# Containment & Recovery of Oil Spills at Sea. Methods and Limitations.

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The ultimate aim of any oil recovery operation at sea is to collect as much floating oil as is reasonably and economically possible. However, a review of past spills shows that rarely is more than 10% of spilled oil recovered from the sea surface. Although many methods of mechanical containment and recovery exist, each has its own limitations which affect the overall success of a recovery operation.

**Methods**

Containment is normally achieved using some type of floating barrier, the majority of which are booms incorporating a freeboard to prevent loss by splashover, a skirt to prevent losses under the boom, flotation provided by air or some buoyant material and some means of providing longitudinal strength to withstand towing or mooring forces.

Booms are generally of the fence or curtain type. Curtain booms generally perform better than fence booms when exposed to current and wave conditions, although they tend to be heavier and more cumbersome, being available in overall heights up to 3.5m for offshore applications. A major consideration for offshore booms is the compromise between the boom strength, weight to allow easy handling and good wave following performance.

Other containment systems utilise solid barriers, such as sweeping arms or the hull of the recovery vessel itself or use some form of net system. The latter are, however, limited to the collection of tar balls and very viscous oils.

Recovery devices can be broadly categorised into mechanical (belt, weir, vortex, direct suction) and oleophilic (rope mop, drum, disc, belt & brush), possessing an affinity for oil. None of these systems can cope with every situation encountered in an oil spill. Each has its own characteristics and limitations in dealing with factors such as viscosity, sea state and debris.

Mechanical belt skimmers operate simply by lifting oil off the water surface to a collection point where the oil is scraped off the belt. Weir skimmers minimise the amount of water recovered by setting the weir height to the oil/water interface. Vortex skimmers utilise an induced vortex to separate the oil and water according to their respective densities. Direct suction devices employ either vacuum or air conveyor systems to recover the oil.

Oleophilic skimmers rely upon the adhesion characteristics of oil. Rope mop devices consist of a continuous mop which is pulled through the oil and then squeezed between rollers, depositing the oil into a tank. Similarly, with oleophilic belt, drum and disc skimmers, the oil adheres to the rotating belt, drum or discs and is scraped off into a sump. A brush skimmer consists of banks of stiff oleophilic fibres mounted on a rotating conveyor. These brushes pass through a comb to remove adhered oil again allowing it to pass into a collection sump.

## Limitations

The primary reason that high recovery rates are often unobtainable is the tendency for oil to rapidly spread and fragment once it has been spilled onto the open sea. However, a successful recovery system needs to solve the interconnected problems of the overall operation, i.e. encountering significant quantities of oil, containment, concentration, recovery and storage. Likewise, the effects of currents, waves and oil viscosity are important. The choice and design of the recovery system is thus a vital factor and the performance of a potential system can be judged against particular performance criteria.

The speed of the recovery vessel, the swath width over which the oil is collected and the thickness and extent of scattering of the oil all determine the encounter rate for a recovery system. While the latter factors are determined by the spreading rate, the time elapsed, the oil type and the degree of emulsification, the swath and operating speed can be varied dependant on certain limitations.

Single-ship systems normally employ a boom attached to an outrigger. However, if the swath is too great, the set-up can become cumbersome and prone to damage in rough weather. For such systems, the most effective way of improving the encounter rate is to increase the operating speed. However, many systems are limited to below 1 knot due to the type and configuration of the boom used. At speeds greater than this, the performance deteriorates and results in loss of oil under the skirt. This can be irrespective of the draught of the boom. Additionally, reflected waves can form inhibiting the collection of oil.

One solution is to use multi ship systems. This can increase the swath measurably and can allow booms to be placed at an angle to the current. Fishing vessels or suchlike can tow containment boom in 'J', 'U' or 'V' configurations, with the recovery device positioned in the apex to collect the concentrated band of oil. However, in the 'J' and 'U' configurations the oil collects where the boom is perpendicular to the flow. Hence towing speeds are severely limited. Indeed, recovery, using such configurations, as in the ALEXANDRIA (South Korea) incident, can be limited by the inability of the towing vessels to travel sufficiently slowly. With the 'V' configuration, no elements of the barrier are perpendicular to the flow but oil may still escape under the skimmer at the apex of the boom. In all configurations, the length of boom deployed between two vessels is limited by the towing capability and manoeuvrability of the vessels and the strength of the boom. These methods are, however, relatively simple to operate providing effective coordination is available, and were used successfully in the VOLGONEFT (Sweden) and AMERICAN TRADER (USA) incidents.

Several skimmers have been designed for operation in faster currents by increasing the area behind the collecting aperture and slowing the oil as it enters the skimmer. In order to achieve such high operating speeds the system has to cope with large volumes of fast-flowing water which may create turbulence. Such devices are particularly effective with 'V' configuration systems.

To some extent the need for a large swath is offset by the tendency of the oil to form windrows whereby the oil becomes concentrated into narrow bands aligned with the wind direction. Any such oil can be collected using a recovery device with a relatively narrow swath. Due to the increased oil thickness within the windrows, a similar encounter rate can be achieved as a device with a larger swath because the water between the windrows is relatively free of oil.

A measure of the overall efficiency of a recovery system, once it has encountered oil, is given by the throughput efficiency. This compares the quantity of oil collected with that encountered and hence highlights the losses which occur from the containment barrier and the recovery device itself. The throughput efficiency tends to decrease with increasing operating speed and worsening sea states notably increasing wave height and more importantly decreasing wavelength. At higher speeds a trade off exists between a reduced throughput efficiency and an increased encounter rate.

Waves lead to the loss of oil from a boom either as a result of splashover or due to poor wave-following characteristics so that bridging occurs between crests. Similarly, the failure of a skimming device to remain in contact with the oil often results in the ingestion of large quantities of water. In addition, turbulence caused by the skimmer movement relative to any waves can lead to loss of oil under the skimmer. Ideally, a recovery device should be small and have a low mass so as to faithfully follow wave movements. Devices that are unable to move independently of any recovery vessel are less effective in higher sea states because they generally move out of phase with the water surface. However, swell, even of a large amplitude, is unlikely to be detrimental if the wavelength is sufficiently long.

The recovery efficiency, the relationship between the quantity of oil and water in the collected material is an important determinant in a system's overall performance. Selective systems such as oleophilic devices recover small quantities of water but are less effective with high viscosities. Such systems can be used with smaller vessels which are generally more readily available and more effective in restricted water depths. In the THUNTANK 5 (Sweden) incident, the Coast Guard used a brush system in 1.5 m waves to recover oil containing only 6% water. Non-selective systems such as weir skimmers entrain larger quantities of water and this often enables them to cope with higher viscosity oils. However, they require the use of vessels with large internal or supplementary, storage capabilities to allow oil/water separation. Such vessels are often not particularly manoeuvrable.

Viscosity has a considerable effect on the efficiency of virtually all recovery devices. Oils with high pour points such as heavy crudes and fuel oils do not flow easily. If the ambient temperature is below the pour point, the oil will effectively behave as a solid and hence be difficult to recover. Viscosity is also affected by the tendency of many oils to form water-in-oil emulsions whereby, in addition to making the oil considerably more viscous, the volume of material is increased by three to four times. Viscosities of the order of 100,000 centistokes are common. The injection of demulsifying agents can be used as a means of reducing this problem and minimising the storage volume required. Conventional weir, vortex, oleophilic rope and disc devices are usually limited to use with oils with a maximum of 10,000 cSt, whereas screw, belt, and air conveyor devices will often perform well with oil with viscosities up to 100,000 cSt.

Mechanical belt or bucket conveyor skimmers were used successfully to recover high viscosity oils during the AMOCO CADIZ (France), EXXON VALDEZ (USA), PORTFIELD (UK) and REGENT STAR (Romania) incidents. The success of such systems is due to the use of mechanical rather than pumping processes to lift the oil off the water. However, such systems are not suitable for use offshore. When viscosities exceed 100,000 cSt, such as with burnt residues as in the HAVEN (Italy) incident, mechanical grabs are the most effective system, although they can only achieve low recovery rates.

The EXXON VALDEZ spill highlighted the problem of increasing viscosity over time. Systems such as weir and oleophilic disc skimmers were able to operate efficiently in the fresh oil found early in the incident. However, with the inclusion of debris and increases in viscosity, recovery was only effective with belt units, skimmers using screw pumps with debris cutters and certain suction devices such as converted dredgers. Due to the very non-selective nature and large pipe diameters of this latter system, debris and highly emulsified oil was recovered without clogging. In the KATINA (Netherlands) spill, oil emulsified within 3 days and mixed with debris leading to pumping difficulties and a reduced recovery rate. These problems emphasise the importance of a rapid response.

Although the theoretical recovery rate is often taken as the sole indicator of a system's capacity, other elements such as how much oil the system has failed to collect should be considered. For example, despite the at-sea response equipment at the AMERICAN TRADER incident having a combined potential recovery rate of over 5,600 tonnes per 8-hour day, the actual recovery rate achieved was only around 450 tonnes (including emulsified oil and free water) in 6 days. Similarly, the skimming capacity available during the MORRIS J BERMAN incident (USA) was well in excess of 21,700 tonnes/day. A maximum of 1400 tonnes was collected over 20 days giving an efficiency of approximately 0.3%.

Successful recovery operations at sea depend as much on the effectiveness of the response organisation as the performance of the equipment. An effective organisation should possess good surveillance information and be able to direct systems to areas where best use can be made of them. The lack of good aerial control during the HAVEN incident impaired the efficiency of the recovery operation. Conversely, during the AMERICAN TRADER spill the poor overall recovery efficiency was enhanced by suitable aerial control from a dedicated helicopter.

Experience from past spills suggests that the more successful recovery operations have generally involved a well prepared organisation with all logistics ready, well trained crews and rapid mobilisation times. The successful deployment of a system requires that all the components of containment, recovery and storage are mastered continuously and that the system remains sufficiently manoeuvrable to follow changes in the distribution of the oil.

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