Guide to oil in water monitoring & discharge

RIVERTRACE

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Introduction

While the intention of MARPOL Annex VI aimed at reducing air pollution from ships' engines is laudable, with the benefit of hindsight it can be seen that regulating for different exhaust components at different times and in different ways has complicated matters more than was probably necessary.

For each component regulated, new technologies have been developed but all are expensive and sometimes also require additional power thus increasing CO2 emissions or else they are seen as somehow cheating the intention of the regulation by moving the emission from air to sea. This latter is particularly true of washwater and more especially from exhaust gas cleaning systems or wet scrubbers used for removing SOx from the exhaust stream of vessels burning fuels containing levels of sulphur above those permitted under MARPOL Annex VI. The Exhaust Gas Recirculation method of reducing NOx emissions also involves washwater treatment and is now being seen as problematic also.

This guide looks at the subject of washwater and examines some of the major issues.

01

What is washwater?

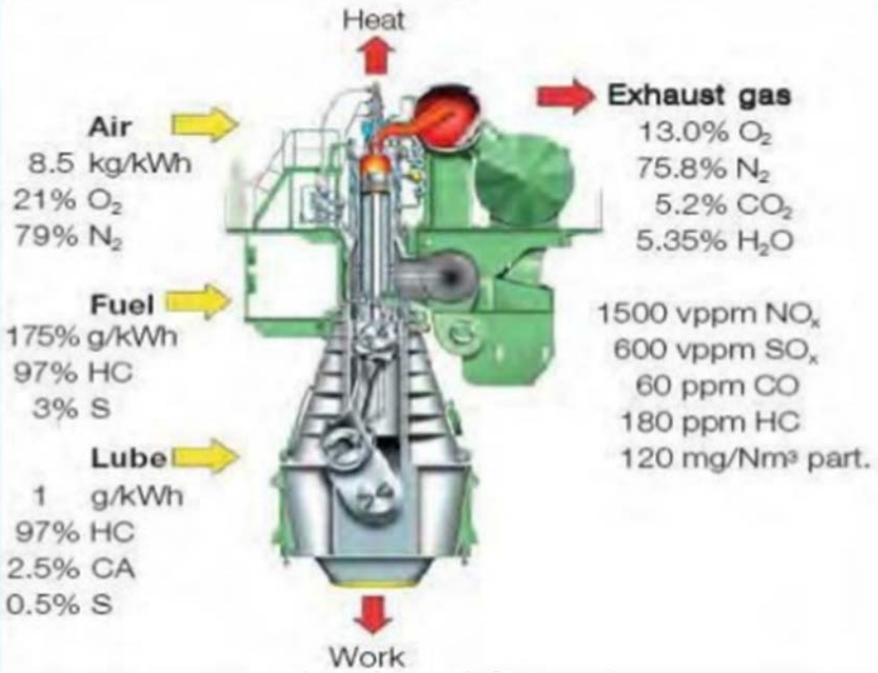
An explanation of how wet scrubbers and EGR systems work with particular regard to the production of washwater.

The chapter will look at the composition of washwater and the polluting components as well as the scientific dispute as to its effects upon the environment.

When fuels are burned in a marine engine, numerous chemical reactions take place in the combustion chamber as the chemicals in the fuel and the upper cylinder lubricant (in a low-speed two-stroke engine) combine with the gases in the inlet air during combustion.

In addition, some of the non-combustible elements in the fuel and products of engine wear are also carried out in the exhaust stream.

Until there was a requirement under MARPOL to reduce and control the emission of some chemical compounds, the exhaust stream was released directly into the atmosphere. When the IMO (and some national governments and regional bodies) set in motion regulation of sulphur oxides (SOx) and Nitrogen Oxides (NOx), shipowners relied upon engine manufacturers, equipment makers and fuel suppliers to provide the necessary means to meet the requirements.



Infographic showing the emissions from Marine Engine Exhaust Gas

As can be seen from the above diagram, a fuel with a 3% sulphur content produces 600ppm by volume of SOx compound in the exhaust. The amount would be increased or reduced depending upon the sulphur content in the fuel which in 2021 is set at 0.1% in ECAs and 0.5% elsewhere.

The diagram takes account only of the hydrocarbon and sulphur content of the fuel so there is no output data for extraneous components of the fuel which are permitted under the ISO 8217 standard for marine fuels or any 'illicit' components that might be present. Most fuels also contain cat fines – particles of aluminium silicate are residues of the refining process.

SOx and scrubbers

It is possible to meet the SOx requirements by using a fuel that does not contain sulphur or only in the low levels permitted by the regulation. Currently available alternative fuels such as LNG and methanol have negligible levels of sulphur, but the vast majority of ships cannot use these fuels and conversions have a heavy capital expenditure associated with them.

There are low sulphur versions of oil fuels but these fuels are more expensive than conventional HFO.

The actual price differential fluctuates continually with the price of crude oil and demand for bunker fuels in general. In an attempt to reduce the capital outlay of conversions or the operational outlay of buying compliant fuels (which incidentally were not available when the regulations were first enacted), an alternative was promised by the development of exhaust gas cleaning systems – commonly labelled scrubbers which remove the Sox content of the exhaust.

Scrubbers were not a new invention, the technology had been in use on shoreside applications for many years before being considered for marine purposes. There were operational issues to be overcome and size was also a problem but the first marine scrubber appeared in 2006 and subsequent years improvements have been made in operational efficiency and size.

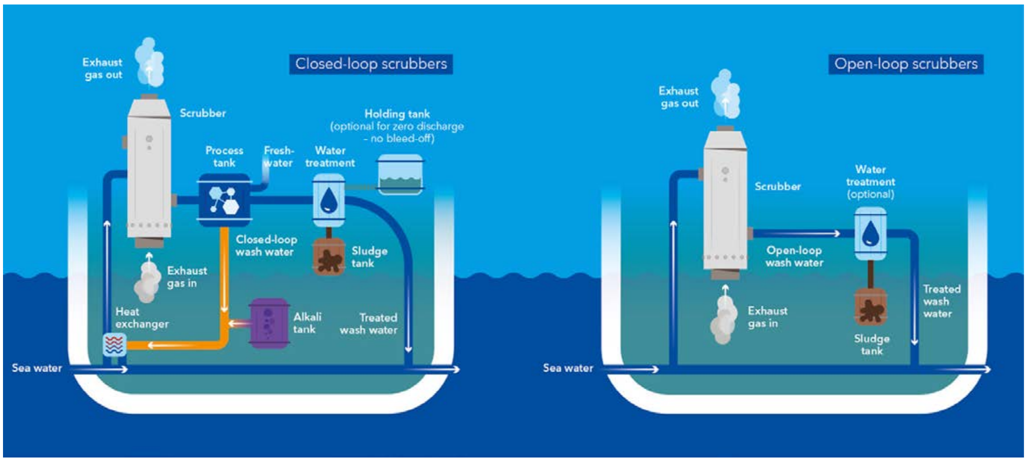
Scrubbers can either be 'dry' or 'wet' with only the latter type producing washwater and therefore relevant to this series of articles. The majority of scrubbers fitted or on order are of the wet type with just a very small number of dry systems so far having been installed.

The wet systems are not the most compact pieces of equipment and would take up considerable space if it were necessary to install them in under deck machinery spaces. Fortunately, they can be installed in the funnel casing and can in some cases replace part of the conventional exhaust system. A scrubber may be a single entry type serving just the main engine, but some are multiple entry and also treat the exhaust from auxiliary engines.

In a scrubber, the sulphur oxides in the exhaust are passed through a water stream reacting with it to form sulphuric acid and are removed from the exhaust gas which then passes out of the system. Sulphuric acid is highly corrosive but when diluted with sufficient alkaline seawater it is neutralised and the washwater can be discharged into the open sea after being treated in a separator to remove any sludge.

The alkalinity of seawater varies due to several reasons. In estuaries and close to land it may be brackish and closer to neutral and in some areas where underwater volcanic activity takes place or in estuarial waters the water may naturally be slightly acidic.

In the shipping sector, wet scrubbers are divided into two types; open loop and closed loop which were developed separately but which are now frequently combined into a hybrid system that can employ the most appropriate technology depending upon prevailing circumstances. Open loop scrubbers have proved the most popular especially for larger ships that make transoceanic voyages and have access to seawater for most of the voyage.



Main types of wet scrubber

In an open loop scrubber, seawater is used as the scrubbing and neutralising medium and no additional chemicals are required. The exhaust gas from the engine or boiler passes into the scrubber and is treated with seawater. The volume of seawater will depend upon engine size and power output but equates approximately to around 40m3 per MWh meaning a quite high pumping capability is required. The system is around 98% effective and even allowing for fuel oil with 3.5% sulphur should have no problem reaching the maximum 0.1% ECA level.

An open loop system can work perfectly satisfactorily only when the seawater used for scrubbing has sufficient alkalinity.

Freshwater and brackish water are not effective, and neither is seawater at high ambient temperature. For this reason, an open loop scrubber is not considered a suitable technology for areas such as the Baltic where salinity levels are not high.

MARPOL regulations require the washwater to be monitored before discharge to ensure that the PH value is not too low.

A closed loop scrubber works on similar principles to an open loop system but instead of seawater, it uses freshwater treated with a chemical (usually sodium hydroxide commonly called caustic soda) as the scrubbing media. This converts the SOx from the exhaust gas stream into harmless sodium sulphate. Unlike the flow through method of open loop scrubbers, the washwater from a closed loop scrubber passes into a process tank where it is cleaned before being recirculated. The freshwater can either be carried in tanks or else produced on board if a freshwater generator is installed on the ship.

In order to prevent a build-up of sodium sulphate in the system, a small amount of washwater is moved at regular intervals either overboard or to a holding tank and new freshwater is added. The volume of washwater required in a closed loop system is around half that of the open loop version however, more tanks are required. These are the process or buffer tank in the circulation system, a holding tank for when discharge to the sea is prohibited and a storage tank able to have a controlled temperature between 20°C and 50°C for the sodium hydroxide which is usually used as a 50% aqueous solution. There must also be storage space for the dry sodium hydroxide.

The hybrid system is a combination of both wet types that will operate as an open loop system where water conditions and discharge regulations allow and as a closed loop system at other times. Hybrid systems are proving to be the most popular because they can cope with every situation.

All scrubber systems require a treatment bypass for when the ship is operating without the need to use the scrubber.

This happens when the ship is using compliant fuels for the area of operation (0.1% in ECAs or 0.5% elsewhere if the fuel contains sulphur) or an alternative fuel such as LNG, LPG, ammonia or methanol

This prevents damage to the scrubber and reduces maintenance. Care needs to be taken to ensure that the scrubber is not causing backpressure to the engine as this could be damaging and will affect NOx reduction systems.

Washwater composition

At the heart of the passionate debate over scrubbers is the potential for the washwater to pollute the oceans rather than exhaust emissions being released into the atmosphere.

Obviously, the prime purpose of the scrubber is to remove SOx and this is done quite effectively. Typically, the SOx in the exhaust stream will be 95% SO2 (sulphur dioxide) and 5% SO3 (sulphur trioxide)

In the seawater used for washing the following chemical reactions occur.

Sulphur Dioxide

SO2 + H2O <> "H2SO3" (sulphurous acid) <> H+ + HSO3– (bisulphite)

HSO3– (bisulphite) <> H+ + SO3 2- (sulphite)

SO32- (sulphite) + ½ O2 <> SO42- (sulphate)

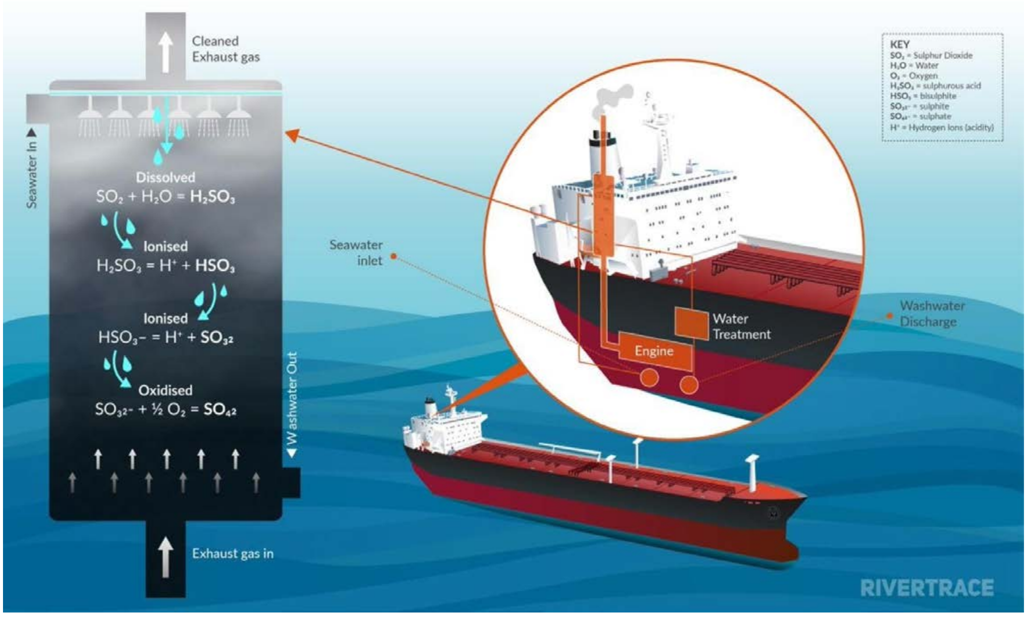
(Note: there is no evidence that sulphurous acid exists in solution, but the molecule has been detected in the gas phase)

Sulphur Trioxide

SO3 + H2O > H2SO4 (sulphuric acid)

H2SO4 + H2O > HSO4– (hydrogen sulphate) + H3O+ (hydronium)

HSO4– (hydrogen sulphate) + H2O > SO42- (sulphate) + H3O+(hydronium)



Infographic showing the chemical reactions of the washwater with exhaust gas

The ionisation to bisulphite and sulphite produces excess hydrogen (H+) ions adding acidity, as does the sulphuric acid formed from sulphuric trioxide. This will be initially neutralised by the seawater's buffering capacity or alkalinity, which is mainly imparted by its natural bicarbonate content. However, once the initial buffering capacity is consumed and the pH reduces to approximately 3, the ionisation of sulphur to sulphite is negligible and exhaust gas cleaning becomes limited.

Manufacturers have optimised the washwater flow to ensure that SO2 can dissolve, and an appropriate amount of buffering capacity is available to enable emissions to be reduced to the required level.

If the flow is too low or the seawater is less alkaline than presumed (This can happen in areas where alkalinity is impacted by outfall from rivers or underwater volcanic activity – which is significant in much of the world's oceans), the ability to dissolve SO2 can be significantly reduced. Seawater temperature also affects the composition, with cooler waters being able to dissolve SO2 more effectively.

The washwater is diluted in seawater before discharge so that the excess acidity (there are limits as to the pH value of wash water under IMO guidelines) is further reduced to a level that is considered by most as acceptable.

The sulphate that is being added to the oceans has been described as harmful but this is disputed. Sulphate is a naturally occurring constituent of seawater. It is soluble and unaffected by the natural pH, temperatures and pressures found in the oceans. A large amount of sulphate in seawater is derived from volcanic activities and degassing at the seafloor. Further, sulphates reach the oceans via river flows, but the concentration in open seawater remains constant at around 2.65 g/l.

More to the point, studies have calculated that if all the sulphur in the world's oceans were to be removed, it would form a layer around the earth about 1.7m thick. All the sulphur in all the known oil reserves would add only another 10 microns to this layer.

Metals and PAHs in washwater

The debate over other constituents in washwater could have more weight as these may genuinely have an impact. However, the washwater does undergo some cleaning before discharge. Particulate matter and other suspended solids removal is a benefit of scrubber operations that is often overlooked.

Typically a scrubber will produce around 0.6 tonnes of sludge for every 100 tonnes of fuel used in the engines. This is not permitted to be discharged to the sea and must be retained. A closed loop scrubber system may produce more sludge. In a ship, without a scrubber, much of what becomes sludge would have been released into the atmosphere and either remain there or end up deposited in the ocean or on land.

Even after treatment for sludge removal on board, some residues will be present in the washwater. Some of this will be unburned fuel but at levels well below the 15ppm or 5ppm detectable by oil content monitors used for bilge treatment monitoring.

Washwater will normally contain some metals which may be undesirable, but their source is debatable. Vanadium – the most commonly found metal in washwater – is likely to have been present in the fuel used and would have been emitted in non-scrubber equipped ships in at least the same quantities.

Many of the other metals were almost certainly present in the seawater taken in by the scrubber. This is especially true of zinc and copper which are found in anodic protection systems and antifoulings on ships' hulls and which will be deposited in the ocean by all ships whether scrubbers are installed or not.

Another component of washwater is Polycyclic aromatic hydrocarbons (PAHs). These are organic compounds with two or more fused aromatic rings. PAHs occur naturally in oil and are also produced as by-products of fuel combustion.

Some of these compounds are carcinogenic and can accumulate in edible shellfish, which gives them a pathway to humans and other species. It is acknowledged that PAHs can form due to incomplete combustion of fuel oils and although engines and boilers are designed to optimise the combustion of fuel, exhaust gases will always contain a proportion of incompletely combusted material.

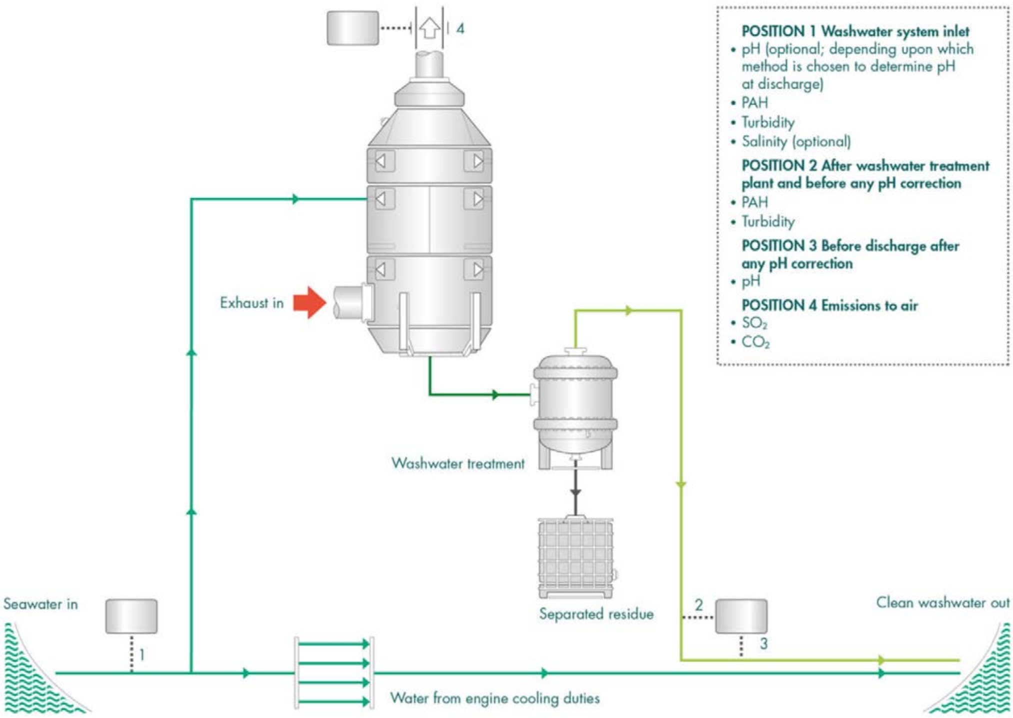
Although some PAHs will be present in the washwater, many of the heavier and more toxic types will be removed especially if they are bound to soot and particulate matter. By contrast, any PAHs present in the exhaust of an unscrubbed ship will be released directly into the atmosphere and will be deposited naturally in the ocean. It should also be noted that PAHs found in the oceans could also have come from non-maritime uses even far inland where they will be washed to the sea by rivers and land runoff.

Measuring at both ends

For a scrubber system, the IMO guidelines require that the washwater discharged from an open loop scrubber is within a certain range of the water taken in for scrubbing use.

Because of this, the monitor must measure more than one characteristic. An ideal monitoring system for a scrubber would measure the polycyclic aromatic hydrocarbon (PAH), turbidity, temperature and pH at both the inlet and the outlet points although under current rules only the pH needs to be measured at the inlet.

The pH value is of particular importance because if there is too great a variance between inlet and outlet readings, the pH of the washwater must be adjusted. This can be done by neutralisation or by dilution. The former involves adding chemicals and the latter the pumping of large volumes of seawater.



Typical scrubber system showing measuring and correction locations.
Source: EGCSA

Exhaust Gas Recirculation

There are various methods of reducing NOx emissions as required under MARPOL but often a combination of methods is needed to meet the compliance levels required. One of these is Exhaust Gas Recirculation (EGR).

NOx is formed when the nitrogen in the charge air combines with oxygen in the combustion process. More NOx is formed at higher combustion temperatures so one means of control is to lower the combustion temperature.

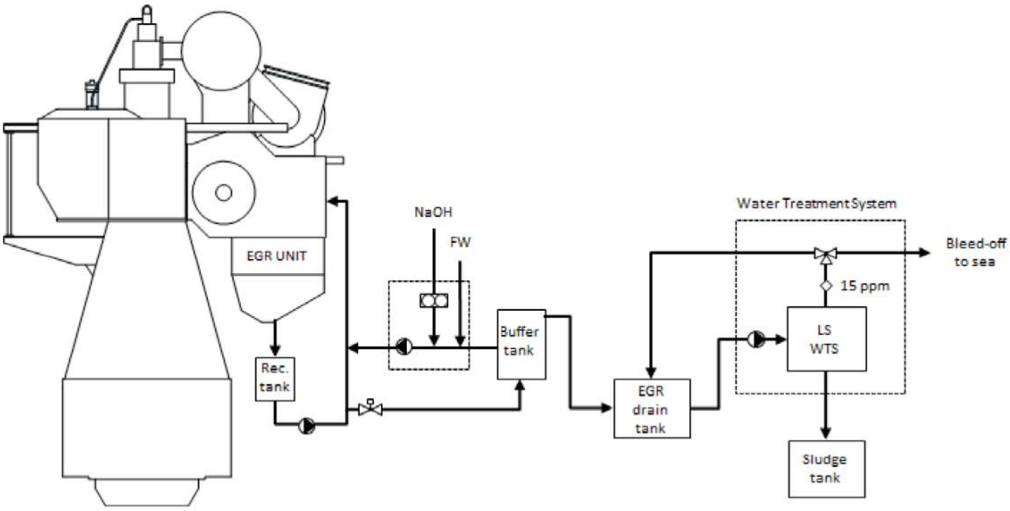
By re-circulating exhaust gas into the charge air, the oxygen content in the cylinder is reduced and the specific heat capacity increased. Both cause lower combustion temperatures and therefore fewer NOx emissions.

In a typical EGR system, a proportion of around 40% of the exhaust gas from the main engine exhaust receiver, instead of being directed to the turbocharger, is passed through a dedicated closed loop scrubber (not the main SOx scrubber if one is fitted) which removes PM and SOx which could cause engine damage and cools the exhaust gas to be re-circulated. The contaminated water from the scrubber must also be cleaned and the sludge generated disposed of ashore which usually involves an additional extra cost.

The re-circulated gases cause oxygen (present as O2) in the scavenge air to be replaced with CO2 which has a higher heat capacity and so helps reduce peak temperatures in the cylinder. The reduced O2 content in the scavenge air also reduces the combustion speed, which further reduces peak temperatures in the cylinder which reduces the formation of NO and therefore NOx.

Since the EGR scrubber and a SOx scrubber work in similar ways, the washwater from both is virtually identical in composition. Although an EGR system scrubs much less of the exhaust so the quantities are different. From a regulatory point of view, the washwater from an EGR system is generally referred to as bleed-off.

After the introduction of the 2020 sulphur cap, some engine makers revised the EGR arrangements for removing sulphur and developed systems more suited to low sulphur fuel for ships not fitted with scrubbers and high sulphur systems for ships with scrubbers. The differences can be seen in the following diagrams of the MAN Energy Solutions EGR arrangements for low-speed two-stroke engines.

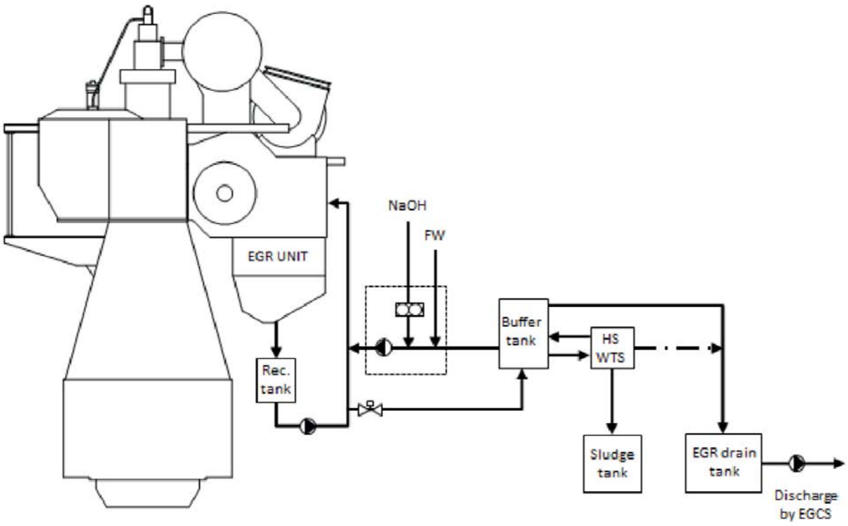


MAN ES Low Sulphur water handling

The LS WTS (water handling system) will be applicable to EGR systems designed for fuels of max 0.5% sulphur.

The main differences between the new LS WTS compared to the previous system are:

- cleaning of water for the EGR process is not required
- the LS WTS is simplified, only handling the bleed-off water from the EGR
- MAN Energy Solutions will not require approval of the LS WTS
- certificates for type approval of oil content meters will be required onboard, including operating and maintenance manuals
- buffer tank is specified by MAN Energy Solutions and can be delivered by any maker: licensee, yard or external supplier.

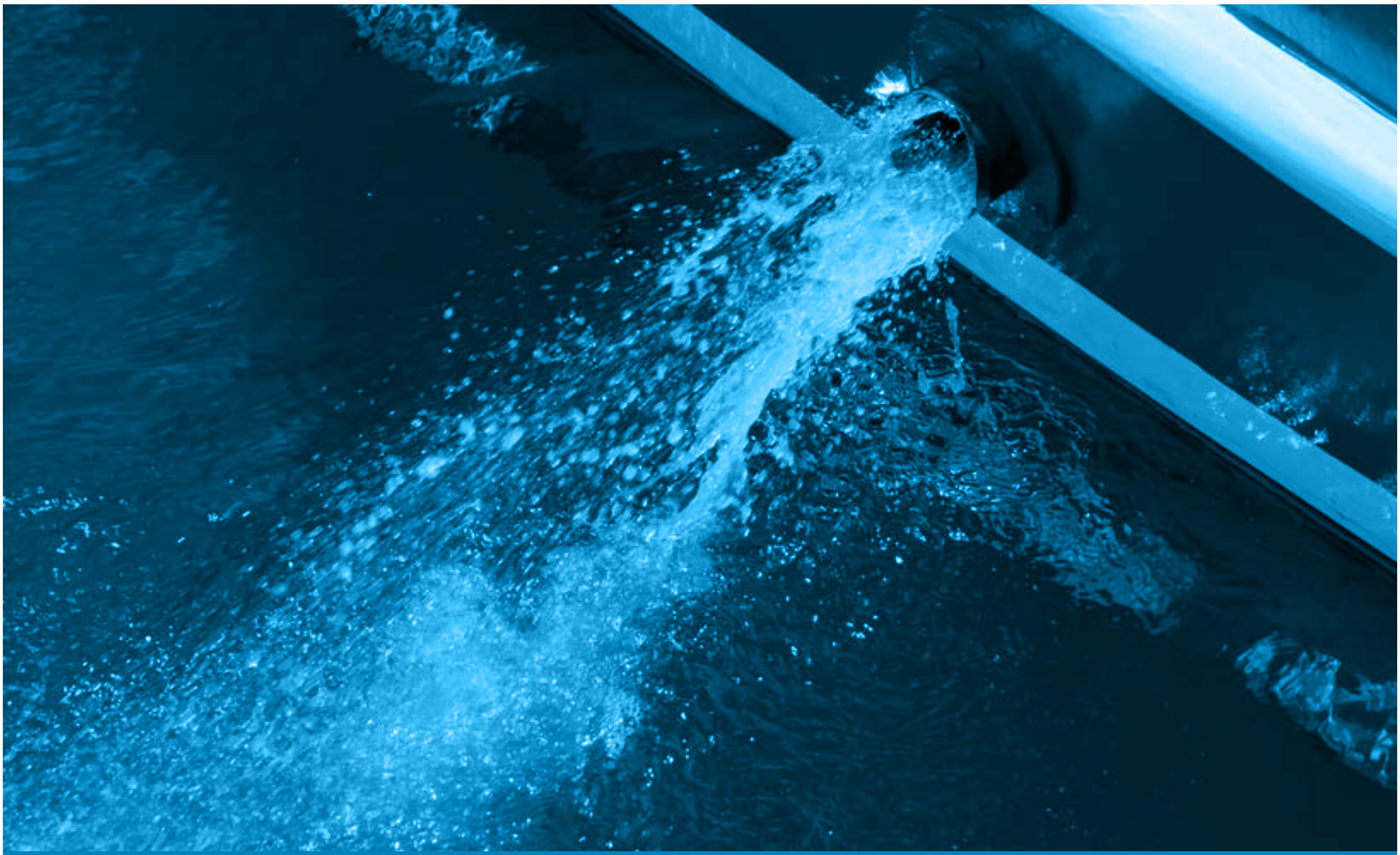


MAN ES High Sulphur water handling

The high-sulphur water treatment system (HS WTS) will apply to EGR systems designed for high-sulphur fuels, i.e. fuels that do not comply with the fuel sulphur limits and, therefore, require installation of a SOX scrubber on board.

The main differences between the new HS WTS compared to the previous system are:

- lower amount of water being circulated to the buffer tank and returned to the engine
- HS WTS is simplified, operating only to maintain the water quality in the EGR circuit
- bleed-off water from the EGR process, which is sent to the EGR drain tank, can be discharged by the exhaust gas cleaning system (EGCS)
- buffer tank is specified by MAN Energy Solutions and can be delivered by any maker: licensee, yard or external supplier.



02 Bilge water & oil water separation

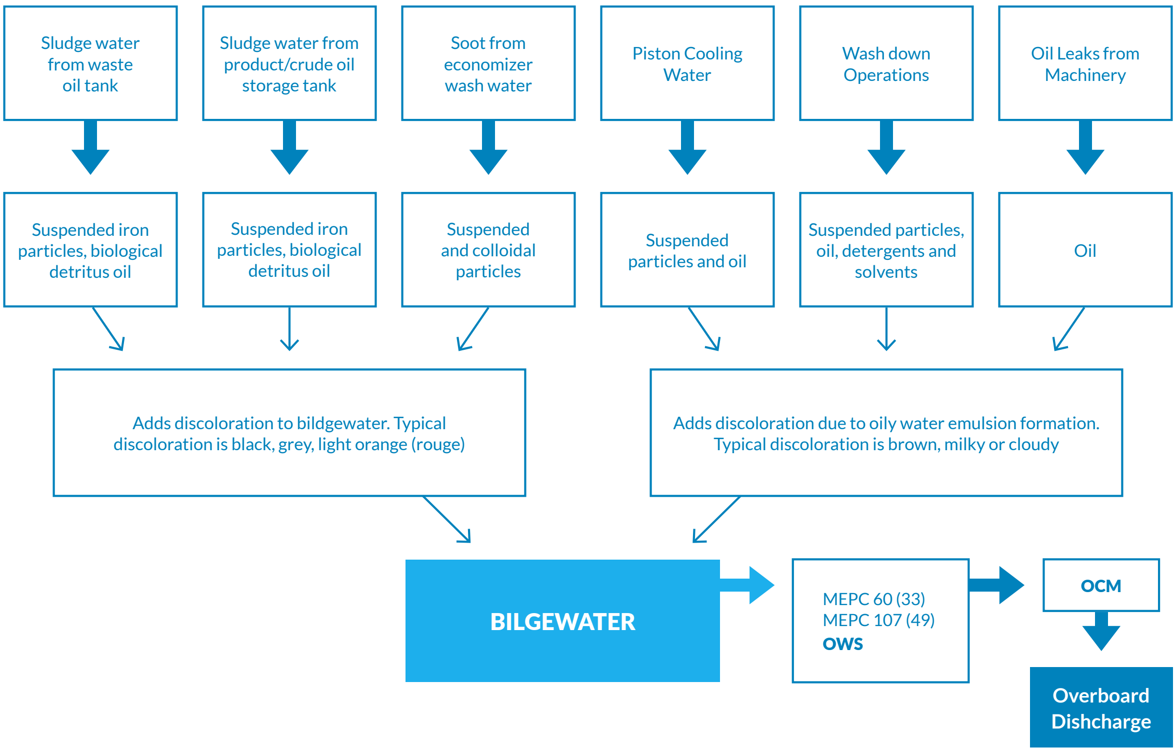
This chapter looks at what bilge water is and the developments in bilge water treatment and the use of the oil water separator.

It also examines the difficult reputation that separators have among some seafarers and the various means used to illegally bypass them.

All ships have bilge wells at the sides of the ships where the lower platform of the engine room meets the sides of the hull.

Even in the most well-maintained engine rooms, the bilge wells will gradually fill with a mixture of water, oils and chemicals that result from everyday activities such as maintenance and cleaning as well as from other sources.

These other sources include the pipework of machinery that can carry hydraulic fluids as well as both seawater and freshwater, leaking pumps and valve glands, solvents used for cleaning machinery when carrying out repairs, accidental spills, overflowing tanks. Then there is the inevitable rust and general dirt and grime that is always present even in the best maintained ships.



Sources of bilge water

Some of the cleaning chemicals can act as an emulsifier, meaning that the oil in the bilge can actually bond with oils and greases making later treatment more of a problem. The mix of products in the bilge can mean that the list of contaminants can be long and include some heavy metals and undesirable chemicals albeit it normally only in minute amounts.

Below the engine room floor plates there are many pipes serving different systems from heat exchangers, boilers, freshwater generators along with fuel lines between tanks and the engines both main and auxiliary. Bilge can also accumulate in other areas of the ship including in cargo holds and bow thrusters.

At intervals, the mixture accumulated in the bilge wells will be pumped to a holding tank for treatment by the oily water separator (OWS). If this was not done the bilge well would overflow into the engine room causing a severe safety hazard.

Bilge from cargo holds often contains nothing more than cargo residue and hold wash water but may contain oil In such cases, the bilge will be pumped to the main bilge holding tank for treatment.

There should be strainers within the bilge well to separate oil large solids that have entered the space and so prevent bilge pumps from blockages and more importantly to reduce the material being sent to the oily water separators for treatment.

Before 1983, it was permissible for ships to pump bilge overboard directly, but with the coming into effect of MARPOL in 1983 that practice ceased. The new rule set a maximum of 15ppm (parts per million) of oil to be permitted in overside discharges. All remaining oil and sludge was to be disposed of ashore or incinerated.

The initial ruling set a performance standard for separators that would need to be type-approved using a mix of clean water and diesel fuel alone. The requirement was changed in 2005 when a new requirement for separators to be able to also deal with emulsified mixes was introduced under MEPC 107(49). This change also brought with it a requirement for recording and monitoring of bilge water treatment.

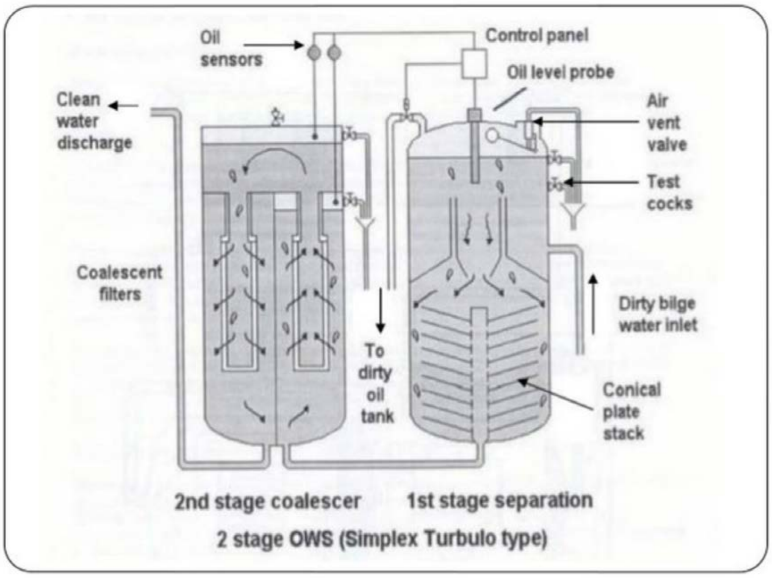
Unloved equipment

Maintaining the bilge oil water separator has never been the easiest or most pleasant task for the engine crew to perform, but after 2005 it became even more difficult. To meet the new requirements, many new oily water separators (OWS) were introduced to the market along with improved monitoring options for the bilge alarm.

Arguably the most common failing of separators is because their operation can be affected by the motions of the ship – especially in heavy weather. Added to this is the fact that space on ships is limited and often equipment is chosen on size rather than the ability to perform adequately in service.

Separation technology

Early separators were mostly of the gravity separation type that employs plate or filter coalescing technology to separate oil and water. The bilge water is usually heated gently to improve separation with the oil gradually settling out above the water content. The oil is then pumped to the holding tank and the water discharged to sea after passing through the oil content monitor. Without further refinements, gravity separators can have difficulty in meeting the 15ppm standard especially when the bilge water contains emulsified oils that do not separate easily.



Gravity separation system

Centrifugal separation

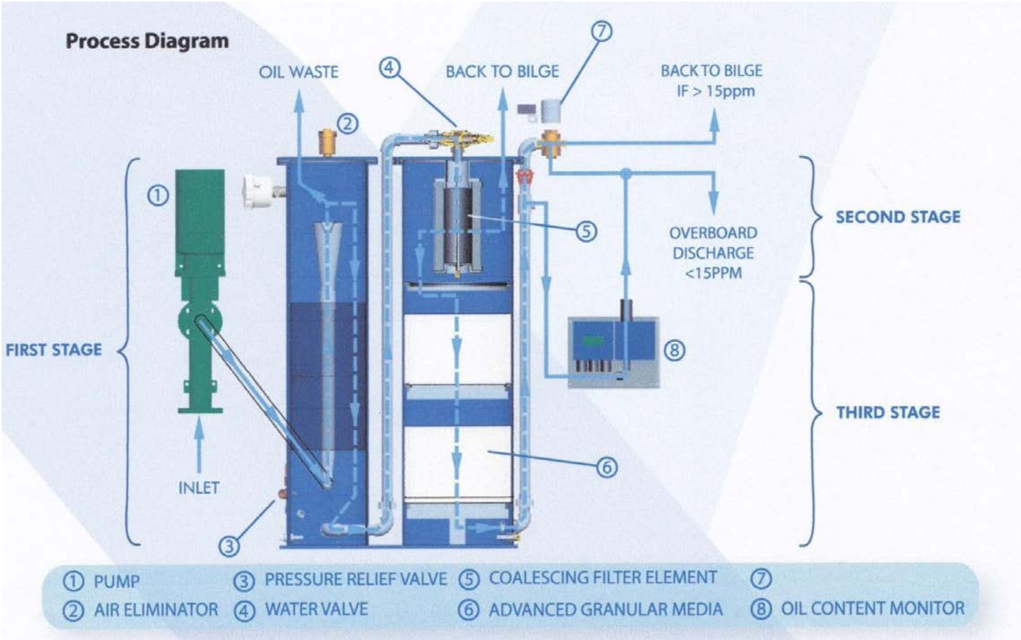
Centrifugal separators also work using the different densities of oil and water but with the centrifuge greatly multiplying the gravity effect as the centrifuge accelerates. This type of separator is more efficient and can generally deal with emulsified oils. Many crew members are familiar with this type of equipment which is also used for preparing fuels and lubes before use by removing sludge and homogenising the fuel or lube. They are more compact than gravity-type separators but have the disadvantage of requiring power to operate the centrifuge and, because of their moving parts, often have a higher maintenance requirement.

Centrifugal separation in Alfa Laval PureBilge

Absorption and adsorption

These are very similar physiochemical processes and can be considered together. In both cases, the bilge water is forced through the sorption media in a reactor or contactor vessel and the oil is removed. When the sorption material has reached its full capacity, it is removed and replaced with fresh material. Some sorption materials can be regenerated onboard, but others will need to be delivered to shore. Popular absorption materials include bentonite and zeolite used as substrates or in cartridges. Typically, 100m3 of bilge water will require 10kg of media.

In some separators, this process may be combined with other methods.



Adsorption – Victor Marine Separator

Flocculation and coagulation

Flocculation and coagulation make use of an emulsion-breaking chemical to treat emulsions after any free oil has been separated. The chemical breaks down the emulsion and the released oil comes together to form flocks which can then be skimmed off leaving the remaining water to go through further filtration stages. This method tends to produce large amounts of sludge and requires an outlay on the chemical reagent.

Biological

Biological treatment employs microbacteria in a bioreactor to literally consume the organic chemicals in the oil, converting it to carbon dioxide and water. It is a slow but effective treatment for oil and emulsions as well as also removing some of the other solvents often found in bilge water. Capital outlay can be high but operating costs are low. Care must be taken to avoid overload on the microorganisms and maintaining the operating temperature within the safe range to avoid destroying them.

Filtration

Membrane technology, ultrafine filtration and reverse osmosis are all physical means of preventing oil and other large molecules from remaining with the water that can pass through the filter barrier. They are efficient but require attention to prevent blocking of the filter or membrane.

Cheating the system

The requirement to install and use a separator is mandatory for all vessels over 400GT as a means to prevent pollution. There are two unrelated reasons as to why seafarers and shipowners risk reputations, fines and even their freedom by ignoring the regulations and discharging bilge water direct to the sea.

From the seafarer's point of view, a separator that is unreliable and which cannot physically cope with treating the amount of bilge generated is a source of much trouble that requires constant attention to the detriment of other duties and perhaps also rest time.

From the owner's point of view, it is the cost of disposing of the oil residue that is the problem. Often this is very costly and on marginally profitable ships something that is best avoided. Although almost none of the operators of ships that have been caught out making illegal discharges have ever admitted that they gave instructions for the action, the prosecuting authorities have nevertheless held them responsible and levied high levels of fines. The main method of cheating the system is the so-called 'magic pipe' which involves inserting a pipe into the feed to the separator from the bilges and diverting the waste directly to the sea. On systems that record the volume of bilge treated, seawater will be added to the feed beyond where the magic pipe is discharging. This has the effect of ensuring quantities treated are credible as well as diluting the bilge to make treatment easier.

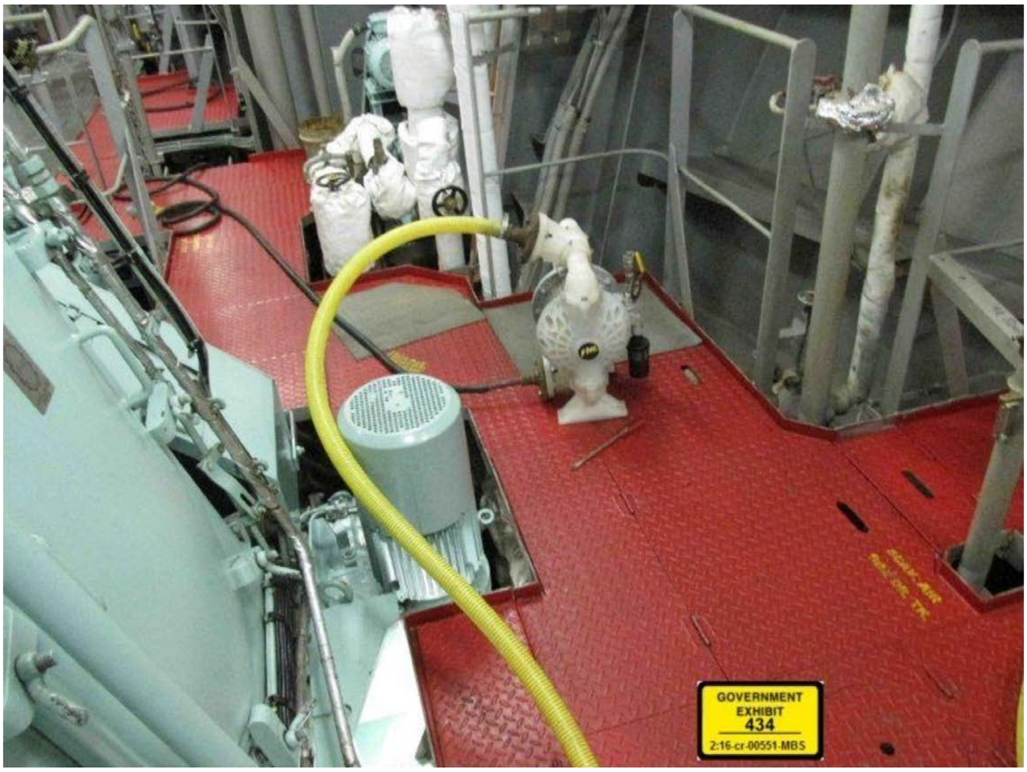


Image showing the so-called "magic pipe" setup. Vessel: Green Sky Credit: DOJ

Some methods of cheating are more sophisticated and involve tampering with the monitoring equipment that determines if the oil content is in line with the maximum 15ppm allowed under MARPOL. If the monitor detects a level above 15ppm, the separator is either shut down automatically or a valve is operated which sends the outlet water back to the bilges.

In normal operation, a monitor may be fooled by suspended solids such as rust and scale which are quite innocuous, but they may not detect the presence of some clear liquid chemicals that could be toxic to marine life when discharged into the sea. It is also possible to fool the monitor by various deliberate means including closing the valve from the separator so that the sight glass of the monitor is continuously monitoring a clean sample. This may not be possible if the monitor includes a flow-measuring component.

The monitor is a crucial component of separators and is often not an in-house product of the separator maker.

There are a small number of specialist monitoring device manufacturers that produce systems for measuring many of the other different discharges permitted from ships such as ballast and scrubber washwater. Many of these monitoring systems have versions that are designed to prevent any deliberate cheating, and some can take a data feed from navigation systems to record precise locations as to where and when separation was carried out.

Illegal discharges that take place on the high seas outside of territorial waters can only be actionable by the flag state. However, if the vessel calls at a port and PSC authorities ask to see the Oil Record Book which details the use of the separator, and a false document is shown, this is considered as a criminal act committed in the Port State's territory and is actionable by the port state. It is by this means that most of the massive fines – often amount to several million dollars – can be levied.

Detection of the crime is made easier by whistleblowers from the crew who can be rewarded by the Port State, observance of the discharge at sea and by PSC inspectors being trained to spot tell-tale signs that a magic pipe has been used.

03 Water Monitoring Technology

A look at the various types of monitoring equipment used for checking and recording water quality and treatment.

It compares the pros and cons of different technologies and their perceived limitations.

This article will deal with the systems designed to monitor water discharged from vessels including bilge water separators, ODME equipment on tankers and exhausts scrubbing systems.

Other shipboard systems that may discharge to the sea and warrant monitoring – black and grey water and ballast water can also prevail of the same technology but applied in different applications.

A variety of technologies are used to detect the presence of oil in water most of which are optical-based. Their effectiveness will vary depending upon a number of factors such as the oil content of the water, the presence of solids such as rust, chemical contaminants and the turbidity of the water. Some systems cope better than others with one or more of these conditions but since the composition and quantity of bilge is never a constant, an element of chance is involved in selecting the most suitable.

The following description of the technologies and their advantages and disadvantages is based upon a whitepaper Choosing the right oil-in-water sensor technology published by leading OCM manufacturer Rivertrace.

Scattered Light

This technology is a popular choice for OCMs on ships because of its relatively low cost and being unaffected by water colour. On the downside, excessive solids can affect readings and the systems must also be calibrated to specific oil types which can lead to deviations if the oil varies.

These monitors measure the intensity of light as it passes through water to indicate oil concentration. Oil particles present in the sample water will scatter (or 'refract') light in correlation to the levels of oil in water: the higher the oil content, the more light is scattered.

Receivers measure the amount of light scattered, from which the concentration of oil in the water can be determined. Scattered wavelength technologies transmit a single wavelength of light such as ultraviolet, infrared or white light with various filters. Each wavelength has its advantages. Infrared light, for example, provides stable measurements across a wide range of temperatures.

Receivers can be placed all around the optical path. Rivertrace's scattered light sensors measure forward scatter, which can be collected at multiple angles to provide additional information that can account for solids in the sample. Solids will also scatter light, but their irregular shapes do not refract light in the same way as oil's spherical molecules. Using multiple angles of sensors highlights the shape of the molecules and enable solids to be discounted.

One challenge associated with scattered light measurements is the phenomenon known as 'fall-off'. Scattering of light peaks at around 100-150 ppm of oil, after which the concentration of oil is so great that it absorbs much of the light transmitted and the proportion of scattered light appears to fall. The level of fall-off is determined by the configuration of the measuring cell as well as the light wavelength and angle at which scattered light is measured. If not accounted for, fall-off can lead to disastrously misleading readings of oil concentration.

Another potential source of inaccuracy is the degradation of the light source over time. This will cause a lower level of light to be transmitted and received. If not accommodated, this can lead to inaccurate results as lower scattered light is recorded. In the first instance, a feedback circuit should monitor the power to the light source to keep it constant. A further, more reliable way of preventing the challenges caused by a degrading light source is to measure not only the scattered light received but also the amount of light transmitted.

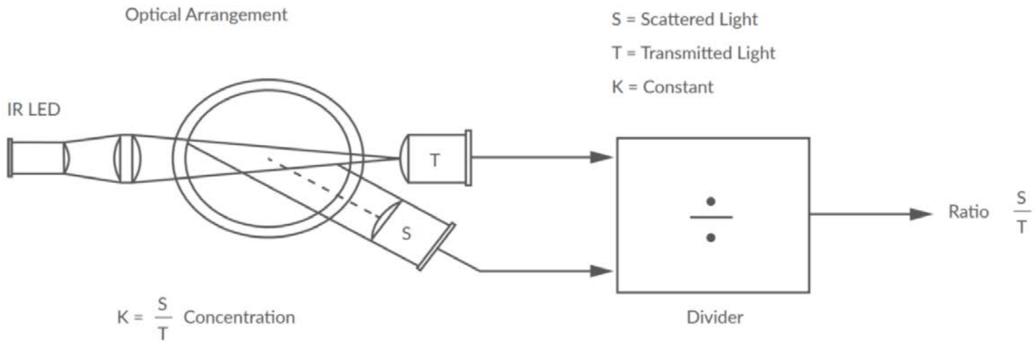


Diagram showing scattered light optical arrangement

Absorbance

Not a common choice for shipboard systems due to high cost but they are more accurate approaching laboratory standards of accuracy.

Absorbance measurement technologies make use of the fact that different particles absorb light of different wavelengths. Hydrocarbons absorb energy at a specific wavelength (3.4µm) and the amount of that wavelength energy absorbed is proportional to the level of hydrocarbons in a sample. By measuring the amount of energy of specific wavelengths absorbed, the concentration of various oils and solids can be determined.

One of the major advantages of using absorbance is that it can be used in dirty water including water containing oil-field chemicals. But measuring fluorescence with UV light can lead to false positives in dirty water. Measuring absorbed light at the right wavelengths reduces this risk.

Fluorescence

Is used in some OCMs for bilge water and is also a reliable technology for scrubber washwater monitoring.

Fluorescence is an accurate technique for detecting oil in water. Developed in the 1960s to detect contaminants in public water supplies, it can identify particles in the range of parts per billion – a far lower concentration than that encountered in most industrial applications.

A straight beam of ultraviolet light at a known wavelength is directed into a glass tube filled with the sample. When oil droplets are excited by ultraviolet light, they will emit light at a different wavelength. This is known as fluorescence light. Each oil molecule has a specific fluorescence wavelength light. In this way, the oil's presence can be accurately detected.

As each species of oil reacts to different light wavelengths, using a single wavelength is ideal in applications dealing with a single, known species of oil. However multiple types of oil and contaminants can lead to inaccurate readings, as they can fluoresce in the same way as the oil being measured. This is particularly true in oilfield applications, where both oil-coated solids and other chemicals can lead to false positives.

Microscopy

This is a good system for measuring oil content in bilge water and as it also detects gas bubbles present it is also useful for scrubber washwater monitoring from both SOx and NOx from EGR systems.

Microscopy is the determination of oil concentration by measuring droplet size through image processing and recognition software. A high-speed camera takes pictures of the sample at a rate of several images per second. These images are analysed against a predefined library of components that can determine the visible differences between oil, gas and solids.

The shape of droplets is a good indicator of an oil and its conditions. For example, oil in ambient conditions is a perfect sphere, while under pressure droplets can change to an egg shape. Gas is a circle with a dark edge and a bright centre. Solids on the other hand have an irregular shape. The software then determines the size and quantity of each object and displays an accurate oil measurement, disregarding unwanted interference from gas and solids.

Microscopy is useful because it is easy to calibrate against a specific shape or image and is unaffected by the intensity or wavelength of available light, oil species and solid particle size.

Its limitations are associated with cell fouling and optical trauma. The accuracy of microscopy is negatively affected by fouling of the optical monitor (or cell) and by anything that causes an unacceptable level of blurring on the lens. To a large extent, the cell can be kept clean with a minimal maintenance regime.

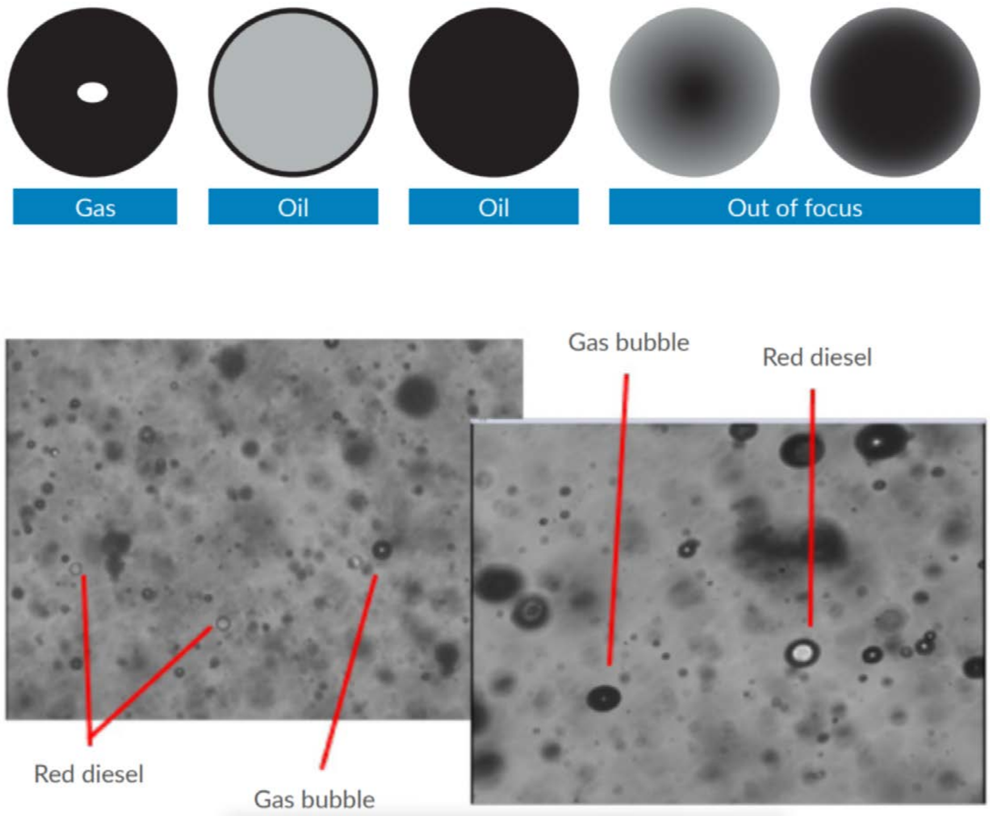


Diagram showing example images from microscopy camera

04 Regulation

An examination of current IMO/MARPOL regulation relating to oil in water discharge operations and data recording and also a discussion on likely future regulation and timetables.

It will also cover some of the more important regional regulation and developments outside of MARPOL.

Sources of rules

Most of the regulation relating to both bilge water and washwater treatment emanates from the IMO through the MEPC committee which is tasked with the oversight and development of the MARPOL convention.

IMO INTERNATIONAL MARITIME ORGANIZATION

Most of the regulation relating to both bilge water and washwater treatment emanates from the IMO through the MEPC committee which is tasked with the oversight and development of the MARPOL convention.

Although regulation and non-mandatory recommendations may be formulated at the IMO, flag states must enact appropriate legislation for them to become law for ships flying that state's flag. Port states are free to legislate as they wish and may have more stringent requirements than the IMO has developed, or they may choose to ignore the IMO rules as they see fit.

This may seem to be an unsatisfactory situation, but it is one that must be lived with. The division between port state and flag state rules does result in some anomalies. For example, Singapore has banned the use of open loop scrubbers in its waters for all ships regardless of flag but it has not prevented Singapore-flagged vessels from using open loop scrubbers in other nations' waters.

Shipowners and operators must at all times obey the appropriate rules from flag and port states but there is nothing to stop them from practising even more stringent standards. Class societies have developed a whole range of 'Clean Ship' notations that recognise the voluntary application of higher standards.

Vessels that have these notations can benefit from them by way of requesting premium freight or charter rates and by incentives from some ports in the form of reduced port dues.

Separators

Since bilge water treatment has been subject to IMO regulation for longer than scrubbers it is appropriate, to begin with the rules applying to separators.

MARPOL Annex 1, Regulation 14 requires all ships above 400gt to be equipped with systems that ensure treated bilge water must have an oil content below 15ppm before discharge to the sea. In addition, flag states must ensure ships under 400gt either have the capacity to store any bilge with an oil content above 15ppm or else be equipped with the treatment system.

Ships must also have an alarm arrangement to indicate when the 15ppm level cannot be maintained by the separator and a means of shutting down the system automatically if the level goes above 15ppm.

Canada has bilge discharge requirements that are stricter than the international 15 ppm standard. The Canadian Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals requires 5 ppm bilge alarms on the Great Lakes.

The IMO's GUIDELINES AND SPECIFICATIONS FOR POLLUTION PREVENTION EQUIPMENT FOR MACHINERY SPACE BILGES OF SHIPS have existed in various forms beginning as MEPC. 60(33) in 1992, through to a revised version MEPC. 107(49) adopted in July 2003 and applicable to ships built after 2005. The latter was amended by MEPC. 285(70) adopted in October 2016 but most of its text remains valid.

It's worth noting that these remain guidelines and are non in fact mandatory but Flag states have generally passed on these recommendations in notices to shipowners and some have given them force of law for their flag vessels.

Classification societies have also adopted the guidelines for use when type-approving equipment. Indeed through IACS they have been instrumental in clarifying some of the requirements including recalibration of monitoring systems.

Advice on operation

Manufacturers of separators and OCMs will provide their own instructions and customer support services but since so many problems appear to have been experienced with the operation of bilge water treatment equipment the IMO has compiled some advice of its own.

The advice is contained in a circular MEPC.1/Circ.677 of 22 July 2009 titled GUIDE TO DIAGNOSING CONTAMINANTS IN OILY BILGE WATER TO MAINTAIN, OPERATE AND TROUBLESHOOT BILGE WATER TREATMENT SYSTEMS. It is a 37-page document that can be used in addition to the manufacturers' guidance and is a useful source of information for ship operators and engineers.

Oil Discharge Monitoring Equipment

Large oil tankers above 40,000dwt have been prevented from using cargo tanks for ballast purposes since the early 1980s and must be built with segregated ballast tanks. Smaller product and chemical tankers often do not have tank capacity to segregate ballast. Such vessels are permitted to use seawater ballast in cargo tanks but conditions for discharging the ballast, which will inevitably contain some oil contamination, are strict to reduce the polluting effect to a controlled minimum.

Even though the larger tankers should not have oily ballast, they will still have oily bilge water to dispose of and also the contents of the slop tanks where water used to clean the cargo tanks is stored.

This might be disposed of ashore at some ports where shore facilities are provided but in the majority of cases discharge overboard is the only option before loading the next cargo.

As with non-tanker vessels, bilge water if treated alone must comply with the rules laid down in MEPC 107(49). However, in both large and small tankers the discharge of other oily water must be managed according to rules and guidelines set out in IMO resolution MEPC.108(49).

Under this resolution, all oil tankers of 150gt and above must have approved Oil Discharge Monitoring Equipment (ODME). A more recent resolution MEPC 240(65) for Bio Fuels, became effective on 1 January 2016.

The resolution is quite an extensive document covering as it does, the installation, operation and maintenance of the equipment but for practical purposes, type-approved systems that are operated and maintained following the makers recommendations are usually more than sufficient to ensure compliance.

Unlike the arrangements for bilge water where the discharge of treated water is permitted if the oil content is 15ppm or less, the discharge criteria for other wastewater from tankers requires a more sophisticated computing arrangement. This is because the rate of discharge of oil is limited to 30 litres of oil per nautical mile regardless of ship size and the total quantity of discharge must not exceed 1/30000 of the total quantity of the residue formed cargo.

The ODME comprises:

- an oil content meter to analyse the content of oil in the water that is to be discharged overboard,
- a flow meter to measure the rate of discharge,
- a computing unit to calculate the oil discharge in litres/nautical miles and the total quantity, along with the date and time identification and
- a control valve to stop discharge when the permissible limit has been reached.

The technology used to measure the oil content in the water is the same as that used in the 15ppm OCMs of other ship types, but the computing functions and flow rates require additional components and technologies. It is these other components that control the separation and discharge operations. Whereas in the bilge treatment, the operation can continue providing the oil content is not above 15ppm, the ODME must cease the overboard discharge if the 30 litres per nautical mile limit is exceeded (as could happen if the ship is moving slowly) or if the overall limit is reached.

There are other restrictions on discharge beyond those mentioned above and these require that the vessel must be underway, it should not be in any special area where discharge is prohibited, and it must be 50 nautical miles away from any land. These restrictions should be monitored and recorded utilizing a GPS input to the data and the record of ODME operation must be retained on board for a minimum of three years.

ODME Recordings and Regulations

To comply with the requirements of MEPC.108(49), the computing and control device must receive the following information:

- the oil content of the effluent ppm;
- the flow rate of discharge m3/hour;
- ship's speed in knots;
- ship's position - latitude and longitude;
- date and time (GMT); and
- status of the overboard discharge control.

The IMO has tried to ensure that the ODME should not be circumvented and lays down in Section 5 of the resolution that it 'should be designed to ensure that user access is restricted to essential controls. Access beyond these controls should be available for emergency maintenance and temporary repair but must require the breaking of security seals or activation of another device that indicates an entry to the equipment.

The seals should be of a design that only the manufacturer or his agent can replace the seals or reset the system following inspection and permanent repairs to the equipment.

It also requires that the accuracy of the ODME – as with the OCM for bilge water – should be verified at IOPP renewal surveys and a calibration certificate attesting to that should be retained on board for inspection purposes.

Washwater Rules for SOx scrubbers

SOx scrubbers were likely not contemplated when the IMO first drew up limits for SOx reduction. The fact that all of the regulations are based upon a maximum percentage of sulphur being allowed in the fuel being used suggests this was the preferred means of control.

Ship operators lobbied for alternatives and won their case with the result that Regulation 4 of Annex VI permits flag states to allow alternatives, including "any fitting, material, appliance or apparatus… if such… methods are at least as effective in terms of emissions reduction as that required by the limit on sulphur content in fuels."

Just as with bilge treatment, there is a limit that must be met but the means of achieving it and functioning of equipment are recommendations rather than mandatory regulation. Two methods of ensuring compliance are described similar to the NOx Code. One involves initial certification of equipment followed by a periodic survey, with continuous monitoring of key system operating parameters and daily emission checks to confirm performance in service.

The other is confirmation by continuous monitoring of exhaust emissions using an approved system, which is also subject to periodic survey, with daily checks of key system operating parameters.

Under both schemes discharges of 'washwater' to sea must be monitored but rather than monitoring the specific emissions rate of SO2 in g/kW h, the ratio of parts per million-sulphur dioxide to percentage-carbon dioxide (SO2 ppm/CO2 %) is allowed.

The guidelines first appeared as MEPC.170(57) in 2008. In 2009 a revised version of the Guidelines for Exhaust Gas Cleaning Systems, – IMO Resolution MEPC.184(59), was adopted and replaced 170(57) in July 2010. This reflected changes to Annex VI and included SO2/CO2 ratios relating to various levels of sulphur-in-fuel as by the Emission Control Areas were established with different rates than the global cap. A further version MEPC.259(68), was adopted on 15 May 2015.

Further changes anticipated

At various times the estimated number of ships likely to be fitted with scrubbers has varied from a handful to around 10,000. As of March 2021, the actual number was slightly under 4,000 but scrubber equipped newbuildings are still being ordered in fairly high numbers and on par with ships being specified for dual-fuel LNG use.

Scrubbers are now seen as a tool to meet the 2020 global sulphur cap and their attractiveness will always depend on the price differential between HFO and 2020 compliant fuels. With a payback time measured in months rather than years when the differential is high, their attraction currently shows no sign of diminishing although the number of 10,000 equipped vessels is now seen as highly ambitious.

Opponents of scrubbers have pushed for scrubbers to be banned or more severe restrictions put on their use. Some countries and individual ports have been swayed by these arguments and imposed bans in territorial waters or defined areas. As of yet, no national flag has imposed a ban on ships under it.

The list of restrictions is lengthening and although it may be of nuisance value to the shipowner, the amount of time spent on the high seas is now where the economics of scrubber use is determined. After a voyage of several days or weeks, half a day in territorial waters at destination ports where the scrubber cannot be used is of small consequence.

For operational purposes, shipowners need to keep appraised of restrictions applying outside of those of the IMO.

The following link is a useful source of reference supplied by the North of England P&I Club. It should be noted it is not exhaustive. https://www.nepia.com/industry-news/no-scrubs-more-ports-declare-ban-on-egcs-discharges-update/

EGR bleed-off rules

Under Regulation 4 of MARPOL Annex VI, alternative means of complying with emission requirements are permitted and the IMO has accepted that EGR systems come under this description. However, it is left to the flag state to approve any system.

EGR systems were not needed by marine engines to comply with Tier I of the NOx regulations but as the rules became more stringent under Tiers II and III EGR systems began to be fitted to engines. Under Tier III (which came into effect in 2016 and applies to engines installed after 1 January 2016) either an SCR system or EGR is essential to meet the rules.

Tier III only applies to ships operating in ECAs which in 2016 meant only the two North American ECA regions. However, at MEPC 71 in July 2017 the Baltic and North Sea sulphur emission control zones were also designed as NOx ECAs with effect from 1 January 2021.

Bleed-off from EGR systems has always been subject to the 15ppm oil content limitation if it was to be discharged to sea and with the introduction of Tier III this was required to be done by an OCM meeting the MEPC.107(49) guidelines.

In view of the fact that when the new Baltic and North Sea NOx ECAs were adopted, the IMO was planning to introduce the Global sulphur cap in 2020 rather than in 2025, it was judged a good time to bring the guidelines up to date.

In 2018, MEPC.307(73) adopted Guidelines for the discharge of exhaust gas recirculation (EGR) bleed-off water, valid for ships with an engine international air pollution prevention (EIAPP) certificate issued after June 2019.

The EGR wastewater handling regulation calls for the specific handling of condensate of exhaust gas depending on the fuel oil sulphur content before it is discharged overboard as bleed-off water.

Ships that are operating with 2020 sulphur compliant fuels are obliged to be fitted with an OCM type-approved to MEPC.107(49) or (if the bleed-off water is combined with the washwater from a SOx scrubber) an MEPC.259(68)-compliant meter that measures PAHs, turbidity and pH. Ships that are SOx scrubber fitted and using fuel with a sulphur content above 0.5% must be fitted with an OCM that is MEPC.259(68) compliant.

Glossary

ECA	Emission Control Areas
EGCS	Exhaust Gas Cleaning System – Often referred to as a Scrubber.
EGR	Exhaust Gas Recirculation
GT	Gross Tonnage
HS	High Sulphur
IACS	International Association of Classification Societies
IMO	International Maritime Organisation
LS	Low Sulphur
MARPOL	International Convention for the Prevention of Pollution from Ship
MEPC	Marine Environment Protection Committee
NOx	Nitrogen oxides
OCM	Oil Content Meter. This is a somewhat generic term for a meter capable of detecting the presence of hydrocarbons in water
ODME	Oil Discharge Monitoring Equipment
OWS	Oily Water Separator
PAH	Polycyclic Aromatic Hydrocarbons
PPM	Parts Per Million. One milligram per litre of water is equal to 1 ppm.
SOx	Sulphur oxides
WTS	Water Treatment System

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