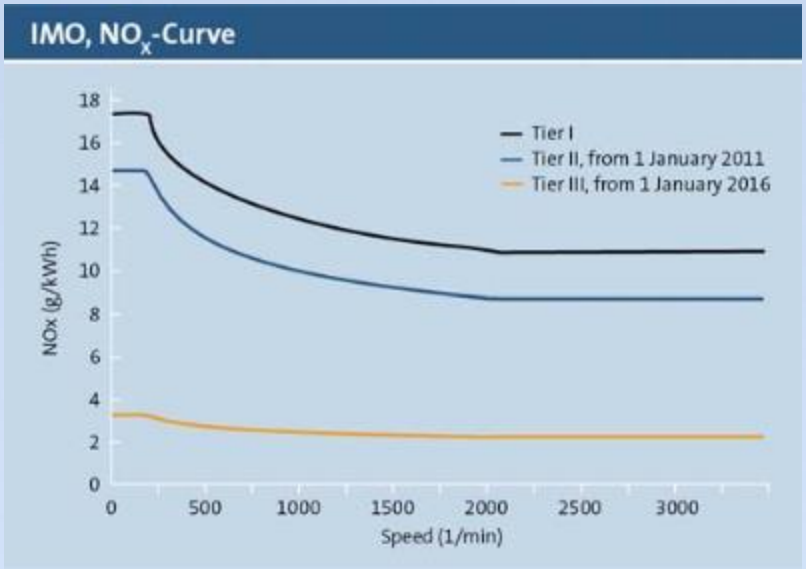
PORTABLE EMISSION MEASUREMENT SYSTEMS (PEMS) (SO_X, NO_X, CO_2)

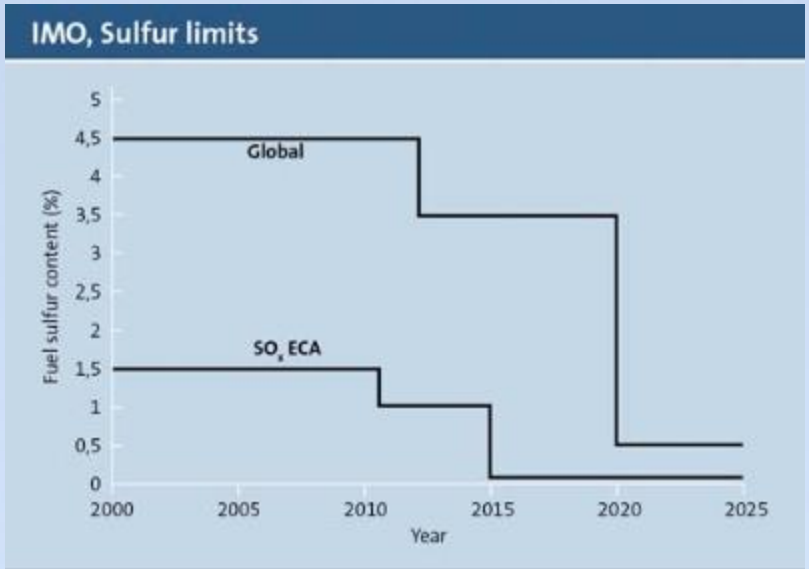
NADINE & KAY PASCHEN
TX MARINE MESSSYSTEME GMBH

WORKSHOP „ABGASNACHBEHANDLUNG“

EMISSIONS

EMISSIONS LIMITS





- NOx limit dependent on engine rated speed.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- Test condition: 25°C air temperature / 25° C water temperature
- Particulate and SOx emissions are limited via fuel quality.

Figures: VDMA brochure (Exhaust emission legislation Diesel and gas engines)

PORTABLE EMISSION MEASUREMENT SYSTEM

Laboratory equipment

Portable Emission Measurement System

EMISSION MEASUREMENT ON BOARD WITH PEMS

- Direct measurement and monitoring on board:
  - compliance with emission limits
  - compliance with regulations
  - or decision-making after modifications
  - etc.

- Allows to bring the ‘laboratory’ to the vessel and test in the field under normal (real world) operating conditions
  - Reduces problems related to sampling

- Can test anywhere, any time

- Can test and analyse independent from authorities*

* Technicians needs an operations & maintenance certificate from PEMS manufacturer

REQUIREMENT PEMS

The use of portable systems has different requirements on measurement technology as laboratory equipment to occur under real world conditions:

- Certification acc. to classification rules
  - Resistance to shock and vibration
  - Temperature variation compensation
  - Etc.
- Size, weight, power consumption
- Easy operation
- Real time Measurement
- Easy of maintenance
- etc.

MARPOL ANNEX VI NTC 2008 MEPC.177(58)

Chapter 2
Surveys and certification

2.1 General

2.1.1 Each marine diesel engine specified in 1.2, except as otherwise permitted by this Code, shall be subject to the following surveys:

.1 A pre-certification survey which shall be such as to ensure that the engine, as designed and equipped, complies with the applicable NOx emission limit contained in regulation 13. If this survey confirms compliance, the

Administration shall issue an Engine International Air Pollution Prevention (EIAPP) Certificate.

.2 An initial certification survey which shall be conducted on board a ship after the engine is installed but before it is placed in service. This survey shall be such as to ensure that the engine, as installed on board the ship, including any modifications and/or adjustments since the pre-certification, if applicable, complies with the applicable NOx emission limit contained in regulation 13. This survey, as part of the ship's initial survey, may lead to either the issuance of a ship's initial International Air Pollution Prevention (IAPP) Certificate or an amendment of a ship's valid IAPP Certificate reflecting the installation of a new engine.

.3 Renewal, annual and intermediate surveys, which shall be conducted as part of a ship's surveys required by regulation 5, to ensure the engine continues to fully comply with the provisions of this Code.

.4 An initial engine certification survey which shall be conducted on board a ship every time a major conversion, as defined in regulation 13, is made to an engine to ensure that the engine complies with the applicable NOx emission limit contained in regulation 13. This will result in the issue, if applicable, of an EIAPP Certificate and the amendment of the IAPP Certificate.

2.1.2 To comply with the various survey and certification requirements described in 2.1.1, there are methods included in this Code from which the engine manufacturer, shipbuilder or shipowner, as applicable, can choose to measure, calculate, test or verify an engine for its NOx emissions, as follows:

.1 test-bed testing for the pre-certification survey in accordance with chapter 5;

.2 onboard testing for an engine not pre-certificated for a combined pre certification and initial certification survey in accordance with the full test-bed requirements of chapter 5;

….

MARPOL ANNEX VI NTC 2008 MEPC.177(58)

Chapter 6

Procedures for demonstrating compliance with NOx emission limits on board

6.2 Engine Parameter Check method

6.2.1 *General*

6.2.1.1 Engines that meet the following conditions shall be eligible for an Engine Parameter Check method:

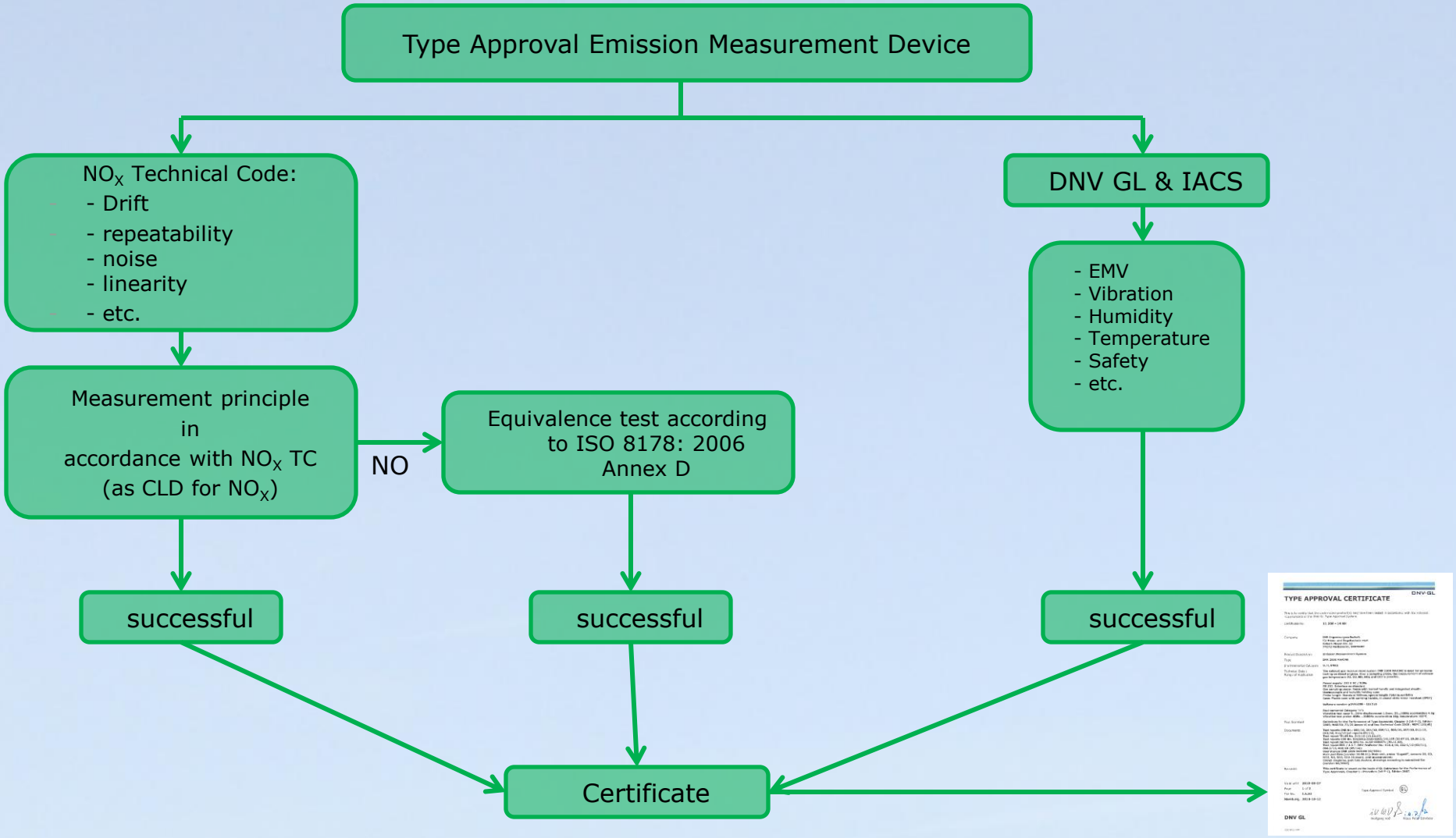
.1 engines that have received a pre-certificate (EIAPP Certificate) on the test bed and those that received a certificate (EIAPP Certificate) following an initial certification survey in accordance with 2.2.4; and

.2 engines that have undergone modifications or adjustments to the designated engine components and adjustable features since they were last surveyed.

6.2.1.2 When a diesel engine is designed to run within the applicable NOx emission limit, it is most likely that within the marine life of the engine, the NOx emission limit may be adhered to. The applicable NOx emission limit may, however, be contravened by adjustments or modification to the engine. Therefore, an Engine Parameter Check method shall be used to verify whether the engine is still within the applicable NOx emission limit.

6.2.1.3 Engine component checks, including checks of settings and an engine's operating values, are intended to provide an easy means of deducing the emissions performance of the engine for the purpose of verification that an engine with no, or minor, adjustments or modifications complies with the applicable NOx emission limit. Where the measurement of some operating values is required, the calibration of the equipment used for those measurements shall be in accordance with the requirements of appendix 4 of this Code.

PEMS TYPE APPROVAL PROCEDURE



EXAMPLE PEMS (IMR 2000 MARINE)

Gas sampling probe

Plastic case (IP67)

Interface for data storage

Probe pre-filter

Protocol-Printer

Gas Conditioning

LCD Display (Measurement values)

Keyboard

Air Temperature, Gas Input, Flue Gas Temperature

PROCEDURES FOR EMISSION REDUCTION

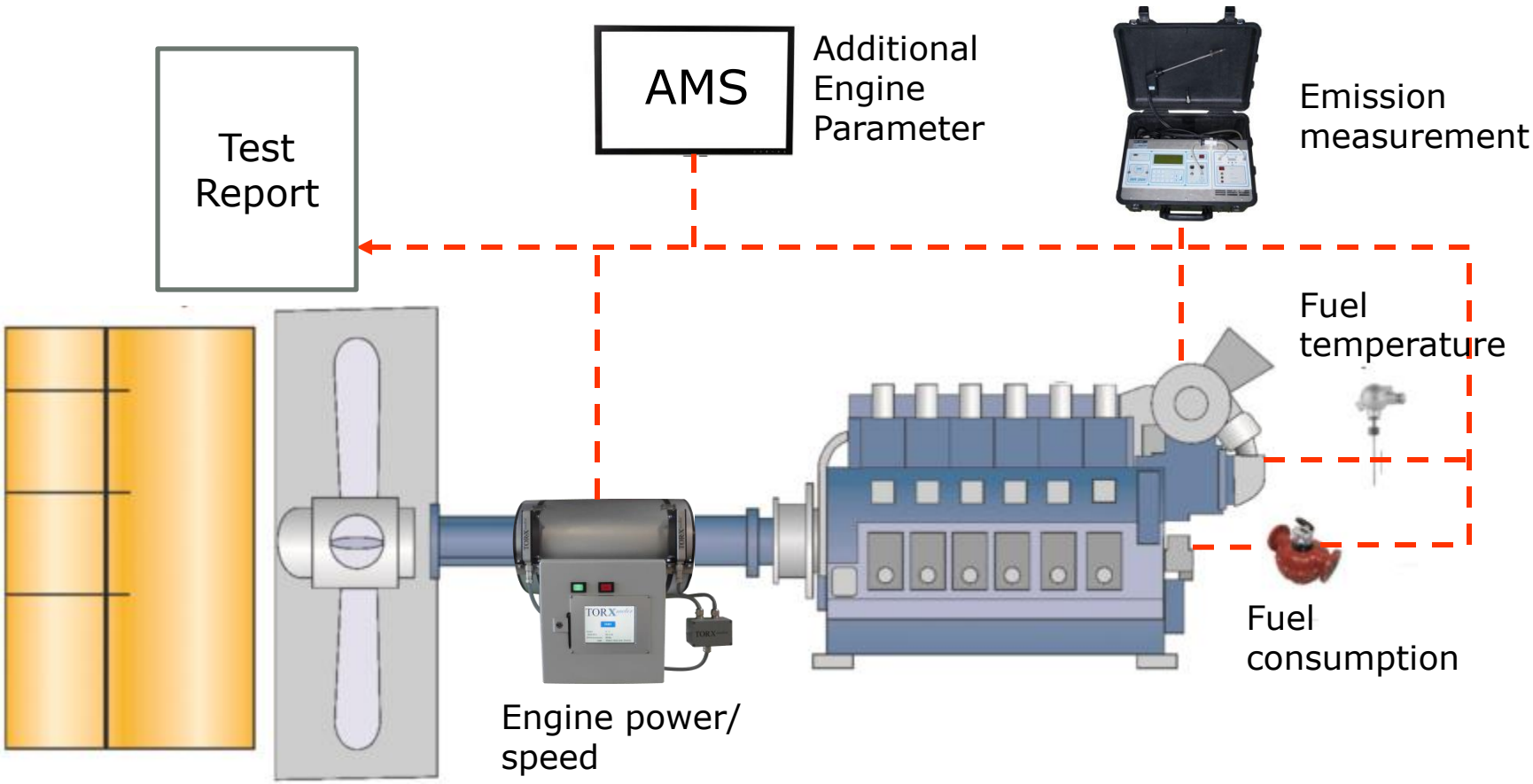
1. Engine internal actions:
- Injection
- exhaust gas recirculation
- Miller
- Boost pressure
- etc.

2. Engine outside actions:
- SCR
- catalysts
- particulate filter
- etc.

3. Fuel and lube oil

→ Demonstrating compliance with NO_X/SO_X emission limits o board

EMISSION MEASUREMENT ON BOARD



HOW TO PERFORM AN EMISSION ACC. TO MARPOL ANNEX VI

Measurement devices

Device	Unit	Check
Engine parameters		
Engine power / speed ☐water brake or ☐generator	kW / rpm	☐ Calibration (date and serial no. checked) ☐ Zero setting
Fuel consumption ☐balance or ☐flow meter	kg/h	☐ Calibration (date and serial no. checked) ☐ Return fuel is respected
Charge air temperature	°C	☐ Calibration ☐ Correct installation
Charge air pressure (if applicable)	bar	☐ Calibration ☐ Correct installation
Coolant temperature inlet	°C	☐ Correct installation
Coolant temperature outlet	°C	☐ Correct installation
Exhaust gas temperature at gas sampling point	°C	☐ Calibration ☐ Correct installation
Exhaust gas backpressure	mbar	☐ Calibration ☐ Correct installation
Fuel temperature before engine	°C	☐ Calibration ☐ Correct installation
Exhaust flow (if applicable)	kg/h	☐ Calibration (date and serial no. checked) ☐ Tightness of system (visual)
Inlet air flow (if applicable)	kg/h	☐ Calibration (date and serial no. checked) ☐ Tightness of system (visual)
Lubricant temperature	°C	☐ Correct installation
Inlet manifold depression	mbar	☐ Calibration ☐ Correct installation
Exhaust gas components		
Nitrogen oxide (NOx)	ppm	☐ Multipoint calibration (date and serial no. checked) ☐ Efficiency test of the NOx converter ☐ CO_2 quench check ☐ Water quench check (if NOx measured on a wet basis) ☐ Span gas certificate
Carbon monoxide (CO)	ppm	☐ Multipoint calibration (date and serial no. checked) ☐ Span gas certificate ☐ Water and CO_2 interference check
Hydrocarbon (HC)	ppm	☐ Multipoint calibration (date and serial no. checked) ☐ Oxygen interference check ☐ Span gas certificate
Carbon dioxide (CO2)	%	☐ Multipoint calibration (date and serial no. checked) ☐ Span gas certificate
Oxygen (O2) (Applicable for IMO approval only)	%	☐ Multipoint calibration (date and serial no. checked) ☐ Span gas certificate
Particulate emissions (PM)	mg	☐ Calibration ☐ Correct installation
Ambient conditions		
Intake air temperature	°C	☐ Calibration (date and serial no. checked)
intake air pressure	mbar	☐ Calibration (date and serial no. checked)
Intake air humidity	%	☐ Calibration (date and serial no. checked)
Other values to be measured if applicable		
Fuel rack position (if applicable)	-	

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Test conditions

Engine power / speed

☐ During each mode of the test cycle after the initial transition period, the specified speed shall be held within ± 1% of the rated speed or ± 3 min-1 whichever is greater except for low idle which shall be within the tolerances declared by the manufacturer.
The specified torque shall be held so that the average over the period during which the measurements are being taken is within ± 2% of the rated torque at the engine's rated speed.

Engine air inlet system

☐ Inlet air depression corresponds with the value for a clean air filter at rated speed and full load.

Value at rated speed and full load _____ mbar

Conditioning of inlet air: Yes, ☐ temperature, ☐humidity / ☐No

Engine exhaust system

☐ Exhaust back pressure corresponds with the maximum value specified by the manufacturer at rated speed and full load. (± 6.5 mbar)

Value at rated speed and full load _____ mbar

Cooling system

☐ An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer shall be used.

Charge air cooling system

☐ Sea water cooled ☐ Fresh water cooled ☐ Radiator cooled / (air to air)

cooling water to charge air cooler thermostatic controlled ☐ Yes / ☐ No

☐ Charge air temperature at the maximum allowed value as specified by the manufacturer, or
This setting shall be used for tests to be in compliance with NRMM

☐ Charge air temperature corresponds to a seawater reference temperature of 25°C
This setting shall be used for tests to be in compliance with RVIR, IMO (for RCD, the manufacturer shall specify a reference temperature)
Reference for air to air radiator cooled engines: 25°C air temperature.

☐ Charge air reference temperature specified by the engine manufacturer.
(According to a sea water reference temperature of 25 °C and the applicable cooling water system, heat exchangers (keel cooling) shall be respected)

Lubricating oil

Specifications of the lubricating oil used for the test shall be recorded and presented with the results of the test.

Make: _____ Type: _____

Fuel oil

Fuel oil in compliance with the requirements of the applicable regulation:

☐ NRMM, RCD: Specified reference fuel oil to be used.
RVIR: Reference fuel oil or fuel oil according to DIN EN 590.
IMO: DM-or RM-Grade according to ISO 8217:2005.

☐ Fuel oil analysis available (copy to GL HO).

☐ Fuel oil sample is taken and will be analysed. Sample number: _____

☐ Fuel oil temperature before engine: _____°C

Crankcase emission

Crankcase ventilation to ☐ Ambient / ☐ Exhaust side before sample point / ☐ Inlet air

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Source: DNV GL SE, 2014-08-20

TEST CYCLES

Cycle			E2			
Power			**100**	**75**	**50**	**25**
Speed			**100**	**100**	**100**	**100**
Power	P	kW	5000	3750	2500	1300
Speed	nd	rpm	1000	1000	1000	1000
Nitrogen Oxides (wet)	NOXw	ppm				
Nitrogen Oxides (dry)	NOXd	ppm	960	900	850	590
Carbon Monoxide (dry)	COd	ppm	64	49	63	161
Carbon Dioxide (dry)	CO2d	%	6,51	6,58	6,92	6,76
Oxigen (dry)	O2d	%	12,14	12,01	11,58	11,79
Hydro Carbons (wet)	HCw	ppm	218	271	292	288
Fuel Consumption	q_{mf}	kg/h	1000	750	570	350
Charge Air Pressure	pC	bar	3,0	1,5	1,5	0,4
Carge Air Temperature	TSC	°C	54	51	50	51
Charge Air Reference Temperature	TSCRef	°C	60	45	50	50
Relative humidity of the intake air	Ra	%	20	30	40	50
Total barometric pressure	pb	mbar	900	950	1000	1050
Inlet Air Temperature	Ta	°C	20	24	25	26
Air Temperatur at RH sensor	TRa	°C	25	25	25	25

Figure 3:

Fuel Data	Hydrogen **H**	ALF	%	13,70	13,70	13,70	13,70
Carbon **C**		BET	%	86,00	86,00	86,00	86,00
Sulfur **S**		GAM	%	0,30	0,30	0,30	0,30
Nitrogen **N**		DEL	%	0,00	0,00	0,00	0,00
Oxigen **O**		EPS	%	0,00	0,00	0,00	0,00

Figure: CIMAC Emission Calculation Check Guide

Test cycle for "Constant-speed main propulsion" application (including diesel-electric drive and all controllable-pitch propeller installations)

TEST CYCLES

In acc. to the requirements of ISO 8178, each measured loadpoint will be fractionised in seven separate cuts.

PROCEDURES FOR EMISSION MEASUREMENT SO_X (ACC.MARPOL)

Revised MARPOL ANNEX VI AND NO_X Technical Code 2008 (2013)

Resolution MEPC.259(68) " Guidelines for exhaust gas cleaning systems"

- Exhaust components: CO_2, SO_2
- "Procedure for demonstrate that the emissions from a fuel oil combustion unit fitted with an EGC will, with that system in operation, result in the required emission value.."
- Analysing equipment:

- CO_2 Analyse
- SO_X Analyse

PEMS EXAMPLES
MEASUREMENT PRINCIPLES

Electrochemical sensors (EC sensors):

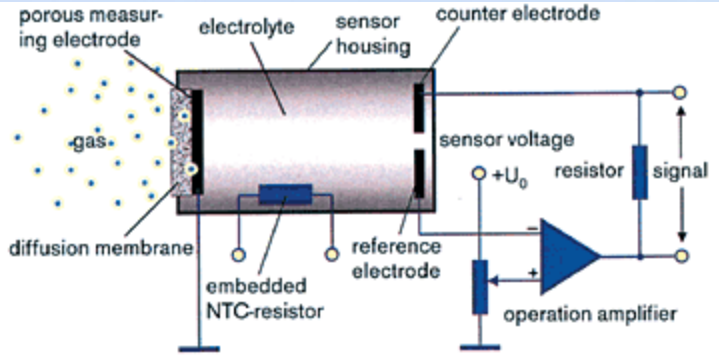
- measure flue gas constituents (O2, CO, NO, NO_2, SO_2, H_2S)
- Principle: the gas diffuses into the sensor, on the measuring electrode it will be oxidized or reduced. The resulting ions diffuse through the liquid electrolyte and on the counter electrode reduced or oxidized.

  Between the two electrodes is a current flow, proportional to the gas concentration.

  A reference electrode generated a constant potential and may prevent a drift of the measured values.

  Depending on the type of gas and gas concentration the sensors generate the electrical signal. The signals are analyzed by the electronics.

  Standard electrochemical sensors are affected by various environmental factors including: temperature, pressure, and other combustion gases.



Electochemical sensor measuring principle

MEASUREMENT CHARACTERISTICS OF THE EC-SENSORS

Environmental influences are to be observed:

- **temperature of the sensors**
  - The sensor temperature is controlled using an internal temperature measurement and used for temperature compensation

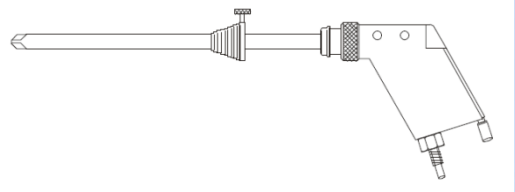
- **relative humidity of the measurement gases**
  - The absolute humidity is reduced by the use of the gas treatment system at a constant low value

PEMS CALIBRATION INTERVALLS

- Prior to each measurement on board a calibration check with “test gas” must be performed
- every year or 1000 measuring hours (whatever comes first)the PEMS needs to be calibrated by manufacturer
- For IMR 2000 Marine the manufacturer offers an “on exchange service”

EMISSION MEASUREMENT ON BOARD

- Start-up des PEMS acc. to manufacturer instruction
- PEMS performs zeroing of the system (Note: non-contaminated area)
- Set up the fuel
- Position exhaust gas probe
  - Main flow (Probe tip in the area of the highest flue gas temperature)
    - The sealing of the measurement port is important in order to prevent the aspiration of unwanted air.
    - Min. 3x diameter from last curvature



- A selected load point must be kept stable (according to NO_X Technical Code 2008). If the load point is stable, start the exhaust gas measurement.

CALIBRATION PROCEDURE

Every instrument that is used for measuring an engine's parameters must be calibrated accordingly to the requirements of the Technical Code.

- calibration validity period depending on:
  - if the measurements are made before achieving a certificate (test bed)
  - if the measurements are made when the engine already is pre-certified (on board-EIAPP)

"Each normally used operating range shall be calibrated. Analysers shall be calibrated not more than 3 month before being used for testing…"

- Testing for regulatory purposes will often require a calibration before and after each test. This self-calibration is easily performed with calibration gases.

TYPE APPROVAL CERTIFICATE

DNV·GL

TYPE APPROVAL CERTIFICATE

This is to certify that the undernoted product(s) has/have been tested in accordance with the relevant requirements of the DNV GL Type Approval System.

Certificate No.	**11 206 - 14 HH**
Company	**IMR Ingenieurgesellschaft für Mess- und Regeltechnik mbH Robert-Mayer-Str. 12 74172 Neckarsulm, GERMANY**
Product Description	**Emission Measurement System**
Type	**IMR 2000 MARINE**
Environmental Category	**D, H, EMC2**
Technical Data / Range of Application	**The exhaust gas measurement system IMR 2000 MARINE is used for emission testing on diesel engines. Over a sampling probe, the measurement of exhaust gas temperature O2, CO, NO, NO2 and CO2 is possible.** **Power supply: 230 V AC / 50Hz RS 232: Interface as standard Gas sampling probe: Probe with heated handle and integrated sheath-thermocouple and lockable holding cone Probe length: standard 300mm, special length 750mm available Case: Plastic case with carrying handle, in closed state water resistant (IP67)** **Software version: p2V91GER - 121210** **Environmental Category "H": Vibration test case: 5...25Hz displacement 1.6mm, 25...100Hz acceleration 4.0g Vibration test probe: 40Hz....2000Hz acceleration 10g, temperature 150°C**
Test Standard	**Guidelines for the Performance of Type Approvals, Chapter 2 (VI-7-2), Edition 2003; MARPOL 73/78 Annex VI and Nox Technical Code 2008 ; MEPC.103(49)**
Documents	**Test reports IMR No.: 003/10, 004/10, 005/11, 006/10, 007/10, 011/10, 013/10, 014/10 (all reports 03/11), Test report TELUS No. 513/10 (13.12.10), Test reports VDE No. 5013982-3950-0001/151165 (20.07.11, 08.06.11), Test report Hörmann IMG No. AU10-000417c (30.11.10), Test report IMR / A.S.T. EMV-Prüflabor No.: 016.1/10, 022-1/10 (03/11), 016.2/10, 018/10 (05/14); User manual IMR 2000 MARINE 02/2014; Main part lists (version 31.08.11): Main unit, probe "Bugatti", sensors O2, CO, NO2, NO, SO2, CO2-IR-board, soot measurement; Circuit diagrams, part lists devices, drawings according to submitted file (version 06/2012)**
Remarks	**This certificate is issued on the basis of GL Guidelines for the Performance of Type Approvals, Chapter 1 - Procedure (VI-7-1), Edition 2007.**

Valid until **2019-09-07**
Page **1** of **2**
File No. **I.A.02**
Hamburg, 2014-10-13

Type Approval Symbol GL

i.V. Wolfgang Voß i.A. Klaus-Peter Schröder

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Further Range of Application

The "IMR 2000 MARINE" is found to be in compliance with the requirements of MEPC.103 (49), Analysing equipment, Sections 1.1 (Emission Species Measurement) and 1.2 (Analyser specifications). This includes some parts of MARPOL Annex VI and the NOx Technical Code 2008, Appendix III and IV, as indicated in the MEPC.103(49).

According to Revised MARPOL Annex VI and NOx Technical Code 2008 the "IMR 2000 MARINE", in combination with other equipment, may be used in the context of:
- **On-board simplified measurement method (NOx Technical Code 2008 6.3),**
- **On-Board Direct Measurement and Monitoring (NOx Technical Code 2008 6.4).**

The Principle of detection for CO2 is according MEPC.103(49), 1.1.3.2.
The equivalence of the alternative sensors for NOx (NO + NO2), CO and O2 have been demonstrated under surveillance and to the satisfaction of GL in accordance with ISO 8178:2006 Part 1, Annex D.
The "IMR 2000 MARINE" must be operated and calibrated in accordance with the requirements and intervals as specified in MEPC.103(49) Section 3.3.

Valid until **2019-09-07**
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File No. **I.A.02**
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Many thanks for your attention

Any questions?

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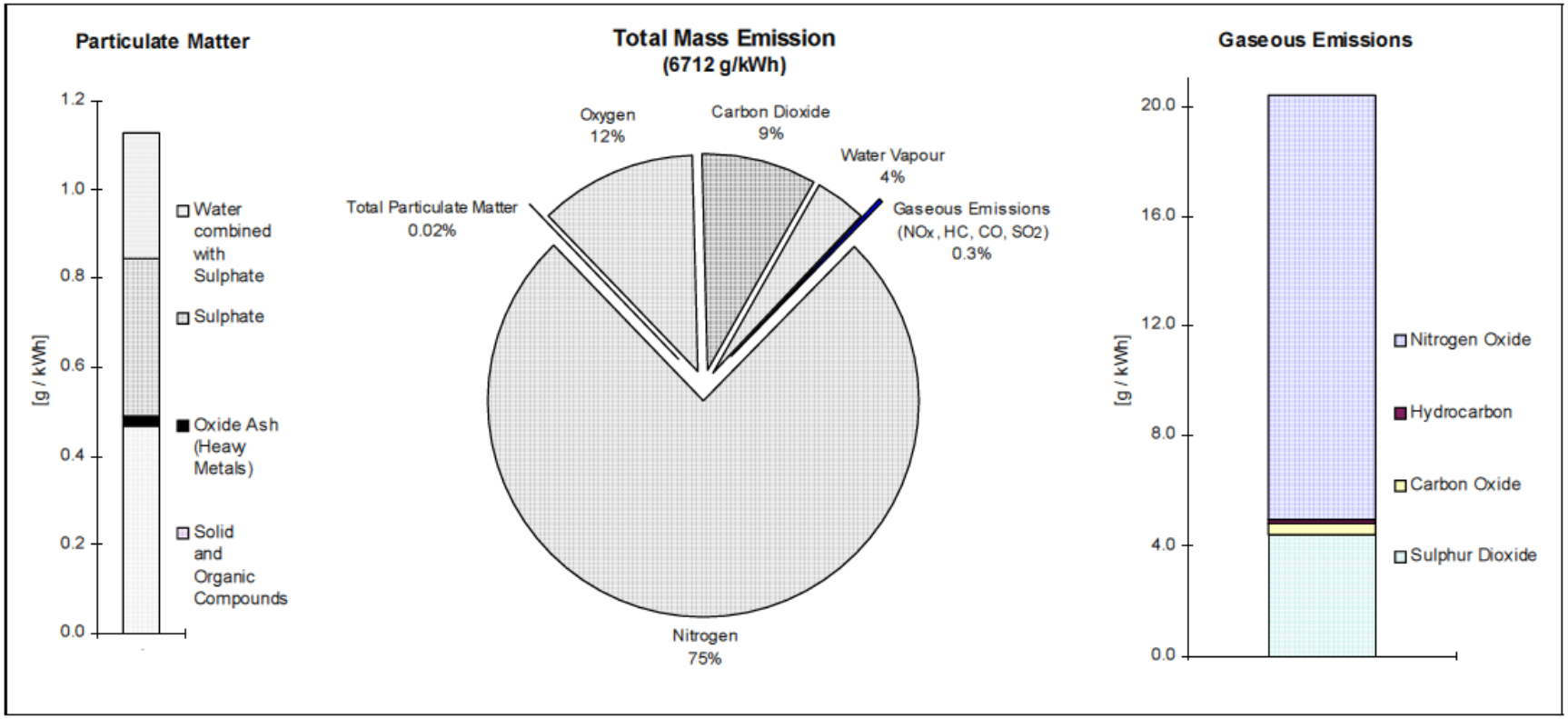
EXHAUST GAS EMISSION OVERVIEW



Composition Exhaust gas 4-Stroke engine (Propellercurve, 75% load, fuel with 2,2% Sulphur content)
Figure: Krapp

EXHAUST GAS EMISSION PARTICULAR MATTER (PM)

Composition:

- solid and organic components,
- Ash,
- sulfates and
- added water with sulfates

Formation of Particular Matters:

- formed during the incomplete combustion of fossil fuels, depends on:
  - Type of fuels (Sulphur content)
  - Combustion conditions, e.g. Combustion temperature

Effects on the environment:

- By adsorptive properties, the toxic substances in the exhaust gas, the existing fine particulates are classified as especially dangerous to carcinogens, as they are transported directly into the human lung.

Measurements (Example):

- Filter paper method: A predetermined gas quantity is soaked through a filter paper. The contaminants in the exhaust gas cause blackening of the filter paper. The evaluation is performed by comparing the filter paper sample with a comparative scale.

EXHAUST GAS EMISSION NITROGEN OXIDES (NO_X)

Composition:
Nitrogen oxide (NO_X) is a generic term for a group of highly reactive gases, containing Different amounts of nitrogen and oxygen.
NO_X is mostly a synonym for the sum of nitrogen monoxide (NO) and nitrogen dioxide (NO2).
Formation of NO and NO_2:
The nitrogen is oxidized with the oxygen (O_2) of the air in the combustion chamber, to NO. (produced by excess air and high temperatures in the combustion chamber)
The NO is highly reactive and therefore reacts in the atmosphere immediately advances to nitrogen dioxide (NO_2).
Effects on the environment:
In the atmosphere, the NO_2 reacts with water and oxygen to form nitric acid. This leads to acid rain.
In addition, the nitrogen oxides react in the atmosphere with reactive hydrocarbons and the solar radiation. This leads to a photochemical ozone creation. This ozone is a reason for the smog in many cities.
Measurements:
- Chemoluminescent detektor (CLD).

EXHAUST GAS EMISSION HYDROCARBON (HC)

Composition:
Aliphatische- and cyclic hydrocarbons.
The aliphatic hydrocarbons play a subordinate role in the damage to the environment.
As an environmentally harmful classify the cyclic hydrocarbons and in particular the sub-group of polycyclic aromatic hydrocarbons (PAH).

Formation of HC:
- incomplete combustion of fossil fuels.
- In exhaust PAHs are bound to the individual soot particles and thus pass into the ambient air.

Effects on the environment:
HC contributes to the photochemical formation of ground-level ozone because it causes other reactive partners within several complex reaction steps, the oxidation of NO to NO without ozone depletion (O3).

Measurements:
- Heated flame ionization detector (HFID).

EXHAUST GAS EMISSION CARBON OXIDES

Formation of CO/CO2:

- incomplete combustion of fossil fuels, depends on fuel
- In the air, the CO immediately to carbon dioxide (CO_2) reacts.

Effects on the environment:

The CO is a strong respiratory poison. It blocks the transport of oxygen to the red blood cells in the body and already performs a low content to disorders of the central nervous system.

Measurements:

Non-dispersive infrared (NDIR)

EXHAUST GAS EMISSION SULPHUR OXIDE (SO_X)

Formation of SO_2:

The sulfur in the fuel reacts with oxygen in the combustion chamber to sulfur oxide (SO_X). The sulfur oxides are only those who have an oxidation number <4, for example, SO_2 and SO_3. These sulfur oxides are also called lower sulfur oxides.

Effects on the environment:

The SO_2 as a strong breathing poison. It leads even at low concentrations to coughing and breathlessness. The SO_2 is freely soluble in water and reacts with water to sulfurous acid.

The sulfur trioxide SO_3 is a white solid. SO_3 becomes with water and excessive heat to sulfuric acid. The formation is highly temperature dependent, as the SO_3 expires at a temperature> 600 ° C back to SO_2 and oxygen.

Measurements:

- non-dispersive infrared (NDIR) or non - dispersive Ultraviolet (NDUV)

PROCEDURES FOR EMISSION MEASUREMENT (MARPOL)

MARPOL ANNEX VI AND NO_X Technical Code 2008 (2013) chapter 5

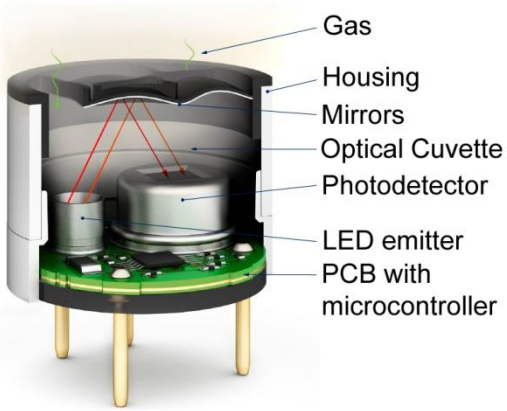
- Main exhaust components: CO, CO_2, HC, NO_X, O_2
- Procedure for demonstrating compliance with NO_X limits on board
- Analysing equipment:

❑ CO Analyse:	Non-Disperse Infrarot (NDIR)
❑ CO_2 Analyse:	Non-Disperse Infrarot (NDIR)
❑ HC Analyse:	heated flame ionization detector (HDIR)
❑ NO_X Analyse:	Chemiluminescent Detector (CLD) or heated Chemiluminescent Detector (HCLD)
❑ O_2 Analyse:	Paramagnetic detector (PMD), Zirconium dioxide (ZRDO) or electrochemical Sensor (ECS)

PEMS EXAMPLES
MEASUREMENT PRINCIPLES

Infrared Sensors:

- measures flue gas constituents (CO_2)
- Principle: is based on the fact that gas molecules are stimulated by IR light of a certain wavelength and so produce vibrations . (radiation source e.g. lamp)
- The infrared light passes through a test selection in which the gas can diffuse
- Through the gas a weakening of the radiation energy will be occur
- The absorption of the infrared radiation, in a specific wavelength range in the measured gas is proportional to the concentration of the gas to be analyzed.
- Compared to the original IR light intensity, the attenuated intensity within a defined fixed optical path is a measure for the gas concentration. infrared sensors gives a linear sensor signal, the signals are analogous to the processes of electrochemical sensors and will be analyzed by the electronics



CALIBRATION GASES

- Shelf life of the gases (document the expiration date of the gases)
- The concentration of calibration and span gases should be specified in volume per cent or volume ppm.
- The concentration must be comparable with national or international gas standards
- Pure gases :
  - The zero check gas -> setting the lower end of the range.
  - Gases that should be obtainable are purified nitrogen, purified oxygen and hydrogen-helium mixture.
- Span gases :
  - setting up the top end of the calibration range.
  - Mixtures of gases that should be obtainable are:
    - CO and purified nitrogen
    - NO_X and purified nitrogen (should not be more than 5% of the NO content)
    - O2 and purified nitrogen
    - CO2 and purified nitrogen
  - other gas mixtures can also be used
    - Requirement that the gases do not react with each other.