6 MARITIME POLLUTION PREVENTION SYSTEMS

6.1 Introduction

6.1.1 Maritime pollution

Oil/water separators are used to ensure that ships do not discharge oil when pumping out bilges, oil tanks or any oil-contaminated space.

International legislation relating to oil pollution is becoming more and more stringent in the limits set for oil discharge. Clean water suitable for discharge is defined as that containing less than 15 parts per million of oil. Oil/water separators using the gravity system can only achieve 100 parts per million (ppm) and must therefore be used in conjunction with some form of filter.

The discharge of untreated sewage in controlled or territorial waters is usually banned by legislation. International legislation is in force to cover any sewage discharges within specified distances from land. As a result, and in order to meet certain standards all new ships have sewage treatment plants installed.

Untreated sewage as a suspended solid is unsightly. In order to break down naturally, raw sewage must absorb oxygen. In excessive amounts it could reduce the oxygen content of the water to the point where fish and plant life would die. Pungent smells are also associated with sewage as a result of bacteria which produce hydrogen sulphide gas. Particular bacteria present in the human intestine known as E, coli are also to be found in sewage. The E. coli count in a measured sample of water indicates the amount of sewage present.

6.1.2 Residues production onboard

Residues onboard can be divided into three major groups:

a) Solid;

b) Liquid not oil-contaminated;

c) Liquid oil-contaminated.

Solid residues onboard can be further sub-divided into organic and non organic.

a.1) Solid organic residues are essentially due to:

a.1.1) Food Waste - waste from food preparation and meals.

a.2) Solid inorganic residues are essentially due to:

a.2.1) Garbage - including paper, glass and metal;

a.2.2) Sanitary Waste - feminine hygiene products;

a.2.3) Plastics - wrapping, containers etc.;

a.2.4) Clinical Waste - used sharps, bandages, etc.

Liquid not oil-contaminated residues can be grouped into two categories:

b.1) Black Water - toilets/heads and urinals;

b.2) Grey Water - showers, laundry, wash-basins.

Liquid oil-contaminated residues are essentially due to:

c.1) Bilge Water - fluids which collect in the hull of a ship.

Table 6.1 shows some figures on residues production onboard per man per day that can be used for merchant vessels design:

Tab. 6.1 – Daily production of residues onboard a merchant vessel per man.

Residue	Galley	Shower	Laundry	Toilets	Total
Water [dm^3]	50	90	10	30	180
Suspended solids [mg/dm^3]	330	80	350	670	1430
Solids [g]	17	7	4	20	48

6.2. The MARPOL 73/78 international convention

International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 is commonly known as (MARPOL 73/78).

The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years.

The International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted on 2 November 1973 at IMO and covered pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage. The Protocol of 1978 relating to the 1973 International Convention for the Prevention of Pollution from Ships (1978 MARPOL Protocol) was adopted at a Conference on Tanker Safety and Pollution Prevention in February 1978 held in response to a spate of tanker accidents in 1976-1977. Measures relating to tanker design and operation were also incorporated into a Protocol of 1978 relating to the 1974 Convention on the Safety of Life at Sea, 1974.

As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument is referred to as the International Convention for the Prevention of Marine Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), and it entered into force on 2 October 1983 (Annexes I and II).

The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes:

a) Annex I: Prevention of pollution by oil;

b) Annex II: Control of pollution by noxious liquid substances;

c) Annex III: Prevention of pollution by harmful substances in packaged form;

d) Annex IV: Prevention of pollution by sewage from ships;

e) Annex V: Prevention of pollution by garbage from ships;

f) Annex VI: Prevention of Air Pollution from Ships.

6.2.1 Annex I: Prevention of pollution by oil

The operational discharges of oil from tankers are allowed only when all of the following conditions are met:

a) The total quantity of oil which a tanker may discharge in any ballast voyage whilst under way must not exceed 1/15,000 of the total cargo carrying capacity of the vessel;

b) The rate at which oil may be discharged must not exceed 60 litres per mile travelled by the ship;

c) No discharge of any oil whatsoever must be made from the cargo spaces of a tanker within 50 miles of the nearest land.

An oil record book is required, in which is recorded the movement of cargo oil and its residues from loading to discharging on a tank-to-tank basis. In addition, the maximum quantity of oil permitted to be discharged on a ballast voyage of new oil tankers was reduced from 1/15,000 of the cargo capacity to 1/30,000 of the amount of cargo carried. These criteria applied equally both to persistent (black) and non-persistent (white) oils.

It was also recognized the "load on top" (LOT) system which had been developed by the oil industry in the 1960s. On a ballast voyage the tanker takes on ballast water (departure ballast) in dirty cargo tanks. Other tanks are washed to take on clean ballast. The tank washings are pumped into a special slop tank. After a few days, the departure ballast settles and oil flows to the top. Clean water beneath is then decanted while new arrival ballast water is taken on. The upper layer of the departure ballast is transferred to the slop tanks. After further settling and decanting, the next cargo is loaded on top of the remaining oil in the slop tank, hence the term load on top.

A new and important feature was the concept of "special areas" which are considered to be so vulnerable to pollution by oil that oil discharges within them have been completely prohibited, with minor and well defined exceptions. The identified "special areas" are:

a) Mediterranean Sea;

b) Black Sea;

c) Baltic Sea;

d) Red Sea and the Gulfs.

All oil-carrying ships are required to be capable of operating the method of retaining oily wastes on board through the "load on top" system or for discharge to shore reception facilities.

This involves the fitting of appropriate equipment, including an oil-discharge monitoring and control system, oily-water separating equipment and a filtering system, slop tanks, sludge tanks, piping and pumping arrangements.

New oil tankers (i.e. those for which the building contract was placed after 31 December 1975) of 70,000 tons deadweight and above, must be fitted with segregated ballast tanks large enough to provide adequate operating draught without the need to carry ballast water in cargo oil tanks.

Secondly, new oil tankers are required to meet certain subdivision and damage stability requirements so that, in any loading conditions, they can survive after damage by collision or stranding.

The Protocol of 1978 made a number of changes to Annex I of the parent convention. Segregated ballast tanks (SBT) are required on all new tankers of 20,000 dwt and above (in the parent convention SBTs were only required on new tankers of 70,000 dwt and above). It was also required SBTs to be protectively located that is, they must be positioned in such a way that they will help protect the cargo tanks in the event of a collision or grounding.

Another important innovation concerned crude oil washing (COW), which had been developed by the oil industry in the 1970s and offered major benefits. Under COW, tanks are washed not with water but with crude oil of the cargo itself. COW was accepted as an alternative to SBTs on existing tankers and is an additional requirement on new tankers.

For existing crude oil tankers (built before entry into force of the Protocol) a third alternative was permissible for a period of two to four years after entry into force of MARPOL 73/78. The dedicated clean ballast tanks (CBT) system meant that certain tanks are dedicated solely to the carriage of ballast water. This was cheaper than a full SBT system since it utilized existing pumping and piping, but when the period of grace has expired other systems must be used.

Drainage and discharge arrangements were also altered in the Protocol, regulations for improved stripping systems were introduced.

Some oil tankers operate solely in specific trades between ports which are provided with adequate reception facilities. Some others do not use water as ballast. The TSPP Conference recognized that such ships should not be subject to all MARPOL requirements and they were consequently exempted from the SBT, COW and CBT requirements. It is generally recognized that the effectiveness of international conventions depends upon the degree to which they are obeyed and this in turn depends largely upon the extent to which they are enforced. The 1978 Protocol to MARPOL therefore introduced stricter regulations for the survey and certification of ships.

The 1992 amendments to Annex I made it mandatory for new oil tankers to have double hulls – and it brought in a phase-in schedule for existing tankers to fit double hulls, which was subsequently revised in 2001 and 2003.

6.2.2 Annex II: Control of pollution by noxious liquid substances

Annex II details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk.

Some 250 substances were evaluated and included in the list appended to the Convention. The discharge of their residues is allowed only to reception facilities until certain concentrations and conditions (which vary with the category of substances) are complied with.

In any case, no discharge of residues containing noxious substances is permitted within 12 miles of the nearest land. More stringent restrictions applied to the Baltic and Black Sea areas.

6.2.3 Annex III: Prevention of pollution by harmful substances in packaged form

States ratifying the Convention must accept Annexes I and II but can choose not to accept the other three - hence they have taken much longer to enter into force. Annex III contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications for preventing pollution by harmful substances. The International Maritime Dangerous Goods (IMDG) Code has, since 1991, included marine pollutants.

6.2.4 Annex IV: Prevention of pollution by sewage from ships

The second of the optional Annexes, Annex IV contains requirements to control pollution of the sea by sewage. A revised Annex was adopted in 2004.

6.2.5 Annex V: Prevention of pollution by garbage from ships

This deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of. The requirements are much stricter in a number of "special areas" but perhaps the most important feature of the Annex is the complete ban imposed on the dumping into the sea of all forms of plastic.

6.2.6 Annex VI: Prevention of air pollution from ships

The regulations in this annex set limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibit deliberate emissions of ozone depleting substances.

6.3 Treatment of sanitary water

6.3.1 Introduction

Two particular types of sewage treatment plant are in use, employing either chemical or biological methods. The chemical method is basically a storage tank which collects solid material for disposal in permitted areas or to a shore collection facility. The biological method treats the sewage so that it is acceptable for discharge inshore.

6.3.2 Chemical sewage treatment

This system minimizes the collected sewage, treats it and retains it until it can be discharged in a decontrolled area, usually well out to sea. Shore receiving facilities may be available in some ports to take this retained sewage.

This system must therefore collect and store sewage produced while the ship is in a controlled area. The liquid content of the system is reduced, where legislation permits, by discharging wash basins, bath and shower drains straight overboard. Any liquid from water closets is treated and used as flushing water for toilets. The liquid must be treated such that it is acceptable in terms of smell and appearance.

A treatment plant is shown diagrammatically in Figure 6.1. Various chemicals are added at different points for odor and color removal and also to assist breakdown and sterilization. A comminutor is used to physically break up the sewage and assist the chemical breakdown process. Solid material settles out in the tank and is stored prior to discharge into the sullage tank: the liquid is recycled for flushing use.

Tests must be performed daily to check the chemical dosage rates. This is to prevent odors developing and also to avoid corrosion as a result of high levels of alkalinity.

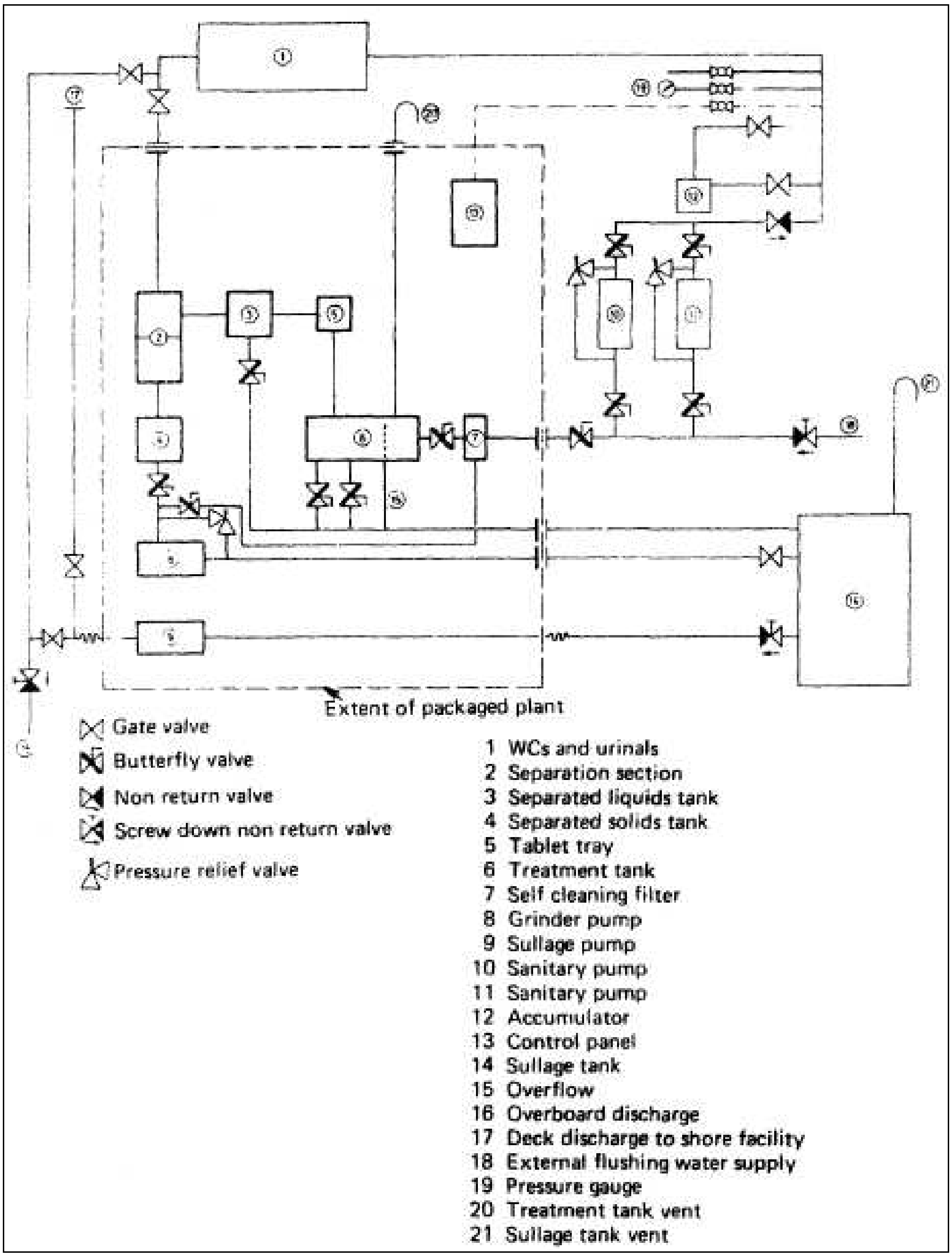

Fig. 6.1 – Chemical sewage treatment plant.

6.3.2 Biological sewage treatment

The biological system utilizes bacteria to completely break down the sewage into an acceptable substance for discharge into any waters. The extended aeration process provides a climate in which oxygen-loving bacteria multiply and digest the sewage, converting it into a sludge. These oxygen-loving bacteria are known as aerobic.

The treatment plant uses a tank which is divided into three watertight compartments: an aeration compartment, settling compartment and a chlorine contact compartment (Figure 6.2).

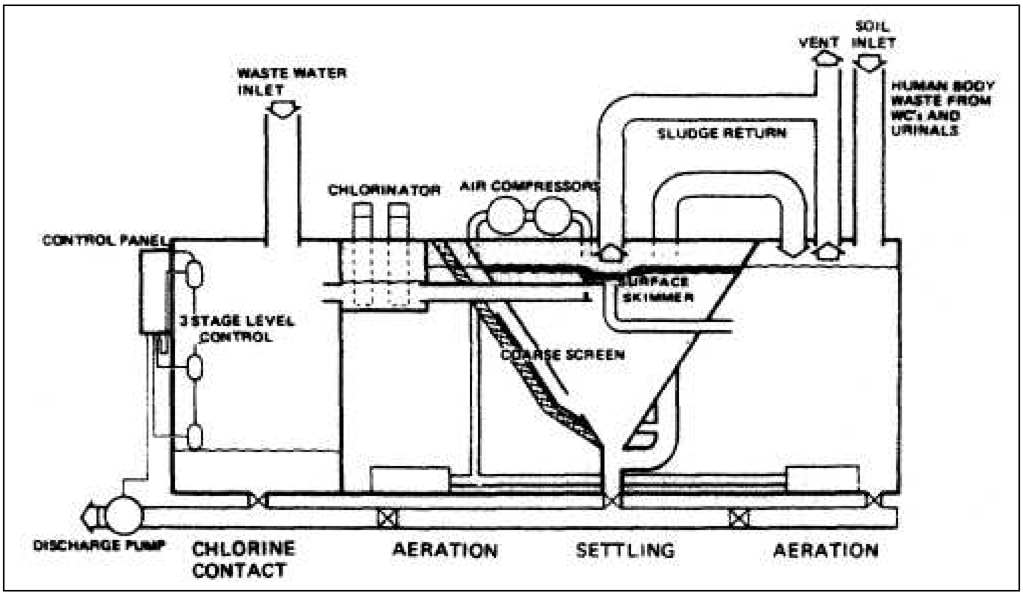

Fig. 6.2 – Biological sewage treatment plant.

The sewage enters the aeration compartment where it is digested by aerobic bacteria and micro-organisms, whose existence is aided by atmospheric oxygen which is pumped in. The sewage then flows into the settling compartment where the activated sludge is settled out. The clear liquid flows to the chlorinator and after treatment to kill any remaining bacteria it is discharged. Tablets are placed in the chlorinator and require replacement as they are used up. The activated sludge in the settling tank is continuously recycled and builds up, so that every two to three months it must be partially removed. This sludge must be discharged only in a decontrolled area.

Figure 6.3 shows a photograph of a typical biological sewage treatment installed onboard. Dimensions of this plant are: 4.6x2.2x2.2 [m], and weight is 7200 [kg] (empty) and 25300 [kg] in total.

Fig. 6.3 – Photograph of a biological sewage treatment plant.

6.4. Water and oil separation

A conventional oil/water separator unit and a parallel plate oil/water separator unit for 100 [ppm] purity are shown in Figure 6.4. The units are first filled with clean water; the oily water mixture is then pumped through the separators inlet pipe into the separating compartments. In the conventional unit some oil, as a result of its lower density, will separate and rise into the oil collection space. The remaining oil/water mixture now flows down the separating compartment, from where outlet pipe should be connected. As illustrated in the bottom diagram, the parallel plate oil/water separator unit has less oil particles in suspension at the bottom due to a coarse filtering obtained with the catch plates, which should allow a100 [ppm] purity at the outlet pipe.

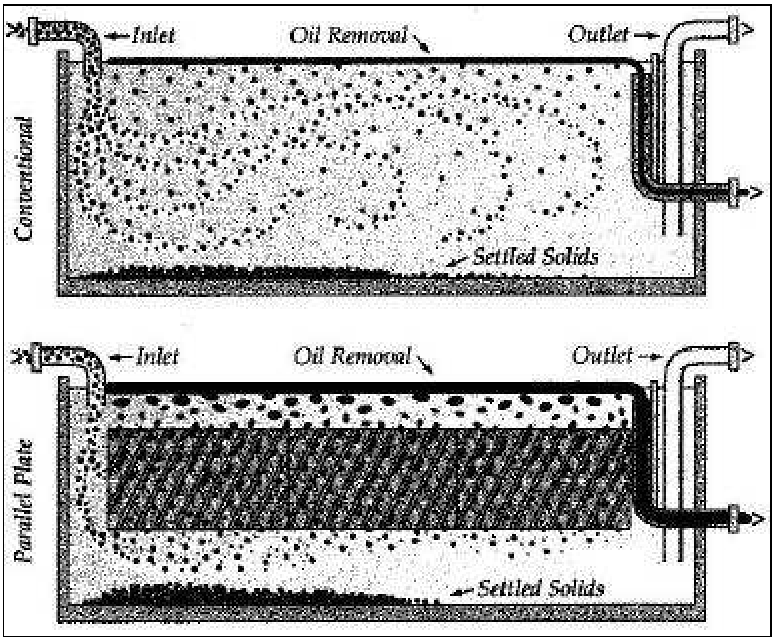

Fig. 6.4 – Conventional oily water separator unit (top) and parallel plate oily water separator unit (bottom).

A complete oil/water separator and filter unit for 15 [ppm] purity is shown in Figure 6.5. The complete unit is also first filled with clean water; the oily water mixture is then pumped through the separator inlet pipe into the coarse separating compartment. Here some oil, as a result of its lower density, will separate and rise into the oil collection space. The remaining oil/water mixture now flows down into the fine separating compartment and moves slowly between the catch plates.

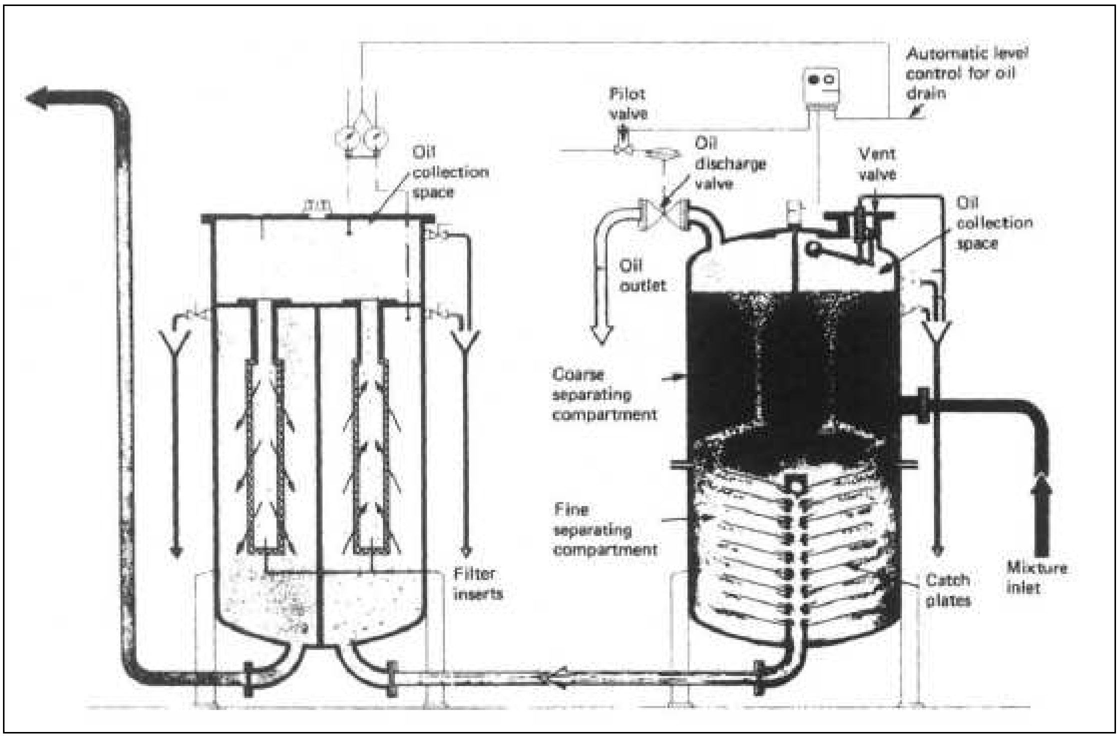

Fig. 6.5 – Oily water separator/filter unit.

More oil will separate out onto the underside of these plates and travel outwards until it is free to rise into the oil collecting space. The almost oil-free water passes into the central pipe and leaves the separator unit.

The purity at this point will be 100 [ppm] or less. An automatically controlled valve releases the separated oil to a storage tank. Air is released from the unit by a vent valve. Steam or electric heating coils are provided in the upper and sometimes the lower parts of the separator, depending upon the type of oil to be separated.

Where greater purity is required, the almost oil-free water passes to a filter unit. The water flows in turn through two filter stages and the oil removed passes to oil collecting spaces. The first-stage filter removes physical impurities present and promotes some fine separation. The second-stage filter uses coalescer inserts to achieve the final de-oiling. Coalescence is the breakdown of surface tension between oil droplets in an oil/water mixture which causes them to join and increase in size. The oil from the collecting spaces is drained away manually, as required, usually about once a week. The filter inserts will require changing, the period of useful life depending upon the operating conditions.

Current legislation requires the use of a monitoring unit which continuously records and gives an alarm when levels of discharge in excess of 15 [ppm] occur. Figure 6.6 shows a photograph of a typical oily water separator plant with a maximum flow rate of 5 [m3/h].

Fig. 6.6 – Photograph of an oily water separator.

6.5 Treatment of solid residues

6.5.1 Introduction

Stricter legislation with regard to pollution of the sea, limits and, in some instances, completely bans the discharge of untreated waste water, sewage, waste oil and sludge. The ultimate situation of no discharge can be achieved by the use of a suitable incinerator. When used in conjunction with a sewage plant and with facilities for burning oil sludges, the incinerator forms a complete waste disposal package.

6.5.2 Incinerator

One type of incinerator for shipboard use is shown in Figure 6.7. The combustion chamber is a vertical cylinder lined with refractory material. An auxiliary oil-fired burner is used to ignite the refuse and oil sludge and is thermostatically controlled to minimize fuel consumption.

A sludge burner is used to dispose of oil sludge, water and sewage sludge and works in conjunction with the auxiliary burner. Combustion air is provided by a forced draught fan and swirls upwards from tangential ports in the base. A rotating-arm device accelerates combustion and also clears ash and non-combustible matter into an ash hopper. The loading door is interlocked to stop the fan and burner when opened. Solid material, usually in sacks, is burnt by an automatic cycle of operation. Liquid waste is stored in a tank, heated and then pumped to the sludge burner where it is burnt in an automatic cycle. After use the ash box cannot be emptied overboard.

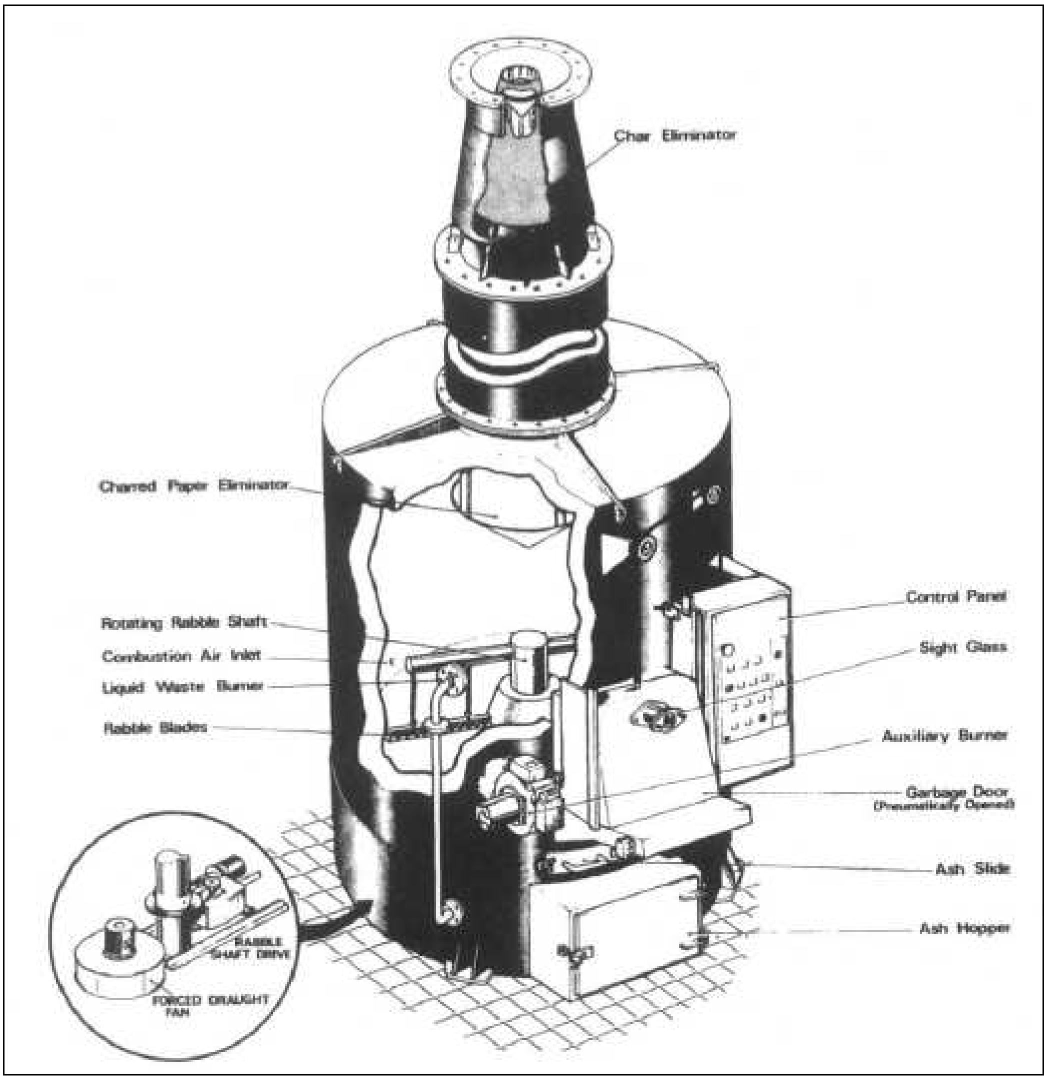

Fig. 6.7 – Incinerator.

6.5.3 Garbage compactor

Volume of garbage such as plastics and metal used for wrapping and containers can be largely reduced by using a compactor (see Figure 6.8). The compacted garbage should be stored onboard for later disposal ashore.

Fig. 6.8 – Garbage compactor.

6.6. Exhaust gas emissions: pollution and treatment

MARPOL Annex VI sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts (see Figure 6.9) and prohibits deliberate emissions of ozone depleting substances. The annex includes a global cap of 4.5% [mol/mol] on the sulphur content of fuel oil and calls on IMO to monitor the worldwide average sulphur content of fuel.

Annex VI contains provisions allowing for special SOx Emission Control Areas (SECAS) to be established with more stringent controls on sulphur emissions. In these areas, the sulphur content of fuel oil used onboard ships must not exceed 1.5% [mol/mol]. Alternatively, ships must fit an exhaust gas cleaning system or use any other technological method to limit SOx emissions. The Baltic Sea Area is designated as a SOx Emission Control area in the Protocol.

Fig. 6.9 – Exhaust gas emissions from ships.

Annex VI prohibits deliberate emissions of ozone depleting substances, which include halons and chlorofluorocarbons (CFCs). New installations containing ozone-depleting substances are prohibited on all ships. But new installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

Annex VI also sets limits on emissions of nitrogen oxides (NOx) from diesel engines. A mandatory NOx Technical Code, which defines how this shall be done, was adopted by the Conference under the cover of Resolution 2.

The Annex also prohibits the incineration onboard ship of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).