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Classification of SO_x Scrubber Installation for ships

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Wärtsilä on suurimpia laivan propulsio ratkaisujen valmistajia maailmassa. Uudet ilmansuojelua koskevat säännökset tiukentavat laivoista tulevia pakokaasujen rikkipäästöjä. Sen vuoksi Wärtsilä on aloittanut SOx pesurin valmistamisen, joka voidaan asentaa sekä olemassa oleviin että uusiin laivoihin.

Laivaluokitus on toimenpide, jolla luokituslaitos varmistaa laivan sekä saa pääkomponenttien luokan sääntöjenmukaisuuden ja laatii luokituksesta todistuksen. Luokittajatahoja on useita. Tässä työssä on tarkoitus käydä läpi ne vaatimukset, jotka Germanischer Lloyd asettaa rikkipesurin asennukselle. Tarkastelussa on erityisesti ensimmäinen kaupallinen rikkipesuri, joka asennetaan 2011 kesän lopussa laivaan Containerships VII.

Tämän työn tuloksia on tarkoitus hyödyntää tulevissa rikkipesureiden asennuksissa.

Avainsanat Rikkipesuri, LaatuLuokitukset, laivan mottoreiden ilmanpäästöt, asennus

ABSTRACT

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Wärtsilä is one of the biggest ship propulsion solution producers in the world. New IMO regulations concerning air emissions have tighten also the limits for sulphur emissions. For this reason Wärtsilä has begun to manufacture SO_x Scrubbers, which can be installed both new build vessels and retro-fitted in existing vessel regardless of engine brand.

Classifications are procedures, where classification society ensures compliance of the ship and its main components with class rules and grants certifications based on fulfilled standards. There are several marine classification societies. The purpose of this work is to present tests to be done and analyse classification regulations especially for Germanischer Lloyd, involved with installation of SO_x scrubber. The empirical part of this work includes analysis of first commercial installation of SO_x Scrubber in Containership VII.

The results of this study will be applied in future SOX scrubber installation projects.

Keywords Classification Societies, Exhaust Gas Cleaning systems, SO_x
Scrubber, air emissions

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ABBREVIATIONS

ADMINISTRATION	Flag State Authorities
ECA	Emission Control Areas
EGC	Exhaust Gas Cleaning
FLAG STATE	State, where ship is registered
GL	Germanischer Lloyd
IMO	International Maritime Organization
MARPOL	Marine Pollution Convention 73/78
MEPC	Marine Environment Protection Committee
SO _x	Sulphur Oxides, SO ₂ and SO ₃
SECA	Special Emission Control Areas
NO _x	Nitrogen Oxides

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APPENDIX 2.

1 INTRODUCTION

1.1 Wärtsilä Finland Oy

This chapter will present Wärtsilä Finland Oy. Presentation will focus to the organisations dealing with SOx Scrubber, its installation and classification.

As said in Wärtsilä Annual Report 2010, “Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets”. Goal is to reach technological innovation and total efficiency maximising environmental and economical performance. In Wärtsilä works approximately 17,500 employees all over the world, since the company has operations in 160 locations in 70 different countries. (Wärtsilä A: 2010)

Wärtsilä organisation is divided into a three different businesses, Ship Power, Power Plants and Services. Ship Power deals with the marine industry, Power Plants with energy solutions on the land and Service is network serving support

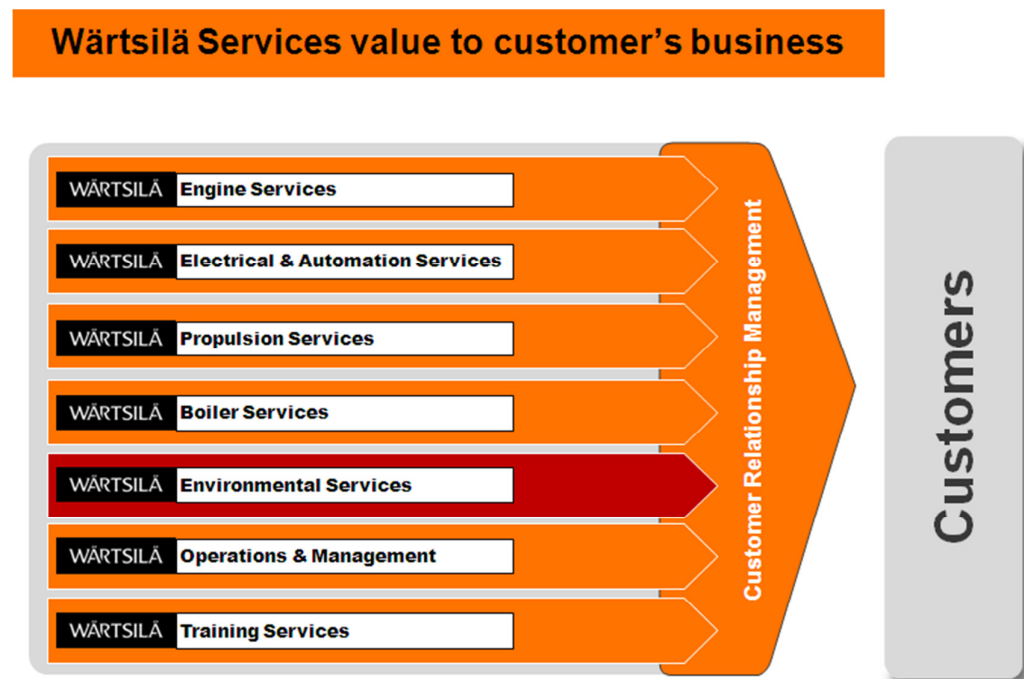


Figure 1 Wärtsilä Services portfolio. (2011 Internal presentation set)

and also availability of Services wherever customers are. (Wärtsilä A: 2010)

This thesis is made for the Service department, and inside of the service department for “Environmental Services” division. Environmental Services is young organisation, it has been founded 2010 to fulfil customers needs in the world of tighten environmental legislation and international regulations.

1.2 Why SO_x Scrubber?

1.2.1 International regulations

A short description of international rules and regulations concerning reduction of Sulphur oxides from ships exhaust gases is provided in this chapter.

1.2.1.1 IMO regulations

The International Maritime Organization is briefly called “IMO” and it “is the United Nations specialized agency with responsibility for safety and security of shipping and the prevention of marine pollution by ships”. IMO has been founded to improve safety at sea in 1948 in Geneva. It does its work at developing international regulations followed by all shipping nations. (IMO A: 2011)

IMO’s interests are in safety and security, but also from early years the threat of marine pollution from ships and especially pollution by oil carried in tankers. It has the Assembly as a governing body, which meets every second year and between these sessions the Council act as IMO’s governing body. IMO presents itself as a technical organisation, and “most of its work is carried out in a number of committees and subcommittees”. Most interesting committee for this thesis is “the Marine Environment Protection Committee” MEPC. It was founded by the Assembly in November 1973 and it is responsible for coordinating the Organisations activities in the prevention and control of pollution of the marine environment from ships. (IMO B: 2011)

IMO has given about 50 regulations and protocols and adopted more than 1,000 codes and recommendations. In early 70's the international pressure pushed to create new instrument for controlling pollution of the seas from ships. International Convention for the Prevention of Pollution from Ships (MARPOL) was a result of this discussion in 1973. While the previous conventions concerned pollution by oil, MARPOL regulates also pollution from chemicals, other harmful substances, garbage and sewage. Referring to MARPOL 73/78 means combination of two protocols. It means that protocol of 1978 has made some modifications to original regulations from the year 1973, MARPOL entered into force in the year of 1983. Protocol has six technical annexes; Annex VI was added to MARPOL Protocol in 1997. This annex is regulating limits on sulphur oxide from ship exhausts. It also regulates NO_x and particulate matter and prohibits deliberate emission of ozone depleting substances. (IMO B: 2011)

Regulation of MARPOL Annex VI has details of special Emission Control Areas (ECA). These areas are Baltic Sea (SO_x), North Sea (SO_x), North American Coastal waters (SO_x and NO_x). Areas are presented below in pictures.

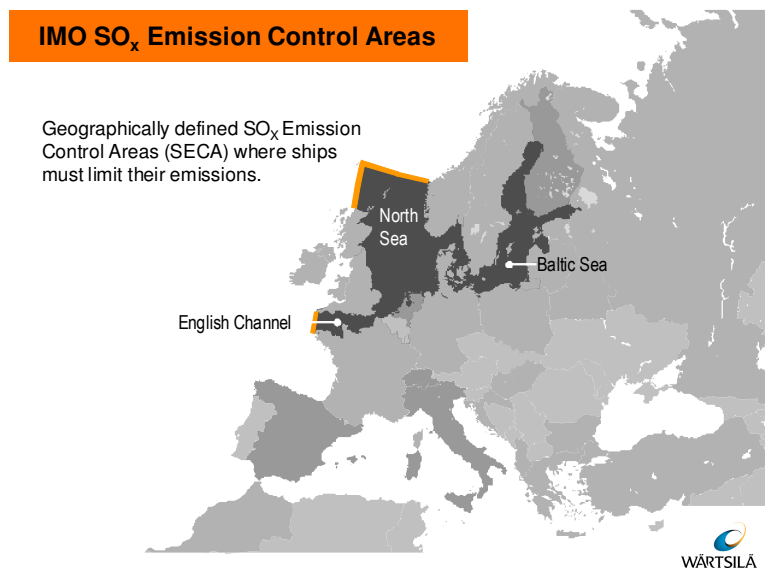


Figure 2 IMO SO_x Emission Control Areas

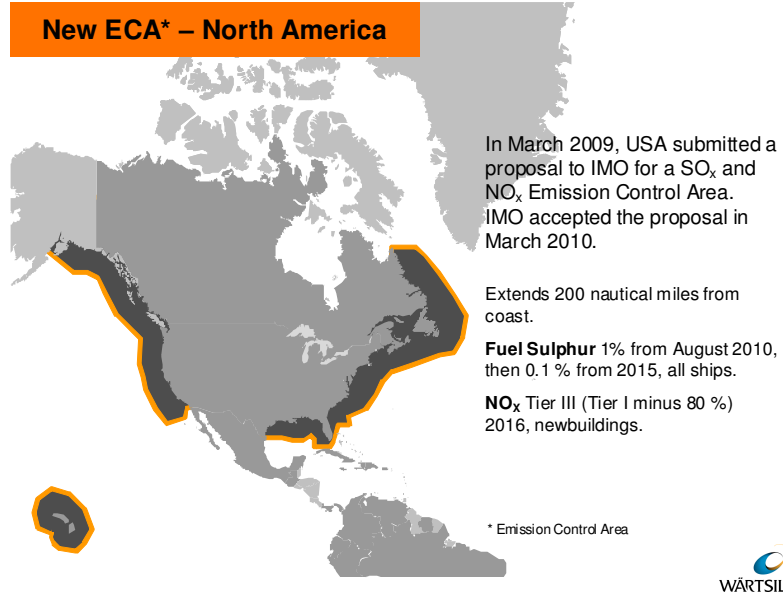


Figure 3 New ECA - North America

Limits of the sulphur content of the fuel are different for ECA's and other areas as mentioned in the table below. Also next table presents the same in figures. (IMO C: 2011)

Outside an ECA established to limit SO _x and particulate matter emissions	Inside an ECA established to limit SO _x and particulate matter emissions
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020*	0.10% m/m on and after 1 January 2015

IMO & EU Sulphur Limits

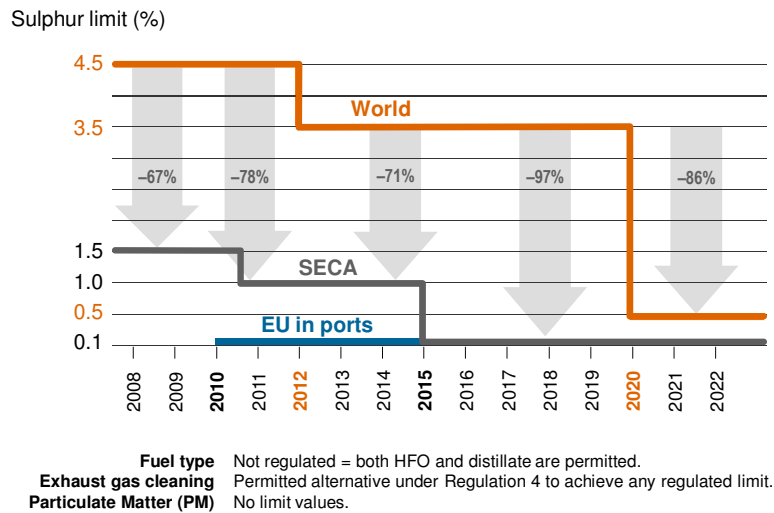


Figure 4 IMO & EU Sulphur Limits

To fulfil the need of more exact information and practical details on exhaust gas cleaning systems IMO has given Resolution MEPC.184(59) named “Guidelines for Exhaust Gas Cleaning Systems”. This Guideline is defining the role of an Administration (Classification Society) and specifying demanded documents to be issued for the certification of the Scrubber system. This resolution is considered in more detail further in this thesis (IMO MEPC.184(59):2009)

1.2.1.2 EU regulations

Also EU regulations have been enacted in order to improve air quality. Directive 93/12/EEC sets maximum sulphur content limit for gas oil, also known as light fuel oil. This oil is used for heating, marine and industrial purposes among others. Directive 2005/33/EC is one of the amendments to first mentioned directive and is regarding to the sulphur content of marine fuels. On 15 of July 2011 the commission adopted a proposal for an amendment of Directive 1999/32/EC where EC aligns latest IMO provision on the sulphur content of marine fuels, is adapting to

the IMO provisions on alternative compliance methods, is going to maintain the link between the stricter fuel standards in SECAs and the fuel requirements for passenger ships in regular service. It is also trying to improve parent directive by harmonising and strengthening provisions for monitoring of compliance reporting. (EU 2007, EU 2011)

1.2.2 National regulations in Finland

In Finland MARPOL 73/78 regulation and so on also MEPC.184(59) has been implemented with fresh law considering environmental protection in shipping 1672/2009 (Merenkulun ympäristönsuojelulaki) and statute 76/2010 (Valtioneuvoston asetus merenkulun ympäristönsuojelusta). These regulations forbid any emissions to air from ships as regulated in this particular law or in EU regulations. Chapter 7 of the law concentrates on emissions to air. According to this law exhaust cleaning systems has to fulfill rules of European communities and those over 130 kWh also has to fulfill rules of MARPOL 78/73.

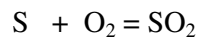
Traffic safety administration of Finland or Classification society authorized by it approves exhaust gas cleaning systems in Finland. Applications for approval must be done in written and approvals are done if MARPOL 78/73 appendix VI demands are fulfilled.

1.2.3 Sodium Oxides and the nature

Air pollution can be demonstrated as an undesirable material in air. To be a pollutant, quantities of the material has to be large enough to produce harmful effects. These materials may damage human health or property, vegetation or the global environment as well as cause aesthetic or smell aspects. Some of these materials enter to the atmosphere from natural resources, but in densely inhabited parts and industrialised countries these materials are mainly from human activities. (De Nevers: 2009)

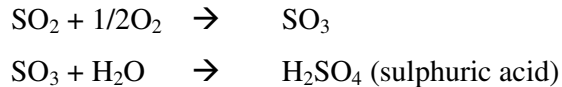
sulphur oxides are compounds of sulphur and oxygen, most common of these are sulphur dioxide SO_2 and sulphur trioxide SO_3 . Sulphur dioxide is a heavy, colourless and poisonous gas smelling like just-stuck match. It can occur in nature for example in volcanic gases but is also prepared industrially. Sulphur dioxides are formed in the combustion of sulphur-containing fuels and measures to control atmospheric pollution by this compound were widely adopted. Sulphur trioxide is a colourless compound. It can exist at room temperature and it is formed by the reaction of sulphur dioxide and oxygen in the presence of catalysts. It fumes in contact with moist air and dissolves in water, liberation much heat and forming sulphur acid. Both of these are very powerful dehydrating agent, they are very corrosive and very reactive chemically. (Britannica: 2011)

Like nitrogen, also sulphur is inert and harmless to humans. They both are necessary for life and are required in animal bodies. The problem is the oxides of sulphur. All organic fuels used contain some sulphur. When we are burning the fuels, the contained sulphur will mostly form sulphur dioxide,



By burning fuels it comes to atmosphere; it will eventually fall with precipitation, mostly in the ocean. Over a time it will come part of a land mass and will enter into fossil fuels and sulphide minerals. (De Nevers: 2009)

When burning the fuel oil in combustion engine, the oxides of sulphur are a direct result. Fuel bound sulphur is rapidly oxidising to sulphur dioxide and small amount of that some 3-5-% may be further oxidised to sulphur trioxide in the combustion chamber and exhaust duct. Amount of sulphur trioxides depends on the combustion pressure, temperature, excess air and content of fuel sulphur. The presence of iron and vanadium oxides is acting as catalyst and contributors to the process. Some of the SO_3 formed during the cooling of the exhaust gas will react with the water vapour present to exist as sulphuric acid and will thereafter absorb water vapour. The rest of it goes as a phase oxidation and condense as sub-micronic droplets or will oxidise onto the particles formed during combustion. (EGCSA: 2011)



SO₂ is directly harmful to human health. At 20 ppb or lower there should not be effects to healthy person, but if the concentration arises around 500 parts per billion effects are fatal, and in between there might be chest pains, breathing problems, eye irritation and a lowered resistance to heart and lung diseases. The normal atmospheric background concentration of SO₂ is generally less than 10 ppb. The formation of sulphates (and nitrates) in the form of aerosols or fine airborne particles can also effect increasing asthma attacks, heart and lung disease and respiratory problems in susceptible population groups. (EGCSA: 2011)

The sulphur oxides can also convert to acids by aqueous phase reactions in the atmosphere precipitated to acid rain in right meteorological conditions. Effect of acid rain depends on the fragility of materials, plants soils and waters involved. If there is no natural alkalinity to neutralise this acidity attack, it can cause aciditation of ground and surface water, deforestation, reduction of aquatic life and building decay. Acidic water leeches out heavy metals. (EGCSA: 2011, Ilmanlaatuportaali:2011)

1.3 Problem statement, methodology and exclusions

In this thesis work intention is to clarify issues concerning Wärtsilä SO_x scrubber classification. Wärtsilä has been selling scrubbers already since 1980's for power plants, but only few years for marine installations, that is why this kind of survey is necessary.

Scrubber and its technology will be presented. Short overall presentation of existing scrubbers is provided, but of course main focus will be in Wärtsilä's own product. The work has been limited to concentrate on Containership VII, where a first commercial Wärtsilä Scrubber installation is made on August-September 2011. This will leave out other ship and engine types.

After that classification societies and systems are in turn. Short presentation of history of classification is provided and also the liability between the classification societies and flag states also referred in the rules as “the Authorities”. When these issues have been clarified, thesis will show what will be necessary actions in classification process for scrubber installation. From classification societies in this thesis is recognised only Germanischer Lloyd, many times referred only as GL or “the Society”. Main focus will be in classification rules and documents needed to attain Classification Society certificates. Compliance with emission limits will be mentioned in some cases.

Rules for Classification of Scrubber Installation will be given in form or a table, but also in written. Installation regulations can't always be excluded from the rules of the product and it is not always even logical to do so. Description of required actions for classification is given in same order with Process and Instrumentation -diagram of Scrubber.

2 SO_x SCRUBBER

The exhaust gas cleaning system provided by Wärtsilä works with fresh water technology in closed loop principle. Fresh water technology means, that the scrubber uses only fresh water in its process, and seawater only in its cooling system. Closed loop principle means, that the fresh water will circulate in closed loop where caustic soda is added in the circulation as per power consumption. A small amount of bleed off is taken to water treatment unit for purification. Cleaned water can be pumped overboard or to the holding tank in case of zero discharge mode. (Wärtsilä D, 2009)

Main focus of this thesis in Containership VII, the first commercial delivery of the Scrubber. The first prototype Marine Scrubber has been installed and commissioned by Wärtsilä to Neste Oil owned product taker MT Suula. MT Suula is registered under Finnish flag and is mainly operating in the SO_x ECA Baltic Sea area. Scrubbers duty in MT Suula is clean exhaust gases from the ship's 4-cylinder inline Wärtsilä auxiliary diesel engine, rated power 680 kW. (Wärtsilä D, 2009)



Figure 5 Wärtsilä Scrubber System onboard MT Suula

The Scrubber is certified for maximum sulphur content in the fuel of 3,5 %. Basic duty of the scrubber is reduce sulphur content in the fuel 97.15% when the content of sulphur reduces from 3,5% to 0,1%. If fuel with higher sulphur content is used mentioned cleaning efficiency is not guaranteed anymore, but can be done, as special case!

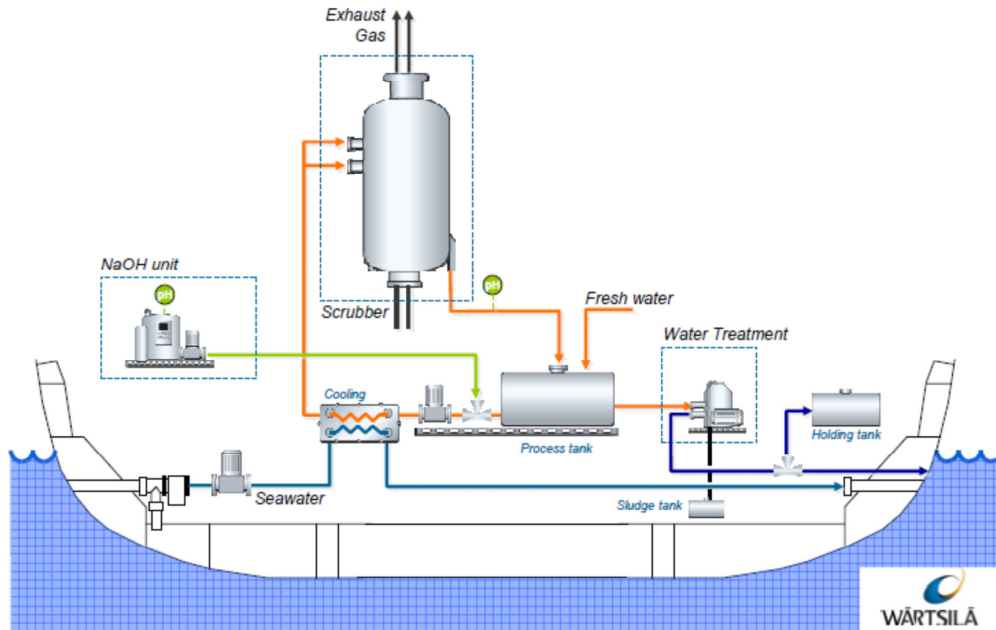


Figure 6 Principle of SO_x Scrubber

To the Containership VII the main stream scrubber is installed to an exhaust gas stream of a main diesel engine. For the process fresh water will be created from sea water with evaporators to water storage tank. From water storage tank fresh water is pumped in closed loop circulation as per the amount taken off for bleed off treatment unit and the amount evaporated in the air. Scrubbing water is sprayed through the packing material in the scrubber unit. The acid com-

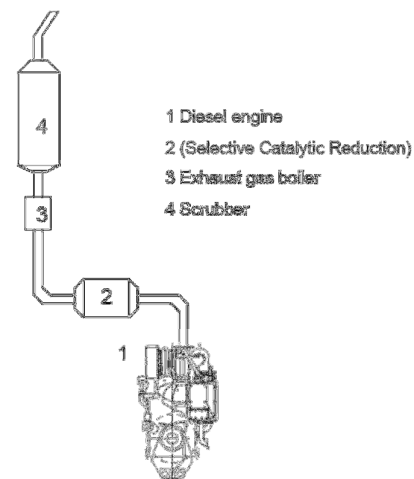
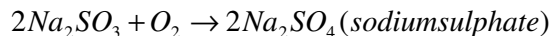
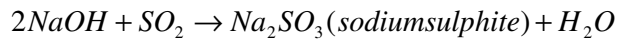
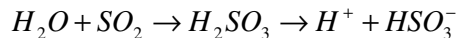


Figure 7. Main stream Scrubber can replace silencer .

ponents in exhaust gases react with the scrubbing water. The alkali NaOH is pumped from the alkali storage tank with alkali feed pump to the suction side of circulation pump unit. (Wärtsilä C: 2011, Safety Concept)

Effluent is lead to bleed of treatment unit where it is cleaned. From water treatment unit sludge will be led to vessel sludge tank whereas cleaned effluent can be pumped overboard or lead to buffer tank in zero discharge -mode. (Wärtsilä C: 2011, Safety Concept)

Related chemistry is based on the use of sodium alkaline to remove sulphur dioxide in the exhaust gas. This gas enters to the scrubber where it comes into close contact with the recirculated alkali solution. In general the reactions between the exhaust gas and the washing liquid are:



As a result of this reaction is the sulfur is removed from the exhaust gas to the scrubbing water. (De Nevers: 2009)

The integrated scrubber is used in case of several main and auxiliary engines and also oil fired boilers installation to clean the exhaust gases with one common unit. It does not increase the exhaust gas back pressure and so on is suitable for oil-fired boilers. This type of scrubber is suitable for all ship types; in particular those using high amount of fuel in EU ports like cruisers and tankers.

Other suitable solutions reducing SOx emissions would be with wet scrubber open loop principle, seawater technology and with dry scrubber.

- Open loop –type scrubber takes water from the sea, uses it for scrubbing, treats it and discharges it back to the sea. Seawaters natural chemical composition is used to neutralize SO₂ removal. This technol-

ogy needs much more energy than close loop system since the amount of water needed is bigger. In the Baltic Sea also seawater content of salt is not high enough to scrub SO_x away from the exhaust gases.

- Dry scrubber is a technology used mainly on land based exhaust gas cleaning. Dry scrubber uses calcium powder as agent for absorption of sulphur. To enable the application and safe space in vessels a special calcium hydroxide Ca(OH)₂ was developed. This method removes more than 99% of the sulphur oxides. “The absorption of sulphur oxides leads to calcium sulphate, commonly known as a gypsum”, presents Couple Systems, owner of the dry scrubber product. (Couple systems, 2011) Disadvantage of a dry scrubber is the big size required.
- Hybrid scrubber is under development. This scrubber can use both closed loop and open loop systems in its function. This is advantage for ships operating also outside of Baltic Sea.

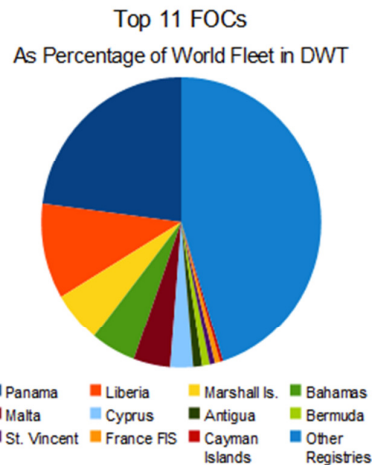
3 CLASSIFICATION

3.1 Classification societies and systems

Classification Societies can be described as independent organizations. These societies are often authorised by flag states to ensure that vessels using their flags are following the rules of international conventions. They arrange inspections and advise on the hull and machinery of a vessel from very beginning of new build-ings to its maintenance. Classification societies are giving certificates to seawor-thy ships of the inspected issues. They ‘certify’ and ‘classify’: ‘certify’ the safety of the ship and ‘classify’ it according to rules of a particular society. (Durr: 2011)

Without the required certificates by the ports-of-call ships will be unable to pro-vide the trading certificates and they are is also without insurance cover. It will be impossible to charter-out his vessel as a usually charter parties require ships to be in the highest class of the classification society. (Durr: 2011)

A flag state is term which means the state the ship is registered under. States wish to have many vessels on their national register to have revenue and more em-ployment. Some of the flag states do not have a desire or an ability to supervise the certification of the vast numbers of vessels sailing under their flags. Some of these surveys are made by classification societies. “The flag of convenience” are those states which provide cheaper registration, surveys and certification work. It also means of course these flag states do not have capability of supervising the safety of its ships. (Durr: 2011)



"Chapter 2, Structure and ownership of the world fleet" (PDF). Review of Maritime Transport 2009 (UNCTAD): 36. December 2009. http://www.unctad.org/en/docs/rmt2009_en.pdf. Retrieved 2010-06-21.

“Port State Control” (PSC) is the body of IMO, who supervises the regulations of IMO have been applied onboard. It means that PSC does the inspection in national ports organized on a regional basis. In IMO webpage it is told, that “A ship going to a port in one country will normally visit other countries in the region before embarking on its return voyage and it is to everybody's advantage if inspections can be closely co-ordinated.”(IMO D 2011)

Marine insurers require ships to be ‘classed’ before underwriting the risks associated with such ship. Presented situation is shown in next picture hopefully to clarify classification societies actions.

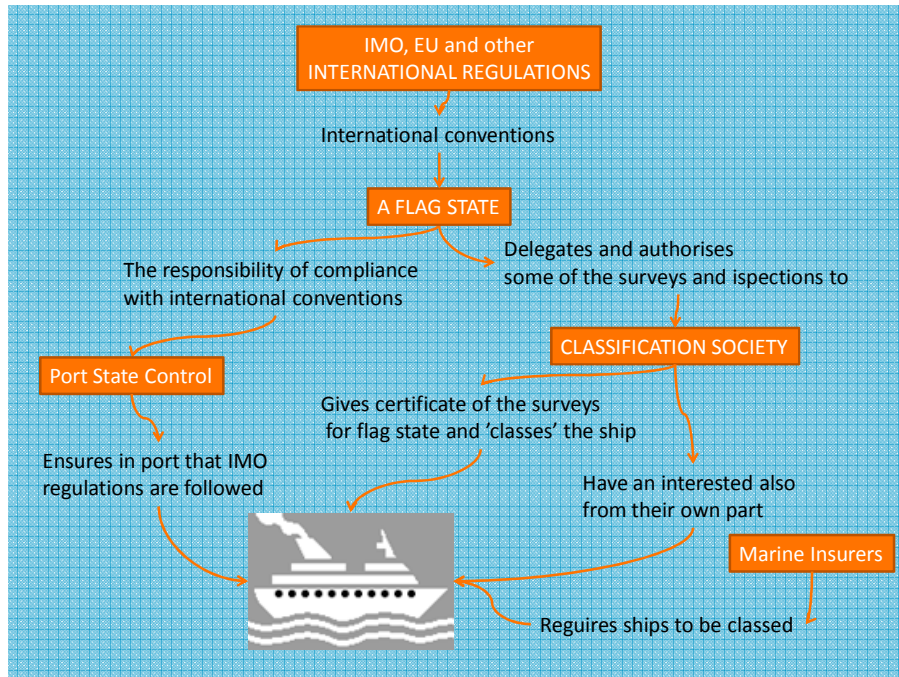


Figure 8 Role of the Classification Societies

3.1.1 Classification regulations meet the national and the international regulations

Rules of Classification and Construction of GL are not affected by national regulations of flag states. Various International conventions are taken into account on GL Rules. GL is making an effort to keep GL Rules up to date with mandatory requirements of IMO regulations. (GL Rules 2011)

International conventions and corresponding laws of flag states will require sometimes some technical surveys. GL will undertake them on request and will act on behalf of the authorities concerned. Also from these acts GL will issue a relevant a certificate. This action is based on respective provisions and includes at least surveys according to (GL Rules 2011 I-0-3A4) :

- the International Convention on Load Lines (**ILC 66**)
- the International Convention for the Safety of Life at Sea (**SOLAS 74**)

- the International Convention for the Prevention of Pollution from Ships (**MARPOL 73/78**)
- the IMO Codes, e.g. on Chemical and Gas Tankers
- the related Conventions of the International Labour Office (ILO)

Next table will show some flag states status of conventions and how they have been organized between flag states and Germanischer Lloyd. (GL A: 2011)

Certificate Country	Int Load line	Int Tonnage	Cargo Ship Safety	Cargo Ship Safety	Cargo Ship Safety Radio	Cargo Ship Safety	Passenger Ship Goods	Dangerous Goods	Security (ISPS)	Compliance	Management Document of	Safety system	Int Anti-fouling	Int Certificate of Fitness Gas (IGC)	Int Certificate of Fitness Chemicals (IBC)	Int Pollution	Int Oil Pollution	Int Pollution Prevention	Int Pollution Prevention	Int Pollution Prevention	Int Air Pollution Prevention
Danmark	o+	o+	o+	o+	o+		o	o+	o+	o+	o+	o	o	o	o+	o+	o+	o+	o+	o+	o+
Finland	Δ+		Δ+	Δ+*		Δ+						o+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ	+	Δ+	
France	o+		Δ+	Δ+		Δ+		Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+	Δ+
Germany	Δ+		Δ+	Δ+	Δ+	Δ	Δ	Δ+	Δ+	Δ+	Δ+	o+	Δ+	Δ+	Δ	Δ+	Δ	Δ+	Δ+	Δ+	Δ+
Norway	o+		Δ+*	Δ+	o			o+	o+	o+	o+	o			o+	o	o+	o+	o+	o+	o+
Norway (NIS)	o+	o+	o+	o+	o	o	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+
Poland	o+	o+	o+	Δ	Δ	o+	o+					o+	o+	o+	o+	o+	o+	o+	o+	o+	o+
Russia	o+	o+	o+	o+	o+	o+	o+		o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+	o+
Sweden	o		o+			Δ+						o	o+	o+	o+	o+	o+	o	o+	o	o
United Kingdom	o+	o+	o+	o+	o+		o+					o+	o+	o+	o+	o+	o+	o+	o+	o+	o+
United States	o	o+	o+	o+			o		o+	o+						o		x			

Δ Survey/Audit for issue of certificate by the flag State administration and/or serving of them (e.g. mandatory periodical surveys)
 + Certain procedural requirements apply
 *Beyond territorial waters of the flag state only
 o Survey/audit and issue of certificate by GL.
 x Survey/audit and issue of certificate by GL. The country has not yet ratified the respective convention.

3.2 Classification in practice

Classification means in practice, that a vessel has been designed and built according to the appropriate rules of a society. These rules relates to all ship, but also to the critical parts and modules.

In other words classification is inspection of third party and its scope is to make a technical review of the design plans and related documents. Scope is also that a classification society surveyor attends at the construction of the vessel. Surveyor also can visit relevant production facilities that provide key components like the steel, engine generators and castings, to verify that the vessel is constructed in accordance with the classification rules. Classification certificate will be issued

when surveyor sees that the vessel meets necessary requirements. Only critical parts are in their interest, not every piece of structure.

Classifications for individual projects, modules or installations are approved case by case. Then The Society will review plans & documents and verify construction and installation. The Society can also make test and approve commissioning of a project.

Type approval certification means, that a manufacturer can produce and deliver components without any other actions from a society based on their own quality systems. Another solution is that not even drawings and calculation reviews are required for every produced unit.

3.2.1 Classification certificate, Material approval and type approval defined by Germanischer Lloyd

In the very beginning of the “Rules and Guidelines” of Germanischer Lloyd they are defining themselves as “independent organization providing worldwide survey and technical certification services”. GL is acting impartially and objectively. Without a certificate issued by GL no statements are allowed to give that production in question is manufactured accordance of GL rules. Although a certificate have been issued, it does not release client from his contractual obligations towards third parties. (GL Rules I-0-1 A General)

For clarify process of classification it is necessary to clarify terms Classification Certificate, Material Certificate, Type Approval, Test approval and Factory acceptance test. Some of the alone or together with one or two of these are usually admitted after certification process. Next chapters clarifies the situation.

3.2.1.1 Class Certificate

Assignment of Class, assignment of the corresponding Character of Classification and Notations and Class Certificate can be issued when applicant shows a proof of compliance with the GL Construction Rules. (GL I Part 0 Section 2 A 3. Class Certificate)

Maintenance work, repairs and conversions of classed ships and special equipment have to be carried out under the supervision of GL to ensure maintenance or reassignment of Class. The areas affected by the conversion should be treated same way as newbuildings, no matter if the concern is about the hull, the machinery including the electrical installation, the inert gas systems, automated systems or other classed equipment are concerned. (GL 1 Part 0 Section B. Validity of Class 3. Repairs, Conversions)

Concerning Surveys for maintenance of class for example in case of repairs of, or modifications to any parts subject to Classification have to be agreed with local representative of GL in due time. (GL I Part 0 Section 3 A) Surveys can be divided to (GL I Part 0 Section 3 B Surveys for maintenance of Class)

- Annual surveys
 - Hull and the machinery including the electrical plant and special equipment classed
- Intermediate Surveys
 - 2,5 years after commissioning and each class renewal
- Class Renewal Surveys
 - hull, machinery, including the electrical plant, and, for any special equipment classed
 - Continuous Class Renewal Surveys
 - Surveys based of Planned Maintenance Systems
 - Surveys based on condition Monitoring Systems

3.2.1.2 Material approval

Material approval by Germanischer Lloyd is based on Standard “EN 10204 Metallic products”. Types of inspection documents according to EN 10204 are:

Classification Certificate (a type 3.2 certificate)

A document signed by a surveyor of the Society (a 3rd party) stating

- Conformity with rule requirements
- That the tests are carried out on the certified product itself
- That the tests are made on samples taken from the certified product itself
- That the tests are performed on presence of the surveyor

Works Certificate (a type 3.1 certificate)

A document signed by the manufacturer stating:

- Conformity with the rule requirements
- That the test are carried out on the certified product itself
- That the tests are made on samples taken from the certified product itself
- That the test are witnessed and signed by a qualified department of the manufacturers

Test Report (TR) (a type 2.2 certificate)

A document signed by the manufacturer stating:

- Conformity with rule requirements
- That test are carried out on samples from the current production

Declaration of compliance with the order (a type 2.1 certificate)

For the construction, repair and equipping ships Germanischer Lloyd has a set of rules “Principles Covering the Manufacture and Testing of Materials” in Chapter II-1-1. These principles cover metallic materials and in which these are produced

and are intended to be general principles, and specific rules will be prescribed in the case of individual product, if needed. For some materials there can be applicable standards and other specifications or conditions which have to be complied by the manufacturer of the material. “Should differences between these Rules and the relevant standards or specifications with regard to their requirements, the test shall take account of the more stringent requirements”, is written in the Rule.

For material approval one should consider at least following issues:

- Manufacturing works should be approved by GL
 - Plant should be equipped so, that materials can be expertly manufactured and worked in accordance with modern technical practice.
 - Necessary testing equipment should be in use for the skilled staff (intern or outside bodies) to perform expertly the tests specified in the Rules. Test should be done in presence of the Surveyor.
 - Manufacturer has to consider his liability in any case.
 - Quality control should be arranged so, that manufacturing and products meet the specific requirements. Record should be kept of manufacture and testing as a part of internal quality control. Also system for product identification should be created.
- Manufacture techniques should be well proven.
 - Also new processes should be approved by GL
 - The requirements relating to chemical composition and properties should be satisfied.
 - Materials should meet sufficient heat conditions, freedom from defects and weldability.

Following documents should be issued to the Surveyor during the testing of materials:

- name of purchaser together with order number
- newbuilding and project number respectively, where known
- item numbers and quantities

- dimension and indication of product
- material grade, type and specification
- application and drawing number, where necessary
- weight of products

In accordance of the Rules or with special agreement, the task of material testing may have been left to the manufacturer. If the task of material testing is left to the manufacturer, the latter shall issue a relevant certificate. For different kinds of certificates different kinds of documents are demanded in addition mentioned before in this chapter. Certificates are presented below in this order:

C-type Certificate Test report of the manufacturer

- manufacturing process
- condition of supply
- details of heat treatment, where necessary marking
- results of non-specific material testing of current production

B-type Certificate Manufacturer's inspection certificate

- manufacturing process
- heat number and chemical composition
- condition of supply
- details of heat treatment, where necessary
- test pressures, where necessary
- results of special tests to be undertaken, where necessary
- results of mechanical tests of the delivery at hand

A-type Certificate Material certificate according to GL Rules

- manufacturing process
- heat number and chemical composition
- condition of supply
- details of heat treatment, where necessary
- test pressures, where necessary
- results of special tests to be undertaken, where necessary
- results

A-type Certificate Alternative verification

Confirmation of a test result of manufacturer and GL

In a case where a product is supplied by a material user or a merchant, the manufacturers certificates should be at disposal and suitable means identified for the

purchaser without amendment. Modifications to the product has to be confirmed with an additional certificate.

3.2.1.3 Type approval testing (TAT)

Type approval test is made for installation, equipment and assemblies which are subject to type testing (GL rules I-1-4 7):

- computer systems for open and closed loop controls and monitoring of essential equipment to ship operation
- remote control systems for the main propulsion plant
- fire detection systems and sensors
- sensors and actuators for specified automation equipment
- machinery alarm systems
- duty alarm systems
- protective devices
- safety devices
- safety systems

Every workshop where engines are assembled and tested has to be approved by GL when new production process is implemented. Engine manufacturer's workshops approval requires that the manufacturer's works are to be audited by GL. There has to be suitable production and testing facilities, competent staff and a quality management system, which ensures a uniform production quality of the products according to the specification. GL is supervising the manufacture of engines with GL Classification and the scope of supervising should be agreed between the manufacturer and GL.¹

Preconditions for the type approval testing are that the tested engine conforms to the specific requirements for the series and has been suitably optimized. The inspections and measurements necessary for reliable continuous operation have been performed during works test carried out by the engine manufacturer and GL has informed of the results of the major inspections. GL has also approved necessary drawings.

¹ GL I Part 1 Chapter 2 Section 2 E

The type approval test is subdivided into three stages. They are Stage A - Internal tests, Stage B - Type test and Stage C - Component inspection and their characteristics have been written in next column.²

Type A Internal tests	Type B Type test	Type C Component inspection
Functional tests and collection of operating values including test hours during the internal tests, which are to be presented to GL during the type test.	This test is to be performed in the presence of GL's representative.	After conclusion of the tests, major components are to be presented for inspection. The operating hours of the engine components, which are to be presented for inspection after t

3.2.1.4 Design appraisal

Design Appraisal, or in GL rules “Plan approval” can be used to clarify classification process in future. Once satisfactory documents of the product have been made, they can be used also in next projects. This is the case of for example pictures of a process, pipelines used or similar equipments used constantly in the projects.

Designs and construction particulars review and appraisal will be exclusively based on GL rules and guidelines. Design appraisal is agreed upon specification of the Classification contract between the Naval Authority or the Shipyard and GL. Design appraisal within the Classification procedure will normally include the review or recalculation of stability investigations. This requires the relevant information, on (e.g. combat-related) damages to be taken into account, to be submitted by the Naval Authority. (GL III – 0, 1.5)

² GL I-1-2 Section 2 E

3.2.1.5 Tests

Tests for equipment can be done on several ways. Test can be conducted at the manufacturer's works, on board and on sea trial.

GL reserve right to demand tests for systems which have safety implications, or in case of extensive automation systems or where individual systems are integrated. This test might be a factory acceptance test (FAT) and can be done in presence of GL. (GL rules I-1-4 7 Tests)

Tests on board include tests during construction/installation. During the period of construction of the ship, installations are to be checked for compliance with the documents which have been approved by GL and with the Rules for Constructions. Those tests already been carried out are to be submitted to the Surveyor on request. (GL rules I-1-4 7)

During commissioning it should be tested satisfactory condition and correct operation of all automation equipment. The tests to be conducted are to be agreed with the GL Surveyor in accordance with the system requirements. A basis for tests should be survey type "Unattended Machinery Spaces Initial".(GL I-1-7 7)

In sea trial the purpose is to prove that all systems are adjusted properly and that ship's machinery operation can be performed without manual intervention. During the sea trial surveyor has to be provided with a list of equipments which are switched of. Only agreed persons are allowed in the engine room during the test period. (GL rules I-1-4 7)

- All systems to be prepared for automatic control and adjusted to the correct settings.
- Manual operated valves shall be completely closed or open.
- All electric equipment is functioning and switched on.
- Main propulsion control shall be on the bridge.
- No alarms shall be manual inhibited.
- The Duty alarm system shall be switched to "Unattended machinery".

Start and the end should be clearly marked on the alarm registration device and communicated between control room and bridge. The minimum test time is four hours. The test shall include at least two hours at 100% main engine load.

3.2.2 Essential vs. non-essential equipment

Machinery of the ship is essential equipment according to rules in Chapter I-1-2 H of Germanischer Lloyd “Rules and Guidelines”. Essential for the ship operation are all main propulsion plants. Essential is defined as operationally important for propulsion and manoeuvrability of the ship, are maintaining ship safety and serve the safety of human life.

In the Rules for electrical and electronic equipment on seagoing ships, equipment have been divided to primary essential and secondary essential equipment. Third group is Non-Essential equipment which are not listed in two other groups and are not essential for ship operation. Essential are equipment necessary for the propulsion and manoeuvrability of the ship, navigation of the ship and are required for maintaining ship’s and human life’s safety. Primary essential are those which have to be in uninterrupted operation and secondary essential are those which has not to be in uninterrupted operation for a short time. ³

³ GL I-1-3

Primary essential	Secondary essential
<ul style="list-style-type: none"> – generator units supplying primary essential equipment – steering gear plant – fuel oil supply units including viscosity control equipment – lubricating oil pumps – cooling water/cooling media pumps – charging air blowers – electrical equipment for oil firing equipment – electrical equipment for thermal oil systems – hot and warm water generation plants – hydraulic pumps for primary essential equipment – controllable pitch propeller installation – electrical main propulsion plants – azimuth drives as sole propulsion equipment – main steam plants – adjusting, control and safety devices/systems for primary essential equipment – Monitoring equipment for primary essential Equipment 	<ul style="list-style-type: none"> – starting installations for auxiliary and main engines – starting and control air compressor – engine and boiler room ventilation fans – fuel oil treatment units – fuel oil transfer pumps – lubrication oil treatment units – lubrication oil transfer pumps – heavy fuel oil heaters – bilge and ballast pumps – ballast water treatment systems – heeling compensation systems – fire pumps and fire fighting plant – hydraulic pumps for secondary essential equipment – electrical equipment for auxiliary steam plants – transverse thrusters, if they are auxiliary equipment – anchor windlass – ventilation fans for hazardous areas – turning gear for main engines – generators supplying secondary essential equipment, only if this equipment is not supplied by generators as under 2.3.1 – lighting system – position and navigating lights, aids and signal equipment – navigational appliances and navigational systems – fire detection and alarm systems – internal safety communication equipment – bulkhead door closing equipment – bow and stern ramps as well as shell openings – control monitoring and safety systems for cargo containment systems – adjusting, control and safety devices/systems for secondary essential equipment – monitoring equipment for secondary essential Equipment

3.3 Responsibilities vendor vs. owner

In IMO Resolution MEPC.184(59) certification of EGC (exhaust gas cleaner) can be applied for by the EGC system manufacturer, ship owner or other party. As a system manufacturer Wärtsilä is obliged to apply for Sox emission Compliance Certificate (SECC). (Wärtsilä B)

Classification societies verify products against their own rules as well as for statutory rules.

Vendor is responsible of classifying its product. It is vendor's responsibility to make sure, that all the projects materials have been certified; designs are made under requirements and communicates with class about plans. Individual unit manufacturer has to be sure, that its product is delivered according to the class rules.

Owner gets the issued certificates. In the end the owner's responsibility rests on paying the bill of manufacturing the ship, which includes also classification processes. Owner is responsible of maintenance and service and has main responsibility for safety in his vessel.

3.4 Classification of SO_x Scrubber Product

SO_x Scrubber Product one has to fulfill regulations of International Maritime Organizations Marine Environmental Protections Committees resolution MEPC.184/59/24/Add1 "Guidelines for Exhaust Gas Cleaning Systems." In the very first article of guidelines it declared, that "The EGC unit should be approved by the Administration taking into account these guidelines."⁴

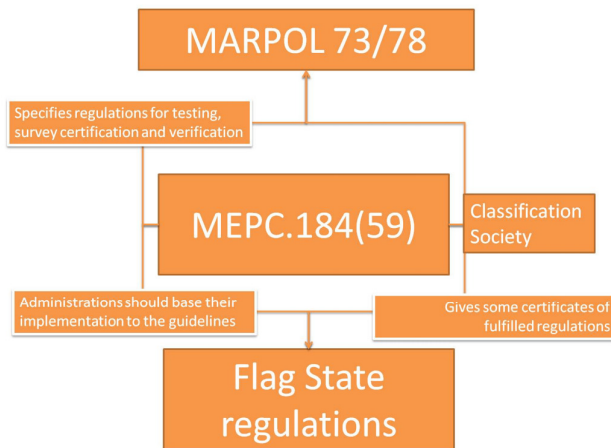


Figure 9 MEPC.184

⁴ MEPC184.59/24/Add1

Germanischer Lloyd refers to MEPC.184(59/24/Add1.) in its Rules & Guidelines Chapter I-1-2 N mentioning that exhaust gas cleaning systems has to comply with the applicable statutory requirements. Sea going ships with wet exhaust gas cleaning system must fulfill rules of MEPC.184(59). MEPC.184(59) refers to MARPOL convention and also invites Administrations (flag states) to base their implementation to these guidelines. More details of implementation of these regulations in Finland have been given before in this thesis in chapter 1.

It has been MEPCs intention to be objective and performance oriented while creating the Guidelines. EGC unit may be approved subject to equipped with continuous emission monitoring system (Scheme B) or periodic parameter and emission checks (Scheme A). Use of SO₂(ppm)/CO₂(%) ratio method will simplify the monitoring of SO_x emission and facilitate approval of an EGC Unit. Purpose is to specify the requirements for the testing, survey certification and verification of EGC systems to ensure that they provide effective equivalence to requirements of MARPOL 73/78.

Wärtsilä Scrubber Classification is following Scheme B of guidelines mentioned above since Wärtsilä SO_x scrubber uses continuous monitoring of emissions. It also fulfills requirements of Scheme A, according which emissions are monitored manually. Scheme B and continuous monitoring demonstrates that the emission from a fuel oil combustion unit fitted with an EGC will, with that system operation, result in the required emission value or below at any load point. Approval of this system needs and demonstrated compliance in service. Administration is needed to approve the monitoring system and the results. Surveys have to be made on installation and also in initial, Annual/Intermediate and renewals survey. Also the Port State Control can check functionality of EGC units. "In those instances where an EGC system is installed, section 2.6 of the Supplement to the ship's International Air Pollution Prevention Certificate should be duly completed."(MEPC.184 59/24 5.3)

For certification according to MARPOL 78/73 Wärtsilä has to issue documents mentioned in next list.

Initials	Document Description	Purpose
SECP	SOx Emissions Compliance Plan	List of each item of oil combustion equipment which is to meet the requirements; the means of demonstration of comparable ratio;
ETM Scheme B	EGC system - Technical Manual for Scheme B	The identification of the Unit; The operating limits; requirements or restrictions; corrective actions in case of exceedances; washwater characteristics and design requirements
OMM	Onboard Monitoring Manual	The Sensors used in evaluating EGC system performance and washwater monitoring; the positioning of monitoring; the analysers to be used; analyser zero and span check procedures; other information data relevant to the correct functioning of the monitoring.
EGC Record Book or electronic Logging system	A record of the EGC unit in-service operating parameters, component adjustments, maintenance and service records appropriate	

While installing SOx Scrubber to a Containership VII, it might be necessary to check that all the Certificates issued are still valid. In the “Questionnaire for Classification of Container Ships (Newbuilding)”⁵ can be found a list of Statutory Certificates / Documents containerships must have on. Scrubber Installation can affect to following:

Certificate	Content of certificate	Scrubber effects
International Load Line Certificate	Ensuring adequate stability and avoid excessive stress on the ship's hull on a result of overloading.	Scrubber has to be installed so, that stability and excessive stress on hull can be avoided.
International air pollution prevention certificate	An international Air Pollution Prevention Certifi-	Should be checked that certificate is still valid

⁵ <http://www.gl-group.com/pdf/F006AE.pdf>

(IAPP), MARPOL VI	cate shall be issued if survey shows that the equipment, systems, fittings, arrangements and material fully comply with the applicable requirements of Annex VI of the MARPOL Convention 73/78.	after Sox Scrubber is installation. Verification of emission levels. Updates to relevant IAPD documentation on the ship.
Document of compliance for the carriage of dangerous goods (SOLAS II-2, Reg.19) – class notation “DG”	The Administration shall provide the ship with an appropriate document as evidence of compliance of construction and equipment with the requirements of regulation II-2/19 of SOLAS 1974. Certification for dangerous goods, except solid dangerous goods in bulk, is not required for those cargoes specified as class 6.2 and 7 and dangerous goods in limited quantities.	Caustic soda used in Scrubber is not a cargo. This certificate is not effected by scrubber.
International Tonnage Certificate (1969)	An International Tonnage Certificate (1969) shall be issued to every ship, the gross and net tonnage of which have been determined in accordance with the Convention.	Depending on the volume of installation, this certificate may be effected and should be checked again after scrubber installation.
International Oil Pollution Prevention Certificate 1973	MARPOL 73/78 Covers prevention of pollution by oil from operational measures as well as from accidental discharges. The 1992 amendments to Annex I made it mandatory for new oil tankers to have double hulls and brought in a phase-in schedule for existing tankers to fit double hulls, which was subsequently revised in 2001 and 2003.	During production, transportation and during pumping ???

4 CLASSIFICATION OF SO_x SCRUBBER INSTALLATION

4.1 Procedure of Classification of Scrubber Installation

The role of the scrubber classification for Containership VII is quite interesting since it is new technology in marine environment and there is not much experience of classification process for scrubber installation before. In this section of the thesis intention is to give an overall picture of the procedure of Classification of Scrubber Installation, although it is not always useful to divide it from the scrubber as classified product. This will be used as a road sign to future classification projects of scrubbers. Although ships are different and also may have been classified in different classification societies, this kind of information from first project is valuable considering fluency of coming projects.

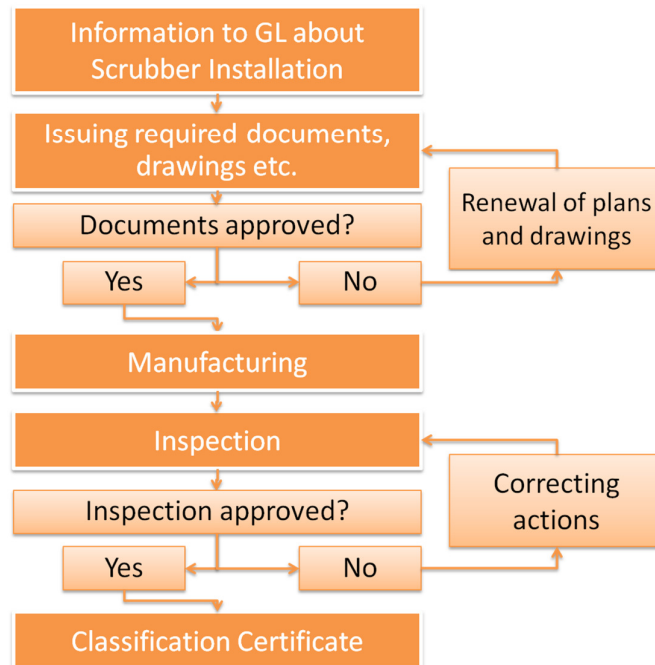


Figure 10 Description of Classification process

Like all the other classification processes dealt with Germanischer Lloyd, also Classification of SOx scrubber installation begins with communication with classification society. GL will be supplied with documents showing plans of intentions and drawings depending on the matter in question. GL will be also invited to inspect the component in question. Process differs if there is a question of material or component. Next pages intention is to follow the process in all the cases concerning Sox Scrubber Classification.

Process will be presented in next chapter in order shown below.

Title of Component, part or module of a Scrubber

- After the title of the component there will be short description of the part or module in hand. Here will be presented how it is working and effecting to other parts involved.

Documents to be issued

- Here will be presented what documents needs to be delivered to the classification society.

Inspections needed

- Tests to be done

Tests required by Classification Society

Additional tests

Point of Inspection

- Are tests done already on the factory, quay trial or in sea trial?

Classification Certificate

- What kind of Certificate will be issued? Is it a material test, test certificate, factory acceptance test or class certificate.



Figure 11 Containership VII

4.2 Plan approval

GL Rule:

I-1-2 N 2.1

Documents for approval

For approval, drawings showing the main dimensions of the systems shall be submitted including documentation concerning installation requirements and operational features. An operation manual shall include instructions for emergency operation, if applicable.

GL Rule

I-1-2 N 2.2

Approval certificate

After successful appraisal of the required documents and successful conclusion of the shipboard test in presence of a Surveyor GL issues an Approval Certificate.

4.2.1 Documents to be issued

Document name:	GL:		FLAG:	
	Approval	Information	Approval	Information
Strengthening side at aft	x			
General Arrangement		x		
Safety plan		x	x	
Scrubber tower arrangement		x		
Tank plan	x		x	
Scrubber foundation		x		
Support tower of Scrubber	x			
Tank structure modification	x			
Equipment container shell plating and installation	x			
Light mast construction and arrangement	x			
New opening at deck A, Fr.18, PS				
Equipment container insulation scheme	x			
Equipment layout engine room		x		
Equipment layout Valve room		x		
Exhaust gas piping scheme	x			
Exhaust gas pipe assembly drawing		x		
Scrubbing water diagram		x		
Alkali service and filling diagram	x			
Equipment container arrangement	x			
Scrubber tower ventilation diagram	x			
Equipment container ventilation diagram	x			
Scheme of Cooling water system	x			
Sanitary fresh water diagram	x			
Technical fresh water diagram	x			
Compressed air diagram	x			
Air and overflow pipe diagram	x			
Scrubber tower drain water diagram	x			
Hydraulic oil system for quick closing valve				
Fire detection, alarms & public address, cabling	x			
Scrubber tower&container Lighting, cabling	x			
Cross section rule check	x			
Scrubber tower Natural frequency analysis		x		
Scrubber PI-Diagram				
- Equipment list		x		
- Total scrubber system		x		
- Exhaust gas system	x			
- Scrubbing water system	x			
- Sea water system		x		
- Bleed-off and effluent system	x			
- Alkali system		x		
- Sanitary and technical water system		x		
- Compressed air system		x		
- Sludge system		x		
Functional description		x		
Safety concept for Sox scrubber	x			
MARPOL				
ETM - EGCS Technical Manual	x			
OMM - Onboard Monitoring Manual	x			
EGC Record Book format	x			
IMO Reporting description				
SECP - Sox emissions compliance plan			x	
Approval of scrubber trial application			x	
Marpol Certification Test Plan		x		
Marpol Certification Test Record Sheets		x		

4.3 Material and procedure approval

4.3.1 Materials to be issued with classification certificate or type approval

Material	Approval Type
Pipes (for ex. plastic pipes after bleed off)	Type approval
Fuel oil meter	Classification Certificate by manufacturer
Steel Frames of equipment container	Material Certificate 3.2.
Scrubber support tower	Material Certificate 3.2.
Welding	Certified Welders
Cables	Type Approval -Note also fire resistance

4.3.1.1 Equipment Container

Equipment container is a storage where is held bleed-off treatment unit, effluent monitoring module, effluent buffer tank and UNIC.

The equipment container is considered as a ship hull structure, not as a “container”. This is the case due to reason that pipe lines and cables are assembled from vessel to container. Regarding steel structure ship hull rules apply. (Strength, material etc). Rules for container do not apply. Equipment container certificate for ship hull structure not affecting longitudinal strength of the hull. Steel frames for equipment container needs to have material certificate 3.2.

Documents to be issued

Equipment Container Structure Drawings	For Approval
Equipment Container arrangement	For Approval

Equipment Container Ventilation Diagram	For Approval
Equipment Container Insulation Scheme	For Approval

Inspections needed

The scope of supply is adequate and the course of actions is correct
Welding visual inspections

Point of inspection

Supplier site / Quay trial

4.4 Installation approvals

4.4.1 FAT's for equipment

Equipment listed below needs to have Factory Acceptance Tests. It means, that these equipment are tested in factory where they are manufactured according to supplier own quality program or in presence of surveyor. Those marked with star are tested in this case according to vendors own test programs.

EQUIPMENT CONTAINER
*EVAPORATOR
*HYDROPHORE MODULE
*ALKALI FEED MODULE
*SCRUBBER UNIT
*SCRUBBING WATER PUMP UNIT
*BLEED-OFF TREATMENT UNIT
EFFLUENT MONITORING MODULE
*CONTINUOUS EMISSION MONITORING SYSTEM
SCRUBBER AUTOMATION
SCRUBBER TOWER (structure check)
ALKALI PIPING (pressure test)
CONTAINER

4.4.2 Steel frame

IACS stands for International Association of Classification Societies. They have created “No 47 Shipbuilding and Repair Quality Standard” to provide guidance where established and recognized shipbuilding or national standards accepted by the Classification Society do not exist. In this guide are instructions for installations of steel frame structures. (IACS 2011)

When installing Scrubber to Containerships VII equipment container faced issues concerning these rules. Squareness of container had to be ensured in the tolerance limits of 15 mm.

4.4.3 Welding checks

Welding and welding inspections are important aspect in shipbuilding. Welding, welders and welding procedures are inspected carefully trough whole building process. Germanischer Lloyd has also many rules for approval for welding, which will be presented here. These rules are made for newbuilding project of a ship, but can also be used for repairing projects.

Function	Description	Documentation available to surveyor during construction
Welding supervision GL Rules Materials and Welding III-1-2B2	Supervision of welding has to be sufficient.	Proof of qualification of the welding supervision personnel ISO 14731/EN719
Welder/operator GL Rules Materials and Welding III-1-2B3	Welders must be qualified and approved every 6 months.	- Individual's identification, - List of valid welder qualification tests.
Welding procedures GL Rules Materials and Welding III-1-2D	All weld joint configurations, positions and materials are to be covered by approved welding procedures. Welding procedure tests shall be carried out under the Society's supervision before starting the fabrication work.	Approved list of all welding procedure specifications relevant for the project. ISO 9956/EN288
Welding consumables GL Rules Materials and Welding III-1-1E	Approved consumables according to relevant base material and material thickness.	- Consumable specification, - Material status
Welding equipment	Correct calibration and maintaining. As scale necessary for proper performance of welding work.	Maintenance and calibration records.
Welding environment IACS Recommendation 47	Satisfactory environment, dry and clean	
NDT (Nondestructive testing)	Carried out by qualified operators	- Welding and NDT plans - NDT reports - Proof of qualifications of the test personnel

Documents to be Issued

Welding workshop approval

Proof of qualification of the welding supervision personnel

ISO 14731/EN719

List of valid welder qualification tests

Approved list of all welding procedure specifications relevant for the project

Consumable specification

Material status

Maintenance and calibration records of equipment

Welding and NDT plans
NDT reports
Proof of qualifications of the test personnel

Class requirements

Report “Welding Workshop Inspection” Surveyors Checklist

Point of inspection

Quay Trial

4.4.4 Pipe pressure tests and installation approval

Piping pressure test are done to all piping lines including water, effluent, alkali and compressed air piping.

Piping is divided to 3 different classes in Germanischer Lloyds rules. These rules can be found in Chapter I-1-2 Section 11. Also for example rules for documents to be approved can be found in I-1-2 Section 11. Most of the pipelines concerning scrubber are in class III but there are some in other categories too.

Medium/type of pipeline	Design pressure PR [bar] Design temperature t [°C]		
	I	II	III
Pipe class			
Toxic media	all		
Corrosive media			
Inflammable media with service temperature above the flash point	all	,	-
Inflammable media with a flash point of 60 °C or less			
Liquefied gases (L.G)			
Steam	PR > 16 or t > 300	PR ≤ 16 and t ≤ 300	PR ≤ 7 and t ≤ 170
Thermal oil	PR > 16 or t > 300	PR ≤ 16 and t ≤ 300	PR ≤ 7 and t ≤ 150
Air, gas Non-flammable hydraulic fluid Boiler feedwater, condensate Seawater and fresh water for cooling Drine in refrigerating plant	PR > 40 or t > 300	PR ≤ 40 and t ≤ 300	PR ≤ 16 and t ≤ 200
Liquid fuels, lubricating oil, flammable hydraulic fluid	PR > 16 or t > 150	PR ≤ 16 and t ≤ 150	PR ≤ 7 and t ≤ 60
Cargo pipelines for oil tankers	-	-	all
Cargo and venting lines for gas and chemical tankers	all	-	-
Refrigerants	-	all	-
Open-ended pipelines (without shutoff), e.g. drains, venting pipes, overflow lines and boiler blowdown lines	-	-	all
1 Classification in Pipe Class II is possible if special safety arrangements are available and structural safety precautions are arranged.			

Figure 12. GL "Classification of pipes into pipe classes" GL Rules I-1-2 11

4.4.4.1 Documents to be Issued

Sanitary Fresh Water Diagram
 Technical Fresh Water Diagram
 Bleed-off & Effluent System
 Thermo Oil
 Sludge Oil Diagram
 Fuel Oil Feed Diagram
 Scheme of Cooling Water System
 Compressed Air
 Alkali Filling & Transfer Diagram
 Scrubbing Water System

4.4.4.2 Inspections Needed

Class Requirements

Leaking tests

GL Rule
 I-1-2 B 2.6.5
**Testing after installation
 onboard**

Piping systems for non-essential services are to be checked for leakage under operational conditions.

Point of Inspection
Suppliers Site, Quay trial

4.4.5 Cabling and cable leadings check and approval

GL rules in Rules & Guidelines chapter I-1-3-12 contains instructions for electrical Cable Network. Rules contains instruction for (A) choosing cables and wires, (B) determination of conductor cross-sections, (C) rating, protection and installation of circuits, (D) installation, (E) requirements of busbar trunking systems intended for the electrical supply of distribution panels and single consumers. Although rules can be found in this chapter, is required to use experienced assembler.

Mentioned section in the rules contains many different kinds of tables for the use of assembler, for example the current-carrying capacities. Instructions can be found also for example arrangement for flat cable configurations containing not more than 6 cables laid side by side or of groupings not more than 3 cables or insulated wires are as follows:

Flat arrangement:

○○○○○○ ○○○○○○ etc.

Groupings of not more than 3 cables:

○○○ ○○○ etc. ○○○○○○
○○○ ○○○ or ○○○○○○ etc.

Figure 13 Arrangement of a cables (GL)

4.4.6 Fire alarm system check and approval (after modification)

In the GL Rules chapter I-1-2-12 can be found rules for “Fire protection and fire extinguishing equipment.” This section of rules apply to fire protection in the ma-

chinery and boiler spaces of passenger and cargo vessels and to fire extinguishing equipment throughout the ship.

Also in GL Rules section I-1-3-D 3 can be found instruction for ship safety systems. There it is said, that fire detection and fire alarm systems are subject to mandatory type approval. Its function is tested and needs also to be approved. To the containership VII was installed 3 extra fire alarms.

4.4.7 Signal tests

I/O points are simulated manually and operation checked before Scrubber commissioning.

4.5 Additional tests at Quay Trial Program

4.5.1 SO_x Scrubber Unit

From process tank the scrubbing water is pumped to the seawater cooler and via pressure line to the scrubber unit together with alkali NaOH. In the scrubber unit water is sprayed through the packing material. The acid gases react with the scrubbing water. From the scrubber unit scrubbing water returns through discharge pipe back to the process tank.

Documents to be issued

Scrubber PI-Diagram (Scrubber Unit)	For Approval
Scrubber tower ventilation Diagram	For Approval
Support tower of Scrubber	For Approval

Class requirements

Leaking tests

Point of Inspection

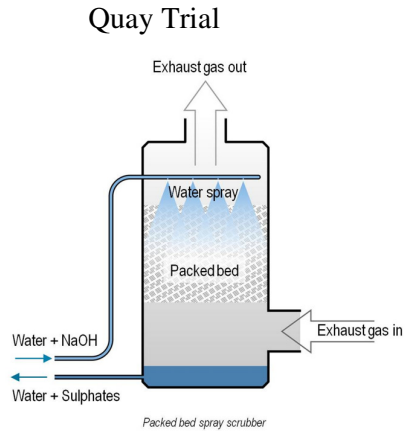


Figure 14. SO_x Scrubber Unit function (Wärtsilä E, 2011)

4.5.2 Exhaust Gas System

A main stream scrubber is installed in the main flow of a particular engine forcing the gas through the scrubber.

Documents to be issued

Exhaust Gas Piping Scheme	For Approval
Scrubber tower drain water Diagram	For Approval
Material Certificate 2.2 (Pipe Class III)	For Approval

Class requirements

Leaking test

- For Scrubber Unit
- Exhaust gas pipes

Point of inspection

Quay Trial

4.5.3 Scrubbing Water System

Scrubbing water pumps are taking water from the wet sump. Water is lead to the scrubber Unit.

Documents to be issued

Scrubber PI diagram

For Approval

Additional tests

Operation of Scrubbing water lower circuit pumps are checked.

Operation of Scrubbing water drain to buffer tank is checked.

Operation of Scrubber droplet separator water supply with the scrubber in manual mode are checked.

Point of inspection

Quay Trial

4.5.4 Sea Water Cooling System

Exhaust gas heat is transferred to scrubbing water and removed in the scrubbing water heat exchangers. The purpose of the cooling is to minimize the water content in the cleaned exhaust gas after the scrubber, thereby minimizing the plume opacity and freshwater consumption.

Documents to be issued

Scheme of cooling system

For Approval

Additional Tests

Operation of SW-cooling water pump for Scrubber is checked.

Function of the temperature regulation valve is checked.

During operation of the pump at full capacity distribution of

cooling water to heat exchangers is checked and adjusted.
Operation of ballast pump cooling for Scrubber is checked.

Point of inspection

Quay trial

4.5.5 Bleed-off transfer and effluent transfer System (BOTU)

To remove the accumulated impurities from scrubbing water a small flow of bleed-off is extracted and led to the bleed off treatment unit. BOTU ensures that effluent fulfills MARPOL quality requirements. From the bleed-off treatment unit the cleaned effluent is lead to overboard discharge.

Documents to be issued

Scrubber PI-Diagram	For Approval
Bleed-off & Effluent System	For Information

Additional tests

Operation of bleed-off valve is checked
Operation of the effluent and the bleed-off transfer pumps are checked
Operation of bleed-off treatment unit pumps are checked

Point of inspection

Quay Trial

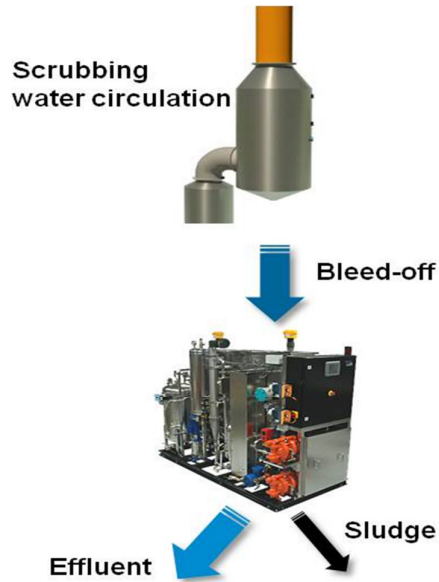


Figure 15. Bleed-off treatment unit (Wärtsilä E, 2011)

4.5.6 Alkali System

Alkali is needed in the process of exhaust cleaning to catch the Sox particles. The alkali (NaOH) solution is pumped from the storage tank with alkali feed pump to the circulation pump.

Documents to be issued

Scrubber PI –Diagram	For Information
Alkali feed diagram	For Approval
Alkali transfer & filling Diagram	For Approval
Alkali feed pump module FAT record	On request

Class requirements

Material tests for alkali containers and lines	For Approval
--	--------------

Additional tests

Function of alkali bunkering lines when bunkering the alkali onboard.

Remote and local sounding and temperature measurement is tested during bunkering.

Function of alkali transfer pump is checked when filling BOTUs.

Point of inspection

Quay trial

4.5.7 Sanitary and technical water system

Documents to be issued

Sanitary Fresh Water Diagram

Additional tests to be done

Operation of four safety shower is checked.

4.5.8 Fresh water supply and scrubber overflow system

Fresh water is used on safety shower system near of caustic soda handling sites.

Water is taken from ships sanitary water system.

Documents to be issued

Technical Fresh Water diagram

Additional tests to be done

Fresh water filling lines are checked when bunkering fresh water onboard.

From technical water storage tank, water is pumped by two hydrophore pumps via the hydrophore tank to the scrubbing water pump module.

- Operation of hydrophore pumps is checked.
- Capacity of pumps is checked.
- Combined capacity of pumps is checked.
- Functionality of scrubber overflow arrangement is checked.

Point of inspection

Quay Trial

4.5.9 Sludge System

Sludge system contains waste water from bleed-off treatment units and from overflow from buffer tank. Waste from sludge system is discharged to port.

Documents to be issued

Scrubber Pi-diagram	For Information
- Sludge system	
Sludge Oil Diagram	For Information

Tests to be done

- Welding Visual Inspections
- Operation of open deck scuppers is checked.
- Operation of BOTU sludge pumps is checked.
- Operation of buffer tank overflow pipe is checked.

Point of inspection

Quay Trial

4.5.10 Emission Monitoring Module (CEMS)

Emission monitoring module (CEMS) is monitoring particles of SO_x from exhaust gas after scrubbing. Certificate to this module will be issued if

- Compliance can be demonstrated (by vendor or class presence)

- Monitoring system is approved
- The results of monitoring are available to demonstrate compliance as required (MEPC.184(59))

Documents to be issued

ETM – B EGC System Technical Manual
CEMS Factory Acceptance Test Report

Inspections needed

The Monitoring system of the EGC system should be subject to survey on installation and at Initial, Annual/Intermediate and Renewals Survey by the Administration. (MEPC.184(59))

Tests to be done

Check of Function

Point of inspection

Sea Trial

4.5.11 Electrical and automation system

Electrical and automation system fulfils needs for control, safety, monitoring and alarms. It is also logging with trending capacity.

For Germanischer Lloyd's side electrical and automation of SOx Scrubber is considered as non-essential equipment, since it is not effecting to ship's main electrical issues.

Documents to be issued

Electrical cabling diagram	For Approval
Type approval for cable penetrations	For Approval

56(65)

Type approval Certificates for cables	For Approval
Scrubber functional description	For Information

Inspections needed

Electrical installation quay trial	For Approval
Type approval for Cable penetrations	For Approval
Type approval Certificates for Cables	For Approval

Point of Inspection

Quay trial

4.5.12 Working Safety

Documents to be issued

Safety Concept for SOx Scrubber	For Information
Safety Plan	
Evacuation Plan	
Fire Detection, alarms & container lightning, cabling	
Scrubber tower & container emergency lightning and exit signs	

Tests to be done

Fire alarms, lightning

4.6 MARPOL Tests

For MARPOL certification is necessary to do tests according to “Scrubber Certification Test Program”. Test will be carried out and measured from every 5 steps as follows:

1. Main engine load 1 010 kW (9 %), scrubber load 19 %
2. Main engine load 3 150 kW (25 %), scrubber load 38 %
3. Main engine load 6 300 kW (50 %), scrubber load 63 %
4. Main engine load 9 450 kW (75 %), scrubber load 85 %
5. Main engine load 12 600 kW (100 %), scrubber load 100 %

Time (UTC):

ENGINE DATA

Engine speed (rpm):

Propeller oil dividing box setting (mm):

Ship speed (knots):

Charge air pressure (kPa):

Turbo speed (rpm):

Fuel feed (lpm):

EXHAUST GAS

Flue gas flow (xx):

Flue gas SO₂ after scrubber (xx):

Flue gas CO₂ after scrubber (xx):

Flue gas NO_x after scrubber (xx):

SAMPLES

Discharge water sample:

Fuel oil sample:

PROCESS DATA

Scrubbing water pressure:

Scrubbing water flow:

Scrubbing water pH, scrubber inlet:

Exhaust gas pressure, inlet:

Exhaust differential pressure:

Exhaust gas temperature, scrubber inlet:

Exhaust gas temperature, scrubber outlet:

Effluent pH:

Effluent turbidity:

Effluent PAH:

Exhaust gas SO₂ after scrubber:

APPROVAL

5 CONCLUSIONS

Pressure for development of new environmental products comes from international needs. International Maritime Organization and European Union are giving regulations concerning emissions to air, which also ship building industry has to consider in their actions. Classification societies are making inspections to new-build vessels, but also old vessels under repair. When installing something new to old ship, many aspects have to be observed. Questions answered in this thesis have been various, since Sox Scrubber to a ship is brand new concept for everyone. Wärtsilä has a leading role in developing this and other new methods of exhaust cleaning.

In this thesis Scrubber Technology has been reflected to Germanischer Lloyd's rules and regulations. Scrubber is considered as non-essential equipment, which has to fulfill rules of MARPOL regulations. Because installing this first commercial Scrubber to Containership VII is also first classification made completely by Germanischer Lloyd, all the actions in both sides has had to be careful, since it is leading the way for further classifications. Chapter 4 of this thesis gives details of classification if installation of Sox scrubber, documents needed for approval and inspections necessary to get certificates.

Further studies are useful on how processes with classification societies could be simplified. Investigations of design appraisal and type acceptance tastings should be made.

Since the whole air-emission legislation is new, also other equipment need similar studies. To reduce Nitrogen Oxide emissions Wärtsilä has created SCR Selective Catalytic Reduction installation caller NOR. Rules for classification of this method are as unclear as SOx Scrubber has also been. Now it seems that there are some clarifications on the way, and these should be closely investigated.

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		Approval	Noted	On request	Responsible organization
Documents to be issued	Alkali System				
	Scrubber PI-Diagram		x		
	Alkali feed diagram	x			Wärtsilä
	Alkali service and filling Diagram	x			Wärtsilä
	Alkali feed pump module FAT record			x	Wärtsilä
Inspections	Material test for alkali containers and lines Note: pipe class 1 pipes				
Point of inspection	Quay trial				
Documents to be issued	Electrical and Automation				
	Electrical cabling diagram	x			Wärtsilä
	Type approval for cable penetrations	x			Wärtsilä
	Type approval Certificates for cables	x			Wärtsilä
	Scrubber functional description		x		
Inspections	Electrical installation quay trial	x			
	Type approval for Cable penetrations	x			???
	Type approval Certificates for Cables	x			???
	Quay trial				
Point of inspection	Quay trial				
Documents to be issued	Sanitary Water System				
	Sanitary Fresh Water Diagram	????			Wärtsilä
	Scrubber PI-Diagram		x		
Inspections	Operation of 4 safety shower will be checked				
Point of inspection					