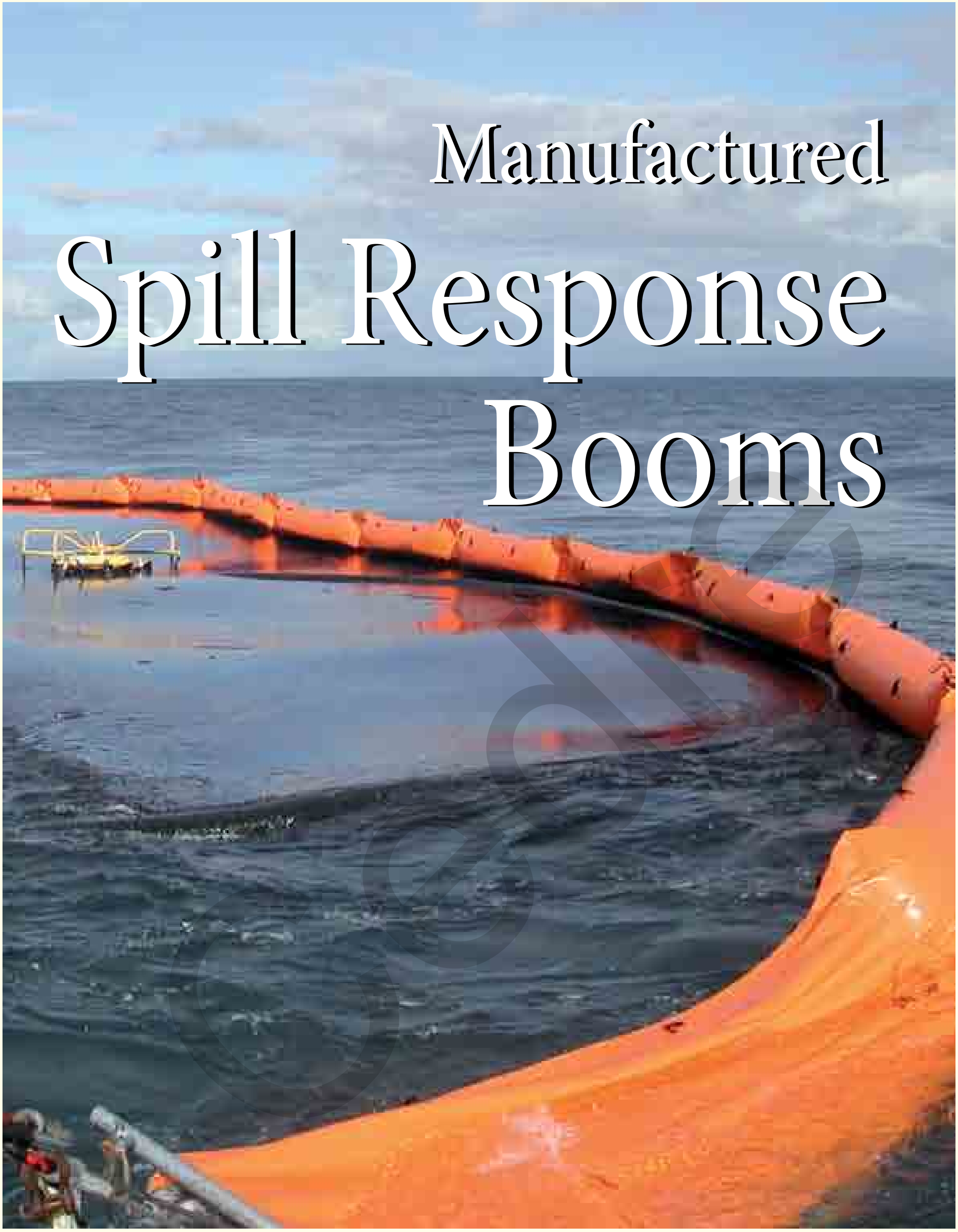
Manufactured Spill Response Booms



OPERATIONAL GUIDE

Cedre

Manufactured

Spill Response Booms

Operational Guide

Information
Decision-making
Response

Guide produced by *Cedre* with funding from TOTAL SA and the French Ministry of Ecology, Sustainable Development, Transport and Housing.

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Cover photo:
Deployment of an inflatable boom from the BSAD Ailette during the Prestige spill.
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Purpose and structure of this guide

Whether to **protect** a sensitive area or to **deflect** or **contain** a slick of floating pollutant in order to recover it, booms are commonly used in spill response operations. These booms will have been chosen, purchased, tried and tested in advance as part of response planning and preparedness actions.

This guide is one of a collection of operational guides produced by *Cedre*. It focuses on **manufactured** (i.e. commercially available) **spill response booms** and attempts to provide an overview of the main models available on the market. *Cedre*'s knowledge on this subject is presented in this guide. On the basis of the information presented and the many illustrations provided, readers will be able to determine the most appropriate equipment for the situation in hand, and then to assess the chosen solution during exercises or training.

This guide is mainly aimed at operating personnel at oil facilities, emergency and defence services, fire brigades, technical local authority staff and, more widely, all personnel liable to be involved in response to a spill in surface waters (sea, shore, river, lake...).

A number of the other guides published by *Cedre* also address the theme of booms:

- the "**Custom-made Spill Response Barriers**" guide lists alternative systems and resources that can be used to contain a spill; these barriers are designed and built on site using locally available, and generally low-cost, materials
- the "**Use of Sorbents for Spill Response**" guide deals with the use of sorbents, including sorbent booms.

"Sorbents" guide

"Custom-made booms" guide

Contents

Preparedness - Response plan

A1

Why use booms?

When a pollutant is spilt into a water body, **various response strategies** may be considered:

- **Leaving nature to do the job**: it can sometimes be preferable to let the natural environment break down the pollutant for various reasons (responder safety, site layout, adverse weather conditions, highly volatile pollutant...)
- **Chemically dispersing** the oil, when all parameters allow (product characteristics, geographical location, weather conditions...)
- **Containing and recovering** the pollutant to remove it from the environment
- **Burning** the pollutant.

Spill response booms can be used **at sea**, **inshore** (in estuaries, ports...), on the shore and in **inland waters** (lakes, rivers...). The purpose of such booms is to:

- **Contain** and concentrate the slick to increase its thickness in order to improve skimmer selectivity or, in some cases, make it possible to burn it
- **Deflect** the slick and direct the pollution towards a recovery area
- **Reduce spreading** from the source
- **Protect a sensitive site** because of its ecological/biological, socio-economic, political or strategic importance.

Dynamic containment operations, Prestige spill, 2002

Boom deployed around the bow of a vessel

- **Contain a slick** in a port, around a vessel or at a natural site to prevent it from being remobilised
- **Contain pollutant and washing effluent** as part of clean-up operations on a polluted site.

Containment of effluents during clean-up operations

As the first equipment deployed to contain the pollution, booms are generally the **first link in the recovery chain** (containment, pumping, storage, transport, treatment...).

Booms can be used **statically** (booms moored to stationary points) or **dynamically** (surface trawling/towing by vessels).

A2

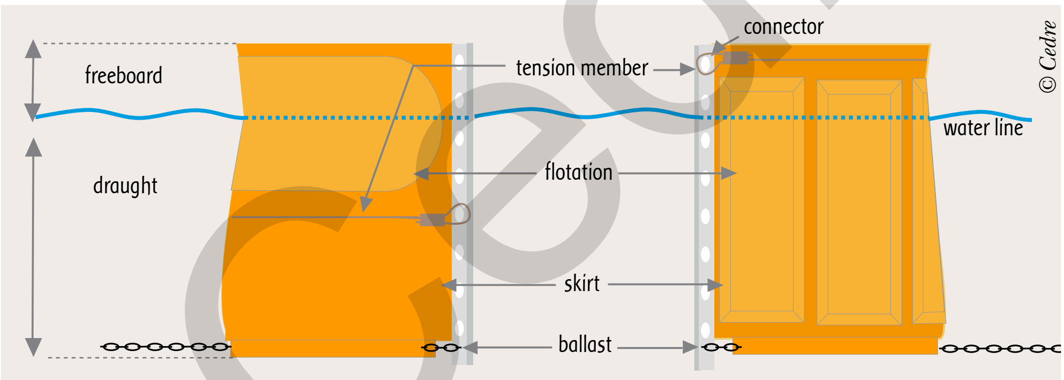
Boom components

Booms contain floating pollutants thanks to a flexible or rigid screen maintained at the surface of the water body by one or more floats. Booms are kept upright in the water by their ballast.

Within a boom section, 5 components can generally be identified:

- **flotation chamber**
- **skirt** or **screen**
- one or more **longitudinal tension members**
- **ballast**
- **connectors**

as well as handling and marking systems (see D4).



Curtain booms have a sub-surface skirt that runs along the full length of the boom and is kept afloat by a solid or air-filled buoyancy chamber

Fence booms are made up of flat sections kept upright by internal or external floats

Flotation chamber

The flotation chamber is the main component of the boom. It provides buoyancy and prevents splash-over. The part above the water surface is known as the freeboard.

In addition to providing stability, the type and shape of the flotation or chamber (cylindrical, square or rectangular blocks, spherical) determine its storage method and its ease of assembly, deployment and repacking. Three types of flotation exist:

1. **Solid flotation** (e.g. foam floats): such booms are ready for immediate deployment but have a higher storage volume.
2. **Inflatable**: these booms take up less storage space but time is required for inflation before deployment.
3. **Self-inflating**: these booms inflate automatically upon deployment and combine the advantages of the two other boom types. They however require regular, careful maintenance.

Skirt

The skirt is the part of the boom that acts as a screen below the water line. It is designed to contain the pollutant that accumulates in front of the boom.

The main characteristics of a skirt are:

- its **material** (fabric with an oil-resistant coating, plastic or rubber) - see A4.
- its **height**
- its **mechanical resistance** (tear, flex, puncture, abrasion)
- its **capacity to stay upright**.

Tension member

The tension member absorbs longitudinal forces exerted on the boom. The most frequently used materials are **fabric webbing**, **cables** and **metal chains**.

To connect both ends of the boom to a mooring and to take the strain of the boom, **chains** or **towing elements** (such as **tow bridles**) will be used.

Mooring chains

Ballast

The purpose of the ballast is to keep the skirt as upright as possible. It can take the form of a **continuous chain** (generally made of galvanised steel), a **cable**, individual weights (made of lead) inserted into the bottom or the skirt or attached to the outside, or a **lower water-filled chamber**. The ballast can also act as the tension member.

As an indication, a boom with a 300 mm high skirt deployed in a 0.7 knot current will need around 1 kg of ballast per metre (boom angle < 20° in relation to the bank).

Connectors

End connectors have two purposes: to ensure an **oil-tight seal** and to **withstand forces exerted** on the boom. The boom can be made oil-tight between sections using overlapping gussets (with press studs or lace-up type), slide connectors, bolt plates or rigid bars.

ASTM connector

The photo above shows an **ASTM-standardised connector**. Such models are commonly found and easy to use. Other connectors are presented in A6.

Before purchasing spill response equipment, **make sure that it is compatible with existing booms or those liable to be mobilised** in the event of a spill.

Handholds

Booms are often fitted with handles or straps.

Handholds

These carry straps, designed to help to deploy and retrieve boom sections, should never be used for towing or mooring purposes. These straps would be at risk of tearing and damaging the floating boom sections.

A3

Boom types and dimensions

Descriptive terms

Boom dimensions are defined as follows:

Dimension characteristics	Example: non-compartmented foam-filled curtain boom - harbour area (example given as an indication)
Freeboard (F)	0.37 m
Draught (D)	0.53 m
Total height (TH)	0.9 m
Section length (between 2 connectors)	50 m
Buoyancy reserve	80 L/lm*
Storage volume/compactness	150 m in a 20 m^3 container (6 m x 2.5 m x 1.4 m)
Total mass per linear metre	8 kg/lm*
Ballast weight per linear metre	4 kg/lm*
Chain tensile strength	15,000 daN

* lm: linear metre

Three categories of booms can be distinguished according to their total height (H = D + F):

- **Lightweight**: H < 0.5 m
- **Medium-weight**: 0.5 m < H < 1 m
- **Heavy-duty**: H > 1 m

For instance, the overall height of booms used offshore can reach up to 3 m.

Generally speaking, the draught represents around 60% of the overall height. The stronger the currents the more the booms will require a low draught-to-overall height ratio.

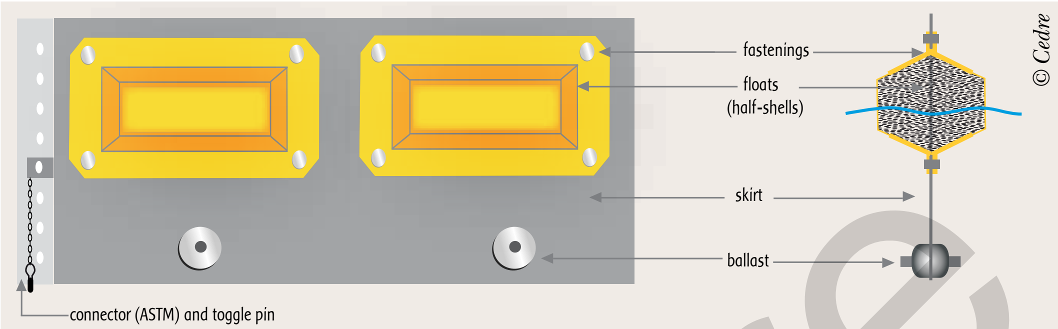
The booming plan, section lengths and number of moorings will be adjusted according to the site's hydrodynamic and meteorological conditions and its geomorphology. Modelling software (FORBAR, Boom Deployment Calculator or more recently the experimental computational software BAR3D) can be used to determine the length of boom sections, the deployment angle and the number and average weight of moorings required ("theoretical data").

The main boom types are commonly divided into two major categories: **fence** booms and **curtain** booms. The different models are described in detail on the following pages.

Fence booms	Curtain booms
Type 1: Permanent Type 2: Foam-filled	Type 3: Foam-filled Type 4: Inflatable Type 5: Self-inflating Type 6: Shore-sealing Type 7: Specific booms

Type 1: Permanent fence boom

Side view and cross-section of a permanent fence boom



Overview

A permanent fence boom is composed of a **rigid or alveolar vertical screen**, kept at the surface by lateral flotation chambers filled with air or expanded foam. These floats are generally made of moulded plastic (e.g. polyethylene).

Floats may be located either on each side of the screen or only on the external side of the boom, so as to provide a smooth inner surface to encourage the oil to flow along the boom and to facilitate cleaning of the boom.

For this type of boom, which is permanently deployed, the **quality of the materials** used is crucial to ensure **long-lasting use**. The screen and floats should show good resistance to abrasion, crushing, UV rays and the pollutant(s) to be contained (see A4). Walkways or pontoons can sometimes serve as permanent booms. Certain stainless steel booms, also used as fireproof booms, can be installed on industrial sites.

Uses

This type of boom is set up to ensure long term resistance to aggression from the aquatic environment, primarily in **calm areas** (stagnant waters) **where immediate response in terms of containment is essential.**

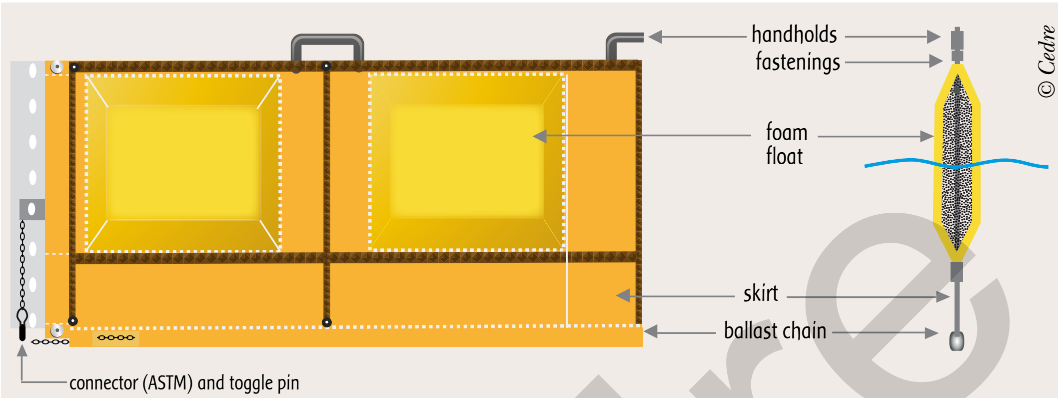
- **Harbour areas**: under oil wharfs or port structures such as walkways.
- **Outfall pipes**: stormwater or wastewater outfall at an industrial site.
- **Protection against litter and debris, protection of water intakes...**

These booms require regular maintenance, in particular to remove aquatic organisms or seaweed that have become caked on and could reduce the booms' buoyancy.


© Cedre

Type 2: Foam-filled fence boom

Side view and cross-section of a foam-filled fence boom



Overview

This is a fence boom as the **float and skirt generally form a single flat section**. They can however be separate on some models.

The rigidity of such booms is obtained either by inserting stiffeners or by directly using a semi-rigid material to form a screen.

The presence of integral foam floats means that the boom can be **deployed and retrieved quickly** and easily. Furthermore, its relatively flat structure facilitates its storage on a reel or in a trailer.

These booms however have lower buoyancy and will therefore be more liable to plane under the effect of current and/or wind. They are nevertheless easy to clean.

Uses

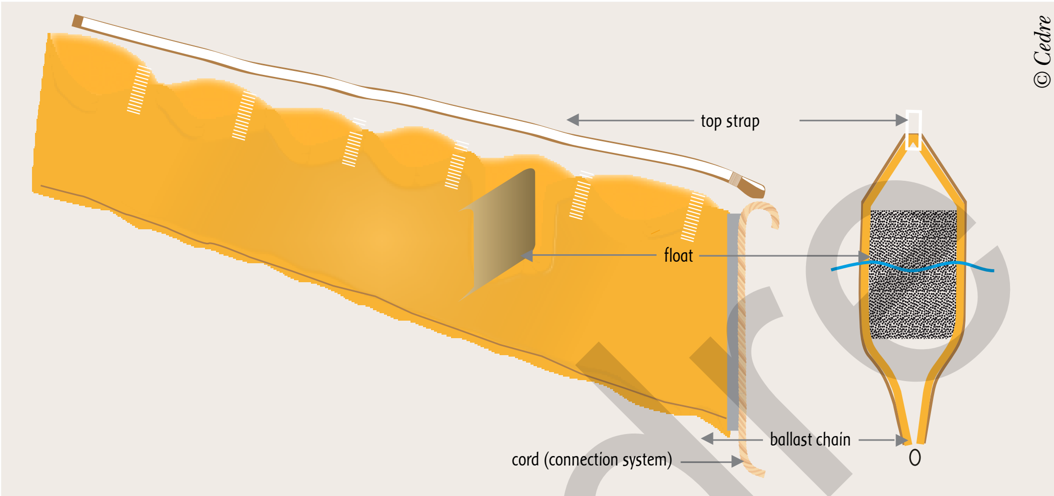
These booms are used for containment or, in some cases, to deflect a spill to a recovery area. They should be used primarily in areas of low current (less than 0.5 knots, variable according to boom dimensions).

This type of boom is designed to respond to spills in **calm to slight conditions** (particularly suitable for use in inland waters).

Containment of oiled loose sorbents by a foam-filled fence boom

Type 3: Foam-filled curtain boom

Diagram illustrating a non-compartmented foam-filled curtain boom



Overview

This is a curtain boom as its **skirt is flexible and independent of the floats**. Two types of foam-filled curtain booms can be distinguished:

- "**Compartmented**" booms, which are kept afloat by cylindrical foam floats alone, positioned end-to-end, or, more rarely, foam beads. These floats are separate from the skirt and can be rigid or flexible.
- "**Non-compartmented**" booms, which are kept afloat both by solid flotation and by the air trapped in the pockets (see diagram above).

These booms take up a large amount of storage space and require suitable **storage containers**.

Uses

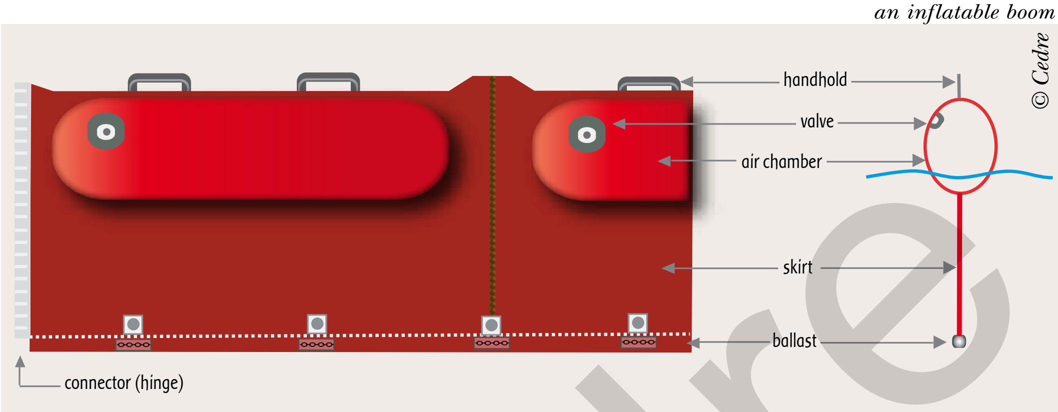
In general, this type of boom is used in areas with current speeds of less than 1 knot, in coastal areas, ports, estuaries and rivers.

These booms are rapid to deploy, have good buoyancy and good shock resistance, yet are more complicated to fold away, repack and clean (penetration of oil into the structure).

Deploying a non-compartmented foam-filled curtain boom

Type 4: Inflatable curtain boom

Side view and cross-section of an inflatable boom



Overview

Inflatable booms are composed of a **cylindrical air-filled flotation chamber and a ballasted skirt**. They are inflated before or as they are being lowered into the water using air pumps or compressors. The **inflation time** therefore has to be taken into account, which may vary according to various factors (operator availability, size of buoyancy chambers, number and diameter of valves). These booms are **less bulky** when deflated, allowing them to be **stored on reels**. Like other boom types, they require regular maintenance, with particular emphasis on checking the conditions of all valves. One of the main risks is that of puncture or of air leaks through seams and joins. To reduce this risk:

- Pay particular attention to the quality of the materials used as well as the manufacturing quality
- Establish deployment procedures and test them
- Take precautions in terms of repacking and storage after use
- Reduce friction against hard surfaces to a minimum during deployment (jetties, slipways...) and once the boom is in place (rocks...), in particular by using tarpaulins or protective fabrics.

Uses

These booms are used in **coastal areas** and **offshore**. They are also recommended for **dynamic trawling operations** in coastal areas. However this type of boom requires space for deployment (on land or on board), sufficient personnel and inflation equipment.

This is the only type of boom that is effective offshore and is the preferred type for deployment from oil spill response vessels during **offshore response operations**.

Inflatable booms can also be deployed in rivers, estuaries and ports, in particular to protect sensitive sites in anticipation of oil washing up on the shore or running off a site on land.

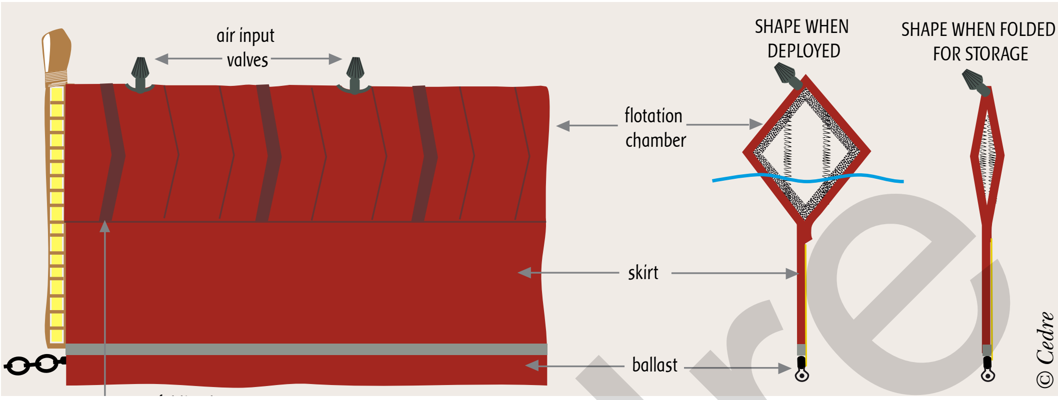
Close-up of a check valve

Deploying an inflatable curtain boom

Deploying an inflatable boom in the open sea

Type 5: Self-inflating curtain boom

Side view and cross-section of a self-inflating boom



Overview

Self-inflating booms have **flotation chambers fitted with one-way check valves that automatically inflate when deployed**. An internal structure deploys the boom and flattens it to repack it. This structure can take the form of a spiral coil, a folding frame fitted with springs or a series of nylon hoops. Self-inflating booms are easy to store and rapid to deploy. The quality of the air valves and their correct operation ensure that the boom remains watertight (contact with water during deployment). These booms are, like inflatable booms, more vulnerable to puncturing and tearing. Their internal structure requires regular examination (spring corrosion). Self-inflating sections should be kept short to maintain the boom's buoyancy in case of a leak.

Uses

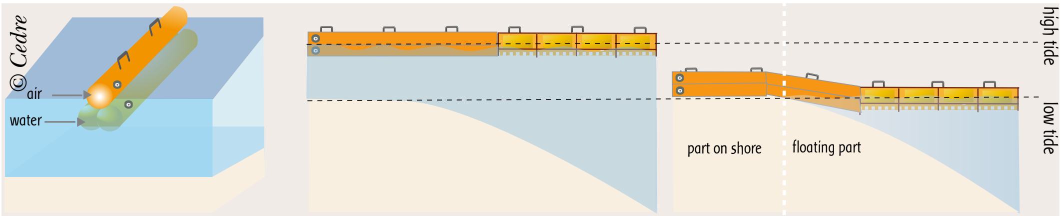
This type of boom is used in **calm waters**, in low currents, but also in **rougher waters** or even offshore in some cases. Their rapid deployment, low storage space (on reel) and low requirements in terms of additional equipment are the main advantages of these booms.

Self-inflating booms are suitable for use at industrial and port facilities requiring **very rapid deployment** of a containment system in case of oil release during loading or unloading operations.

Deploying a self-inflating boom

Type 6: Shore-sealing boom

Diagram illustrating how a shore-sealing boom works



Overview

These booms are composed of one (or two) **lower water-filled chamber(s) acting both as skirt and ballast, and one upper air-filled chamber** providing buoyancy for the whole boom.

They are used in shallow waters or directly on the sediment, in areas uncovered at low tide. The lower chambers act as ballast when the boom is floating and lie on the ground when the boom is on the shore. As the tide goes out (ebb tide), the boom settles on the mud or sand. As the tide comes in (flood tide), the boom recovers its role as a floating screen. Its purpose is to form an **oil-tight seal between the sediment and the high water mark on the foreshore**.

Uses

These booms are recommended in **very shallow waters** and are suitable for containing oil released during **shoreline clean-up operations.** They are also suitable for use in inland waters. Ideally used along the banks of channels, they are deployed in some cases on sites with a high tidal range and shallow depth, to complete a length of traditional booms at each end. They must therefore be fitted with compatible connectors. For instance, they can be used to block the entrance to a port where, at low tide, water only remains in a small part of the channel.

As these booms are heavy when filled with water, they are difficult to move. Their position should therefore be accurately studied, taking into account the maximum high water level.

Deploying a shore-sealing boom from a slipway

Using a shore-sealing boom on marshland

Type 7: Specific booms

Fire-resistant and fireproof booms

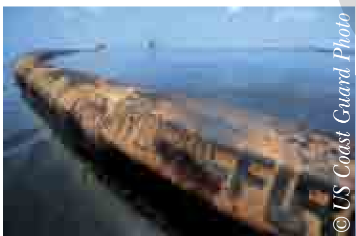
Fire-resistant booms are designed to maintain their integrity during **containment operations on a burning slick (controlled in situ burn or accidental fire)**.

- Some are **stainless steel flat or fence booms**, whose storage and deployment can be problematic (high weight per unit length). These booms are designed more for permanent use in a harbour to prevent pollution incidents.
- Others are **curtain booms** made of stainless steel floats and a flexible fabric made of a **ceramic alloy**. The fabric is covered with a **silicon coating**, an elastic material that is extremely resistant to high temperatures (up to 1,000 °C).

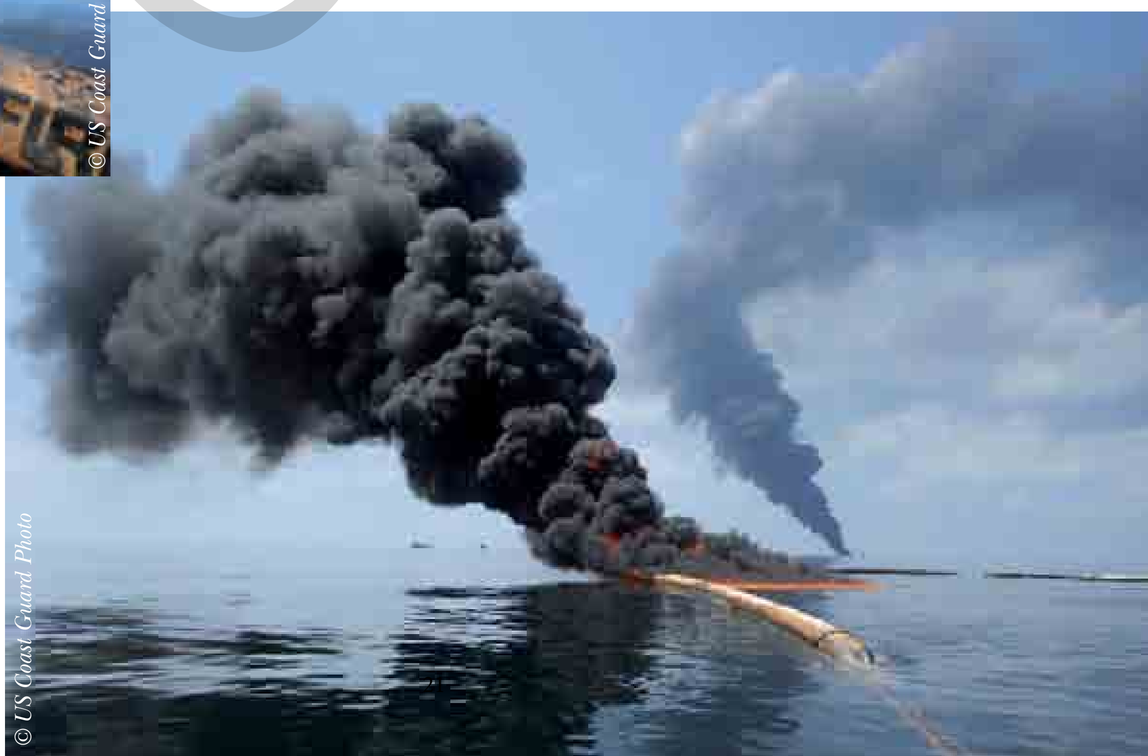
Certain fire booms are fitted with an **internal water-cooling system** which reduces the temperature and therefore protects the boom's structure. This type of boom was used in 2010 during in situ burning operations in the Gulf of Mexico following the Deepwater Horizon rig disaster. Two burn techniques were used during these spill response operations:

- isolated burns with containment by fire booms
- burns fed by towing (2 vessels conducting pair trawling) to contain and ignite the trapped slicks.

The operations conducted in the Gulf of Mexico showed significant differences in terms of the reuse of the different models mobilised (variable according to the quality of the materials used).



Use of fire-resistant booms, Deepwater Horizon spill, 2010



Trawl booms

Some companies market containment booms designed to "trawl" oil at the surface. These systems comprise inflatable elements designed to collect and concentrate pollutants at speeds of up to 2.5 knots, or more for some models. They can be used in a **V- or U-configuration and towed by a single or pair of vessels.** Floating oil is deflected towards the apex of the boom, where a storage tank can be attached (detachable fine-mesh cod-end or containment pocket where the oil can be concentrated and pumped out). **The efficiency of these towed systems will be optimal on highly viscous and weathered oils** (heavy fuel oil or emulsified crude). They will rapidly reach their efficiency limit with light products (diesel, light crude, fresh heavy fuel oil...), even if the use of sorbents (pads, booms) at the end of the pocket can help to recover small quantities of oil.

Some trawl booms comprise recovery systems. These booms are either short and trawled at the side of the vessel, or longer (up to 300 m) and towed by two vessels. In this case, the boom design may include a pipe for pumping out the oil.

Trawl boom towed by two vessels

Boom attached to an outrigger and comprising a recovery system, deployed from a single vessel

Sorbent booms with ballasted skirt

Single-use sorbent booms with a ballasted skirt are designed for **first line emergency response.** They are used to retain, contain and absorb oil on calm waters. They are only absorbent on one side; the other side forms an oil-tight seal and strengthens the boom. The sorbent is composed of a **hydrophobic, oleophilic material**, which is generally synthetic (polymer fibres: polypropylene, polyurethane, polystyrene).

Sorbent boom with a skirt

Sorbent boom with a ballasted skirt

Testing a sorbent boom with a ballasted skirt

Flood protection booms

Initially used for protection against flooding, some of these booms can be diverted from their original use to be deployed as part of spill response operations.

To maintain water flow and prevent oil leaks due to overflow, suitable booms can be used to allow an underflow (opening systems, or ducts, designed to regulate the flow).

Deploying a flood protection boom

Submersible booms

Submersible booms can be used in areas where there is a local pollution risk (ports, terminals, refineries). The boom permanently sits on the sediment at the bottom and its floats are filled with water. When it is required, a compressor blows air into the boom through pipes, pushing out the water and causing the boom to rise to the surface. This system, which must be clearly indicated (before conducting maritime or dredging operations), requires regular maintenance and cleaning, to prevent it from being colonised by animal or plant species.

Flexible booms

These booms are designed to form an oil-tight seal between a vertical dock wall and a ship's hull. They can be rapidly set up for containment following a spill or leak during oil transfer, for instance in the area below a loading arm.

Maritime operations booms

Maritime operations boom: view of the geotextile skirt

Initially designed to stop debris from construction sites (dust, oil, plastic bags, floating debris...) from invading port waters, maritime operations booms can be diverted from their original use for spill response operations.

These booms comprise:

- A subsurface part composed of geotextile (50 – 100 µm filter), 2.5 to 5 m deep, ballasted by a chain and attached to floats
- Floats, generally flat and made of foam.

Bubble barriers

A vertical stream of bubbles, emanating from a perforated pipe on the bottom, creates a counter-current at the surface, preventing the oil from drifting.

These bubble barriers are sometimes used to protect entrances to ports and drydocks and areas of relatively low current. The main advantage of a bubble barrier is that it avoids positioning conventional means such as floating booms at the surface, which can disrupt navigation and vessels' manoeuvres. Their efficiency however becomes rapidly limited in rough waters (waves, current).

Periodical maintenance visits (by divers) and activation during exercises should be organised to ensure that the nozzles releasing the pressurised air are not plugged by sediment or marine organisms. The air compressor should also be regularly revised to ensure the system functions correctly. Like for submersible booms, the position of bubble barriers should be indicated at the surface to prevent them from being deteriorated during dredging operations or by anchors.

Boom materials

The environments in which booms are deployed can be aggressive:
- exposure to UV, spray, seawater
- contact with pollutants (oil, chemicals) and debris
- presence of natural objects (branches, trunks, rocks, outcrops...)
- stress due to currents (bottom profile, tides, influence of surface wind).

Connectors, tension members, ballast

The use of aluminium or steel treated against corrosion (zinc galvanising, chrome plating, coating with special resin) impedes the degradation of boom fittings.

Skirt and flotation

Various coatings are used in the manufacture of skirts and floats. Below is a table comparing their properties:

Coating	Water-tightness	Oil resistance	Chemical resistance*	UV resistance	Wear and tear resistance	Heat resistance
PVC < 1000 g/m²	Good	Good	Good	Poor	Poor	Poor
PVC > 3000 g/m²	Very good	Very good	Very good	Very good	Very good	Very good
Polyurethane	Good	Very good	Good	Good	Very good	Very good
Vulcanised neoprene	Very good	Good	Very good	Very good	Very good	Poor
Hypalon®	Good	Very good	Very good	Very good	Very good	Very good

** Contact tests between different plastics and chemicals (ethylene glycol, aniline, ethylbenzene) and traction trials – Cedre 2007*

Very good   Good   Poor

In the case of permanent booms, the floats are either moulded out of HDPE (high density polyethylene), or made of fibreglass reinforced polyester, filled with polystyrene. These two materials have almost identical resistance (impacts, UV, oil) and buoyancy. HDPE ages better in the case of prolonged contact with water. For booms with integrated flotation, whether permanent or not, the flotation takes the form of beads, foam blocks or rectangular or cylindrical blocks. The materials used are as follows:
- **polyethylene**: semi-rigid, durable material that is oil resistant but sensitive to high temperatures and UV rays
- **polystyrene**: lighter material than other plastics, it provides greater buoyancy
- **polyurethane**: very versatile material, available in flexible, semi-rigid or rigid form. Polyurethane foam is oleophilic, i.e. it absorbs oil, and is therefore generally covered with an oil-tight envelope.

Standardisation

A5

The International Organization for Standardization (ISO) has developed various standards relating to oil spill booms, in particular for tests conducted on plastics. Standards are also issued on a national scale, for instance in France by the French standardisation association AFNOR. In the appendices, the acceptable limits for spill response booms are presented with reference to these standards.

French standard NF T71-100

As an example, in France, a commission comprising around 20 members including *Cedre*, AFNOR, Sycopol and port managers was set up in 1995.

Based on this group's work, the standard NF T71-100 was established in order to ensure consistency in the terminology and presentation of spill response booms' performance. With this standard, spill response managers and manufacturers benefit from a single frame of reference.

Standard ISO 16446:2002

This international standard provides a method used to connect two booms fitted with different connectors, through the use of a standard adapter.

One end of this adapter is connected to the existing connector while the other is made of a flat bolt plate. This standard determines the hole positions and diameters for these adapters (see A6).

ASTM standards

The American Society for Testing and Materials (ASTM) has developed several standards specific to spill response, a few of which deal with booms. They are listed in the appendices to this guide. One of them describes the most universally used connector, known as the ASTM connector.

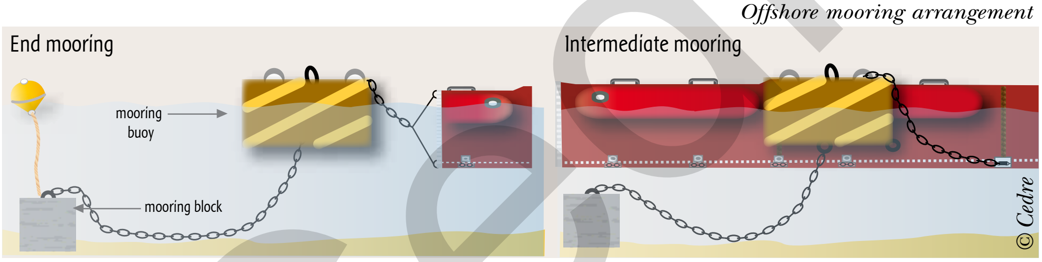
Moorings and accessories

Offshore mooring arrangements

Setting up a boom in the open sea requires the presence of one or more anchoring points on the bottom. These may be **mooring blocks**, **anchors** or **driven piles**. These mooring points are connected by a **chain** (and/or **rope** in the case of a lightweight boom) to a **floating drum or buoy** to which the booms are moored.

The **mooring line** arrangement can be supplemented by a marker buoy at the surface, indicating the location of the anchoring arrangements, in particular if the mooring is permanently left in place.

Offshore mooring arrangement



To save time during deployment, it is useful, wherever possible, to leave offshore anchoring points in place.

Mooring blocks

Mooring blocks are used to withstand tension of up to around 100 kN (kilo Newtons). It is generally accepted that a subsurface block of concrete has a restraining force equal to half its weight in air. They are positioned using specialised vessels at sea (specially designed catamaran or buoy tender) or using lifting machinery if the mooring area is next to a dock.

Mooring floats and mooring block lifting floats (or air lift bags) are used to lift mooring blocks from the bottom in order to reposition them.

Embedding phenomena (mooring block becoming embedded in the sediment) should be taken into account, as they can complicate lifting operations, despite having improved the anchor's hold.

Anchors

The use of anchors is a **rapid solution** which does not require major logistical equipment. This is **recommended for short lengths of lightweight booms in shallow waters** (5 metres maximum). If the anchor is well positioned on the bottom, it can hold up to 10 times its weight according to the nature of the bottom. The most favourable sediment types are sand or soft clay. On rocky bottoms, the risks of catching and dragging are high.

Tandem anchoring

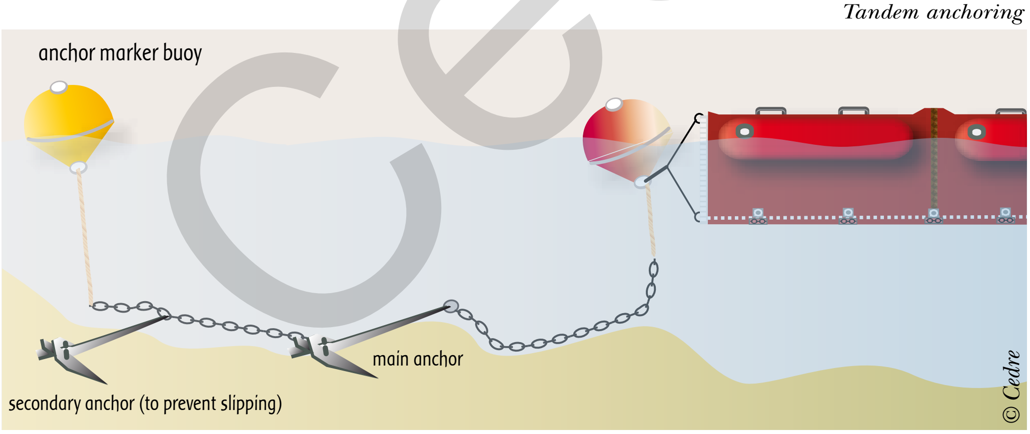
In areas of strong current, the boom may be moored using several anchors in series. This tandem anchoring technique maintains sufficient tension and prevents the anchor from moving (slipping).

The chain between the anchors should be at least 5 metres long to prevent the tandem anchor from entering the furrow of the primary anchor. The hold of the anchoring arrangement is at least twice the hold of a single anchor. The anchor with the best hold should be positioned first and the heaviest anchor last.

Multiple anchor moorings

Multiple anchors can also be set using identical chain lengths at a 10 to 30° angle. The hold of the anchoring arrangement is less than twice the hold of a single anchor, but this system reduces the swinging circle and distributes the load in various directions, which can be an advantage in sites subject to tidal currents.

Tandem anchoring



Driven piles

In the same way as on the foreshore or on a bank, metal (or wooden) piles can be driven into the bottom in the open sea. These mooring points are reliable but nevertheless require heavy machinery to put them in place and have the drawback of constituting a permanent obstacle for navigation, or for machinery when on land.

Mooring drums or buoys

Mooring buoys can be either **rigid cylindrical floats** (generally made of stainless steel) or **inflatable conical floats** that are quick to deploy. They can weigh up to a tonne and measure up to two metres in diameter. They have **rings** for mooring and handling. They also sometimes have a manhole for maintenance, as well as a handrail to facilitate berthing. Partially immersed, they have a central lug to which the mooring line is attached. According to the boom's dimensions and characteristics, buoys attached to the mooring lines may be sufficient.

Inflatable conical buoy (left) and metal drum (right)

Anchoring and mooring lines

Anchoring lines can, like all mooring lines, be made of **synthetic rope**, **steel cable**, **chain** or a **combination of several of these materials**.

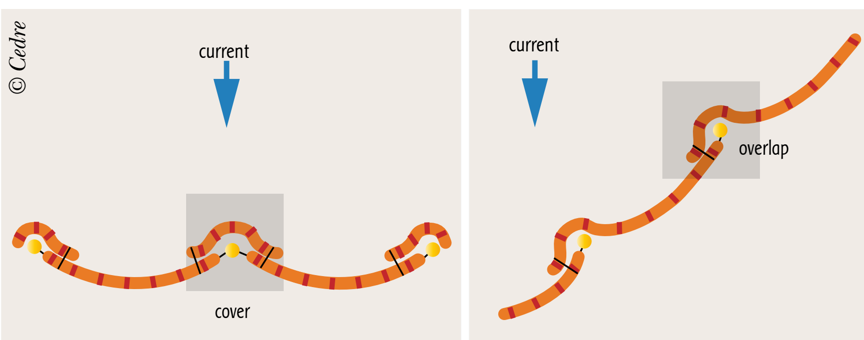
A length of heavy chain or the addition of an intermediate weight between the anchor and the rope considerably improves an anchor's hold and the boom's behaviour at the surface (shock absorber effect).

The ratio between the length of anchoring line and the water depth (between 3 and 5 to 1) must be respected.

The length of mooring lines should be adjusted according to the swell and tidal range. If they are too short, the boom will not correctly adopt the shape of the waves. Furthermore, the sharp wrenching action of waves is liable to move mooring blocks and deteriorate the boom's structure.

Oil-tightness and connection between sections

A boom comprising separate sections may be at risk of leaks from the section joins. This problem can be resolved by **doubling up the boom at each intersection by adding a cover section or overlapping sections.** To ensure an oil-tight seal, a boom in a single uninterrupted section can be used and intermediate moorings can be attached to floating drums.



Cover or overlap at boom intersections

On land mooring arrangements (temporary or permanent)

A mooring point should be positioned on land in an **accessible area** to ensure easy maintenance and periodical control of its condition.

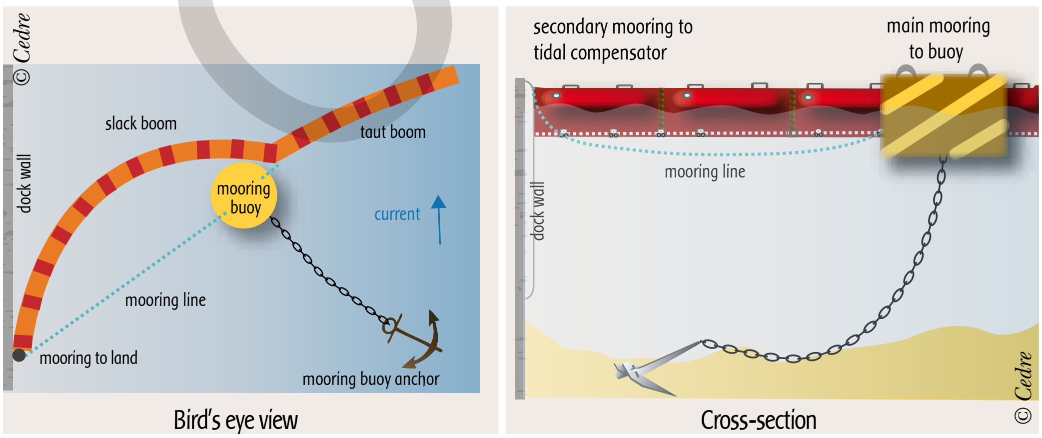
Mooring to a dock or bank

In most protective systems, the boom is connected to land at both ends, creating an oil-tight barrier and taking the strain of the boom. The dimensions of the mooring points must be sufficient to withstand the forces exerted on the boom. The use of port infrastructures and equipment (mooring rings, bollards, riprap, mooring posts), metal piles or make-do structures (tree trunks, buried mooring blocks, auger anchors) should be prioritised, if their position complies with the booming plan.

Before deploying the boom, always remember to moor one end to land.

Boom moored to bollard (top)
Boom moored to tree trunk (bottom)

Mooring technique to wharf



In areas with high currents, moorings to land should be doubled up where possible. The strain should not be placed on the last section, whose job is to provide an oil-tight seal. The boom should be attached to a mooring point (mooring drum/buoy) a dozen metres from the shore. This arrangement simplifies maintenance around the mooring and reduces the risk of the chain breaking.

Tidal compensators

During containment operations in ports and harbours, in particular in tidal areas, the pollutant is liable to escape between the end of the boom and its mooring (wharf, vessel).

To prevent leaks, the mooring should be **adapted to the tidal range or variations in water level**. Tidal compensators are designed to allow the boom to rise and fall with water movements and provide an oil-tight seal, whatever the water level.

It is better for the boom to be connected to the compensator with a quick disconnectable connector (ASTM standard). To prevent corrosion problems, the compensator can be fitted with an electrolysis prevention system and made of stainless steel or aluminium.

Manufacturers have developed **different rail systems, with or without integrated floats**.

T-shaped slide rail with Teflon® bearings

Sliding cylindrical float on permanent rail

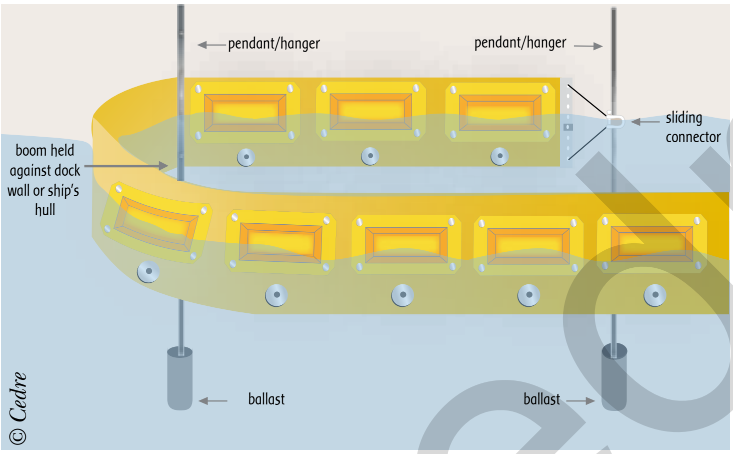
Sliding cylindrical tube inside permanent slide rail

Restraining cables

The purpose of these systems is to:

- moor a boom to a wharf or vessel in areas where the water level varies
- form an oil-tight seal by pressing the boom against the hull or wharf
- attach permanent booms under walkways or piers.

These systems can be used as **tidal compensators.** In this case, sliding shackles or hooks are directly connected to the ballasted cable. The boom will rise and fall with the variations in water level (tides) while remaining flush with the vertical dock wall, ship's hull or angled surface.



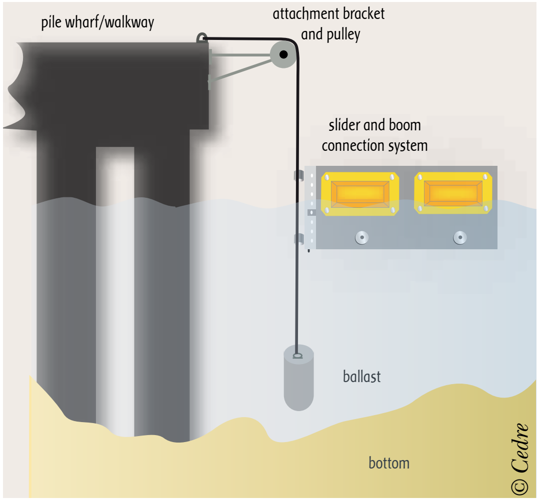
Set-up involving a restraining cable against a hull or dock wall

Ballasted rope to hold boom against dock wall

Cable taut between two vertical anchor rings

Cable attaching a boom to a rocky shore

Other example of sliding system on maintenance cable (pile wharf)



Cable taut between two vertical anchor rings

Magnetic anchors

Magnetic anchors are very useful to attach response booms to **metal surfaces on land** (piles, walkways, dolphins) or to a **ship's hull**. They are often used together with restraining cables so that the boom can rise and fall as the water level varies.

Their main advantage is that they are **quick to install** when connecting a boom to a metal surface. However magnetic anchors need to be **moved up and down** according to the water level variations (tides or loading/unloading operations).

Capstans

To deploy a boom in a port or harbour, a capstan, a **vertical-axled windlass**, can be used. It is essential to make sure that the capstan is powerful enough to take the strain generated by towing the boom. Capstans can be used together with **guide rollers** to reduce wear due to chafing of the boom's mooring line against the edge of the dock wall.

Magnetic anchor on a ship's hull

Boom interconnection and towing systems

Boom interconnection systems

When deploying a boom, several sections need to be connected up. The connectors used must provide an **oil-tight seal** between the skirt and float of each section, and **withstand forces exerted on the boom**.

Before choosing a connection system, in terms of **compatibility**, it is important to find out about the connectors of the booms already present on site or that partners (neighbouring industrial firms, port operators) are liable to mobilise in the event of a spill.

Bolt plates

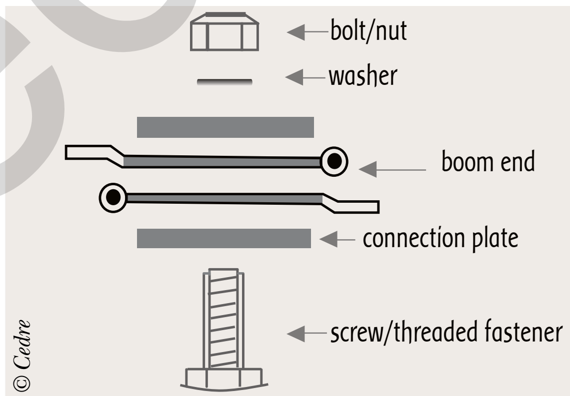
In France, CETMEF (the French centre for maritime and river technical studies) has, for instance, standardised the hole positions of bolt plates, to allow interconnection between different boom types. Two bolt plates are fixed to a section (one on the skirt and one on the float).

Flexible grooves, articulated vertebrae

Other connectors, such as flexible grooves and articulated vertebrae, are sometimes used in France. Booms that use these types of connectors should be fitted with strips at each end.

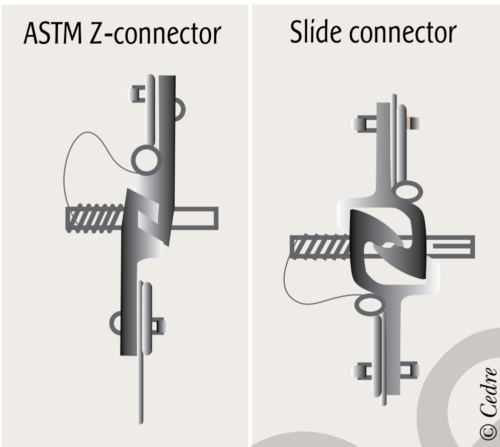
Bolt plate connector

Breakdown of a bolt plate connector



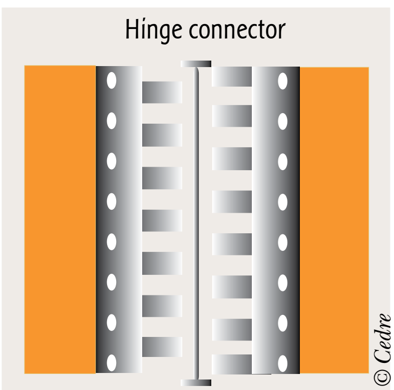
ASTM

In 1986, the American Society for Testing and Materials developed a standard connection system for booms (ASTM standard F962-04), in order to enable the interconnection of different spill response booms, whatever their size, shape or manufacturer. The advantages of this connector are that is its sexless (neither male nor female), it does not require any specific tools for assembly and it is quick and easy to connect.



Top-down view of the main types of ASTM Z-connectors and slide connectors

However, this ASTM connector is not recommended beyond a certain tension. When using inflatable booms for response at sea, bolt plate or hinge connectors should be used wherever possible.



Hinge connector

The international standard ISO 16446:2002 provides a method used to connect two booms fitted with different connectors, through the use of a standard adapter.

Towing systems

Towing systems are generally composed of:

- a steel tube fitted with a connection system suited to the boom (fastenings) and cables (bridle, asymmetrical to distribute the strain of towing), connected to the sling
- a galvanised or stainless steel towing sling (or heaving line), fitted with a towing ring and attached to the tube with shackles.

Towing an inflatable boom

Paravane

A paravane (or water kite) is a hydrodynamic system based on a **deflection principle**. Relatively complex to deploy, it nevertheless can be used to deploy and maintain various types of booms on a water body with a **constant current or flow.** It is composed of several vertical fins positioned below a float. It can be deployed from the banks of a watercourse or from a dockside and will pull the boom upcurrent, while the other end is moored to a point on land to hold it in place. As paravanes have a non-negligible draught, it is best to deploy them from a dockside into sufficiently deep water (1 m). A **recovery system** can be positioned at the end of the pocket formed by the boom along the bank. They can also be used at sea from a single vessel for towing/trawling operations.

Close-up of a paravane on a bank before being deployed

Boom deployment using a paravane and associated recovery system

Operational limits for boom deployment

The limitations on the use of booms are related to the possibility of maintaining an effective containment or protection system, without compromising human safety. These limitations are connected both to operational aspects of their deployment and maintenance, and to mechanical and hydrodynamic phenomena which reduce their efficiency.

The operations manager must analyse the situation to define the conditions of use of the booms available, taking into account their operational limits.

Environmental limitations (swell, sea state, current)

Although no set rule can be given, it is generally accepted that sea state 5 and/or a current speed greater than or equal to 3 knots is the upper limit for boom usage. See E4 "Beaufort and Douglas scales".

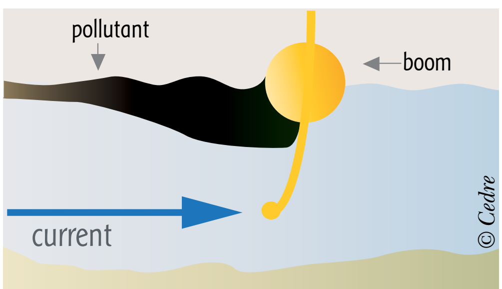
Possible leak scenarios

In general, in low currents, an oil slick that comes into contact with a boom will take on the configuration illustrated in the diagram below (optimal configuration).

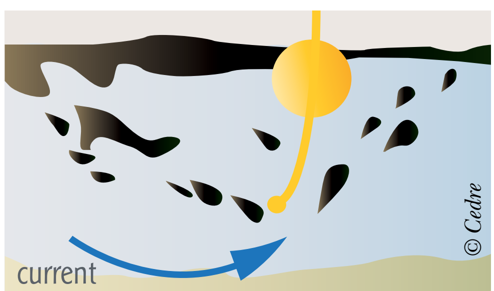
However, various hydrodynamic phenomena or factors relating to boom behaviour reduce a boom's ability to contain floating pollutant. Six main mechanisms which lead to reduced boom efficiency in real conditions can be identified. The appearance of these failures is naturally dependent on the environmental conditions and the nature and properties of the pollutant, as well as the boom's characteristics.

1. Entrainment

Due to hydrodynamic phenomena, droplets are pulled away from the underside of the slick and carried under the boom. Such leaks are a major drawback for boom usage, as they can occur in low currents: the commonly accepted value is 0.7 knots for a boom perpendicular to the current. This phenomenon is aggravated as slick thickness and current speed increase.



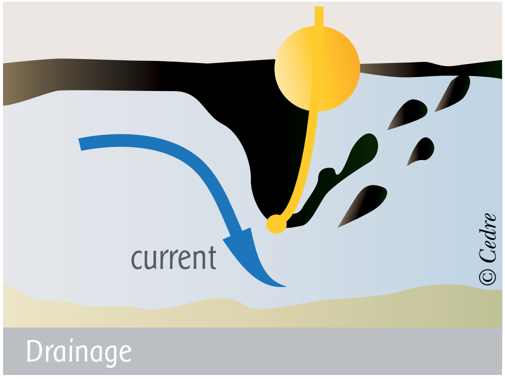
Optimal containment



Entrainment

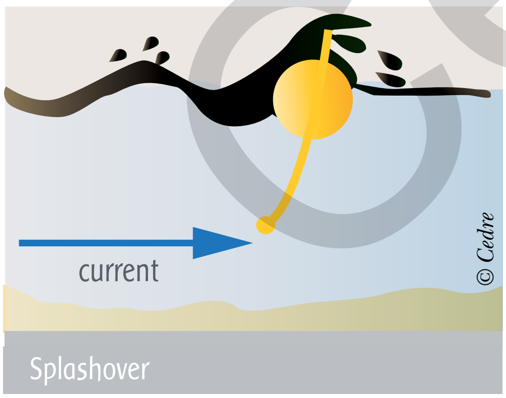
2. Drainage

In the case of relatively dense oil, the slick can become thick enough to be swept under the skirt, a phenomenon aggravated by water surface agitation.



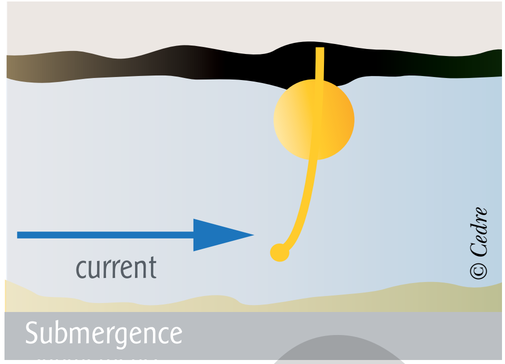
3. Splashover

In choppy or rough seas, a certain quantity of oil can often splash over the boom's freeboard (in particular when the boom's draught is low). This phenomenon is aggravated by waves with high amplitudes and low wavelengths.



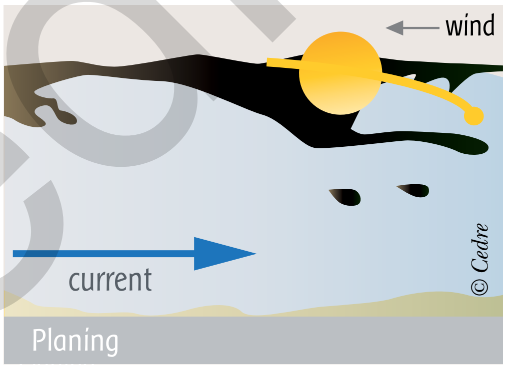
4. Submergence

When containment booms are moored in areas of strong current or towed at excessively high speeds, they can become submerged. The risk of deterioration is very high, as the boom will have reached its upper usage limit.



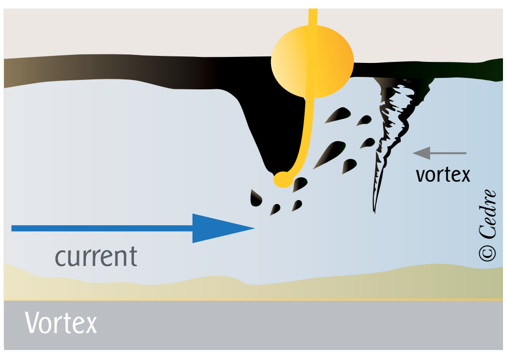
5. Planing

High wind and/or strong current in opposing directions can cause the boom to plane at the surface, especially if there is little ballast weighing down the skirt.



6. Vortex

Often when towing speed is too high or in areas of strong currents, vortex effects can be created behind the boom, dragging droplets of pollutant from the recovery area under the boom.



Depth

In shallow waters, the lack of depth under the boom causes the current to accelerate and can cause drainage or entrainment of collected oil under the boom. **In theory, the water depth below the boom should be at least 5 times the boom's draught** to prevent leaks and to achieve the theoretical conditions for efficient containment. It is generally accepted that, for medium-weight booms (0.70 m draught) and for average viscosity oils, oil will leak under the boom at a current speed of at least 0.7 knots perpendicular to the boom deployed on a water body less than 5 times as deep as the boom's draught.

Sediment type

To reduce risks of deterioration, it is best to avoid placing the boom in surf zones or in areas where there is a risk of it being caught (rocky outcrop, foot of cliff, wreck, deteriorated port structure...).

Tensile stress limitations

Floating booms are subject to tensile stress due to wind, currents and agitation of the water surface (chop, swell). To reduce the stress exerted on the boom and its mooring system, below are a few practical rules:

- **reduce the angle of deployment**
- **place moorings close together**
- **do not attempt to overtighten the boom (risk of boom breaking or tearing).**

In order to reduce tension-related risks, the resistance of boom elements should meet the minimum values indicated in the appendices.

Deployment rate limitations

Deployment speeds are highly variable according to the type of boom used. In normal deployment conditions, we can consider that the following times are required:

- approximately 10 minutes to deploy 100 m of foam-filled curtain boom stored in a container
- approximately 30 minutes to deploy 100 m of inflatable boom stored on a reel.

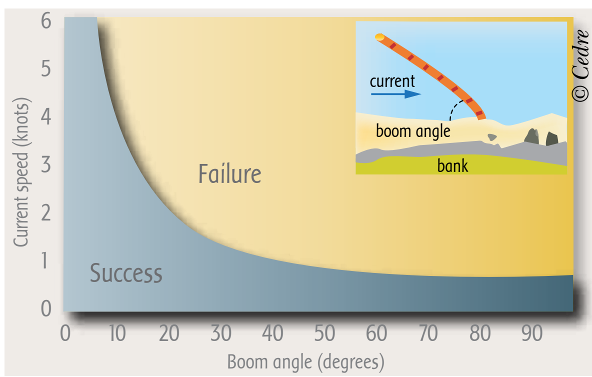
The deployment rate varies according to:

- the chosen configuration (boom length, number of moorings...)
- the site characteristics (accessibility, current speed, sea state...)
- the available deployment means (response time, personnel and their level of qualification, nautical means).

Current speed limitations

It has been demonstrated through experiments and feedback from real spills that the oil containment capacity of a boom placed perpendicular to the current is limited to a speed of 0.35 m/s or 0.7 knots. For higher speeds, the boom should be angled in relation to the current, in accordance with a certain number of rules.

Boom success according to current and deployment angle



In the presence of current speed S, the angle between the perpendicular plane to the current and the tangent to the boom should satisfy the inequality:

$$\text{Cos} \leq 0.35/S$$

S: current speed in metres per second

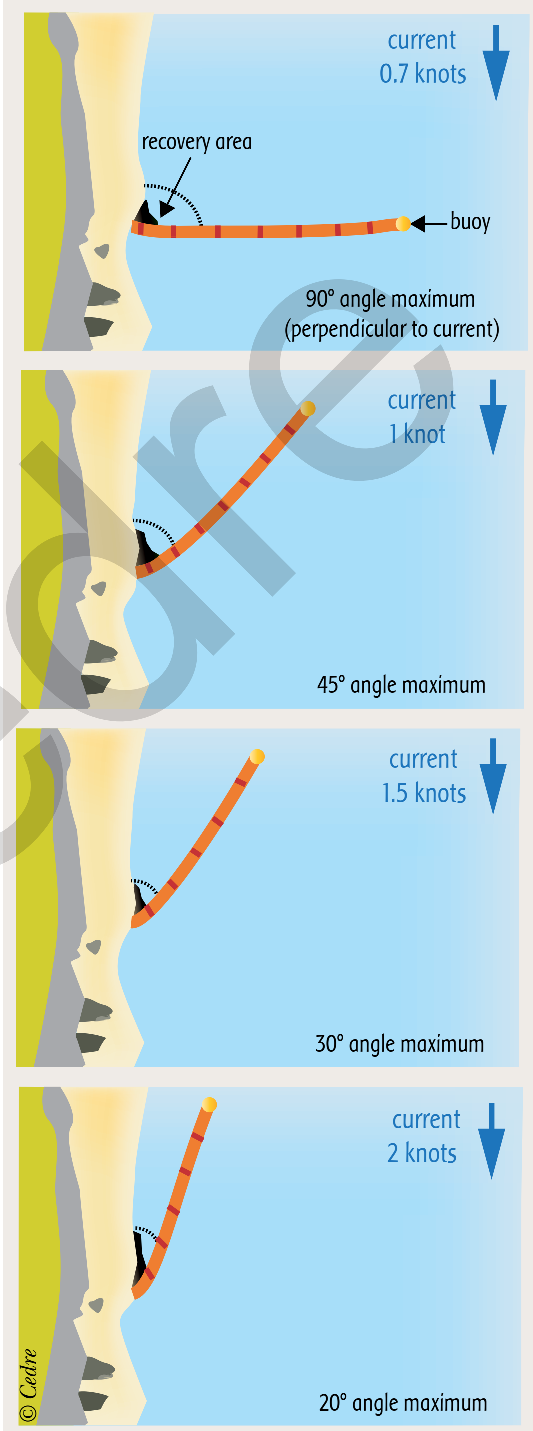
Over and above this formula, it is important to note that:

- **the current speed, running perpendicular to the boom, should be less than 0.35 m/s (or 0.7 knots)**
- **an angle of less than 15° will require excessive lengths of boom. It is preferable in this case to deploy several booms in a cascade or herringbone configuration, or even to decide not to use booms.**

An oblique arrangement will deflect the oil to areas where the current is lower and where it is easier to contain and recover it by pumping. This position is therefore recommended in almost all cases.

Beyond a speed of 2 knots, the containment capacity of most booms becomes very limited. In this case, it is preferable to arrange several sections in series with reduced angles of deployment to attempt to capture as much pollutant as possible.

Variation in boom deployment angles according to current speed



Dynamic trawling limitations

During boom towing operations by a single or pair of vessels as part of a dynamic slick containment operation, the following rules should be followed to prevent pollutant leaks or boom rupture:

- use **inflatable booms** where possible
- **keep the vessels' speed down to 0.5 knots, or 1 knot at most** (according to the size of the vessels and booms used, and the sea and weather conditions in the area)
- opt for **vessels able to work at very low speeds** to avoid damaging the towed boom
- in the open sea and in certain cases, the chosen strategy may be to **set up the containment system in a "stationary" position** (pair of support boats and port tugs for instance), in relation to the trajectory or direction of drift as slicks are pushed by the wind and surface currents. **In these circumstances, aerial guidance is a key element in the success of containment and recovery operations.**

Chemical containment limitations

A chemical spilt at sea can react in different ways. Changes of state, at varying rates, can limit the use of booms. In the case of a spill, reference should be made to the **Standard European Behaviour Classification (SEBC)**. This classification is based on the main physical and chemical properties of the substance, i.e. its state (solid, liquid or gas), its relative density with respect to water, its partial vapour pressure and its solubility in water. It indicates the pollutant's behaviour (sinker, evaporator, dissolver...).

In all cases, it is essential to **ensure that the substance to be contained is compatible with the boom's various components** (fabric, glue, connectors...).

SEBC category		Example of products	Boom usage
E	Evaporators	Hexane, benzene, gasoline	Generally not recommended
F	Floaters	Phthalates, heavy fuel oils, vegetable oils	Recommended
E and F	Floaters and evaporators	Styrene, xylene, aniline, ethylbenzene, crude oils	Possible, or in some cases recommended
F and D	Floaters and dissolvers	Diesel	Possible
D	Dissolvers	Acetones, acids, alcohols, ammonia	Not recommended
S	Sinkers	Dimethyl disulphide	Not recommended

Storage, pre-positioning and right-sizing

Booms are often deployed in an emergency to respond to a spill. Boom storage locations and methods should therefore be chosen and prepared to **enable rapid response and easy deployment, preferably close to high risk sites.** Contingency plans should define the locations that will ensure maximum efficiency in case of deployment. Furthermore, storage locations and methods that are appropriate for repacking will facilitate regular deployment exercises.

Storage solutions

The boom's storage solution and pre-positioning are predominant factors in its deployment time.

The different boom storage solutions are as follows:

- **vertical/horizontal reel** for inflatable/flat/self-inflating booms
- **crates/pallets** for small booms and single-use booms
- **containers or trailers** for solid flotation booms
- **floating pontoon in port area**, pre-positioned for rapid response in an emergency
- **floating pontoon on "lift"**
- storage system that can be **towed at high speed**.

Boom on a reel stored in a container

Boom on a floating pontoon

Boom on a pallet

Spill response pontoon on a "lift"

A few manufacturers also propose storage systems that can quickly be towed to a spill location (tow speed of up to 10 to 15 knots). The boom is packed into a large strapped bag that can be opened from the vessel to deploy the boom.

For successful future deployment, it is essential to correctly repack the boom after use.

Boom stored in a towable bag

Pre-positioning

Boom stockpiles should be pre-positioned as close to the potential pollution area as possible, and even on the water body in some cases. A reel can be positioned on the deck of a ship, a pontoon, barge, dock or jetty, ideally **near to high risk areas so as to reduce deployment time**.

Booms can also be stored in a trailer or container. With this option, booms can be deployed from land at different points on the same site.

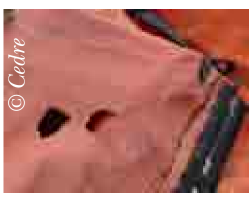
The boom and its accessories should be protected from the sun's rays, frost, weather (spray, wind...), acid attacks by bird droppings and rodents to prevent premature deterioration.

Reel stored on a trailer

In areas where the climate is humid (tropical or equatorial), it is important to make sure that the packaging is not airtight to prevent mould from forming and deterioration of the equipment.

During storage, to prevent premature deterioration, booms must be well protected against external attacks.

Sheet metal protecting a boom stored on a reel against severe weather and rodents



Boom damaged by a rodent

Examples of stockpile sizes (as an indication)

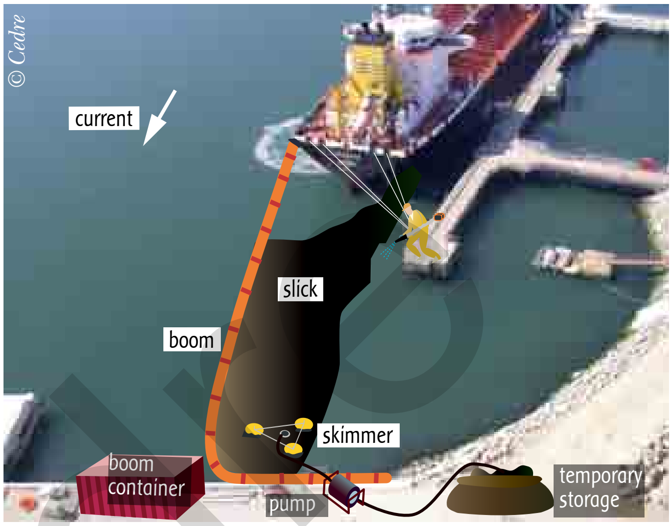
EXAMPLE 1: Protecting an oil terminal against a spill of FO/DFO/HFO

Scenario: Leak or rupture at flange, pipe or loading arm or collision with another ship

Consequences:

Substance spreads along and around the ship and slicks drift under the influence of tidal currents and wind on site at the time of the spill.

Response set-up - spill response equipment deployed



Spill response equipment required (as an indication):

Equipment	Quantity
Foam-filled curtain boom stored in container	2 x 150 m
Tidal compensator	2
Magnetic anchor	4
Displacement pump	1
Self-adjusting weir skimmer	1
Temporary storage tank	2 x 10 m^3
Sorbent boom with ballasted skirt	5 x 10 m
Sorbent boom	5 x 10 m
Multi-purpose motor pump to assist with containment and rinsing	1
Sorbent pads	2 bags of 100 pads
Transport trailer or container	1
Tow kit (tow bridle, steel cable...)	1

In addition to this equipment, nautical means will be required (pilot boat, tug and/or other available launch) to deploy floating booms, trawl slicks, protect water intakes on the shore, deploy skimmers and collect floating polluted debris.

A sanitation truck or vacuum truck should also be on site to regularly pump the pollutant collected into tanks on the dock.

After settling and pumping off the pollutant, the "clean" water should be released into the containment area.

Recovering a contained slick using an inflatable boom from the BSAD Ailette, Prestige, 2002

EXAMPLE 2: Recovering a slick of heavy fuel oil (HFO) at sea

Scenario: Major spill in the open sea, slight sea conditions.

Consequences: Pollutant spreads and drifts in slicks, pushed by the current and wind.

Setting up a boom in a J-configuration, CMA CGM Strauss spill, 2010

Spill response equipment required:

Equipment	Quantity
Inflatable boom, stored on reel	1 X 200 m
Self-adjusting weir skimmer with integrated pump	1
Heat pump for inflation	2
Hydraulic pump unit	1
Supply vessel	1
Port tug	1
Onboard storage tank (ship's own tanks)	Volume > 500 m^3

It is essential to have an aircraft (helicopter or plane) in order to guide spill response vessels to areas of high pollutant concentrations.

Equipment stockpiles, assistance conventions, insurance, hire/loan

Equipment stockpiles

Oil Spill Response is currently the largest international oil spill response cooperative. Based in Europe, it also has regional offices in Asia and the Middle East. For more information see: www.oilspillresponse.com

Other cooperatives work in a similar way: Clean Caribbean & Americas, Alaska Clean Seas, Marine Spill Response Corporation, Eastern Canada Response Corporation, Australian Marine Oil Spill Centre, NOFO.

FOST (Fast Oil Spill Team) is an oil spill response equipment stockpile that belongs to the Total group. It is based in the Bouches-du-Rhône area of France. It has the necessary equipment for response in France or abroad at oil facilities operated by the Total group or by other companies having signed an agreement with FOST. The team is staffed with skilled personnel from the Marseille marine fire department (BMPM). Its equipment stockpile includes nearly 5 km of boom (in 2011) and is ready to be sent by road or by air in an emergency. For more information see: www.fost.fr

French organisation

France has **14 marine pollution response stockpiles** along the French coastline, 8 in mainland France and 6 in overseas French territories, with over 50 km of booms (in 2011), mainly intended to protect sensitive sites. These centres are managed by the French Ministry of Ecology. For more information see: www.cetmef.developpement-durable.gouv.fr

Assistance agreements between port organisations

It is recommended that agreements be drawn up between port organisations to pool response equipment in case of a spill. It is important to check that these agreements are renewed and to regularly run response equipment deployment exercises between organisations within the same port area, without forgetting the local authorities.

Hire/loan of spill response equipment

Such agreements can be made between port or industrial organisations, in particular with contractors specialised in spill response that are able to rapidly provide equipment. It is important to check that the response equipment is interconnectable and compatible. In the case of hire or loan, it is important to find out about the repayment or replacement terms in the event of damage to equipment.

Insurance

Equipment deployed during exercises or in response to real spills can, in some cases, be insured against damage when used on site, or even against acts of vandalism.

Situation assessment

An islet protected by booms, Deepwater Horizon spill, 2010

When and where are booms used?

Conditions of use

The nature of the pollutant influences the decision on whether or not to use a boom. Below is a list of the main substances for which the use of booms is possible or not recommended.

Usage possible	Usage not recommended
• Oil in different forms (slicks, tarballs, emulsion) • Debris • Vegetable oil (castor, soybean, oleic acid) • Floating chemicals that evaporate slowly (phthalates) • Styrene, xylene, aniline, ethylbenzene (near coast or in port areas)	• Very volatile light oil (explosion risk, rapid evaporation) e.g. gasoline • Chemicals that dissolve or sink (acids, sodas, acetone, alcohols) • Chemicals that evaporate quickly (benzene, hexane)

B1

Floating booms can be deployed for the following operations:

- containing a spill
- trawling in the open sea or a port area
- protecting a sensitive site by surrounding it or deflecting the pollutant
- containing a spill in a port from a ship at dock
- inshore response, as part of so-called "second row" operations, in addition to offshore operations conducted by specialised vessels
- assistance in the recovery of polluted effluent from onshore clean-up
- deflecting a slick on a watercourse
- retaining a slick at the coast or on the bank of a water body to prevent it from being remobilised and polluting another site.

Spill response boom set up to contain any leaks, Melbridge Bilbao, 2001

Environments

Spill response booms can be used on different types of water bodies. According to the environment (offshore, inshore, port, inland waters) and the related constraints (hydrology, currents, weather conditions), booms are used differently.

Offshore

In the open sea, pollution response equipment must be deployed rapidly once an incident has occurred so as to limit drift and reduce the quantity of pollutant liable to wash up onshore. Such pollution may result from a shipwrecking or a platform incident, from an accidental or deliberate release.

In this case, booms can be used:

- **dynamically**, towed by one or more boats which recover the pollutant at the surface
- **quasi-statically**, downwind of slicks and in line with the current so as to collect "streams" of pollutant drifting at the surface in the boom
- **statically**, to contain a spill at the source (around a wreck for instance).

Boom around the wreck of the MV Princess of the Stars, 2008

Inshore

Near the coast, booms are often used as **protective means**. According to the type of site, its morphology and the currents present, they can also be used to **deflect the pollutant to facilitate its recovery** or to **contain the slick** at the coast to prevent it from polluting other sites.

- **Cliffs**: generally in exposed areas, with difficult access and are rarely priority sites for protection. Only cliffs in sheltered areas can, in some cases, be protected.
- **Rocks**: given the difficulty involved in their clean-up and their ability to trap pollutant, rocky coasts are worth protecting. Nevertheless, they can only be effectively protected if they form a bay subject to little wave action and currents.
- **Pebble beaches/spits**: in sheltered areas, such sites can be protected, a measure which is mainly justified by the difficulty in cleaning such sites when polluted.
- **Sandy beaches**: when such beaches are within bays (lower exposure), they can either be protected or be used to trap the pollutant. Cleaning a sandy beach may be strategically "preferable" over clean-up operations on rocky substrates. However, in both cases, booms can be useful either to protect them or to deflect and contain the pollutant.
- **Marshes**: such environments are priority sites for booming, as long as the waves and currents do not exceed the booms' efficiency limits. Pollutant should not be deliberately trapped in these areas, due to their difficult access, long self-cleaning times and high sensitivity.
- **Lagoons**: as it is difficult to protect lagoons at their mouth, booms may be laid within the lagoon itself, where currents are low.

- **Estuaries**: estuaries can be protected by laying booms to deflect the slick to a recovery area that can be accessed by terrestrial vehicles or to a "sacrificial" site, considered to be less sensitive. For tidal areas (variation in water level), booms should have good shore-sealing capacities. Few estuaries can however generally be protected as currents are often too strong.

Port areas

In ports and harbours, potential spill locations are generally known. In some cases, the use of **permanent booms** may be considered. These areas often have low currents, meaning that different types of booms can be used. The same cannot be said for certain ports in estuaries, where changes in current direction will need to be anticipated by setting up suitable moorings.

Clean-up sites

In the case of clean-up operations on banks or shores, booms are used to **contain run-off** at the water surface until it is recovered.

Inland waters

Lakes

In lakes, currents may be created by watercourses or other mechanisms, such as wind action at the water surface. In such cases, response techniques using spill response booms will be subject to the same constraints as offshore.

When the water body is calm and a potential pollution risk has been identified (e.g. presence of a petrochemical plant nearby), booms can be set up permanently.

Rivers

According to the flow rate and currents in the river, booms will be laid at varying angles (herringbone or chevron configuration). In this way, the slick will be deflected to an area of the watercourse where the flow is slower to facilitate recovery. Floating debris (branches, litter...), carried by the current and trapped in the booms, should be prevented from disturbing recovery operations and damaging the equipment.

Small watercourses

Booms will be laid across streams, from one bank to the other, so as to form a barrier to trap any passing pollutant.

Containing and recovering oil using a boom and sorbents

Selection criteria

			Fence booms: Permanent	Fence booms: Foam-filled	Curtain booms: Foam-filled: Compart-mented	Curtain booms: Foam-filled: Non-compart-mented	Curtain booms: Inflatable	Curtain booms: Self-inflating	Curtain booms: Shore-sealing
LOCATION/ ENVIRONMENT	OFFSHORE		Unsuitable	Unsuitable	Unsuitable	Unsuitable	Recommended	Can be considered in certain conditions	Can be considered in certain conditions
	PORTS		Recommended	Recommended	Recommended	Recommended	Unsuitable	Recommended	Unsuitable
	ESTUARIES		Unsuitable	Unsuitable	Can be considered in certain conditions	Can be considered in certain conditions	Recommended	Unsuitable	Recommended
	BEACHES/COASTAL AREAS		Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Recommended
	INLAND WATERS		Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions
ENVIRONMENTAL CONSTRAINTS	Swell/waves	Up to 2 m	Can be considered in certain conditions	Unsuitable	Unsuitable	Can be considered in certain conditions	Recommended	Can be considered in certain conditions	Unsuitable
		< 1 m	Can be considered in certain conditions	Unsuitable	Can be considered in certain conditions	Recommended	Recommended	Can be considered in certain conditions	Can be considered in certain conditions
	Surface current	> 1 knot < 3 knots	Can be considered in certain conditions	Unsuitable	Can be considered in certain conditions	Unsuitable	Recommended	Can be considered in certain conditions	Can be considered in certain conditions
		0.5 – 1 knot	Can be considered in certain conditions	Unsuitable	Recommended	Can be considered in certain conditions	Recommended	Can be considered in certain conditions	Can be considered in certain conditions
		< 0.5 knots	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended
	Bottom	Use on foreshore	Unsuitable	Unsuitable	Can be considered in certain conditions	Unsuitable	Can be considered in certain conditions	Can be considered in certain conditions	Recommended
	Wind	> 20 knots	Unsuitable	Unsuitable	Can be considered in certain conditions	Can be considered in certain conditions	Recommended	Can be considered in certain conditions	Can be considered in certain conditions
RESISTANCE – STORAGE - DEPLOYMENT	Storage on reel		Unsuitable	Recommended	Unsuitable	Unsuitable	Recommended	Recommended	Recommended
	Storage in container		Recommended	Recommended	Recommended	Recommended	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions
	Resistance to floating debris		Recommended	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions	Unsuitable	Unsuitable
	Resistance to trawling or towing		Unsuitable	Unsuitable	Can be considered in certain conditions	Recommended	Recommended	Can be considered in certain conditions	Unsuitable
	Easy cleaning		Can be considered in certain conditions	Recommended	Can be considered in certain conditions	Unsuitable	Can be considered in certain conditions	Can be considered in certain conditions	Can be considered in certain conditions

Recommended Can be considered in certain conditions Unsuitable

This multi-criteria approach should be interpreted with care. The table above is a guideline for the choice of spill response booms, which should be fine-tuned on a case-by-case basis.

Logistical requirements

Deploying a boom using earthmoving equipment

For sensitive sites identified in contingency plans as liable to require protection by floating booms, it is advisable to list the equipment required to deploy such booms in the appendices to the contingency plans (site protection plans, booming plans).

Equipment

Specific equipment is required to transport and prepare booms for deployment:

- Vehicle, such as a van or four-wheel drive, for transport on site
- Crane, lifting arm or power lift truck to lift the boom and its accessories
- Power shovels to lay out mooring blocks at low tide
- Specially designed catamaran or specialised vessels (lifting arm and quarterdeck) to lay moorings
- Keel boat (pilot boat, small tug, harbour launch, long boat) with motor suitable for slow towing speeds
- If necessary, small boats to guide deployment and conduct maintenance on the water and/or ensure diver safety (if mobilised)
- Portable compressor or backpack thermal blower to inflate booms
- Generator/hydraulic power pack/electricity supply for reels
- Heaving line
- Equipment to connect sections and moorings: chains with shackles, hooks, straps...
- Tractor or earthmoving equipment to handle the boom from a dock or bank, as well as for repacking
- Transceiver with programmed channels (VHF or walkie talkie)

Retrieving a fence boom from a wharf following deployment

Using a power shovel to help deploy a boom

Human resources

To set up a boom from a port, at least 4-5 people are required.

- 1 team leader on the dockside accompanied by an operator in contact with the boat who will check that the boom is deployed correctly and moor it to land if necessary
- 2/3 people on the boat (1 pilot, 1 worker, 1 adaptable operator in charge of radio liaisons during operations).

To ensure safety on the water (operators and equipment), it is advisable to have divers on site during boom deployment and retrieval operations, as well as for boom maintenance on the water.

The number of people required will of course vary according to the type of boom used on site, the length of boom, as well as the prevailing current and weather conditions. It is useful for the appendices of contingency plans (site protection plans, booming plans) to specify the human resources required.

Response - Practical datasheets

Precautions prior to response

When conducting spill response operations, operators must be **provided with suitable Personal Protective Equipment (PPE) according to the tasks in hand (handling, lifting, aquatic environment...) but also to the substances to be contained and recovered.**

To select suitable PPE for the given requirements, the Material Safety Data Sheet (MSDS) should be consulted. MSDS provide information on the pollutant's characteristics, the risks for operators, the possible impacts on the environment in the event of a spill and the pollutant's behaviour in the environment.

When deploying a boom, operators must be equipped with:

- A life jacket, in the case of personnel working on board boats and at the water's edge
- Safety footwear (for safety reasons, wear shoes rather than boots when working on board boats)
- Protective helmet
- Work gloves
- Hearing protection earplugs (if there is a power pack or other source of noise)
- Protective goggles (generator or power pack operators)...

If the operators are liable to come into **contact with the pollutant**, additional equipment may be provided:

- Resistant, waterproof gloves and coveralls that comply with the standards in force (mechanical, chemical, biological risks...)
- Protective goggles
- Protective mask with filter cartridges suitable for the vapours emitted by the pollutant, if necessary
- H_2S detector
- Self-Contained Breathing Apparatus (SCBA) if the pollutant produces toxic or particularly nauseating vapours.

Suitably equipped operator (PPE) for the task in hand

C1

Practical boom deployment datasheets

- Sheet 1: Deploying a boom
- Sheet 2: Protecting a sensitive site by closing it off
- Sheet 3: Protecting a sensitive site by deflecting the pollutant
- Sheet 4: Containing a slick around a ship
- Sheet 5: Dynamically recovering a slick offshore
- Sheet 6: Dynamically recovering a slick in coastal waters
- Sheet 7: Deploying a floating boom in a river
- Sheet 8: Using booms at clean-up sites

Deploying a boom

Before deployment

- Check that the boom is not liable to be damaged on rough surfaces during deployment (chafing).
- Facilitate boom deployment with **ground mats or tarpaulins** laid on the ground. In some cases, especially when deploying a boom in a harbour from the dockside, **guide rollers or corner protectors can help with deployment**.
- Ensure that mooring and connection elements are fully compatible.
- Fully unroll and preposition the boom in a "concertina" configuration on the slipway.
- **Place a buoy at the end of the boom on the bridle to prevent it from sinking** and so that it can easily be lifted on board or towed if necessary.
- **Always moor the other end of the boom to land**.
- In areas with currents, ensure that the mooring arrangements are sufficient (double mooring).

During deployment

- Ensure the boom does not twist.
- **Tow at low speed** (3 to 5 knots at the most) and constantly control the speed of deployment.
- Take into account the wind or cross-current: ideally deploy the boom in the same direction as the wind and/or current and hold the boom in place using additional semi-rigids to prevent it from grounding or disturbing traffic. Work at slack water whenever possible.
- Ensure constant communication (VHF, walkie talkie, or else mobile phone) between the on scene commander on land and the boat pilot.

During containment, deflection, protection or trawling operations

- Ensure that the boom is not under excessive strain (high risk of deterioration and tearing).
- Have the boom configuration (boom laying plan) and moorings regularly monitored by an operator (especially before spring tides or in deteriorating weather conditions).
- Make sure that no floating debris builds up, as this could damage the boom.

Deploying a non-compartmented foam-filled curtain boom

Protecting a sensitive site by closing it off

Environment: coastal and port areas, estuaries, marshes, inland waters, leisure areas.

Deploying an inflatable boom between two walls at a harbour entrance

Deploying a foam-filled fence boom to close off a harbour entrance

Equipment required to protect a harbour entrance

Boom	• Medium-weight curtain, fence (most commonly used) or inflatable boom, to be chosen according to the site. • Shore-sealing boom (in the case of a gentle slope and foreshore at low tide).
Nautical means	• Small tug/pilot boat • Semi-rigid support boat.
Mooring equipment	• If intermediate moorings are required: mooring blocks, metal drums or buoys, anchors, piles... • System for mooring to land (maintenance cables fixed vertically to dock wall or tidal compensators).
Additional equipment	• VHF, walkie talkie, radiocommunication means. • Heat pump for inflation (for inflatable booms), deployment mat, PPE and safety equipment (life jackets, life rings).

Set-up time: less than one hour (to close off 100 m), variable according to the length of boom and the site's constraints.

Number of operators required: 1 operations manager and 2 assistants; 1 driver; 3 workers (1 on each boat and 2 on land); boat crews. Other operators may be required to help prepare the boom on land.

After use: see C3 C4 C5 C6

Advantages	Drawbacks
• Protects port facilities and sensitive areas against floating pollution.	• Requires regular surveillance and maintenance (variable duration). • May disturb maritime traffic (certain systems have gates).

Deploying a spill response boom to protect a harbour entrance

1. The boom is unrolled on a slipway or flat area close to the water, prepositioned in a concertina configuration to facilitate deployment.
2. The support boat catches hold of the end of the boom and passes it to the pilot boat which will tow the boom. The other end of the boom is moored to land.
3. The boom is towed on the water at low speed.
4. The boom is moored to cables by the fastenings provided. The operators make sure the system is held in place and forms a watertight seal (against the dock wall and at the ends of the boom).

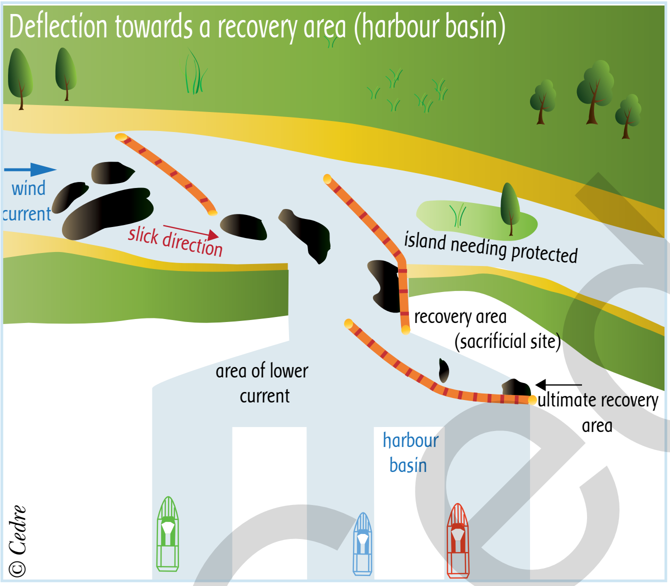
Boom deployment phases at a port entrance channel

Tips and pointers

- Organise a briefing before deployment at which the operations and manoeuvres will be clearly explained and the roles of each operator clearly allocated.
- Establish the boom laying plan according to currents and site exposure (improvisation = acute risk).
- Use the currents and wind to your advantage to facilitate deployment.
- Work at slack water wherever possible in tidal areas.
- Set up a gate, i.e. an opening (removable boom sections) between two mooring points, in the middle of a length of boom to facilitate navigation and avoid blocking traffic (fishing ports, passenger ferry traffic...).
- Anticipate changes in current direction by setting up a double mooring.
- Do not keep the boom overly taut (risk of rupture, tearing and planing).
- Where possible, deploy the boom at a slightly oblique angle to deflect the pollutant towards a containment/recovery area that can be accessed from land, thereby prevent the pollutant from accumulating in the middle of a section.

Protecting a sensitive site by deflecting the pollutant

- **Environment**: coastal and port areas, estuaries, marshes, inland waters, leisure areas.



- **Set-up time**: around 2 - 3 hours (to deploy three 30 m sections).
- **Number of operators required**: 1 operations manager and 2 assistants – 1 driver – 2 workers on board and the crew. Other operators may be required to help prepare the boom on land.

- **Equipment required to deflect a spill at the entrance to a harbour basin**

Boom	• Medium-weight curtain, fence (most commonly used) or inflatable boom, to be chosen according to the site. • Shore-sealing boom (in the case of a gentle slope, uncovered at low tide).
Nautical means	• Small tug/pilot boat/semi-rigid. • A paravane may be used from land.
Mooring equipment	• If intermediate moorings are required: mooring blocks, metal drums or buoys, anchors, piles... • System for mooring to land (restraining cables fixed vertically to dock wall or tidal compensators).
Additional equipment	• VHF, walkie talkie, compact radiocommunication means. • Heat pump for inflation (for inflatable booms), deployment mat, safety equipment (life jackets, life rings).

- **After use**: see C3 C4 C5 C6

Advantages	Drawbacks
• Prevents certain sites from being polluted by deflecting the pollutant towards areas considered "less sensitive" and more favourable to containment and recovery. • Holds well in current when correctly angled.	• Requires an area to be "sacrificed" to recover the pollutant. • Requires regular surveillance and maintenance. • Requires recovery operations to be carried out during containment to reduce risks of leakage.

Different set-ups to protect a sensitive site by partially closing it off

Deflection boom moored to a tree trunk

Protecting water intakes at a turbot farm, Prestige spill, 2002

Setting up a deflection boom using a paravane

Deploying an inflatable boom across a river

Tips and pointers

- Deflect and channel the pollutant towards a calm area to facilitate its recovery.
- Where site conditions allow, set up booms in series.
- Ensure deflection booms are set up at the correct angle according to the current recorded on site. Find the right compromise between angle and containment efficiency.

Containing a slick around a ship

4 SHEET

- **Environment**: open sea, sheltered area, port area, waterway.

Spill response boom deployed around a ship, Rokia Delmas spill, 2006

- **Set-up time**: around 2 - 3 hours
- **Number of operators required**: 1 operations manager and 2 assistants, 2 workers on board and the crew, variable number according to size of vessels.

- **Equipment required**

Boom	• Lightweight, medium-weight or even heavy-duty (offshore) boom
Nautical means	• Small tug/pilot boat (only in sheltered area or harbour)/semi-rigid.
Mooring equipment	• For intermediate moorings in the water: mooring blocks, metal drums or buoys, anchors, piles. • For mooring to land: restraining cables, tidal compensators or fixed mooring from one land. • Magnetic anchor.
Additional equipment	• VHF, walkie talkie, compact radiocommunication means. • Heat pump for inflation (for inflatable booms), safety equipment (life jackets, PPE, life rings).

Advantages	Drawbacks
• Reduces the impact of the pollutant by containing it as it is released from the ship until lightering operations can begin.	• Difficult to implement in rough seas and areas of strong current. • Requires pumping/recovery equipment to reduce leakage.

- **After use**: see C3 C4 C5 C6

Containing a spill around a ship

Containment around a ship at dock

(Examples of manoeuvres given as an indication only)

1. Tow the boom gradually in the same direction as the wind and/or current.
2. Attach the first end to a mooring on land. If necessary, connect the boom to intermediate anchoring points.
3. Moor the other end of the boom to land or to the ship so as to surround the vessel and prevent leakage (if available, use magnetic anchors).

Containment around an oil tanker at a wharf

Containment in the open sea

- Assistance from a support boat may prove necessary to hold the boom in place around the leaking ship.
- The boom laying plan should facilitate recovery of the pollutant from a containment area, ideally positioned downwind of the ship.

Booms deployed around the grounded Rokia Delmas, 2006

Specific case of wrecks

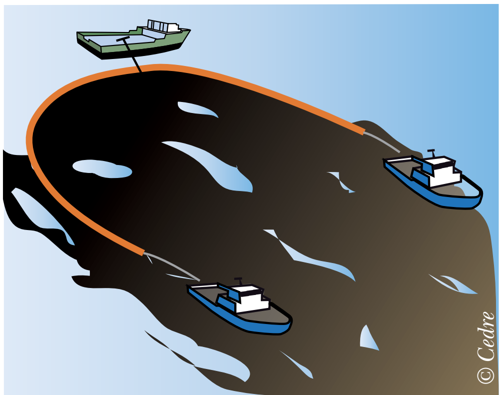
During operations to pump oil out of a wreck, a spill response boom (preferably inflatable) is placed at the surface directly above the wreck or at a position calculated according to the current and depth in the area. This will help to recover any residues that rise to the surface in the event of leakage when connecting up pipes for pumping or in the case of deliberate controlled release.

Tips and pointers

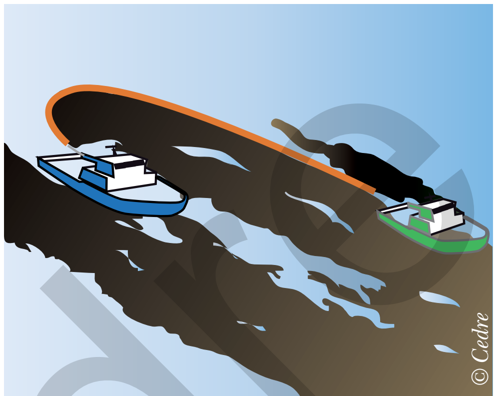
- In the case of current and wind in the same direction, the ship does not need to be completely surrounded: the boom can be placed at the end of the ship (downcurrent or downwind), between the ship and the wharf, to form a containment area.
- Place the boom downwind of the ship in the sheltered area created by the ship's hull.
- Current reversal (such as tides) or a change in wind direction requires surveillance by response vessels to prevent the boom from being pushed against the leaking ship. In this case, systems of outriggers can be set up.

Dynamically recovering a slick offshore

- **Environment**: open sea. Slight to moderate conditions (sea state 4 to 5 at most).



Recovery in a U-formation (static situation)



Recovery in a J-formation (dynamic situation)

- Equipment required

Boom	• Boom (inflatable), heavy-duty (height > 1 m).
Nautical means	• A supply vessel for positioning the boom on the water and deploying the skimmer, with internal storage capacities (integral tank in the vessel's structure and, if possible, a heating system to facilitate the pumping of viscous products). Onboard storage capacities placed on deck can also be used. • A port tug, trawler or large launch with sufficient motor power to tow the length of boom and to open and maintain the containment area.
Aerial support	• Helicopter, guidance plane or other aerial means (microlight, drone)
Additional equipment	• VHF, walkie talkie, radiocommunication means. • Heat pump for inflation, safety equipment (life jackets, life rings). • In the case of light or crude oils, explosive atmosphere measurements must be taken and suitable PPE worn (respirator masks, gloves...).

- **Set-up time**: around 2 hours (inflation, boom launch and operational set-up).
- Number of operators required: around 10 (variable from one case to another).

- **After use**: see C3 C4 C5 C6

Advantages	Drawbacks
• Reduces the impact of the pollution on the shoreline by removing as much pollutant as possible from the sea.	• Requires large storage capacities onboard to reduce transfer to land (perform settling at sea). • The recovery/containment system's efficiency is highly dependent on the sea and weather conditions in the area.

Setting up dynamic recovery

1. The boom is inflated and deployed from the spill response support boat.
2. A port tug catches hold of the free end of the boom and moves upstream, bypassing the drifting slick as best it can, to finally position itself upstream of the support boat so that the towed boom forms a J-configuration. The slick enters the containment system and accumulates at the apex of the boom.
3. The slick collected at the apex of the boom is recovered by pumping.

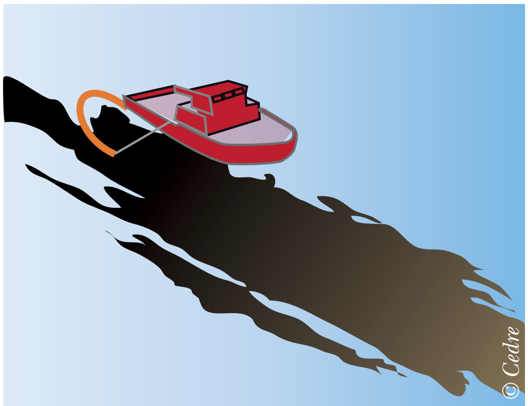
Trapping a slick, Prestige spill, 2002

Tips and pointers

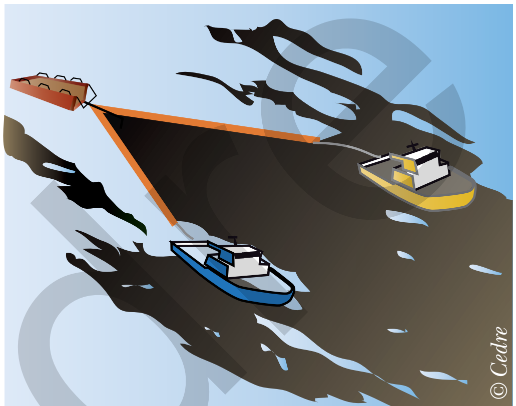
- Use very manoeuvrable boats, able to work at low speeds (< 2 knots).
- Do not suddenly accelerate, change speed or turn.
- Position the apex of the boom as close to the supply vessel as possible to reduce the length of pipes required by the skimmer (head loss).
- Once the quantity of pollutant collected in the boom is considered sufficient, rapidly deploy the skimmer to prevent leakage.
- Guide vessels using aerials means (plane, helicopter, drone...) to help to detect slicks.
- Place tracking devices on the slicks to monitor their drift (marker buoys).
- Prevent the slick from being broken up by spill response vessels as far as possible, in particular in the case of heavy viscous products that can be pumped.
- Doppler current meters can be fitted to the apex of the boom to ensure that the towing speed is not in excess of the boom's capacities.

Dynamically recovering a slick in coastal waters

- **Environment**: port areas, estuary areas, shallow coastal waters (in which offshore spill response vessels cannot work due to the depth).



Recovery by a single vessel fitted with an outrigger



Recovery in a V-formation with a recovery barge

- **Equipment required**

Boom	• Medium-weight curtain or inflatable boom or even sorbent boom (preferably with ballasted skirt, used exclusively in very sheltered areas to recover sheen).
Nautical means	• Nautical support: 1 or 2 light boats with low draught and sufficient motor power (> 55 hp), trawler, oyster barge... • 1 paravane (optional, use manoeuvrable boats where possible).
Additional equipment	• VHF, walkie talkies, cables or hawsers for towing, outrigger if trawling by a single vessel.

- **Set-up time**: around 30 to 45 minutes (or more according to where the boats and booms are pre-positioned).
- **Number of operators required**: 1 pilot and 2 workers on each boat (variable according to size of boats).

Advantages	Drawbacks
• Can be used to work dynamically to collect slicks from shallow areas where offshore vessels cannot be used. • Can be used to recover pollutant from difficult access areas.	• Delicate operations requiring thorough training for crews and suitable boats. • Requires good knowledge of the response area (sand banks, currents) • Inefficient operations in rough waters.

- **After use**: see C3 C4 C5 C6

SHEET 6

Dynamic towing (surface trawling)

Towing a sorbent boom with ballasted skirt or medium-weight curtain boom using a single vessel

1. Install an outrigger protruding by at least 3 metres either towards the front or the rear of the vessel according to attachment possibilities.
2. Attach each end of the boom (maximum 15 metres long) to the outrigger using towing slings or hawsers.
3. When the system reaches saturation, tow it at low speed (< 0.7 knots) to land (or a vessel) for recovery.

A paravane can also be used to hold the boom apart from the boat.

Towing a curtain boom using a pair of vessels

1. Place the boom in the water and tow the end of it behind one of the boats.
2. Once the boat is close to the slick, the second boat catches hold of the free end of the boom and adopts a U-configuration. This set-up is positioned into the current and is towed at very low speed (less than 0.7 knots).
3. When the system reaches saturation, tow it to land at low speed and recover the pollutant (or use a third vessel to collect the pollutant from the apex of the boom).

Towing a boom in a U-configuration using a boat and a paravane

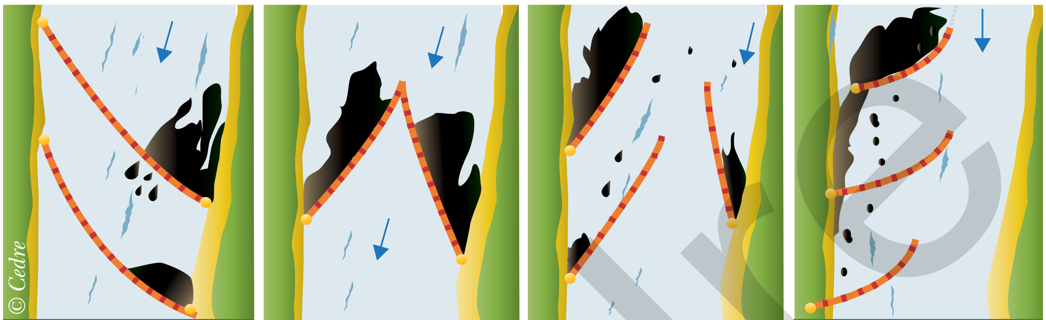
Boom in a U-configuration towed by a pair of vessels

Tips and pointers

- Use a boat with a V-shaped hull where possible (semi-rigid).
- Direct boats from a high point overlooking the water body (on a hill or roof of a building) and communicate by VHF.
- Use sufficiently powerful boats with a low draught and good drift resistance (lateral traction).
- Contain small quantities by managing the transfer of the collected pollutant to land or to another vessel, rather than letting large quantities build up, which could be liable to escape from the containment area.
- In optimal sea and weather conditions, one technique that can be considered consists of closing off the booms to form a circle after each containment operation and leaving the enclosed slicks to drift until recovery means are deployed.

Deploying a floating boom in a river

- **Environment**: rivers, calm sections of rivers and estuaries, continental waters in general



Oblique configuration in series | Chevron configuration | Herringbone configuration (each side of river) | Cascade configuration

- **Equipment required to deploy a spill response boom obliquely on a river**

Boom	• Floating booms (fence or curtain).
Nautical means	• Motor boat except for shallow, narrow watercourses where the boom can be deployed on foot.
Mooring means	• If intermediate moorings are required: mooring blocks, metal drums or buoys, anchors, piles. • Heaving line. • On land mooring arrangement. • In areas of constant current, where the water is deep enough, paravane systems can provide good results.
Additional equipment	• VHF, walkie talkie, radiocommunication means. • Deployment mat, safety equipment (life jackets, life rings).

- **Set-up time**: variable according to the system to be deployed.
- **Number of operators required**: 1 pilot and 1 worker on the first boat, 1 operations manager and 2 operators on land. 2 operators on the second boat according to availability.

Advantages	Drawbacks
• Channels the pollutant upstream of the site to be protected. • Response means required are easy to deploy (lightweight equipment).	• Can disturb navigation. • Efficiency limit (if current > 2 knots) and irregular recovery. • Difficult to define equipment deployment areas (pollutant drift).

- **After use**: see C3 C4 C5 C6

Example of deployment: oblique configuration

1. Grab hold of the tow bridle and attach it to the boat. Tow the boom at low speed, ensuring that it is correctly deployed.

2. Moor the end of the boom to the bank, in compliance with the predefined angle (use a heaving line if necessary).

3. Protect the bank next to the recovery area with sorbent (or protective sheeting). Using a fire hose with a flat spray, creating a surface current, helps to contain the pollutant in the area where the skimmer is deployed.

4. At the end of the operation, retrieve the boom via the slipway using the carry straps. After the boom has been cleaned and dried, fold it in such a way as to ensure rapid and efficient deployment when next used.

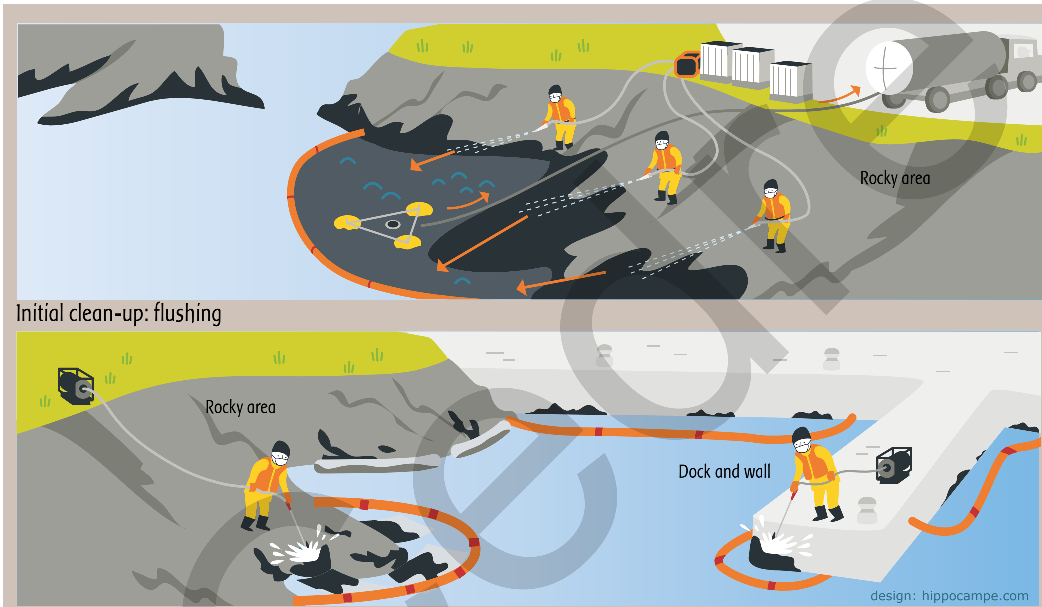
Deploying, using and folding away a boom on a river

Tips and pointers

- The presence of floating debris in the containment area can impede pollutant recovery. In some cases, booms can be protected from floating debris by nets stretched across the surface, upstream of the boom. Maintenance should be periodically performed on these nets.
- On waterways, the passing of vessels generates a bow wave that places a strain on the moorings and alters the boom's buoyancy. If clean-up operations are in progress, the speed at which passing vessels are allowed to travel should be reduced (less than 3 knots) and the systems set up may be larger than necessary where required.
- A counter-current is generally observed in the recovery area along the bank: ensure this recovery area is fully oil-tight to stop any pollutant from moving upstream.

Using booms at clean-up sites

- **Environment**: coastal and port areas, estuaries, banks... (any polluted coastal or inland waters requiring clean-up operations)



Initial clean-up: flushing

Final clean-up

- **Equipment required to deploy a spill response boom**

Boom	• Shore-sealing boom, lightweight floating boom (if recovery on water), fence boom, sorbent boom with ballasted skirt or ordinary sorbent boom.
Additional equipment	• Shovels, power shovels, planks... • Geotextile. • Sorbents (pads, booms, mats...). • Washing equipment (pressure washers...).

- **Set-up time**: variable according to the system to be deployed
- **Number of operators required**: at least 2

Advantages	Drawbacks
• Reduces dispersion of the pollutant and traps washing effluent, with a view to recovery.	• Is dependent on tides. • Complex in difficult access areas (cliffs with no access by land, rocky outcrops...).

- **After use**: see C3 C4 C5 C6

Setting up a clean-up site

Containment and recovery of effluent on the water surface

The aim is to set up a system to recover floating effluent from washing operations, in front of clean-up sites.

Floating or sorbent booms are used, moored to the shore. The pollutant is recovered, by sorption or pumping, from accumulation areas.

Effluent contained by booms at a riprap clean-up site

Containment and recovery of effluent on the foreshore

The aim is to recover effluent from washing and draining operations on the beach. Run-off is channelled using trenches and pits (lined with tarpaulins or planks). A shore-sealing boom can be used to retain the effluent. A dam can also be built by covering bunds of sand with tarpaulins.

View of a clean-up site and a section of shore-sealing boom used to contain polluted effluent

Tips and pointers

- In sheltered areas with low current, ordinary sorbent booms can help to contain a spill. These booms are very lightweight. Models with integrated ballasted skirts also exist on the market.
- Use a fire hose connected to a motor pump to help push the effluent (polluted water and washing residues) towards a recovery area.

How to clean booms

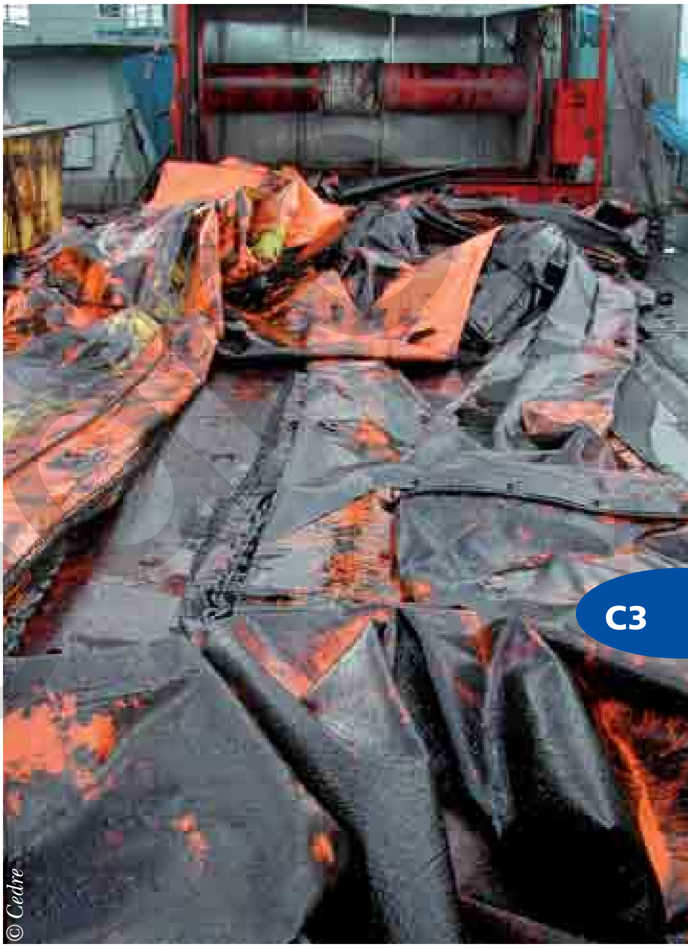
> Weathered oil that has dried onto a boom makes it difficult to clean and can be very problematic. Booms should therefore be cleaned as soon as possible after use.

As an indication, below is an inventory of the equipment required to clean 100 m of lightweight fence boom:

- Watertight washing platform (minimum surface area of 20 m x 5 m) with gutter and oil separator (drydock or treatment facility).
- Sorbents: 2 x 30 m rolls of sorbent and 20 m of sorbent boom (if risk of effluent leaking into a water body)
- Geotextile (150 g/m^2 non-woven geotextile to protect ground), around 50 m^2.
- Washing agent without surface-active agents (80 litres), sprayer.
- High pressure washer with suitable nozzle (80 bar pressure) and motor pump (with connectors, hose, jerrican, funnel), fuel.
- Fresh water (around 5 m^3).
- Brush, shovel, bucket, big bag, storage skip for waste recovery and storage (oiled sorbents, damaged booms...)
- Vehicle/lifting equipment for waste removal (tractor, loader or crane; equipped with hooks and straps).

To estimate the time required to clean a boom, allow approximately:

- one hour for 50 m of boom for slightly adhesive products,
- one hour for 10 m of boom for viscous products.



State of a boom after a containment/recovery operation at sea, Prestige spill, 2002

The phases involved in cleaning a boom are:

- Preparing the washing area.
- Spraying with washing agent if necessary.
- Leaving agent to take effect (at least 15 minutes).
- Brushing the boom.

High pressure washing of a spill response boom

- Cleaning with water using fire hoses or cold or hot water pressure washers with a suitable nozzle.
- Low pressure rinsing with fresh water to remove the oily film and small tarballs formed by the previous actions.
- Quick rinsing of the cleaning area, if necessary.
- Washing the second side possibly followed by further washing of the first side if it has been recontaminated.
- Drying and talcing.
- Repacking the boom (reel, container, trailer...) See C5 .
- Closing down the clean-up site.

- Rinse the chain casing with fresh water to prevent seawater from corroding it. Ideally, dry before repacking.
- Adjust the washing pressure and temperature (80-90 bars, 80°C max) to avoid damaging the boom fabric.
- Never let the nozzle of the pressure washer come into contact with the boom fabric, in particular in the case of inflatable booms.
- Recover or filter washing effluent.
- Hang the boom up to wash it where possible.

Machines have been designed to wash booms. Some of these machines were invented during the operations in the Gulf of Mexico in 2010, following the Deepwater Horizon rig explosion. Permanent washing benches that can be used to hang booms up also exist, making it easier to clean them (access to both sides).

Mobile cleaning barge

How to maintain booms and their accessories

The maintenance operations that should be performed on the boom when out of the water are as follows:

- **Repair torn fabric** using the kit provided by the supplier that should contain at least: pieces of plastic fabric, tube of glue, solvent, pair of scissors... The humidity and temperature of the glueing environment are very important for the success of these repairs.
- **Oil** shackle pins.
- **Mouse** shackle pins.
- **Talc** fabric.
- **Check and/or replace plastic "fuse" bolts** at the bottom of the fabric, designed to give way before the fabric tears.
- **Check inflation valves**, spring/valve system.

In the case of inflatable booms, make sure all the air has been removed from the air chambers. The humidity in the air could damage the boom during storage.
Also **check that the inflation valves are functioning correctly** and regularly **test their pressure resistance.**
Finally, it is important to **check the quality of welds in the fabric.** After use, oil or other pollutants can enter the fabric, and are liable to affect the boom's mechanical properties.

Regular checks on so-called "additional" equipment such as reels, mooring arrangements, tow lines, thermal or hydraulic generators... should also be planned.

Plastic "fuse" bolt

Inflation valve

Pieces of fabric joined together by heat sealing

C4

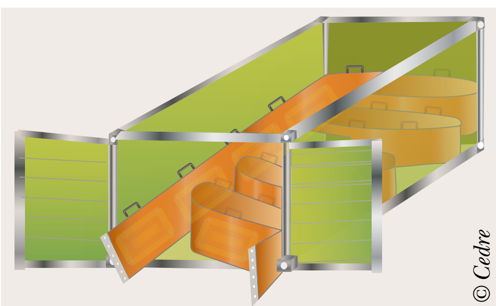
How to repack booms after use

Once the boom has been **cleaned, dried and talced** (see C3), it will need to be repacked. Before doing so, it is important to check all the points required for it to function correctly using a complete checklist.

CHECKLIST	
Check the condition (wear, oxidation, deformation) of: • the chain • the fastenings • the connectors • the tow bridle	 ❑ ❑ ❑ ❑
Presence and condition of all fuse bolts	❑
Signs of chafing, tearing, breaking...	❑
Condition of heat seals in the fabric	❑
In the case of inflatable, self-inflating and shore-sealing booms: • identify deflated sections • check valves are in good working order	 ❑ ❑

Following these checks and any resulting repairs, the boom will be **repacked in such a way as to ensure rapid and efficient deployment when next used**. The boom fabric should be talced before repacking.

Once repacked, it is important to protect the boom (rain, spray, sun, bird droppings, rodents...). To prevent such attacks, a closed container is often the chosen storage solution.

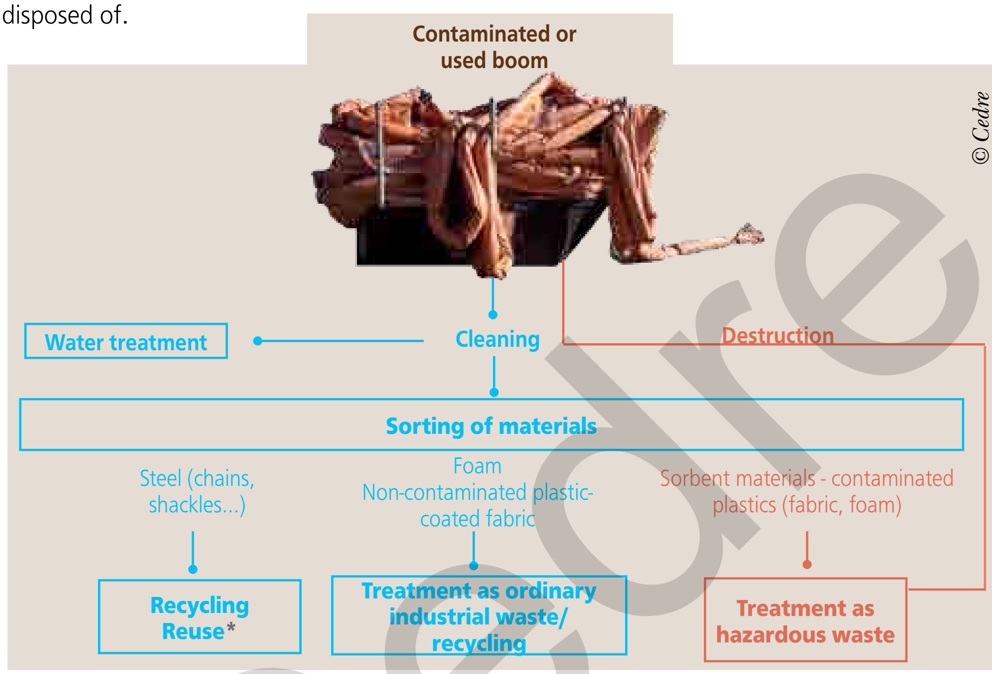


Method of folding a boom stored in a container so as to facilitate its deployment and mooring

Non-compartmented foam-filled curtain boom in a container

What to do with booms at end of life

The methods of disposing of used booms depend on the observed degree of oiling of the sections to be disposed of.



Collection and transportation

The collection and transportation methods for used booms are identical to those of the products with which they have been polluted. For instance, in Europe oiled waste is subject to the ADR regulation (European Agreement concerning the International Carriage of Dangerous Goods by Road) for oil.

Treatment as ordinary industrial waste

According to the locally available disposal facilities, waste may be:
- buried at landfill sites
- incinerated with or without energy recovery
- recycled.

Waste will only be sent to landfill if recycling and incineration are not possible in technically and economically acceptable conditions.

Treatment as hazardous waste

Contaminated, hazardous waste is either incineration at specialised hazardous waste treatment plants, or buried at specialised hazardous waste storage facilities.
A hazardous waste tracking slip should be provided by the waste producer and transferred to each party involved, from collection and transport to treatment. In France, this tracking slip must be kept for 5 years.

Recycling

Recycling involves reintroducing elements of the boom into the production cycle from which they were obtained, to totally or partially replace new raw materials.

* Many boom components can be reused to build custom-made booms: fabric, foam, chains...

Monitoring and evaluation

D

Boom failure due to currents

Dos and don'ts

D1

◗ Do not moor the boom using the handholds often positioned at the top of the floats or flotation chambers.

▶ Attach the boom by the ballast chain or tension member.

◗ Do not allow a gap between two sections of boom.

▶ Check that connections are oil-tight (compatibility issues or rupture due to excessive tension).

◗ Do not deploy a boom hastily (to prevent it from twisting for instance).

▶ Guide and control its deployment in the water.

- **Do not attach a boom to a fixed mooring in an area where the water level varies.**
  - Use tidal compensators or set up surveillance.

- **Do not store booms in conditions in which they may be exposed to the sun (UV rays), severe weather, spray or rodents.**
  - Prioritise the storage of booms in closed containers, placed in a shelter or barn or cover with tarpaulins.

- **Do not deploy a boom immediately next to an area of stronger current** (bridge piers, narrowing of a river bed...).
  - Shift the boom laying plan to a calmer area.

- During **dynamic recovery** operations on the water, **do not tow the boom at a speed that is liable to make it sink or cause leakage.**
  - Adjust the speed to ensure the best result in terms of recovery.

Booms' weaknesses

Among the main weaknesses identified for booms, we find:

- inflatable air chambers sensitive to pressure loss, puncture, chafing or piercing due to rubbing against rough surfaces.
- connection elements (shackles, connectors, fastenings, connection to compensator).
- insufficiently sized anchors, liable to slip.
- colonisation by aquatic organisms (algae, barnacles), attached to the underwater part of the boom, liable to alter its balance during long periods of use or permanent deployment.
- weathering due to environmental factors (temperature, UV, salt, spray).
- tensile strength for towing or trawling.
- quality of materials and fittings used (prioritise the use of equipment that has been tested and is reputed to be reliable).
- electrolysis of metal parts.
- strain on the chain.

Boom ripped away from a tidal compensator

Broken chain causing a tear

Breaking away of boom sections at a connection during recovery operations at sea (Prestige spill, Spain)

A tear caused when towing an inflatable boom, due to excessive towing strain

Practice, training and exercises

Training and exercises involving both site operators and external operators (berthing station, pilotage, port authority) should be **carried out periodically**, in the same way as fire drills.
Such exercises should be organised as regularly as possible to **maintain a good level of knowledge and ensure a rapid response**, taking into account staff changes where relevant.

During exercises, the response strategies described in the **contingency plan** are implemented. Through such exercises, operators are able to familiarise themselves with the handling of spill response equipment and, in particular, to practise manoeuvring the nautical means involved in deploying and retrieving booms.

Exercises, combined with planned training actions, can be used to validate or improve pre-established boom laying plans.

Briefing during a practical training course

Boom deployment exercise on a river

Marker systems

Setting up a light signal on a mooring buoy

D4

When deploying booms at sea or in inland waters, it is important to indicate the presence of the boom by:

- positioning **light signals on mooring buoys**
- positioning **light signals at gates** if navigation is not suspended (entrance to port or navigation channel)
- informing:
  - the maritime authorities in charge of traffic surveillance (MRCC...) of the presence of the boom so that they can issue a **navigational warning** (broadcast by VHF and displayed at port authorities).
  - the navigational control authority, for waterways and locks.

It is recommended to use booms that can be easily seen (bright colours, reflective strips). Additionally, flashing lights or metal plates designed to reflect waves (radar) can be used.

Organise regular patrols on site to check that light signals are in good working order and the system is properly in place.

Maintenance on the water

Once the floating boom has been positioned on site, it is important to control its efficiency throughout the pollution threat.
Regular checks should be conducted according to the type of boom and local conditions, to determine the state of the boom and in particular sensitive points such as:

- **The general set-up**: check that the moorings and boom are still in their initial configuration, especially when the tides change. Increase the resistance of mooring points, or add additional moorings if required.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- **Oil-tight seal**: check that the boom has not been damaged by a passing boat (as a preventative measure, set up light beacons to indicate its presence); check that the shackles connecting two booms are screwed tight (if necessary, mouse them with wire to prevent them from coming loose).
- **Flotation integrity**: ensure that the flotation chamber or an inflatable or self-inflating boom is not punctured (leaking), deflated or permeable. In some cases, it may be wise to add flotation to improve the boom's hold.
- **Seaweed and shells**: clean the boom on land or from a boat using a fire hose or, if it is heavily encrusted, using a pressure washer (it is also possible to use a hand scraper or brush).


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- **Condition and wear of ropes**: monitor their condition if they are subject to chafing against a metal or concrete part. Replace them if worn.
- **Debris**: regularly remove floating debris (plant matter, plastic...) trapped in the boom.


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Monitoring actions are conducted from a small light craft, possibly with assistance from divers for small-scale repairs. More major maintenance operations (for instance repairing a torn boom) require the boom to be brought on land.

D5

Media impact of boom deployment

Communication actions will be carried out close to the pollution areas and clean-up sites. In the presence of the media and general public, it is sometimes necessary to explain that a **floating boom is not an impassable obstacle** and that, above a certain current speed, even if the boom is correctly positioned, there is a **risk of leakage**.

Yet booms are often the first response strategy deployed when responding to a spill on a water body. Often brightly coloured and easily visible, they clearly demonstrate to the media and general public that response measures are being taken. They are often the "material evidence" that operators have access to response resources.

However, **boom deployment is not justified in all situations**:

- When the environment and weather conditions do not allow for their use. In these conditions, it is preferable not to use booms rather than putting operations at risk, causing damage to the equipment, giving rise to images of leaks of pollutant escaping behind the boom which will inevitably be exploited by journalists and will jeopardise the credibility of operations.
- When the system proves to be inefficient, it does not contain the pollutant sufficiently to enable its recovery.

D6

Further information

Glossary and acronyms

ADR: the European Agreement concerning the International Carriage of Dangerous Goods by Road.

AFNOR: French standardisation association.

ASTM: the American Society for Testing and Materials, which develops standards on materials, products, systems and services.

Big bag: large flexible container fitted with loops for lifting.

Bund: construction or earth dyke, possibly held by a stone supporting structure.

CETMEF: French centre for maritime and river technical studies.

Chrome plating: galvanisation with chrome.

Coating: protective layer, generally made of plastic, applied to fabric.

DaN: a decanewton is equivalent to 10 newtons. One newton is the unit of force required to accelerate a mass of 1 kilogram at a rate of 1 m/s^2. One newton is therefore required to increase the speed of a mass of 1 kilogram by 1 metre per second. The forces exerted on booms are sometimes given in tonne-force. (1 tonne-force = 981 DaN).

Debris: various forms of waste, of both anthropogenic and natural origin, floating at sea or on the shore.

DFO: Domestic Fuel Oil.

Draught: the height of the underwater section of a floating object (boom, vessel).

Drydock: basin from which the water can be drained to carry out maintenance work on vessels.

DTEX: weight in grams of 10,000 m of textile yarn.

Effluent: waste waters or liquid waste released into the water during clean-up operations in spills response.

Fittings: all deck accessories (such as shackles, carabiners, cleats, navigation lights, windlass...) found on small vessels.

FO: Fuel Oil.

Foreshore: section of the shore between the high and low water levels.

Freeboard: the height of the above-water section of a floating object (boom, vessel).

Galvanisation: application of a metal salt (zinc, chrome, copper) to a metal to protect it against corrosion.

Hawser: thick rope used to moor vessels.

HDPE: high density polyethylene.

HFO: Heavy Fuel Oil.

High tide mark: the highest point on the foreshore reached by the high tide.

H_2S: hydrogen sulphide, chemical compound composed of sulphur and hydrogen, responsible for the foul odour of rotten eggs, toxic for human health at concentration of over 14 mg/m^3, i.e. 10 ppm.

ISO: International Organization for Standardization.

Knot: unit of speed equal to 1 nautical mile per hour, i.e. 1,852 m/h or 0.514 m/s.

Mooring: mooring a boom involves attaching it to a dock or floating objecting using hawsers (or mooring line).

Mousing: binding of two parts (shackle and pin) by looping wire through both parts to prevent them from coming loose.

MRCC: Maritime Rescue Coordination Centre.

PVC: polyvinyl chloride.

SEBC: Standard European Behaviour Classification of chemicals spilled into the sea.

Shackle: U-shaped metal part used to link two chains together.

Sling: rope or chain designed to seize goods and hook them onto the hoist of a crane to load and unload them.

SNSM: French national sea rescue society.

Sorbent: any product designed to absorb liquids released into the environment to facilitate their recovery.

Spray: droplets formed by breaking waves and carried by the wind.

Supply boat: vessel with a large storage capacity on deck and in its tanks.

Swinging: the swinging circle is the area swept by a vessel around its mooring.

Tarball: small ball of weathered oil (1 to 10 cm), a microtarball is less than 1 cm in diameter.

TH: Total Height (for a floating boom: TH = Draught + Freeboard).

Tidal range: vertical difference between low tide and high tide levels.

Vortex: whirlpool movement that can be observed when emptying a bath for instance.

Wavelength: in a marine context, the distance between the peaks of two waves.

Wharf: a platform built on pilings, alongside which a vessel can berth.

AFNOR standards

As the French standardisation association, AFNOR develops French standards (NF), which may be based on European (EN) and/or international (ISO) standards. Below is a list of the French standards relating to the limits of spill response booms.

Characteristic	Standard	Content	Example of acceptability limit for a medium-weight spill response boom (to protect a sensitive site on the Atlantic coast of France)
Tensile strength	NF EN ISO 1421 (2011)	Rubber- or plastic-coated textiles. Determination of tensile strength and elongation at break	Whole structure: 5,000 daN Fabric and connector: 250 daN/5cm
Temperature of use	ISO 4675 (1990)	Rubber- or plastic-coated textiles. Low-temperature bend test	Fabric: resistance up to -15 °C
Puncture resistance	ISO 7765-2 (1994)	Plastics film and sheeting. Determination of impact resistance by the free-falling dart method	Fabric: 40 daN
Tear strength	NF EN 1875-3 (1998)	Determination of tear strength Part 3: trapezoidal method	Fabric: 20 daN
Abrasion resistance	NF EN ISO 5470-1 (1999)	Determination of abrasion resistance. Part 1: Taber abrader	Weight loss by abrasion < 0.04 %
Resistance to hydrostatic pressure	NF EN 1734 (1997)	Determination of resistance to water penetration. Low-pressure method	Successfully completed the water impermeability test
Adhesion resistance	NF EN ISO 2411 (2000)	Determination of coating adhesion	Coating adhesion to textile > 10 daN
Fabric heat resistance	NF EN 12280-1 (1998)	Accelerated heat ageing tests. Part 1: heat ageing of vulcanized or thermoplastic rubber	Loss of physical and mechanical characteristics following 168 hours of artificial ageing at + 70°C (< 5 %)
Fabric resistance to hydrocarbons and washing agents	NF ISO 1817 (2011)	Determination of the effect of liquids	Loss of physical and mechanical characteristics below 5 %

E2

ASTM standards

Boom specifications

- ASTM F1523-94 (2007): Selection of booms in accordance with water body classifications. This guide provides recommendations on the selection of containment boom in accordance with water body classifications. It distinguishes 4 main situations: calm waters, calm waters with current, sheltered waters and open sea, and, based on this classification, defines the most appropriate boom characteristics.

Boom characteristics	Calm waters	Calm waters with current	Sheltered waters	Open sea
Total height (1) (cm)	15-60	20-60	45-110	>90
Minimum ratio Buoyancy reserve/ weight	3:1	4:1	4:1	8:1
Total tensile strength (DaN)	680	2300	2300	4500

(1) This refers to the total height, allowing for a minimum freeboard of 33% of the total height for calm waters, protected areas or open sea and up to 50% for strong currents.

- ASTM F2682-07: Determining the buoyancy to weight ratio of oil spill containment boom. This ratio refers to the gross buoyancy (=weight of the volume of water taken up by a totally submerged boom) divided by the weight of the dry boom.
- ASTM F818- 93 (2009): Standard terminology relating to spill response barriers. This document is a glossary of all the technical terms relating to spill response barriers and used in the various ASTM standards.
- ASTM F1093-99: Standard test methods for tensile strength characteristics of oil spill response boom. This guide defines the method used to measure the tensile strength of the skirt and mooring:
  - test benches: boom length, towing system, type of connectors
  - cyclic fatigue testing: tensile strength repetition from manufacturer resistance data
  - measurement of maximum load before connection breaking or skirt tearing.
- ASTM F2084-01: Collecting containment boom performance data in controlled environments. This standard provides a guide for evaluating the retention capacities of containment booms at different towing speeds and in different sea conditions.

In situ burning

- ASTM F2152-07: Evaluating the performance of fire-resistant oil spill containment boom. This guide covers a set of criteria to evaluate the minimum performance required by fire-resistant booms: fire resistance (in kwh/m²), buoyancy reserve, tensile strength and tear resistance (in N).

Connectors

- ASTM F962-04 (2010): Standard specification for oil spill response boom connection (Z-connector).
- ASTM F2438-04 (2010): Standard specification for oil spill response boom connection (slide connector).

These guides specify the requirements for the design of ASTM connectors (material characteristics, part design: toggle pin and connection shackle...). These two types of connectors (Z-connector and slide connector) are interconnectable.

Beaufort and Douglas scales

Beaufort Scale and sea state description

The Beaufort Scale is an empirical measure of average wind speed over a ten minute period that is used for maritime purposes. It comprises 13 classes. At sea, it is practical to be able to estimate wind speed by simply observing the effects of wind on the sea surface.

FORCE	DESCRIPTION	WIND SPEED KNOTS	WIND SPEED KM/H	SEA CONDITIONS
0	Calm	1	1	Smoke rises vertically. Sea surface smooth and mirror-like
1	Light Air	1 to 3	1 to 5	Scaly ripples, no foam crests
2	Light Breeze	4 to 6	6 to 11	Small wavelets, crests glassy, no breaking
3	Gentle Breeze	7 to 10	12 to 19	Large wavelets, crests begin to break, scattered whitecaps
4	Moderate Breeze	11 to 16	20 to 28	Small waves becoming longer, numerous whitecaps
5	Fresh Breeze	17 to 21	29 to 38	Moderate waves taking longer form, many whitecaps, some spray
6	Strong Breeze	22 to 27	39 to 49	Larger waves, whitecaps common, more spray
7	Near Gale	28 to 33	50 to 61	Sea heaps up, white foam streaks off breakers
8	Gale	34 to 40	62 to 74	Moderately high waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks
9	Strong Gale	41 to 47	75 to 88	High waves, sea begins to roll, dense streaks of foam, spray may reduce visibility
10	Storm	48 to 55	89 to 102	Very high waves with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility
11	Violent Storm	56 to 63	103 to 117	Exceptionally high waves, foam patches cover sea, visibility more reduced
12	Hurricane	64 and +	118 and +	Air filled with foam, sea completely white with driving spray, visibility greatly reduced

Source: NOAA

Douglas Sea Scale

The sea state is the description of the sea surface under the influence of the wind (which generates waves) and swell. The Douglas Sea Scale is used by crews and provides 9 classes for "wind sea height".

Force	Description	Height in metres*
0	Calm	0
1	Rippled	0 to 0.1
2	Smooth	0.1 to 0.5
3	Slight	0.5 to 1.25
4	Moderate	1.25 to 2.5
5	Rough	2.5 to 4
6	Very Rough	4 to 6
7	High	6 to 9
8	Very High	9 to 14
9	Phenomenal	14 and +

* (measurement of the difference between the crest and trough of a wave)

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