Viswa Scrubbers A unique horizontal design for Marine Exhaust Gas scrubbing

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Introduction

The International Maritime Organization (IMO) is one of the United Nation's divisions tasked with the responsibility of safety, security and minimizing marine and atmospheric pollution by shipping.

The IMO has been working to reduce harmful impact of shipping on the environment since the 1960s. Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL Convention) was adopted in 1997, to address air pollution from shipping. Annex VI seeks to minimize air pollution from substances such as SOx, NOx, Ozone Depleting Substances (ODS); regulation of shipboard incineration discharge and control of emissions of Volatile Organic Compounds (VOC).

The IMO has set a global limit of 0.5% of sulfur content in marine fuels starting on 1st January 2020. The current sulfur limit is 3.5%. In more restricted Emission Control Areas (ECA) the sulfur content in marine fuels can only be 0.1%. Ship owners will have to decide between using high Sulfur fuel along with an exhaust gas scrubber, or using distillates or other alternate fuels with very low Sulfur content. The cost and availability of alternative fuels such as LNG and the cost of retrofitting existing ships make this least viable and least likely choice for ship owners. Distillate fuels or low sulfur blends will be available. However, the possible poor quality of blends will give rise to associated problems in storage and use in the engines. The differential costs between high sulfur fuel oil and the lower sulfur blends or distillates will increase as 2020 approaches and likely stay increased for the near future. The lead time for refineries to prepare to make all the heavy fuel to distillates is also not sufficient to meet the 2020 regulations. This makes the use of heavy fuel oil with the use of a scrubber the most attractive and economical option.

All of the marine scrubber manufacturers currently use the vertical in-line scrubber design. There are many disadvantages associated with the vertical scrubber design. In this paper, we will present Viswa Scrubber, the only horizontal scrubber in the marine field and discuss the reason for and the advantages of the unique horizontal design. Incidentally, Viswa Scrubber was a Finalist in the Best Technology for Cleaner emissions, awarded by Lloyds List. This was the only scrubber chosen in this category.

Background and Types

Scrubbers are an assorted group of air pollution control equipment which are used to remove certain gases or particulate matter from an exhaust gas stream.

They have been used widely in land-based applications. They are used for acid fume scrubbing, chemical fumes, paper and pulp industry, food processing industry, steel manufacturing industry, power plants, fertilizer and pharmaceutical industries.

Scrubbers are divided into the more common wet scrubbers which use a liquid to perform "scrubbing" or dry scrubbers which use a dry sorbent or dry spray absorbers.

Wet scrubbers work on the principle of a scrubbing liquid interacting with the exhaust stream to cause mass transfer of the gas into the liquid. This is dependent on the liquid to gas ratio (L/G ratio). The liquid quantity is often expressed in gallons per minute (gpm) of liquid and the gas volume is expressed as actual cubic feet per minute (acfm) of gas. This ratio is determined by the required concentration of the pollutant gas in the exhaust stream after scrubbing, solubility of the gas pollutants, the dwelling time of the gases in contact with the liquid, the temperature of the gases being scrubbed, the concentration of pollutants and particulate matter in the gas stream, and the mass transfer characteristics. Increasing L/G ratio usually increases the scrubbing efficiency of the equipment. However, this has to be weighed against the operational costs and an optimal L/G ratio can be reached in wet scrubbers.

There are many types of wet scrubbers. The most common ones are the spray towers, cyclonic scrubbers, tray towers/chambers, venturi and packed bed scrubbers.

Spray towers/chambers: They are characterized by the scrubbing liquid goes through spray nozzles and comes out as droplets. Using the increased surface area from multiple small droplets, there is more efficient scrubbing of the exhaust gas. The droplets must have uniform spray distribution and adequate size. If the header pressure is reduced, the droplet size can increase thereby reducing the effectiveness of scrubbing. Particulate removal happens due to impaction of the particulate matter on the droplets. They usually have lower power consumption, lower fouling and lower operating costs.

Cyclonic scrubbers: The exhaust gas stream enters the cyclonic spray tower at a tangent to the wall. The gas inlet is narrowed which furthers increases the velocity of the gas. The gas flows in a cyclonic manner within the cyclonic scrubbers. The scrubbing liquid is usually sprayed from nozzles in a central pipe. The liquid droplets are subject to the centrifugal

force as a result of the spinning motion of the gas stream. This causes them to be moved to the scrubber walls. The droplets fall to the bottom of the scrubber along with the particulate matter. The cost of a cyclonic scrubber is more than a spray tower/chamber and the operating costs are also higher.

Tray towers/chambers: Tray tower/chamber scrubbers consist of a tower or chamber with perforated trays. The exhaust gas mixes with the liquid over the tray with increased gas liquid contact compared with the spray tower/chamber designs. The trays used are called impingement trays. There is liquid flow over these trays which can remove certain gases and particulate matter. Due to the low velocity of the liquid, the L/G ratio can be small for these. Baffles can be placed before the impingement trays with settling out of the particulate matter before it goes through the perforation of the impingement tray. The cost of a tray chamber is higher than a spray chamber and operating costs are also more.

Venturi scrubbers: Venturi scrubbers use the velocity change and energy of the exhaust gas stream to convert the scrubbing liquid into small droplets and maximize the interaction between the exhaust gas and the liquid.

A venturi has a converging part, throat and a diverging part. The exhaust gas stream enters the converging part. As the diameter decreases in the throat, the velocity of the exhaust gas increases. This increased gas velocity is able to convert the liquid into small droplets enabling improved mixing of the gas and liquid and scrubbing. Venturis can remove both particulate matter and gases. Venturis are among the best in the wet scrubbers at removing particulate matter. However, venturi scrubbers are more expensive, consume more energy, have higher pressure drops and have higher operational costs.

Packed bed scrubbers: Packed chamber/tower scrubbers contain a bed of packing material. The packing material provides a larger surface area for gas-liquid contact. The scrubbing liquid is used to wet the packing material and form a thin film. The exhaust gas interacts with the liquid all over the surface area of the packing material. Packing materials are available in an assortment of shapes, weights, pressure drop, surface areas, corrosion resistance and cost. Packed bed scrubbers can provide ideal gas removal/scrubbing with optimized L/G ratio.

Many scrubber systems have one or more of these different components to achieve the total scrubbing requirements needed from the system.

Modes

Open Loop: The scrubber can be used in the open loop mode where the scrubbing liquid is sea water. The sea water's natural alkalinity is used to "scrub" the SOx from the exhaust gases. The wash water is then treated and discharged back into the ocean after treatment.

Closed Loop: The scrubber can be operated in the closed loop mode when the alkalinity of the sea water is not adequate or where there are regulations for no discharge of the used sea water. In closed loop, sea water with an alkaline substance such as sodium hydroxide (caustic soda) is used for scrubbing. The wash water is recirculated and a small quantity keeps getting bled off. This is treated by the wash water treatment equipment and then discharged into the sea. Any loss of water from this operation is replaced by additional water. If water cannot be discharged, then it can be stored in a holding tank.

Hybrid operation: The scrubber can be used in both closed and open loop modes. The closed loop mode can be used while in port and during maneuvering. A switch to the open loop mode can be made in open seas.

Flow patterns of Exhaust Gas and Scrubbing Liquid

Counter current flow: The scrubbing liquid and the exhaust gas flow in opposite directions in a tower. The countercurrent flow is best suited for conditions where the peak of the SOx concentration may not be predictable and where there can be large variation in the SOx concentration.

Co current flow: The exhaust gas and liquid stream move in the same direction. These are not as effective as the counter current scrubbers. Co current scrubbers maybe used when space is limited and if high efficiency scrubbing is not needed.

Cross current flow: The exhaust gas and the scrubbing liquid flow at right angles to each other. The liquid usually flows vertically down and the exhaust gas flows horizontally. This type of scrubber can be used where space is a premium and where lower pressure drop is desired. The operating costs are also lower in this scrubber when compared with the countercurrent scrubber. This scrubber is suited for applications where the maximum SOx concentrations are known and predictable.

Viswa H Scrubber:

The Viswa H scrubber was developed after 4 years of working on vertical scrubbers. This idea was developed to address concerns raised by ship owners and operators on installation, access, service and maintenance.

The exhaust gas volume coming from the main engine depends on the MCR (maximum continuous rating). Other factors that will need to be considered in the estimation of the exhaust gas volume are whether the auxiliary engine is to be connected, if there is a boiler exhaust that has be connected, the time the ship is in the ECA (emission control area) and out of the ECA regions. The exhaust gas coming from the main engine usually comes out at around 250 C.

The mechanism of SO_2 absorption in seawater is impacted by several factors such as the sea water temperature, partial pressure of SO2, seawater salinity, seawater alkalinity, interfacial contacting area between the exhaust gas and the seawater and residence time. The absorption capacity of the sea water declines with reducing salinity and alkalinity.

The temperature of the exhaust gas where it meets the sea water for majority of the scrubbing needs to be lowered so that the efficiency of the sea water scrubbing can be maximized. Scrubbing also necessitates a large contact area between the exhaust gas and the seawater.

For these reasons, the Viswa H scrubber consist of 2 main portions. The first part of the scrubber cools the large volume of exhaust gas. This not only improves the efficiency of scrubbing but also lowers the exhaust gas volume to be scrubbed by condensation of the contained water. The cooling is performed by a spray chamber with proprietary internals.

The exhaust gas is then sent to a packed bed chamber (the second portion of the scrubbing system) where there is a large surface area for the exhaust gas and the sea water to interact. The majority of the scrubbing is performed here at a temperature similar to the ambient temperature of the sea water. The packed bed is one continuous bed with baffles so that the exhaust gas stream is exposed to native clean sea water multiple times as it moves through the packed bed.

Due to a large amount of water contained in the “scrubbed” exhaust gas, this is passed through a demister which facilitates removal of entrained water droplets from the exhaust gas. The exhaust gas is then released to the atmosphere “scrubbed” of the SOx content through a vertical funnel or a vertical exhaust pipe. The exhaust gas is heated prior to exhausting to atmosphere to avoid water condensation and consequent white smoke.

The wash water or effluent water as it is known contains dissolved SOx and nitrogen oxides (NOx) in the form of sulfuric and nitric acids. The pH of this wash water is low. Wash water also contains traces of oil, heavy metals, PAH (polycyclic aromatic hydrocarbons) and particulate matter (PM) from the exhaust.

Wash water treatment involves removal of the suspended solids and neutralizing the acidic pH. The wash water is passed through a multicyclone which filters out particles greater than 30 microns in size. These solids gets stored in a sludge tank and can be disposed to a separate reception facility. The sludge cannot be incinerated on board the ship. The remaining wash water can be neutralized by “reaction water” (sea water) to raise the pH of the wash water.

The discharge wash water should have a pH greater than 6.5 measured at the ship’s overboard discharge. During maneuvering and transit, a maximum pH difference of 2 is allowed between the ship’s inlet and overboard discharge.

The maximum continuous PAH concentration in the discharged wash water should not be greater than 50 ug/L phenanthrene equivalence (PAHphe) above the inlet water PAH concentration.

The maximum continuous turbidity in wash water should not be greater than 25 formazin nephlometric units (FNU) or 25 nephlometric turbidity units (NTU) or equivalent units, above the inlet water turbidity.

The wash water can contain nitrates to what is expected with a 12 percent removal of NOx from the exhaust or within 60 mg/L (1 mM) normalized for a wash water discharge rate of 45 t/MWh.

On all Viswa H scrubbers there is a wash water treatment plant whether it is open loop or hybrid mode. The treatment plant consists of a hydrocyclone and sludge tank. On hybrid designs, a small portion of the wash water is bled off and treated to remove suspended solids through a hydrocyclone. The suspended solids are held as sludge and disposed of in a similar manner to the open loop design. The treated bleed-off wash water can be discharged at open sea or can be held onboard. Additional make up water is added to the hybrid system as needed.

In addition to these components, the Viswa H scrubber comes prewired with instrument panel and mounted on a skid. The skid- based design allows for easy installation and ease of use and disassembly if needed on the concept of plug-and-play. Each module of the scrubber system including all the instruments connect to a main control panel. The display of this can be hard wired or can be shown on a tablet for the on board application.

The Continuous Emission Monitoring System (CEMS) is vital to the scrubbing system and this data feeds into the Viswa Energy Efficiency Management System (VEEMS). The VEEMS integrates data from different locations and creates a One Stop Shop to provide monitoring on board and also for the office side of the Ship owners and operators. The data from VEEMS can help collect and evaluate Energy Efficiency data (including CO2 emissions, amount of fuel consumed), IMO MRV (monitoring, reporting and verification module), Environmental data such as SOx and NOx emissions and Prescriptive and predictive analytics among other functionalities. This makes all aspects of the ship readily accessible and allows for critical analysis and decision making.

Advantages of Viswa H scrubber:

The advantages of Viswa H scrubber include lower weight, significant ease of installation, lower immobilization time for installation, stability, ease of access for service and maintenance, lower weight to carry for all future voyages and hence lower fuel use and overall lower power consumption. The VEEMS is a key component to making the entire scrubbing system transparent, verifiable and easy to use. Each one of these advantages has tremendous repercussions in the installation and maintenance of the scrubber system for the life of the ship. Due to the combination of a spray chamber and a packed bed, the efficiency of the Viswa H scrubber system is very high.

Retrofit versus New Build:

A lot of owners and operators worry about the retrofitting old ships. With the ease of placement and installation of the Viswa H scrubber, retrofitting scrubbers is not a problem

Commissioning and Troubleshooting:

During the period of commissioning, a Viswa team will sail with the ship to commission the scrubber. Throughout the commissioning both the on-board team and the office team can be in constant communication with the VEEMS display being readily available to both teams. Troubleshooting is also made

easy with availability of all data to personnel on board and in the office.

Manholes have been placed in the scrubber. These can be opened and the inside of the scrubber can be examined as needed. Given the height of the horizontal scrubber, there is easy access to view the inside of the scrubber.

Class Certification:

The Guidelines permit two basic Schemes to be used for approval, Scheme A or Scheme B.

Scheme A is based on initial emission performance unit certification together with a continuous parameter check of operating parameters and daily exhaust emission monitoring.

Scheme B is based on continuous exhaust emission monitoring together with a daily parameter check of operating parameters.

A majority of ship owners and operators have chosen Scheme B certification.