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Limits and measurement methods for exhaust pollutants from marine engines (CHINA I, II)

船舶发动机排气污染物排放限值及测量方法（中国第一、二阶段）

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Limits and measurement methods for exhaust pollutants from marine engines (CHINA I, II)

1 Scope

This standard specifies the emission limits and measurement methods for the exhaust pollutants of compression ignition engines and ignition gas fuel (including diesel and natural gas dual fuel) engines (hereinafter referred to as: marine engines) used for ships.

This standard is applicable to the type test, production consistency inspection, durability requirements of category 1 and category 2 marine engines (including main engines and auxiliary engines) which have a rated net power greater than 37 kW for inland vessels, coastal vessels, river-sea ships, channel ships and fishing ships. This standard also stipulates the emission requirements for ships and marine engines after rebuilding.

This standard does not apply to emergency marine engines used for ships, marine engines installed on lifeboats, marine engines on any equipment or devices used only in emergency situations.

Category 3 marine engines implement the requirements of GD 01.

Marine engines which have a rated net power not exceeding 37 kW implement the GB 20891 standard.

2 Normative references

The contents of this standard refer to the following documents or their clauses. For the cited documents without dates, the valid version applies to this standard.

GB 252 General diesel fuels

GB 20891 Limits and measurement methods for exhaust pollutants from diesel engines of non-road mobile machinery

GB/T 6072.3-2008 Reciprocating internal combustion engines - Performance - Part 3: Test measurements

GB/T 6379.2-2004 Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of

3.6

Category 1 marine engine

Marine engines which have a rated net power greater than or equal to 37 kW and a single cylinder displacement of less than 5 L.

3.7

Category 2 marine engine

Marine engines which have a single cylinder displacement greater than or equal to 5 L and less than 30 L.

3.8

Category 3 marine engine

Marine engines which have a single cylinder displacement greater than or equal to 30 L.

3.9

Dual fuel marine engine

Marine engines which burn either gas fuel or fuel oil, or burn both fuel oil and gas fuel.

3.10

Type test

A type finalization test carried out for the trial-produced new product after finishing the design of a marine engine type, for the purposes of verifying whether the product meets the technical requirements of this standard.

3.11

Marine engine type

The same category of marine engines with no difference in the basic characteristic parameters as listed in Appendix AA.

3.12

Marine engine family

A group of marine engines with similar exhaust characteristics designed by the manufacturer in accordance with the provisions of Appendix AB. All

3.19

Rated speed

Refers to the speed at rated power output indicated on the marine engine's nameplate and technical document.

3.20

Percent load

The percentage of the maximum torque that can be obtained at a certain speed of the marine engine.

3.21

Intermediate speed

For marine engines designed to work at non-constant speeds, when operating according to the full load torque curve, the speed that meets one of the following conditions:

- If the calibrated maximum torque speed is between 60 ~ 75% of the rated speed, the intermediate speed takes the calibrated maximum torque speed;
- If the calibrated maximum torque speed is lower than 60% of the rated speed, the intermediate speed takes 60% of the rated speed;
- If the calibrated maximum torque speed is higher than 75% of the rated speed, the intermediate speed takes 75% of the rated speed.

3.22

Useful life

As specified in clause 5.2.3 of this standard, the service time as confirmed during type test that can guarantee the normal operation of the marine engine's emission control system and complies with the relevant emission limits of gaseous pollutants and particulate matter.

3.23

Rebuilding marine engine

Dismantle, inspect and/or replace parts of the marine engine or part of marine engine system, reassemble the marine engine or marine engine system, to increase the life of the marine engine.

3.24

4.4 Exemption for type test

For marine engines with special purposes such as export, exhibition, rescue, emergency, matching test, etc., it may submit an application to the competent department to be exempted from type test. The information submitted to the competent authority shall include model, power, manufacturer, use, emission standard stage reached, quantity and production date.

5 Technical requirements and tests

5.1 General

The manufacturer shall take technical measures to ensure that the marine engine's emission control system operates normally under the normal working conditions and within the specified service life; the pollutant emission meets the requirements of this standard.

Without the type test, it shall not make any modification on the pollution control technical measures or devices (such as fuel system, electronic control system or after-treatment system, etc.) of the manufacturer that may affect emissions.

5.2 Provisions for exhaust pollutants

5.2.1 Test procedures and sampling system

The measurement and sampling procedures of marine engine's exhaust pollutants are carried out in accordance with the provisions of Annex BA in Appendix B. The test cycle is carried out in accordance with the provisions of Table B.1, or Table B.2, or Table B.3, or Table B.4, or Table B.5 in Appendix B.

Exhaust pollutants from marine engines shall be measured using the system described in Appendix C.

If other systems or analyzers are approved to obtain the following equivalent results to the test system specified in Appendix C, they can also be used:

- The system used to measure gaseous pollutants in the original exhaust gas (see Appendix C, Figure C.1);
- The system used to measure gaseous pollutants in the full-flow dilution system (see Appendix C, Figure C.2);
- The system used to measure particulate matter in a full-flow dilution system, which is used in the single filter paper (using a pair of filter papers throughout the test cycle) method or multiple filter paper (using a pair of filter papers per working condition) method (see Appendix C, Figure C.12).

The marine engine installed on the ship shall meet the following requirements for characteristics during the type test of the marine engine:

5.3.1 The intake air pressure drop shall not exceed the pressure drop specified in Annex AA.1.17 for engines that have been type-tested.

5.3.2 The exhaust back pressure shall not exceed the back pressure specified in Annex AA.1.18 for engines that have been type-tested.

5.3.3 The position and reference distance of the exhaust after-treatment device in the exhaust pipeline shall meet the requirements of Annex AA.2.

6 Provisions on the control of sulfur oxide emissions from ships

6.1 Inland vessels, river-sea ships and fishing ships operating in inland rivers shall use diesel fuel that complies with GB 252.

6.2 For coastal vessels, channel ships and fishing ships operating in offshore areas, if marine fuel oil is required for the design of marine engine, it shall use the low-sulfur marine fuel oil complying with national standards and regulations; for ships with pollution control devices, if its sulfur dioxide (SO_2) emissions do not exceed the use of low-sulfur marine fuels, it may use other fuels and the ship shall be clearly marked.

6.3 For the ships covered by this standard, if the design of the installed marine engine requires the use of other fuels (such as NG fuel and mixed fuel, etc.), it shall use the commercial fuels that meet the standard.

7 Production consistency inspection

Manufacturers shall take measures in accordance with the requirements of Appendix G, to ensure production consistency. The measured values of engine's gaseous pollutants and particulate matter in the production consistency inspection shall be corrected according to the actual deterioration coefficient (or deterioration correction value).

7.1 General requirements

7.1.1 For the marine engine type (or family) that has been officially put into production after the type test, the manufacturer must take measures to ensure that the relevant information of the marine engine it produces is consistent with the information of the type test (Appendix A) of the marine engine type (or family).

8 Marine engine's label

8.1 The marine engine manufacturer shall fix a label to each marine engine during production. The label shall meet the following requirements:

a) The label cannot be removed without destroying the label or damaging the appearance of the marine engine;

b) It is legible throughout the life of the marine engine;

c) It is fixed on the parts required for the normal operation of the marine engine, which shall not need to be replaced during the entire lifetime of the marine engine;

d) The position of the label shall be clearly visible when the marine engine is installed on the ship.

8.2 After the marine engine is installed on the ship, if the marine engine's label becomes inconspicuous due to the mechanical cover, the marine engine manufacturer shall provide the ship manufacturer with an additional label. The attached label shall meet the following requirements:

a) The label cannot be removed without destroying the label or damaging the appearance of the marine engine;

b) It is fixed on the parts required for the normal operation of the marine engine, which shall not need to be replaced during the entire lifetime of the marine engine.

8.3 The label shall contain the following information:

a) The power stage and limit stage corresponding to the marine engine;

b) The model, family name, power parameters of marine engine;

c) Marine engine's production date: year, month and day ("day" is optional. If the production date has been marked on other parts of the marine engine, the label need not indicating it repeatedly);

d) The full name of the marine engine manufacturer;

e) The type of fuel used by marine engines (e.g.: diesel, marine distillate, NG, etc.);

f) The type of aftertreatment device (e.g. selective catalytic reduction device, exhaust gas washing equipment, particulate trap, etc.) shall be indicated for those with aftertreatment device;

exceed 15%

9.5 Intake method

- Normally aspirated
- Boosted
- Turbocharged

9.6 Combustion chamber type

- Separated combustion chamber
- Open combustion chamber

9.6 Valves and airways - Structure, size and number

- Cylinder head
- Cylinder liner
- Crankcase

9.7 Fuel injection system

- Combined pump-tube-nozzle system
- Inline pump
- Distribution pump
- Single pump
- Pump nozzle

9.8 Fuel supply system (gas engine):

- Mixing unit
- Gas inhalation/injection (single point, multiple points)
- Liquid jet (single point, multiple points)

9.9 Ignition system (gas engine)

9.10 Other features

- Exhaust gas recirculation

Appendix A

(Normative)

Type test related information

It shall follow the requirements below to provide the relevant information of the marine engine and its emission control system.

If there is a schematic diagram, it shall fully explain the details in an appropriate proportion. Its format size is A4 or folded to this size. If there are photos, the details shall be displayed. If the marine engine type or marine engine family is controlled by a microprocessor, it shall provide relevant information.

Parent engine/Marine engine type [1]: ____________________________

A.1 Overview

A.1.1 Brand: _____________

A.1.2 Parent engine and marine engine family (if applicable) [1] name: ______

A.1.3 Name and address of manufacturer: _____________

A.1.4 Name and address of authorized agent (if any) of the manufacturer: ___

A.1.5 Location and fixing method of marine engine's label: ____________

A.1.6 Address of final assembly plant: ______________

A.2 Ancillary documents

A.2.1 The basic characteristics of the (parent engine) marine engine and relevant test data. (See Annex AA)

A.2.2 The basic characteristics of marine engine family. (See Annex AB)

A.2.3 The basic characteristics of each marine engine type in the family. (See Annex AC)

A.2.4 Photos and/or drawings of the parent engine/engine type.

A.2.5 List other ancillary documents (if any).

A.3 Date, file

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[1] Cross out those that are not applicable.

AA.1.13.1 Liquid cooling

AA.1.13.1.1 Liquid properties: ____________

AA.1.13.1.2 Circulation pump: yes/no [2)]

AA.1.13.1.3 Characteristics or brand and model (if applicable): ________

AA.1.13.1.4 Drive ratio (if applicable): ___________

AA.1.13.2 Air cooling

AA.1.13.2.1 Fan: yes/no [2)]

AA.1.13.2.2 Characteristics or brand and model (if applicable): _________

AA.1.13.2.3 Drive ratio (if applicable):

AA.1.14 Allowable temperature of the manufacturer

AA.1.14.1 Liquid cooling: Maximum temperature at the outlet of the cooling liquid: _____________ K

AA.1.14.2 Air cooling: Reference point: ____________ Maximum temperature at the reference point: ________________ K

AA.1.14.3 The maximum temperature of the air at the outlet of the intake intercooler (if applicable): ____________ K

AA.1.14.4 The maximum exhaust temperature in the exhaust pipe near the outlet flange of the exhaust manifold or supercharger: ___________ K

AA.1.14.5 Lubricating oil temperature: Minimum ____ K, Maximum ____ K

AA.1.15 Supercharger: yes/no [2)]

AA.1.15.1 Manufacturer: ___________

AA.1.15.2 Model: ___________

AA.1.15.3 System description (e.g.: maximum boost pressure, waste gas bypass valve (if any)): _____________

AA.1.16 Intercooler: yes/no [2)]

AA.1.16.1 Manufacturer: _______________

[2)] Cross out those that are not applicable.

AA.2.1.1.14 Type of reagent:

AA.2.1.1.15 Reagent concentration:

AA.2.1.1.16 NO_X sensor manufacturer:

AA.2.1.1.17 NO_X sensor model:

AA.2.1.2 Oxygen sensor: yes/no [1)]

AA.2.1.2.1 Manufacturer: _____

AA.2.1.2.2 Model: _____

AA.2.1.2.3 Location: _____

AA.2.1.3 Air jet: yes/no [1)]

AA.2.1.3.1 Type (pulsating air, air pump, etc.): _____

AA.2.1.4 EGR: yes/no [1)]

AA.2.1.4.1 Characteristics (flow rate, etc.): _____

AA.2.1.5 Particulate trap: yes/no [1)]

AA.2.1.5.1 Manufacturer: _____

AA.2.1.5.2 Model: _____

AA.2.1.5.3 The size, shape and volume of the particulate trap: _____

AA.2.1.5.4 Type and structure of particulate trap: _____

AA.2.1.5.5 Location (reference distance in exhaust duct): _____

AA.2.1.5.6 Regeneration method or system, description and/or drawings: ___

AA.2.1.6 Exhaust gas washing equipment: yes/no [2)]

AA.2.1.7 Other systems: yes/no [2)]

AA.2.1.7.1 Type and function: _____

AA.3 Fuel supply

AA.3.1 Fuel transfer pump

Pressure [1)]: _______ kPa

Annex AB
(Normative)
Basic characteristics of marine engine family

AB.1 Public parameters

AB.1.1 Combustion cycle: _____

AB.1.2 Cooling medium: _____

AB.1.3 Inhalation method: _____

AB.1.4 Combustion chamber's type/structure: _____

AB.1.5 Air valve and air port's structure, size and quantity: _____

AB.1.6 Fuel system: _____

AB.1.7 Marine engine management system:

According to the form or list provided, the following items can be proved to be the same:

- Supercharged intercooling system [1)]: _____
- Exhaust gas recirculation [1)]: _____
- Water jet/emulsification [1)]: _____
- Air jet [1)]: _____

AB.1.8 Exhaust aftertreatment [1)]: _____

Provide a form or list (for exhaust aftertreatment devices): _____

According to the form or list provided above, it can be proved that the ratio of "system capacity/fuel supply per stroke" is the same or the lowest for the parent engine.

AB.2 List of marine engine families

AB.2.1 Name of marine engine family: _____

AB.2.2 Specifications of marine engines in this family (see Table AB.1):

Annex AC
(Normative)
The basic characteristics of marine engine type in the family [1)]

AC.1 Description of marine engine

AC.1.1 Manufacturer: _______

AC.1.2 The marine engine number of the manufacturer: _______

AC.1.3 Cycle: four-stroke/two-stroke [2)]

AC.1.4 Number and arrangement of cylinders: ________

AC.1.4.1 Bore: __________ mm

AC.1.4.2 Stroke: ________ mm

AC.1.4.3 Ignition sequence: ___________

AC.1.5 Displacement: _________ cm^3

AC.1.6 Volume compression ratio [3)]: _____________________

AC.1.7 Top view of combustion chamber and piston: ___________

AC.1.8 Minimum cross-sectional area of intake and exhaust ports: ___ cm^2

AC.1.9 Description of the combustion system: ______________

AC.1.10 Intermediate speed: ______________ r/min

AC.1.11 Rated speed: ____________ r/min

AC.1.12 Fuel [4)]: __________

AC.1.13 Cooling system

AC.1.13.1 Liquid cooling

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1) For the case of several parent engines, this Appendix shall be submitted separately.

2) Cross out those that are not applicable.

3) Note the tolerance.

4) For those which can use multiple fuels and/or mixed fuels, it shall describe them separately.

AC.1.17 Intake system

According to the power measurement method stipulated in GB/T 21404-2008, based on the test conditions specified in this standard, at the rated speed of the marine engine and 100% load, the maximum allowable intake pressure drop: ________ kPa

AC.1.18 Exhaust system

According to the power measurement method stipulated in GB/T 21404-2008, based on the test conditions specified in this standard, at the rated speed of the marine engine and 100% load, the maximum allowable exhaust back pressure: ________ kPa

AC.2 Measures to prevent air pollution

AC.2.1 Additional pollution control devices (if any, not included in other items)

AC.2.1.1 Catalytic converter: yes/no [2)]

AC.2.1.1.1 Manufacturer:

AC.2.1.1.2 Model:

AC.2.1.1.3 Number of catalytic converters and catalytic units:

AC.2.1.1.4 The size, shape, volume of the catalytic converter:

AC.2.1.1.5 Type of catalytic reaction:

AC.2.1.1.6 Total precious metal content:

AC.2.1.1.7 The ratio of precious metals:

AC.2.1.1.8 Carrier (structure and material):

AC.2.1.1.9 Pore density:

AC.2.1.1.10 Type of catalytic converter's housing:

AC.2.1.1.11 Position of the catalytic converter (position and reference distance in the exhaust pipeline):

AC.2.1.1.12 Metering pump manufacturer:

AC.2.1.1.13 Metering pump model:

[2)] Cross out those that are not applicable.

AC.2.1.6.5 Location (reference distance in exhaust duct): ______

AC.2.1.6.6 Regeneration method or system, description and/or drawings: ___

AC.2.1.7 Exhaust gas washing equipment: yes/no [2)]

AC.2.1.8 Other systems: yes/no [2)]

AC.2.1.8.1 Type and function: ______

AC.3 Fuel supply

AC.3.1 Oil transfer pump

Pressure [1)]: ______ kPa

AC.3.2 Injection system

AC.3.2.1 Fuel injection pump

AC.3.2.1.1 Manufacturer: ______

AC.3.2.1.2 Model: ______

In the full-load oil supply position, the pump speed is: _____ r/min (rated and maximum torque), the oil supply amount [1)]: ____ mm^3 per stroke (or cycle); or characteristic curve (explain the test method used: on the marine engine / on the oil pump test stand [2)])

AC.3.2.1.3 Fuel injection advance

AC.3.2.1.3.1 Fuel injection advance curve [1)]: ______

AC.3.2.1.3.2 Static injection timing [1)]: ______

AC.3.2.1.4 High-pressure fuel pipe

AC.3.2.1.4.1 Length: ____ mm

AC.3.2.1.4.2 Inner diameter: ______ mm

AC.3.2.1.5 Fuel injector

AC.3.2.1.5.1 Manufacturer: ______

AC.3.2.1.5.2 Model: ______

AC.3.2.1.5.3 Opening pressure: ______ kPa[1)]

Or characteristic curve [1) 2)]: ______

test is considered valid:

$$0.93 \le f_a \le 1.07$$

B.2.2.3 Supercharged intercooling system

The temperature of the supercharged air must be recorded. At the rated speed and full load, the temperature of the supercharged air shall be kept within ±5 K of the maximum supercharged air’s temperature as specified by the manufacturer, meanwhile the temperature of the cooling medium shall not be less than 293 K (20 °C) .

If a laboratory system or external fan is used, the supercharged air temperature shall be set within ±5 K of the maximum supercharged air temperature as specified by the manufacturer at rated speed and full load. The cooling medium temperature and cooling medium flow rate of the supercharged air cooler at the above set points shall not be changed during the entire test. The volume of the supercharged air cooler shall be based on good engineering experience and shall be applied on ship.

B.2.3 Intake system

The test marine engine shall be equipped with an air intake system. The air intake pressure drop shall be within ±300 Pa of the upper limit as specified by the manufacturer: under the operating conditions specified by the manufacturer for the maximum intake air flow rate, the intake pressure drop as caused by clean air filter or intake muffler.

If the laboratory system can represent the actual operating conditions of the marine engine, it may use the laboratory system.

B.2.4 Exhaust system

The test marine engine shall be equipped with an exhaust system. The exhaust back pressure is within ±650 Pa of the upper limit as specified by the manufacturer, that is, the exhaust back pressure generated under the working conditions of the marine engine's rated power.

If the engine is equipped with an exhaust aftertreatment device, the exhaust pipe shall have a straight pipe segment of at least 4 times pipe diameters upstream of the expansion portion containing the aftertreatment device. The distance from the exhaust manifold flange or the turbocharger outlet to the exhaust aftertreatment device shall be the same as the actual application or within the technical requirements of the manufacturer. Exhaust back pressure or intake resistance shall follow the same standards as above and can be set using valves. During simulation experiments and engine calibration, the contents of the aftertreatment device can be removed and replaced with an particulate value of the diluted air. The dilution air shall be filtered. It shall measure the background particulate value before, during, or after the test.

B.3.5 Adjust the dilution ratio

The setting of the dilution air shall ensure that the surface temperature of the filter paper does not exceed 325 K (52 °C) in each test condition. The total dilution ratio shall not be less than 4.

For the single filter paper method of the full-flow dilution system, under all working conditions (except for the first 10 seconds of each working condition for systems without bypass capability), the sampling mass flow through the filter paper and the diluted exhaust mass flow shall maintain a constant ratio. The deviation of the mass flow ratio shall be controlled within ±5%. For the single filter paper method of the partial-flow dilution system, under all working conditions (except for the first 10 seconds of each condition for systems without bypass capability), the sampling mass flow through the filter paper shall be kept constant. The deviation shall be within ±5%.

B.3.6 Measurement of background dilution air concentration

For a system that controls the dilution ratio by measuring the concentration of CO_2 and NO_X, it shall measure the content of CO_2 and NO_X in the dilution air at the beginning and end of each test. The background concentration of CO_2 and NO_X in the dilution air measured before and after the test shall be within 100 ppm or 5 ppm, respectively.

When using a diluted exhaust analysis system, the relevant background concentration shall be determined based on the dilution air collected into the sampling bag throughout the test.

Continuous background concentration measurement (without sampling bag) needs to be measured at least three times before the test, close to the middle of the test cycle and after the test, and averaged. At the request of manufacturer, background measurement can be ignored.

B.3.7 Check the analyzer

It shall calibrate the zero point and range point of the emission analyzer.

B.3.8 Test procedure

B.3.8.1 Test cycle

B.3.8.1.1 For main marine engines operating according to propulsion characteristics, the test shall be carried out cyclically according to the four operating conditions in Table B.1.

The fuel temperature shall be measured at the position specified by the manufacturer or at the inlet of the fuel injection pump. The position of the measurement point shall be recorded.

B.3.8.4 Analyzer response

Exhaust gas shall pass through the analyzer at least in the last 3 minutes of each working condition. The output of the analyzer shall be recorded by a tape recorder or equivalent data acquisition system. If the diluted CO and CO_2 gases are measured by the method of sampling bag, exhaust gas shall enter the sampling bag in the last 3 minutes of each working condition; then analyze the sampling bag and record the results.

B.3.8.5 Sampling of particulate matter

The single filter paper method or the multiple filter paper method is used for particulate sampling. Since the results produced by using different methods may be slightly different, the method used must be explained together with the results.

For the single filter paper method, the weighting factor in the test cycle shall be considered during the sampling process; meanwhile the sampling flow rate and sampling time shall be adjusted accordingly.

Sampling must be done at the end of each working condition as much as possible. The sampling time for each working condition is at least 20 seconds for the single filter paper method and at least 60 seconds for the multiple filter paper method. For systems without bypass function, the sampling time for each working condition must be at least 60 seconds for single filter paper and multiple filter paper methods.

B.3.8.6 Marine engine status

Under each working condition, when the marine engine is stable, it shall measure the speed and load, intake air temperature, fuel consumption, intake or exhaust flow rate of the marine engine.

If it is not possible to measure the exhaust flow, or the intake flow and fuel consumption, it may only measure the fuel consumption and then use the carbon balance method to calculate the exhaust flow.

It shall record the measurement data required for the calculation of emission results.

B.3.9 Inspection of analyzer

After the emission test, it shall use zero gas and the same span gas to re-check

Annex BA
(Normative)
Measurement and sampling procedures

BA.1 Measurement and sampling procedures

It shall use the system as specified in Appendix C to measure the exhaust pollutants of the marine engines submitted for testing. Appendix C describes the recommended gaseous pollutant analysis system (see clause C.1.1) and the recommended particulate matter dilution and sampling system (see clause C.1.2).

BA.1.1 Technical specifications of dynamometer

It shall use a dynamometer with appropriate characteristics to complete the test cycle as specified in Table B.1, Table B.1, or Table B.2, or Table B.3, or Table B.4, or Table B.5 of clause B.3.8.1. The measuring instruments of torque and rotation speed shall make the measured shaft end power within the allowable power range through additional calculations.

The accuracy of the measuring equipment shall not exceed the maximum limits as given in Table BA.1.

BA.1.2 Exhaust flow

Measure the exhaust flow according to one of the methods mentioned in clause BA.1.2.1 to clause BA.1.2.4.

BA.1.2.1 Direct measurement method

Using a flow nozzle or equivalent flow meter system [1)] to directly measure the exhaust flow.

BA.1.2.2 Measurement method of intake air flow and fuel consumption

It shall use the air flow meter and fuel flow meter that meet the accuracy specified in Table BA.1 to measure the intake air flow rate and fuel consumption.

The exhaust gas flow is calculated as follows:

$G_{EXHW} = G_{AIRW} + G_{FUEL}$ (wet-base exhaust volume flow)

or

$V_{EXHD} = V_{AIRD} - 0.766 \times G_{FUEL}$ (dry-base exhaust volume flow) (computer, data logger) can achieve sufficient accuracy and resolution below 15% of full scale, the measured concentration below 15% of full scale is also acceptable. In this case, additional calibration points shall be added to ensure the accuracy of the calibration curve (see clause BB.1.5.5.2).

The electromagnetic compatibility of the equipment shall reach a level that minimizes additional errors.

BA.1.4.1.1 Measurement error

The analyzer shall not deviate from ±2% of the nominal calibration point reading or 0.3% of full scale, whichever is greater.

BA.1.4.1.2 Repeatability

For 2.5 times the standard difference of 10 repeated response value as measured by a given calibration or span gas, for these gases exceeding 155 ppm (or ppm C_1), it shall not exceed ±1% of the full-scale concentration of the range; for these less than 155 ppm (or ppm C_1), it shall not exceed ±2% of the full-scale concentration of this range.

BA.1.4.1.3 Noise

In all application ranges, the peak-to-peak response value of the analyzer to zero gas, calibration gas or span gas within 10 seconds shall not exceed 2% of full scale.

BA.1.4.1.4 Zero drift

Zero response is defined as the average response to zero gas (including noise) over a 30-second interval.

For the lowest range used, the zero drift for 1 hour shall not exceed 2% of the full range of the range.

BA.1.4.1.5 Range point drift

Range response is defined as the average response to span gas (including noise) over a 30-second interval.

For the lowest range used, the range point drift for 1 hour shall not exceed 2% of the full range of the range.

BA.1.4.2 Gas drying

The selected gas drying device must have the least effect on the concentration of the measured gas. It shall not use chemical desiccant to remove the moisture in the sample gas.

above methods may also be used. The total exhaust mass flow must be used to calculate exhaust emissions.

If the composition of the exhaust gas is affected by the exhaust gas aftertreatment system, the exhaust gas sampling shall be downstream of the exhaust gas aftertreatment system. When a full-flow dilution system is used to measure particulate emissions, gaseous pollutants can also be determined from exhaust gas measurements after dilution. In the dilution channel, the exhaust gas's sampling probe shall be close enough to the particulate matter sampling probe (see DT in clause C.1.2.1.2 and PSP in clause C.1.2.2). For the emission measurement of CO and CO_2, it may choose to take the sample gas into the sample gas bag and determine it by measuring the concentration of the sample gas bag.

BA.1.5 Measurement of particulate matter

The measurement of particulate matter requires the use of a dilution system. The dilution system is divided into a full-flow dilution system and a partial-flow dilution system. The flow capacity of the dilution system shall be sufficient to completely eliminate the condensation of water in the dilution and sampling system, meanwhile make the temperature of the diluted exhaust gas immediately upstream of the filter paper holder do not exceed 325 K (52 °C). If the air humidity is high, the dilution air is allowed to dehumidify before entering the dilution channel. If the ambient temperature is lower than 293 K (20 °C), it is recommended to preheat the dilution air to exceed the upper temperature limit of 303 K (30 °C). However, before introducing exhaust gas into the dilution channel, the temperature of the dilution air shall not exceed 325 K (52 °C).

For the partial-flow dilution system, as shown in EP and SP in Figure C.3 to Figure C.11 of clause C.1.2.1.1, the particulate sampling probe shall be close to and located upstream of the exhaust sampling probe. The exhaust sampling probe is defined in clause C.1.1.1.

The partial-flow dilution system is designed to divide the exhaust flow into two parts, a small part of which is diluted by air and used for the measurement of particulate matter. It is very important to accurately determine the dilution ratio. Different gas splitting methods can be used; the splitting method used largely determines the sampling system and sampling procedure used (see clause C.1.2.1.1).

Measuring the mass of particulate matter requires a particulate sampling system, particulate sampling filter paper, a microgram balance, a weighing chamber that controls temperature and humidity.

Two methods can be used to sample particulate matter:

Annex BB
(Normative)
Calibration procedure

BB.1 Calibration of analytical instruments

BB.1.1 Overview

Each analyzer shall be calibrated as often as necessary to meet the accuracy requirements of this standard. For the analyzers listed in clause BA.1.4.3, this Annex describes the calibration method used.

BB.1.2 Calibration gas

It must follow the storage date of all calibration gas.

It shall record the expiration date of the calibration gas as specified by the manufacturer.

BB.1.2.1 Pure gas

The following working gas shall be available; the content of impurities in the gas shall not exceed the following limit requirements:

- Pure nitrogen, with impurities: $C_1 \leq 1$ ppm, CO ≤ 1 ppm, $CO_2 \leq 400$ ppm, NO ≤ 0.1 ppm

- Pure oxygen: purity > 99.5%v/v O_2

- Hydrogen-helium mixed gas (40 ± 2% hydrogen, helium is used as balance gas), in which impurities: $C_1 \leq 1$ ppm, $CO_2 \leq 400$ ppm

- Synthetic air, with impurities: $C_1 \leq 1$ ppm, CO ≤ 1 ppm, $CO_2 \leq 400$ ppm, NO ≤ 0.1 ppm; oxygen content 18% ~ 21%v/v

BB.1.2.2 Calibration gas and span gas

It shall have a mixture of the following chemical components:

- C_3H_8 and synthetic air

- CH_4 and synthetic air

- CO and pure nitrogen

- NO and pure nitrogen (NO_2 content in the calibration gas shall not exceed 5% of NO content)

BB.1.5.3 NDIR and HFID analyzer

The NDIR analyzer shall be adjusted as necessary; the combustion flame of the HFID analyzer shall be adjusted to the best (see clause BB.1.8.1).

BB.1.5.4 Calibration

It shall calibrate the working range normally used.

It shall use synthetic air (or nitrogen) to calibrate the zero position of CO, CO_2, NO_X, HC and O_2 analyzers.

Introduce appropriate calibration gas into the analyzer. Record its value. Establish a calibration curve according to clause BB.1.5.5.

If necessary, check the zero calibration again and repeat the calibration procedure.

BB.1.5.5 Establish calibration curve

BB.1.5.5.1 General

The calibration curve of the analyzer shall consist of at least six calibration points (excluding zero points) that are as evenly distributed as possible. The maximum nominal concentration shall be equal to or higher than 90% of full scale.

The calibration curve shall be calculated by the method of least squares. If the degree of the polynomial used is greater than 3, the number of calibration points (including zeros) shall be at least equal to the degree of the polynomial plus 2.

The difference between the calibration curve and the nominal value of each calibration point shall not be greater than ±2%. It shall not be greater than ±1% of full scale at the zero point.

According to the calibration curve and calibration point, it can verify whether the calibration is correct. It shall indicate the different characteristics of the analyzer, especially:

- Measuring range
- Sensitivity
- Date of calibration

BB.1.5.5.2 Calibration below 15% of full scale

The calibration curve of the analyzer shall be composed of at least 10

BB.1.7.4 Add oxygen

Adjust the analyzer to the NO mode. Use a T-shaped connector, to continuously add oxygen or synthetic air to the gas flow, until the indicated concentration is about 20% lower than the calibration concentration as given in clause BB.1.7.2. Record the indicated concentration (c). The ozone generator does not work during this process.

BB.1.7.5 Excite ozone generator

Adjust the analyzer to the NO mode. Excite the ozone generator to generate enough ozone to reduce the NO concentration to the point approximately 20% less than the calibration concentration given in clause BB.1.7.2 (minimum 10%). Record the indicated concentration (d).

BB.1.7.6 NO_X mode

Adjust the analyzer to the NO_X mode. Allow the mixed gas (containing NO, NO_2, O_2 and N_2) to pass through the converter. Record the indicated concentration (a).

BB.1.7.7 Stop exciting ozone generator

Adjust the analyzer to the NO_X mode. Stop exciting the ozone generator. Allow the mixed gas described in clause BB.1.7.6 to pass through the converter. Record the indicated concentration (b).

BB.1.7.8 NO mode

When the ozone generator stops excitation, switch to NO mode. The flow of oxygen or synthetic air is also cut off. Analyze the NO_X reading of the analyzer, which shall not deviate from the measured value according to clause BB.1.7.2 by more than ±5%.

BB.1.7.9 Test interval

Carry out the efficiency test of the converter before each calibration of the NO_X analyzer.

BB.1.7.10 Efficiency requirements

The efficiency of the converter shall not be lower than 90%, but it is recommended to exceed 95%.

Note: In the most commonly used range of the analyzer, if the ozone generator cannot reduce the NO concentration from 80% to 20% according to BB.1.7.5, it shall use the highest range that can achieve this reduction during the test.

after regular maintenance.

The response coefficient shall be determined in accordance with the provisions of clause BB.1.8.2. The test gas used and the recommended response coefficient are as follows:

Propane and pure nitrogen $0.95 \leq R_f \leq 1.15$

This value refers to the response coefficient when R_f is 1 relative to propane and synthetic air.

The oxygen concentration of the air in the FID burner shall be within ±1 mole% of the oxygen concentration of the air in the burner used in the most recent oxygen interference check. If the difference is large, the oxygen interference check shall be performed and the analyzer shall be adjusted if necessary.

BB.1.9 Interference effects of NDIR and CLD analyzers

In addition to the gas analyzed, other gases present in the exhaust can interfere with the reading in a variety of ways. Positive interference in NDIR instruments means that the interfering gas produces the same effect as the measured gas, but the degree of influence is small. The negative interference that occurs in NDIR instruments refers to the fact that the interference gas expands the absorption band of the measured gas; while the negative interference that appears in the CLD instrument is due to the extinction effect of the interference gas. Before the analyzer is put into use and after regular maintenance, the interference check shall be carried out in accordance with the provisions of clause BB.1.9.1 and clause BB.1.9.2.

BB.1.9.1 CO analyzer's interference check

Water and CO_2 can interfere with the performance of the CO analyzer. Therefore, at room temperature, CO_2 span gas with a concentration of 80% to 100% of the maximum working range used during the test shall bubble up from the water, meanwhile the response value of the analyzer shall be recorded. If the CO range is equal to or higher than 300 ppm C_1, the response value of the analyzer shall not be greater than 1% of full scale. If the CO range is less than 300 ppm C_1, the response value of the analyzer shall not be greater than 3 ppm.

BB.1.9.2 Extinction check of NOX analyzer

The two gases that have a light-extinction effect on CLD (or HCLD) analyzers are CO_2 and water vapor. The extinction response of these gases is proportional to their concentration. Therefore, it is required to use a test method to measure the extinction at the highest concentration considered by test experience.

Annex BC
(Normative)
Data determination and calculation

BC.1 Data determination and calculation

BC.1.1 Determination of gaseous pollutant data

For the determination of gaseous pollutants, it shall average the readings recorded in the last 60 seconds of each operating condition. It shall be based on the average of the recorded readings and the corresponding correction data to determine the average concentration (conc) of HC, CO, NO_X and CO_2 (if using carbon balance method) for each operating condition. If it can ensure access to equivalent data, it can use a different form of record.

It may determine the average background concentration ($conc_d$) from the readings of dilution air sampling bag or continuous background readings and corresponding correction data.

BC.1.2 Particulate matter

The determination of particulate emissions shall record the sampling mass ($M_{SAM,\ i}$) or volume ($V_{SAM,\ i}$) which passes the filter paper at each working condition.

After the test is completed, the filter paper shall be returned to the weighing chamber for stabilization for at least 1 hour, but not more than 80 hours; then weighed. Record the total mass of the filter paper and subtract its net mass (see clause B.3.1). The mass of particulate matter (M_f for single filter paper method, $M_{f,\ i}$ for multiple filter paper method) is the sum of the mass of particulate matters collected in the primary and secondary filter paper.

If background correction is performed, it shall record the dilution air mass (M_{DIL}) or volume (V_{DIL}) and particulate matter's mass (M_d) through the filter paper. If multiple measurements are made, it shall calculate the M_d/M_{DIL} or M_d/V_{DIL} for each measurement and take the average.

BC.1.3 Calculation of gaseous pollutants

The final results of the test shall be calculated according to the following procedures.

BC.1.3.1 Determination of exhaust flow

It shall determine the exhaust flow rate (G_{EXHW}, V_{EXHW} or V_{EXHD}) of each working

Annex BD
(Normative)
Determination of degradation coefficient

BD.1 Overview

This Annex specifies the method for determining the degradation coefficient or degradation correction value.

BD.2 Determination of deterioration coefficient or deterioration correction value

BD.2.1 The manufacturer shall use a good engineering method as the basis, adopt a test cycle that can represent the deterioration of the emission performance of the engine in use, to run the durability test. The durability time shall not be less than the allowable minimum test time as specified in Table 2.

BD.2.2 Durability test can be carried out on the engine bench, or the endurance test method of accelerated aging can be used. The relevant accelerated aging factor is determined by the manufacturer according to good engineering methods.

BD.2.3 During the durability test, in addition to the daily maintenance recommended by the manufacturer or under the effective supervision of the testing agency, it shall not perform maintenance or replacement of key emission components.

BD.2.4 The manufacturer shall adopt good engineering methods to determine the emission durability test engine. The test engine shall be able to represent the emission degradation characteristics of the engine family using the DF value during type test. Based on a reasonable technical analysis, engines with different cylinder bores, different strokes, different configurations, different intake management systems, different fuel systems can be regarded as having the same emission degradation characteristics.

BD.2.5 Emission tests shall be conducted at several intervals selected at the end of the run-in period, at the end of the durability test, during the durability test.

BD.2.6 Emission durability test and emission test can be carried out in the manufacturer; but it shall be under the effective supervision of the testing agency.

BD.2.7 The degradation coefficient or degradation correction value shall be determined separately for each pollutant. For the NO_X + HC degradation

- Have a minimum inner diameter of 5 mm;

- Be installed in the dilution channel DT (see clause 1.2.1.2), where the dilution air and exhaust gas are fully mixed (e.g., about 10 times the pipe diameter downstream from the point where the exhaust gas enters the dilution channel);

- Be far enough (radial) from other sampling probes and pipe wall, to avoid the influence from vortex or wake flow;

- Be heated, to keep the temperature of the airflow at the outlet of the sampling probe at 463 K (190 °C) ± 10 K.

(3) SP3 diluted exhaust CO, CO_2, NO_X sampling probe (only used in Figure C.2)

The sampling probe shall:

- Be located on the same plane as SP2;

- Be far enough (radial) from other sampling probes and pipe wall, to avoid the influence of vortex or wake flow;

- Heat and insulate the entire length, to keep the temperature above 328 K (55 °C) to prevent moisture condensation;

(4) HSL1 heating sampling pipeline

The sampling tube transports the sample gas from the sampling probe to the split point and the HC analyzer.

The sampling line shall:

- Have a minimum inner diameter of 5 mm and maximum inner diameter of 13.5 mm;

- Be made of stainless steel or polytetrafluoroethylene (PTFE);

- If the exhaust temperature at the sampling probe is equal to or lower than 463 K (190 °C), keep the wall temperature of each control heating part at 463 K (190 °C) ± 10 K;

- If the exhaust temperature at the sampling probe is higher than 463 K (190 °C), keep the wall temperature above 453 K (180 °C);

- Keep the gas temperature before heating filter (F2) and HFID at 463 K (190 °C) ± 10 K.

(14) NO

(H)CLD analyzer for measuring NO_X; if using HCLD analyzer, the temperature shall be kept at 328 K to 473 K (55 ~ 200 °C).

(15) C converter

A converter used before CLD or HCLD analyzers to catalytically reduce NO_2 to NO.

(16) B condensation tank

In order to condense the moisture in the exhaust gas sample, the temperature of the condensation tank shall be maintained at 273 K to 277 K (0 to 4 °C) by the use of ice or a condenser. If the analyzer is measured in accordance with clause BB.1.9.1 and clause BB.1.9.2 to avoid the interference from water vapor, the condensation tank is optional.

It is not allowed to use chemical desiccant to remove moisture from the sample gas.

(17) T1, T2, T3 temperature sensors

Used to monitor airflow temperature.

(18) T4 temperature sensor

The temperature of the NO_2 - NO converter.

(19) T5 temperature sensor

Used to monitor the temperature of the condensation tank.

(20) G1, G2, G3 pressure gauge

Used to measure the pressure of the sampling pipeline.

(21) R1, R2 pressure regulating valve

Control the pressure of HFID air and fuel, respectively.

(22) R3, R4, R5 pressure regulating valve

Control the pressure of the sampling line and the gas flow to the analyzer.

(23) FL1, FL2, FL3 flowmeter

process can be achieved by different types of dilution systems. Regarding the subsequent collection of particulate matter, the entire diluted exhaust gas or only partially diluted exhaust gas can be used to pass through the particulate matter sampling system (Figure C.13 in clause C.1.2.2). The first method is called the full-flow sampling type; the second method is called the partial-flow sampling type.

The calculation of the dilution ratio depends on the type of dilution system used.

The following types of dilution systems are recommended:

- Isodynamic system (Figure C.3 and Figure C.4)

  With these systems, the flow rate into the transfer tube is similar to the exhaust volume flow rate in terms of airflow velocity and/or pressure, so it is necessary to obtain an undisturbed or uniform exhaust flow at the sampling probe. This can usually be achieved by using rectifiers or straight pipe segments upstream of the sampling point. The split ratio can be calculated from the easily measured pipe diameter. It shall be noted that the isodynamic is only similar to the flow conditions and not the size distribution. The latter is generally not necessary because the particulate matter is small enough to flow with the exhaust streamline.

- Flow control system with concentration measurement (Figure C.5 to Figure C.9)

  This system collects sample gas from the total exhaust flow by adjusting the dilution air flow and the total dilution exhaust flow. The dilution ratio is calculated according to the concentrations of tracer gases such as CO_2 and NO_X naturally generated in the exhaust of the marine engine. The concentration of the tracer gas in the diluted exhaust gas and dilution air needs to be measured, whilst the concentration of the tracer gas in the original exhaust gas can be obtained by measurement. If the fuel composition is known, it can also be calculated based on the fuel flow rate and carbon balance formula. The system can be controlled by the calculated dilution ratio (Figure C.5 and Figure C.6) or by the flow into the transfer tube (Figure C.7, C.8 and C.9).

- Flow control system with flow measurement (Figures C.10 and C.11)

  This system collects sample gas from the total exhaust flow by setting the dilution air flow and the total dilution exhaust flow. Calculate the dilution ratio based on the difference between the two flows. Since the relative difference between the two flows will cause a large error at high dilution ratios, it is necessary to calibrate the two flowmeters accurately (Figure C.8 and the above Figures). If necessary, as long as the dilution exhaust flow aftertreatment devices), any measures to reduce pressure fluctuations shall not alter the performance of the marine engine or cause particulate matter deposition.

For systems that do not use an isokinetic sampling probe, it is recommended that the straight pipe is within six pipe diameters upstream and three pipe diameters downstream of the probe tip.

(2) SP sampling probe (Figure C.5 to C.11)

The minimum inner diameter shall be 4 mm. The minimum diameter ratio of the exhaust pipe to the probe shall be 4. The probe shall be an open tube, directly facing upstream of the centerline of the exhaust pipe, or the multi-hole probe as described in SP1 in clause 1.1.1.

(3) ISP isokinetic sampling probes (Figures C.3 and C.4)

The isokinetic sampling probe must be installed on the center line of the exhaust pipe, facing upstream. The EP part must meet certain flow conditions, meanwhile the ISP is designed to provide a certain proportion of the original exhaust sampling. The minimum inner diameter shall be 12 mm.

The control system must achieve isokinetic exhaust splitting by keeping the pressure difference between EP and ISP to zero. Under this condition, the exhaust velocities in EP and ISP are the same. The mass flow through ISP is a constant part of the exhaust flow. The ISP must be connected to a differential pressure sensor. The fan speed and flow controller are used to make the pressure difference between EP and ISP be zero.

(4) FD1, FD2 shunt (Figure C.8)

A set of venturi or flow orifice plates are installed in the exhaust pipe EP and the transfer pipe TT, respectively, to provide a certain proportion of the original exhaust sample gas. A flow control system consisting of two pressure control valves PCV1 and PCV2 is necessary, to achieve a certain proportion of exhaust split by controlling the pressure in EP and DT.

(5) FD3 shunt (Figure C.9)

Install a set of pipes (multi-pipe components) in the exhaust pipe EP, to provide a certain proportion of the original exhaust sample gas. One of them sends the exhaust gas to the dilution channel DT, whilst the other pipes send the exhaust gas to the buffer chamber DC. These pipes must have the same size (same diameter, length, bending radius), so the to maintain the pressure difference between EP and ISP to zero. It can be adjusted by the following steps:

(a) In each working condition, control the speed and flow of the exhaust fan (SB), to keep the speed of the exhaust fan (PB) stable.

or

(b) Adjust the exhaust fan (SB) to stabilize the mass flow of the diluted exhaust and control the flow of the exhaust fan, so adjust the exhaust sampling flow in a certain area at the end of the transfer pipe (TT) (Figure C.4) .

In the pressure control system, the error in the control loop shall not exceed ±3 Pa; the pressure fluctuation in the dilution channel shall not exceed ±250 Pa of the average value.

For multi-tube systems (Figure C.9), in order to achieve proportional flow splitting, a flow controller must be used, to maintain the pressure difference between the outlet of the multi-tube unit and the outlet of the TT to be zero. It is adjusted by controlling the air flow into the DT at the TT outlet.

(10) PCV1, PCV2 pressure control valves (Figure C.8)

For dual venturi or dual-flow orifice systems, in order to achieve proportional split, two pressure control valves must be used, to control the back pressure of EP and the pressure of DT. The two valves shall be installed downstream of SP in EP and between PB and DT, respectively.

(11) DC buffer chamber (Figure C.9)

The buffer chamber shall be installed at the outlet of the multi-tube unit, to reduce the pressure fluctuation of the exhaust pipe EP.

(12) VN Venturi tube (Figure C.7)

The Venturi tube is installed in the dilution channel DT, to generate a negative pressure in the outlet area of the transfer tube TT. The gas flow through TT is determined by the momentum exchange in the Venturi area, which is proportional to the flow of the pressure fan PB, resulting in a constant dilution ratio. Since the momentum exchange is affected by the TT outlet temperature and the pressure difference between EP and DT, the actual dilution ratio is slightly lower at low loads than at high loads.

(13) FC2 flow controller (Figure C.5, C.6, C.10 and C.11, optional)

of the dilution channel downstream of the exhaust gas entering the dilution channel;

- The minimum inner diameter is 12 mm;

- The wall temperature can be heated to not more than 325 K (52 °C) by direct heating, or as long as the air temperature before the exhaust gas enters the dilution channel does not exceed 325 K (52 °C), it can also be preheated by the dilution air;

- It shall be thermal insulated.

(20) DT dilution channel (Figures C.3 to C.11)

The dilution channel:

- Shall be of sufficient length to allow exhaust gas and dilution air to be fully mixed under turbulent conditions;

- Shall be made of stainless steel and have:

- A thickness to diameter ratio of less than or equal to 0.025 for dilution channels which have an inner diameter exceeding 75 mm;

- A nominal wall thickness of the dilution channel not less than 1.5 mm for dilution channels which have an inner diameter less than or equal to 75 mm;

- An inner diameter of at least 75 mm for partial-flow sampling type;

- A recommended inner diameter of at least 25 mm for full-flow sampling type;

- May use the direct heating method to heat the wall temperature to be not more than 325 K (52 °C); or may use preheating by dilution air as long as the air temperature before the exhaust gas enters the dilution channel does not exceed 325 K (52 °C);

- Shall be thermal insulated.

The exhaust of the marine engine and the dilution air shall be fully mixed. For partial sampling systems, after the system is put into use, under the operating state of the marine engine, the quality of the mixture is checked by the CO_2 concentration distribution map (at least 4 measuring points with approximately equal spacing) in the channel. If necessary, a mixed flow orifice can be used.

Note: If the ambient temperature near the dilution channel (DT) is lower exhaust back pressure measured with the CVS system and the static exhaust back pressure without the CVS system shall be kept within ±1.5 kPa.

When flow compensation is not used, the temperature of the gas mixture before PDP shall be within ±6 K of the average operating temperature during the test.

Only when the PDP inlet temperature does not exceed 50 °C (323 K), flow compensation is used.

(3) CFV critical flow venturi

By keeping the flow blocked (critical flow), the CFV measures the total diluted exhaust flow. Under the same speed and load of marine engine, the difference between the static exhaust back pressure measured with the CVS system and the static exhaust back pressure without the CVS system shall be kept within ±1.5 kPa. When flow compensation is not used, the temperature of the gas mixture before the CFV shall be within ±11 K of the average operating temperature during the test.

(4) HE heat exchanger (optional if EFC is used)

The heat exchanger shall have sufficient capacity to maintain the temperature within the range as required above.

(5) EFC electronic flow compensation (optional if using HE)

If the inlet temperature of the PDP or CFV is not maintained within the above-specified range, in order to continuously measure the flow rate and perform proportional sampling control in the particulate matter sampling system, a flow compensation system is required.

To achieve the above purpose, the continuously measured flow signal is used to correct the sample gas flow through the particulate sampling filter paper of the particulate sampling system (see Figures C.13 and C.14).

(6) DT dilution channel

For the dilution channel:

- Its diameter shall be small enough to form turbulence (Reynolds number greater than 4000); its length shall be long enough to allow the exhaust gas and dilution air to be fully mixed. Flow mixing orifice plate can be used;

- The diameter is at least 75 mm;

- Can use direct heating method to increase the wall temperature to no more than 325 K (52 °C); or use dilution air preheating, as long as the air temperature before the exhaust gas enters the dilution channel does not exceed 325 K (52 °C);

- Can be thermal insulated.

C.1.2.2 Particulate matter sampling system (Figures C.13 and C.14)

To collect particulate matters on particulate sampling filter paper, a particulate sampling system is required. For partial-flow dilution and full sampling, all the diluted exhaust gas flows through the filter paper; the dilution system (see Figures C.6 and C.10 in clause C.1.2.1.1) and the sampling system usually form a whole. For partial-flow dilution or full-flow dilution systems, for partial sampling situation, only part of the dilution exhaust gas passes through the filter paper (see Figures C.3, C.4, C.5, C.7, C.8 , C.9 and C.11 in clause C.1.2.1.1 and Figure C.12 in clause C.1.2.1.2); meanwhile the sampling system is usually other units.

In this standard, the double-stage dilution system DDS (Figure C.14) of the full-flow dilution system can be regarded as a specific modification of the typical particulate sampling system as shown in Figure C.13. The double-stage dilution system includes all important components of the particulate matter sampling system, such as filter paper holders, sampling pumps, and other dilution system features, such as the dilution air source and the secondary dilution channel.

In order to avoid any influence of the control cycle, it is recommended that the sampling pump be operated throughout the test cycle. For the single filter paper method, in order to allow the sample gas to pass through the sampling filter paper within the specified time, a bypass system shall be used. The influence of the switching process on the control cycle must be minimal.

Description - Figures C.13 and C.14

(1) PSP particulate sampling probe (Figures C.13 and C.14)

The illustrated particulate matter sampling probe is the guiding part of the particulate matter transfer tube PTT, meanwhile

- It shall face upstream and be installed in a place where the dilution air and exhaust gas are fully mixed, that is, on the center line of the dilution channel DT of the dilution system, at a place about 10 times the diameter of the dilution channel downstream of the exhaust gas entering the dilution channel;

- The minimum inner diameter is 12 mm;

more than 325 K (52 °C); or use dilution air preheating, as long as the air temperature before the exhaust gas enters the dilution channel does not exceed 325 K (52 °C);

- Can be thermal insulated.

(3) SDT secondary dilution channel (Figure C.14)

The diameter of the secondary dilution channel shall be at least 75 mm, meanwhile the secondary dilution channel shall be long enough, to provide a minimum residence time of 0.25 seconds for the sample gas of the double-stage dilution. The primary filter paper holder FH shall be within 300 mm of the SDT outlet.

Secondary dilution channel:

- Can use direct heating method to increase the wall temperature to no more than 325 K (52 °C); or use dilution air preheating, as long as the air temperature before the exhaust gas enters the dilution channel does not exceed 325 K (52 °C);

- Can be thermal insulated.

(4) FH filter paper holder (Figure C.13 and C.14)

For primary filter paper and secondary filter paper, one filter paper filter chamber or separate filter chamber can be used. It needs to meet the requirements of clause BA.1.5.1.3.

Filter paper holder:

- Can use direct heating method to increase the wall temperature to no more than 325 K (52 °C); or use dilution air preheating, as long as the air temperature does not exceed 325 K (52 °C);

- Can be thermal insulated.

(5) P sampling pump (Figures C.13 and C.14)

If FC3 is not used for flow correction, the particulate matter sampling pump shall be located far enough away from the channel, so that its intake air temperature remains constant (±3 K).

(6) DP dilution air pump (Figure C.14) (only for full-flow double-stage dilution system)

The dilution air pump shall be able to provide secondary dilution air with a temperature of 298 K (25 °C) ± 5 K.

------ The End ------