PAPER ON EMISSION LEGISLATION
(NRMM IN INLAND NAVIGATION AND SULPHUR GAP FOR SEAGOING VESSELS)
THE EFFECTS AND IMPLEMENTATION OF NRMM IN ESTRIN

THE LEGISLATION

The European Regulation 2016/1628 is in force for engines intended for non-road machinery, including marine engines. The aim of this so-called 'Non Road Mobile Machinery' (NRMM) regulation is that the new EU Stage-V emission requirements will have to lead to a reduction in air emissions from inland waterways.

The NRMM Regulation sets out limit values for carbon monoxide emissions (CO), hydrocarbons (HC) and nitrogen oxides (NO_x) for inland waterway engines. In addition, in addition to requirements for the maximum weight of particulate matter (PM), it has also been chosen to impose standards for the number of solid particulate particles (PN). No_x emissions by 70-84% and PM are 92.5% lower than current requirements for CCR-II engines.

The entry into force of THE REGULATION (EU) 2016/1628 (NRMM) OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2016 on rules on emission limit values for pollutants and particulate matter and type-approval for mobile machinery not intended for road, amending Regulations (EU) No 1303/2016. 1024/2012 and (EU) No 1024/2012 167/2013, and amending and repealing Directive 97/68/EC, means that as of 1-1-2019 for engines with a power of power from > 19kW to < 300 kW for new-build vessels, they must meet the new requirements (also known as Stage-V) and after 1-1-2020 for engines with a power of > 300 kW for new-build vessels.

There are still transitional provisions if engines meet the conditions for 'transitional engine'. These 'transition engines' may be built in/accepted for 18/24 months respectively, i.e. until 31-12-2020 for engines < 300 kW and until 31-12-2021 for engines > 300kW.

There are several categories of engines based on the type approval. This depends on whether it is a propulsion or auxiliary engine (incl. bow thruster engines) with a fixed or variable speed.

The manufacturer shall ensure the type-approval. The requirements for this are detailed in the NRMM. Even when there is a 'transitional engines’.

In fact, NRMM means that manufacturers of diesel engines should **not** be allowed to, after respectively 1-1-2019 and 1-1-2020, market engines which do not have type-approval.

IMPLEMENTATION IN TECHNICAL REGULATIONS[1]

As regards the Technical Regulations in inland navigation, the ROSR (legislation for vessels on the Rhine) and directive 2006/87 EC (for vessels on all other EU inland waterways) were merged into ES-TRIN 2017 as of 7 October 2018.

ES-TRIN is evaluated and adjusted every 2 years.

ESTRIN 2019 is the European standard for the adoption of the technical requirements for inland waterway vessels by 1-1-2020.

[1] How to deal with the implementation of NRMM rules in inland navigation is regulated in ES-TRIN 2019 Article 9.

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ES-TRIN 2019 states that internal combustion engines must meet the requirements of Regulation (EU) 2016/1628 .
Only internal combustion engines of the categories are

a) IWP,
b) IWA,
c) NRE with a reference capacity of less than 560 kW or
d) engines recognized as equivalent in accordance with Regulation (EU) 2016/1628,installed.

This conformity of the engines should be demonstrated by a type-approval.

The engines must be indicated on the certificate. This means that an inspection body (for the Netherlands these are the Private Institutions (Pi's) and Class) must establish that the engine complies with the required emission on the basis of the type of approval, the installation in accordance with the type of approval checks, issue an installation declaration and ensures that the new engine is entered into the vessel's certificate.

Stage-V Standards

Stage-V emission limit values for engines in non-road mobile machines (category NRE) are shown in Table 4.
These standards apply to diesel engines (CI) from 0 to 56 kW and to all types of engines above 56 kW. Engines of more than 560 kW used in generator sets (NRG category) must meet the standards set out in Table 5 (NRSC and NRTC test cycles).

Table 4
Stage V emission standards for nonroad engines (NRE)

Category	Ign.	Net Power	Date	CO	HC	NOx	PM	PN
		kW		g/kWh				1/kWh
NRE-v/c-1	CI	P < 8	2019	8.00	7.50[a,c]		0.40[b]	-
NRE-v/c-2	CI	8 ≤ P < 19	2019	6.60	7.50[a,c]		0.40	-
NRE-v/c-3	CI	19 ≤ P < 37	2019	5.00	4.70[a,c]		0.015	1×10^{12}
NRE-v/c-4	CI	37 ≤ P < 56	2019	5.00	4.70[a,c]		0.015	1×10^{12}
NRE-v/c-5	All	56 ≤ P < 130	2020	5.00	0.19[c]	0.40	0.015	1×10^{12}
NRE-v/c-6	All	130 ≤ P ≤ 560	2019	3.50	0.19[c]	0.40	0.015	1×10^{12}
NRE-v/c-7	All	P > 560	2019	3.50	0.19[d]	3.50	0.045	-

[a] HC+NOx
[b] 0.60 for hand-startable, air-cooled direct injection engines
[c] A = 1.10 for gas engines
[d] A = 6.00 for gas engines

Table 5
Stage V emission standards for generator set engines above 560 kW (NRG)

Category	Ign.	Net Power	Date	CO	HC	NOx	PM	PN
		kW		g/kWh				1/kWh
NRG-v/c-1	All	P > 560	2019	3.50	0.19[a]	0.67	0.035	-

[a] A = 6.00 for gas engines

Stage-V Regulation introduced a new limit for emissions of particle numbers.

The PN limit is designed to ensure that a highly efficient particle control technology, such as wall flow particle filters, is used on all the engine categories involved. The Stage-V Regulation also tightened the mass-based PM limit for different engine categories, from 0.025 g/kWh to 0.015 g/kWh.

Phase III A (CCR II) standards introduced emission limit values for engines used in inland waterway vessels, Table 6. Engines are divided into categories based on displacement (swept volume) per cylinder and net output power. The engine categories and standards have been harmonized with US standards for ship engines.
There are no phase III B or phase IV standards for vessels.

Table 6
Stage III A emission standards for engines in inland waterway vessels

Category	Displacement (D)	Date	CO	HC+NOx	PM
	dm^3 per cylinder		*g/kWh*		
V1:1	D ≤ 0.9, P > 37 kW	2007	5.0	7.5	0.40
V1:2	0.9 < D ≤ 1.2		5.0	7.2	0.30
V1:3	1.2 < D ≤ 2.5		5.0	7.2	0.20
V1:4	2.5 < D ≤ 5	2009	5.0	7.2	0.20
V2:1	5 < D ≤ 15		5.0	7.8	0.27
V2:2	15 < D ≤ 20, P ≤ 3300 kW		5.0	8.7	0.50
V2:3	15 < D ≤ 20, P > 3300 kW		5.0	9.8	0.50
V2:4	20 < D ≤ 25		5.0	9.8	0.50
V2:5	25 < D ≤ 30		5.0	11.0	0.50

The emission limit values for inland waterway vessels have been significantly tightened under the Stage V Regulation (Stage V). The limits of phase V, Table 7, apply to propulsion engines (IWP) and auxiliary engines (IWA) of more than 19 kW, including engines of all types of ignition.

Table 7
Stage V emission standards for engines in inland waterway vessels (IWP & IWA)

Category	Net Power	Date	CO	HC[a]	NOx	PM	PN
	kW		*g/kWh*				*1/kWh*
IWP/IWA-v/c-1	19 ≤ P < 75	2019	5.00	4.70[b]		0.30	-
IWP/IWA-v/c-2	75 ≤ P < 130	2019	5.00	5.40[b]		0.14	-
IWP/IWA-v/c-3	130 ≤ P < 300	2019	3.50	1.00	2.10	0.10	-
IWP/IWA-v/c-4	P ≥ 300	2020	3.50	0.19	1.80	0.015	1×10^{12}

[a] A = 6.00 for gas engines
[b] HC + NOx

UNDER WHAT CONDITIONS CAN TRANSITIONAL MOTORS BE INSTALLED?[2]

Instead of an Stage V IWP, IWA and equivalent engines, a transitional engine can be installed on board a barge provided:

1. The production date of the vessel not older than 18 months after the start of the transitional period (being 30.6.2020 for P < 300 kW and 30.6.2021 for P ≥ 300 kW); and
2. The engine complies with the last entry into force emission limits as defined in the relevant legislation applicable on 5 October 2016 (being RVIR CCNR II or Directive 97/68/EC); and
3. The engine has not been marketed later than 24 months from the applicable date for placing on the market as indicated in Annex III of the Directive (EU) 2016/1628 (being 1.1.2021 for P < 300 kW and 1.1.2022 for P ≥ 300 kW); and
4. The vessel did not enter the market later than 24 months from the applicable date for the placing on the market as indicated in Annex III of the Directive (EU) 2016/1628 (being 1.1.2021 for P < 300 kW and 1.1.2022 for P ≥ 300 kW); and
5. The engine Manufactured Is before the start of the transition period (Being 1.1.2019 For P < 300 Kw And 1.1.2020 For P ≥ 300 (kW).

The transitional period for NRE engines, used instead of IWA and IWP, shall be the same as applicable to the IWA and IWP engines (same dates as above).

Note: the last applicable emission limits as defined in Directive 97/68/EC of 5 October 2016 are:
1. In the case of propulsion and auxiliary engines of more than 560 kW:
    - V (37 kW ≤ P) - EU-stage IIIA
2. In the case of auxiliary engines under 560 kW:
    a) For variable-speed engines, the categories
    - K (19 kW ≤ P < 37 kW) - EU stage IIIA
    - P (37 kW ≤ P < 56 kW) - EU stage IIIB
    - R (56 kW ≤ P < 130 kW) - EU internship IV
    - Q (130 kW ≤ P ≤ 560 kW) - EU internship IV

    b) For engines with a constant speed the categories
    - K (19 kW ≤ P < 37 kW) - EU stage IIIA
    - J (37 kW ≤ P < 56 kW) - EU stage IIIA
    - I (56 kW ≤ P < 130 kW) - EU stage IIIA
    - H (130 kW ≤ P ≤ 560 kW) - EU stage IIIA

WHAT MODIFICATIONS TO ENGINES ARE ALLOWED?[3]

A modification that does not result in change of emission related parameters, including drawings and descriptions included in the approval type information package, is permitted.

Additionally, an engine must be installed in accordance with the manufacturer's installation guidelines. Failure to comply can be seen if they are not compliant (not meeting the type of approval) of the engine.

[2] *Reference is made to: Directive (EU) 2016/1628, Article 3(33), Article 3(32), Article 58(3)(5)(6) and (7)*
[3] *Reference is made to: Directive (EU) 2016/1628, Articles 8, 9 and 10*

Where a person modifies an engine in such a way that it no longer meets the emission requirements laid down in the type-approval, that person is responsible for regaining a type of approval or re-complying with the emission requirements for the motor category or sub-category.

Where an importer/ distributor modifies the engine in such a way that it may be that the engine meets the emission requirements as laid down in the type of approval is at stake, the importer/distributor will be seen as the manufacturer (Original Equipment Manufacturer (OEM)) and thus become fully responsible for obligations such as warranty, product description, liability) as a manufacturer, including compliance with the emission requirements as laid down in the type Approval.

If an OEM or instance acting as an OEM does not follow the manufacturer's instructions or makes adjustments to the engine which negatively affects engine emissions, this OEM will be seen as a manufacturer and thus fully responsible for obligations as a manufacturer, including compliance with emissions requirements as laid down in the type of approval.

The motor manufacturer may carry out modifications to the engine in such a way that the engine becomes a different type of approval from that manufacturer, even if the engine with its properties is going to belong to another category or sub-category. The engine manufacturer is responsible for meeting the engine applicable type approval, including the necessary emission markings on the engine.

Using another fuel as indicated in the type of approval or addition to the fuel also results in a change in the type of approval.

ADJUSTMENT OF TYPE APPROVAL[4]

A modification/modification of an engine type that changes one of the data included in the information package, including fuel, drawings and descriptions, requires that type approval be changed.

Only the engine manufacturer, as holder of the type of approval, requests such a change and comes from the type approval authority (in Nederland the RWD) which originally certified the engine type. If the approval authority finds that inspections or tests should be repeated for the submission of a change, it shall inform the manufacturer accordingly. Where the data contained in the information package has been changed without the need to repeat inspections or tests, such an amendment shall be called a 'revision'. In other cases, it is called an extension and the extension of the type approval number should be indexed.

If the production of the original engine type is to continue in addition to the modified engine type, the modified engine type may need to become an additional engine type. In the case of an engine family, if the parameters of the modified engine type remain within that of the engine family, the additional engine type may be added to the engine family and retain the same type approval number with or without indexation the Extension number depends on whether additional tests were needed.

If there is no engine family or if the modified engine does not fit within the family parameters, a new type approval must be granted.

[4] *Referenced to: Directive (EU) 2016/1628, Article 3(50), 8 and 27 in line with Chapter VI and the Implementing Directive (EU) 2017/656, Annex I including the Annexes*

ENGINES OF PLEASURE CRAFT[5]

Engines for recreational craft not defined in EU Directive 2013/53/EU and which are not excluded from the scope of Directive (EU) 2016/1629 by operating normally on tidal water and which only temporarily sail on inland waterways are subject to the requirements of Regulation (EU) 2016/1628.

In short; The propulsion plant of recreational craft sailing on the EU should also meet NRMM emission requirements in the case of new construction or replacement after 1-1-2020 and therefore need to be equipped with Stage-V engines.

AFTERTREATMENT SYSTEMS

According to Regulation (EU) 2016/1628 , an after-treatment system necessary to meet the applicable emission limit values is part of the engine. EU type-approval is granted as a single unit for the entire system.

A single entity (OEM) must take responsibility for the type-approval and placing on the market of that fully approved unit. Only combinations in accordance with EU type-approval are allowed. It is not permitted to market an engine without the necessary type-approval and then to set up an exhaust post-treatment system without type-approval of the entire system in accordance with the requirements of Regulation (EU) 2016/1628 and 2017/654.

Any additional after-treatment or other devices installed in the exhaust system shall **not** be considered as part of the engine's emission control system and shall not be considered when inspection of an engine for the conformity with type-approval of Regulation (EU) 2016/1628. Additional equipment installed should not violate the installation of the engine manufacturer requirements, for example exceeding the exhaust backpressure limits.

EXCHANGE ENGINES

Definition 'exchange engine' means An engine that:

1. only used to replace an engine already on the market and is mounted in mobile machines not intended for the road, and

2. meets an emission phase lower than that applicable to the date on which the engine is replaced;

REPAIR OF ENGINES[6]

When is a repair of a propulsion engine so extensive that the repaired engine should be considered a replacement engine? Is the replacement of the engine block considered a simple repair or as a replacement for the engine in particular?

In accordance with Chapter 24 of the ROSR (or Chapters 24 and 24a of Directive 2006/87/EC), replacement engines could only be installed until 31 December 2011 and under certain conditions.

Under ES-TRIN 2017, Article 9.01, fourth paragraph, the installation of replacement engines ('exchange engines') is expressly prohibited.

[5] *Reference is made to: Directive (EU) 2016/1628, Article 2*

[6] Reference is made to Chapter 9, in particular Article 9.01 - Repair of an existing engine and a replacement engine

This results in the following question: What repairs are allowed on an existing propulsion engine installed on board a ship, especially with regard to the replacement of parts?

Answer:
Allow repairs are;

- Repairs carried out in accordance with type-approval and the existing type of approval process report of engine characteristics are, and
- Provided that the identity of the repaired engine can be traced back to the engine originally placed on the market and installed on the vessel, where no new engine is created by that repair.

Explanation:
This option provides for the need to set a limit to what is considered a repair and in this way enables the competent authority to check.
The owner of the ship must be able to provide evidence regarding the traceability of the engine and the repairs carried out on this engine. This option is entered by the following arguments;

- EU regulations are based on the criterion of placing on the market (Directive 97/68/EC, Regulation (EU) 2016/1628).
  A repair should not lead to the marketing of a new engine. If the identity of the engine remains unchanged, the engine can be used and restored to infinity.

- Where an engine has been placed on the market in accordance with Regulation (EU) 2016/1628, Directive 97/68/EC or before this Directive, there is no restriction on the repair or reconstruction of an engine with parts or parts to the extent that the original specifications of the engine emission control system are respected.

- The origin of the parts (including the engine block) does not affect, but these components must comply with the manufacturer's specifications to comply with type-approval.

Note:
An engine should also be considered as a replacement engine if, as a result of a repair, it should be classified in another engine category in accordance with the NRMM Regulation.

GLOBAL SULPHUR GAP PER 1-1-2020 FOR SEAGOING VESSELS[7]

From 1st January 2020, the limit for sulphur in fuel oil used on board of ships operating designated emission control areas will be reduced to 0,50% m/m (mass by mass), from 3,50% m/m in order to reduce SO_x emission.

This limit is set in Annex VI of the International Maritime Organization (IMO) of the International convention for Prevention of Pollution from Ships (MARPOL).

To comply, ships can;

- use a compliant fuel oil with a sulphur content of max. 0.50%
- if exceeding the 0,50%, use an Exhaust Gas Cleaning System (scrubber)
- use an alternative fuel such as LNG or Methanol

The main type of “bunker” oil for ships is heavy fuel oil, derived as a residue from crude oil distillation. Crude oil contains sulphur which, following combustion in the engine, ends up in ship emissions. Sulphur oxides (SO_x) are known to be harmful to human health, causing respiratory symptoms and lung disease. In the atmosphere, SO_x can lead to acid rain, which can harm crops, forests and aquatic species, and contributes to the acidification of the oceans.

IMO regulations to reduce sulphur oxides (SO_x) emissions from ships first came into force in 2005, under Annex VI of the International Convention for the Prevention of Pollution from Ships (known as the MARPOL Convention). Since then, the limits on sulphur oxides have been progressively tightened.

From 1 January 2020, the limit for sulphur in fuel oil used on board ships operating outside designated emission control areas is reduced to 0.50% m/m (mass by mass).
For ships operating outside designated emission control areas the previous limit for sulphur content of ships’ fuel oil was 3.50% m/m, the limit for seagoing vessels is 0.50% m/m, since1 January 2020.

There is an even stricter limit of 0.10% m/m in effect in emission control areas (ECAS) which have been established by IMO. This 0.10% m/m limit applies in the four established ECAS: the Baltic Sea area; the North Sea area; the North American area (covering designated coastal areas off the United States and Canada); and the United States Caribbean Sea area (around Puerto Rico and the United States Virgin Islands).

Fuel oil providers supply fuel oil which meets the 0.10% m/m limit (such as marine distillate and ultra low sulphur fuel oil blends) to ships which require this fuel to trade in the ECAs.

For comparison:

Already since January 1st 2011, the maximum sulphur content in gasoil for inland navigation is **0.001% m/m**, being 10 mg/kg. In inland navigation mainly EN 590 diesel fuel is used.

[7] Information form IMO and Annex IV IMO/MARPOL

Occurring problems[8]

Regretfully in January 2020 there was a four- to five-month backlog of vessels that should have been retrofitted by the end of 2019. The number of vessels that need to be retrofitted has accumulated so it will probably take until April or May to complete all scrubber installations. The reasons for the backlog are manifold. Material shortages and limited yard capacity are the biggest issues.

For example, there is only a limited number of manufacturers of GRE pipes in China where most scrubbers are installed. Designers and yards have a high workload of retrofit installations, and lack of staff has doubled the installation time at yards from 40 to 80 days.

From 1 January 2020 vessels must run on very low-sulphur fuel oil (VLSFO) or with scrubbers. If a scrubber has not been installed in time, operators need to switch to VLSFO until a scrubber has been installed and approved.

An even harder deadline is 1 March 2020: from this date on, even the carriage of high-sulphur fuel oil (HSFO) on vessels without scrubbers is prohibited. This means that operators of ships not equipped with scrubbers must remove all HSFO from board and clean the tanks. They will only be allowed to carry HSFO again and use it as fuel after installing a scrubber system.

The price of a scrubber is about 200 USD per tonnes of fuel, long-term precise price predictions are very difficult. Choosing the right material and coatings to avoid corrosion of the piping is essential as well. GRE pipes with a diameter of up to one metre need supporting struts to avoid damage when litres of heavy wash water flushes through them.

Presently already noted problems are leakage and corrosion of SO_x scrubber overboard pipes, sensor failures are also a big concern, and adhering to planned maintenance intervals is of utmost importance. When a sensor fails, the control system can get the wrong data and cause an incorrect or unnecessary operational response.

Misleading sensor data can also falsely suggest that emissions are within limits and only when the emissions are checked by an authority will this be detected. This can lead to high fines and even in some the responsible officer might even be arrested.

Some EU and Chinese ports have fitted sensors at the quayside, and on some occasions, PSC officers equipped with a handheld sensor have boarded to check emissions. In for instance the Netherlands drones are also used in some areas to measure vessel emissions.

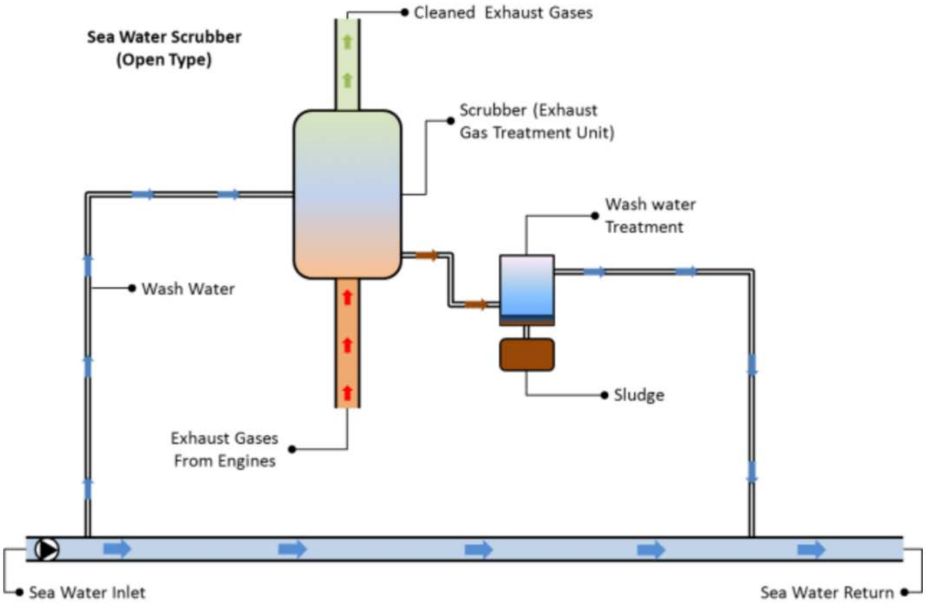
The effects of low sulphur fuel on the engine is also an subject to be looked into, as is the methods / procedures of switching over in time from HSFO to VLSFO when approaching ECAS areas.

[8] Publication DNV-GL 16-1-2020

Scrubber systems

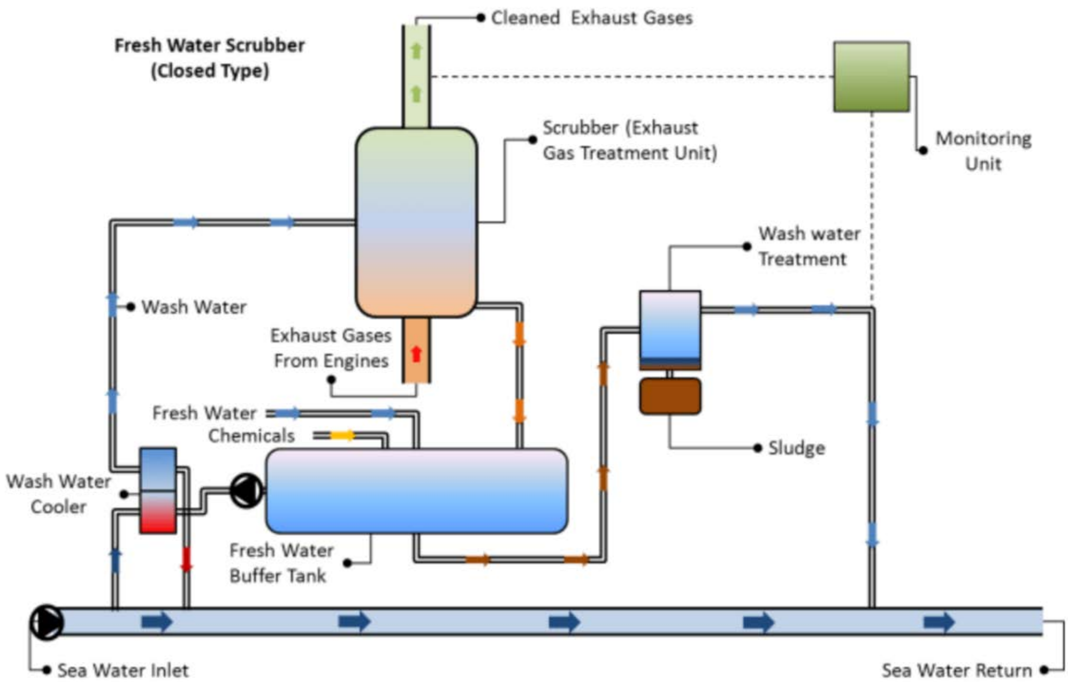
Open type Scrubber

The open type uses sea water to wash the exhaust gases. The wash water is then treated and discharged back to sea, with the natural chemical composition of the seawater being used to neutralize the results of SO_2 removal. Open seawater typically systems use 45m^3/MW h for scrubbing.



Closed type Scrubber

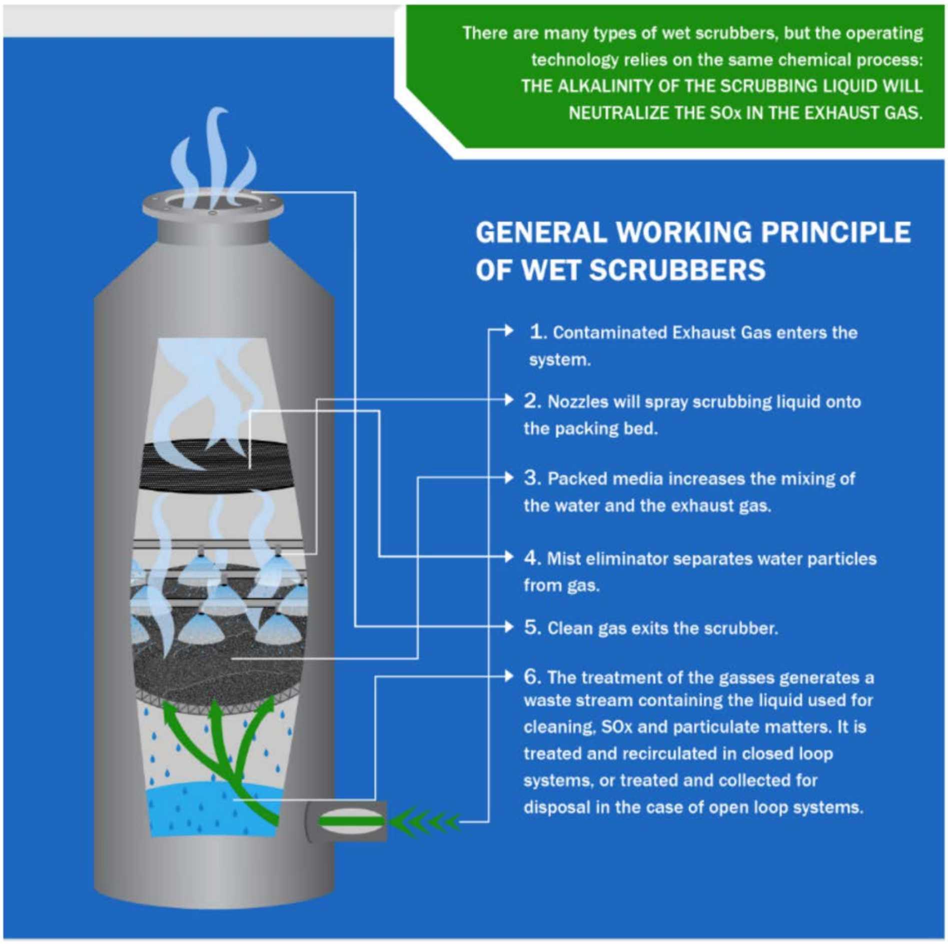
The closed type uses fresh water in "closed" fresh water circuit that is treated with an alkaline chemical such as caustic soda neutralization and scrubbing. The wash water is re-circulated and the losses is made up with additional freshwater. A small quantity of the wash water is bled off to a treatment plant before discharge to sea. Typically closed freshwater systems have a discharge rate of 0.1- 0.3m^3/MW h. The system could also be designed with a holding tank for zero discharge for a certain period.



Hybrid Scrubber

A hybrid is, as the name suggests, some kind of mix between both systems. At Wärtsilä the name is used to identify a system that can run in both open loop and closed loop, enabling flexibility for customers operating in both low and high alkalinity areas. The term “hybrid” is also being used for other products, such as an open loop system where caustic soda (NaOH) is being added to the water to give the alkalinity already in the seawater an extra boost.

General working principle of a wet scrubber



AFTER TREATMENT SYTEMS INLAND NAVIGATION

Soot filter

A diesel engine emits soot particles, they are collected in modern diesel engines in a DPF or soot filter. The particulate filter is part of the exhaust system, the soot filter is the component that filters harmful particles out of the exhaust gas. After a certain number of business hours, the soot filter has become full of soot particles. The filter is then automatically burned clean, converting the soot particles into carbon dioxide (water and ash). This clean burn is called regenerating.

Different sensors in or on the filter measure values such as pressure and temperature. The engine computer (ECU or Motor management system) checks these values and when necessary it starts regenerating the particulate filter. In practice, however, we notice that this process, however, is little or nothing.

Soot filter systems often use high-quality and robust Silicon Carbide filter elements. These elements consist of a porous ceramic material in which the channels are sealed around and around on one side. In this way, a very good filtering of the exhaust gases is obtained. In the channels a thin layer is deposited that consists of soot and ash. This thin layer ensures the final fine filtering of the soot particles.

The ash in the exhaust gases comes from the fuel and lubrication oil and remains in the back of the channels while the soot burns. This process is called regenerating.

There are two methods to regenerate the soot stored in the filter:

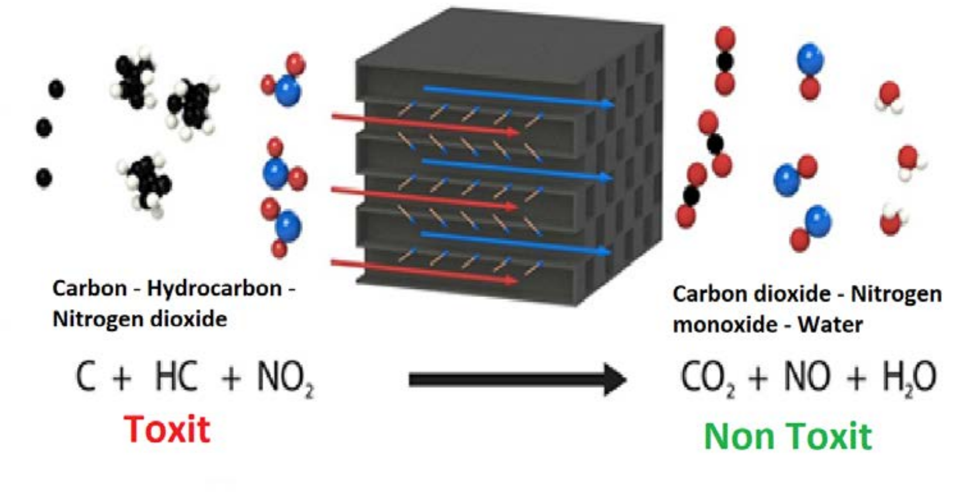
The first method is to combine the combination of oxidation catalyst (DOC) with a non-coated soot filter. This method is very much applied in the automotive industry and road transport.
The oxidation catalyst is equipped with precious metal such as platinum or palladium and converts part of the nitric oxide (NO) which is in the exhaust gases into nitrogen dioxide (NO_2). This nitrogen dioxide is normally only formed in the atmosphere.
Nitrogen dioxide is a reactive substance that oxidizes (burns) the soot stored in the particulate filter (carbon and hydrocarbons) to carbon dioxide (CO_2) and water (H_2O).
The design of the oxidation catalyst should be carefully adjusted to the engine to prevent too much nitrogen dioxide from forming.

This can lead to a yellow/brown discoloration of the exhaust gases in certain situations. For this reason, this method of regeneration is usually combined with an SCR system to reduce excess nitrogen oxides.

A great advantage of this method is that the regeneration of soot filters already takes place at low temperatures (between 250-400°C) and, as it were, continuously regenerate. An important plus is that replacement and operating costs are significantly lower than in the second method.

One limitation is that the oxidation catalyst can only be applied with ultra-low sulphur fuel such as EN590. In sulphurous fuel such as DMA or DMX, the oxidation catalyst would prematurely lose its effect by attaching the sulphur to the precious metal.

Chemical reactions NO_2 regeneration filter

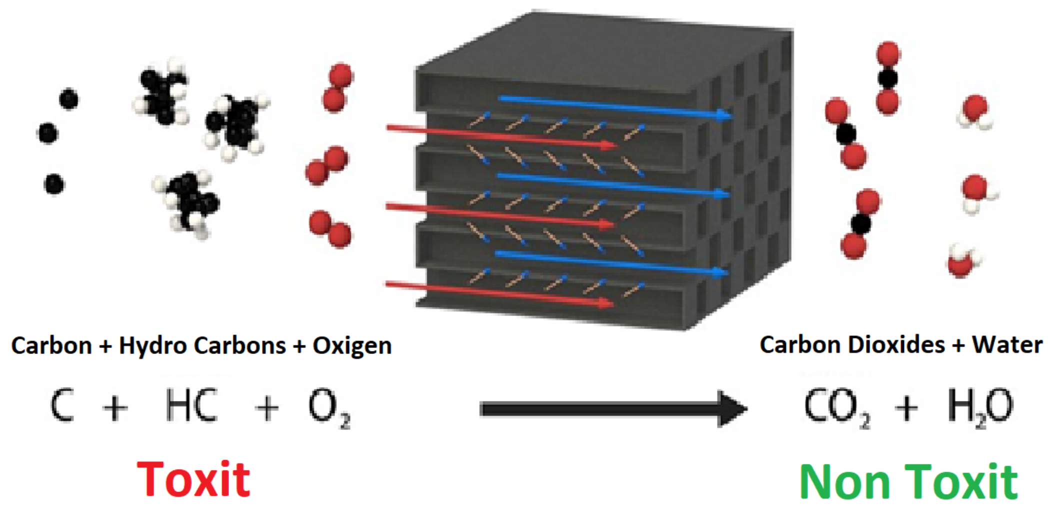


The second method for regenerating the soot filters is to provide the soot filters with a catalytic layer or coating. This layer reduces the oxidation or combustion temperature of the soot stored in the filter. Without this coating, soot would not burn until about 600°C. With the catalytic "sidekick", the oxidation temperature can be reduced to around 350 - 400°C. Because this temperature is higher than the first method, in most cases a form of active regeneration is required, periodically increasing the temperature of exhaust gases with a burner or electrical heating element above 500°C.

Advantage of this method is that certain types of coated soot filters (called cDPF) are reasonably resistant to sulphur. The high regeneration temperatures also allow the sulphur to oxidize and do not remain in the filter.

Drawback is that the coating will have to be replaced relatively quickly and eventually the complete soot filters. In addition to the fact that more frequent active and at a higher temperature, operating costs in this method are higher that with the first method.

Chemical reactions O_2 regeneration filter



Disadvantages of a particulate filter may be that the soot filter system functions less well at some point, for example, because the installation does not get to temperature properly (low power sailing) short. Or the soot filter (DPF) is too full of ash particles which means that the storage capacity has become insufficient. The resulting soot and ash accumulation in the soot filter with adverse points as a result:

- Rise in oil levels
- High regeneration frequency.
- Car goes into emergency run (reduced power)
- Higher fuel consumption
- Display or interference memory failures

Causes of this may include:

- Faulty exhaust gas recirculation system (EGR).
- Turbo or turbo control.
- Leakage of inlet air cooling system.
- Air mass gauge measures traffic value.
- Sensors in the exhaust are faulty or give wrong value.
- Extreme pollution of the intake manifold.
- The maximum storage capacity has been achieved by high number of turning hours.

Life of a particulate filter

De lifetime depending on the type of particulate filter. Soot filters that have a catalytic coating last significantly less than filters without this coating.

The life of a catalytic coated soot filter is affected by fuel quality, (sulphur content), lubricating oil quality, exhaust gas temperature, regeneration temperature and mechanical damage during maintenance (rinsing).

With an uncoated filter, the influence of fuel and lubrication oil quality is less. Furthermore, the filter is not sensitive to exhaust gas temperature and regeneration temperature. For EN590 inland inland applications, the expected life span is above 40,000 hours.

SCR Catalyst

There are many types of catalysts. The common SCR catalysts consist of a combination of titan oxide with a very small amount of bound vanadium oxide as active substance. Within this group there are many variations. There are full extrudate catalysts. These consist entirely of active ceramic material. And there are catalysts with metal substrate as a base. In addition, there are thermal-stabilized variants that can be applied again at higher temperatures. Every choice has its downside. Catalysts suitable for low temperatures give a worse NO_x reduction at high temper times and vice versa. The standard SCR catalysts that we apply for EN590 fuel in inland navigation meet between 220 and 520 °C in the temperature area.

For the SCR De-Nox systems, a urea solution is injected into the hot exhaust gases. Urea is a connection between carbon and ammonia. The chemical composition is $CO(NH_2)_2$

Above 200°C, the bound ammonia is released. This ammonia is used to reduce harmful nitrogen oxides.

When the combustion temperature increases, the efficiency increases and reduces CO_2 emissions, but emissions of nitrogen oxides are also increasing. At high temperatures, nitrogen can connect to oxygen and form harmful nitrogen oxides.

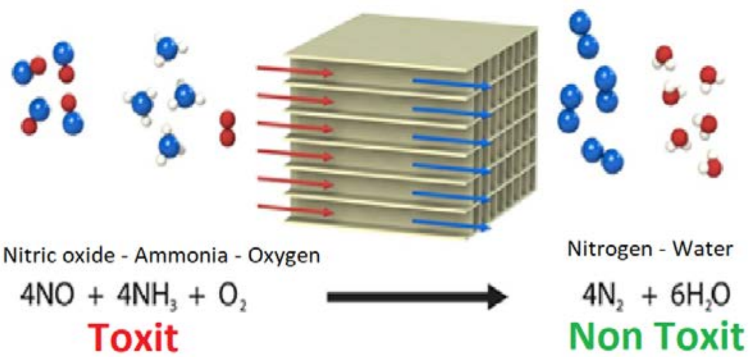
Because it is virtually impossible to prevent nitrogen oxides from being released at a high combustion temperature, it has been chosen to cause nitrogen oxides to occur in the engine but to capture them before they end up outdoors.

An oxidation catalyst or Diesel Oxidation Catalyst (DOC) is made from very thin corrugated layers of stainless steel with a very thin layer of particles of precious metal such as Platinum and/or Palladium. This precious metal reduces the oxidation (=combustion) temperature of hydrocarbons (CH) and carbon monoxide (CO). The diesel air and fat soot disappears as a result. An oxidation catalyst becomes active from around 200°C.
In addition, some of the nitric oxide (NO) contained in the exhaust gases will be oxidized to nitrogen dioxide. This last substance can be used to oxidize (burn) the soot stored in the particulate filter into carbon dioxide. In addition, a correct balance between NO and NO_2 ensures a fast and very high NO_x conversion at relatively low temperatures.

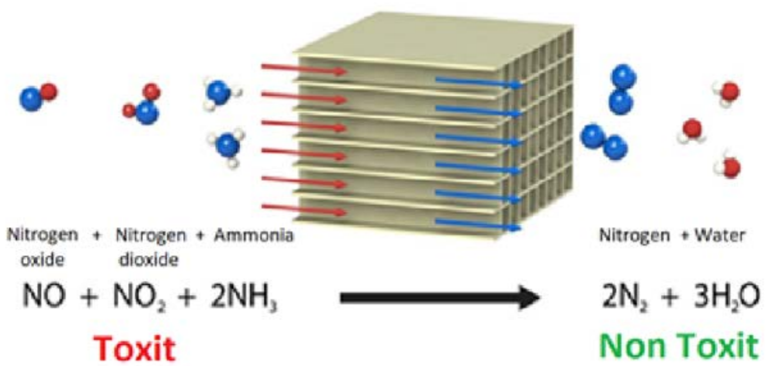
An SCR system reduces harmful nitrogen oxides (NO_x) using ammonia (NH_3) and a catalyst. The term SCR stands for Selective Catalytic Reduction, which means that under the influence of the catalyst material the ammonia reacts only with the nitrogen oxides and therefore not with other substances in the exhaust gases.

The SCR process is complex. For example, there are multiple reactions that ultimately all result in the harmful NO_x being converted into harmless nitrogen (N_2) and water (H_2O).

Standard SCR reaction



Quick SCR reaction



When an oxidation catalyst is placed for an SCR catalyst, part of the NO is converted into NO_2. This NO + NO_2 provides an extra quick reaction with NH3 that occurs at low temperature. In the case of too high a conversion from NO to NO_2, more urea would be needed to reduce the NO_x.

<u>Life of a catalyst</u>

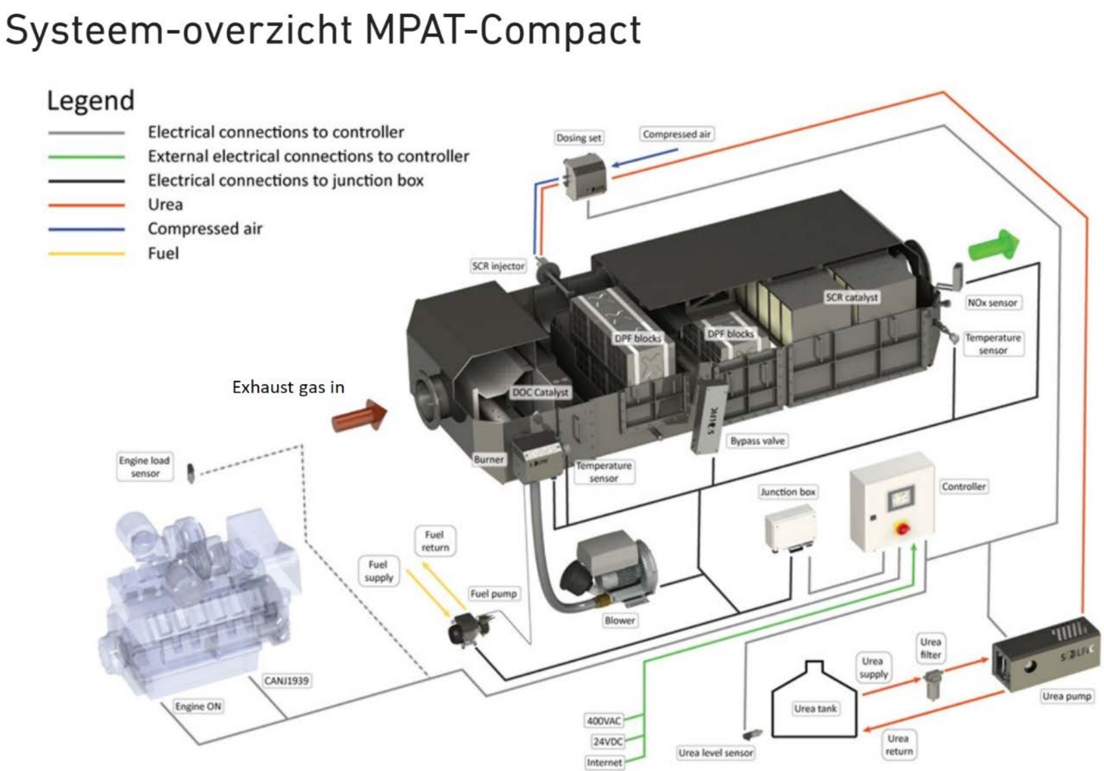
A catalyst thus accelerates a certain chemical reaction without the catalyst material itself being consumed. Theoretically, therefore, a catalyst should last indefinitely. The surface of the catalyst is, if you look at it under a microscope, very porous. The NO_x and ammonia molecules flow through this spongy surface and react with each other. Now, however, the catalyst is outdated under the influence of temperature and contaminants in the exhaust gases. In fact, the sponge gets clogged and the surface is getting smoother. The activity is thus decreasing.

<u>Urea</u>

Urea is also known as a basic substance for fertilizer, for example. It also occurs naturally in urine, for example. The urea used in SCR systems has been dissolved in water. A common solution is 32.5% urea in water. Under the well-known brand name Adblue, this road transport solution is used. The reason for this is that this solution has the lowest freezing point, namely -11°C. At this temperature, the urea crystallizes and blockages in the injectors and pipes can occur.
Another name for the 32.5% solution is also called AUS32 or DEF (Diesel Emission Fluid)

In industry and maritime transport, a solution of 40% is common. The advantage of this is that less water needs to be transported for the same amount of urea. It is important that the storage tank does not fall below the freezing or crystallization point of 0°C.

Below is an overview of a combined particulate filter/catalyst installation:



IMPORTANT FACTS

The above gives a statement of the laws and regulations and the emission requirements to be met by engines with incorporated after treatment plants by 1-1-2019 and 1-1-2020 respectively.

These are particularly stringent requirements for which no engines are actually available for the higher power range per 1-1-2020. For the time being, thanks to the transitional periods (up to 18 months from 1-1-2020), engines of the type CCR II will still be manufactured before the start of the transition period (being 1.1.2019 for $P < 300$ kW and 1.1.2020 for $P \geq 300$ kW) can be placed in new construction vessels. Provided that the date of production of the vessel does not exceed 18 months after the start of the transitional period as described above.

Things needing attention:

1. According to Regulation (EU) 2016/1628, an after-treatment system necessary to meet the applicable emission limit values is part of the engine. In other words; the after-treatment plant is an **inseparable part** of the engine as regards the type of approval of the engine. No other after-treatment plant can be put behind, nor other parts not listed in the type of approval specification. One of the consequences of this is that a product or other type of engine , with, for example, slightly more or less power, in the case of serious damage to the engine, also requires a type of after-treatment plant belonging to that other engine or engine!

2. Every 5 or 7 years, depending on the type of vessel, re-certification must be carried out by a Class Office or Private Institution. This is called an "Interim inspection".
   Article 9.07 of the ES-TRIN 2019 states, with regard to this 'Interim inspection', states that the Commission of Experts (in the Netherlands is a private institutions mandated by IL&T (PI's) and Class) has to determine whether "***the built-in engine still meets the technical requirements relating to the emission level of harmful gases and air pollutants, even after it changes or modifications"***.
   This is difficult to enforce, since in the 5 or 7 years maintenance of the engines is/should be performed such as (depending on the number of turning hours) setting of valves, replace/ maintenance of atomizers, replace piston rings, inspection of bearings etc.
   Proper verification by the Commission of Experts could only take place if such maintenance and/or repair work is carried out exclusively by the manufacturer (the person who has issued the type of approval), indicating that the manufacturer has not made any changes to the engine with regard to the specification/parts specified in the type of approval.
   In short, maintenance should always be carried out by the official manufacturer, with reports of work carried out en materials used, which may have (higher) costs consequences.

3. If damage is serious, no exchange engine may be built in. Reference is made to the above stated "REPAIRS TO ENGINES"

4. Because the engine and after-treatment plant form a single whole, the engine day valuation should be taken into account in the future.

5. The damage sensitivity of after-treatment plant in still unknown, so also the cost of the various parts. It is clear, however, that an after-treatment plant requires more attention from the skipper/owner bag with regard to, among other things, timely replenishment of urea, clean of the catalyzer and the like.

6. Due to the higher costs of a propulsion plant (engine with after-treatment plant) and the long transition, it is to be expected or is there a chance that ships with existing CCR II engines will continue to repair them as long as possible in order to avoid the installation of a more expensive Stage-V engine. What this will mean for the sensitivity of the engines and the costs is still unclear.

7. Existing working vessels did not have to be certified before 1/1/2019, working vessels from after 1 July 2009 must be certified. As of 1-1-2019, all working vessels longer than 20 m or having a displacement of more than 100 m^3 should therefore be certified after 1-1-2019. This means that the engines installed in working vessels after 1 January 2019 with fixed installed engines also have to meet the NRMM emission requirements.

8. Fuel additions, including the addition of a certain percentage of bio, provided not laid down in type-approval, can cause problems with emissions results and therefore in fact also with type approval. This could lead to additions to the fuel obtaining type-approval, warranty e. d. expires.

9. To what extent is the life expectancy of a particulate filter and/or catalyst in relation to the life expectancy of an engine, bearing in mind that the aftertreatment is one with the engine where type approval is concerned?

OTHER PROPULSION SYSTEMS

Apart from or precisely by NRMM emission requirements, there have been more and more developments in the field of alternative (cleaner) fuels and alternative propulsion systems, which, according to IVR, also deserves the attention of insurers.

Each fuel and system has its (technical) advantages and disadvantages. The following is a (as complete as possible) overview of recent developments in this area and will also focus on the points of interest.

ALTERNATIVE FUELS

GTL (Gas-to-Liquids)

GTL is a synthetic, liquid fuel made of natural gas and enters into inland waterways. The first reactions are positive.

The fuel burns more efficiently than conventional, petroleum-based, standard diesel. With the greatest advantage of being less local emissions and less soot.

GTL is virtually Sulphur-free, has a high cetane number and is virtually aromats free. It is not toxic, virtually odorless and well biodegradable. GTL can be applied directly without investments in infrastructure or adaptation to diesel engines.

GTL alone is not enough to meet the NRMM emission requirements. Also when using GTL, after-treatment and thus type approval of motor with after-treatment will be required or an exemption will be requested.

The European legislature (CESNI/CCR) is critical of exemptions. Exemption suffered only for one specific vessel and should be requested through the Commission of Experts (in the Netherlands through the Pi's and Class Offices). Unfortunately, the application procedure takes a long time, from at least 1 year to 2.5 years.

The long-term consequences for using GTL in standard diesel engines related to wear, maintenance and life span of the various components is not yet known.

GTL can be used seamlessly in diesel engine. However, as with any transfer to a fuel other than conventional diesel, older vessels should be used to look for possible fuel leakage by shrinking gaskets. GTL does not contain aromats that ensure the so-called 'seals well' as when using conventional diesel. When another product is then used (with aromas), the gaskets will swell again and no more leakage occur. It is good to check the rubber seals on the engine and the bunker tank for leaks in particular in the first period. Experience shows that older seals in particular can leak.

Ordinary diesel, with bio component, can contain much more water than GTL. So you would think gtl therefore offers less breeding ground. But almost all manufacturers indicate that GTL is as sensitive to bacterial and fungal growth as the other diesels. After all, these bacteria need water to grow in and that water can also end up in GTL. According to EG Fuel, GTL is less susceptible to bacterial formation. Several users endorse this and say in practice that bacterial growth in GTL than in ordinary diesel.

Food for thoughts:

It is not clear whether when using GTL in new engines, the warranty is maintained by the manufacturer. The case is to request this in a timely manner from the manufacturer.

Addition of bio components to diesel

For several years, diesel fuel has added bio-component. There is also much less Sulphur in fuel than before (Sulphur content has been reduced from 1000 ppm to 10 ppm.). This makes the diesel fuel scraper and reduces lubrication. IVR published[9] a comprehensive report on this in 2010 on the potential consequences and risks of reducing Sulphur content in inland waterways.

Biodiesel attracts up to 8x more moisture than normal diesel. Moisture is a first source of possible problems. How does moisture (eventually water) get into the fuel tank now?

Temperature fluctuations, dark spaces, long storage (e.g. after a winter) and poor sealing of the fuel filling opening ensure that moisture/condensation is given a chance. Now there's always a percentage of moisture in fuel. Diesel can absorb up to 0.02% water, without losing quality. If there is more 0.02% moisture in the diesel, this will slowly sink to the lowest point of your fuel tank. Too much moisture reduces the lubricating effect of the diesel fuel and will eventually lead to bacterial growth. Bacteria are recognizable as a black sludge. This bacterial growth must be removed from the diesel before they can clog the fuel filter. If fuel filters become completely clogged, your engine will no longer run, with all the consequences.

FAME (Fatty Acid Methyl Esters) is the cheapest solution for this alternative diesel part and is made by turning oils – such as frying fat – into fatty acid esters.

The mixing is (yet) not an obligation for inland navigation, however, to comply with the agreements of the Climate Agreement and to achieve the mixing obligation for the other sectors (road traffic), may be mixed in inland navigation which may include as Reduction.

Although the supplied (bio) fuels all have to meet European specifications, problems are sometimes experienced.

"Previously, crops were used as soy and palm oil, because they were fully available. Recently, these food crops may or may no longer be used as biofuel for sustainability reasons and, for example, the aforementioned used frying fat is used as a base. As a result, the fuel composition changes, because properties of substances in detail are different.

The composition can also change due to changes in the fossil part of the fuel, because it may have a different origin (from Russia, Norway, Saudi Arabia to the US) and is therefore not constant.

From the environmental point of view, adding bio-component and the decrease in Sulphur in diesel are great developments. However, in practice, biodiesel and the decrease in Sulphur do cause problems.

Inland navigation, the VOS ULS 2011 is a specification specifically used for inland navigation. The VOS ULS 2011 specification is broadly the same as the EN590 specification, but focused on inland navigation. The fact is that in the new VOS ULS 2011 gas oil it is not always prevented for logistical

9 "The possible consequences and risks of reducing Sulphur content"- 2010

reasons. For the VOS ULS 2011 gas oil is aimed at a maximum FAME percentage equal to the EN 590 (0.30% v/f).

The minimum amount of bio to be added in inland gas oil can range from[10] 5 to 7 %, resulting in possible damage (blockage filters by bacteria formation). It is unclear what the legal policy will be with regard to the maximum of this addition in inland navigation. The fact is that the addition of max. 10 % bio in road traffic petrol has already caused problems. From commercial consideration and CO_2 compensation it is interesting for suppliers to add bio.

Biofuels

Biofuel is a collective name for fuels made from biomass. There are different species. For example, biodiesel, bioethanol, biogas or bio-butanol.
Biofuels are made from plant material or waste:

- Biofuels from plant material
  Most biofuels are from plant material such as palm oil, rapeseed, sugar cane, corn and grain. This material often comes from tropical countries. Production can be at the expense of farmland for food crops.
- Biofuels from waste
  It is also possible to make biofuels from waste. For example, from waste from fodder, discarded frying fat, wood chips or algae. No additional agricultural land is required for this purpose.

For inland navigation, the use of Hydrotreated Vegetable Oil (HVO) and biodiesel currently seem to be the most obvious options. They can be used immediately. These biofuels can be mixed without problems and no modifications to the engine need to be made. 'Biodiesel can be added to diesel without problems. This is already happening a lot in road transport. The renewable diesel HVO can be tracked up to a rate of 30% to 40% and still complies with the specifications. It is identical to GTL, burns nicely and reduces soot. A 30% increase in HVO in diesel reduces CO2 emissions by about 27%. Also, HVO can be used without modifications in existing engines. So it is an interesting option for inland navigation. The disadvantage is the higher operating costs, because these fuels are more expensive.

Even with the use of biofuels, no NRMM emission requirements are currently met and will probably remain necessary after-treatment of exhaust gases.

As an alternative to gas oil, the inland waterway entrepreneur could also opt for methanol or the renewable bio-methanol available in the near future, which is no longer different from regular methanol at all. The advantage of methanol is that it burns even cleaner than HVO or biodiesel. To use it, the inland navigation entrepreneur must invest in a renewal of the engine. Another option, further in the future, would be the use of methanol that was created through the Method of Power to Liquid (PTL). This is a chemical process in which a liquid energy carrier can be produced from electricity. It is also called Power to X, solar fuel, e-fuel or wind fuel. However, this process is still under development.

[10] *Reference is also made to the IVR leaflet 'Inland waterway fuels in January 2011'.*

LNG (Liquified Natural Gas)

Methane is the main component of LNG. LNG is lighter than air, liquid at about-163 ºC, flammable, but with a high Self-ignition temperature: 595 ºC (~210 ºC for diesel). LNG does not contain Sulphur (no SO_x emissions).

LNG is a clear, colorless, non-toxic liquid, which occurs when natural gas is cooled to about -160°C. As a result, it shrinks to 1/600th of its original volume and is easier to store and transport.

LNG meets all new environmental requirements for inland navigation without after-treatment techniques. Indeed, the reduction of harmful emissions is significant: 80% reduction in nitrogen emissions (NOx), 99% in the case of particulate reduction (pm) and CO_2 emissions are also 20% lower.

A focus[11] is methane slip emissions (= unburned methane). It is limited to a maximum of 6.19 grams of HC per kWh in the NRMM Directive for 2019/2020. If the gas engines are further developed and dedicated gas engines are applied, methane emissions can be further reduced.

Without adjustments, the transfer to bio-LNG can also be effortlessly switched. This clean and CO_2-neutral fuel is increasingly emerging and stems from sources such as manure and other organic waste. This allows bio-LNG to be generated locally. Once the production capacity of this fuel is large enough, bio-LNG (also known as LBM) will be the logical successor to LNG.

LNG also requires storage tanks that, if they need to be built into the ship, are also at the expense of the cargo compartment. The alternative is placement on deck. Furthermore, the installation must be equipped with pumps and evaporators. By the way, there is a rapid development towards increasingly compact systems. LNG is therefore particularly interesting for use in new construction. For the smaller engines it remains interesting to exchange the engine. The investment depends at a time on the need and type of solutions offered by the market. In 2011, Wärtsilä de Bit Viking, a product tanker, converted from diesel to dual-fuel powered, was a very far-reaching refit. Conversion is an expensive option that in this case was only possible thanks to subsidization of the switch to the cleaner fuel.

The multi-investment for a vessel on LNG depends heavily on the type of ship, but is about €1.5 million.

Suppliers of gas engines in shipping are plentiful.

Methanol

Methanol is an organic chemical compound of the alcohol group of substances with the chemical formula CH_3OH. Methanol is mainly used in the petrochemical industry as a raw material for the production of other chemicals such as formaldehyde and acetic acid.

The use of methanol as an alternative, low-carbon fuel has attracted great interest, as the raw material natural gas for the production of methanol can also be produced using renewable raw materials.

The use of methanol in the maritime industry is currently limited to two ro-ro passenger ships and a number of sea transport chemical tankers that use methanol from their cargo as fuel.

When using methanol as a fuel, it should be borne in mind that methanol is toxic and has a low flash point of only 12 °C. The flash point describes the minimum temperature in which a liquid releases a vapor in sufficient concentration to form a combustible mixture with air. Methanol lights up without

[11] Comments National LNG platform

visible flame. Compared to diesel fuels, the physical properties of methanol require additional equipment for detecting leaks and dealing with them.

Additional methanol treatment measures are required. Methanol can result in poisoning when ingested, in case of contact with the skin or inhalation of methanol vapors. High toxicity can result in blindness with an intake of no more than 10 ml of pure methanol. The intake of 30 ml of pure methanol may be fatal, although the average lethal dose is approximately 100 ml.

Methanol can also be used as a fuel cell fuel cell system that power an electric propulsion engine, although the output is still limited and only applicable for small low power systems.

Hydrogen[12]

With a boiling temperature of -253 °C and a melting temperature of -259.2 °C, hydrogen is an almost permanent gas. Since the critical temperature at -239.96 °C is also extremely low, a pressure increase to support liquefaction (critical pressure 13.1 bar) is only limited.

With its divers ignition and detonation limit values hydrogen can ignite in a large number of concentrations compared to other fuels. In an incineration process, this would allow very lean air/hydrogen mixtures. The difference between the ignition and detonation limits lies with the type of combustion. Deflagration refers to a subsonic combustion, detonation to a supersonic combustion. The self-ignition temperature of hydrogen is higher than that of other fuels, but the minimum ignition energy is significantly lower.

Hydrogen is a colorless and odorless, nontoxic gas at room temperature. It is extremely light compared to air (kgt = 1.29 kg/m³) and volatile air quickly in.

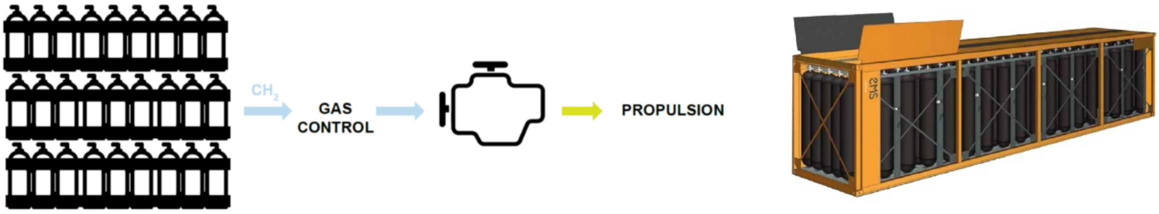
Hydrogen evaporates easily and spreads through a variety of materials due to the small molecule size. This makes the storage and transport of hydrogen quite complex. To deal with this, special steel or diffusion barrier layers must be used. Moreover, the glare of materials that comes into contact with hydrogen is an important problem. Hydrogen is a slightly flammable gas that is ideal for its properties as fuel. The handling requires a major concern and compliance with the safety regulations. However, the necessary safety regulations do not have to differ significantly from other fuels, as the hazards are very similar. The necessary training measures, as is the case for LNG tankers, are required for the use of hydrogen .

There are several methods for the production of hydrogen, such as:

1. By reforming fossil fuels, for example:
    1. Steam reform, being an endotherm catalytic reaction of light hydrocarbons with water vapor
    2. Partial oxidation is suitable for the reform of heavy hydrocarbons using oxygen
    3. Autothermal reform is a combination of steam reform and partial oxidation that benefits from the benefits of both ways of reforming.
2. Electrolysis:
   Electrolysis is the conversion of electrical energy into chemical energy. In the case envisaged, this means the degradation of water molecules (H_2O) in hydrogen (H_2) and oxygen (O_2) by applying direct current

[12] *Reference is made to the feasibility study of Marigreen of October 2018 "perspectives for the use of hydrogen as fuel in inland waterways".*

The two main variants for transporting and storing hydrogen are under pressure in liquid and gaseous form.



An innovative example of particular importance for shipping is to store the hydrogen in standard intermodal cargo containers as indicated above.

<u>Engine adjustment</u>
The conversion of hydrogen to mechanical energy using internal combustion engines seems beneficial for several reasons. In particular, applications that require high propulsion power and low energy consumption for aid companies can benefit from direct conversion.

Most of the propulsion systems currently available in inland waterway vessels are based on internal combustion engines. The use of hydrogen as fuel offers the possibility to adapt existing engine concepts to hydrogen in addition to the new design of engines specifically designed for hydrogen as fuel.

The properties of hydrogen as fuel differ significantly from current fuels, so that various changes in the design of an internal combustion engine are needed.
Customizing to i.e.;

- Injection system
- Turbocharger and intercooler
- Ignition system
- Lubrication system
- Cooling system
- Valves control
- Compression ratio
- Crankcase ventilation

is necessary.

It can be concluded that the use of hydrogen as a fuel for barge is still in a pilot phase, but looks promising.

ALTERNATIEVE VOORTSTUWINGSSYSTEMEN

Dual fuel engines:

These are engines that can run both gas (LNG) and diesel.

LNG Dual Fuel engines have been in use in coastal and sea shipping for more than 10 years. In the meantime, these engines are also supplied for inland navigation. The LNG Dual Fuel engines are specifically designed as a Dual Fuel engine which requires only a limited amount of pilot fuel. Nevertheless, the Dual Fuel engine can run entirely on diesel. As a result, there is a ratio of 1% diesel and 99% LNG.

Various dual-fuel engines have already been installed in inland navigation. This is often LNG/diesel.

For the use of LNG for propulsion in inland navigation, clear regulations have now been laid[13]down in ES-TRIN 2019 as regards installation, safety requirements, bunkering, crew etc.

These requirements can also be applied to new alternative fuels with a flashpoint of 50 °C or less. However, fuels other than LNG require a recommendation/exemption.

However, there are already a number of vessels that have the engines running on LNG.

Diesel electric drive:

Diesel electric or LNG electric propulsion has been enormously in the spotlight lately, with a view to possible fuel savings and emission emissions reduction. A ship with (diesel) electric propulsion has several generator sets on board, which together provide the full power supply of the electrical propulsion. If the maximum power is not fully required, (single) generator sets can be stopped, saving fuel and reducing$_{CO2}$ emissions.

Especially with ships that already need large generators for other large consumers on board, such as large cargo pumps or on-board mesh sets, a Diesel/LNG Electric propulsion can be interesting.

However, there are also disadvantages to a (diesel/LNG) electrical propulsion. The investment is a lot higher than with diesel direct propulsion. In addition, the electrical components each have a loss of efficiency, which can amount to around 13% in total.

As with the hybrid shape, generator sets provide the necessary amount of power. Of course, the sets can be switched on or off. The size of the generator sets can be determined as desired. Moreover, it is no longer necessary to put the sets in line with the screw shaft. They can be placed in any place.

The generator sets are powered by diesel or LNG. At the moment, the generator sets mainly still use diesel.

[13] Reference is made to ES-TRIN 2019 - PART II ADDITIONAL REQUIREMENTS FOR SPECIFIC EQUIPMENT ON BOARD - ANNEX 8 ADDITIONAL PROVISIONS FOR VESSELS POWERED BY FUELS WITH A FLASHPOINT OF 55 °C OR LESS .

Use of Euro-6 truck engines

Euro-6 truck engines in principle meet NRMM emission requirements, with which the idea has arisen to also apply these engines in inland waterways.

Currently, projects are underway to marinize Euro-6 truck engines. This means that the air cooling of the engine present in lorries, for inland waterways in a engine room, the cooling must be converted into a water cooling.

Another important feature of the Euro-6 engine to meet the emission standard is that engine power is controlled by emissions. Changes comes the emission outside the permitted values, the engine decreases in power and will eventually stop.

Inland navigation legislation states that an engine is automatically allowed to fall back into power or stop in the event of a malfunction. Understandably, because if a ship sails into a lock and the engine power suddenly decreases or the engine stops automatically, this can lead to disastrous consequences.

The decrease in power in the case of a deviation in the emission of a Euro-6 engine is automatically electronically controlled. It seems difficult for the time being to adjust this electronic, inland waterway, power reduction in such a way that the engine does not stop in the case of emission change or to have the engine meet the emission requirements without having this electronic power reduction.

Recently, the DAF/PACCAR Euro VI MX11 and -13 Stage-V engines were approved for naval application. The MX series more than more than more than adequately comply with the IWW Stage V emission legislation. Result: up to 98% less nitrogen oxides, 99% less soot and fuel use (read CO2 emissions) are guaranteed to be 16% lower than that of the previous generation of CCR2 ship diesels.

The state-of-the-art diesel engine comes including an ex-factory after-treatment unit, consisting of an SCR catalyst and DPF particulate filter. To achieve the Euro VI emission levels, the MX engines are supplied including after-treatment unit. This after-treatment unit consisting of an SCR catalyst and DPF particulate filter has very compact dimensions (approximately 750 x 750 x 500 mm), replaces the standard silencer and is virtually applicable in any engine room.

For the MX11 series, the power range is between 220 and 330 kW and for the MX13 between 315 and 319 kW. So still in the somewhat lower power ranges.

Fully electric drive

At the moment, the first fully electric ship to be powered by PM engines is under construction. In April this year, the ship will be on the way.

The ships are equipped with giant E-power boxes for the drive, each the size of a container of 20 feet (6 meters). They bring the energy to the electric engine. The small ships can sail for 15 hours, the large ones (which have four power boxes on board) would come to 35 hours of autonomy. The batteries can also be exchanged or recharged at container terminals if necessary.

Because there is no longer a classic engine room, some space is ultimately saved: there is an 8% gain compared to a similar classic fossil fuel ship.

Electric motors and batteries are also built into older ships, the so-called retrofitting. The new ships could sail independently, without skipper, although autonomous sailing on most waterways would not be discussed for the time being.

The batteries are still quite pricey, although the developments in this are fast.

Currently, lithium ion batteries are often used which have a high risk of fire in the event of damage or overload.

In France, trials are currently being done with sodium ion batteries. With the exception of the material, the operation of a sodium ion battery is similar to that of a lithium-ion battery, but sodium ion batteries will limit a number of limitations of current dominant lithium-ion batteries around the charging speed, fire hazard, life span, use of rare earth metals or production costs. Charging would take only a few minutes and the life span would be 10 years, i.e. three times longer than that of lithium-ion batteries at an equivalent cost. It is still unclear when batteries available for inland waterway with sufficient capacity will be available.

For smaller vessels, such as open canal boats and Amsterdam's canal boats, a full electric drive, partly due to the additional emission requirements imposed by the local authorities, is increasingly applied.

These are smaller relatively low-power drives, often powered by Lithium-ion batteries. Also in the pleasure boating electric drive more and its way. It must be noted that there is still ignorance among owners about the use of lithium-ion batteries and the requirements.

As mentioned, Lithium-ion batteries/accumulators are used for the electric drive.

'Lithium-Ion' accumulators occur in various substances and have various advantages compared to conventional accumulators (with Lead or Nickel/Cadmium) such as a longer service life due to more charging and discharge cycles and higher energy density, or a lot of energy at a small volume. Lithium-Ion is a collective name for rechargeable accumulators with the free ions of the Lithium fabric as an energy carrier. It is known that these accumulators pose a high risk in the case of a misapplication in which a 'Thermal Runaway' can be caused with a fire or worse as a possible result, an explosion.

For canal boats of the 'Amsterdam Canal Type', the requirements of the Inland Navigation Ruling Annex 3.3 applies; reference is made to the ES-TRIN (Annex 1.1a of the same ruling).

Since 7 October 2018, ES-TRIN has been in force for inland waterway vessels. It contains the technical requirements to be met by vessels. For 'Lithium-Ion' accumulators is only described in Art 10.11 paragraph 15 that they must be inspected in accordance with standards EN 62619 and EN 62620. However, no further regulations were included for the installation, installation, maintenance, prevention of a calamity and the fight against a calamity at these accumulators.

In the case of new construction, refurbishment or conversion (N.V.O.), transitional provisions art.32.05 for ships on the Rhine and outside the Rhine should meet the accumulators and requirements, as well as in the case of certificate extension after 1-1-2025. The same applies to the accumulator management system in terms of the monitoring of the accumulators in respect of, among other things, the charging state, thermo management, capabilities management etc..

As of 1-1-2020, ES-TRIN 2019 is in force in which the new Chapter 11 includes 'Special provisions for electric drives'. Ships where the electric drive is installed before 1-1-2020 does not have to meet these requirements, as described above.

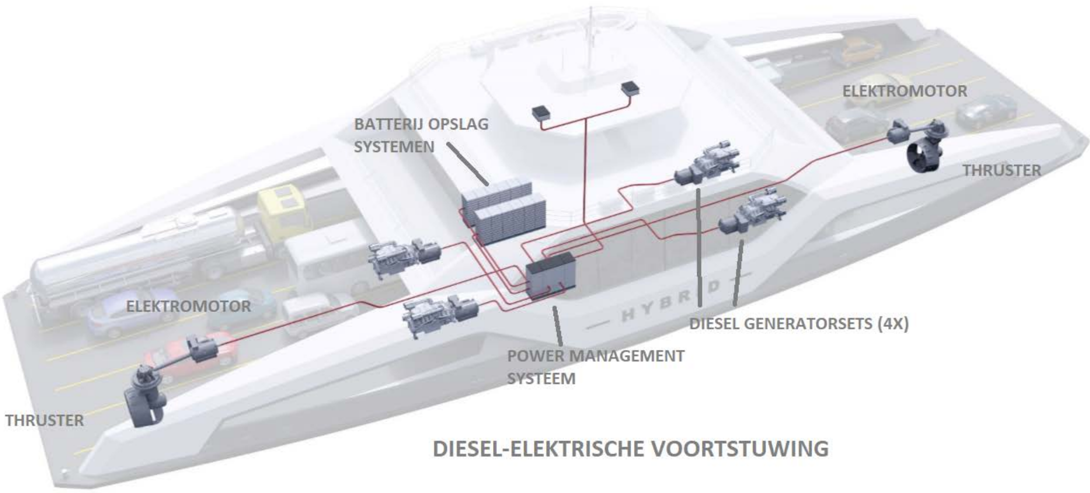
Chapter 11, Article 11.01 General provisions state:

1. The main electric drive of a vessel shall consist of at least:
   a) two power sources, regardless of the number of main drives,
   b) a switching device,
   c) an electric drive motor,
   d) the steering adjustments, and,
   e) pending on the construction of the electric main drives the corresponding power electronics.
2. If an electric main drive is equipped only with one drive motor and the vessel does not have any other ship propulsion that ensures sufficient drive power, the main electric drive shall be carried out in such a way that at least in the following situations the movement is ensured at its own power with the necessary maneuverability:
   a) after a failure in the power electronics or
   b) after a failure in the control and control of the of the propulsion installation.

This requires somewhat costly investments.

Hybrid drive:

Below is schematically displayed an example of an hybrid drive, being diesel generator sets that provide for the power supply for electric motors drive on the screw shaft/thruster, but there is also a battery storage to be able to sail for a short time without the diesel generator sets.



These systems are more complex and often more expensive than the old diesel engine with flexible coupling, turning clutch, screw shaft and screw. The advantage is that the engines often run a constant speed and can be handled well with low emission and low wear.

When batteries are also used, special attention to the installation of the batteries with risk analysis will be necessary, including the fire hazard in case of overload or damage to the batteries.

ITEMS FOR CONSIDERATION

Above, a (not complete) overview has been given of the latest developments in the field of emission requirements, fuels and propulsion systems in the field of navigation.

This includes a number of cases for parties concerned, such as;

1. For example, what can be classified as "the engine" in the above sketch of a diesel / hybrid propulsion system in the context of the insurance policy?
2. What is covered by the 'engine' in such a case?
3. What if the warranty expires through the use of addition and to the fuel, the application of other (cheaper) fuel and/or the type approval expires?
4. What if an engine is damaged in such a way that a new engine needs to be installed and the owner wants a different manufacturer, type or power, so that the after-treatment system also needs to be replaced/adjusted?
5. To what extent are the risks of Lithium-Ion accumulators recognized and incorporated into the insurance policy?
6. To what extent should the relatively limited life span of Lithium-Ion batteries be taken into account?
7. What when not certified batteries/accumulators are applied and cause problems / fire?
8. How can insurers/owners respond to an increase in the regulatory addition of bio in regular diesel with possible damage consequences?
9. Will the total new installation be reimbursed for the replacement of existing engines due to damage engine including after-treatment plant due to the new legislation?
10. To what extent does it not having timely added urea and/or carried out maintenance of the after-treatment plant coverage consequences?

We did not discuss other issues which are a spinoff of the desire/need for more efficient, and environmentally friendlier inland navigation. Developments such as;

- Autonomous sailing
- Vessel train with remotely controlled connections
- Increase of cybersecurity due to more and more automation on board, on shore and within ship to board communication and control.

However each of fore mentioned subject by itself is too complex to in short comment on the consequences for parties interested, apart from the fact that most are still in a pilot/research phase. Nevertheless these also are subjects which will need constant follow up and in time evaluation as well.

With respect to the most recent propulsion and environmental related developments, we hope to herewith have given some information and things to think about for the near future.

Henk Arntz BSc
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