WÄRTSILÄ SCRUBBER

PRODUCT GUIDE

November 2014

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1 Nomenclature & Abbreviations

The following is a list of abbreviations used in this document. Detailed terminology is presented in Chapter 10 Scrubber Nomenclature.

BOTU	Bleed-off treatment unit
CEMS	Continuous emission monitoring system
EGC	Exhaust Gas Cleaning
EGC Unit	Exhaust Gas Cleaning Unit, also known as a Scrubber
EGD	Exhaust Gas Declaration
EGCU	Exhaust Gas Cleaning Unit –type Scrubber
EMM	Effluent monitoring module (Closed loop)
ETM A/B	Exhaust Gas Cleaning Technical Manual for Scheme A/B
FNU	Unit used for measuring turbidity
HMI	Human-Machine Interface – automation system
IAMCS	Ship automation system
IMO	International Maritime Organization
I/O	Input / Output (referring to communication terminals)
MARPOL	The International Convention for the Prevention of Pollution from Ships
MCP	Main control panel (for scrubber automation)
MCR	Maximum continuous rating
OMM	Onboard Monitoring Manual
PLC	Programmable logic controller
SECA	SOx Emission Control Area
SECP	SOx Emissions Compliance Plan
SWMM	Sea water monitoring module
VSD	Variable speed drive
WWMM	Wash water monitoring module
CO_2	Carbon dioxide
SO_2	Sulphur dioxide
NaOH	Caustic soda (Alkali)

2 Introduction

2.1 General

This Product Guide describes the technical installation matters related to exhaust gas cleaning systems used for Sulphur emission control purposes in marine environment. This guide is intended to give technical support in the early design phase. Any data and information herein is subject to revision without notice. For contracted projects, specific instructions are delivered.

This document provides general guidance regarding scrubber onboard space reservation, system and tank design and other similar issues.

2.2 EGC System types & installations

Wärtsilä offers three different types of EGC Systems: Closed loop systems (CL), Open loop systems (OL) & Hybrid systems (HS). The table below describes the solutions:

Table 1 EGC System types & installations

EGC System type	Water source	Alkali required	Scrubber types available	Seawater alkalinity requirements
Closed loop (CL)	Seawater	Yes	EGCU & Inline	None
Open loop (OL)	Seawater	No	EGCU & Inline	>1000µmol/l
Hybrid System (HS)	Seawater	Yes	EGCU & Inline	None

2.3 Performance

The EGCU Scrubber unit is designed to operate with a maximum of 3,5%S heavy fuel oil. The SOx reduction efficiency corresponds to a reduction of fuel Sulphur content from 3,50%S to 0,10%S.

The Inline Scrubber unit is designed to operate with a maximum of 2,5%S heavy fuel oil. The SOx reduction efficiency corresponds to a reduction of fuel Sulphur content from 2,50%S to 0,10%S.

2.4 Dimensioning of scrubbers for a specific gas flow

As a general rule, scrubbers should be dimensioned for 100% of the gas flow of the connected combustion unit(s).

An Integrated Scrubber can be dimensioned for a smaller gas flow than the total exhaust gas of the connected combustion units. This could be the case when all generator engines are connected to the scrubber, as generally not all generator engines are fully loaded simultaneously. This arrangement will require agreement between the Owner / Operator and the relevant Classification Society, and will be detailed in an Exhaust Gas Declaration (EGD).

Subject to confirmation from the classification society, a scrubber (Main Stream, Integrated or Multi-inlet) can be dimensioned for a smaller gas flow than the exhaust gas of the combustion unit(s) at full load, provided that such a compliance principle is based on a realistic operating mode. In such cases the SECP and EGD should specify operating modes when the ship is compliant by fuel and when by scrubbing. Any engine load exceeding the scrubber capacity would automatically open the exhaust gas bypass line, and the ship is responsible for compliance. Adjusting the set point of the load control system of main propulsion engines or generator engines normally used on ships to a value corresponding to the scrubber capacity is a convenient way of ensuring that the scrubber capacity is not exceeded, and the ship stays in “scrubber compliance mode”.

3 Rules and regulations

3.1 General

The core purpose behind exhaust gas cleaning is the global need to reduce the amount of Sulphur oxides being emitted to the atmosphere by combustion units using fuels containing Sulphur.

Several major marine legislators have recently imposed rules and regulations concerning different methods of limiting the Sulphur footprint generated by marine traffic. These new rules not only limit the amount of Sulphur ships are allowed to emit into the atmosphere, but also set a variety of discharge water quality requirements for the exhaust gas cleaning systems being used.

The following list details the main legislative requirements having an effect on the use of exhaust gas cleaning:

- The International Maritime Organization (IMO)
    - Marpol Annex VI
    - Resolution MEPC.184(59) Guidelines for Exhaust Gas Cleaning Systems
- European Union (EU)
    - EU Sulphur Directive 2012/33/EU
    - EU Marine Equipment Directive (MED) 96/98/EC as amended by 2012/32/EU
- US EPA Vessel General Permit
- Classification society requlations

3.2 IMO MARPOL

3.2.1 Regulations

The IMO Annex VI serves as the base of worldwide marine sulphur reduction requirements. IMO MARPOL legislation limits the use of fuels containing sulphur as follows:

Global limit sulphur %:
- 3.50% from 1.1.2012
- 0.50% from 1.1.2020, possibly to be postponed to 1.1.2025.

Emission Control Areas sulphur %:
- 1.00% from 1.7.2010
- 0.10% from 1.1.2015

Fuel types are not regulated, leaving also room for alternative compliant solutions such as exhaust gas cleaning (ref: MARPOL Annex VI Regulation 4).

The discharge water quality restrictions have been defined in the IMO Scrubber Guidelines MEPC.184(59), launched in 2009.

The following discharge water qualities have been given limit values:
- pH
- PAH
- Turbidity
- Nitrates

3.2.2 MARPOL Documents

The MEPC.184(59) lists a variety of documents to be generated for a ship using exhaust gas cleaning as means of meeting the emission legislation requirements. These documents must be approved by the Administration. The following contains a short summary of the documents:

SECP

The SO_x Emissions Compliance Plan is a document describing all the possible alternatives of the particular ship is capable of using in order to meet the emission requirements set for the sulphur emission control areas (SECAs). These alternatives mainly consist of 3 different scenarios, which are;

1) Using compliant fuel (<0.10%S),
2) Using different fuels inside and outside SECA – areas (<0.10%S inside SECA), and
3) Using an EGC System.

The SECP also lists all the combustion units onboard and which of them are connected to the exhaust gas cleaning unit(s).

ETM-A/B

Under MEPC.184(59) there are two possible compliance routes, Scheme A or Scheme B;

1) Scheme A – EGC System Approval, Survey and Certification using Parameter and Emission Checks,
2) Scheme B – EGC System Approval, Survey and Certification using Continuous Monitoring of Emissions.

The ETM-A/B is the main technical manual that describes a variety of relevant key process parameters of the particular exhaust gas cleaning system. These key border-values have been confirmed by the administration, meaning that when the exhaust gas cleaning system is being used, it should stay within the limits at all times to ensure compliance.

The ETM also states the corrective actions to be performed in case exceedances are occurring.

OMM

The Onboard Monitoring Manual is a document listing all the essential sensors used to demonstrate system compliance. These sensors mainly consist of exhaust gas monitoring, key-process parameters (such as scrubbing water pressure and flow) and discharge water quality monitoring.

The OMM states all the service, maintenance and calibration requirements for these essential sensors together with the component / sensor part manuals. These service, maintenance & calibration tasks must be performed in due time and the corresponding notes must be written in the EGC Record Book. With completed records, the ship is able to effectively demonstrate that the EGC system is working in compliance and that the sensor values used to determine compliance are trustworthy.

The OMM also states how the monitoring system surveys are to be performed.

EGC Record Book

The EGC Record Book is a set of forms that are required to be used to log events affecting and repairs to the sensors monitoring EGC System compliance. Such events are for example all the service, maintenance and re-calibration that is being done for the sensors listed in the OMM, when wash water residues/sludge is being offloaded to a port reception facility or in the case of closed loop the delivery of and consumption of chemicals for maintaining system performance (e.g. Sodium Hydroxide [Caustic Soda] NaOH).

As an alternative to using the EGC Record Book, similar log can be kept as a part of the ship’s Planned Maintenance System (PMS).

Exhaust gas declaration

This document states the exhaust gas flow values from the connected engines to be used to determine EGC System capacity requirements.

3.3 EU

The European Union has introduced a Sulphur Directive, which has great impact on the local marine traffic inside EU SECAs. This directive is mostly following the IMO MARPOL Annex VI, with a few additional requirements.

Summary of the EU Sulphur directive, applicable to ships of all flags:

- All ships in SOx ECA
    - 1.00% until 31.12.2014
    - 0.10% from 1.1.2015
- All ships outside SOx ECA
    - 3.50% from 1.1.2012
    - 0.50% from 1.1.2020
- Passenger vessels operating on regular services to or from EU port
    - 1.5% until 1.1.2020
- Ships at berth in EU
    - 0.1% from 1.1.2010

3.4 US EPA: Vessel General Permit (VGP)

From December 19th 2013, commercial ships operating closer than 3 miles from US coast line, must obtain coverage under Vessel General Permit in order to be allowed to discharge into the sea. The allowed discharge limits are similar to the IMO legislations in terms of having limit values for pH, PAH, Turbidity, Nitrates and Nitrites. The discharge of washwater from the exhaust gas scrubber treatment system must have a pH of no less than 6.0 measured at the ship’s overboard discharge, with the exception that during maneuvering and transit, the maximum difference between inlet and outlet of 2.0 pH units is allowed. This difference is to be measured at the ship’s inlet and overboard discharge.

3.5 Classification Societies

Several Classification Societies have already developed their own rules to incorporate the use of emissions abatement technology and to ensure that the use of this equipment will have no adverse effect on the safety of the ship. In terms of MARPOL compliance, most Classification Societies are designated as Recognised Organisations and are able to act on behalf of Flag State Administrations and are given a mandate to survey and verify emission abatement system compliance on their behalf.

Point worth noticing is that the rules concerning Exhaust Gas Cleaning Systems developed by different Class Societies may differ between each other.

4 System Description

This chapter describes the difference between the three EGC System types (CL, OL & HS).

4.1 Closed Loop System (CL)

In Closed loop scrubbing process, the scrubbing water is pumped through a sea water heat exchanger to the scrubber. Scrubbing water is sprayed towards the exhaust gas flow via spray nozzles inside the scrubber. Scrubbing water is also sprayed to the venturi exhaust gas inlet(s).

Scrubbing water passes through the packed bed inside the scrubber and is eventually collected and removed through the sump at the bottom. The scrubbing water absorbs Sulphur oxides, heat and other components from the exhaust gas stream. The heat is removed in a sea water heat exchanger. Scrubbing water pH, and thus the cleaning efficiency, is automatically monitored and controlled by alkali dosing.

As the scrubber overall dimensions, together with space for the auxiliary equipment and maintenance, are exceeding e.g. conventional silencer dimensions, a slightly larger engine casing area may be required. In new building projects, it is important that functionality of the EGC system is considered in the ship project design phase in order to provide efficient scrubber system together with optimized space utilization.

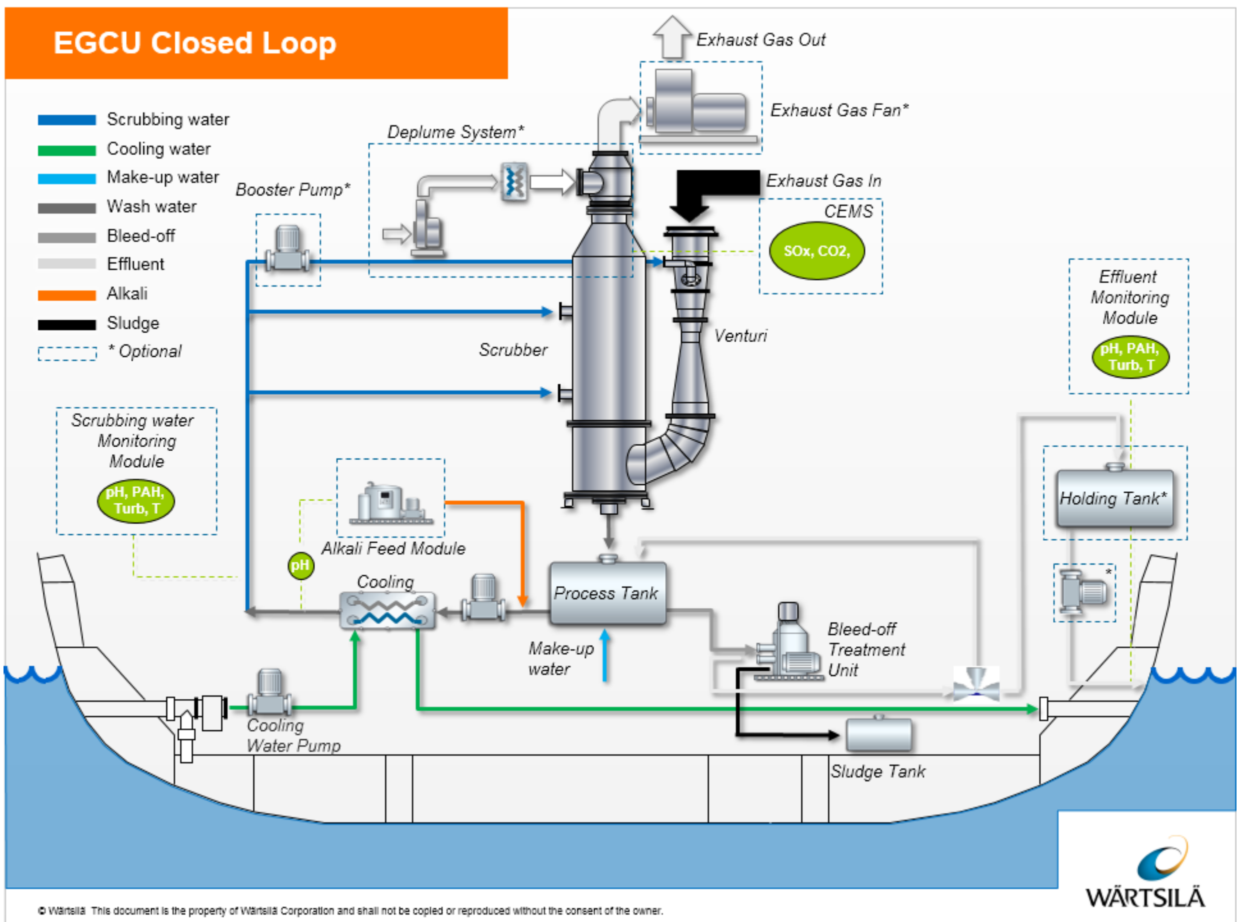


Figure 1: - Closed Loop system with EGCU Scrubber unit

A Closed Loop Srubber is designed for continuous operation at full specified gas flow. Main stream scrubbers are typically dimensioned for 100% engine load.

Typically the system is specified for following operation:

- Any fuel Sulphur content up to 3.50% with EGCU Scrubber unit. 2.50% with Inline Scrubber unit.

- Any load not exceeding the design load.
- Exhaust gas cleaned to a level where exhaust gas SO_X-emission is not exceeding an equivalent of fuel Sulphur content of 0.10%.
- Temporary operation without sea water cooling. In such case the water consumption and the exhaust gas back pressure are higher, and the exhaust gas plume is more visible. The water content in the exhaust gas is higher, and the risk of condensation and droplets is higher if the exhaust pipe after the scrubber is not insulated. Operation at full load should be avoided without cooling water.

The following operation modes are not permitted:

- Using fuel with Sulphur content exceeding 3.50% (2.50% with Inline Scrubber unit).
- Exceeding the design load.
- Dry running of scrubber (hot exhaust gases are not allowed to enter scrubber when the scrubbing water is not circulated). However, the scrubber can be bypassed by closing the exhaust branches to scrubber. In such cases compliance with the regulations is to be achieved by using fuel with appropriate Sulphur content.
- Wet running of scrubber with alkali injection out of operation.

4.2 Open Loop System (OL)

The system is sea water based, operating in open loop designed to use the natural buffering capacity of sea water for the removal of SOx.

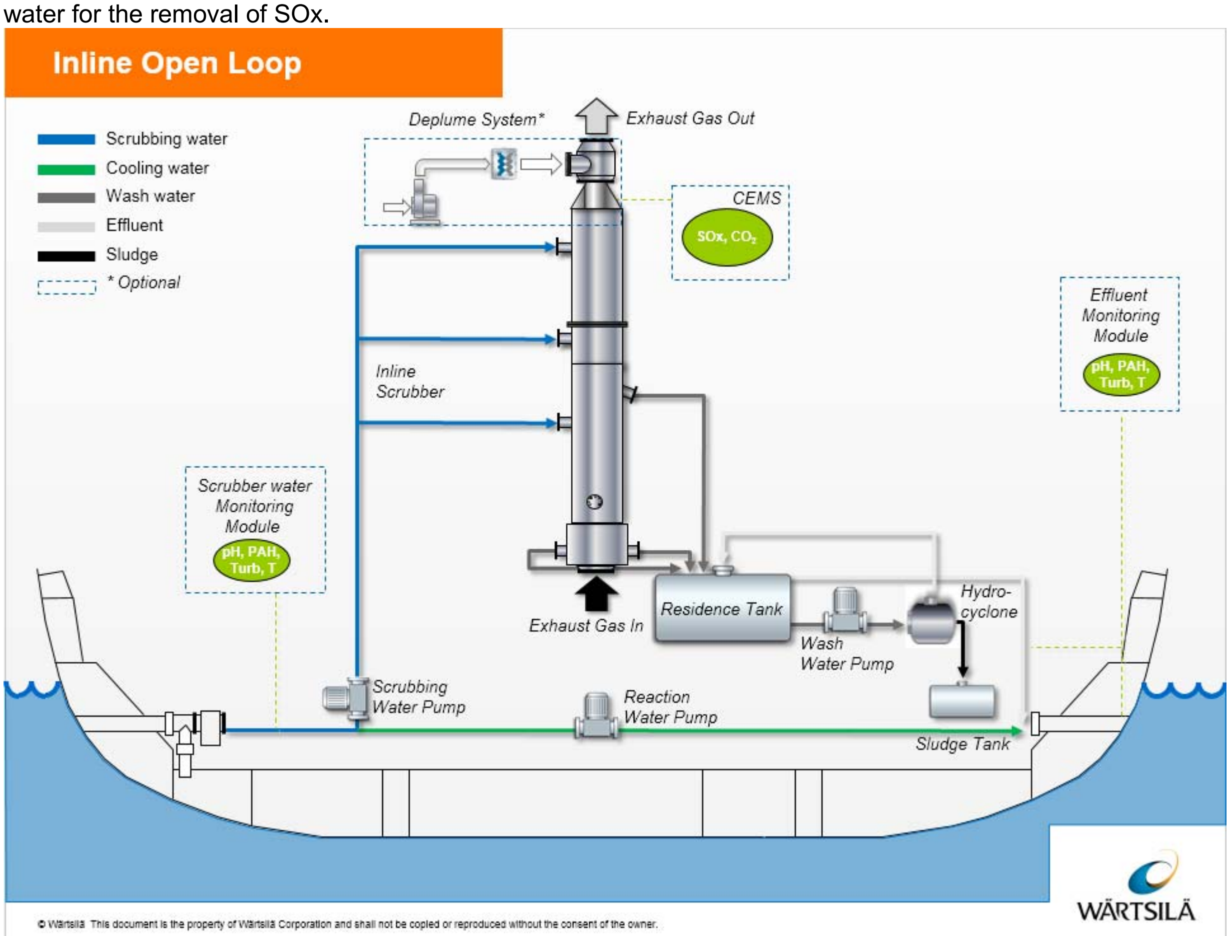


Figure 2: - Open Loop system with Inline Scrubber unit

The scrubber can be sited in either the engine casing or funnel, depending upon the space available or specific requirements of the client downstream of other components such as silencers and/or economizers in the exhaust gas system. Exhaust gas inlets for the EGCU Scrubber are arranged via a venturi or a series of venturi's sited at the side of the scrubber, generally in the vertical plane but other positions can be considered during planning of the system specification and layout. The Inline Scrubber is introduced with exhaust gas vertically from the bottom without a venturi. In multi inlet systems, the system is typically provided with an exhaust gas fan while in the single inlet system, the necessity of an exhaust fan is more depending on the combustion unit and the resulting back pressure of the complete exhaust piping.

The scrubbers are designed for continuous operation at the full specified exhaust gas flow. All scrubbers are typically dimensioned for 100% of the exhaust gas capacity of the connected machinery. Where this exceeds the current design parameters for scrubbers; multiple scrubbers would be specified to share the required gas capacity.

Typical design specification is for the following operation:

- Any fuel Sulphur content of up to 3.50%. 2.50% with Inline Scrubber unit.
- Any machinery load up to design maximum load.
- Exhaust gas cleaned to a level where exhaust gas SOx-emission is not exceeding an equivalent of fuel Sulphur content 0.10%
- Continuous operation.
- Operation in by-pass mode.

The following operating modes are not permitted:

- Consumption of fuel with Sulphur level exceeding 3.50% (2.50% with Inline Scrubber unit), without prior agreement with Wärtsilä.
- Exceeding maximum design load of the connected machinery, or limits stated in the Exhaust Gas Declaration.
- Prolonged dry running of the scrubber.

4.3 Hybrid systems (HS)

Wärtsilä Hybrid scrubbers are a combination of open loop and closed loop sea water scrubbers. Both methods, open loop and closed loop, are operated using only sea water as scrubbing water. During closed loop operation, caustic soda (sodium hydroxide, NaOH) is added to the scrubbing circulation water. In both operation modes, the scrubbing water is released back to the sea after it has been processed in water treatment plants. However, in closed loop operation, the scrubbing water is recycled several times within the system and the amount of wash water produced and sea water consumed is thus minimized. Due to the minimized effluent flow of closed loop operation, a “zero discharge mode”, where no discharge to sea exists, is possible by directing the effluent flow in to a holding tank.

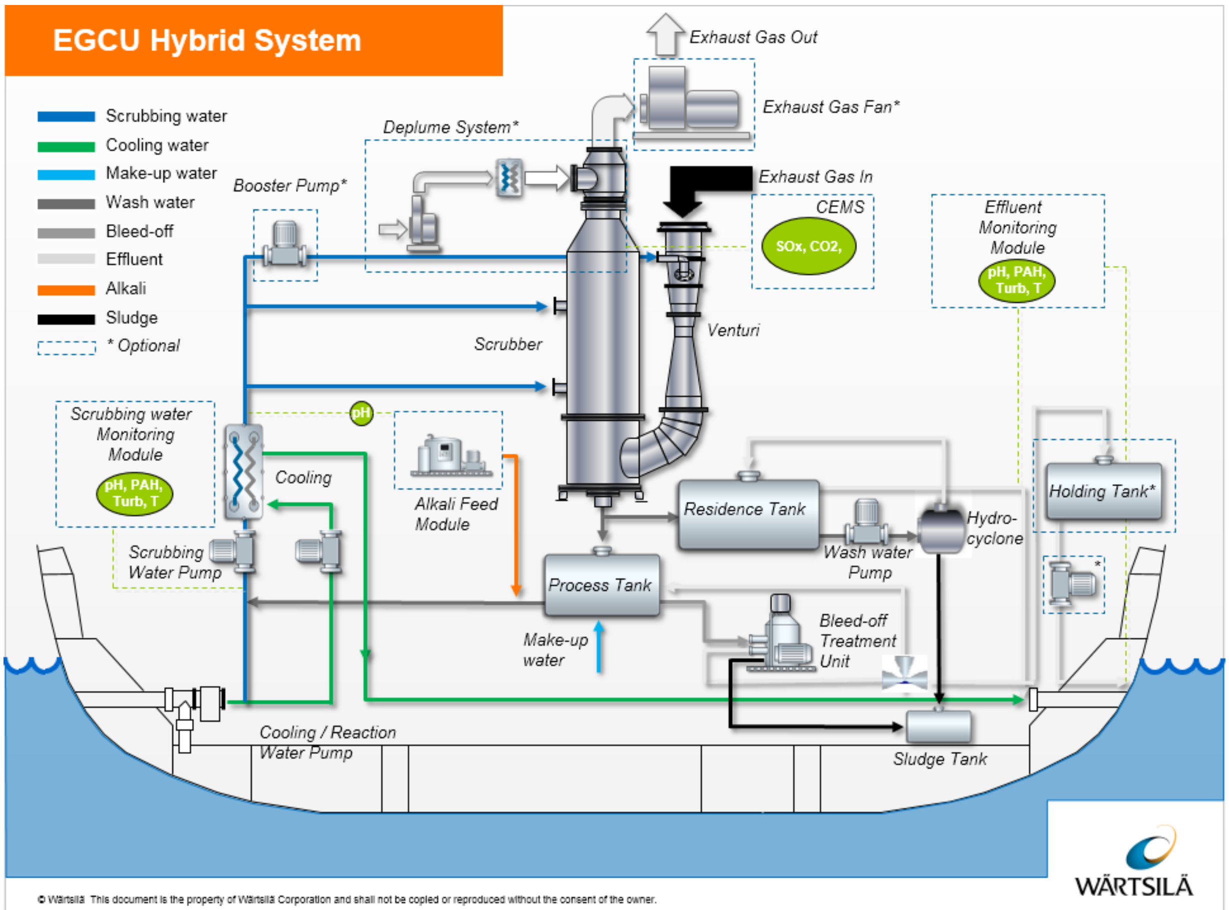


Figure 3: - Hybrid system (HS) with a EGCU Scrubber unit

As the same scrubbing water pumps, piping and nozzles are being used in both operation modes, Open Loop mode and Closed Loop mode cannot be used simultaneously.

In most applications it is possible to shut off one spray nozzle layer during closed loop operation in order to save electric power used for pumping. The feasibility of this operation with less scrubbing water is dependent on the actual scrubbing water pump configuration.

5 Scrubber units and piping systems

5.1 Scrubber unit

Wärtsilä offers two kinds of scrubber units to its customers: The EGCU Scrubber and the Inline Scrubber.

Figure 4: - EGCU Scrubber with single inlet (left) and Inline Scrubber (right)

5.1.1 Scrubber unit dimensioning

The scrubber unit dimensions mainly depend on the exhaust gas mass flow and the necessity to limit the gas velocity within the scrubber to 3 to 3.5m/s (this encourages water to drop out of the scrubbed gas flow), as higher velocities will cause water to be carried away with the gas flow where it exits the funnel top and higher pressure drop. Typically the scrubber unit is in 2 or more pieces depending on the number of venturis. The bottom part of the scrubber is attached to the main scrubber body with a flange connection. When the scrubber is installed into the ship the bottom part can be disconnected from the main scrubber body if this is needed due to space or lifting requirements. Especially in retrofit installations this feature of the Wärtsilä scrubber can be a big benefit.

The cross-section of the scrubber unit main body is round, which provides a rigid structure. The scrubber unit is equipped with mounting brackets/feet in the bottom part. The unit has also mounting brackets for lateral supports in the top cone.
The venturi exhaust gas inlet(s) to the EGCU unit can be installed longitudinally, transversally or in any arbitrary direction in the ship. Both scrubber units and the ancillary components are designed to operate in maximum static and dynamic inclinations set by classification societies.
The scrubber unit weight is affected by both size (scantlings) and material choice. As a standard concept the scrubber unit is manufactured in high grade alloy steel to resist corrosion, and should be suitable for the life of the ship.

The scrubber unit can be selected according to the following criteria:

1. Scrubber dimensioning criteria include gas flow, gas inlet temperature, permitted pressure drop, and some other parameters such as water capacity. The indicated scrubber capacity (MW) is only indicative as the final scrubber selection needs to be based on the actual maximum gas flow that is to be fed into the scrubber. Additional project specific conditions may apply, and have to be considered on a case-by-case basis, such as oversized units e.g. for reduced pressure drop or exceptionally high temperatures.

2. Engine exhaust gas temperature in the engine maker’s documentation is typically given in ISO 3046 conditions at different loads. Typically the highest temperature is at 100% load. From this figure the expected temperature drop over the exhaust gas boiler may be deducted, and a project specific

allowance (maybe 30…100°C) added for variations in ambient, engine and exhaust gas boiler conditions.

3. For rough orientation, typical specific exhaust gas flow at full power of 2-stroke engines is 7.5…9.5 kg/kWh and 4-stroke engines 6.0…8.5 kg/kWh.
4. The standard scrubber dimensioning is based on diesel engine exhaust gas flow in ISO 3046 conditions and nominal scrubber pressure drop of 1500 Pa (150mmWG).

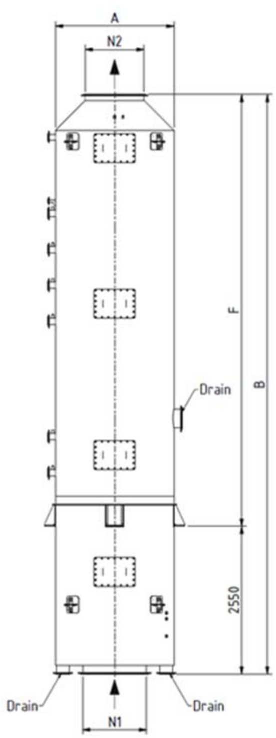
This data is indicative, and subject to diesel engine specific exhaust gas data, pressure drop limitations, maximum fuel Sulphur content of 3.50%, and cooling system specification (Closed Loop and Hybrid systems only).

The design fuel consumption for EGC System dimensioning is 200 kg/MWh or 6000 Nm3/MWh.

5.1.2 Dimension tables

Inline scrubber

Dim.	Description	12,6 kg/s	15,5kg/s	18,6kg/s	22,1kg/s	25,9kg/s	29,9kg/s	34,3kg/s	38,9kg/s
	MW	5,9	7,2	8,7	10,3	12	13,9	15,9	18,1
A	Vessel diameter	1850	2050	2250	2450	2650	2850	3050	3250
B	Total height	10000	10000	10500	11000	11500	11500	12000	12500
C	Overall length	2240	2440	2660	2900	3120	3380	3600	3850
D	Overall width	2240	2440	2660	2900	3120	3380	3600	3850
F	Overall height	7450	7450	7950	8450	8950	8950	9450	9450
N1	Inlet nominal bore	900	1000	1100	1200	1300	1400	1500	1500
N2	Outlet nominal bore	800	900	1000	1100	1200	1300	1400	1400
	Total dry weight	4200	4600	5000	5800	7500	8000	8600	10000



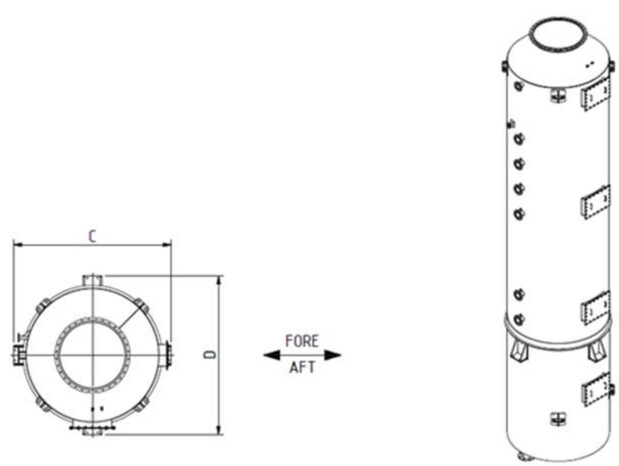


Figure 5: - Inline Scrubber dimensions

EGCU Scrubber

Single-entry Scrubber

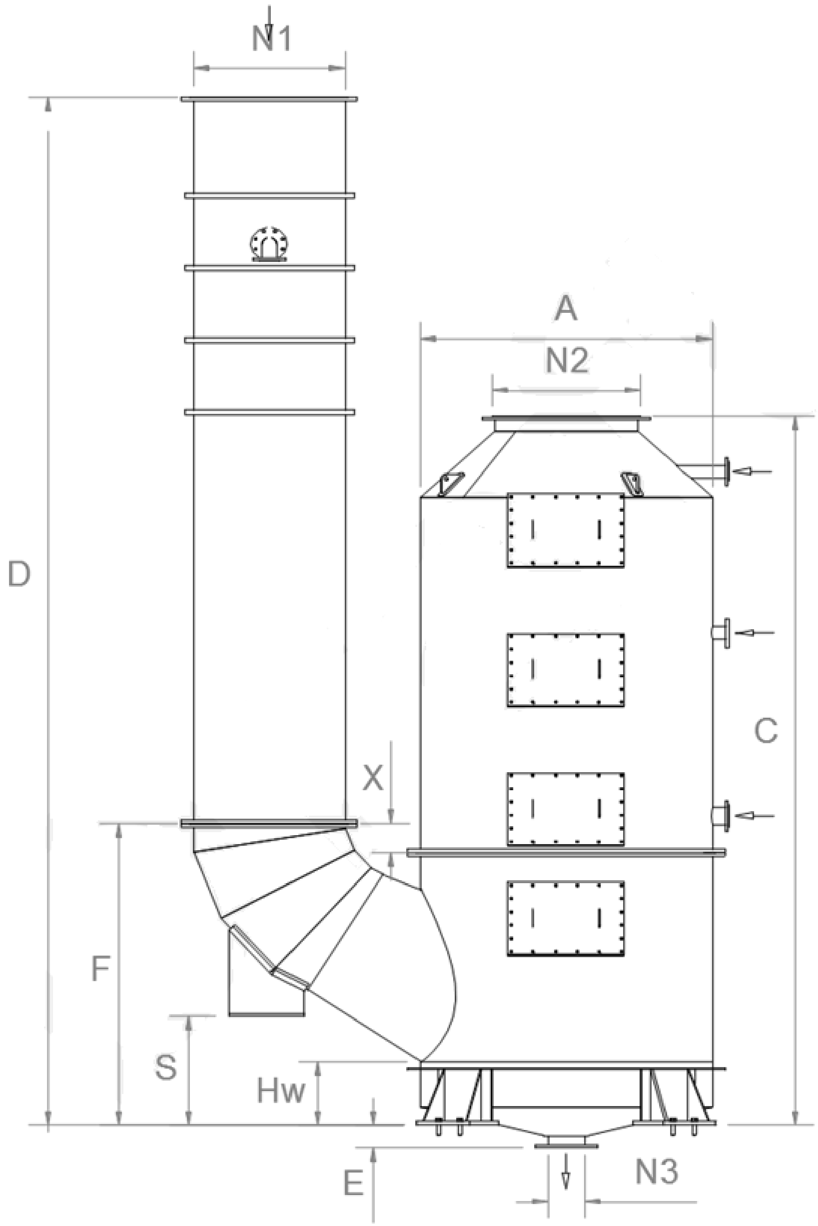


Figure 6: - Single entry EGCU scrubber

Table 2 EGCU unit dimensions, 1 inlet

Dim.	Description	1 MW	2 MW	4 MW	6 MW	8 MW	11 MW	15 MW
	Exhaust Gas Mass Flow kg/s	2.15	4.30	8.60	12.90	17.20	23.65	32.25
A	Vessel Diameter (mm)	850	1350	1750	2000	2500	2900	3500
B	Overall Length (mm)	1730	2240	3295	3850	4660	5360	6250
B1	Overall width (mm)	1250	1580	1980	2240	2740	3140	3660
C	Outlet height (mm)	4020	4460	4835	5810	6150	6935	8205
D	Inlet height (mm)	4670	5200	7015	8495	9635	10665	12130
E	Drain below base (mm)	40	120	150	190	250	315	595
F	Scrubber inlet height (mm)	1480	1660	2050	2435	2985	3330	3680
X	Difference between bottom part and inlet (mm)	0	0	200	200	250	150	300
S	Distance between support (mm)	690	745	745	790	1015	1160	1260
N1	Inlet nominal bore (mm)	400	600	900	1100	1300	1500	1700
N2	Outlet nominal bore (mm)	400	600	850	1000	1100	1300	1600
N3	Drain nominal bore (mm)	150	200	273	400	400	450	500
	Dry weight (tonnes)	1.2	2.0	2.8	4.1	5.9	7.4	10.4
	Wet weight (tonnes)	1.5	2.7	3.7	5.4	8.6	11.5	16.9
Hw	Water level (mm)	600	500	435	420	550	580	610
	Water weight (tonnes)	0.30	0.7	1.0	1.3	2.8	4.1	6.5

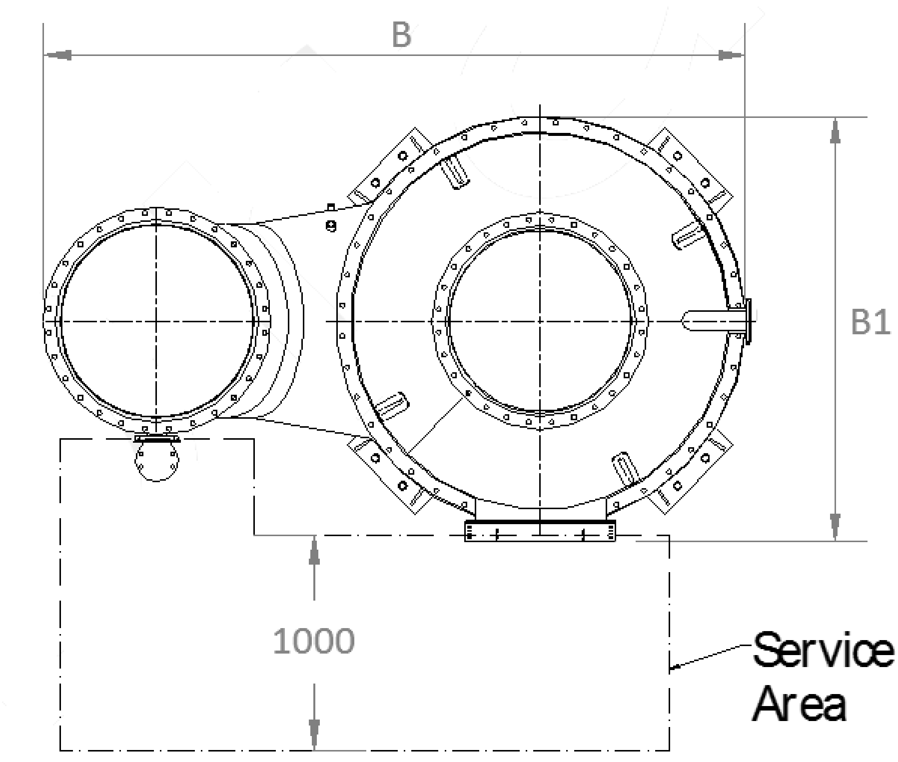


Figure 7: - Single entry EGCU scrubber

Double Entry Scrubber

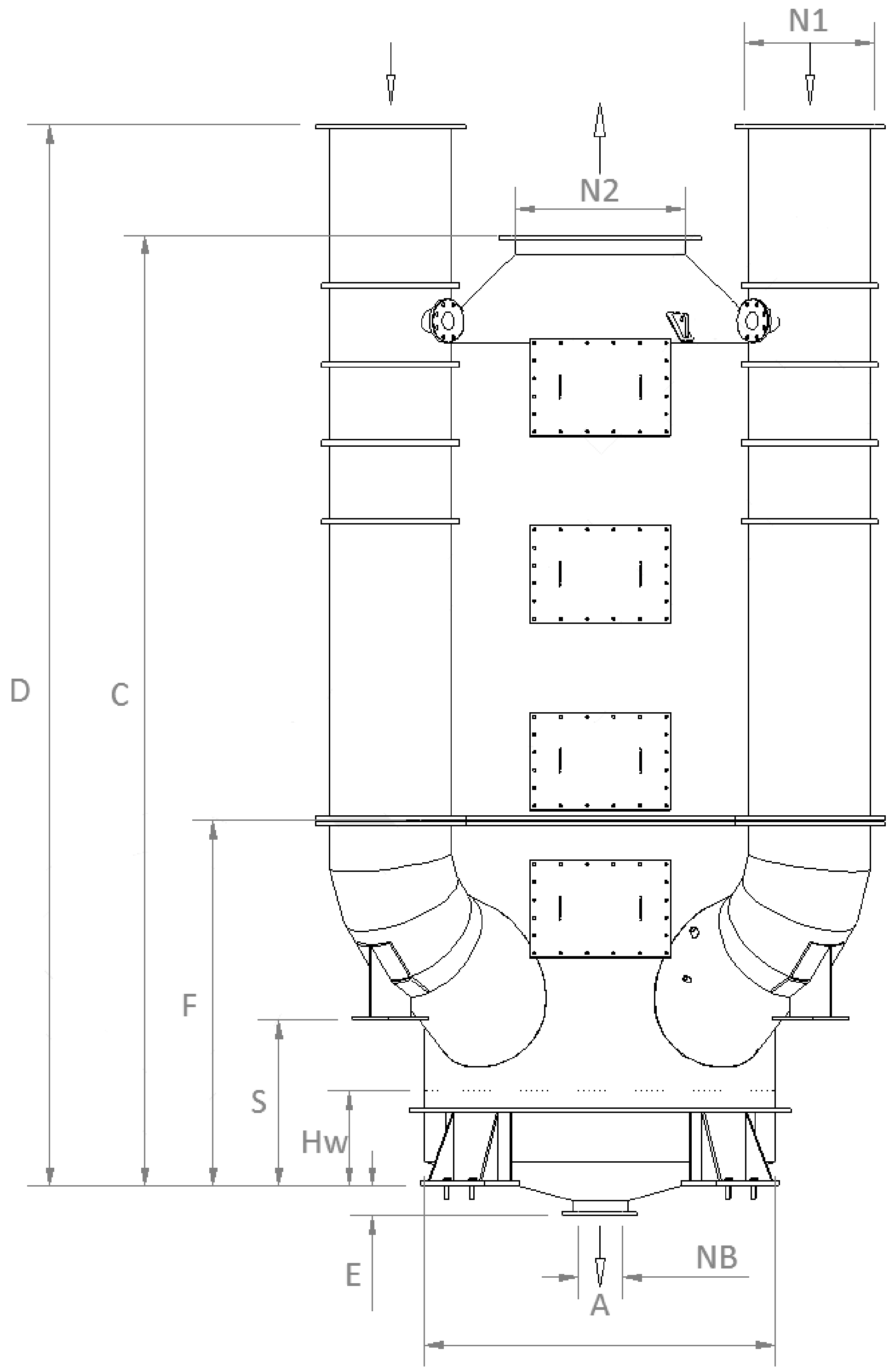


Figure 8: - Double Entry EGCU Scrubber

Table 3 EGCU unit dimensions for sizes 2-15MW, 2 inlets

Dim.	Description	2 MW	4 MW	6 MW	8 MW	11 MW	15 MW
	Exhaust Gas Mass Flow kg/s	4.30	8.60	12.90	17.20	23.65	32.25
A	Vessel Diameter (mm)	1350	1750	2000	2500	2900	3500
B	Overall Length (mm)	2065	2860	3390	4115	4895	5810
B1	Overall width (mm)	2070	2565	2900	3600	4085	4750
C	Outlet height (mm)	4460	4835	5810	6150	6935	8205
D	Inlet height (mm)	4850	5400	6785	7690	9240	10030
E	Drain below base (mm)	120	150	190	250	315	595
F	Scrubber inlet height (mm)	1660	1860	2235	2735	3180	3380
X	Difference between bottom part and inlet (mm)	0	0	0	0	0	0
S	Distance between support (mm)	770	845	1000	1420	1435	1415
N1	Inlet nominal bore (mm)	400	600	750	900	1100	1320
N2	Outlet nominal bore (mm)	600	850	1000	1100	1300	1600
N3	Drain nominal bore (mm)	200	273	400	400	450	500
	Dry weight (tonnes)	2.1	2.8	4.1	5.7	7.6	11.0
	Wet weight (tonnes)	2.7	3.8	5.4	8.5	11.7	17.5
Hw	Water level (mm)	500	435	420	550	580	610
	Water weight (tonnes)	0.7	1.0	1.3	2.8	4.1	6.5

Table 4 EGCU unit dimensions for sizes 20-70MW, 2 inlets

Dim.	Description	20MW	25MW	30MW	35MW	40MW	45MW	50MW	55MW	60MW	65MW	70MW
	Exhaust gas flow (kg/s)	43.0	53.75	64.5	75.25	86	96.75	107.5	118.25	129	139.75	150.5
A	Vessel diameter	4100	4500	5000	5400	5800	6200	6500	6800	7100	7400	7700
B	Overall length	6150	6850	7600	8350	8850	9400	9800	10350	10750	11100	11400
B1	Overall width	5800	6450	7150	7800	8300	8800	9200	9650	10050	10350	10650
C	Outlet height	8850	9200	9550	9900	10300	10650	11000	11350	11750	12100	12500
D	Inlet height	6400	6900	7400	7900	8350	8800	9200	9600	10000	10350	10700
E	Drain below base	950	1000	1050	1100	1150	1170	1200	1200	1250	1300	1300
F	Total height	9800	10200	10600	11000	11400	11800	12200	12600	13000	13400	13800
G	Angle between inlets	70	70	70	70	70	70	70	70	70	70	70
N1	Inlet nominal bore	1350	1500	1600	1750	1850	2000	2100	2200	2300	2400	2500
N2	Outlet nominal bore	1800	2000	2200	2400	2550	2700	2800	3000	3100	3200	3300
N3	Drain nominal bore	550	600	700	800	800	900	900	1000	1000	1000	1000

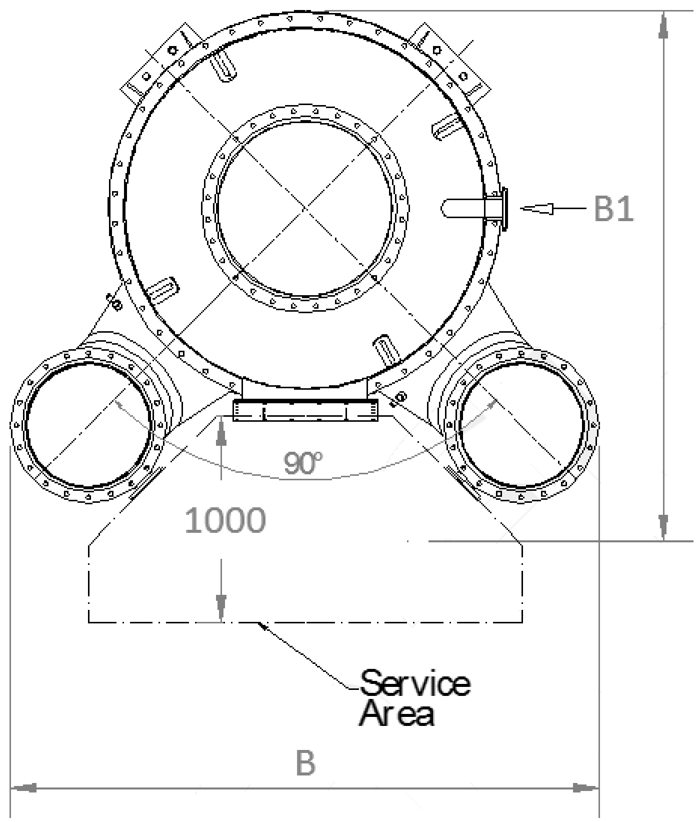


Figure 9: - Double Entry EGCU Scrubber

Triple Entry Scrubber

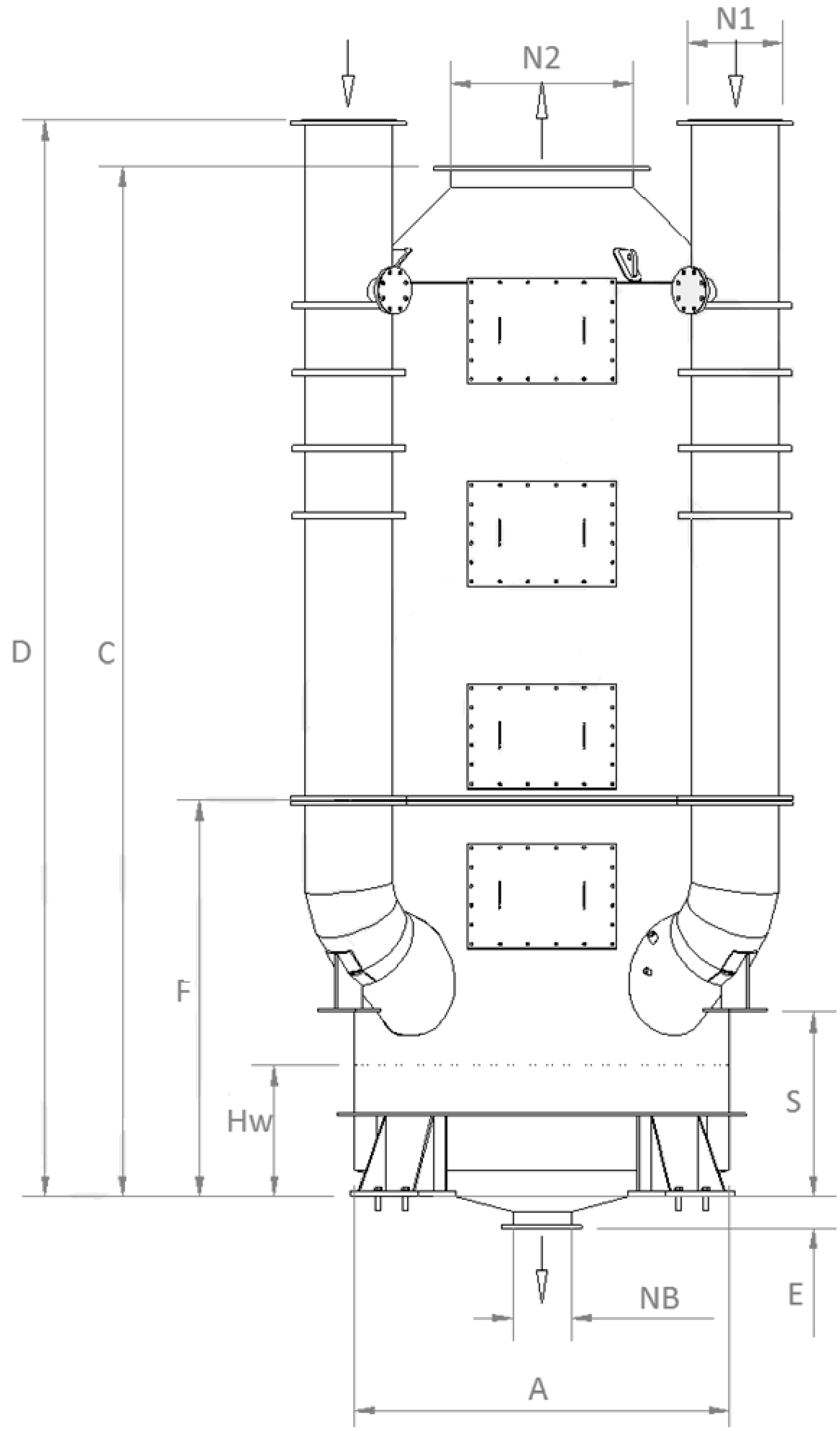


Figure 10: - Triple Entry EGCU Scrubber

Table 5. EGCU unit dimensions, 3 inlets

Dim.	Description	4 MW	6 MW	8 MW	11 MW	15 MW
	Exhaust Gas Mass Flow (kg/s)	8.60	12.90	17.20	23.65	32.25
A	Vessel Diameter (mm)	1750	2000	2500	2900	3500
B	Overall Length (mm)	3100	3975	4915	5780	6700
B1	Overall width (mm)	2600	3140	3860	4500	5250
C	Outlet height (mm)	4835	5810	6150	6935	8205
D	Inlet height (mm)	5050	5775	7285	8135	9080
E	Drain below base (mm)	150	190	250	315	595
F	Scrubber inlet height (mm)	1860	2235	2735	3180	3380
X	Difference between bottom part and inlet (mm)	0	0	0	0	0
S	Distance between support (mm)	865	1020	1500	1465	1445
N1	Inlet nominal bore (mm)	40	600	750	900	1000
N2	Outlet nominal bore (mm)	850	1000	1100	1300	1600
N3	Drain nominal bore (mm)	273	400	400	450	500
	Dry weight (tonnes)	2.8	4.3	6.0	7.6	11.0
	Wet weight (tonnes)	3.8	5.6	8.7	11.7	17.4
Hw	Water level (mm)	435	420	550	580	610
	Water weight (tonnes)	1.0	1.3	2.8	4.1	6.4

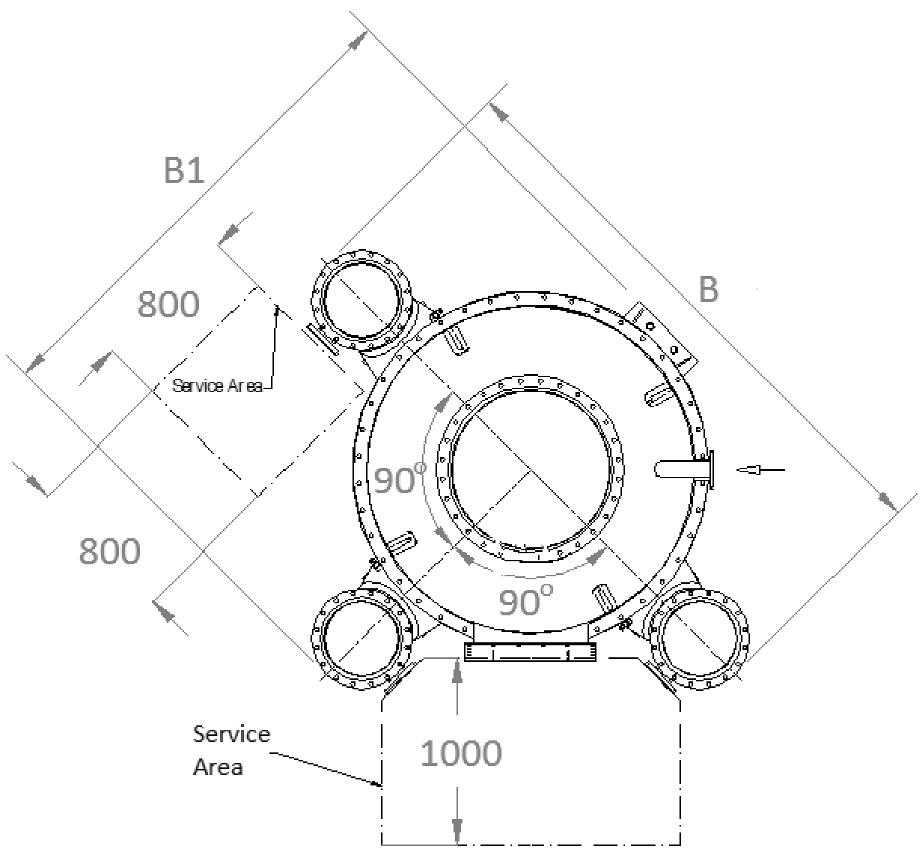


Figure 11: - Triple Entry EGCU Scrubber

Quadruple Entry Scrubber

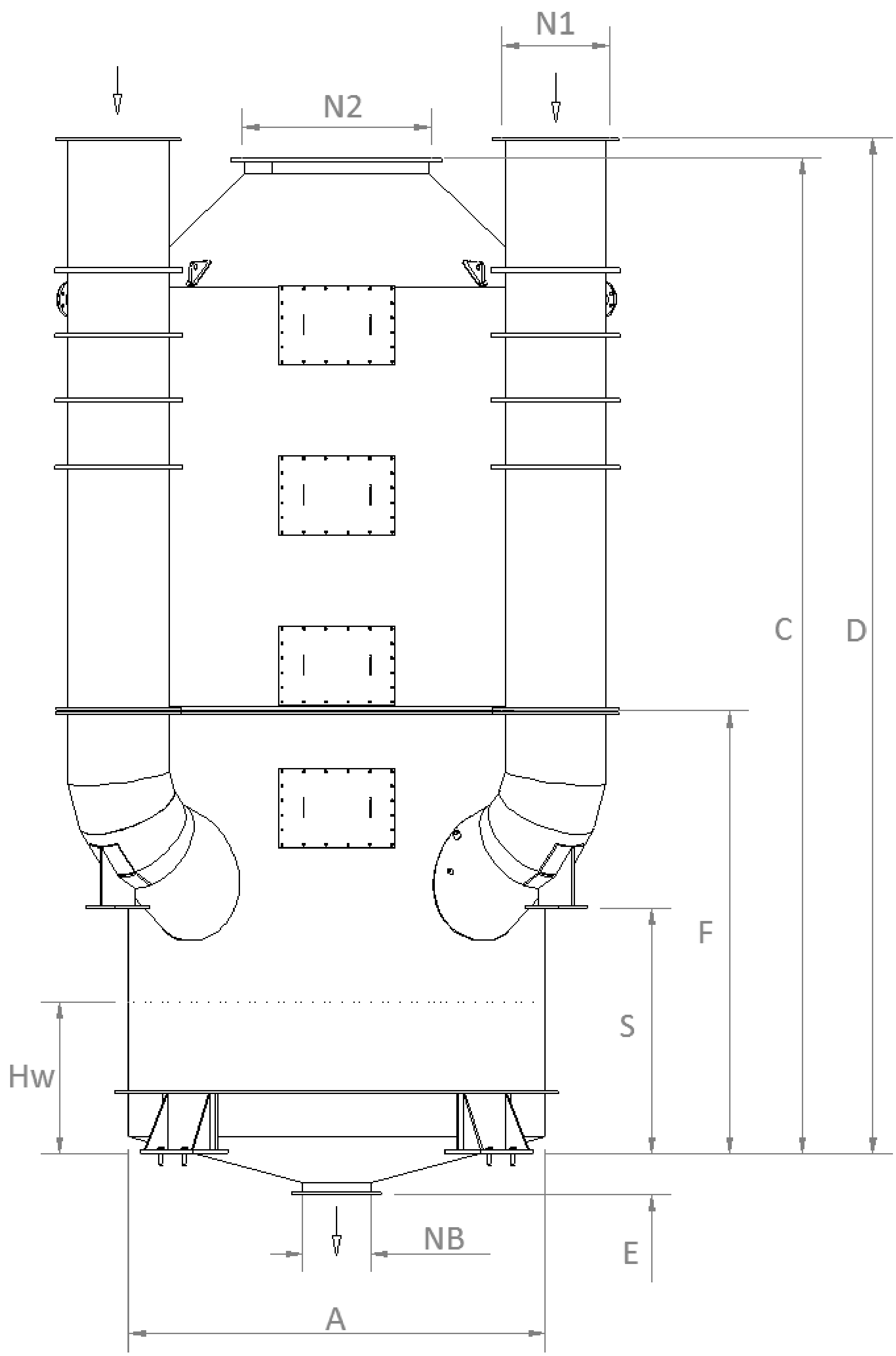


Figure 12: - Quadruple Entry EGCU Scrubber

Table 6 EGCU unit dimensions, 4 inlets

Dim.	Description	6 MW	8 MW	11 MW	15 MW
	Exhaust Gas Mass Flow kg/s	12.90	17.20	23.65	32.25
A	Vessel Diameter (mm)	2000	2500	2900	3500
B	Overall Length (mm)	2530	3750	4235	5010
B1	Overall width (mm)	2900	3385	4025	4810
C	Outlet height (mm)	5810	6150	6935	8205
D	Inlet height (mm)	5425	6275	7730	8335
E	Drain below base (mm)	190	250	315	595
F	Scrubber inlet height (mm)	2235	2735	3180	3380
X	Difference between bottom part and inlet (mm)	0	0	0	0
S	Distance between support (mm)	1040	1520	1545	1458
N1	Inlet nominal bore (mm)	400	600	750	910
N2	Outlet nominal bore (mm)	1000	1100	1300	1600
N3	Drain nominal bore (mm)	400	400	450	500
	Dry weight (tonnes)	4.1	5.9	7.7	10
	Wet weight (tonnes)	5.6	8.7	11.7	17.4
Hw	Water level (mm)	420	550	580	610
	Water weight (tonnes)	1.3	2.8	4.1	6.4

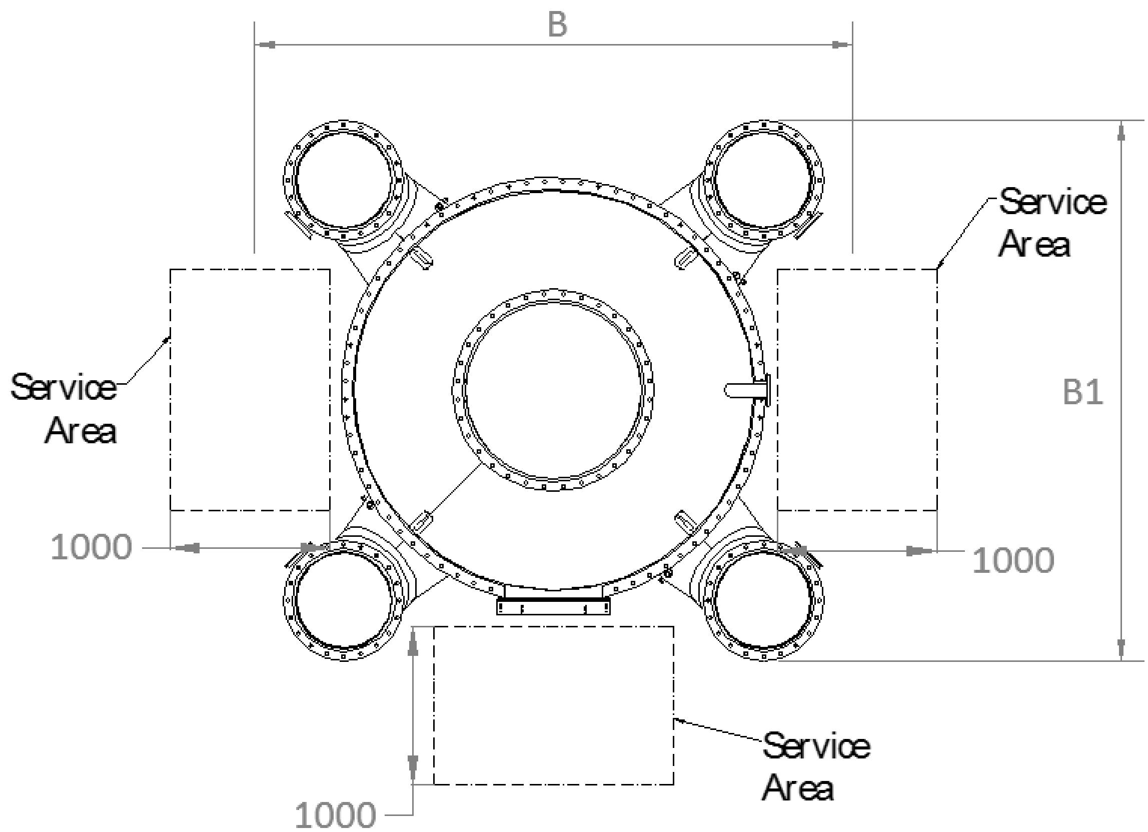


Figure 13: - Quadruple Entry EGCU Scrubber

5.2 Exhaust Gas System

5.2.1 General

Typically the exhaust gas cleaning unit is placed in the engine casing in the funnel downstream of the silencer. Exhaust gas is usually introduced to the system from fuel oil combustion equipment via a 3-way bypass damper. The 3-way damper is used to guide the gas flow either to the EGC unit or to the bypass.

All EGCU Scrubber unit inlets are equipped with venturis that are connected to the lower part of the scrubber body. Sea water is injected into the venturi through nozzles with the direction of the water spray being in line with the exhaust gas flow, pre-conditioning the exhaust gas (imparting a suction effect on the exhaust gas). Further scrubbing water is injected counter current to the exhaust gas flow in the main body of the scrubber at the wet filters to encourage intimate mixing of the exhaust gas and sea water. Cleaned and scrubbed exhaust gas exits the scrubber vertically through the top section. The scrubber should always be installed in the vertical position to ensure correct counter flow of sea water to exhaust gases.

5.2.2 Main stream system

A main stream scrubber serves one combustion unit only. Typically this is a single inlet system, but it can also be a multi inlet system in case of a very large combustion unit. In many cases the main stream EGC unit does not require an exhaust fan, but this should be verified based on back pressure limitations. It could be that with complex exhaust piping (or for oil fired boilers) a fan will be required.

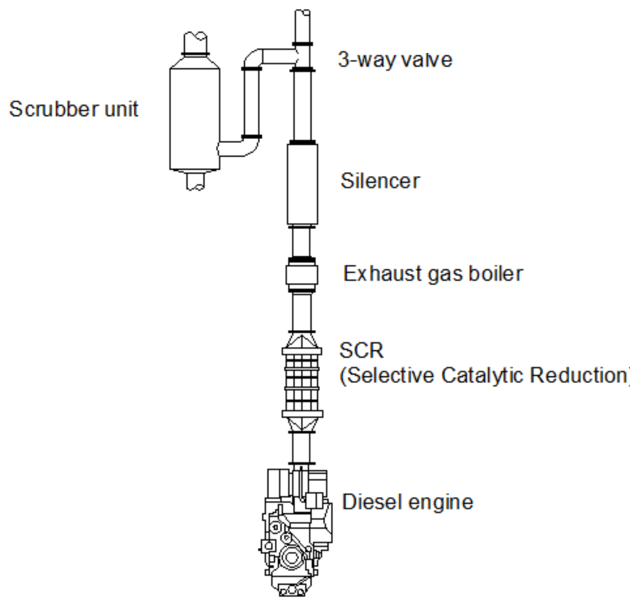


Figure 14: - Main Stream EGCU Scrubber

5.2.3 Integrated system

In an integrated system several combustion units are connected to one exhaust gas scrubber. The 3-way bypass dampers in suction branches enable the possibility to isolate combustion units from the system for example in cases where not all combustion units are operating. The correct exhaust gas flow direction is ensured with an exhaust fan which is also used to compensate the back pressure effect of the scrubber.

In many cases, one integrated scrubber per ship is the most practical and economical solution. However, a configuration consisting of two integrated scrubbers may be preferred for ships with two funnels located with a distance from each other. Integrated system typically consists of a multi inlet scrubber.

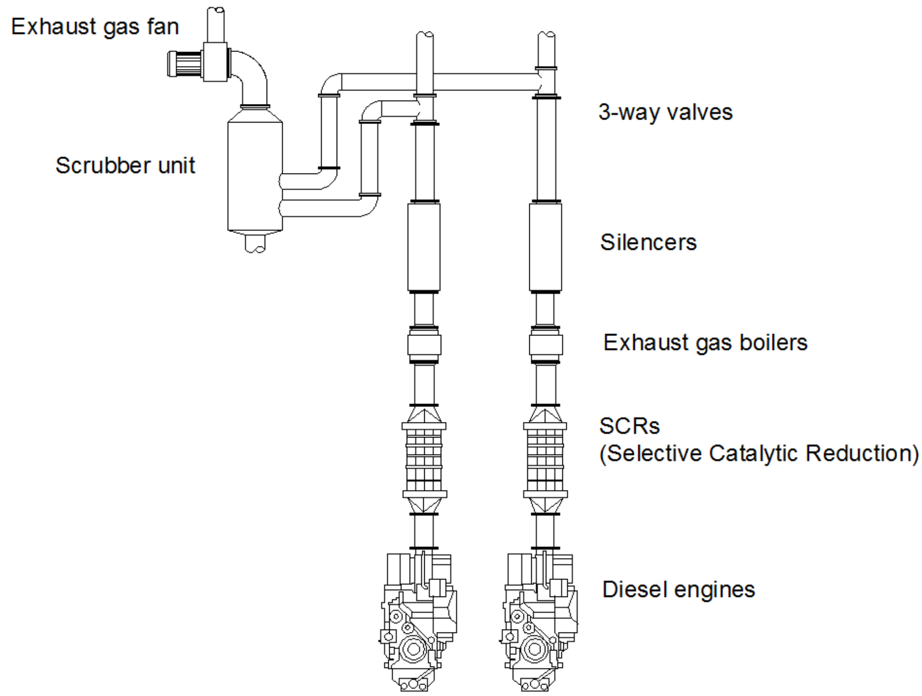


Figure 15: - Integrated EGCU Scrubber

5.2.4 Exhaust gas back pressure

The exhaust gas pressure loss over the exhaust gas scrubber at design conditions is typically 1500 Pa (at 100% MCR) for all scrubbers in the Wärtsilä portfolio. Depending on the diesel engine and exhaust pipe arrangement, such pressure loss is possible to accommodate within the permitted back pressure, but should be verified. In retrofit installations the exhaust gas system back pressure should be measured onboard (a separate guideline can be supplied by Wärtsilä).

5.2.5 Noise attenuation

The scrubber unit provides some noise attenuation. However, it is recommended to install the scrubber after normal exhaust gas silencers that would in any case be necessary for bypass operation.

5.2.6 Single inlet system

The single inlet scrubber has only one gas inlet so it very often is a main stream scrubber. It is however possible that there are two combustion units connected to one venturi making it an integrated system (and requiring the use of an exhaust fan in the system). Typically an exhaust fan is not needed for a single combustion unit.

5.2.7 Multi inlet system

In a multi-inlet scrubber, there are several venturis connected to the scrubber. Typically the multi inlet system is an integrated system (with several combustion units connected) requiring an exhaust fan, but it can also be arranged that for one large engine exhaust it is divided into two venturis (no other combustion unit connected) making it a mainstream scrubber.

The multi-inlet arrangement is a practical way of saving space for the EGC units.

5.2.8 Exhaust gas fan

The frequency controlled exhaust gas fan is used to compensate the EGC system back pressure and to prevent back flow to standing combustion units in integrated systems. Typically the fan is not required in main stream systems but this should be always verified to avoid too high back pressure for the combustion unit.

The fan speed is controlled based upon the pressure difference measurement over the by-pass flap in the damper or the pressure level at inlet side of the scrubber, depending on the bypass damper arrangement.

For each installation the most feasible fan configuration will be selected, taking into consideration reliability issues, redundancy, safety, space limitations, noise and simplicity.

The fan module, including the fan foundation with vibration isolators, electric drive motor, starter, bearings and the fan is typically designed for mounting adjacent to the top of the scrubber unit. The fan materials are selected according to the temperature and gas conditions after the scrubber.

Normal operating temperature for the fan is from 30°C to 60°C (maximum 100°C in case the system is provided with deplume system). Typically the exhaust gas is saturated (RH100%) when the deplume system is not in operation.

The exhaust gas flow in the dimension table represents the maximum total flow in ISO 3046 conditions. The nominal temperature for the exhaust gas is 40-45°C after the scrubber. The stated motor power is typical for the fan in a well-designed exhaust gas pipe layout. It is possible that bigger motor has to be used depending on the system layout.

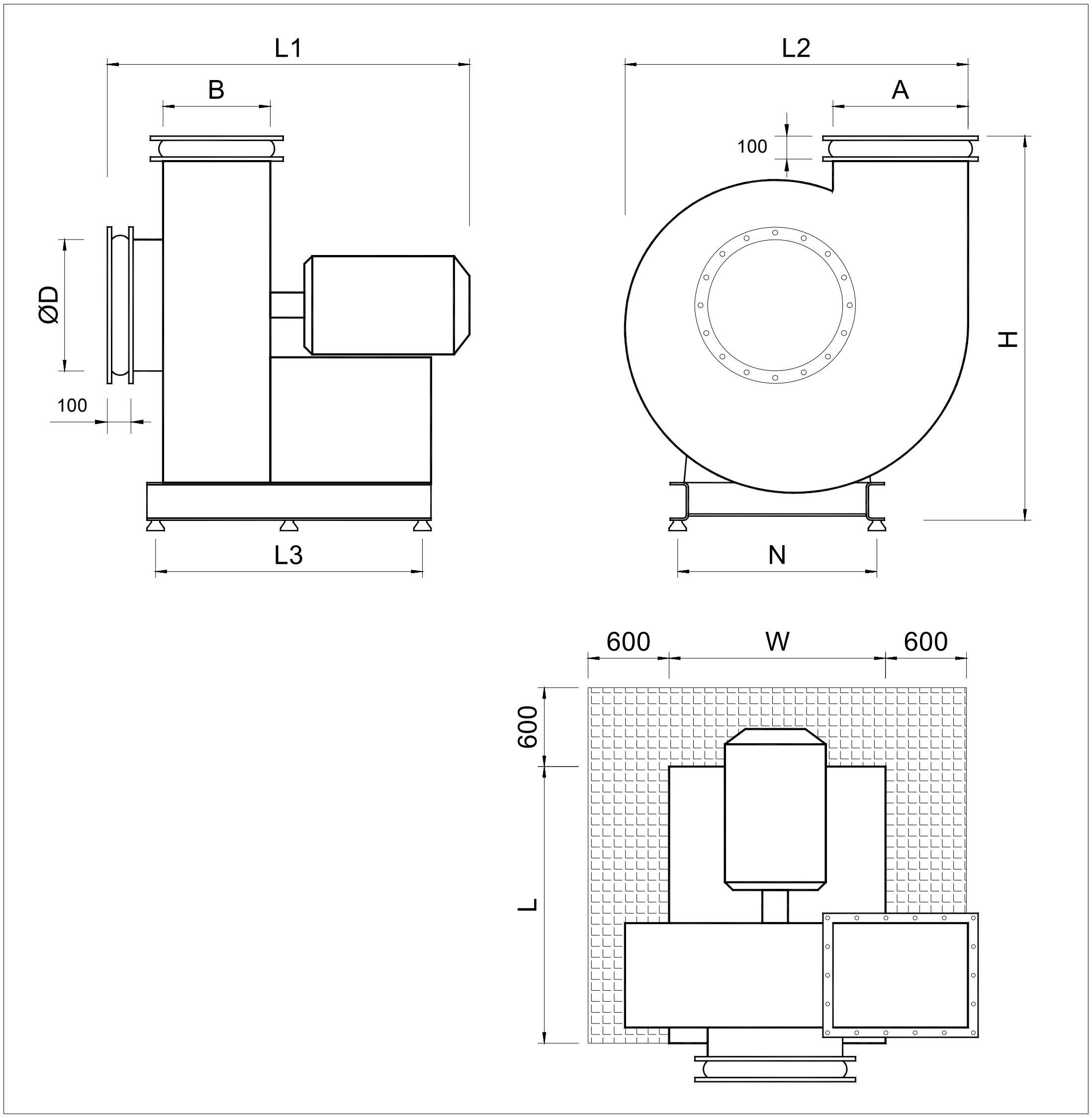


Figure 16: - Exhaust gas fan dimensional drawing

Table 7 Exhaust gas fan dimensions

Type	Capacity (kg/s)	Motor (kW)	A (mm)	B (mm)	H (mm)	N (mm)	ØD (mm)	L1 (mm)	L2 (mm)	L3 (mm)	L (mm)	W (mm)	Weight (kg)
EGF01	**5.9**	25.3	500	400	1468	740	500	1305	1272	1000	1060	800	640
EGF02	**7.4**	34.5	560	450	1633	850	560	1355	1422	1100	1160	910	750
EGF03	**9.3**	42.5	630	500	1830	930	630	1405	1600	1150	1170	1000	970
EGF04	**11.5**	36	710	560	1978	1050	710	1522	1798	1300	1270	1120	1160
EGF05	**15.8**	54	800	630	2220	1170	800	1675	2000	1350	1480	1250	1750
EGF06	**19.3**	90	900	710	2410	1320	900	1825	2240	1450	1580	1400	2250
EGF07	**23.5**	108	1000	800	2639	1520	1000	2182	2506	1750	1780	1600	2850
EGF08	**28.5**	132	1120	900	2922	1720	1120	2282	2808	1850	2080	1800	3450
EGF09	**37.8**	192	1250	1000	2639	1520	1250	2525	2506	2000	2280	1800	3550
EGF10	**45.2**	240	1400	1120	2922	1720	1400	2731	2808	2120	2480	1800	3900
EGF11	**52.1**	240	1500	1120	3300	1720	1500	2731	3200	2120	2680	1800	4700
EGF12	**64.1**	250	1600	1250	3300	1720	1600	4325	3200	4050	4130	1800	7800
EGF13	**76.1**	315	1800	1400	3615	1920	1800	4615	3590	4200	4280	2000	8400
EGF14	**97.2**	450	2000	1600	3970	2120	2000	5190	4000	4950	5030	2200	10500

The system can be equipped with parallel installation of two fans in cases when the gas flow is too large for one fan or when higher system redundancy is desired. When double fan configuration is selected, the system can be specified with a possibility to operate also with only one fan. This kind of system can typically achieve 60…65% of the maximum gas flow with only one fan running as indicated in the fan curve.

To enable one fan running mode in two fan configuration, the fans have to be provided with shut-off dampers to prevent the fresh air leakage through the fan that is not operating. The shut-off dampers should be installed at the fan inlet to enable the possibility for fan maintenance while continuing the operation with the other fan.

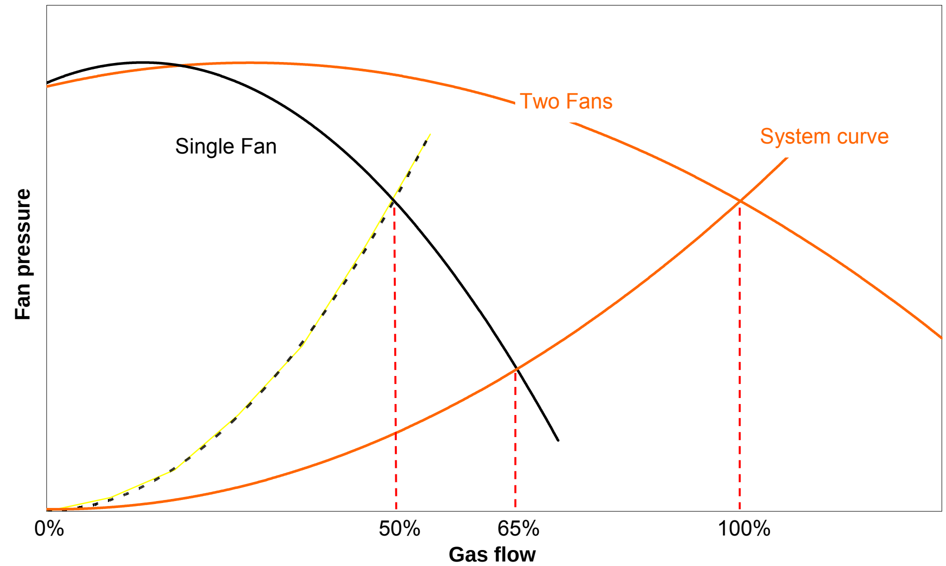


Figure 17: - Example of exhaust gas fan pressure in double fan configuration

5.2.9 Bypass damper

A Bypass damper is fitted in between the connected diesel engine(s) and the Scrubber to enable bypassing the scrubber unit.

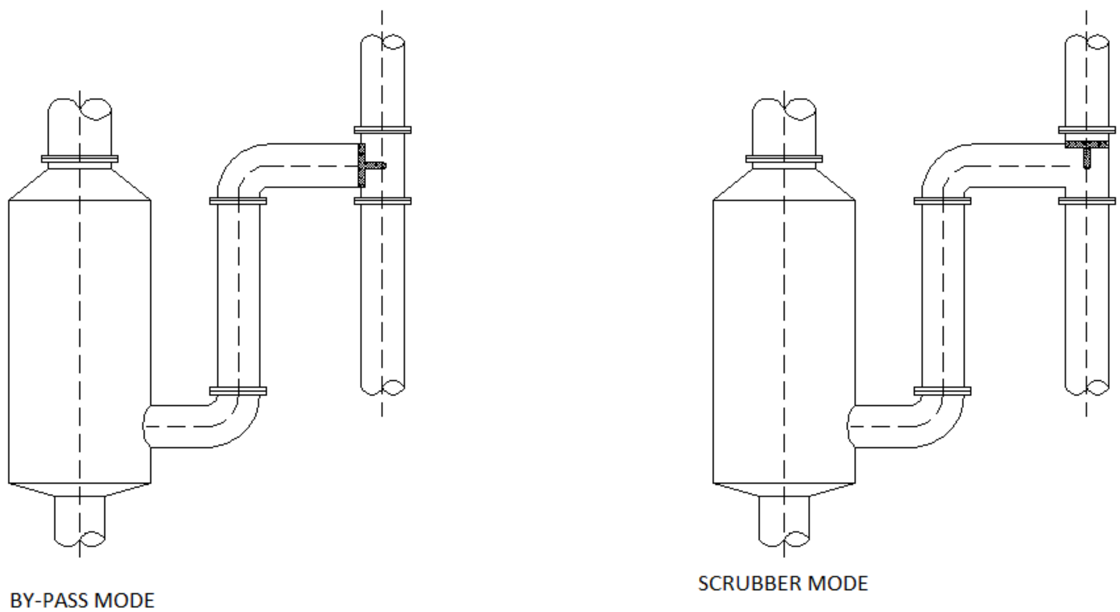


Figure 18: - Exhaust gas cleaning unit in normal mode (right) and bypass mode (left)

5.2.10 Bypass damper design

Each exhaust gas pipe is equipped with a 3-way bypass damper enabling the exhaust gas to be led directly to atmosphere in case the scrubber is not in use.

Bypass dampers are available in two different outlet angles to scrubber, 60° and 90°. The dimensional drawing for each pipe size can be obtained in the figures in this chapter.

The bypass dampers have flaps and shaft inside the exhaust pipe and for this reason it generates some back pressure to the system. It is recommended that when selecting damper size the velocity in the damper inlet is kept below 30 m/s, preferably closer to 25 m/s.

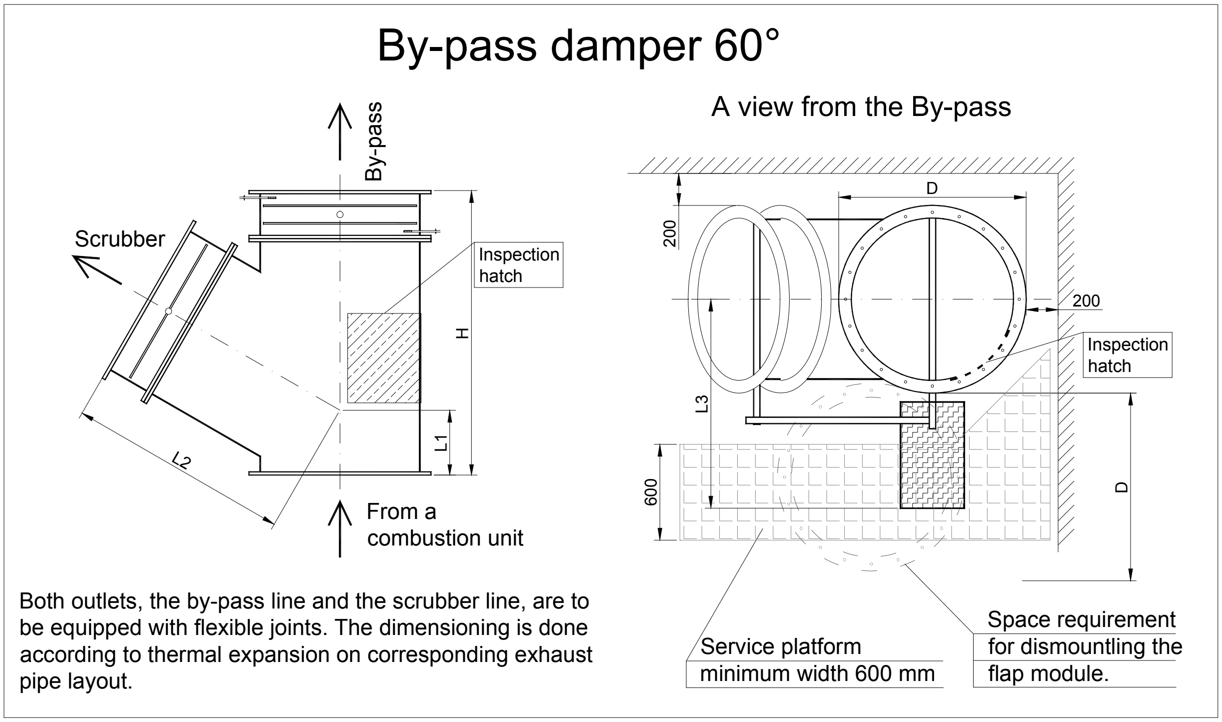


Figure 19: - Bypass damper with 60° angle to scrubber

Table 8 - 60° bypass damper dimensions

Pipe size	dØ (mm)	DØ (mm)	H (mm)	L1 (mm)	L2 (mm)	L3 (mm)	Weight (kg)
DN300	324	440	940	180	650	840	196
DN350	356	490	1000	190	700	865	238
DN400	406	540	1060	200	750	890	270
DN450	457	595	1120	220	810	928	332
DN500	508	645	1180	235	860	953	371
DN550	559	703	1240	250	910	992	457
DN600	610	755	1300	260	970	1018	517
DN700	711	860	1420	295	1070	1090	630
DN800	813	975	1540	330	1180	1148	759
DN900	914	1075	1660	370	1290	1198	910
DN1000	1016	1175	1780	405	1390	1413	1031
DN1100	1120	1305	1900	425	1500	1478	1161
DN1200	1220	1375	2020	445	1610	1513	1309
DN1300	1320	1466	2140	480	1720	1558	1445
DN1400	1420	1575	2260	510	1830	1613	1707
DN1500	1520	1666	2380	535	1930	1658	1861
DN1600	1620	1790	2500	560	2040	1720	2118
DN1700	1720	1866	2620	600	2150	1798	2295
DN1800	1820	1966	2740	630	2250	1848	2518

The flap modules are dismountable for service and this should be taken into account in the layout design. For cleaning and inspection of the flaps there is a hatch in the damper shell. Additionally inspection hatches are needed in the exhaust pipe close to the flaps.

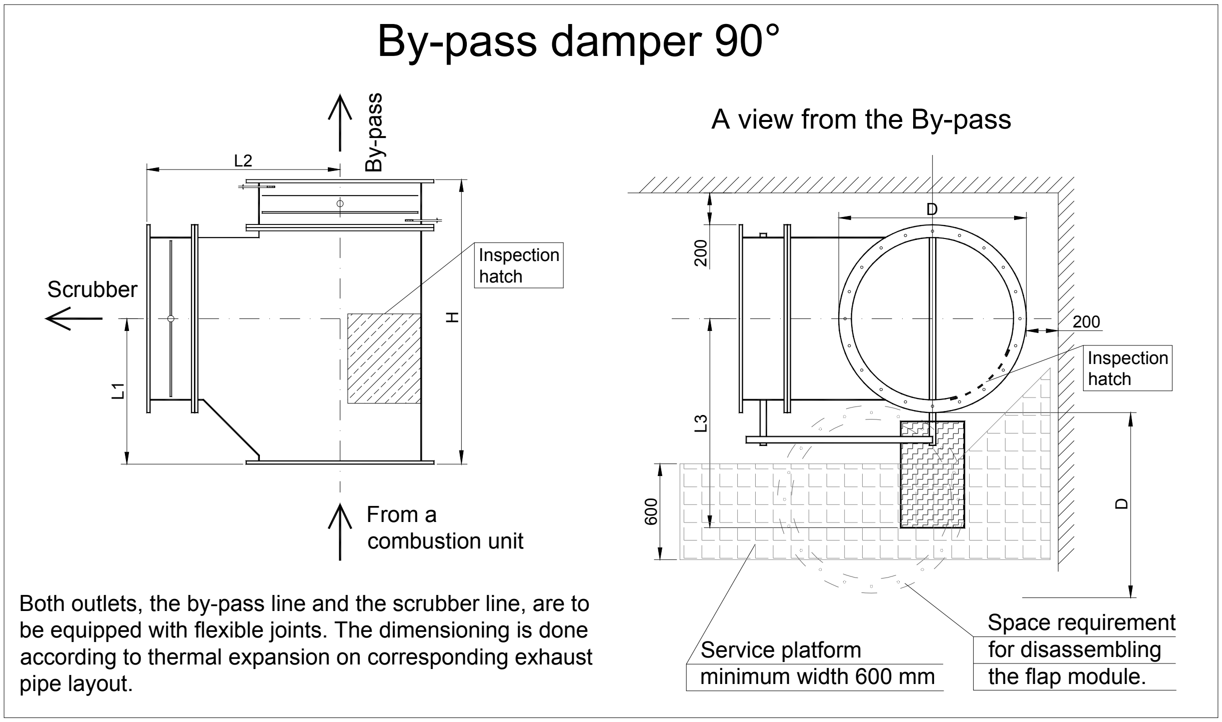


Figure 20: - Bypass damper with 90° angle to scrubber

Table 9: - 90° bypass damper dimensions

Pipe size	dØ (mm)	DØ (mm)	H (mm)	L1 (mm)	L2 (mm)	L3 (mm)	Weight (kg)
DN300	324	440	780	360	520	840	193
DN350	356	490	810	380	550	865	232
DN400	406	540	900	435	620	890	266
DN450	457	595	970	485	660	928	326
DN500	508	645	1020	510	710	953	361
DN550	559	703	1120	590	760	992	448
DN600	610	755	1160	630	810	1018	506
DN700	711	860	1370	670	940	1090	670
DN800	813	975	1490	710	1010	1148	790
DN900	914	1075	1660	840	1080	1198	914
DN1000	1016	1175	1830	960	1200	1413	1046
DN1100	1120	1305	1990	1060	1300	1478	1183
DN1200	1220	1375	2140	1160	1420	1513	1339
DN1300	1320	1466	2290	1260	1520	1558	1481
DN1400	1420	1575	2390	1310	1570	1613	1728
DN1500	1520	1666	2520	1390	1640	1658	1884
DN1600	1620	1790	2650	1470	1720	1720	2138
DN1700	1720	1866	2780	1550	1800	1798	2305
DN1800	1820	1966	2920	1630	1940	1848	2549

5.2.11 Bypass damper control and monitoring

The bypass dampers are automatically controlled by the automation system which will open the bypass if triggered by the safety functions.

The damper actuator is fail safe type so that in case of lost signal or pressure on the actuator the bypass line opens by a spring or similar positive means not requiring external energy.

The flap positions are detected by position switches. The flap position will enable/disable the pressure difference based exhaust gas fan control from the individual damper.

All inputs for the damper operation including the pressure measurement and the position switch signals are connected to the connection cabinet attached to the damper shell.

5.2.12 Bypass damper sealing air system

In order to secure the damper tightness, two different methods are available – sealing air system and pressure control system.

The sealing air system is based on the clean air supply in between two flaps. Both bypass line and scrubber line are equipped with double flaps that form the pressurized sealing air chambers. Typical needed air flows are listed in table below for different damper sizes. Total sealing air flow can be calculated with the info of installed dampers. It is beneficial to use warm sealing air; cold outdoor air is not allowed.

Table 10 - Sealing air flow

Sealing air flow for different damper sizes [kg/s]									
	DN500	DN630	DN700	DN800	DN900	DN1000	DN1200	DN1400	DN1600
No EG fan in system	0,32	0,41	0,45	0,52	0,59	0,65	0,78	0,91	1,04
System with EG fan	0,19	0,24	0,27	0,31	0,35	0,38	0,46	0,54	0,62

5.2.13 Bypass damper outdoor installation

The bypass damper should be installed inside casings. In case the bypass damper has to be located externally (which is not desirable), a special protective weather cover should be used. As the damper operation is essential for ship safety, the damper actuator and other equipment have to be properly covered against ice and snow. An example sketch of the cover is shown in figure below.

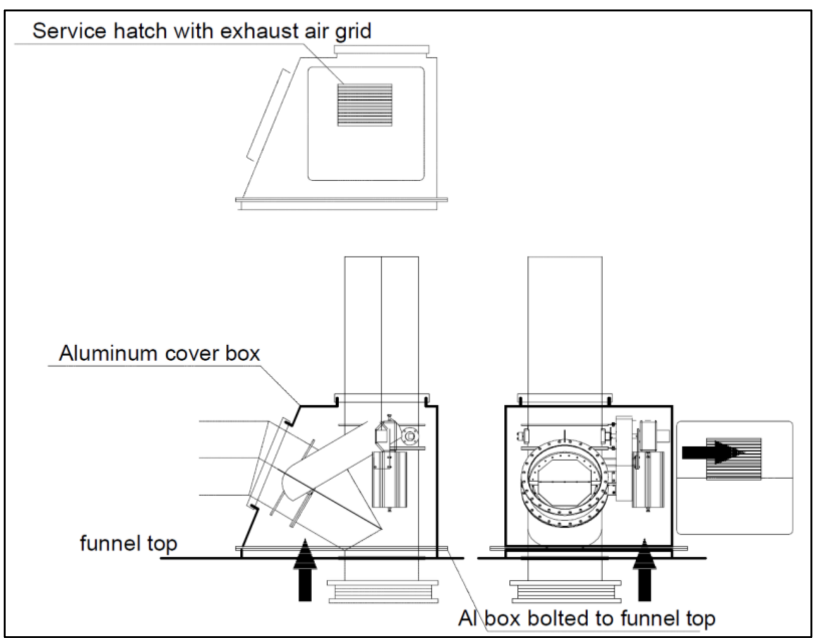


Figure 21: - Weather cover to be used in outdoor installations

5.2.14 Plume enclosure

If no dedicated deplume system is assembled in the system, the engine room ventilation exhaust air from the engine casing can be conducted to an open-ended jacket surrounding the exhaust gas outlet pipe in the funnel. Thus humid gas from the scrubber is mixed with dry air from the engine casing, reducing humidity and plume opacity. This is achieved by arranging the jacket as an enclosure with an upper end clearly above the end of the stack.

5.2.15 Exhaust gas pipes

All parts of the exhaust gas system before and after the scrubber are optimized concerning pressure losses to maintain acceptable exhaust gas back pressure at the engine outlet.

To avoid droplet entrainment with the gas flow, the flow velocity after the scrubber is kept low (not exceeding 15 m/s at full power), welding seams should be smooth and knuckles avoided.

Thermal insulation of the exhaust gas pipes after the scrubber can be omitted as the system is not designed for dry running of the scrubber. In case of Closed Loop scrubbers specified also for (temporary) operation without cooling, the exhaust gas after the scrubber can be warm and have high water content. In such cases thermal insulation can be considered to minimize the amount of condensation.

A catcher flute can be installed in the upper end of the exhaust pipe after the scrubber to prevent condensation exiting the stack.

Hot uninsulated exhaust pipes can be used in the funnel area as on any ship, under the following conditions:

1. In the funnel, being an open area.
2. Not in the engine casing (being Category - A Machinery Space).
3. Engine room ventilation exhaust air can be conducted through the area, provided that the engine casing can be isolated from the funnel with fire dampers.
4. Insulation for noise absorption purposes can be installed in the area.
5. Any possible common boundary of funnel with interior spaces fulfill A-0 fire insulation standard as a minimum.
6. Pressurized fuel oil and lubricating oil pipes are not installed in the same area.
7. Danger to persons onboard due to hot surfaces is minimized.

After the scrubber the exhaust gas has high relative humidity. Corrosion resistant materials should be used.

In integrated scrubber systems the exhaust gases are collected into one common manifold connected to the scrubber unit, with the same diameter as the scrubber unit's exhaust gas inlet connection. To compensate for pipe bends, the diameter of the manifold is slightly larger than diameters usually used in exhaust gas pipes. The diameter can be smaller in the beginning and increase towards the scrubber inlet as more pipes are connecting to the manifold.

The exhaust gas suction branches should be connected to the manifold in such a way that the exhaust gas flow from different pipes do not interfere with each other. Pipe joints should not be opposite to each other. To keep the flow resistance low the connections to the manifold should be smooth and directed towards to the scrubber inlet.

The size of the bypass damper and the suction branches can be as usually used in exhaust gas pipes, or slightly larger in case additional pipe bends are included.

5.2.16 Deplume system

When the exhaust gas meets scrubbing water inside a scrubber, it forms saturated steam, which is visible in open air. In order to avoid such phenomena, a deplume system can be installed to mix hot dry air into the exhaust gas stream after the scrubber. This reduces the relative humidity of the mixture and makes is less visible once the plume exits the exhaust gas pipe into open air.

Inline Scrubber deplume

New deplume design for Inline scrubber

Scrubber Diameter	[mm]	1 850	2 050	2 250	2 450	2 650	2 850	3 050	3 250
Scrubber Gas Flow	[kg/s]	12,6	15,5	18,6	22,1	25,9	29,9	34,3	38,9
Deplume Air Ratio	-	33%	33%	33%	33%	33%	33%	33%	33%
Deplume Air Gas Flow	[kg/s]	4,2	5,1	6,2	7,3	8,5	9,9	11,3	12,8
Total Deplume Gas Flow	[kg/s]	16,8	20,6	24,8	29,4	34,4	39,8	45,6	51,7
Total Height	[mm]	900	950	1 000	1 050	1 100	1 250	1 250	1 250
Inlet Diameter	[mm]	800	900	1 000	1 100	1 200	1 300	1 400	1 400
Outlet Diameter	[mm]	786	886	986	1 086	1 186	1 286	1 386	1 386
Outer Diameter	[mm]	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 600
Overall Length	[mm]	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 700
Deplume Air Inlet Width	[mm]	700	800	900	1 000	1 100	1 050	1 200	1 350
Deplume Air Inlet Height	[mm]	500	550	600	650	700	850	850	850
Deplume Weight	[kg]	269	304	340	378	417	480	511	518

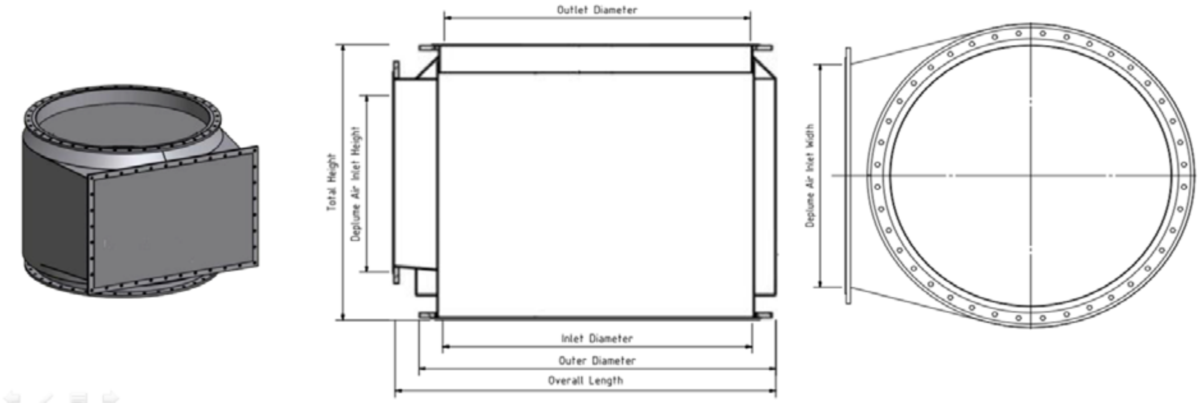


Figure 22: - Inline Scrubber deplume

EGCU Scrubber deplume

Dim. [mm]	1 MW	2 MW	4 MW	6 MW	8 MW	11 MW	15 MW
A (NB pipe)	400	600	850	1000	1100	1400	1500
B (NB pipe)	400	600	800	1000	1100	1300	1500
C (NB pipe)	250	350	500	600	700	800	900
D (NB pipe)	600	900	1200	1400	1600	1900	2100
E	25	35	50	55	65	80	90
F	480	550	760	1000	1150	1400	1580
G	650	850	1150	1400	1650	1950	2150
H	275	325	400	500	600	700	800
Weight (kg)	180	310	470	610	760	990	1110

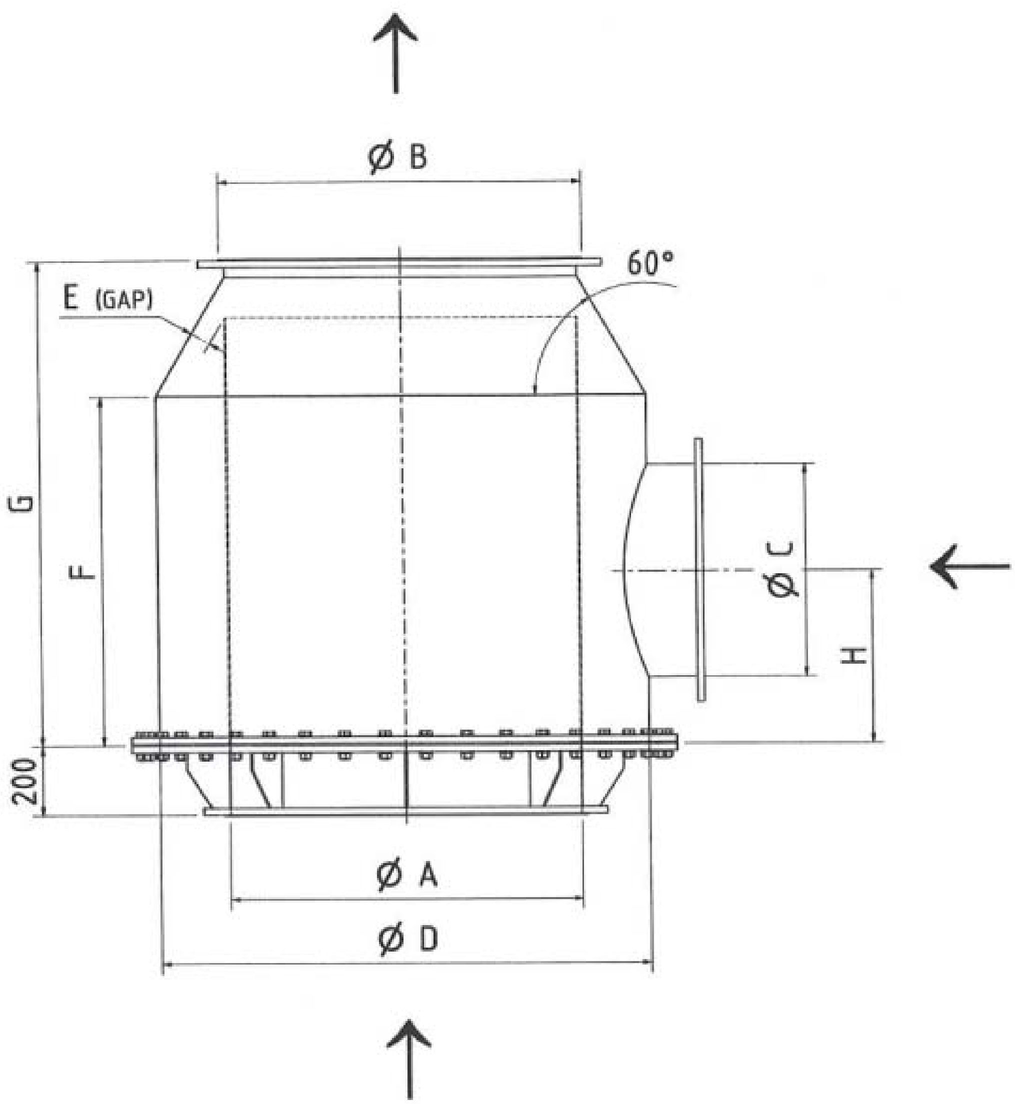


Figure 23: - Deplume mixing unit dimensions

5.2.17 Interconnecting of exhaust gas pipes

In integrated exhaust gas cleaning units and multi inlet cleaning units the exhaust gas pipes from diesel engines can be interconnected under the following conditions:

- Back-flow of hot, dirty gases into a standing engine shall be prevented in a reliable manner. Open bypass valve in the standing engine or boiler in combination with continuous under pressure conditions at the valve preventing any such back-flow in case of a leaking valve is acceptable.
- Inadvertent choking of an engine in question shall be prevented in a reliable manner. A bypass pipe designed to permit full aspiration of an engine in question with open bypass valve is acceptable.
- Generally it should be noted that it is not recommended to connect oil fired boilers to the same scrubber unit as diesel engines, due to the operating requirements of oil fired boiler combustion units.

In new building ships Safe Return to Port (SRTP) regulation requirements can be fulfilled with one integrated scrubber unit. For vessels with several engine casings adjacent to each other the following arrangement is proposed:

- Exhaust pipes from different fire zones are routed purely through their own engine casings up to the funnel, avoiding exhaust gas pipe penetrations through main fire bulkheads.
- The funnel is above the top of the fire zones, separated from the engine casing with A60 fire insulation and remote controlled fire flaps.
- The funnel area can be common for several engine casings and the scrubber unit located in funnel.
- One Integrated Scrubber cleaning the exhaust gases from all exhaust pipes from the engine casings.

5.3 Scrubbing water systems

5.3.1 Closed loop

When the scrubber system is working in closed-loop principle; the scrubbing water is circulated several times inside the system. Only small bleed-off is extracted from the loop and sea water and alkali are added. Flow rate of scrubbing water is related to actual dimensions of scrubber unit and total water balance.

When the scrubber system is working in open-loop principle, scrubbing water is pumped into the scrubber(s) and discharged back to the sea via water treatment and monitoring systems. Same scrubbing water (sea water) is not circulated inside the system.

Scrubbing water is introduced to the scrubber(s) via several inlets around the scrubber unit. Scrubber construction is relatively similar in all open-, closed- or hybrid scrubbers. The scrubbing water flow in closed loop mode is smaller than in open loop mode.

Scrubbing water pumps are installed to perform the scrubbing water feed into the scrubber(s). The amount and size of these pumps depends from the installation and from the desired EGC operational profile. Hybrid system is usually capable to use same scrubbing water pumps for both operating modes; closed loop and open loop.

In most cases, the scrubbing water pumps are variable speed driven.

Typical scrubbing water flow for closed loop is approximately 45 m3/MWh with 3,5%S -> 0,1%S.

5.3.2 Open Loop

In the open loop scrubbing system sea water is used as the scrubbing medium. The scrubbing process relies upon the natural buffering capacity of sea water to neutralize the acidic components of the scrubbed combustion process gases. The buffering capacity of the sea water is summarized in the term “alkalinity” which is related to “salinity” in fully marine waters. The salinity/alkalinity of the sea water will affect the ability of the sea water system to neutralize the acids scrubbed from the exhaust gases. Salinity in marine waters will vary depending upon the location, time of year and proximity to coastal regions.

The use of sea water in the open / closed loop systems assists in the pre-conditioning of the exhaust gas to be scrubbed in lowering the gas temperature thus reducing the gas velocity. The design of the Exhaust Gas Unit is such that intimate mixing of the sea water and exhaust gas is arranged to ensure mass transfer of the SO_2 content in the exhaust gas to the sea water through its natural affinity to the bicarbonate / carbonate content of the sea water.

The open loop system is arranged as a single pass through of the sea water. In other words the sea water is pumped to the scrubber where the products of combustion are absorbed, this water is then treated to remove solids (particulate matter) from the water before the water is discharged overboard; the sludge is retained on board for separate disposal.

Typical scrubbing water flow for open loop EGCU Scrubber is 45 m3/MWh with 3,5%S -> 0,1%S.
Typical scrubbing water flow for open loop Inline Scrubber is 55 m3/MWh with 2,5%S -> 0,1%S.

5.3.3 Sea water quality

For all practicable purposes all naturally occurring sea water contains impurities or dissolved chemicals known as “salts”. These salts in sea water are obtained from dissolved chemicals and sediments carried with coastal water runoff and the solvent action of sea water on the sea bed plus volcanic activity on the ocean floor. These salt concentrations are affected by temperature and water exchange, e.g. movement of water through the “Danish Straights” to the Baltic Sea.

Bicarbonate (HCO_3) is the key component in sea water which allows the SO_2 absorbed in scrubbing to be buffered in the sea water. This naturally occurring capacity of seawater to prevent pH of sea water becoming highly acidic through absorption of SO_2 is the basis for sea water scrubbing. In some circumstances where the buffering capacity is low (in brackish or fresh water – for example in the Baltic Sea or Great Lakes in the

North America) additional sea water or the addition of alkali solutions (sodium hydroxide) may be used to assist in neutralization (raising the pH) of the scrubbing sea water. Refer to section 5 for Alkali Handling requirements and systems.

5.3.4 Sea water flow

This system comprises standard high discharge head sea water pumps for scrubber water supply, normally arranged so that the total capacity of the scrubbing water required (typically $45m^3$/MWh for a fuel containing up to 3.5% m/m Sulphur) is provided by pumps of 50% capacity plus one stand-by of the same capacity to provide system redundancy.

5.4 Water treatment systems, Closed loop (CL)

5.4.1 General

To remove the accumulated impurities from the closed loop scrubbing water, a small flow called “bleed-off” is extracted from the circulation. Bleed-off is led to the bleed-off treatment unit(s) (BOTUs). Bleed-off contains traces of hydrocarbons and combustion products, and pH is typically close to neutral. In the treatment, the bleed-off is divided into effluent and sludge. Clean effluent is discharged overboard, or led to the effluent holding tank for a scheduled and periodical discharge. Effluent quality monitoring is arranged before the discharge.

5.4.2 DAF Bleed-off treatment unit

Wärtsilä DAF bleed-off treatment unit is a complete system designed for cleaning bleed-off from sea water scrubber(s). The system is fully automatic and can be also operated from a local control panel. The unit is designed to fulfil the discharge water requirements in scrubber guideline in IMO resolution MEPC.184(59).

The number of BOTUs is project specific and depends on bleed-off flow rate. Typically one stand-by BOTU is specified for each scrubber system for situations where one of the BOTU(s) is out of operation or under maintenance. For larger installations, the number of BOTUs is higher.

As a rule of thumb, the bleed-off can be estimated to be 50-110 litres/MWh/% of fuel S, depending on the density of the bleed-off. The amount of generated effluent is very close to the bleed-off flow, as hydrocarbons and sludge separated in the treatment unit represents only a minor percentage of the total volume flow.

The unit consists of chemical module and main module. The modules can be separated if necessary. If they are separated, the chemical pipes have to be replaced or extended. In case the distance is more than 300 mm also the electrical cabling has to be replaced or extended.

The main module consists of an influent feed pump, a chemical dosing system, a flotation stage based on dissolved air flotation, sludge removal system, discharge holding tank and effluent discharge pump.

In normal operation, the bleed-off is extracted from the process tank to the bleed-off buffer tank. The bleed-off flow from the process tank to the bleed-off buffer tank is controlled by scrubber automation based on the density setpoint, fuel sulphur content and engine fuel consumption. The density is measured with density sensors.

5.4.3 Buffer tank

The aeration of the bleed-off is done in the buffer tank to increase the oxygen content in the bleed-off. Aeration blowers feed air to diffusers at the bottom of the tank. It is necessary that the buffer tank is dimensioned big enough for allowing enough residence time for the aeration system to oxidize the sulphites to sulphates. The buffer tank is equipped with a level sensor.

Usually two air blowers are installed. One blower is running continuously and the other blower is in stand-by. The operator can locally manually choose which blower is running and which is in stand-by.

The pressure in the supply line to the aeration tank is measured with a pressure sensor. If the pressure is too low, an alarm is given. In case of sensor failure, alarm is given.

5.4.4 Bleed-off recirculation pump

Bleed-off recirculation pump is continuously running when the level in the buffer tank is above the lowest limit. The bleed-off is circulated from the buffer tank for mixing of NaOH in order to maintain the desired pH level in the tank. The return line is taken before the pre-conditioning water (if needed) is mixed with the bleed-off and the mixture fed to the BOTU units.

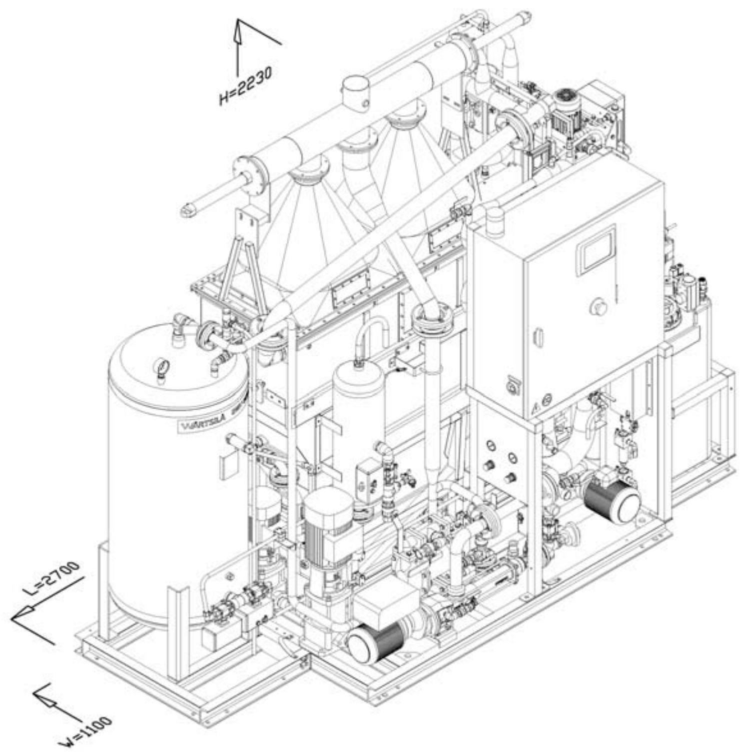


Figure 24: - Bleed-off treatment unit in one piece

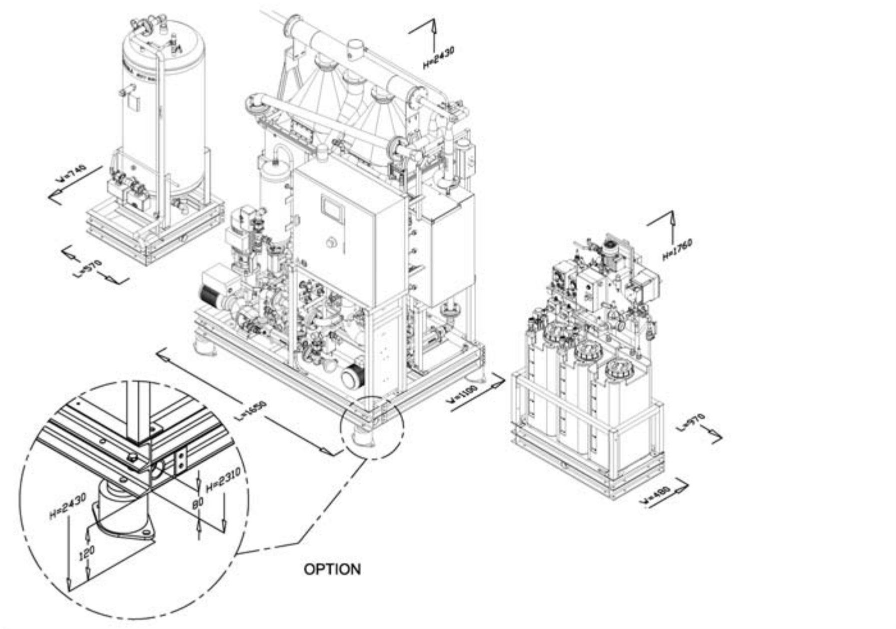


Figure 25: - Bleed-off treatment unit with separated chemical modules

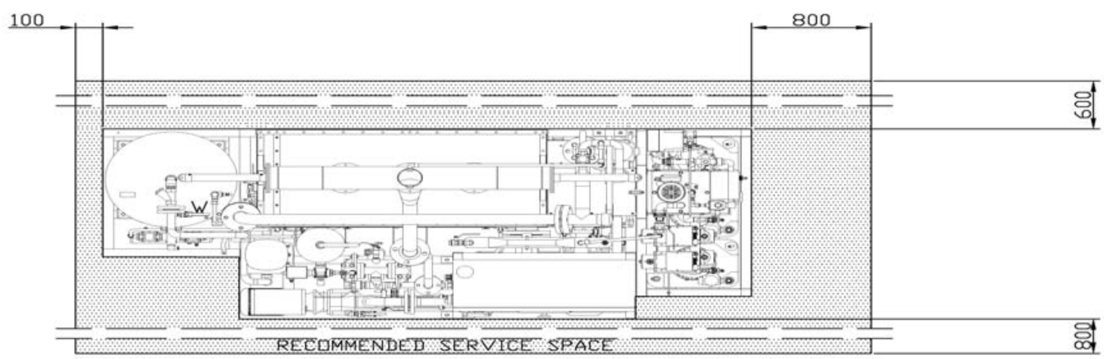


Figure 26: - Bleed-off treatment unit recommended service space

5.4.5 Technical data

BOTU Technical data:

Type:SWT 3500

Capacity:3.5m^3/h

Dry weight:880 kg

Weight in operation:2450 kg

Total water volume:1.57 m^3

Length:2700 mm

Width:1100 mm

Height:1930 mm

Installed electric power:5 kW

Consumed power:3 kW

Voltage:3 x 380-480 VAC

Fuse:16 A

Frequency:50/60 Hz

The location of the treatment unit(s) onboard the ship is project specific. The unit could be inside the engine room, funnel extension, scrubber tower or in the specific equipment container. In case the unit is located above ship's rolling centre, vertical location should be as low as possible to minimize transverse accelerations.

The chemicals used in the unit are taken from small chemical tanks built on the unit. The alkali built-on tank can be filled by pumping alkali from the scrubber alkali tank by the alkali transfer pump. The coagulant and flocculant tanks can be filled by a hand pump or pouring directly from the chemical canister.

5.4.6 Centrifugal Separator Bleed-off treatment unit

As an alternative solution for DAF BOTU, Centrifugal Separator BOTU can be also utilized to treat the closed loop bleed-off. The Separators are fully mechanical, and do not require any chemicals to be used. The working principle of a centrifugal separator is based on different densities being separated by a fast rotating bowl. The sedimentation becomes more effective with a higher clarification surface area and a shorter sedimentation path.

The unit of measurement for separators is "times g-force". The maximum g-force of a bowl depends on the diameter of the bowl and of the bowl speed. The maximum g-force is mainly limited by the bowl material (stainless steel).

The Centrifugal Separator is of self-cleaning type. The cleaning process is monitored and controlled via control cabinet and a timing unit. The sludge collected in the sludge holding space is discharged to the EGC Sludge tank on regular intervals.

Technical information:

- Max 7000l/h processing capacity per unit. Several units can be used.
- Max density 1,25g/ml (15^{o}C)
- Weight 1060 kg
- Bowl speed 8000rpm
- Bowl weight 206 kg
- Power consumption 15-18kW, less than 1kW in stand-by
- Technical water consumption 10-20 liters/hour
- Working air consumption 0,01Nm3/h
- Working air supply pressure 3-10bar

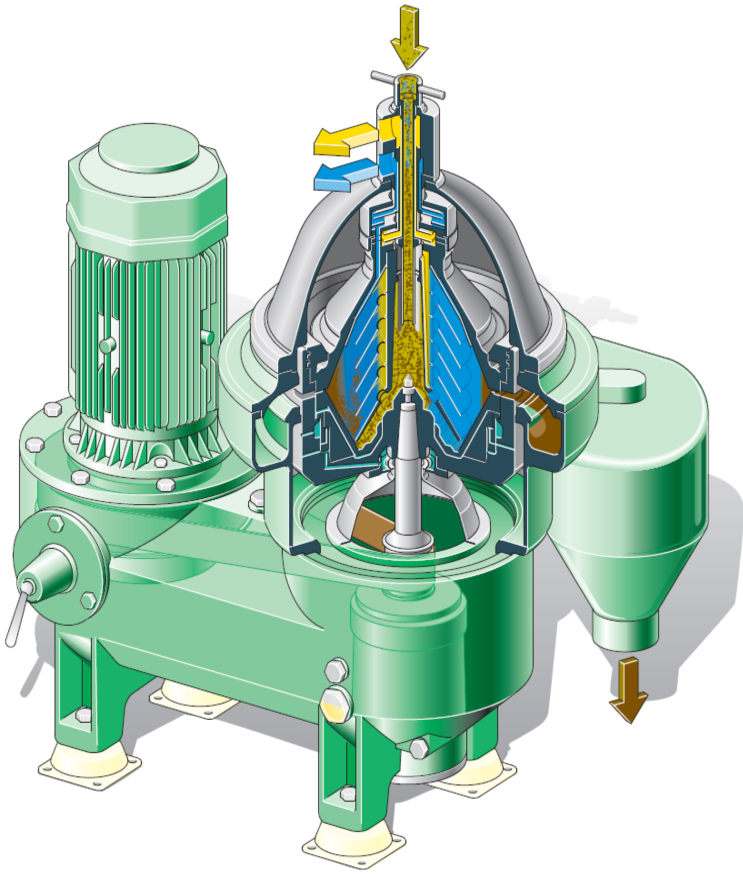


Figure 27: - Centrifugal Separator

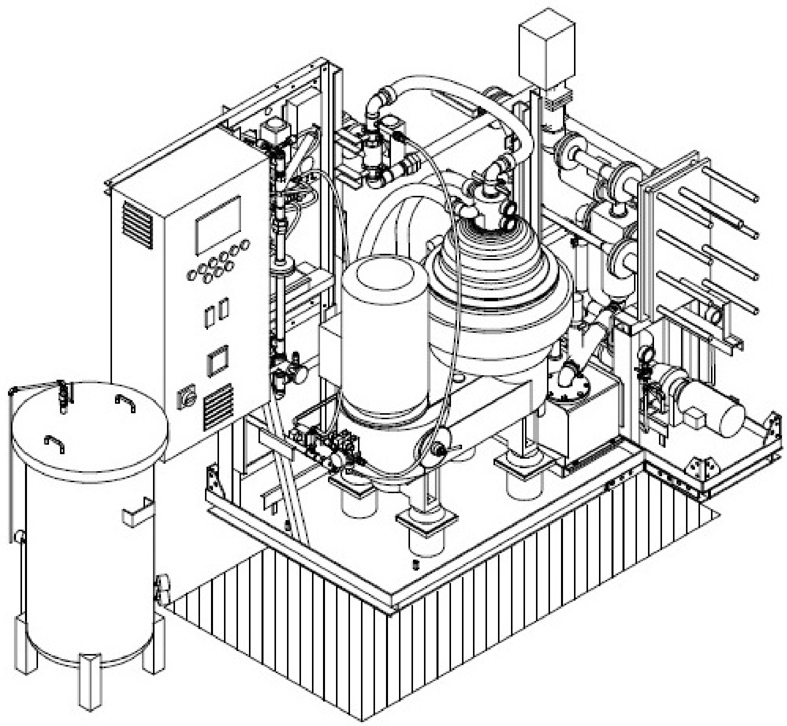


Figure 28: - Centrifugal Separator installation

5.4.7 Holding tank

In operational situations where effluent discharge needs to be avoided, the effluent can be diverted from the effluent monitoring module (EMM) to an effluent holding tank for later scheduled and periodical discharge. The volume of such storage tank should be dimensioned according to the time the scrubber system is to be operated without discharge.

The recommended tank material is black steel. Internal tank coating is recommended to avoid corrosion. The tank should be provided with low suction for complete draining prior to maintenance. There should also be air pipe from the tank.

The holding tank should be provided with the following alarms:

- Level low
- Level high

The holding tank should be provided with the following indications:

- Local level gauge (tank)
- Local level gauge (tank's water lock)
- Local temperature gauge

The holding tank should be provided with a standard 600 mm x 400 mm manhole.

5.5 Water treatment systems, Open Loop (OL)

This system relies upon the use of hydrocyclones to clean wash water from the scrubber. In order to provide the necessary differential pressure across the hydrocyclones and in some cases to aid over board discharge wash water pumps are provided. These pumps have internal components manufactured in Super Duplex or similar material in order to withstand the corrosion effects of the low pH washwater returning from the scrubbing process. As in the case of the supply pumps wash water pumps are provided with redundancy.

In addition to the above pumps for open loop operation it may be necessary to have reaction water pumps to provide additional fresh sea water when operating in port to assist in the neutralization of the wash water in order to meet the pH requirements of discharge water as detailed in MEPC.184(59) section 10.1.2.1. An alternative to dedicated reaction water pumps would be to utilize seawater already in use on board such as machinery cooling system or ballast water supplies and divert this into the washwater overboard discharge stream of the scrubbing system. The pumps for this service would be manufactured as standard seawater pumps.

Incorporated into the open loop system is a residence tank. This tank is to be coated internally in order to resist the corrosion effects of low pH wash water from the scrubber. The main purpose of this tank is to provide a residence period for the wash water to allow gas and air to separate out from the water to aid the particulate matter removal in the hydrocyclones of the products of combustion that are held in the gas/air stream(s). This separation allows the particulate matter to settle out and become “wetted” (free of the gas / air bubbles) where it can then be captured in the hydrocyclones and subsequently collected in sludge holding tank(s). The residence tank is typically arranged and sized to provide a residence time of a minimum of 2 minutes for the wash water in the system (the larger the tank the better depending upon space availability).

Sludge tanks generally are in the form of a standard IBC container of $1m^3$ capacity. Positioning of these tanks should be arranged to allow tank exchange when full. The contents of the full tank(s) are to be disposed of ashore and cannot be incinerated on board or disposed of to the sea, MEPC. 184(59) section 10.4. The tanks are arranged such that all services are provided in the lid of the tank in order to facilitate easy replacement of tanks when full without the need for extensive disconnection and reconnection. The sludge collected in these tanks from de-sludging the hydrocyclones (normally once a day) is allowed to settle and the separated water is then pumped back into the residence tank to pass it through the hydrocyclones again before discharge with the wash water overboard.

The seawater supply and discharge wash water are monitored for pH, temperature, turbidity and PAH (as a measure of the hydrocarbon content of the wash water) as required by MEPC.184(59) section 10.

5.5.1 Residence tank

In open loop, the scrubbing water returning from the EGC Unit(s) (named as wash water) is led into a residence tank. This tank works as a storage tank from which wash water is being pumped to the hydrocyclones to be cleaned. The residence tank has its own inner structure that has an important role in the cleaning process as well.

Residence tank dimensions

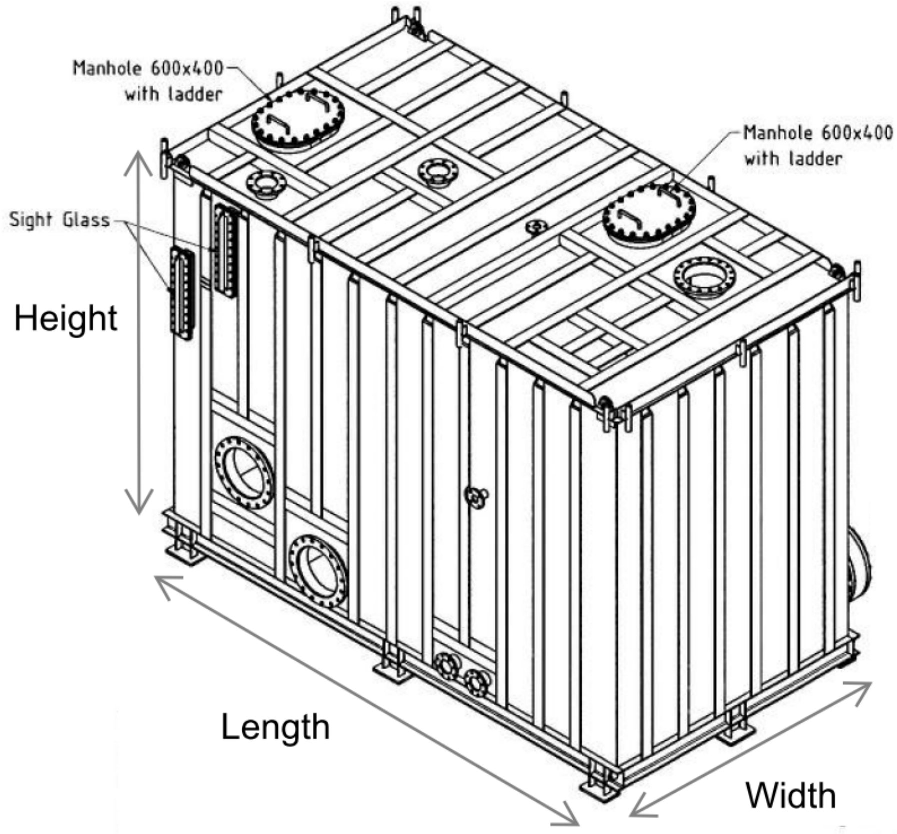


Figure 29: - Residence tank dimensions

Table 11 Residence tank dimensions per gas flow

Gas flow		Volume	Height	Length	Width
[kg/s]	MW	[m³]	[m]	[m]	[m]
2.15	1	1.9	1.8	1.4	0.7
4.30	2	3.8	1.8	2.0	1.0
8.60	4	7.5	2	2.7	1.4
12.90	6	11.3	2	3.4	1.7
17.20	8	15.0	2.2	3.7	1.8
23.65	11	20.6	2.5	4.1	2.0
32.25	15	28.1	2.5	4.7	2.4
53.75	25	46.9	2.7	5.9	2.9

5.5.2 Hydrocyclones

Scrubber Hydrocyclone dimensions

Table 12 - Hydrocyclone max. washwater flow amount per gas flow

Gas flow [kg/s]	MW	Max. flow per unit [m^3/h]	Number of units
2.15	1	220	1
4.30	2	220	1
8.60	4	220	1
12.90	6	300	1
17.20	8	390	1
23.65	11	500	1
32.25	15	890	1
53.75	25	630	2

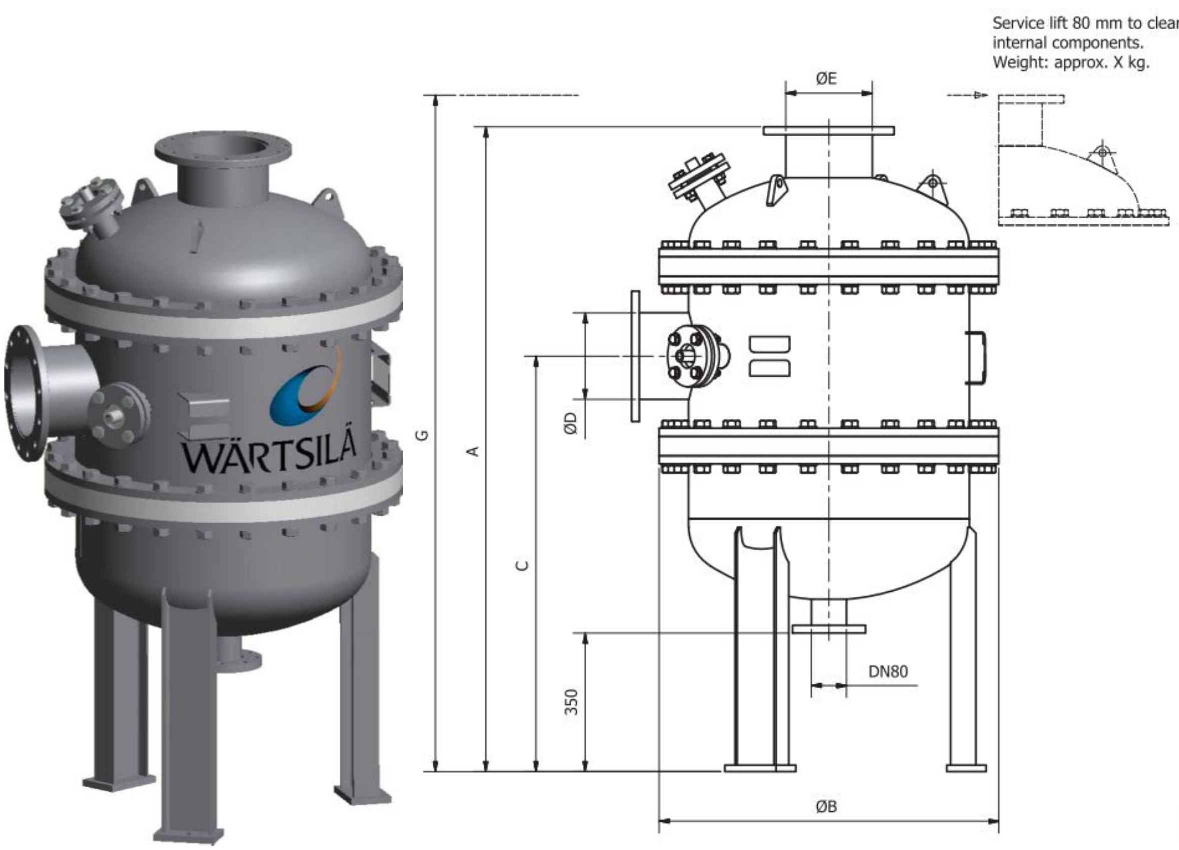


Figure 30: - Hydrocyclone figures

Table 13 - Hydrocyclone filter assembly dimensions

Dim. (mm)	Description	24”	28”	32”	36”	40”	48”
A	Overall height	1550	1650	1650	1750	1750	1800
B	Overall diameter	755	860	975	1075	1175	1405
C	Inlet height	1050	1050	1050	1150	1100	1150
D	Inlet pipe size	DN200	DN200	DN200	DN250	DN250	DN300
E	Outlet pipe size	DN200	DN200	DN200	DN250	DN250	DN300
G	Service height	1630	1730	1730	1830	1830	1880
W	Inlet position	450	500	550	650	700	900
X	Weight top unit (kg)	55	65	75	105	110	200
	Max flow rate (m^3/h)	220	330	390	500	630	890
	Dry weight (kg)	350	420	500	715	590	1160
	Wet weight (kg)	650	740	1100	1360	1710	2120

5.6 Alkali System

Alkali is automatically added to the scrubbing water circulation to maintain the process pH and consequently the SO_X removal efficiency. Typically 50% NaOH (Sodium Hydroxide), also known as Caustic Soda or Lye, solution is used as alkali. In some cases 20% NaOH solution can be considered due to its low freezing point.

Main components in alkali system are alkali feed module, alkali transfer pump and alkali storage tank. The alkali feed module consists of two chemical dosing pumps. One pump is normally in operation and the other as stand-by.

Fresh alkali is automatically fed to the process as required by process chemistry. The main input data for alkali feed control are Sulphur content of the fuel and engine load. The main control is automatically adjusted based on measured pH of scrubbing water to compensate the possible variation and inaccuracy in fuel Sulphur data or engine load. The engine load can be derived from fuel flow, fuel rack position or generator load in case of diesel generator. The Sulphur content of fuel in use is to be entered / typed into the system by the operator based on e.g. Bunker Delivery Note.

Caustic soda bunkering areas, tanks and sounding pipes, and feed module should be provided with warning signs to ensure that all crew members are aware of the hazards involved in general and in particular when any maintenance or repairs are made. The warning sign to be used is standard “corrosive” sign, with text “Sodium Hydroxide Solution” and “UN 1824” nearby. Additionally texts “NaOH Solution” and “Caustic Soda Solution” can be included as well.

Figure 31: - “Corrosive” sign.

Safety stations (with shower and eye wash) should be arranged for relevant alkali handling areas, such as bunker stations, alkali feed module area and bleed-off treatment units. If the safety shower is located outdoors, it must be insulated and heat traced in order to prevent freezing. The requirements for the safety shower are defined e.g. in standard SFS 5411.

The safety showers should be clearly marked with dedicated signs.

Figure 32: - Safety shower and eye wash signs

Following personal protective equipment must be worn when handling alkali:

- Impervious overalls
- Protective clothing
- Chemical boots
- Safety helmet
- Safety goggles or face shield

All locations where alkali is handled are to be provided with good ventilation. See Appendix 1 for more information of NaOH.

5.6.1 Consumption

Alkali consumption depends on the concentration of the solution, engine operating power, engine specific fuel oil consumption and fuel Sulphur content. The alkali supply is automatically controlled based on these parameters.

Indication of the alkali consumption can be seen in the figure below. It also indicates the relations of the affecting parameters.

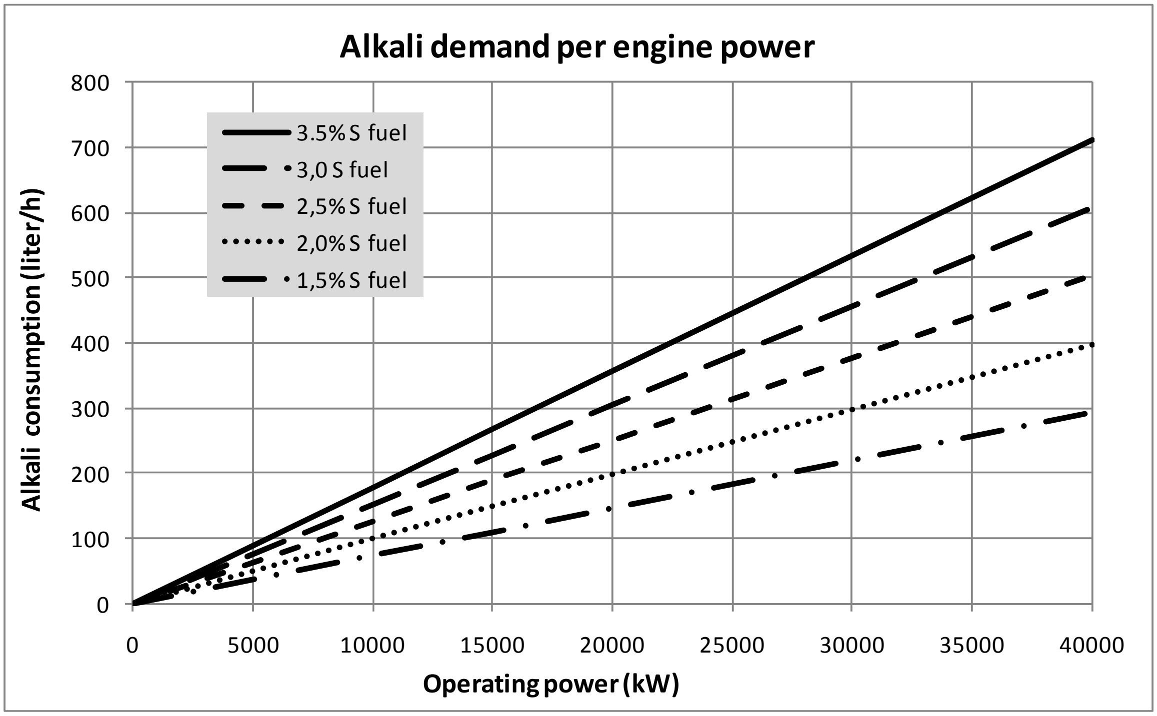


Figure 33: - Alkali consumption per operating power

As a rule of thumb the alkali consumption can be estimated to be 5 liters/MWh/fuel S %.

In case 20% NaOH solution is used, the consumption will be proportionally higher than for 50% solution. The alkali consumption in design conditions is given in the relevant project documentation.

5.6.2 Storage

Onboard storage capacity is dictated by the following parameters: vessel autonomy, alkali consumption and vessel's operation profile and area.

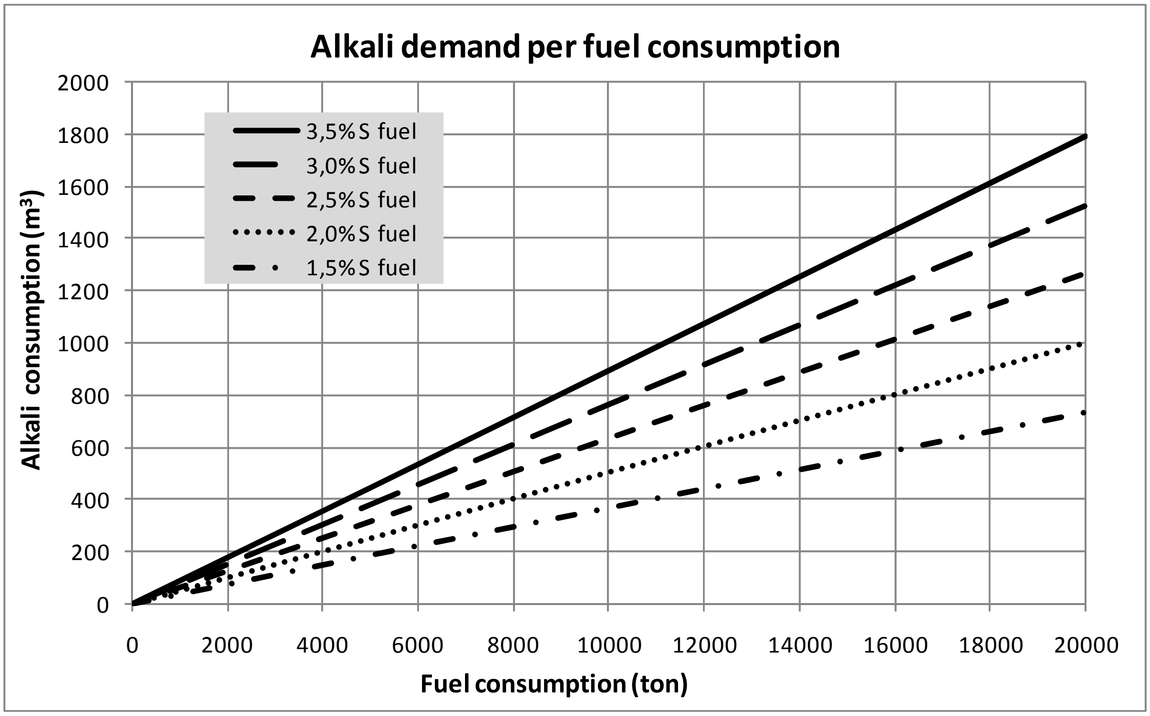


Figure 34: - Alkali consumption per consumed fuel

Required storage tank capacity can be calculated e.g. by comparing it to the fuel consumption. If ship's annual fuel consumption is 10 000 tonnes and average fuel Sulphur content 2.50%, the corresponding alkali consumption is 630 m^3 per year. If alkali is bunkered every two weeks the required amount is $24m^3$. On top of this; some margin should be added to take into account the effect of possible higher Sulphur content fuel or different combustion equipment operating profile.

For vessels that are operating in regular routes or in specific areas, the storage capacity could be equal to the fuel bunkering interval. To minimize the transportation costs and ease the bunkering arrangement, tank capacity should be adequate to receive the total volume from one delivery truck. The ideal storage capacity should be at least 1.5 times the volume of the truck.

It is recommended that two separate (preferably adjacent) structural tanks are provided for alkali. This configuration would allow continuous scrubber operation during the tank surveys, inspections and cleaning. When tank location and volume are outlined, high density of 50% caustic soda solution and the margin against overfilling (15-20%) are to be considered. Recommended cleaning interval for storage tanks is 4 years. A single tank configuration can be used, if operation and regulation compliance with low Sulphur fuel is a possible and feasible alternative during the above mentioned periods. Due to the relatively high density of caustic soda a low center of gravity for storages may be favorable regarding vessel stability.

There is generally no limitation to tank geometry. Tank bottom should preferably be sloped towards drain pipe. Tank for 50% NaOH should be dimensioned for specific density of $1.52t/m^3$; this is to include the hydrostatic pressure head to the air vent above the bulkhead deck. Tank should be externally or internally stiffened. Integrity of storage tank and related air vents should be hydrostatically tested prior the tank coating. Air vents need to be arranged from the highest points designed according to rules of applicable classification society.

General shipbuilding steels can be used for tank construction. In each case when tank construction involves structural members special consideration by classification society is required. The temperature limits should be considered as above a temperature of 49°C carbon steel is susceptible to stress corrosion cracking, also known as "caustic embrittlement". If higher tank temperatures are expected, special measures including weld stress relieving and use of alternative materials should be considered case by case.

NOTE: any part of tank or tank fittings which may come in to contact with caustic soda should not contain the following metals or alloys: aluminum, magnesium, zinc, brass, and tantalum. Caustic soda corrodes these metals and the reaction may generate flammable hydrogen gas. Particularly reaction with aluminum is vigorous. Long term exposure to caustic soda can deteriorate materials containing silica e.g. glass. It is recommended to check supplier's compatibility information regarding gaskets for manholes and flanged tank fittings. Typically PTFE or EPDM should be used. Viton is not suitable as gasket or sealing material.

5.6.3 Storage tank heating

50% caustic soda will solidify at temperatures below 12°C and therefore the tank should preferably be located so that it shares common boundaries with engine room as far as possible. If the tank temperature is expected to drop below 16°C additional heating should be provided. The recommended storage temperature is between 25 and 35°C. Corrosive properties of caustic soda are aggravated at temperatures above 49°C (when carbon steel is used) and thus caustic soda storage should not have common structures with e.g. heated fuel oil service and settling tanks. Also other heat sources that may locally increase temperature inside the tank to exceed the afore mentioned value (e.g. exhaust gas or steam pipes) should be isolated from tank structures.

Storage tank heating requirement can be determined by calculating heat transfer through each tank boundary. The same heat transfer coefficients through the external tank walls that are typically used for heavy fuel oil are applicable. In some cases external tank insulation could be considered to reduce heat losses.

If heat losses from the tank are excessive, heating with water circulation in carbon steel coils can be used. To avoid corrosion of heating coils external surface, inlet water temperature should remain below 49°C. For example, returning LT cooling water can be utilized for heating and heating coils can be connected in parallel to the central cooler. The central cooler pressure drop or a dedicated circulation pump can be used for induced circulation depending on the pressure drop in the tank heating system. Coils should be installed to an approximate height of 300 mm from tank bottom and located so that thermal agitation pattern will occur.

Heating coils should be positioned to provide heating particularly in suction pipe area. Heating coil dimensioning is based on the differential temperature (Δt) between the lower storage temperature (25°C) and the arithmetic mean temperature of incoming / outgoing circulating water. Mean heat transfer coefficient from water coils to caustic soda can be estimated to 60 W/ (m^2 x °C), if turbulent flow conditions can be achieved.

An alternative heating method will be to provide a separate caustic soda circulation through an external heat exchanger. Thus the heating media can be low pressure steam or high temp heat recovery water. In these cases the appropriate heat exchanger material should be selected, for example nickel. If heat losses are moderate, also external electric heating can be used. Heating elements are adhesive and attached directly to the tank wall under the insulation. Also in these cases the specified heating elements should not exceed maximum surface temperature and be thermostatically protected.

5.6.4 Storage tank fittings and instruments

When anywhere in the alkali system (bunkering, transfer, and feed) the lines are to be located below the alkali storage tank level, the storage tank should be equipped with a quick closing valve. The quick closing valve is either connected to the emergency stop, or has an own lever. If quick closing valve activation is based on a lever, the release system should be hydraulic.

The primary suction should be located approximately 100mm from storage tank bottom. Tanks should also be provided with low suction for complete draining prior to maintenance. Diameter is according to installation specific system diagram. Each connection below the maximum surface level should be provided with safety quick closing valves.

Alkali tank filling line should be led below the minimum service level and should be provided with vacuum breaker provision (hole) (anti syphon) at the upper end where siphon effect may occur. Piping should be sloped downwards without pockets. Filling line is typically DN 80 and provided with DIN 2633 flange at bunker station. Filling pipe material recommendation is AISI 316L or black steel DIN 2448. Transport trucks are provided with several different connection types depending on supplier and country. Adapters may be required.

After bunkering the transport truck's delivery hose and the filling line are to be cleaned with compressed air. Also the tanks in the truck are to be cleaned with water. Therefore compressed air and water connections should be located near to bunkering stations.

Caustic soda storage tank should be provided with the following alarms:

- Temperature high (set point 45ºC, if provided with heating)
- Temperature low (set point 20ºC, if relevant)

- Level low (e.g. 30%)
- Level high (e.g. 85%)

Caustic soda storage tank should be provided with the following indications:

- Local level gauge (hydrostatic type with sensor isolating valve). Sight glasses are not recommended.
- Local temperature gauge (gauge with stainless steel pocket)

Each caustic soda storage tank should be provided with a standard 600 mm x 400 mm manhole.

Instead of sounding pipe an approved type local hydrostatic level indicator can be used, note that devices need to be calibrated for caustic soda density. Relevant classification society's rules concerning sounding requirements should be verified.

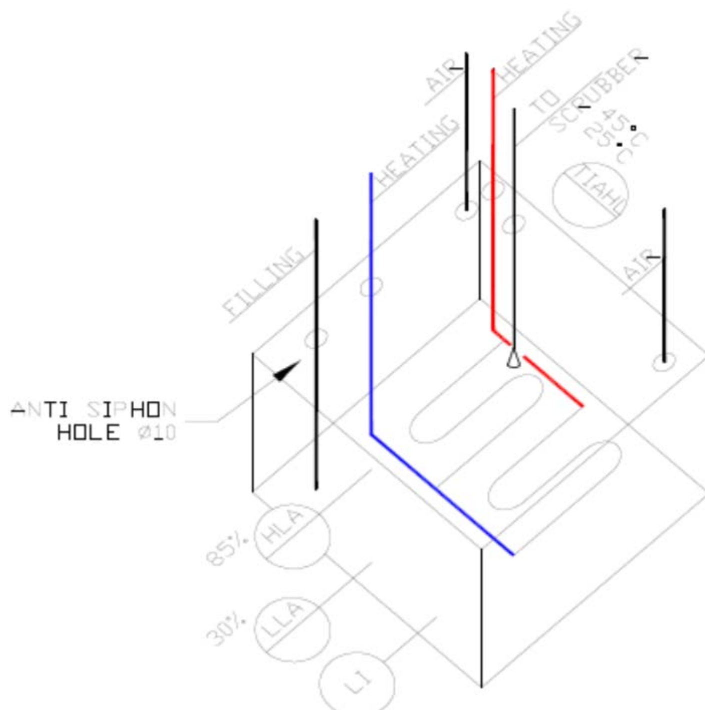


Figure 35: - Caustic soda storage tank fittings

Alkali storage tank air and overflow pipe are led in similar way as normal air and overflow pipes (e.g. above bulkhead deck and overboard). To prevent spraying of alkali, the air pipe end should be protected by a plate or similar means.

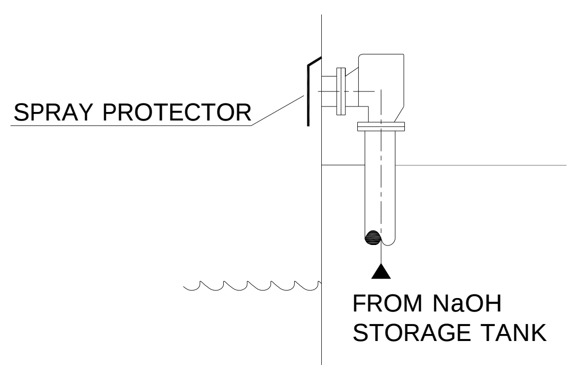


Figure 36: - Example of "spray protector" plate for alkali storage tank air and overflow pipe.

5.6.5 Alkali feed module

Alkali feed module consists typically of two pumps. In normal operating conditions one pump is in operation and the other pump in stand-by. The complete module includes also valves, sensors and filters. To prevent any splashes in case of leakages the module is equipped with a drip tray. To minimize the suction line length the preferred location of the alkali feed module is near the storage tank.

Alkali feed module shutdown is connected to the emergency stop. The module is equipped with drip tray. The drip tray drainage should be arranged with one of the following alternatives:

- Alternative 1, automatic quick closing valve. Drip trays are to be provided at the lowest point with such a leak detector that automatically activates the NaOH storage tank quick closing valve. Drip trays are to be of adequate capacity to receive such leak quantity which may escape from the system prior to closing of the quick closing valve, including quantity in the supply pipe. Leak detection and quick closing system are to be of fail to safe type. Such drip trays are without drainage.
- Alternative 2, automatic drainage to safe tank. Vertical conditions permitting, drain pipes from the drip trays are to allow free flowing back to the NaOH storage tank or any other suitable tank. Such drain pipes should be of adequate size, and provided with heating where necessary to avoid stiffening (solidification) of the caustic soda. A sensor in the drip tray triggers an alarm in case of leakage.
- Alternative 3, alarm. A sensor in the drip tray triggers an alarm in case of leakage.

5.6.6 Alkali transfer pump

The alkali transfer pump is used for pumping the alkali from the storage tank to fill small tanks in bleed-off treatment units. The bleed-off treatment unit uses the alkali in the treatment process. The pump can also be used to empty the alkali storage tank e.g. in case of tank service or inspection.

The alkali transfer pump capacity could be e.g. 10… 15m^3/h, depending on size of the alkali tank and required time for emptying the tank.

5.6.7 Alkali specification

Wärtsilä scrubber system typically uses 50% NaOH solution as neutralizing agent in the process. In some cases, for example in arctic environment, 20% NaOH solution is feasible due to its low freezing temperature.

The customer/operator should acquire the chemical according to the following specification.

50% NaOH solution specification (typical for marine scrubber):

<u>SODIUM HYDROXIDE (NaOH) 50% SOLUTION - TECHNICAL QUALITY</u>

TECHNICAL NAME:	SODIUM HYDROXIDE SOLUTION 50% (WATER SOLUTION)
CHEMICAL FORMULA:	NaOH (aq)
CAS N:o	1310-73-2
EINECS N:o 21	5-185-5
ADDITIONAL TRADE NAME(S):	CAUSTIC SODA 50%, LYE 50%

<u>CHEMICAL COMPOSITION</u>

SODIUM HYDROXIDE	NaOH 45… 52%-weight
CHLORIDE (Cl)	< 0.1%-weight as NaCl

20% NaOH solution specification (to be agreed upon project specific basis):

SODIUM HYDROXIDE (NaOH) 20% SOLUTION - TECHNICAL QUALITY

TECHNICAL NAME:	SODIUM HYDROXIDE SOLUTION 20% (WATER SOLUTION)
CHEMICAL FORMULA:	NaOH (aq)
CAS N:o	1310-73-2
EINECS N:o	215-185-5
ADDITIONAL TRADE NAME(S):	CAUSTIC SODA 20%, LYE 20%

CHEMICAL COMPOSITION

SODIUM HYDROXIDE	NaOH 17… 23%-weight
CHLORIDE (Cl)	< 0.1%-weight as NaCl

5.7 Make-up water systems

5.7.1 General

In closed loop operation, the scrubbing water is circulated several times through the scrubber before being extracted from the process as bleed-off. This bleed-off needs to be replaced with similar sized flow of new make-up water in order to maintain a stable water level in the process tank. The make-up water used is sea water. The amount of make-up water added is typically less than 1% of the total closed loop scrubbing water flow.

5.7.2 Water quality

Closed loop operation is not dependent on sea water quality as added caustic soda (NaOH) works as the reacting agent. Therefore sea water quality doesn't need to be monitored.

5.8 Cooling water systems

Exhaust gas heat is transferred to the scrubbing water and is removed in the sea water heat exchanger. The purpose of the cooling is to minimize the water content in the cleaned exhaust gas after the scrubber, thereby minimizing plume opacity and sea water consumption. The cooling has negligible effect on Sulphur removal efficiency from the exhaust gases.

The system is typically designed for sea water temperature maximum of 32 °C. Alternatively, a different temperature can be specified if requested. In cold environment, minimum sea water temperature is ensured by a thermostatic valve and a recirculation line to avoid crystallization of the sulphates in scrubbing water. A sufficient sea water flow is needed to ensure the scrubbing water cooling.

Closed loop can be operated without cooling system, but in that scenario the loss of scrubbing water due to evaporation will be higher. This results in a larger need for replacing make-up water. Another consequence of the increased evaporation will be the visible plume of steam left behind.

Open loop system doesn't require cooling systems to be installed as the scrubbing water in the process is not warming up enough during the single-time visit it makes in the scrubbing unit before being discharged back to the sea.

5.9 Sludge system

5.9.1 Open loop

Sludge from hydrocyclones is collected in standard IBC containers. The amount of sludge generated from normal combustion is approximately 0,1 kg/MWh. In some cases when operating in shallow water the amount of sludge may increase due to the capture of estuarine sand and silt.

In general the collected sludge is similar to engine room sludge. The composition of the sludge is mainly hydrocarbons, soot and metals. The sludge and water phase very quickly separate allowing the water phase to be returned for final cleaning prior to discharge which keeps the quantity of collected sludge for disposal as small as possible.

Scrubber sludge could be stored with engine room sludge but due to its concentrated nature may become difficult to pump if allowed to settle. If disposal with normal engine room sludge is arranged the scrubber sludge should be pumped into the normal sludge stream during disposal to ensure mobility and mixing. Scrubber sludge cannot be disposed of to the sea or incinerated on board.

5.9.2 Closed loop

Impurities separated from the bleed-off form sludge in the treatment unit, sludge production depending on fuel oil quality.

The composition of the sludge is mainly water, hydrocarbons, soot and metals. The amount of water is aimed to be kept as minimal as possible, without losing the ability to pump the mixture.

The scrubber sludge can generally be stored in the same tank as other engine room sludge. However, the current DNV regulation specifically requires separate tanks to be used for both scrubber sludge and engine room sludge. Scrubber sludge is not permitted to be incinerated onboard.

The amount of sludge produced is approximately 3,5kg/MWh for DAF-BOTU systems and 5,5kg/MWh for Separator-BOTU systems.

5.9.3 Dewatering sludge

A Dewatering unit is capable to dewater 100l/h of sludge to generate nearly solid material with density of 1,035kg/m3.

With the dewatering unit the sludge generation drops to 0,05kg/MWh for Hydrocyclones (OL), 1,0kg/MWh for DAF-BOTU (CL) and 0,5kg/MWh for Separator-BOTU (CL).

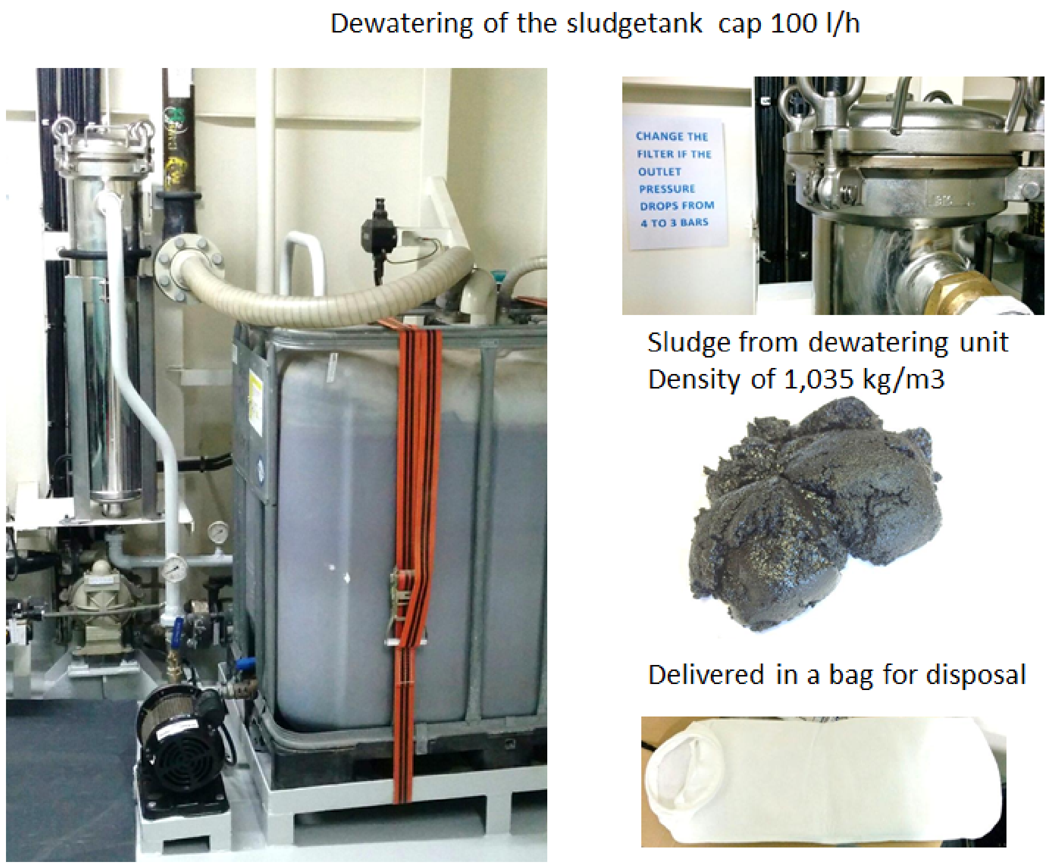


Figure 37: - Dewatering sludge

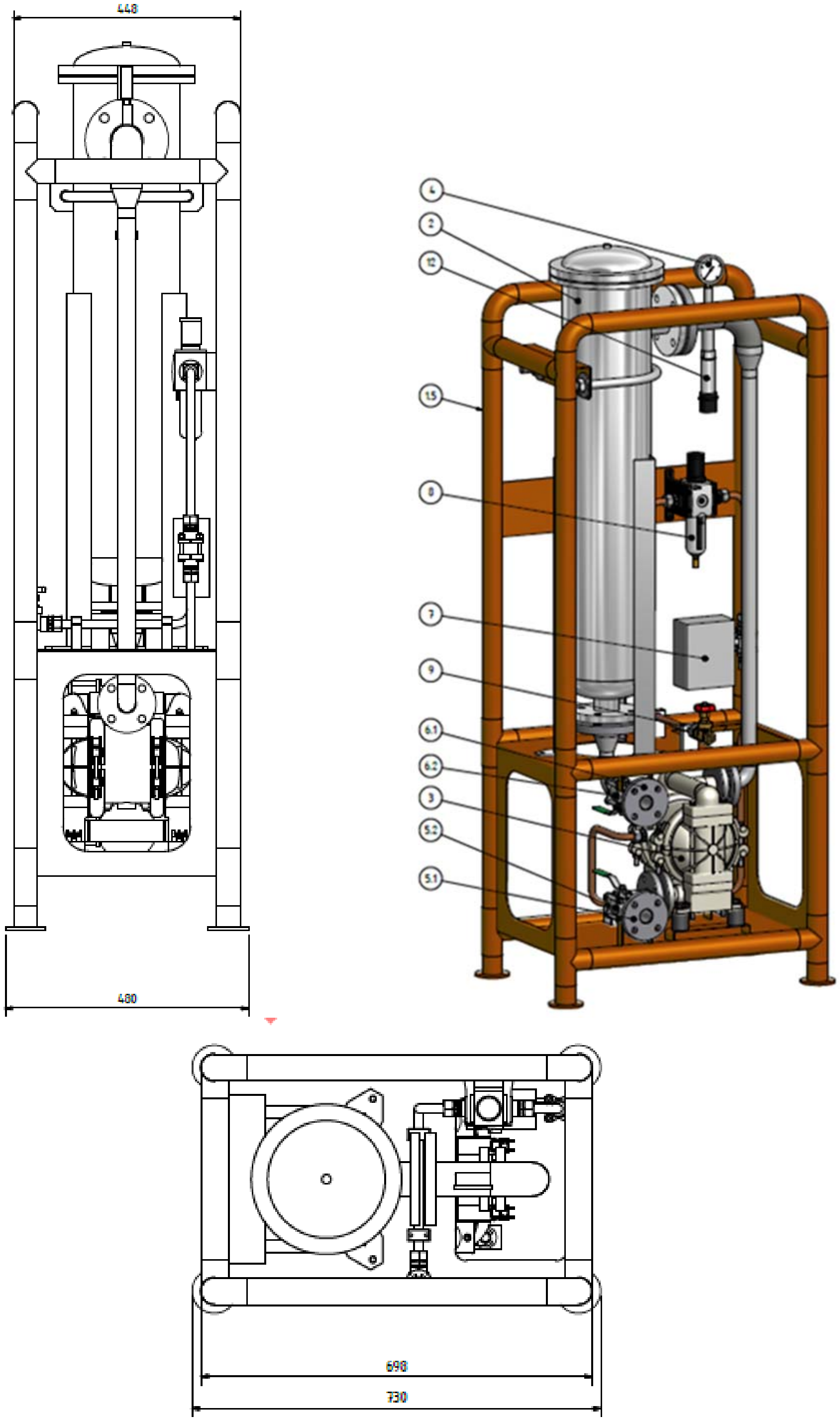


Figure 38: - Sludge dewatering unit

5.10 Power demand

The power demand of Wärtsilä Closed Loop Scrubber in normal conditions varies between 1.0 – 1.5% of the installed nominal engine power. The power consumption is lower in colder sea water temperatures than in tropical conditions. The power demand of the Integrated Closed Loop Scrubber with fan increases towards top ship speeds to around maximum of 2.5%.

The power demand of Wärtsilä Open Loop Scrubber is typically between 1.5 – 2.5% of the installed nominal power being scrubbed. This power demand comprises the power to drive system pumps and monitoring equipment. An Open Loop Scrubber with a fan has a slightly higher power demand.

The total power of power supplies connected to ancillary devices is somewhat higher, to allow for variations in ambient and operating conditions, system tuning, selection of standard components and margins. Due to embedded frequency converters and control algorithms, the power demand is optimized e.g. at reduced power and reduced sea water temperature, depending on the system.

The total power consumption of the scrubber system will be determined depending on the final configuration and plant size.

6 Materials

The following contains a summary of the piping materials and coating substances to be preferred with Wärtsilä EGC Systems:

6.1 Piping materials

Recommended Piping Materials
Doc ID: DBAD201146 - Revision date: 10.07.14

Piping / Equipment	Note	Sketch reference	Recommended material and internal protection	Alternative material	4* Design pressure Bar(g)	Design temperature °C
Scrubbing water Cooling water Reaction water	1*	1	GRE	CS with PE lining	10	40
Scrubbing water - Scrubber type 4	3*	1b	254SMO	254SMO is minimum quality grade of material	10/0,1	40/160
Wash water - Closed loop	1*	2	GRE	CS with PE lining	10	60
Wash water	2*	3	GRE	NA	10	60
Wash water - Scrubber type 4	3*	3b	254SMO	254SMO is minimum quality grade of material	10/0,1	60/160
Wash water		4	GRE	NA	10	60
Effluent water Bleed off water		5	GRE	Duplex steel	4	60
Make-up water		6	GRE	CS with PE lining	10	40
Sludge water	5*	7	GRE	PE or PP piping	4	60
Alkali supply (NaOH)		8	SS316L	NA	10	55
Vent lines from tank(s) to atmosphere		9	CS with PE lining	GRE For sludge tank: PE/PP	0,5	60

Piping / Equipment	Note	Sketch reference	Recommended material and internal protection	Alternative material	4* Design pressure Bar(g)	Design temperature °C
Deplume air, up to closing valve		10	CS with priming	NA	1	80
Deplume air, from closing valve to deplume unit		10b	CS with epoxy lining	NA	1	80
Thermal oil line / Steam / Hot water		11	CS	SS316	10	180
Exhaust line from scrubber to atmosphere		12	CS with PE or Epoxy lining	Duplex steel	2	80
Instrument air piping		NA	Copper tubing	SS316 tubing	10	60
Working air piping		NA	CS	HDG CS	10	60

Abbreviations:
GRE - Glass reinforced epoxy
CS - Carbon steel
PE - Polyethylene (plastic)
PP - Polypropylene (plastic)
HDG - Hot Dip Galvanized
NA - Not applicable
SS316L - Specific material quality
SS316 - Specific material quality
254SMO - Specific material quality
Duplex - Specific material quality

1* Some water lines needs to be of pressure class PN16.
2* Discharge line, from above ship water line to overboard, to be of CS with proper lining and pressure class PN16.
3* Design temperature and pressure for 1b and 3b is normally 10 bar/40°C/60°C. For emergency running (Dry running) is design T and P, 0,1 bar/160°C. The 1b and 3b pipe spool is connected to the scrubber, with a design temperature of 400°C.
4* Typical design pressure and temperature. Values can be project specific.
5* PE and PP piping to be marine approved.

Printed version of this document may not be topical. For latest version ref to document stored on Wärtsilä server.

6.2 Tank coatings

Internal tank coating is recommended to avoid corrosion that may occur particularly on tank upper parts. Major suppliers have epoxy resins that are suitable for this purpose. Suppliers' recommendation is to be followed concerning intended use, surface preparation and application.

In the following some example coatings from Jotun, Teknos and Tikkurila are presented. Other products with similar properties can also be used.

Table 14: - Example products for tank coating from Jotun

Coating for buffer and alkali tanks	
Product	**Jotun Marathon 2:1**
Description	High solids, two-pack epoxy coating reinforced with glass flakes. Steel structures subject to aggressive exposure, both atmospheric and mechanical. For aggressive chemical exposure.
Temperature	Max 70 ºC
Specific gravity	
Film thicknesses	400 µm
Colours	Limited selection
Pre-treatment	SA2½ (ISO 8501-1)
Surfaces	All surfaces should be clean and free from contamination. The surface should be assessed and treated in accordance with ISO 8504. The temperature of the substrate should be minimum 10 ºC and at least 3 ºC above the dew point of the air, temperature and relative humidity measured in the vicinity of the substrate. The coating should not be exposed to oil, chemicals or mechanical stress until cured.
Drying times	Dust dry after 5.5 hours. Touch dry after 12 hours. Fully cured after 7 days.
Thinner	Jotun Thinner No.17
Primer	Marathon 2:1, Pink
Finish	Marathon 2:1, Grey

Table 15: Example products for tank coating from Teknos

Coating for buffer and alkali tanks	
Product	**Teknos Inerta 280**
Description	Used as coat in epoxy systems inside kerosene and oil tanks. Withstands aliphatic hydrocarbons, alkaline solutions and acids.
Temperature	Withstands +70 ºC in immersion
Specific grafity	1.5 kg/l
Film thicknesses	500 µm
Colours	Red, green or white
Pre-treatment	Sa2½ (ISO 8501-1)
Surfaces	The surface must be dry and least 4 weeks old. The relative humidity of the concrete should not exceed 80%. The surface temperature should remain at least 3 ºC above the dew point. The temperature of the ambient air, surface or paint should not fall below +10 ºC.
Drying times	Dust dry after 3 hours. Touch dry after 4 hours. Fully cured after 7 days.
Thinner	Teknosolv 6560
Primer	Teknos Inerta 280
Finish	Teknos Inerta 280

Table 16: Example products for tank coating from Tikkurila

Coating for buffer and alkali tanks	
Product	**Tikkurila TEMALINE BL TE5**
Description	Two component, solvent free epoxy coating. Suitable to be used as a heavy duty coating on steel and concrete surfaces exposed to chemical and mechanical stress in immersion. Good resistance to acids, alkali and salts in immersion. Suitable for coating of lead-free tanks.
Temperature	Withstands +150 ºC dry heat and +60 ºC in immersion
Specific gravity	1.4 kg/l (mixed)
Film thicknesses	500 µm
Colours	Red and green
Pre-treatment	Sa2½ (ISO 8501-1)
Surfaces	All surfaces must be dry. The temperature of the ambient air, surface or paint should not fall below +10 ºC during application and drying. Relative humidity should not exceed 80 %. The surface temperature of the steel should remain at least 3 ºC above the dew point.
Thinner	Thinner 1031 or acetone
Primer	TEMALINE BL
Drying times	Dust dry after 8 hours. Touch dry after 12 hours. Fully cured after 7 days.
Finish	TEMALINE BL
Coating for buffer tank	
Product	**Tikkurila TEMALINE LP PRIMER**
Description	A two component, amine adduct cured epoxy paint. Resistant to splashes and immersion in water and chemicals. Used as coat in epoxy systems inside kerosene and oil tanks. Withstands aliphatic hydrocarbons, alkaline solutions and mild acids.
Temperature	
Specific gravity	1.4 kg/l (mixed)
Film thicknesses	300 µm
Colours	Light grey and reddish brown
Pre-treatment	Sa2½ (ISO 8501-1)
Surfaces	All surfaces must be dry. The temperature of the ambient air, surface or paint should not fall below +10 ºC during application and drying. Relative humidity should not exceed 80 %. The surface temperature of the steel should remain at least 3 ºC above the dew point.
Thinner	Thinner 1031
Drying times	Dust dry after 6 hours. Touch dry after 16 hours. Fully cured after 7 days.
Primer	TEMALINE LP PRIMER
Finish	TEMALINE LP PRIMER, TEMALINE LP 60

7 Automation

7.1 Definitions

List of definitions, in alphabetical order, with complete meaning and description:

DOL: Direct-On-Line (Starter type)
ECR: Engine control room
ER: Engine room
FC: Funnel casing
GPS: Global Positioning System
HMI: Human Machine Interface
IAS: Integrated Automation System
PLC: Programmable Logic Control
PMS: Power Management System
P&ID: Piping and Instrument Diagram
TD: Technical Description
VSD: Variable Speed Drive System

7.2 General description

7.2.1 Control system philosophy

The Wärtsilä philosophy is to make the system safe, efficient and compatible regarding both the choice of equipment and the way software is developed. The control system is a PLC based system with distributed I/O and a range of components including operator stations, data logger, starters, and VSD and monitoring systems. As internal communication Wärtsilä use MODBUS TCP which is both robust in relation to noise and allows multiple independent transactions on a single line in addition to a large number of concurrent connections. For external communication in addition to hard wire Wärtsilä mostly use MODBUS RS485 which makes it easy for the ship system and other subcontractors to integrate with the Wärtsilä Scrubber System. Keeping to the regulatory requirements according to Classification requirements a dynamical process that Wärtsilä take very seriously. Wärtsilä are in frequently contact with Classification and the system is designed with safety in mind.

7.2.2 Electrical and automation panels

The general approach for the automation system is to locate panels close to the main components which they control. Thus troubleshooting is simplified, cabling is reduced, and it is simpler to develop and maintain an overview of the automation system. Dependent of the panel’s desired function, it contains some of, or several of these components: PLC, Data logger, Operator screen, Remote I/O (handling input and output signals from instruments and valves etc.), Starters (VSD, DOL or Y/D) for pumps or fans.

7.2.3 System block diagram

The system block diagram is a document where components or panels are represented by blocks. The diagram shows the connection between all main components and interface with other systems. The purpose of the diagram is to give an overall understanding of the concepts.

7.2.4 List of components/panels

Tag No. (Panel)	No. of units	Equipment/function	Description	Location
+MCP	1	Main Control Panel	PLC/Distributed I/O /Network Switch/Touch Screen/Data logger	
+CEMS	1	Continuous Emission Monitoring System	Gas Analyser instrument	
+TSP	1	Touch Screen Panel	Touch Screen (Operator station)	
+NS1	1	Network Switch Panel (often located in Funnel)	Network Switch	
+NS2	1	Network Switch Panel (often located in Engine Room)	Network Switch	
+SWMM	1	Scrubbing Water Monitoring Module	Water monitoring instrument (in)	
+WWMM	1	Wash Water Monitoring Module	Water monitoring instrument (out)	
+EMM	1	Effluent Monitoring Module	Effluent monitoring, closed loop	
+RET	1	Water Treatment Open Loop Panel	Distributed I/O/starter panel	
+PRT	1	Process Tank panel	Distributed I/O/starter panel	
+WTP	1	Water Treatment Plant panel	Distributed I/O/starter panel	
+HC1-	X	Hydro cyclone HC-XXX Panel	Distributed I/O/starter panel	
+SC1-	X	Scrubber SC-200/SC-400 Panel	Distributed I/O/starter panel	
+SWP1-	X	Scrubbing Water Pump Panel	Starter panel	
+SWCP1-	X	Scrubbing Water Cooling Pump panel	Starter panel	
+RWP1-	X	Reaction Water Pump panel	Starter panel	
+SFWP1-	X	Scrubbing Fresh Water Pump Panel	Starter panel	
+HCP1-	X	Hydro cyclone Pump 1-	Starter panel	
+EGF	X	Exhaust Gas Fan	Starter panel	
+DAF1-	X	Deplume Air Fan	Starter panel	
+VBP1-	X	Venturi booster pump	Starter panel	
+WMP100	1	Water Monitoring Pump 100	Water Monitoring circulation pump (in)	
+WMP700	1	Water Monitoring Pump 700	Water Monitoring circulation pump (out)	
+WMP701	1	Water Monitoring Pump 701	Water Monitoring circulation pump (out)	
+WP1-	X	Water Pump panel	Starter panel	
+TRP1	X	Transfer Pump Panel	Starter panel	
+AFM	X	Alkali Feed Module	Functional system that supplies and controls alkali dosage to the process	
+BOTU1-	X	Bleed-off Treatment Unit	Unit for treatment of bleed-off water	
+ISP	1	Intrinsic Safe Panel	A boundary between a safe area and a hazardous (Ex) area	

Table 17 - List of components/panels

7.2.5 List of control & monitored points

The I/O list is a document containing list of instrumentation/components which serve as an input or output of the control system.

The list contains following information:

- Instrumentation/components, Tag no.
- Instrumentation/components, Type/Description
- Mounting location
- Service description
- Type of signal
- Control System
- Range and set point
- I/O number assignment (rack, slot, channel number)

7.2.6 System alarms

The system alarms are divided in to various groups in order of importance.
In general there are 3 types of warnings/actions:

-Audible and Visual alarm
-Instant shutdown
-Cool down (Normal system stop)

Subsystems like the Sludge system and the Alkali system can have alarms without the whole Scrubber system shutting down.
(If the subsystems are shut down over time, the rest of the Scrubber system may also shut down due to e.g. a low pH alarm.)

The alarms from the Scrubber system to the Ship system (IAS) are generally divided into two main alarm types, Critical and Non critical.

7.2.7 Second alarm

The alarm connection is based on a potential free circuit and the Ship system will be able to detect alarms in terms of whether the circuit is open or closed. In a normal situation the circuit is closed. If the circuit is open, there is an alarm. And if a second alarm occurs while there already is an existing alarm, the circuit will close for 5 seconds and then open again. If a third or fourth alarm occurs etc., the alarm will again close for 5 seconds.
(Function will be the same for both hardwired and Modbus)

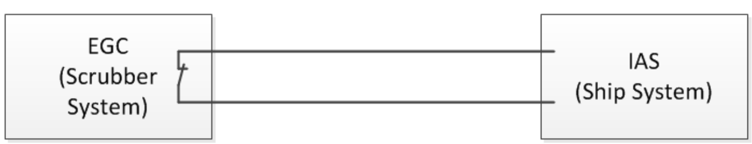


Figure 39: - Alarm connection principle

7.3 System configuration

7.3.1 Communication

System communication is established as a ring network.
In a ring network, all devices or network infrastructure components are connected in a loop. Through this type of topology, a network redundancy is achieved.
Any cable in this system can be damaged, without leading to problems with communication.

The Fibre optical ring is used at the upper level and Modbus TCP Ethernet (copper cable) at the lower level.

We use fibre optic cable, due to the great uncertainty about the length between the panels, electrical disturbance and communication speed.
The Fibre optical cable is less affected by the environment.

The fibre optical ring is connected to switches located in the Main Control Panel (+MCP), Network Switch Panel 1 (+NS1) and Network Switch Panel 2 (+NS2). Each Network Switch Panel is located as close to a group of scrubber equipment as possible, to not exceed the 100m limit of the copper (Cat 5e) Ethernet ring.

The number of Ethernet rings may vary, depending on how the equipment will be arranged on the ship.

Ethernet rings can be arranged as shown in figure below.

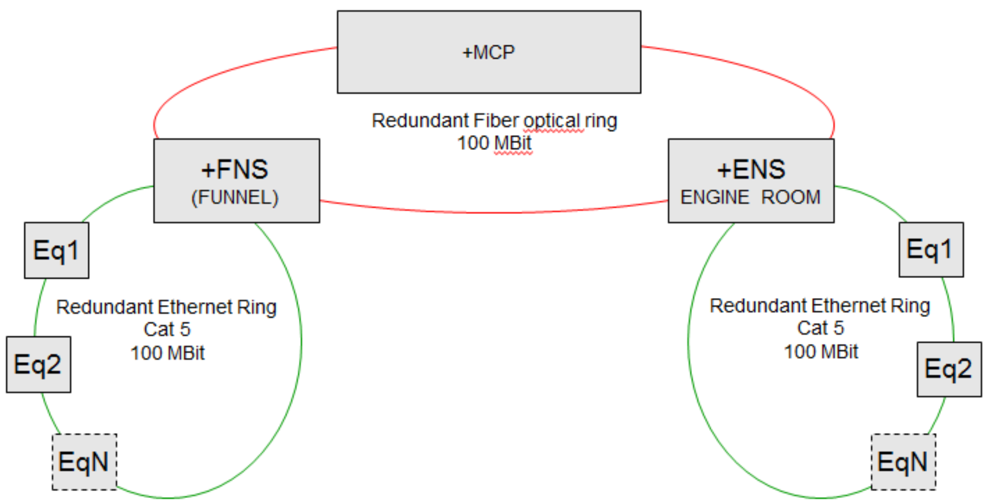


Figure 40: - Communication

7.3.2 Redundant Power Supply

The Main Control Panel (+MCP) is provided with redundant 220VAC power from ship power distribution system. The 220VAC power supplies are connected independent to different 220VAC/24VDC power supplies.

Equipment such as Ethernet switches, remote I/O, starter and internal components in +MCP, which require 24VDC, will be provided with redundant 24VDC power supply from +MCP.

If a fault occurs in one of the power supplies, an alarm is generated.

Redundant 24VDC power supply is arranged as shown in the diagram below.

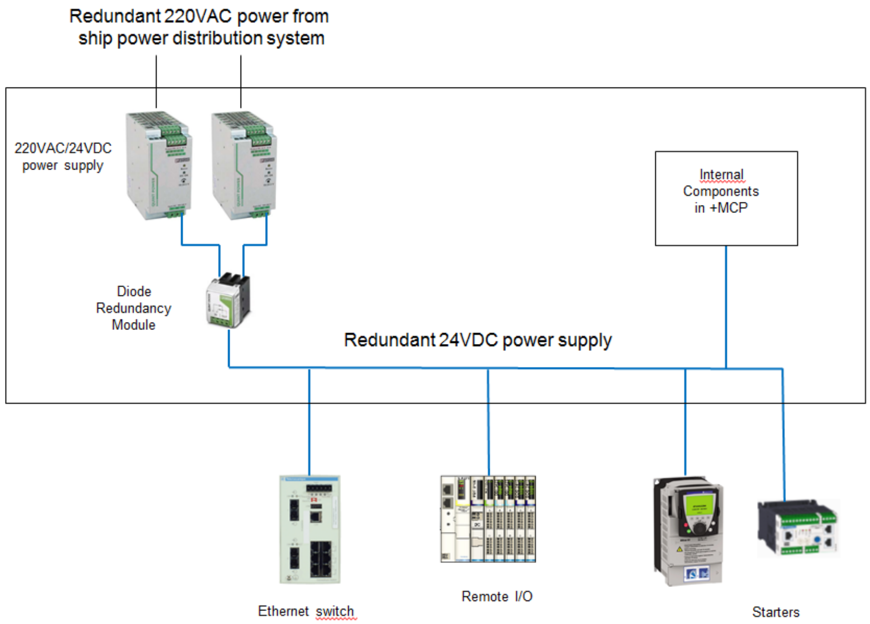


Figure 41: - Redundant Power Supply

7.4 Main automation equipment and control

7.4.1 Electrical and automation Panels (Wärtsilä)

Main Control Panel (+MCP)

The PLC, Data logger and the Operator Screen are located in the Main Control Panel (+MCP).
A remote I/O is also located in the +MCP, which processes the input and the output signals from emergency stop, safety shutdown, switch failure and power supply failure.
It also contains the link between ship automation system (Modbus and hardwired signals) and the ship GPS system.
Figure 4 below gives an overview of the components in the +MCP and how they interact.

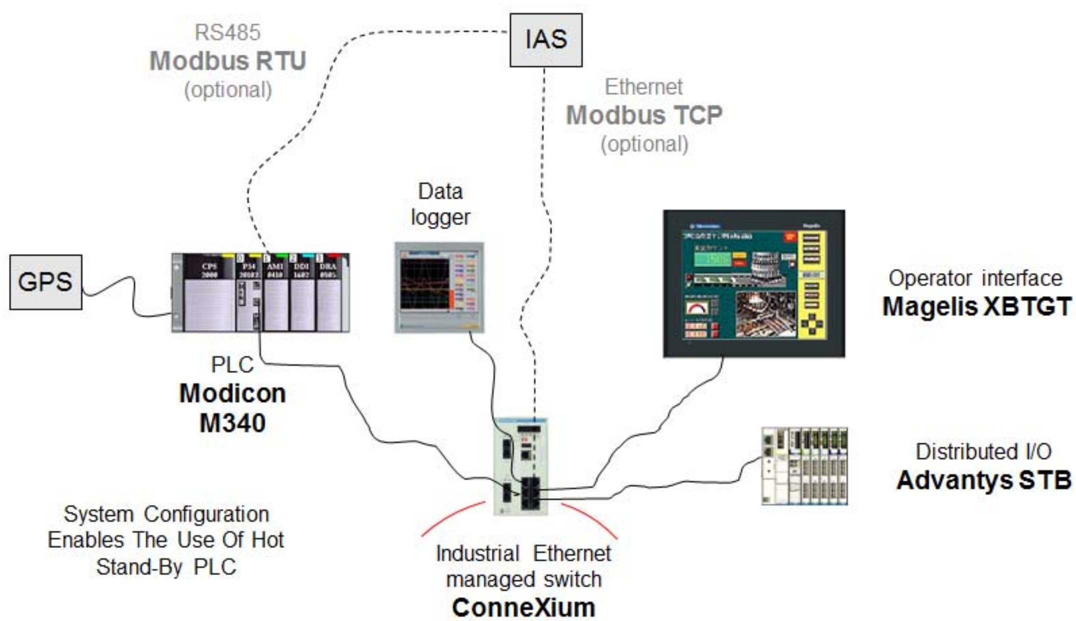


Figure 42: - Overview of the +MCP

+MCP main functions:

- PLC (Control, monitoring and some alarms)
- Safety shutdown system (Specialy required class shutdown alarms)
- Emergency stop system
- Datalogging
- HMI (operator screen)
- Links to ship system

Touch Screen (+TSP)
This is a panel with an additional operator screen which is a duplicate of the main screen (in +MCP). Used to control and monitor the scrubber system. The operator screen is often placed in the Engine Control Room. (Can be loose supply, or fitted in a panel)

Network switch (+NS1, 2…)
The +NS panel contains an Ethernet switch which is the link between the fibre optic and the copper (Cat 5e) ring.
The fibre optic cable utilizes the possibility for more than 100m of cable (Limit of Cat5e), and the advantage of little disturbance from the surroundings.
Cat5e cable is run between local panels, with as short distance as possible.

Effluent Monitoring Module (+EMM)
The effluent monitoring module panel (+EMM) is a remote I/O panel for the effluent, and monitor pH, PAH and Turbidity in the water before discharge overboard.
All I/O is processed in the PLC, located in the +MCP.
Emergency stop is hardwired from +MCP.

Residence Tank Panel (+RET)
The residence tank Panel (+RET) is a remote I/O Panel for the water treatment. These panels, processes the input and output signals for instruments and valves for the different water treatment systems.
All I/O is processed in the PLC, located in the +MCP.
The starter for the tank ventilation fan (DOL or VSD, see el.drawings for details) is also located in this panel.
Emergency stop is hardwired from +MCP.

Process Tank Panel (+PRT)
The process tank Panel (+PRT) is a remote I/O Panel for the closed loop process tank. These panels, processes the input and output signals for instruments and valves in and around the process tank.
All I/O is processed in the PLC, located in the +MCP.
The starter for the tank ventilation fan (DOL or VSD, see el.drawings for details) is also located in this panel.
Emergency stop is hardwired from +MCP.

Water Treatment Plant panel (+WTP)
The water treatment plant panel (+WTP) is a remote I/O panel for instruments and valves in a water treatment system.
All I/O is processed in the PLC, located in the +MCP.
Emergency stop is hardwired from +MCP.

Hydrocyclone I/O Panel (+HC1, 2...)
The hydrocyclone I/O Panel (+HC1, 2…), contains a remote I/O, inputs and the outputs signals from instruments and valves in and around the hydrocyclone. The number of hydrocyclone I/O Panels, varies with the number of hydrocyclones installed.
All I/O is processed in the PLC, located in the +MCP.
The starter for the hydrocyclone pump (DOL or YD, see el.drawings for details) is also located in this panel.
Emergency stop is hardwired from +MCP.

Scrubber I/O Panel (+SC1, 2…)
The scrubber I/O Panel (+SC1, 2….), contains a remote I/O, input and output signals to and from instruments and valves in and around the scrubber. The number of scrubber I/O Panels, varies with the number of scrubbers installed.
All I/O is processed in the PLC, located in the +MCP.
The starter for the sealing air fan (DOL or VSD, see el.drawings for details) is also located in this panel.
Emergency stop is hardwired from +MCP.

Scrubbing Water Supply Pump starter panels (+SWP1, 2…)
Scrubbing water supply pump starter (DOL, YD or VSD) supplies water to the scrubber(s), and vary in size and number from project to project.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Scrubbing Cooling Water Pump starter panels (+SWCP1, 2…)
Scrubbing cooling water pump starter is always a VSD starter, and feeds heat exchangers with cooling water.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.

•Refer to el. drawings and system specification for details.

Reaction Water Pump panels (+RWP1, 2…)
Reaction water pump starter is a DOL, YD or VSD, and supplies sea water to increase pH in washwater overboard discharge in an open loop scrubber systems.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Scrubbing Fresh Water Pump starter panels (+SFWP1, 2…)
Scrubbing fresh water pump starter is a DOL, YD or VSD and supplies fresh water to scrubber(s), and vary in size and number from project to project.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Exhaust Gas Fan starter panels (+EGF1, 2…)
The exhaust gas fan starter is always a VSD starter, controlling the speed of the exhaust gas fan. The purpose of this fan is to lower the back pressure across the scrubber particularly in the case of integrated scrubbers or scrubbers for oil fired boilers.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Deplume Air Fan starter panels (+DAF1, 2…)
The deplume air fan starter is always a VSD starter, controlling the speed of the deplume air fan. The purpose of this air fan is to provide air to the deplume unit and to add some assistance to back pressure control.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Venturi Booster Pump starter panels (+VBP1, 2…)
The venturi booster pump is always a VSD starter, controlling the speed of the venturi booster pump. The purpose of this pump is to raise water pressure in the venture, to increase the particulate matter removal.
Controlled and monitored over Modbus TCP from +MCP.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Water Monitoring Pump P-100 starter panel (+WMP100)
The water monitoring pump P-100 starter is always a DOL. Feeding the inlet water monitoring system with sea/process water to ensure that the acquired measurements can be made. This pump runs when the scrubbing water supply pumps runs.
Emergency stop is hardwired from +MCP.
•Refer to el. drawings and system specification for details.

Water Monitoring Pump P-700 panel (+WMP700)
The water monitoring pump P-700 starter is always a DOL. Feeding the outlet water monitoring system with wash/discharge water to ensure that the acquired measurements can be made. This pump runs when supply or discharge pumps runs.
Emergency stop is hardwired from +MCP.
•Refer to el. drawings and system specification for details.

Water Monitoring Pump P-701 panel (+WMP701)
The water monitoring pump P-701 starter is always a DOL. Feeding the outlet water monitoring system with wash/ discharge water to ensure that the acquired measurements can be made. This pump runs when supply or discharge pumps runs.
Emergency stop is hardwired from +MCP.
•Refer to el. drawings and system specification for details.

Water Pump panel (+WP1, 2…)
The water pump starter (DOL, YD or VSD) are commonly used in various transfer purposes.
Emergency stop is hardwired from +MCP.
Size and layout is depending on system configuration.
•Refer to el. drawings and system specification for details.

Alkali Feed Module panel (+AFM1, 2…)
The alkali feed module Panel (+AFM1, 2….), contains a remote I/O, input and output signals to and from instruments and valves in and around the alkali feed system. The number of alkali feed module Panels, varies with the size of the scrubber system.
All I/O is processed in the PLC, located in the +MCP.
Emergency stop is hardwired from +MCP.
•Refer to el. drawings and system specification for details.

Bleed-off Treatment Unit panel (+BOTU1, 2…)
The bleed-off treatment unit Panel (+BOTU1, 2….), contains a remote I/O (or PLC), inputs and outputs signals to/ from instruments and valves in and around the bleed-off treatment system. The number of bleed-off treatment units, varies with the size and amount of scrubbers in the system.
All I/O is processed in the PLC, located in the +MCP.
Emergency stop is hardwired from +MCP.
•Refer to el. drawings and system specification for details.

Intrinsic Safe Panel (+ISP)
The intrinsic safe panel's purpose is to establish a boundary between a safe and a hazardous (Ex) area. As an example there shall not be a risk of any sparks/arc's in a hazardous (Ex) area because of a short circuit etc.

7.4.2 Electrical and automation Panels (Sub Supplier)

Continuous Emission Monitoring System (+CEMS)
The continuous emission monitoring system is a gas analyser, reading SO_2 and CO_2 (NOx).
Values sent via Modbus TCP to the control and monitoring system.
System layout is depending on supplier.
•Refer to el. drawings and system specification for details.

Scrubbing Water Monitoring Module panel (+SWMM)
Water monitoring system seawater inlet reading: PAH, pH, Turbidity and temperature.
(In hybrid and closed loop systems water density is included)
Values sent on Modbus TCP to control and monitoring system.
System layout is depending on supplier.
•Refer to el. drawings and system specification for details.

Wash Water Monitoring Module panel (+WWMM)
Water monitoring system washwater overboard discharge reading: PAH, pH, Turbidity and temperature.
Values sent on Modbus TCP to control and monitoring system.
System layout is depending on supplier.
•Refer to el. drawings and system specification for details.

7.4.3 PLC

The list below gives an overview of the components that are used.

Table 18 - Components used in PLC

Description	Maker	Product type	Product ID
Processor module	Schneider Electric	Modicon M340	BMXP342000
PLC rack 4 module	Schneider Electric	Modicon M340	BMXXBP0400
Power Supply	Schneider Electric	Modicon M340	BMXCPS2010
Ethernet nodule	Schneider Electric	Modicon M340	BMXNOE0100
Com module	Schneider Electric	Modicon M340	BMX NOM0200

A secondary PLC will be installed; this can be manually started in case of PLC malfunction. This is a copy of the main PLC.

The components have the following characteristics:

- Hot-swappable modules
- Programming trough USB or Ethernet
- Program can be changed without PLC software
- Integrated web server for control and diagnostic

7.4.4 Remote I/O

The list below gives an overview of the components that are used.

Table 19 - Components used in I/O

Description	Maker	Product type	Product ID
Network Interface Module	Schneider Electric	Modicon STB distributed I/O solution	STBNIP2311
Power Supply	Schneider Electric	Modicon STB distributed I/O solution	STBPDT3100K
16 digital input	Schneider Electric	Modicon STB distributed I/O solution	STBDDI3725KS
16 digital output	Schneider Electric	Modicon STB distributed I/O solution	STBDDO3705KS
4 digital output	Schneider Electric	Modicon STB distributed I/O solution	STBDDO3415K
2 analog input	Schneider Electric	Modicon STB distributed I/O solution	STBACI1230K
2 analog output	Schneider Electric	Modicon STB distributed I/O solution	STBACO1225K

The components have the following characteristics:

- Modular distributed I/O system
- Up to 32 modules for each network connection
- Dual Ethernet ports, supporting redundant network
- No programming needed, all done in the PLC

7.5 Network switch

The network switches that are being used are an Industrial Ethernet Managed Switch.

Description	Maker	Product type	Product ID
Ethernet TCP/IP managed switch	Schneider Electric	ConneXium	TCSESM063F2CU1

The network switch has the following characteristics:

- Interface, 2 Fibre-optic and 6 copper connections
- Supports dual redundant Ethernet networks (Ring)
- Redundant power supply
- Ring coupling
- Rings supporting MRP (Media Redundancy Protocol), Fast HIPER Ring and RSTP
- Alarm function: Power supply fault, Data link status and High temperature
- Fully configurable

With a managed switch, it is possible to configure or control the parameters of the device (manage them) and to get access to its internal information.

Redundancy network

By implementing a ring architecture, or a coupled ring, will provide protection against losses of network segments. The ring is constructed using the HIPER-Ring ports. If a section of the line fails, a ring structure of up to 50 switches transforms back to a line-type configuration within 0.2 seconds.

Redundancy power supply

The network switches will be provided with redundant power supply from the Main Control Panel (+MCP), which in turn gets redundant supplies from the ship's power distribution system.

7.5.1 Operator screen

The Operator screens are 15" graphical touch screen with colour.

Description	Maker	Product type	Product ID
Touch screen	Shneider Electric	Magelis XBTGT	XBTGT7340

The Touch screen has the following characteristics:

- 15" graphical touch screens
- TFT Display supporting 65000 colours
- Variable link with PLC
- Web gate and data sharing

7.5.2 Data logger

The Datalogger that is being used is as follows:

Description	Maker	Product type	Product ID
Graphic Datalogger	Eurotherm		6180 XIO

The Datalogger has the following characteristics:

- Tamper proof data logger
- Ethernet connection
- FTP server
- Update database on LAN
- CF-card data storage
- Log 120 variables in 12 groups

7.5.3 Starters

Frequency converters (VSD)

Altivar 61 VSD

The Frequency converters have the following characteristics:

- 200 to 690V
- Monitor values like Temp, Speed, Power, and Voltage…
- Dual Ethernet ports supporting redundant communication

Direct on line starters (DOL)

Tesys T

(DOL) starts are provided for the pumps and most of the fans. Control of this Equipment is provided by a Schneider Tesys T which communicates over Modbus TCP.

The Tesys T have the following characteristics:

- Smart motor protective relay
- Provides Protection, Monitoring and Control
- Control DOL, YD… Starters
- Protects against Phase Loss, Locked Rotor, Over Temp…
- Monitor Voltage, Current, Frequency, Running Time…
- Dual Ethernet ports supporting redundant communication

7.6 Operator station

1. Main operator station is the HMI located in +MCP
2. Secondary operator station (Usually in ECR)
3. Ships automation system IAS (Optional, by serial Modbus line)

7.7 Fallback state – behavior in the event of a network fault

7.7.1 Distributed IO (STB NIP 2311)

The module can be configured to recognize up to three controllers as a master controller. The module should continuously maintain an open connection with at least one master controller.
If the module loses all connections with any of the master controllers:

- It waits a prescribed time (Holdup Time) for a master controller to establish a new connection with the module.
- If no new connection is established before the timeout period expires, the module sets island outputs to their fallback states.

Holdup Time:

- Use the spin control to enter a value of 0 or 300...20000 ms (in increments of 10ms). (Default =1000 ms.)
- The Holdup Time is the period of time that outputs retain their current state without receiving a write command from a master controller. When this period expires, outputs are set to their fallback state.

7.7.2 Motor Starter (TesysT LTM R)

When communication between the LTM R controller and either the network or the HMI is lost, the LTM R controller is in a fallback condition. The behavior of logic outputs O.1 and O.2.

Fallback setting selection can include:

Table 20 - Fallback setting selection

Port Fallback Setting	Description
Hold (O.1, O.2)	Directs the LTM R controller to hold the state of logic outputs O.1 and O.2 as of the time of the communication loss.
Run	Directs the LTM R controller to perform a Run command for a 2-step control sequence on the communication loss.
O.1, O.2 Off	**Directs the LTM R controller to turn off both logic outputs O.1 and O.2 following a communication loss.**
O.1, O.2 On	Directs the LTM R controller to turn on both logic outputs O.1 and O.2 following a communication loss.
O.1 On	Directs the LTM R controller to turn on only logic output O.1 following a communication loss.
O.2 On	Directs the LTM R controller to turn on only logic output O.2 following a communication loss.

The LTM R is configured to “OFF” in the event of communication loss.

Holdup Time:

- Enter a value in sec. (Default =1 s.)
- The Holdup Time is the period of time that outputs retain their current state without receiving a write command from a master controller. When this period expires, outputs are set to their fallback state.

7.7.3 Motor Starter VSD (Altivar 61)

In the event of a network fault, the drive reacts as:
Drive fault

[Freewheel]:	Freewheel stop (factory setting)
[Ramp stop]:	Stop on ramp
[Fast stop]:	Fast stop
[DC injection]:	DC injection stop

The fault displayed will depend on the source of the communication fault.

[Modbus com.]	For integrated Modbus
[CANopen com.]	For CANopen
[Com. network]	For a network card
[External fault com.]	For Ethernet card FDR and IP faults

7.8 Emergency stop and safety shutdown

7.8.1 Emergency Stop

The emergency stop is activated with a push button.

When the button is pressed:

- All pumps and fans shut down.
- Power is removed from all PLC outputs.
- All valves to safe position.
- Alarm is generated in the control system.
- Control system is set to “stop” mode.

The entire emergency stop system is hardwired and independent of the PLC.
The emergency stop button is located at the control station and around main system components.
The emergency stop button has to be manually de-activated before the system start-up sequence can be started.
The illustration below gives an overview of how the safety shutdown and emergency stop is arranged.

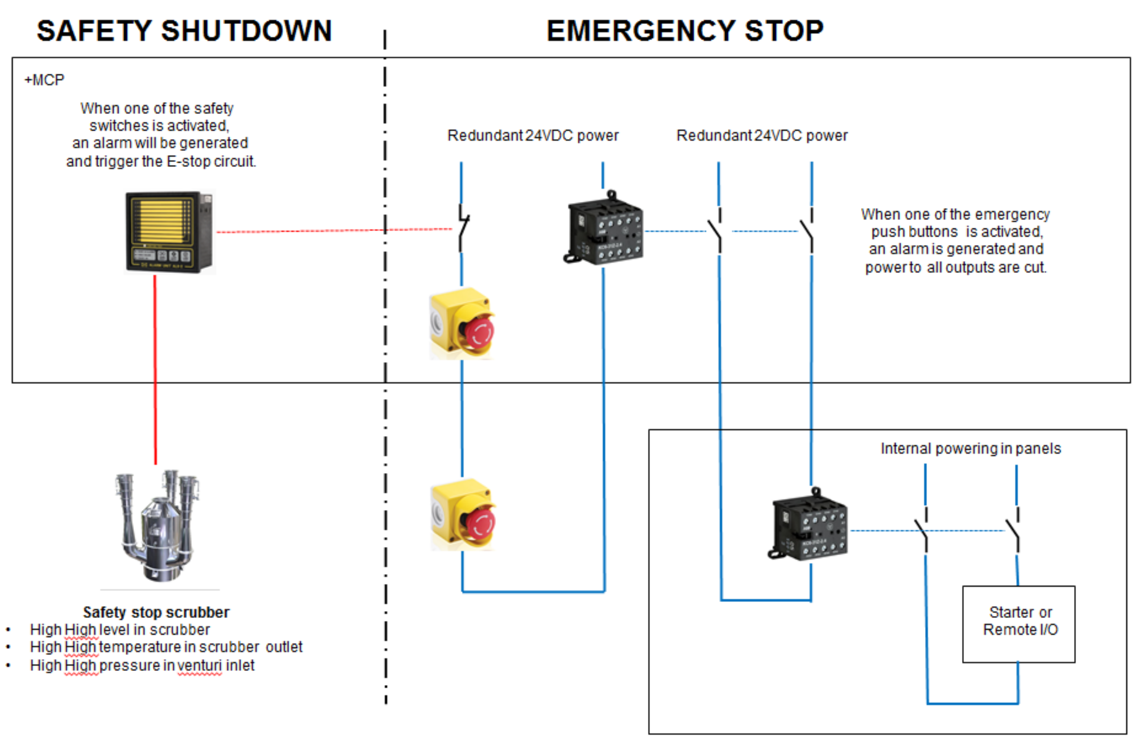


Figure 43: - Emergency stop

7.8.2 Safety shutdowns

The following signals cause immediate system shutdown, and for scrubbers with exhaust gas bypass valve, immediate release of that valve:

1. High-high level in scrubber
2. High-high temperature scrubber outlet
3. High-high pressure venturi inlet

Safety shutdown is similar to emergency stop:

- All pumps and fans shut down.
- Power is removed from all PLC outputs.
- All valves to safe position.
- Alarm is generated in the control system.
- Control system is set to “stop” mode.

The safety shutdown function is hardwired and independent of the PLC.

The illustration above gives an overview of how the safety shutdown and emergency stop is arranged.

7.8.3 Black-out arrangement

Black-out passively stops the system, and after black-out the system will automatically re-set the scrubber system to “stop” mode.

In case of a long black-out in cold conditions, the risk of too low NaOH or scrubbing water temperature needs to be noted.

7.9 System interfaces

7.9.1 Common alarm

The control system is provided with N.C. alarm contacts hardwired to the ship alarm system, contact will open at:

- Loss of power.
- PLC fault.
- System alarms.

These are divided into:

- Critical alarm
- Non-Critical alarm

7.9.2 Ship control system (IAS, PMS, GPS…)

Required interface:

- GPS
- Engine/Boiler run signal
- Engine/Boiler load signal

Optional costumer interface:

- Alarms
- Valve positions
- Values
- Etc.

7.10 Emergency operations

In an unlikely event of a total control system failure, the system has to be operated manually. This means local start of pumps and fans and manual override of valves.

7.11 Redundancy

The availability and functionality of the scrubber has no impact on the availability of the connected engine(s) or boiler(s), because redundancy is ensured either by the capability of hot running or by an exhaust gas bypass valve. Therefore the scrubber and all ancillary systems are categorized as non-essential systems, the only exception being the exhaust gas bypass valve.

There are also no exhaust gas emission related requirements for redundancy. The ship specific SOx Emissions Compliance Plan (SECP) specifies: *In case of malfunction of the system the ship will as soon as possible take corrective actions to restore compliant functionality, or stop using non-compliant fuel. Regulation 3 of MARPOL Annex VI states that “the emission regulations do not apply to any emission resulting from damage to a ship or its equipment, provided that all reasonable precautions have been taken after the occurrence of the damage or discovery of the emission for the purpose of preventing or minimizing the emission”.*

8 Maintenance

As a general rule, maintenance and inspections can be carried out during normal ship operation, including port calls. Maintenance of the scrubber system is composed of generic maintenance tasks of individual pieces of equipment, such as valves and actuators, pumps, electric motors, heat exchangers, tanks, water treatment units, instruments etc.

These components should be inspected regularly for leaks etc, and maintenance work carried out as recommended by the individual component manufacturers, which is summarized into one scheduled maintenance table for the whole scrubber system in the scrubber User's Manual.

In the scrubber unit the need for maintenance is minimal. There are no parts to be greased or oiled. Visual internal inspections of scrubber housing, packed bed (wet filters), spray nozzles, droplet separator and mechanical condition generally should be performed annually, at which time it should be ensured that there is no damage or corrosion of the internal surfaces of the structure of the scrubber, in particular in way of welded connections. Any detected defects should be rectified, and deposits cleaned.

Maintenance openings (hatches) with flange are provided in the scrubber unit for access. The hatches are big enough for a service mechanic to climb in and transport tools and service equipment in and out of the scrubber. The droplet separator is inside the scrubber unit in sections that are installed through an opening from above. Access to droplet separator from above is also preferred as the elements are inspected while walking/crawling on them.

Depending on the scrubber type and configuration, the scrubber unit may contain e.g. the following maintenance openings:

- One hatch above droplet separator
- One hatch above the bottom of packing bed
- One hatch above the bottom of scrubber

The radial orientation can be selected freely, and it does not have to be the same for each hatch. Hatches at spray nozzle level can be omitted if visual view and access to nozzles can be arranged via other maintenance openings; e.g. with scaffolds from bottom to lower stage spray nozzles or with safety harness from droplet separator level to upper stage spray nozzles. Spray nozzles are inspected visually from upper hatch while spray is on (with no exhaust gas) and if the spray pattern is in condition, there is no need to actually climb to each nozzle.

Welding to the structure of the scrubber body including the outside shell should not be carried out without prior consultation with Wärtsilä.

Outside the scrubber, the access area to the hatches should be reasonable. A small platform of approximately $1m^2$ in front of each hatch should be available.

The Continuous Emission Monitoring System (CEMS) needs to be checked and calibrated periodically and filters should be cleaned or replaced at prescribed intervals.

Hydrocyclone filters of Open Loop scrubbers require internal inspection at intervals of approximately 2 years (unless the system monitoring indicates internal fouling). At such time the cover should be removed after isolating the hydrocyclone from the system, and individual cyclone elements removed and the stem 'O' ring seals renewed.

It is essential that the complete system is shut down and isolated (except where stand-by components are provided) and access is proven to be safe, before any maintenance on the system or its components particularly those components where internal access is required, is commenced. This is particularly important for those systems incorporating alkali dosing!

Detailed maintenance instructions are given in the User's Manual, and they should be followed in conjunction with general good housekeeping.

9 Appendixes

9.1 Appendix: NaOH

9.1.1 General

- Typical commercial solution is 50% (weight). Characteristics of 50% solution are:
    - o Density 1.52 t/m^3
    - o Solidifies ("freezes") at 12˚C
    - o Should be kept above 20˚C when pumped
    - o Boiling point ca. 145 ˚C
    - o Transported typically at 20… 40˚C
    - o pH 14
    - o In some cases 20% solution is interesting, at its freezing point is -30˚C. See below. For on deck storage on ships operating in cold environment this could be potential. The two commercially interesting solutions (20 % and 50 %) are shown in the figure below.

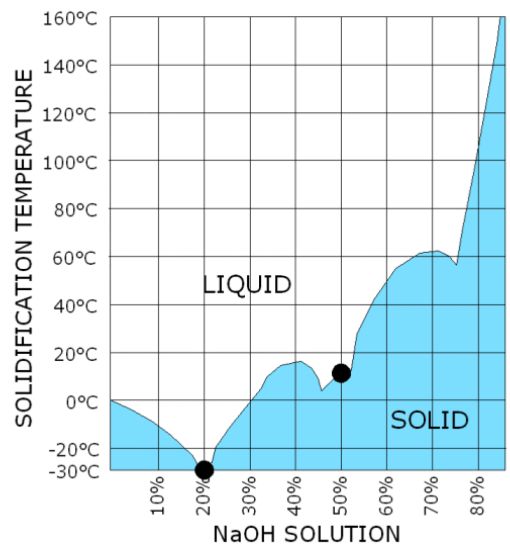


Figure 44: - Solidification temperature of NaOH solution.

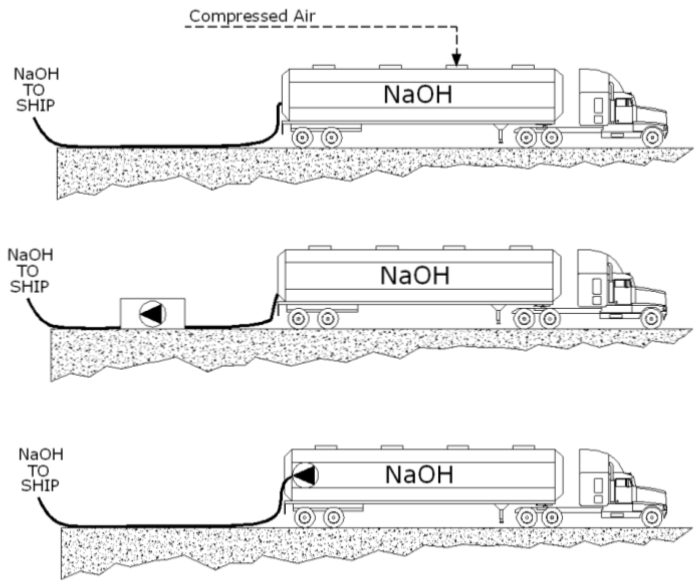
9.1.2 Safety aspects

- Colorless and odorless.
- Causes eye and skin burns: eye and safety showers needed in handling areas.
- Aspiration hazard: ventilation of gases has to be taken care of.
- No fire risk.
- May react with water producing heat and gases, thus affecting fire extinguishing strategies in NaOH storage area.
- Can produce flammable gases when reacting with some metals (e.g. aluminum in contact with NaOH produces hydrogen).
- Liquid should be protected from atmospheric moisture to avoid absorption of carbon dioxide from the air: air pipes, etc. needs to be designed accordingly.

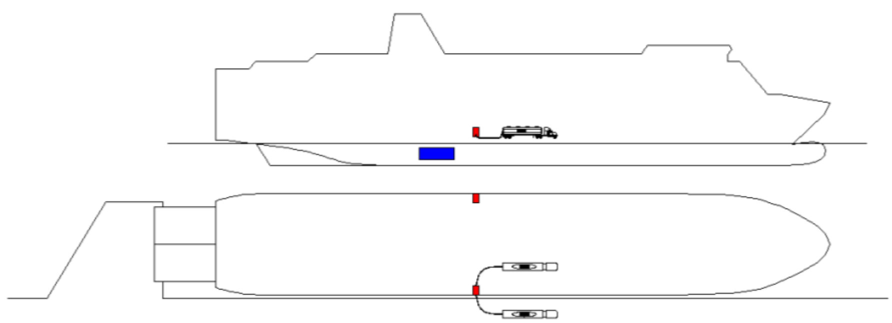
- Contact with aluminum, zinc, brass and tin to be avoided.

9.1.3 Delivery

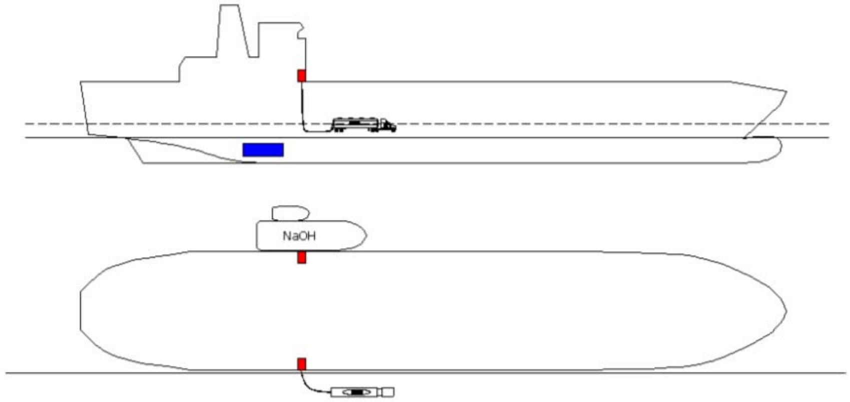
- Smaller quantities (< 5m^3) can be delivered in containers.
- Typically delivered by a tank truck.



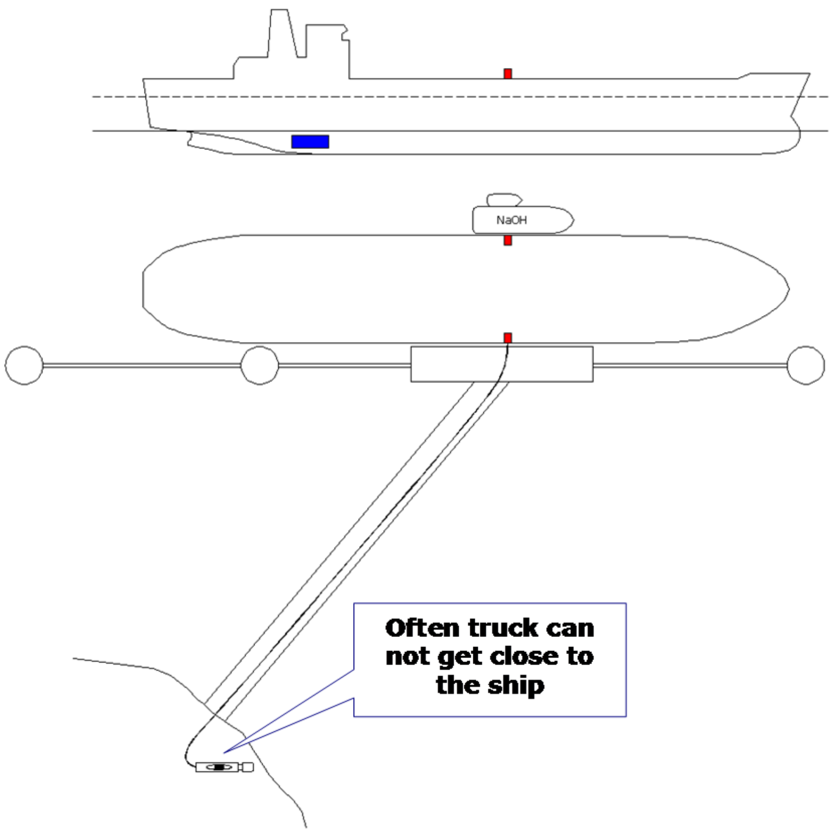
- Delivery to Ferry, RoPax, Cruise Ship



- Delivery to Dry Cargo Ship, Container Ship



- Delivery to tanker



10 Scrubber Nomenclature

Absorber
(Term used in land-based systems, not in marine)

Aeration
Process where air is mixed with water

Alkali
Alkaline chemical (pH > 7 e.g. sodium hydroxide) that is used to neutralize acidic components from e.g. in exhaust gas or process liquids

Alkali Feed Module
Functional system that supplies and controls alkali dosage to the process

Alkali Storage Tank
Tank for storage of alkali

Alkalinity
Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH

Bleed-off
A stream of water that is extracted from the closed loop circulation to remove contaminants

Bleed-off Treatment Unit (BOTU)
Unit for treatment of bleed-off water

Booster Pump
Pump used to supply high pressure scrubbing water to a venturi of a scrubber

Buffer Tank
Tank for liquid flow control purposes

Caustic Soda
(See sodium hydroxide)

Closed loop
Process principle in which the bulk of the scrubbing water is re-circulated

Coagulation
Phenomenon that is often utilized in conjunction with flocculation in water treatment systems. Coagulation chemical neutralizes Zeta potential of colloids and breaks the dispersion

Continuous Emission Monitoring System (CEMS)
Monitoring system provided to monitor emissions to air after scrubbing

Cooling Water
Medium: (typically sea water) that is used for cooling of the scrubbing water

Cooling Water pump
Pump that provides Medium (typically sea water): for cooling of the scrubbing water

Deplume
A unit provided at the cleaned exhaust gas outlet from the EGC unit (scrubber) to mix the cleaned gas and additional heated air supply to reduce the visible plume of the saturated cleaned exhaust gas

Deplume Air Fan
A fan provided to supply additional heated air in the deplume to reduce a visible plume from the funnel outlet

Deplume Air Heater
Heater provided to heat additional air supply for the deplume

Deplume system
Process of conditioning the cleaned / scrubbed exhaust gas to reduce a visible plume at the funnel discharge

Dissolved Air Flotation (DAF)
Technology based on micro bubbles used to separate impurities from bleed-off

Droplet Separator
Separates droplets of scrubber water from the gas flow inside the EGC unit (scrubber)

Dual Water Hybrid Scrubber
EGC system capable of alternating between open loop and closed loop mode, and also running in a combined open and closed loop mode, called hybrid mode

Effluent
Cleaned (closed loop) bleed-off containing dissolved salts, resulting in high density. Corresponds to open loop wash water discharge

EGC Unit (Scrubber) (term used in marine systems)
The unit for washing SO_2 from exhaust gas stream with scrubbing water

Effluent monitoring module (EMM)
Module provided for monitoring the quality of closed loop effluent before discharge to the sea

Exhaust Gas Fan
Fans installed to assist in back pressure control through the EGC unit (scrubber) particularly when operating integrated EGC units (scrubbers) and main stream EGC units (scrubbers) for boilers

Exhaust Gas Recirculation (EGR)
Exhaust gas recirculation for the purpose of NOx reduction of a diesel engine

Flocculation
A process that is often utilized in conjunction with coagulation in water separation process. Colloids are collected to flocks by help of flocculants (e.g. polymer) to enhance separation efficiency

Flotation
Water separation technique in which light-weight impurities are lifted to surface, often with help of micro air bubbles (see DAF), and removed with weir or mechanical skimmer

Flue Gas Desulphurisation (FGD)
A term that is in general use for non-marine applications, more common for stationary installations

Fresh Water
Fresh water can be produced on-board or it is bunkered from ashore. Fresh water quality varies depending on its origin and suitable quality requirements have to be confirmed for each use/purpose

Fresh Water Closed Loop Scrubbing
Scrubbing process that uses fresh water (not sea water) and dosing of alkali to absorb SO_2 from exhaust gas stream

Fuel Oil Combustion Unit
A unit as defined in the legislation such as main or auxiliary diesel engines or oil fired boilers consuming hydrocarbon fuels

Heat exchanger
Used for scrubbing water cooling with cooling (sea) water. Can be also used to heat the deplume air.
Holding Tank

Tank designated to hold water on board to provide for temporary zero discharge, where required. Can apply to closed loop and sea water hybrid (closed) loop operation

Hybrid Scrubber
EGC system capable of alternating between open loop and closed loop mode
Hydrocyclone
The unit that incorporates a number of hydrocyclone elements to make up a treatment unit of required treatment capacity

Hydrocyclone element
A single element used as a water separation technique in which impurities in water are separated based on density differences

IBC Sludge Tanks
Portable IBC (e.g. $1m^3$) containers for collection of sludge removed in the water treatment plant

Integrated EGC Unit (scrubber)
A single EGC unit (scrubber) for cleaning the exhaust gases of several fuel oil combustion units

Lye
(See sodium hydroxide)

Main Stream EGC Unit (scrubber)
A single EGC unit (scrubber) for cleaning the exhaust gas from a single fuel oil combustion unit

Make-up Water
Fresh or sea water that is added to EGC unit scrubbing water to replace any process water losses

MCR
Identifying the Maximum Continuous Rating (power / load) of the fuel oil combustion equipment connected to the EGC unit (scrubber)

Open loop scrubbing
Scrubbing principle based on sea water without recirculation

Packed Bed
Layer of material installed in the scrubber to increase the liquid to gas contact surface

Particulate Matter (PM)
This derives from the combustion process in the engine or boiler and is the by-product from incomplete combustion and comprises unburned fuel and ash in either solid or liquid droplet form

Pre-Conditioning Water
Water used to pre-condition the bleed-off prior to entry into the BOTU

Process Tank
Water from some types of EGC units (scrubbers) running in a closed loop mode (or in some scrubber types in the hybrid mode) flows into the process tank by gravity, and is pumped back to the scrubber. Process tank can be a part of pumping module.

Reaction Water
Water used to increase the pH of the wash water of an open loop scrubber

Reaction Water Pump
Pump supplying sea water to be mixed with the wash water of an open loop scrubber

Residence Tank
Tank to which wash water from the EGC unit (scrubber) is led by gravity for wetting of particles and de-aeration, which in turn leads to more efficient water cleaning in the water treatment plant. Typically this tank is used in sea water open loop systems

Scrubber
The unit for washing SO_2 and PM from exhaust gas stream with scrubbing water (EGC Unit in IMO documents)

Scrubbing
Extraction of SO_x and PM from the exhaust gas using sea water with or without the addition of Sodium Hydroxide (Open/Closed loop)

Scrubbing Water
General term for the water used in the process of removing Sulphur oxides and PM from the exhaust gas

Scrubbing Water Monitoring Module
Module provided for monitoring the quality of scrubbing water to the EGC system, in open loop systems

Scrubbing Water Pump
Pump that provides sea water for open loop, sea water hybrid circulation and circulation of process water in closed loop

Separator
Equipment with rotating bowl for water treatment by centrifugal force

Settling
Water separation technique in which impurities in water are separated by gravity

Sludge
Sludge contains the impurities (such as oil, particulate matter) separated from the wash water or bleed-off

Sodium Hydroxide (Caustic soda, Lye)
Chemical formula NaOH. A chemical that is used to absorb SO_2. Commercially available as water solution and granulates. (*See alkali)*

Venturi
Exhaust gas inlet section to the EGC unit (scrubber), for pre-treatment of the exhaust gas before passing into the main body of the EGC unit

Washwater
Water in open loop systems is the water exiting the scrubber and discharged overboard following water treatment

Washwater Monitoring Module
Module provided for monitoring the quality of washwater before discharge back to the sea, in open loop systems

Washwater Pump
Pumps provided to ensure required differential pressure of the wash water across hydrocyclone unit for efficient operation

Water Treatment Plant
Generic term for the processes provided for cleaning the scrubbing water comprising;

Hydrocyclones for open loop sea water systems
Centrifugal separators for sea water hybrid (closed) loop systems,
BOTU for sea water closed loop systems,
Flocculation system