydraulics and power lines, embedded on deck. If this option is taken up, it must be studied during ship design. If it is not possible to embed plugs, cables and pipes, these must travel across the deck and protectors must be used.

Fig.4.2.6.a - Cable protector (Photo UTM)

4.2.6.1. Tie-downs

For fixing and stowing equipment on deck it is useful to install tie-downs (anchors) and container bases welded to the deck.
Some material may be movable along the deck with cleats, bits, bollards, fairlead blocks etc. It is therefore desirable to have "tie-down" anchors on deck. Ideally the anchors must match the deck beams to provide

required structural support. This means that the separation between the anchors (tie-downs) is a clear frame, roughly 600 mm.
If a denser pattern is needed, i.e., a smaller distance between tie-downs, they can be welded directly to steel on deck. During ship design the safe working load (SWL) must be defined. An SWL of 2 tonnes per tie-down is normal.
Cleats, eyebolts, etc. can be located on deck in this way to facilitate operations with new mooring, pulleys, blocks and snatch, fairleader blocks, etc. It can also be useful to install these "tie-downs" on the gunwale or above the bulwark to optimize use of the movable gear.

(Photos UTM)

Fig.4.2.6.1.a - Tie down *Fig.4.2.6.1.b - Eyebolt and cleat on gunwale*

The bulwarks on the main deck usually support many structures such as water pipes, air pressure and hydraulic pipes and vents. It may be worth having some removable sections of bulwark for installations such as ROVs and LARS, especially on the starboard side and quarter. External and removable ramps for seismic airgun operations could be worthwhile add-ons to consider.

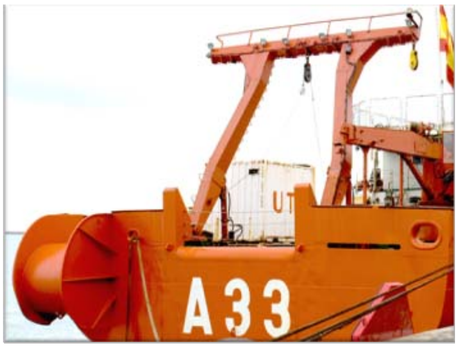


Fig. 4.2.6.1.c - External ramp for seismic deployment on BIO Hesperides (CSIC). (Photo UTM)

The tie-downs for these purposes could be screwed. For container anchorage, tie-downs for slings must be installed externally to the container basement.
Container basements may be used for installing other movable equipment simply by building a steel plate or beam for support. These are useful for installing movable winches, capstans, etc. ROV LARS (launch and recovery systems) can also be installed in line with container footprints.
If this option is utilized, all winches can be moved from one place to another. The only thing that must be considered is the power supply (hydraulic and electric) and cooling, which must be the same, with all-interchangeable plugs.

Fig. 4.2.6.1.d - Cover for stern ramp on R/V Sarmiento de Gamboa. (Photo CSIC)
The vertical grating is to break waves.

4.2.6.2. Hydraulic, electric, cooling and data lines

In the design of a new ship, the pathway of pipes and cables must be studied carefully. Good planning and layout will improve interoperability and interchange of winches and other equipment, containers, etc. Hydraulic pipes and cable could be installed below deck and emerge in the middle of the deck from below using fast, retractable plugs. The path of cooling water pipes must also be planned. It is important to consider bringing cooling water to every part of the deck for future installations.

4.2.7. Steering

One of the main elements in a deployment operation is the steering of the ship, especially when the ship is moving, but also when on station. Even with DP, manoeuvrability and care on the part of the crew are essential for safe deployment of the equipment. It is because of this that visibility of the aft side of the vessel, directly and not through cameras, is critical in the design. Usually, the bridge should have a design that allows the mate in charge to operate the ship, if possible, from the stern and from the port and starboard wings of the wheelhouse.
When on station, the ship maintains its starboard bow windward, even when DP is available. This prevents the cable falling over the side touching the hull or passing under the keel. For work without DP, the vessel will remain slightly downwind causing the cable to fall with an angle towards the bow and starboard. Due to this angle, a length of cable longer than the depth deployment is required. If DP is used, the vessel will hold its position and the cable will fall apeak saving time during the operation. DP is thus an important tool for deployment of equipment, not only for ROV operations.

4.3. Description and kinematics of operations

All drawings include in this paragraph will be done by a subcontractor, C.N.P. Freire. They are the property of the EUROFLEETS2 Consortium and shall not be copied, shown or sent to a third party without the consent of the EUROFLEETS2 Coordinator ([32]).

Basic Operations

The basic operation in an RRV consists of the deployment of equipment using cables. Today AUVs of some size also need deployment and recovery using cables, winches and frames. The following operations are considered as representative of those carried out on board an RRV:

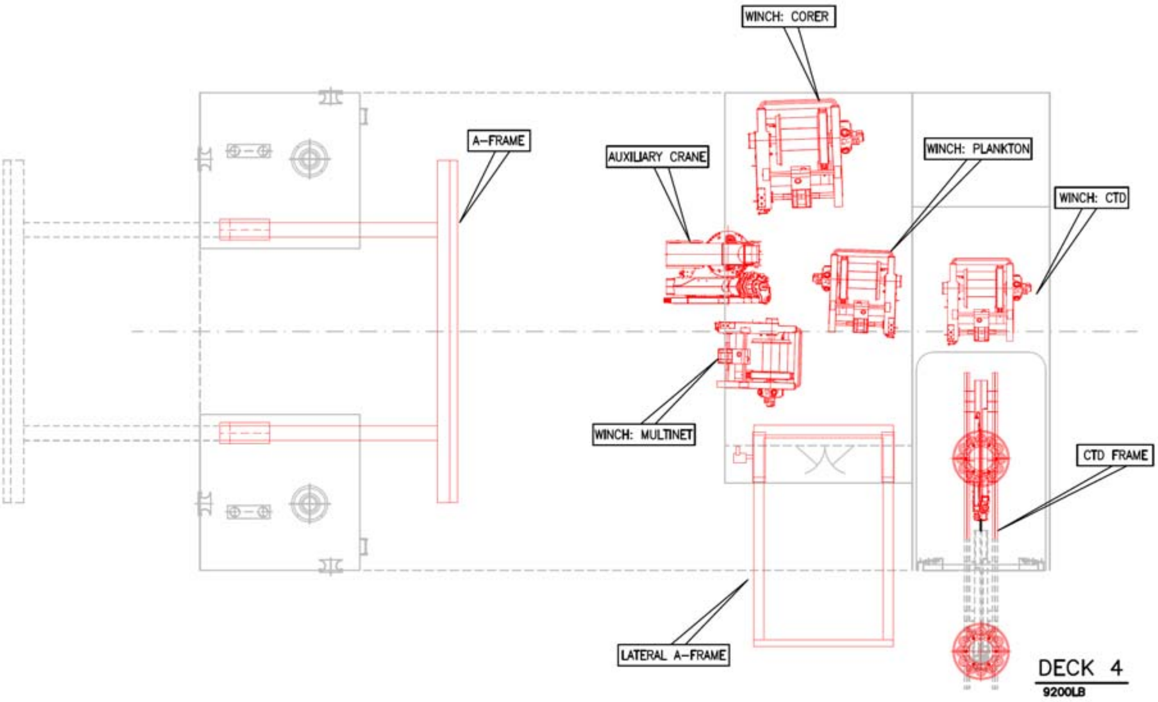
- CTD rosette deployment on station on the starboard side, coax cable
- Corer deployment on station on the starboard side
- Plankton net deployment towing on the starboard side, 6 mm traction cable
- Multinet, electronic with coax cable, deployment and towing astern
- Fishing net trawling recovery
- ROV operation

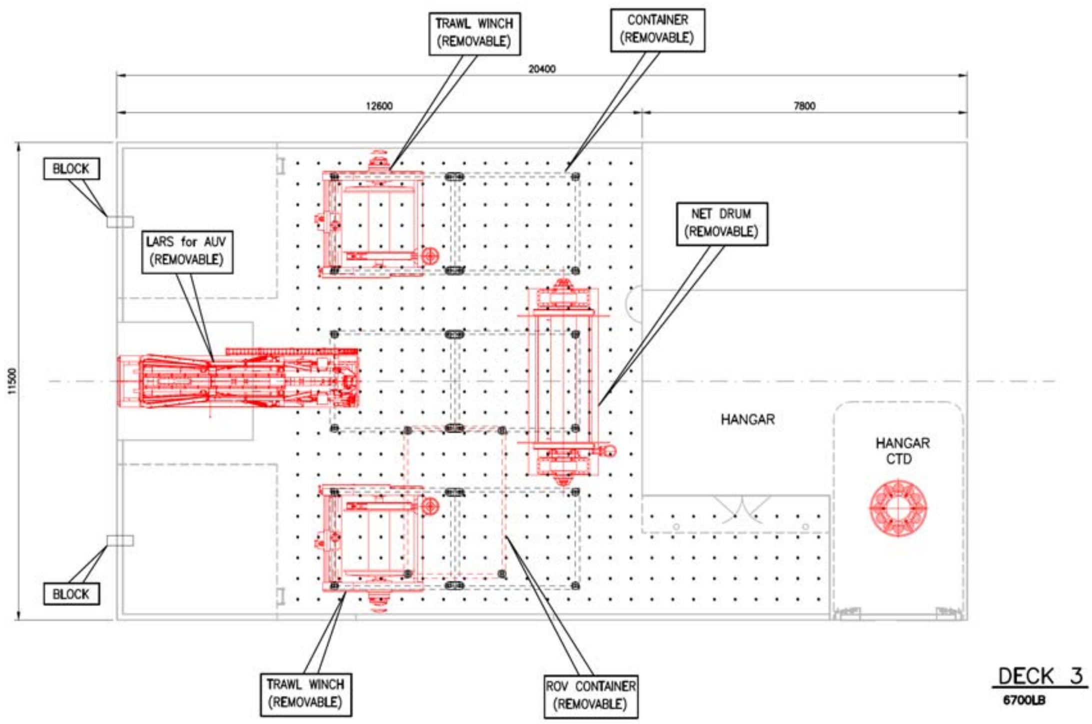
Other operations are more complicated and need to be described because they are more complex. These are:

- Seismic streamer and airgun deployment
- Double towing (e.g. Side Scan SONAR with depressor)

A simple deck arrangement and a fixed number of winches have been considered here. Other options are also possible and may be convenient depending on the main work of the RRV. These are general recommendations for a multipurpose RRV. Some RVs have a handbook with a description of operations.

A. CTD rosette deployment on station on the starboard side, coax cable (EM)
B. Corer deployment on station on the starboard side
C. Plankton net deployment towing on the starboard side, 6 mm traction cable
D. Deep tow, with coax (EM) cable, deployment and towing astern
E. Fishing net trawling recovery
F. ROV operation
G. Seismic streamer and airgun deployment
H. Double towing (e.g. Side Scan SONAR with depressor)


WINCH: CORER
A-FRAME
AUXILIARY CRANE
WINCH: PLANKTON
WINCH: CTD
WINCH: MULTINET
CTD FRAME
LATERAL A-FRAME
DECK 4
9200LB


TRAWL WINCH (REMOVABLE)
CONTAINER (REMOVABLE)
20400
12600
7800
BLOCK
LARS for AUV (REMOVABLE)
NET DRUM (REMOVABLE)
11500
HANGAR
HANGAR CTD
BLOCK
TRAWL WINCH (REMOVABLE)
ROV CONTAINER (REMOVABLE)
DECK 3
6700LB

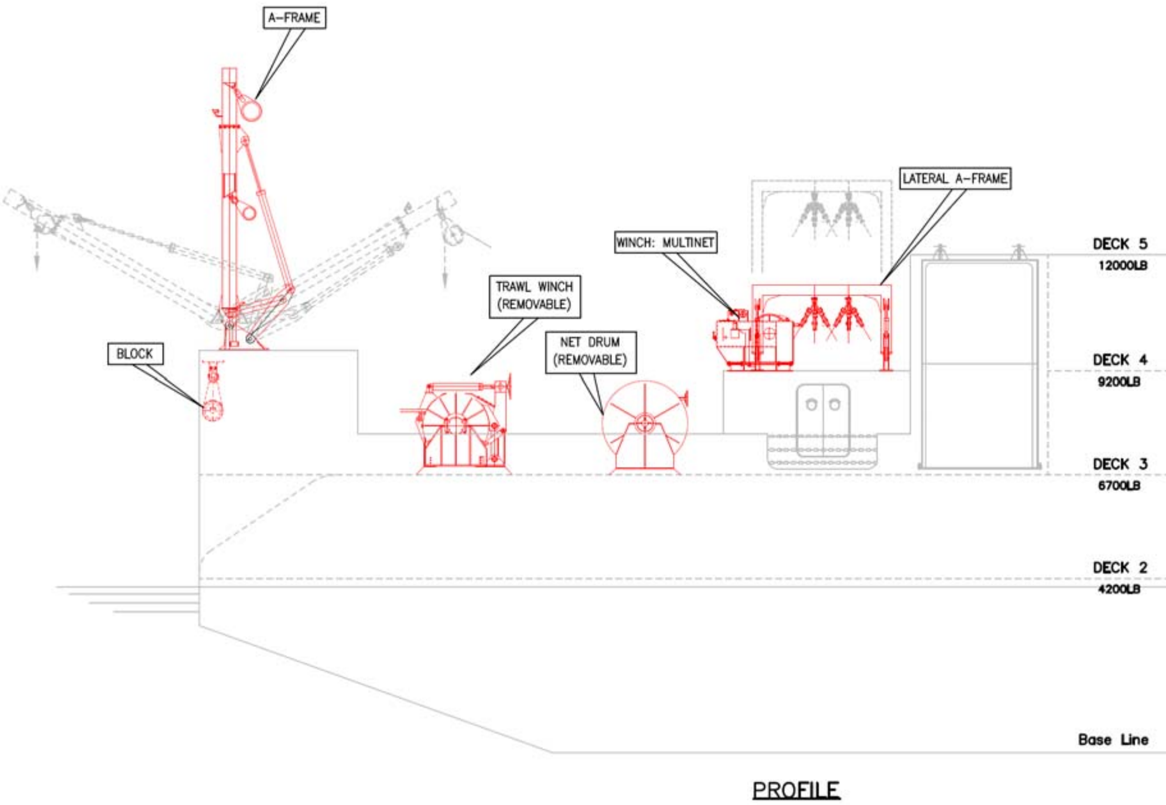


Fig. 4.3.a – Working Deck General arrangement

4.3.1. <u>CTD Rosette deployment on station on the starboard side and coax (EM) cable</u>

In this operation two options have been considered: with and without side hangar. The CTD Rosette system has an air weight, with water inside all the bottles, of approximately 500 kg. Usually some more weight can be added using lead tablets. This ensures a taut cable to avoid kinking. Lowering speed must be slow at the beginning of the haul, trying to maintain a certain tension. Speed can be increased once more cable is paid out, and normally is about 60 mpm maximum. CTD haul is a “free to rotation” cable situation. Ship roll can produce sudden load decrease and can produce hockles and kinking. Operation in this case must be done with the ship facing the waves. Cable paying speed should be adequate for the load and can be increased once some length of cable is paid out and the load increased. Speeds between 30 mpm to 60 mpm maximum are common.

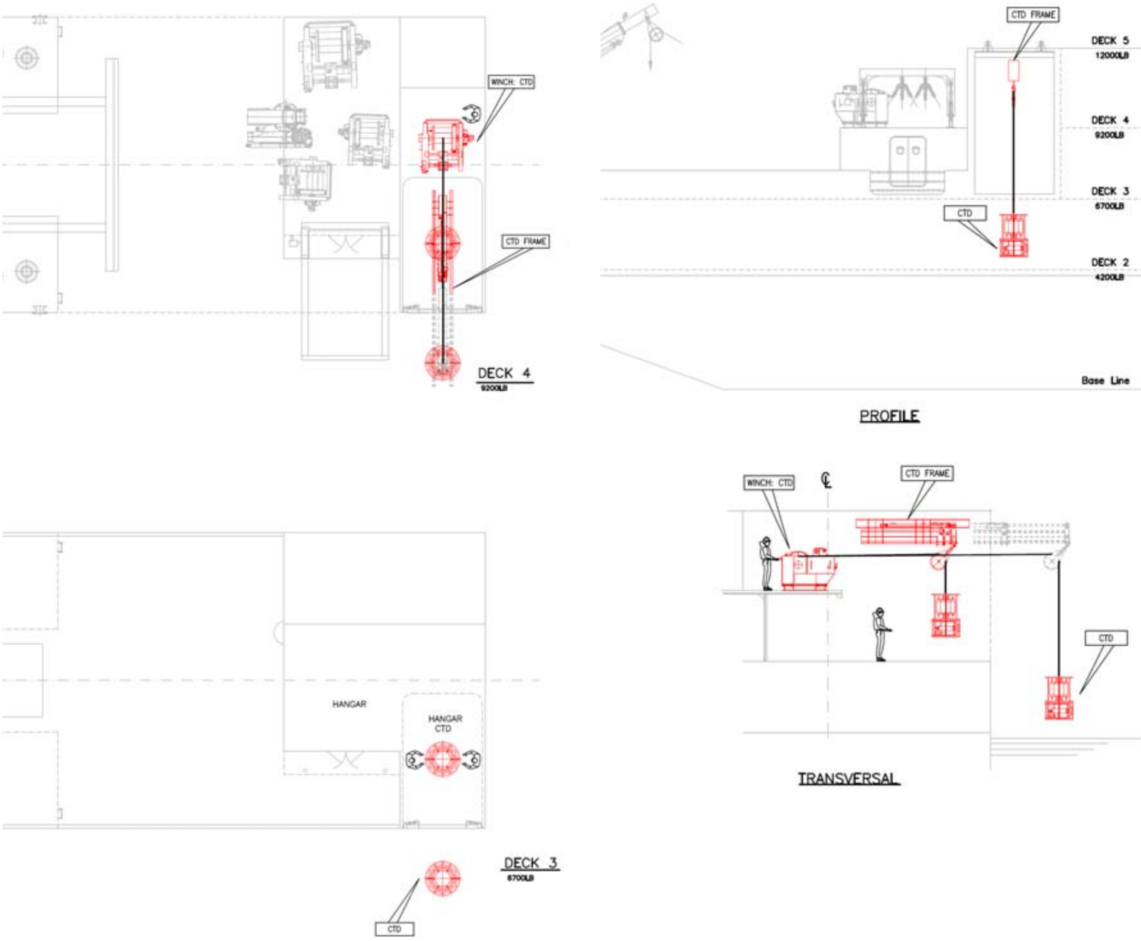


Fig. 4.3.1.a – CTD deployment principle

Video below shows an example of CTD deployment. This video is also available on Eurofleets2 Website (*http://www.eurofleets.eu*)

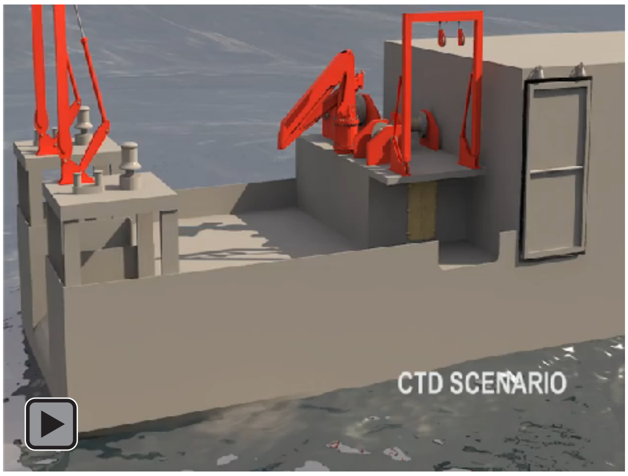


Fig. 4.3.1.b – Example of CTD deployment

4.3.2. Corer deployment on station on the starboard side

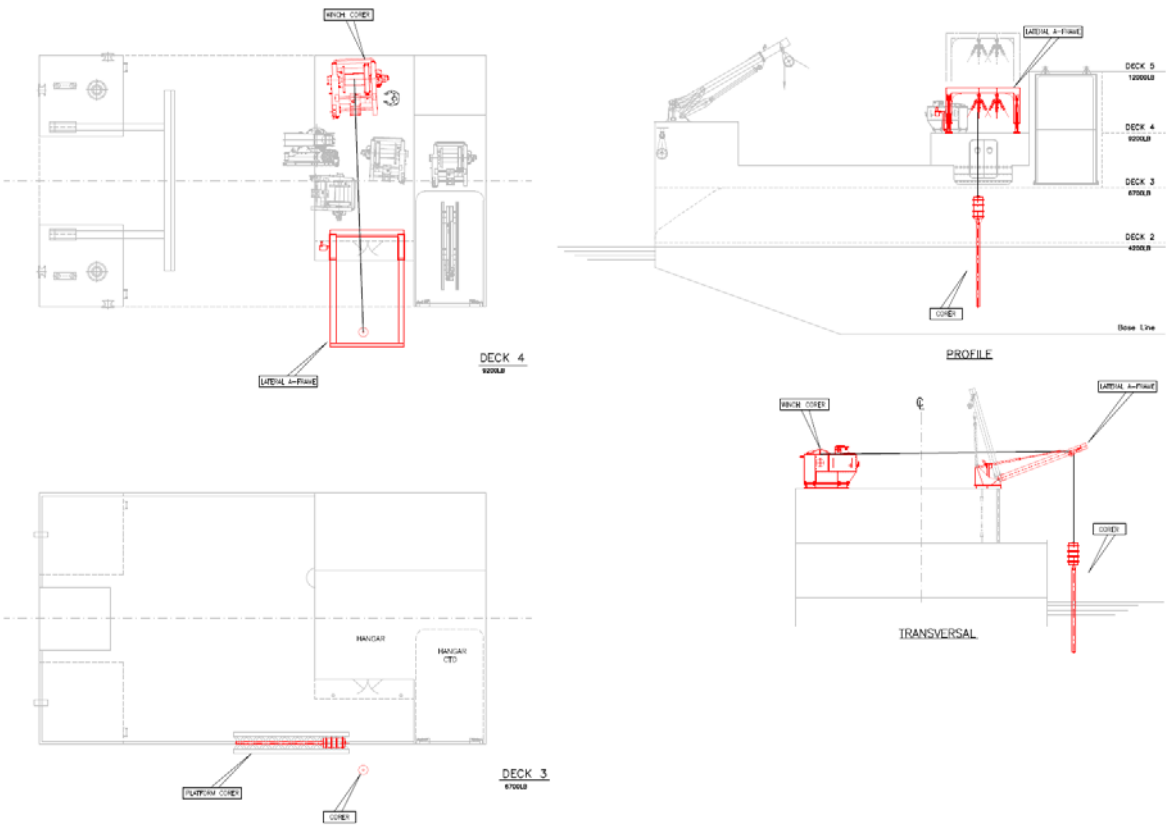


Fig. 4.3.2.a – Corer deployment principle

Video below shows an example of corer deployment. This video is also available on Eurofleets2 Website (*http://www.eurofleets.eu*)

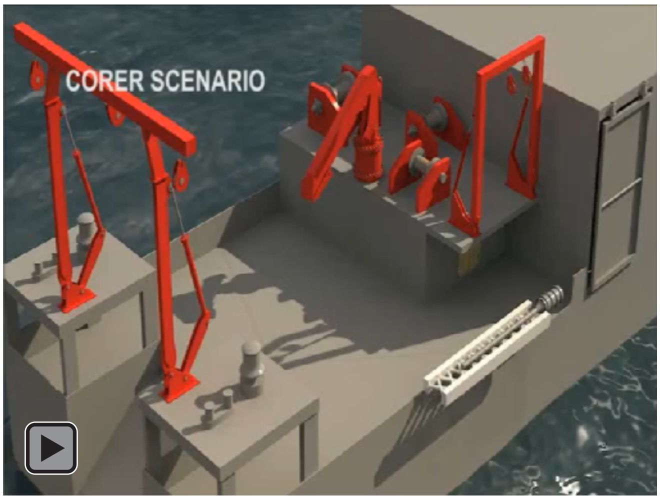


Fig. 4.3.2.b – Example of corer deployment

4.3.3. Plankton net deployment

Plankton net operation is an example of "towing aside" operation. Because of the interest in fish off the ship's wake, plankton nets are deployed over the side. This is because many fish larvae, especially, are found close to the surface.
To prevent the cable approaching the hull or passing under the keel, it is usually recommended that ships go slightly to starboard

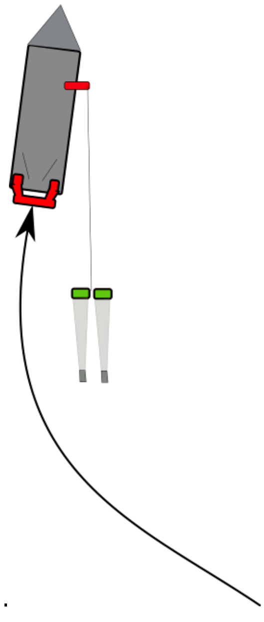


Fig. 4.3.3.a – ship goes slightly to starboard

Bongo nets and other towed plankton nets are hauled with a depressor to facilitate sinking
Bongo type plankton nets and other plankton nets that are lowered should be towed with a depressor to facilitate sinking of the net. Cable diameter is also important because a very heavy cable will sink faster than the net. A wire diameter of 6 mm is recommended.

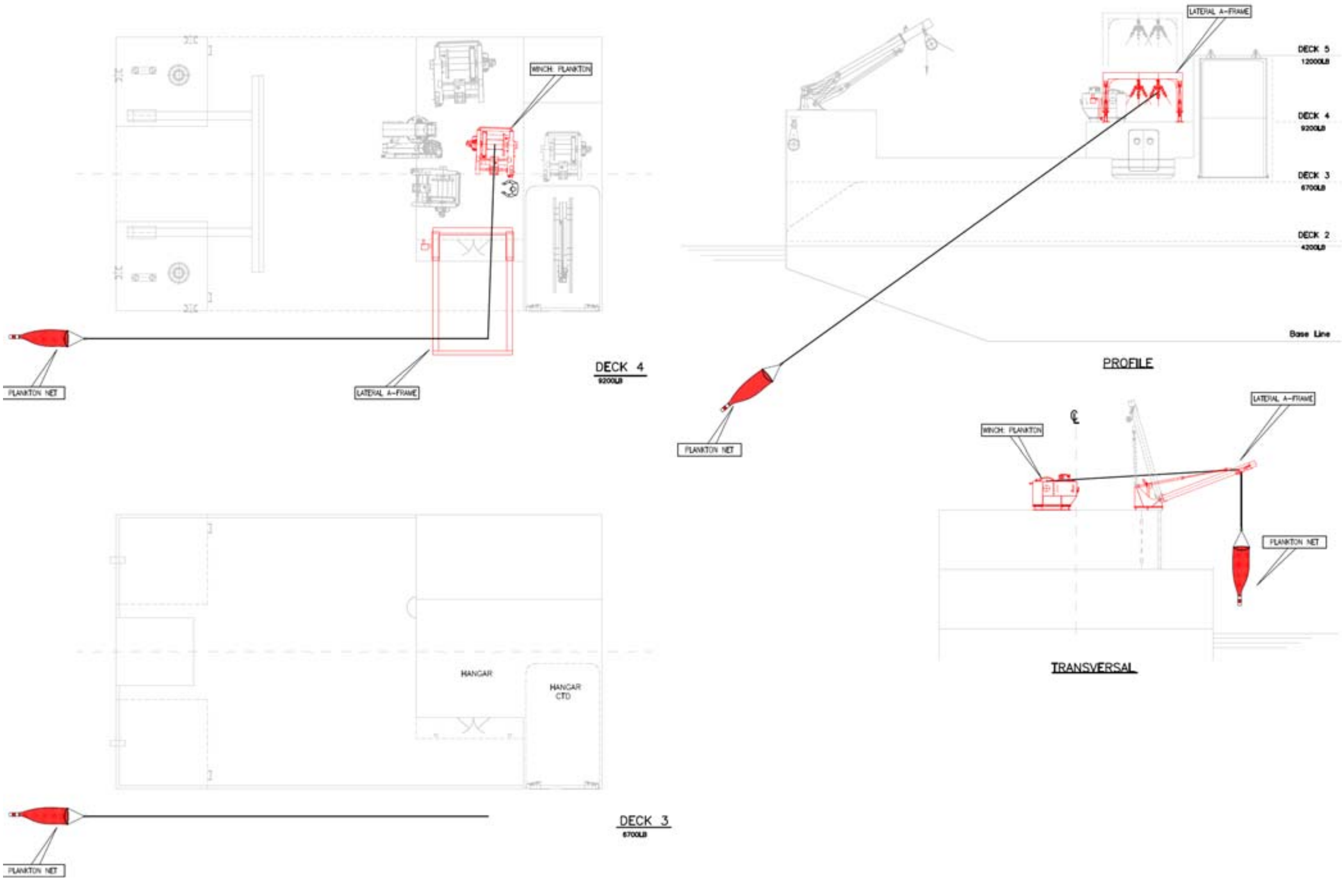


Fig. 4.3.3.b – Plankton net deployment principle

Video below shows an example of plankton net deployment. This video is also available on Eurofleets2 Website (*http://www.eurofleets.eu*)

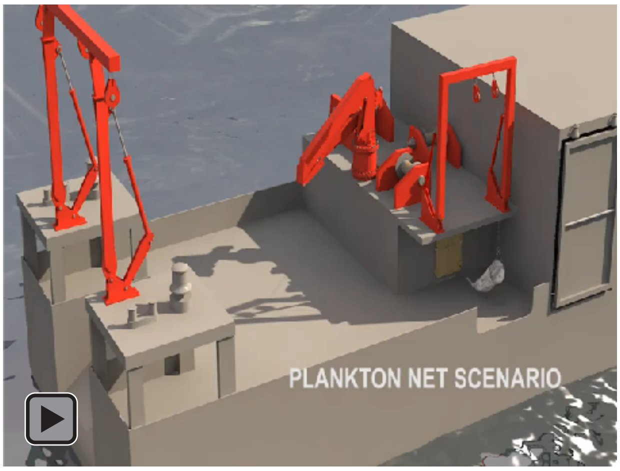


Fig. 4.3.3.c – Example of plankton net deployment

4.3.4. Multi-net deployment

Multinet operation is an example of “astern” operation. Type of cable is important because a very heavy cable will sink faster than the net. A coax cable is usually used.

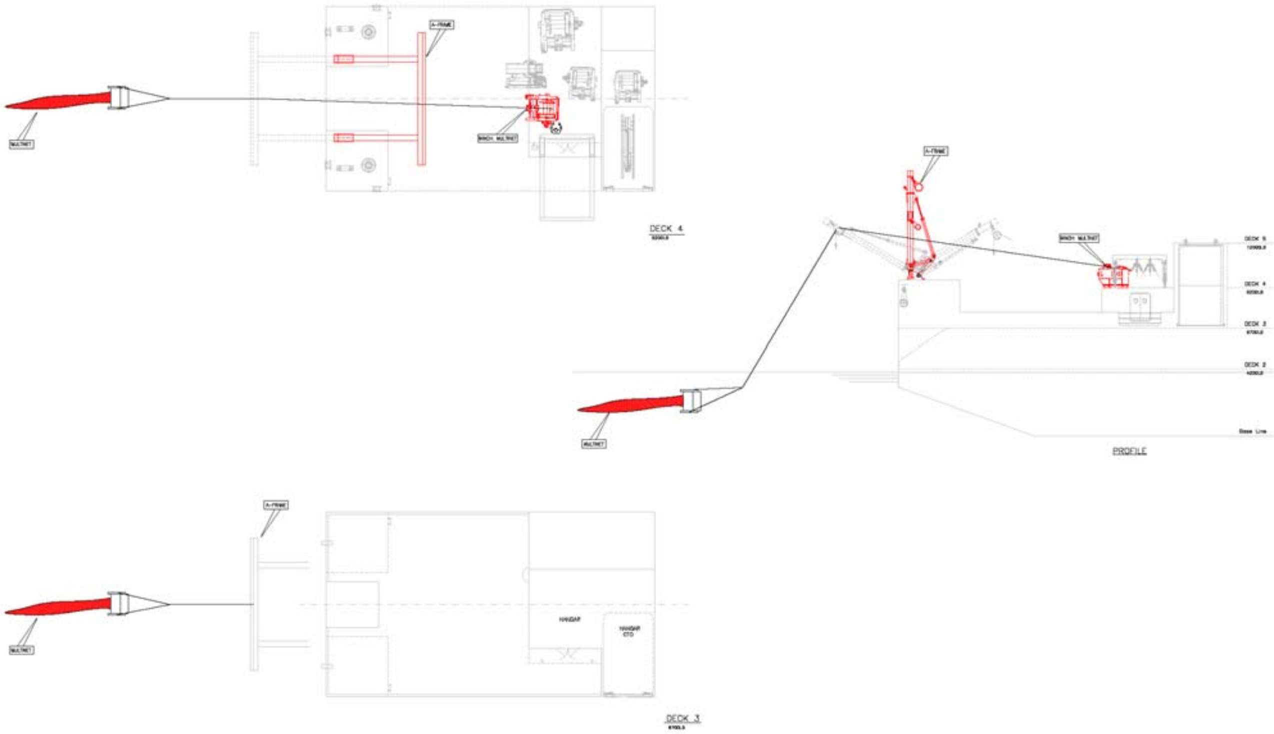


Fig. 4.3.4.a – Multinet deployment principle

Video below shows an example of multinet deployment. This video is also available on Eurofleets2 Website (*http://www.eurofleets.eu*)

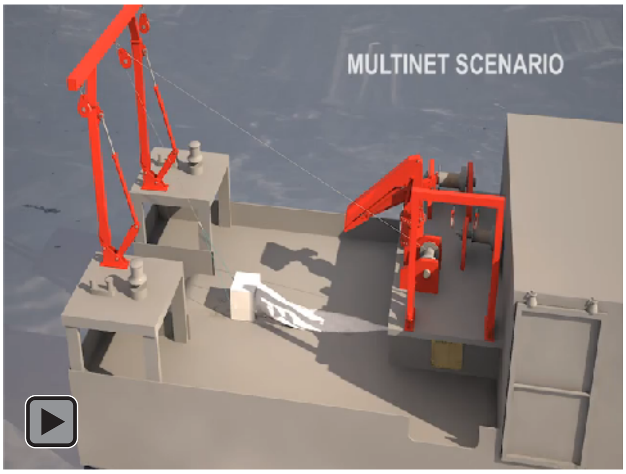


Fig. 4.3.4.b – Example of multinet deployment

4.3.5. Fishing research vessel scenrio

Deployment of pelagic or bootom net requires specific winches and deck arrangements.

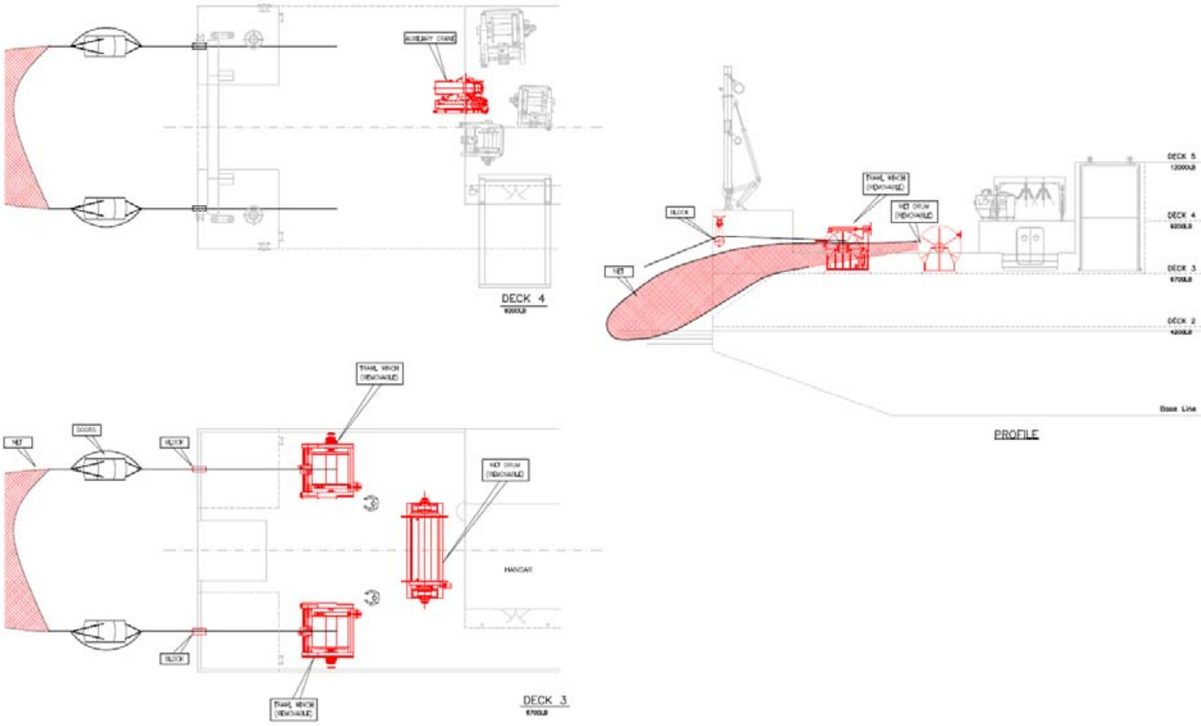


Fig. 4.3.5.a – Pelagic and bottom net deployment principle

Video below shows an example of pelagic and bottom net deployment. This video is also available on Eurofleets2 Website (http://www.eurofleets.eu)

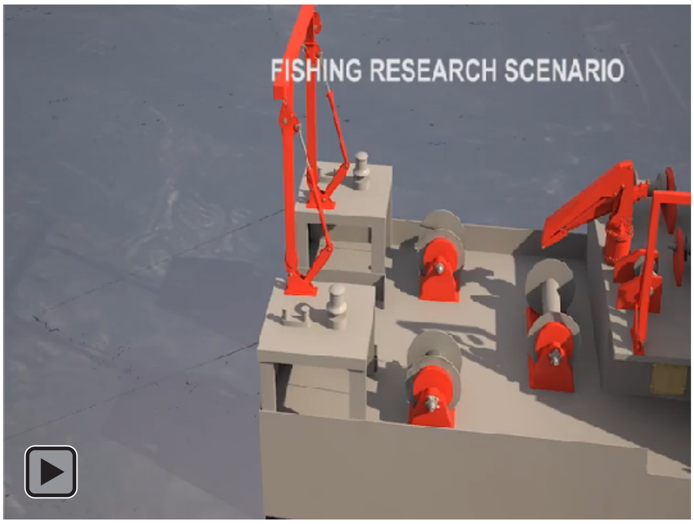


Fig. 4.3.5.b – Example of pelagic and bottom net deployment

4.3.6. ROV deployment

ROV operation requires special gear for launch and recovery. Some ROVs are deployed using TMS or a garage to facilitate tether recovery

Fig. 4.3.6.a – ROV on Sarmiento di Gamboa. (Photo CSIC)

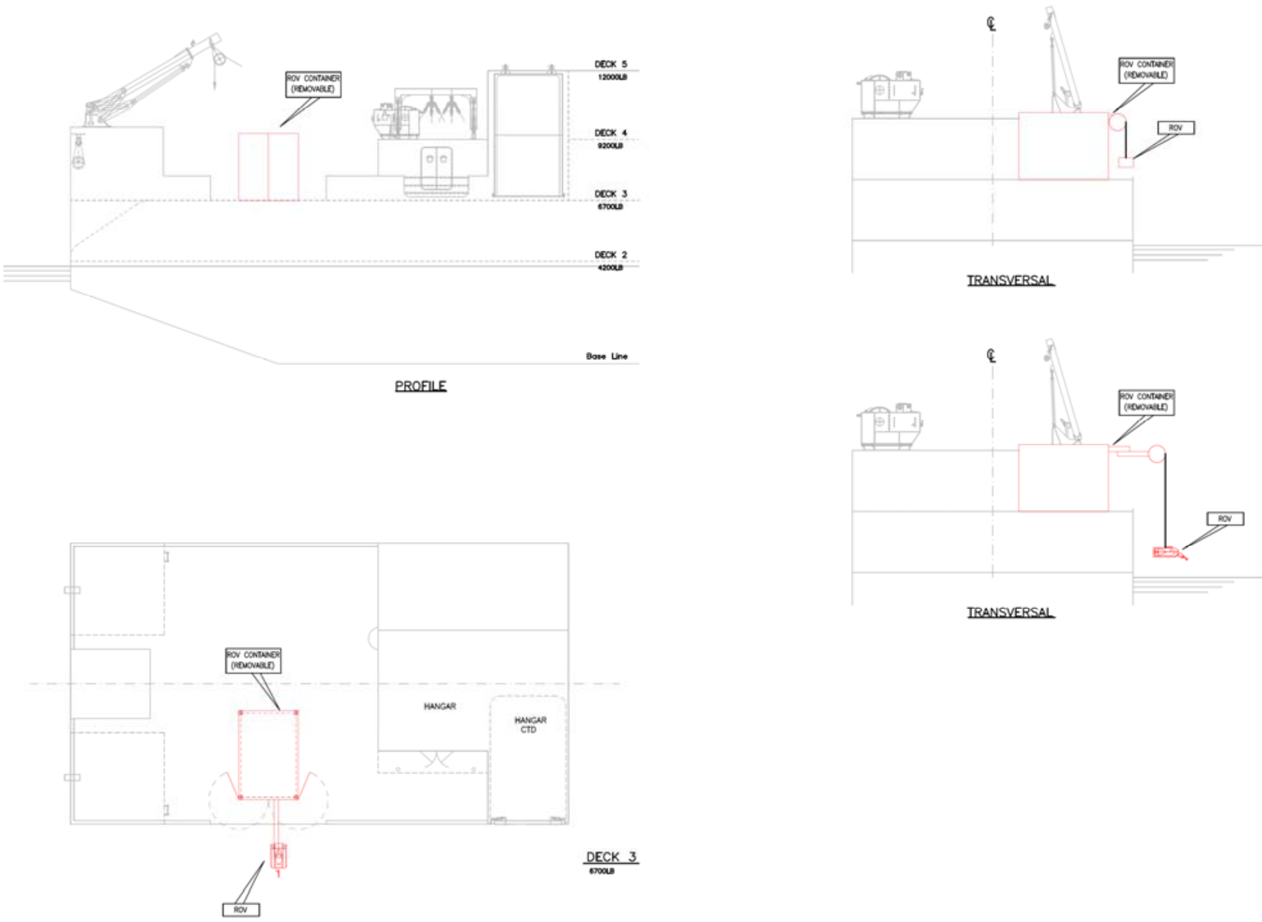


Fig. 4.3.6.b – ROV deployment principle

Video below shows an example of ROV deployment. This video is also available on Eurofleets2 Website (*http://www.eurofleets.eu*)

Fig. 4.3.6.c – Example of ROV deployment

4.3.7. AUV deployment

AUV operation requires special gear for launch and recovery.

Fig. 4.3.7.a – AUV deployment principle

Video below shows an example of AUV deployment. This video is also available on Eurofleets2 Website (*http://www.eurofleets.eu*)

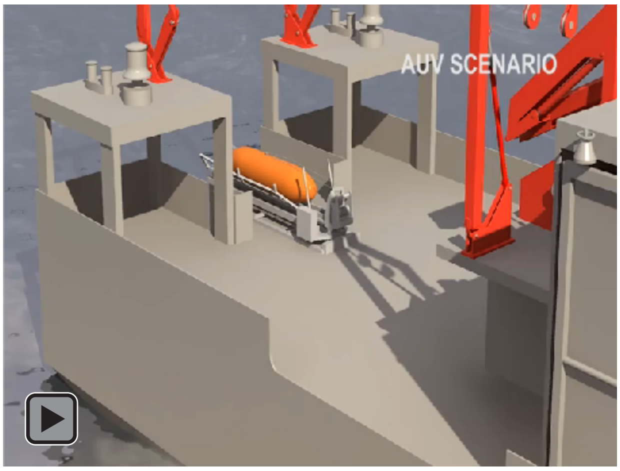


Fig. 4.3.7.b – Example of AUV deployment

4.4. Matrix for equipment operations

Device	***Ship_conditions***	***Ship side (pref.)***	***Cable/Wire rope***	***Cable diam***
CTD Rosette	on station	starboard	Coax cable	10 mm
SSS (Side Scan Sonar)	towing	stern/starboard	Coax cable	11 mm
MOCNESS	towing	stern/starboard	Coax cable	11 mm
LHPR	towing	stern /starboard	Coax cable	11 mm
BONGO	towing	starboard	wire rope	6 mm
SVP (Sound Velocity Profiler)	on station	starboard	//	6 mm
VP2	on station	starboard	wire rope	6 mm
Benthic sledge	trawling	stern	wire rope	14 mm
Neuston sledge	trawling	starboard	wire rope	14 mm
Bottom trawl	trawling	stern	wire rope	14 mm
Pelagic trawl	trawling	stern	wire rope	14 mm
IKMT	trawling	stern	wire rope/cable	14 mm
Agassiz dredge	trawling	stern	wire rope	14 mm
Rock dredge	trawling	stern	wire rope	14 mm
Gravity corer	DP station	starboard	wire rope	14 mm
Piston corer	DP station	starboard	wire rope	14 mm
Multicorer	DP station	starboard	wire rope	14 mm
Van Veen grab	DP station	starboard	wire rope	6-14 mm

5. Deck structures and facilities

5.1. Mobile equipment

5.1.1. Container couplings and other screws on deck

One of the objectives of research vessels is to be as multipurpose as possible. One solution is to have a deck which is the most flexible, with many configurations for container location and a matrix of tapping. This matrix allows the operator to fix many items on the deck with more flexibility.

Moreover, the deck should be equipped with several container couplings to allow several positions for 10' and 20' containers depending on the vessel scenario. This flexibility ensures the vessel will be more flexible for a defined scenario but also for the future.

It is important to have flexibility over the work deck to configure container fittings matrix. Normally container fittings are available in double configuration so it is possible to divide a 20' container footprint with two internal double fitting leaving a flexibility for even 5' quarter containers. It is believed to be rationale that 5' container footprint case is useful for refrigerated/frozen storage, general purpose accessories/spares storage, horizontal bins for bulk use etc. As a general terminology, a container size of 5' is called as quadcon, 10' as bicon and 1/3 of 20' as tricon. All of these options can be laterally coupled to corner castings each other with horizontal twistlocks within 20' container footprint. It is also possible to use corner castings as temporary fixing points for low performance beam/rod and/or instrument hanging on/aside a container. Sliding doors can be fitted to containers which give also a flexible use onboard.

Fig.5.1.1.a - 10' Portable Lab Container R/V TUBITAK MARMARA. (Photo TUBITAK)

Container deck fittings have internationally accepted dimensions in transport industry. Adapter plates can be used to make a temporary foundation for irregular base shaped equipment fixing & lashing. It is of greatest importance to make foundation calculations for dynamic loads, reaction forces according to the class requirements for lifting equipment.

Twistlocks give high safe loading capacities each calculated and tested for fittings providing very small footprint for equipment fixing on the working deck. This gives efficient use of working deck where effective area is relatively limited for regional research vessels.

Direction for the 20' container matrix can be planned supporting two main directions relative to the A-Frame leaving enough deck space for different scenarios. In any case, building a matrix for 20' containers covering 10' and even 5' partitions will give maximum flexibility for the work deck in the future. In the matrix configuration, the length of the working deck can be evaluated to install a 20' container along the ship leaving enough space for doors and manoeuvring equipment. 20' length along the ship is a good minimum for work deck of a regional vessel.

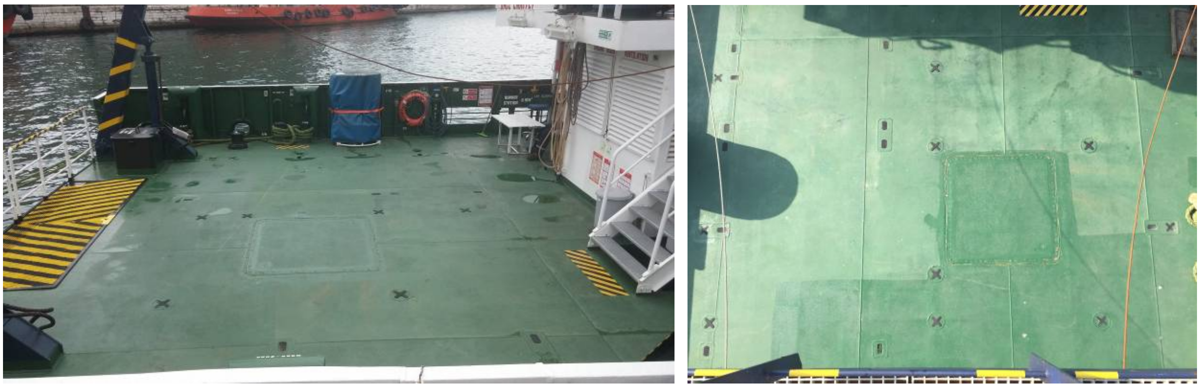


Fig.5.1.1.b - Working Deck R/V TUBITAK MARMARA. (Photo TUBITAK)

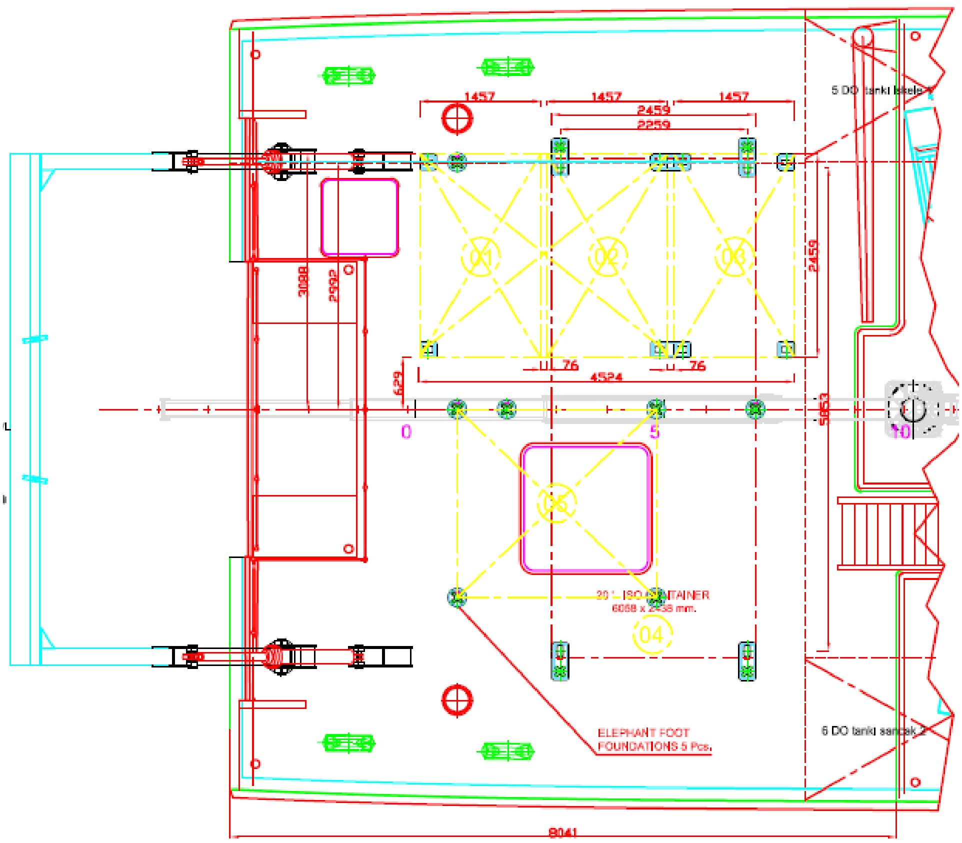


Fig.5.1.1.c - General Arrangement of Working Deck R/V TUBITAK MARMARA. (Drawings TUBITAK)

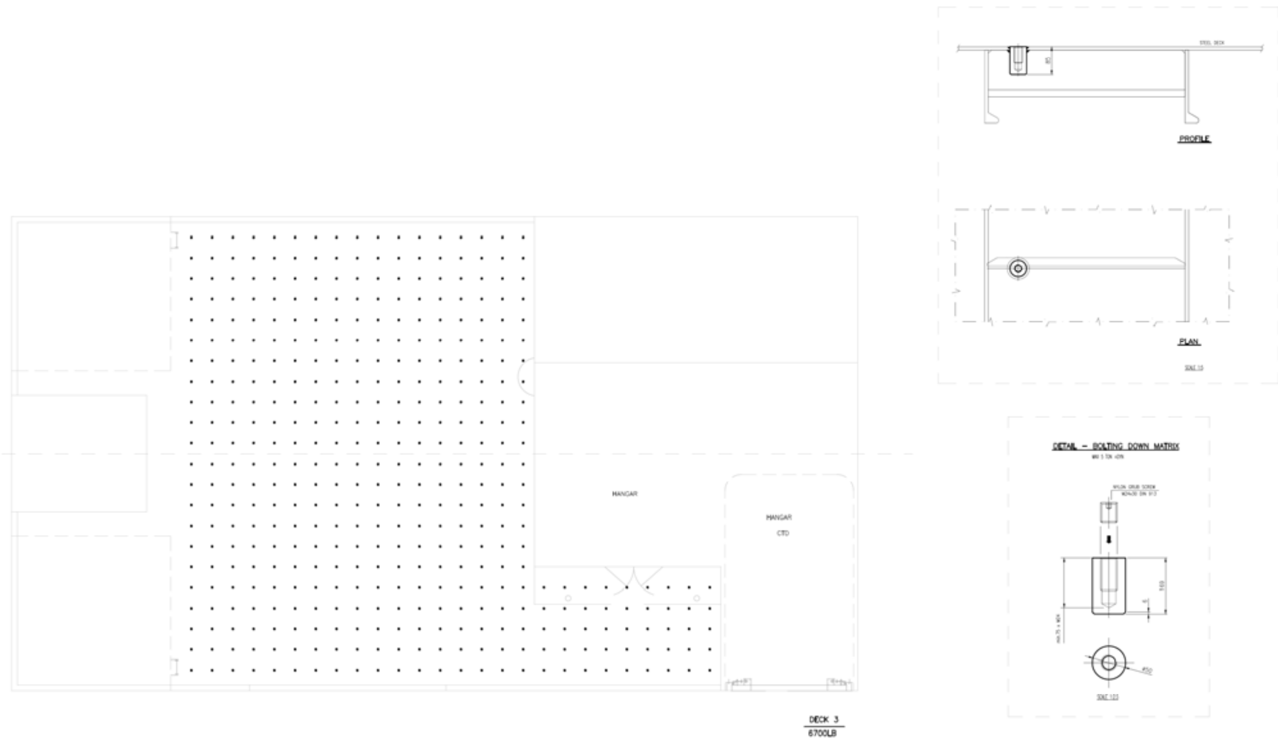


Fig.5.1.1.d - Matrix Arrangement Principle of Working Deck (32)

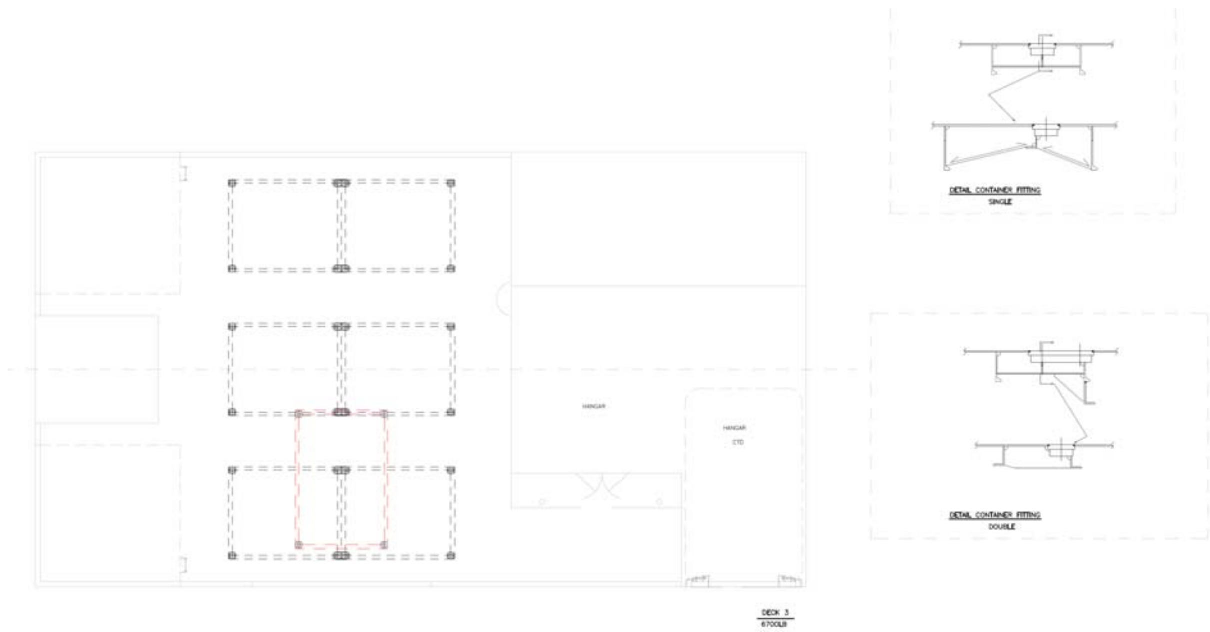


Fig.5.1.1.e – Containers Arrangement Principle of Working Deck (32)

A maximum capacity for a regional class research vessel can be planned as 3 of 20' containers. This option is the maximum scientific closed space scenario which provides nearly doubled closed lab area onboard. The overall weight and effects on ship stability is of course issues those have to be carefully considered for this extreme closed lab space scenario.

Lashing pots or elephant toes in flush type of installation give possibility for equipment fixing over the work deck. Using this kind of fixing provides custom design working tables, stainless steel fish sorting tables, sediment washing tables etc. It is also possible to plan deck sockets and container fittings in the foredeck where applicable.

5.1.2. *Use of Moon pool*

A moon pool is an opening in the floor or base of the hull, platform, or chamber giving access to the water below, allowing technicians or researchers to install or lower tools and instruments into the sea. It is very useful to fix new sensors on the hull without any specific works. It provides shelter and protection so that even if the ship is in high seas or surrounded by ice, researchers can work in comfort rather than on a deck exposed to the elements. Water will not enter the ship because it is contained inside the moon pool's walls, moving up and down like a piston as the ship rides the waves. A larger moon pool can also allow divers or small submersible craft to enter or leave the water easily and in a more protected environment.

Moon pools can be used in chambers below sea level, especially for the use of scuba divers, and their design requires more complex consideration of air and water pressure acting on the moon pool surface. In a research vessel, the moon pool is usually above sea level, and is open to the air above. The chamber above the moon pool is also connected to the open air via staircase wells and passages.

Different shapes of moon pool exist for research vessels; the most usual are square or round. Moreover, to be more efficient, indexation can be installed inside to be sure of equipment's position when it is at the bottom. To submerge a sensor (hydrophone, speedometer, video-camera) via the moon pool, a sub-hull support may be used. This is a square or tubular support made of synthetic resin which can be pneumatically locked in position to maintain the sensor in a rigid but adjustable distance under the ship hull.

5.1.3. *Step Deck & Stern Platform*

Regional research vessels have the advantage of relatively low freeboards that can support easier recovery and deployment of equipment. Knuckle boom cranes are nearly a world standard for this kind of ships proving flexible deck operations. These cranes have very wide working space as well as considerable outreach off the ship. It is possible to use these knuckle boom cranes to serve over the transom for lifting several equipment, nets inside/through the A-Frame.

In the early design phase of the research ship, a step deck can be designed as a structural part of working deck over the transom. This ramp like part of the deck can be used as a optional/void space between the main deck and the transom. A steel gridded platform structure can be built by perforated steel to be used for washing/draining purposes. The L shaped platform can be installed/attached to the hinges welded on the transom stern. The number of joints/hinges can be selected according to the loading cases. It is important to use this platform as part of the deck allowing water drainage to the sea. The step deck is a structural part/member of the deck and therefore it can be used as the main deck in terms of local strength. However, the platform is relatively weak to handle regular uniform loading conditions which is typically 3-5 tons/m2 for a regional research vessels.

Fig.5.1.3.a - Step Deck & Stern Platform on R/V TUBITAK MARMARA. (Photo TUBITAK)

Sediment sampling is an important part of marine research where the wet materials are discharged on the working deck. These samples are often being washed and filtered by sea/fresh water to eliminate unnecessary part of the sediment and particles etc. This process is mainly carried out near the stern of the ship where the rest of the sand/mud particles may be sent back to sea.

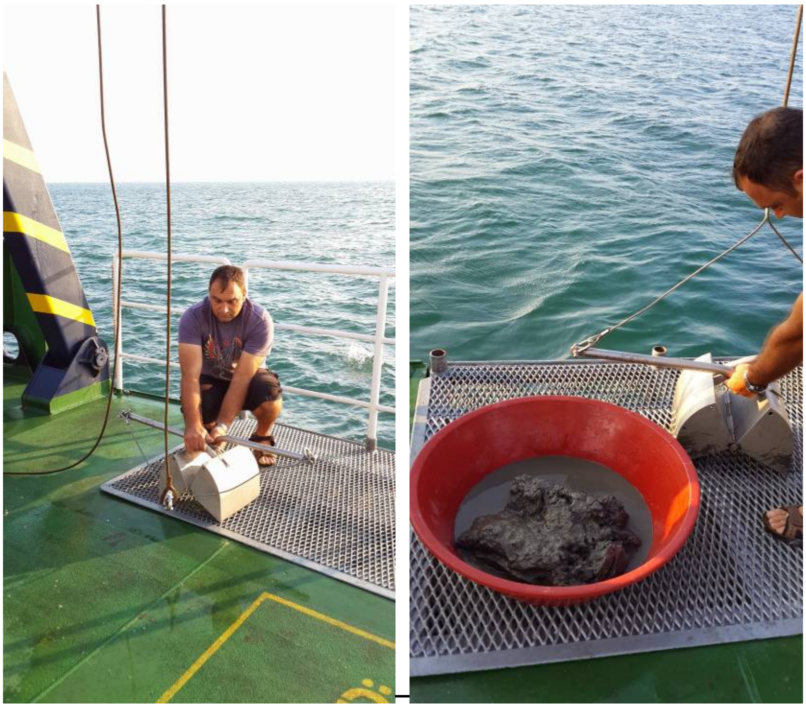


Fig.5.1.3.b - Sediment Sample Discharge and Drainage Stern Platform on R/V TUBITAK MARMARA. (Photo TUBITAK)

Fig.5.1.3.c - Sediment Sample Water Drainage Stern Platform on R/V TUBITAK MARMARA. (Photo TUBITAK)

The platform is operated with two hydraulic pistons powered from the hydraulic center of the vessel. A dedicated single line is pressured at 80Bars in series connection for two pistons so that the platform moves in synchronous mode. As the pistons move forward, the platform rotates on the axis where the hinges are located/welded on the transom plane axis. The platform makes a rotating motion sweeping 1800 leaving the step deck fully open. The design has smart details so that the platform is rotated 1800 with only single piston stroke. The end of the pistons moves within a limited angle of 100 while the piston traverses forward. The platform stops when the transom end faces the transom plane supported by the rubber fenders. The pistons turn into unloaded condition when the rotation finishes where the platform is hanging on the hinges/rotating joints.

Fig. 5.1.3.d - Step Deck & Stern Platform on R/V TUBITAK MARMARA. (Photo TUBITAK)

The system is a custom design solution requested by TUBITAK and designed/manufactured by the hydraulic sub-system manufacturer of the ship, DATA Hidrolik Corp. ([29]). The hydraulics is fully integrated with existing auxiliary hydraulics system supporting A-Frame and Capstans. The advantage of this dual use & integration is increased reliability with fully supported keep up services.

5.2. Storage

Different stores and storage spaces should be defined in the vessel's general arrangement:

- *Electronic stores* dedicated to store electronic spare parts for the computer and scientific equipment
- *Scientific stores* to store all scientific hardware required for a current mission, as well as packaging material and tote boxes
- *Used and unused chemical products store* to store chemical products for current and planned missions, as well as chemical waste and residues. In general, chemical waste, discharges and residues have their own packaging, either specific bins or boards for solid waste and tanks or jugs for chemical

discharges. This should be a specific cabinet located outside or near a hangar. It needs to have independent ventilation

- *Lithium cell storage* Lithium cells must be stored in an external locker located on the shelter-deck, for example below stairs. This locker must be made of steel and be internally insulated. A watertight door must be provided.

All storage locations must be fitted with lighting, ventilation, bilge/drainage plus grating on the floor in the path of traffic areas where relevant, and marine type flexible shelves for storage of equipment. It may be useful to define shelf dimensions to hold storage boxes of "Europe" standard type and in line with common agreement. A securing system must be provided to maintain boxes in position. Shelves must be fitted with holding and lashing systems for storage boxes and spare parts. Moreover, one part of the floor area must be kept available for storing large devices and packages. These must be secured using screw plugs.

5.3. Deck spaces

5.3.1. Freeboard and bulwark

Freeboard

Freeboard is the distance from the waterline to the freeboard deck of a fully loaded ship; it is measured amidships at the side of the hull. The freeboard deck is the deck below which all bulkheads are made watertight; above it that precaution is not necessary. Freeboard represents the safety margin showing to what depths a ship may be loaded under various service conditions. Freeboard is determined by the design of the vessel, particularly the shape and dimensions of its watertight hull. This is an important measurement since it determines how much weight a vessel can carry or how it will perform in wind and waves.

For a research vessel, the freeboard should be a compromise between safety of vessel and the height at the stern to minimize the sway when launching equipment by A-Frame or crane. The objective is to have the freeboard as small as possible whilst having a safe vessel.

Bulwark

The bulwark is the part of a ship’s side above the deck. It is around one meter high, depending on regulations. To launch some equipment easily over the side, usually, some parts of the bulwark are removable. This characteristic allows more flexibility for launching or for installation of mobile A-frames and LARS. This should be defined by the naval architect as the vessel design must take into account several launching scenarios for several types of mobile equipment.

5.3.2. Ramps

For improved trawl launching operations, the vessel may be equipped with a stern ramp. This ramp helps the trawl to move from the deck to the sea and vice versa. Small stern trawlers are often designed without a ramp, which is replaced with a special round to trawl to arrive on the deck. The angle of the ramp is around 45° between the deck and the bottom of vessel.

In the same way, to help launch new generation seismic airguns equipped with flexible floats, specific ramps may be integrated in the vessel stern. The bending radius is crucial when launching these floats. To be compliant with supplier recommendations, the use of a ramp is a great help. It is the easiest solution for launching and retrieving these specific floats without any damage.

5.3.3. *Free space on deck*

To optimize multipurpose operations with the vessel, one of the more useful solutions is to create a deck with a maximum of free space and equipped with a lot of tapping and/or container couplings (see §5.1.1). In this way, the space may be arranged in line with scheduled operations. One advantage of this type of deck is to be suitable for many kinds of operation (fishing, equipment launching etc).

5.4. Hangar

The hangar is a sheltered area that opens onto the stern work deck. Submarine systems (or heavy instrumentation) may be stored, maintained and prepared in it. It will also host standard ISO 20' containers. Typical operations conducted in-hangar include checking operations before and after diving, preparing systems and instruments (setting handling riggings, tools, etc.), preventive maintenance and required repairs (dismantling subsystems for transferring them to laboratories, direct actions on systems).

Hangar dimensions should be consistent with the systems to be stored inside. The naval architect has to find a compromise between laboratory spaces, hangar space and work deck spaces. This compromise will depend on each operator following their own priorities.

Hangars should be developed with

- openings to the work deck. These could be roll tops, which can protect hangars from weather conditions. In this case, it is useful to fit them with a door opening to access the hangar when they are closed.
- gantry of 1 or 2 t for load transfers. Additionally, the installation of some suspension points of 2 or 5 t may be useful.
- local heating or cooling system to maintain temperature inside the hangar between 15°C and 25°C with the roll top closed, according to the environmental conditions for the vessel.
- adequate lighting.
- electrical interconnection cabinets must be provided to power containers and maintenance tools.
- network interconnection cabinets for connecting scientific containers and system containers to on board networks. This must include telephone, intercom and on-board computer networks, as well as system dedicated networks and alarms.
- compressed air inlets, as well as sea water and fresh water inlets, designed to serve all maintenance areas and both scientific and system containers directly.
- a location dedicated to maintaining the rechargeable batteries.

5.5. Hold and hold hatch

Holds are very useful for storing large amounts of material on board. A hatch should be installed on the main deck to open the hold. Dimensions and numbers of holds depend on the general arrangement of the vessel. Only one hold is necessary for mission cargo. This hold should be filled with miscellaneous material on shelves, but also, if possible, be able to store one or two 20' containers, with it being possible to open container doors. Holds must be equipped with lashing points to be provided on bulkheads and overhead.

In general all hatches must be constructed and have sill heights etc. in accordance with the "International Load Line Convention", and be equipped with locking devices acceptable for the class. All hatches must be lockable in opened and closed position. On the weather deck, hatch covers closed by cleats must be key closed. More generally, hatches must have the same specific load, insulation and strength as the adjacent deck.

5.6. Laboratories

The wide variety of science activities conducted concurrently means that modern research vessels are built with plentiful laboratory spaces, often sub-divided into ultraclean, clean, normal, and temperature-controlled areas, with sufficient flexibility to be used for multiple needs. Specific laboratory needs are often provided through the use of containerized laboratories, while there is also a requirement for a substantial scientific stores area, including areas for frozen and refrigerated sample storage. The following paragraphs describe these different kinds of laboratories.

5.6.1. Wet laboratories

This laboratory should directly open onto the deck and the starboard alleyway. It is intended for the early management of biological and geological samples, for maintaining and conditioning CTD profilers, for water sampling and analysis as well as for conducting operations on cores. It may be transformed into a laboratory for preparing required equipment or into a testing laboratory. The laboratory floor may be flushed using high pressure water.

For CTD conditioning, the area must be centred around the point where the CTD profiler is to be set down. The CTD profiler must be carried into laboratory from its set-down point, located in the starboard alleyway beneath the CTD profiler hydrology A-frame or telescopic beam.

To have a more flexible laboratory, several screw plugs should be fitted to allow for equipment securing and to install any additional removable benches. Moreover, benches must be fitted with sinks with cold and hot fresh water inlets and clean sea water inlets, and at least one distilled water inlet.

All plugs (electricity, network, etc.) should be at least IP66.

5.6.2. Dry laboratories

This laboratory is intended for collecting data from physical and chemical sensors and for archiving sorted biological and geological data, designed to analyse and process samples and perform various chemical and biological analyses.

Benches must be fitted with sinks with cold and hot fresh water inlets and a clean sea water inlet. As for the dry laboratory, a screw plug network must be fitted for fixing and securing equipment. Means shall also be provided for installing any additional removable benches.

5.7. Lab-containers & other scientific containers

Because of multipurpose objectives and space constraints on a regional research vessel, one solution is to have several specific containers which can be fixed on deck using container couplings (see §5.1.1). These containers may be laboratories defined for one type of operation (chemistry, biological, etc) or specific spaces such as a fish sorting room. These containers may need sea/soft water plugs, electricity plugs and sometimes distilled water plugs and compressed air plugs.

5.8. Services (standard)

5.8.1. Fresh water

A centralized fresh water plant must be provided to serve separate points including all laboratories, hangars and decks for container connection. The fresh water is necessary to clean scientific tools, scientific equipment such as CTD, nets and so on. All connections should be of the threaded type for easy maintenance; welded connections should be avoided. Fresh water should be distributed by standard taps or push and plug taps.

5.8.2. Sea water

A centralized clean sea water plant must be provided to serve separate points including all laboratories, hangars and decks for container connection. The sea water is necessary to clean some scientific tools and to cool some equipment such as compressors. All connections should be of the threaded type for easy maintenance; welded connections should be avoided. Moreover, sea water plugs should be also used for some specific measurements, such as those performed by a ZooCam or Flowcam. Sea water should be distributed by standard taps or push and plug taps.

It is necessary to have two independent plants, one with a constant flow for scientific equipment units, and a second independent one for multipurpose uses.

5.8.3. Air Pressure

A centralized air pressure plant, usually at 7 bars, is necessary to supply tools or specific equipment such as seismic apparatus. Working air main lines on deck must be arranged with cocks fitted with snap couplings to take air hoses. Wherever required, pressure reducing valves in the airline from the general purpose air systems to the subject units must be installed. An air outlet, usually stainless steel Push-Pull connectors with plugs, should be fitted in each laboratory, hangar and deck. These outlets are useful for tools.

5.8.4. Data lines

In addition to conventional power and lighting distribution systems, a research vessel includes a complete network (LAN) of data transmission cables (analogue and digital) dedicated to scientific equipment. These sensitive cables require precautionary measures concerning cable runs, shrouding and glow screening. These specific cables should be fitted with plugs in each laboratory, hangar and deck, in cabinets dedicated to mobile equipment.

5.8.5. Power supply

The common power distribution is usually 400-V, triple-phase, 3 wires with an insulated neutral point. The distribution for lighting and low power is a 230-V IT system, single-phase with an insulated neutral point. The UPS-system is a 230-V, single-phase, 50-Hz insulated system. Each insulated neutral system should be provided with an insulation monitoring and alarm device with an insulation resistance meter. All these types of power are distributed in laboratories, hangars and decks for dedicated mobile equipment, containers, computers etc.

Moreover, the entire electric installation must be completed with due regard to glow screening. Electromagnetic compatibility should ensure high performance and efficiency of radio and navigation equipment, safety equipment, data processing networks and scientific equipment. This limitation of interference should be achieved as follows:

- For LAN, scientific, electronic, radio and navigation equipment, by arranging cable runs suitably, taking into account the different types of cables.
- For data processing networks (LAN), by selecting appropriate cables with satisfactory shield and strength armour characteristics.

In laboratories, hangars and decks, all electrical equipment must be located where, as far as practicable, it is not exposed to risk of mechanical injury or damage from water, steam, oil or excessive heat. Where unavoidably exposed to such risks, the equipment must be suitably protected or enclosed and plugs should have appropriate IP ratings.

6. Conclusions and recommendations

Research vessels are required to support increasingly complex, multidisciplinary research, which will drive many aspects of design, including power plant and propulsion, laboratory and work deck layout, handling gear, launch and recovery, and equipment changeover. Because technology changes rapidly and ship lifetime is over 30 years, future oceanographic ship design will need to be highly adaptable.

Research vessel work decks must be designed with flexibility in mind, with deck areas as flush as possible and open to the fitting of a wide variety of equipment (deck socket matrix) and containers. Decks must be able to handle increasingly heavy systems, including moorings, fleets of underwater vehicles, samplers and winches. Ideally, research vessels would be designed with low freeboard to facilitate deployment and recovery in rough seas. It is important to define a general list of equipment which can be installed on board and if the detailed list is not available, at least, a list of type of equipment considered. Even a multipurpose vessel won't be able to install, launch and recovery all existing sea scientific tools. A choice should be done before drawing the working deck.

The safe handling of larger and more complex instruments in high sea states (up to sea state 6) means that handling equipment is critical. Deployment over the side should be preferred to increase the environmental operating weather windows and to allow safer operations. The installation of heave compensation, to uncouple packages from ship motion, is also becoming increasingly common on CTD winches. General purpose RV ships require a permanent installed suite of winches (direct pull and traction) to perform CTD activities, coring and trawling missions. As flexibility is of prior importance, moon pools of various diameters will offer a perfect means to lower equipment below the keel of the ship. Moreover, launch and recovery over the side should be chosen wherever possible. This manoeuvring limits disturbance motions due to roll and pitching of the vessel.

Dynamic positioning is critical to handle deployment, recovery and operation of underwater vehicles and systems. Design conditions should strive to maintain position in at least sea state 6-7 and 30-40 knots wind speed. There is also the need to balance this requirement against that of acoustic quieting being as quiet as possible.

There will be a need to increase laboratory surfaces and numbers, ranging from ultra clean to normal spaces with enough flexibility to be used for multiple needs. Hangars to allow storage, maintenance and preparation of underwater systems are highly recommended.

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