Guideline No.M-25(201510)

M-25 SILENCERS AND SPARK ARRESTERS

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Foreword

This Guideline constitutes the CCS rules, and establishes the applicable technical requirements for survey and test of classified ship products and licensed statutory products.

This Guideline is prepared and updated by CCS and issued on http://www.ccs.org.cn. Any feedback on this Guideline from users is welcomed via ps@ccs.org.cn.

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Contents

SILENCERS AND SPARK ARRESTERS

1 Application

This Guideline applies to silencers and spark arresters in the exhaust system of the marine diesel engine, which may be provided as a reference for silencers and spark arresters in the exhaust system of the boiler and other burning equipment.

2 Normative references

(1) GB/T 700-2006 CARBON STRUCTURAL STEEL;

(2) GB/T 3241-2010 ELECTROACOUSTICS — OCTAVE-BAND AND FRACTIONAL-OCTAVE-BAND FILTERS;

(3) GB/T 3785.1-2010 ELECTROACOUSTICS. SOUND LEVEL METERS. PART 1: SPECIFICATIONS;

(4) GB/T 4237-2007 HOT ROLLED STAINLESS STEEL PLATE, SHEET AND STRIP;

(5) GB/T 4760-1995 ACOUSTICS — MEASUREMENT PROCEDURE FOR SILENCERS;

(6) GB/T 6881.1-2002 ACOUSTICS — DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING SOUND PRESSURE — PRECISION METHODS FOR REVERBERATION ROOMS;

(7) GB/T 6882-2008 ACOUSTICS — DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING PRESSURE - PRECISION METHODS FOR ANECHOIC AND HEMI-ANECHOIC ROOMS;

(8) GB/T 7724-2008 ELECTRONIC WEIGHING METER;

(9) ISO 7325:2003 ACOUSTICS — LABORATORY MEASUREMENT PROCEDURES FOR DUCTED SILENCERS AND AIR — TERMINAL UNITS — INSERTION LOSS, FLOW NOISE AND TOTAL PRESSURE LOSS;

(10) ASTM E11-2004 STANDARD SPECIFICATION FOR WIRE CLOTH AND SIEVES FOR TESTING PURPOSES;

(11) EN 1834-1:2000E RECIPROCATING INTERNAL COMBUSTION ENGINES-SAFETY REQUIREMENTS FOR DESIGN AND CONSTRUCTION OF ENGINES FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES-PART 1:GROUP II ENGINES FOR USE IN FLAMMABLE GAS AND VAPOUR ATMOSPHERES;

(12) SAE J342 JAN91 SPARK ARRESTER TEST PROCEDURE FOR LARGE SIZE

ENGINES;

(13) SAE J350 JAN91 SPARK ARRESTER TEST PROCEDURE FOR MEDIUM SIZE ENGINES;

(14) SAE J997 MAR2013 SPARK ARRESTER TEST CARBON;

3 Terms and definitions

3.1 Silencer

Device preventing or weakening sound energy transmission with air passing through.

3.2 Spark arrester

Device used to arrest the sparks in the exhaust emitted from the internal combustion engine and the boiler

3.3 Noise attenuation $\triangle L_p$

Quantity used to evaluate the acoustic performance of silencers, in dB(A). Depending on the testing methods, such indicators as insertion loss, transmission loss, terminal sound pressure level difference and sound attenuation are used to evaluate the noise attenuation. For the purpose of this Guideline, the insertion loss applies.

3.4 Insertion loss $\boldsymbol{D}$

Sound power level difference of the radiated noise at the air outlet before and after the installation of the silencer, in dB(A).

3.5 Total pressure $\boldsymbol{p_t}$

Air flow pressure measured at the small hole when the mouth of the closing duct aims in the direction of the air flow, in Pa.

3.6 Static pressure $\boldsymbol{p_s}$

Air flow pressure measured at the small hole when the air flow sweeps past the duct wall of the small hole, in Pa.

3.7 Kinetic pressure $\boldsymbol{p_v}$

Kinetic energy of the air flow per unit volume, in Pa.

Notes:

① At the given test point, the kinetic pressure in direct proportion to the square of the air velocity, and the sum of the kinetic pressure and the static pressure equals to the total pressure.

② The kinetic pressure along the duct section and corresponding to the average air velocity is the average kinetic pressure, the sum of which and the static pressure equals to the average total pressure.

3.8 Pressure loss Δp_t

Difference of average total pressure at the inlet and the outlet of the silencer, in Pa. If the area of the inlet and the outlet of the silencer is the same and no significant change occurs to the temperature or air density along the silencer, the pressure loss equals to the static pressure difference.

3.9 Pressure loss coefficient ξ

A dimensionless quantity, indicating the ratio of the silencer pressure loss to the kinetic pressure upstream the silencer.

3.10 Sound pressure reflection coefficient r_a

Ratio of the sound pressure reflected from the interface (surface) to the incident sound pressure at given frequency and under given conditions.

3.11 Anechoic termination

Device used to reduce the terminal sound reflection at the receiving end in the test duct.

3.12 Collection efficiency η

Quality ratio of the particles collected by the spark arrester to the particles entering the spark arrester.

3.13 Substitution duct

Rigid duct that has the same length and the same interface section as the sample and does not absorb sound.

4 Drawings and documents

4.1 Drawings and documents to be submitted for approval:

(1) General assembly drawing;

(2) Product performance specification table (including the model, noise attenuation, nominal diameter, physical dimensions, pressure loss, application temperature, rated flow and other parameters of all series of products to be approved);

(3) Drawings of main parts and components (such as the outer cylinder, acoustic cylinder, head, etc.);

(4) Test program;

(5) List of physicochemical properties of main parts and components;

4.2 Approval drawings and documents at least including:

(1) Technical characteristics of the product;

(2) Product drawings and technical documents on related products and manufacturing processes, including the process flow;

(3) Type test program;

(4) List of suppliers of the product raw materials and the main parts and components;

(5) Quality assurance system documents —including the quality manual — and procedures on product quality control, main product manufacturing, inspection and test equipment;

(6) Other valid documents, reports and certificates indicating the manufacturing capability and quality level of the applicant as regard to the product within the approval scope;

(7) Enterprise registration certificate, business license, qualification certificate and/or production license (if any);

(8) Nameplate, identification sign, instructions for use/operation, quality certificate (including the standards employed, product properties, quality assurance, liabilities and other information) of the marine product passing CCS product inspection are to be prepared in languages specified by the orderer and at least in English if used for international ships;

5 Technical requirements

5.1 Classification

5.1.1 By the noise attenuation level, silencers are classified into three categories: Levels L ($10 \leq \triangle L_p < 20$ dB(A)), M ($20 \leq \triangle L_p < 30$ dB(A)) and H ($\triangle L_p \geq 30$ dB(A)).

5.1.2 Silencers are also classified into silencers and spark arrester, depending on the availability of the function of spark arresting.

5.2 Appearance quality

5.2.1 The air flow direction is to be marked at a conspicuous position on the surface of the silencer and spark arrester.

5.2.2 The silencer and spark arrester surfaces are to be free from burr, sharp edges, corrosion or bruise.

5.2.3 The silencer and spark arrester weld seams are to be free from air hole, weld flash and welding spatter.

5.2.4 The silencer and spark arrester are better to be coated with heat insulating materials, and the coating surface is to be free from any pit or crack.

5.3 Materials

5.3.1 The materials used for the silencer and the spark arrester are to comply with the following requirements:

(1) Corrosion resistant or undergoing corrosion resistance treatment;

(2) Flame resistant without smoke toxicity;

(3) High temperature resistant;

(4) Asbestos-free.

5.3.2 In general, the shell and structure materials of the silencer and the spark arrester are better to be the same as or equivalent to those listed in Table 5.3.2.

Selection of silencer shell and structure materials Table 5.3.2

Name	Grade	Standard No.
Carbon structural steel	Q235	GB/T 700-2006
Stainless steel	06Cr19Ni10	GB/T 4237-2007
	06Cr18Ni11Ti	

5.4 Design and structure

5.4.1 The silencer and the spark arrester are to have sufficient structural strength and corrosion resistance.

5.4.2 The silencer and the spark arrester are to be equipped with seats. For large equipment, lifting lugs are to be available for easy lifting.

5.4.3 The silencer and spark arrester structures are to be such that internal cleaning and inspection are easy to perform, and the spark arrester is to be furnished with air or steam flushing device or other cleaning devices and drain valves or cocks

5.4.4 Anti-explosion equipment is also to be provided for the spark arrester used in the exhaust duct of the gaseous propellant engine.

.5.5 Joints

The flange joint of the silencer and the spark arrester are to comply with the requirements specified in recognized standards.

5.6 Dimensional tolerance

The dimensional tolerances of the silencer and the spark arrester are to comply with the requirements marked on the drawings. The machining dimensions and the welding structure dimensions without tolerance marks are to meet the requirements specified in recognized standards.

5.7 Properties

5.7.1 Noise attenuation and pressure loss

The insertion loss and pressure loss test is to be carried out in accordance with Article 7.3 of this Guideline, and the noise attenuation and the pressure loss of the silencer, besides meeting the design requirements proposed by the designer, are to comply with the requirements for corresponding category of silencers specified in Table 5.7.1.

Noise attenuation and pressure loss Table 5.7.1

Silencer category	Noise attenuation [a] dB(A)	Pressure loss [a] Pa
Level L	10–19	≤ 800
Level M	20–29	≤ 1200
Level H	≥ 30	≤ 1500
a Under the working conditions of the burning equipment exhaust velocity of 35 m/s and exhaust temperature of 300°C		

5.7.2 Function of spark arrest

The particle collection test is to be carried out on silencers and spark arresters with the function of spark arrest in accordance with Article 7.6 of this Guideline, and the collection efficiency of each group of particles at each flow point is not to be less than 80%.

5.8 Airtightness

For silencers and spark arresters, leakage is not allowed at the maximum working pressure.

6 Raw materials and parts

The main raw materials of the shell, acoustic parts, heat insulating parts and others are to be included into QVL, and their manufacturers are not allowed to be changed without approval by the Society.

7 Type test

7.1 Selection of typical products

The type test is to be performed to no less than two units for each series of products. If the maximum nominal diameter of the series of products to be approved is 400 mm or above, the nominal diameter of one of the typical products is not to be less than 400 mm.

7.2 Type test items

The type test items for the silencer and the spark arrester are listed in Table 7.2.

Type Test Items **Table 7.2**

No.	Test item	Type test
1	Visual inspection	The silencer appearance quality is to be checked by means of visual inspection, and the results are to comply with 5.2.
2	Material of main parts	The silencer material certificate is to be reviewed, and the results are to comply with 5.3.
3	Dimension inspection	The physical dimensions and flange joint dimensions, etc. are to be inspected, and the results are to comply with 5.5 and 5.6.
4	Airtightness	The silencer airtightness test is to be done at no less than two times of the maximum working pressure or 0.1 bar, whichever is higher, and the pressure is to be kept for 3 min to make sure no leakage occurs.
5	Insertion loss	The insertion loss determination is to be performed according to 7.4.
6	Pressure loss	The pressure loss determination is to be performed according to 7.5.
7	Function of spark arrest	The collection efficiency test is to be performed according to 7.6, and the results are to comply with 5.7.2. In the meanwhile, the back pressure at each point is to be measured according to 7.7.

For the silencer and spark arrester test methods, other recognized test methods are acceptable besides the requirements mentioned in this Guideline , provided that relevant test methods will be specially considered and approved by CCS.

7.3 Test device requirements

7.3.1 Silencer test devices

For the insertion loss and pressure loss test of the silencer, the test devices are generally to include: main duct, Low-noise flow source, noise source, receiving end, measurement instrument, silencer to be tested, etc., as shown in Fig. 7.3.1(1);

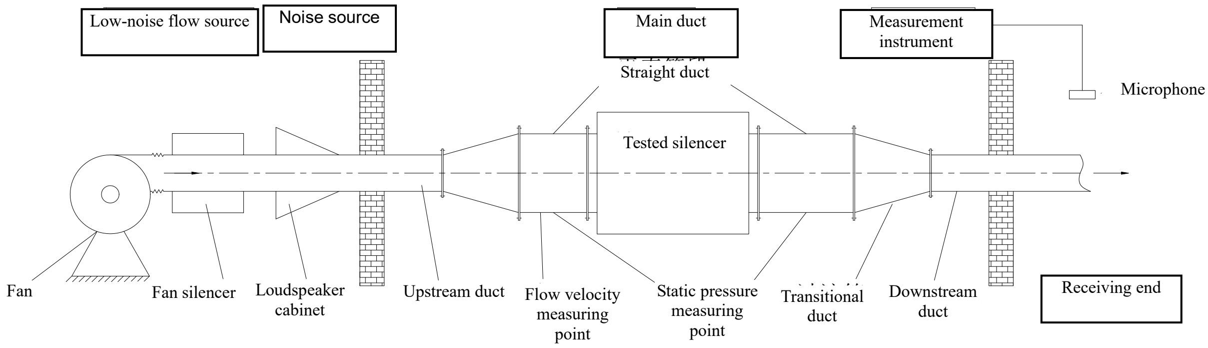


Fig. 7.3.1 (1) Schematic diagram of silencer test devices

(1) Main duct

① The main duct is the fundamental duct system of the test device, including the upstream duct and downstream duct of the tested silencer and the straight duct, transitional duct and substitution duct connected to the tested silencer. Vibration reduction and sound insulation measures are better to be taken to the outer duct wall. The centerline of the main duct is to coincide with that of the noise source.

② The straight part of the upstream and downstream ducts of the tested silencer is not to be less than three and five times of the equivalent duct diameter respectively

③ The wall of the transitional duct is to be flat, and its centerline is to coincide with the axes of the main duct and the inlet and outlet flanges of the tested silencer. The expansion angle of the transitional duct side wall is not to be larger than 30°.

(2) Low-noise air source

① Low-noise air source is a device providing the main duct with stable low-noise air flow, generally composed of the following:

— Fan: to produce the air flow. The fan air pressure is to comply with the requirements for silencer pressure loss measurement, and the air flow with the requirement that the flow velocity in the main duct be no less than rated flow velocity (for which references may be made to Table 7.3.1 (1) if unable to be determined). The fan is to be installed in an enclosure with good acoustic performance, and the fan outlet is to be connected to the duct system with hoses.

— Fan silencer: to reduce the fan air noise so as to make sure the noise from the fan to the main duct within the test frequency does not affect the test results.

Flue gas velocity of different equipment **Table 7.3.1(1)**

Equipment	Flue gas velocity m/s
Two-stroke diesel engine	25 ~ 35
Four-stroke diesel engine	30 ~ 50
Main boiler	7 ~ 10
Auxiliary boiler	15 ~ 20

② The low-noise air noise is to have control devices such as valves or transmissions in order to regulate the air velocity in the tested silencer.

(3) Noise source

① The noise refers to a device providing the main duct with stable noise. In general, the signal generator and the power magnifier are employed to drive one or more loudspeakers installed in the sound-insulated closed cabinet.

② The loudspeaker cabinet is to provide enough sound insulation and vibration insulation measures are to be taken at its connection to the main duct.

③ The noise source is to comply with the requirement that the sound pressure level at each test point within the test frequency is at least 6 dB (10 dB at best) greater than the background noise. In case that the sound pressure level of the noise source is 10 dB (or below) smaller than the background noise, corrections are to be made in accordance with Table 7.3.1 (2). In addition, during the test, the octave sound pressure level radiated by the noise source to the main duct is to keep stable with a variation not greater than ±0.5 dB over time.

Background noise correction K of frequency band sound pressure level dB **Table 7.3.1(2)**

Sound pressure level difference	6	7	8	9	10
Correction value K	1.3	1	0.7	0.6	0.5

(4) Receiving end

① The facilities at the receiving end are used for the sound pressure measurement so as to obtain the insertion loss of the tested silencer. The three forms of the receiving end include:

— reverberation room;

— semi-anechoic room;

— test duct with anechoic termination.

② In the case of the reverberation room receiving end, the requirements specified in Appendix E of GB/T6881.1 are to be met. The outlet of the main duct is to be 1 ~ 1.5 m into the reverberation room for a diffuse acoustic field, as shown in Fig. 7.3.1 (2).

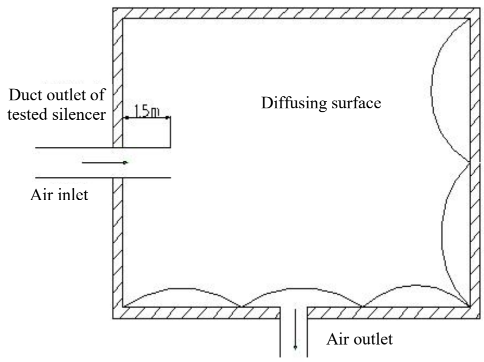


Fig. 7.3.1 (2) Reverberation room receiving end

③ In case of the semi-anechoic room receiving end, the requirements specified in Appendix A of GB/T6882 are to be met. The outlet of the main duct is to be flush with the rigid wall so that the indoor acoustic field strictly meets the semi-free acoustic field conditions, as shown in Fig. 7.3.1 (3).

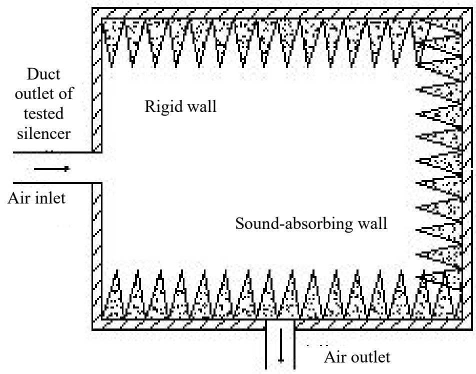


Fig. 7.3.1 (3) Semi-anechoic room receiving end

④ In the case of the test duct with anechoic termination, the outlet of the main duct is to be furnished with anechoic termination. In regard to the anechoic termination, Appendix C of GB/T 4760-1995 may be referenced for purpose of its design, and the sound pressure reflection coefficient r_a of the anechoic termination duct mouth is not to exceed the limits listed in Table 7.3.1(3).

Sound pressure reflection coefficient limits of anechoic termination **Table 7.3.1(3)**

Nominal frequency Hz	50	63	80	100	125 and above
Sound pressure reflection coefficient r_a	0.4	0.35	0.3	0.25	0.15

Besides the above three categories of receiving end facilities, the essentially free-field conditions complying with the requirements in Article 5.2.4.4, ISO 7325:2003 is also to be accepted.

7.3.2 Spark arrester test device

For the spark arrester collection efficiency test, the test device generally includes the fan, main duct, flowmeter, particle loading device, back pressure test device, tested specimen, particle collection device, etc., as shown in Fig. 7.3.2. It is allowed that the test device of silencers used also for spark arresters.

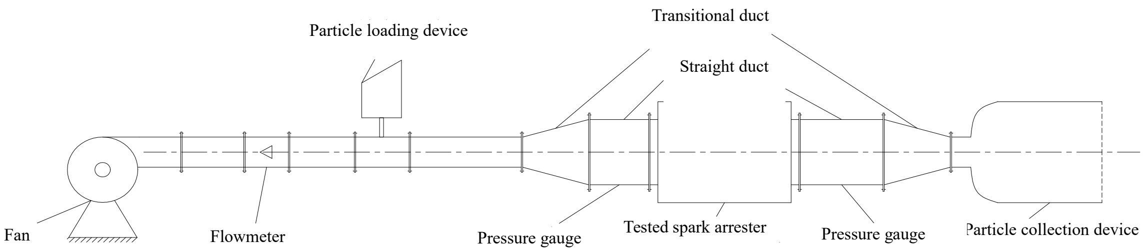


Fig. 7.3.2 Schematic diagram of spark arrester test devices

(1) Main duct

① The main duct is the fundamental duct system of the test device, including the upstream duct and downstream duct of the tested spark arrester and the transitional duct connected to the tested spark arrester.

② The straight part of the upstream and downstream ducts of the tested silencer is not to be less than three and five times of the equivalent duct diameter respectively.

③ The wall of the transitional duct is to be flat, and its centerline is to coincide with the axes of the main duct and the inlet and outlet flanges of the tested spark arrester. The expansion angle of the transitional duct side wall is not to be larger than 30°.

(2) Fan

The fan is to be stable and adjustable in flow, and the adjustment scope of the fan flow is to comply with the spark arrester test requirements.

(3) Particle loading device

The particle loading device is to be such that the particles of required weight are loaded into the air flow at a uniform rate within the specified time. During this process, the particles loaded are not to suffer from damages such as abrasion and extrusion.

(4) Particle collection device

The particle collection device is used to collect the particles uncollected by the spark arrester. During this process, the particles collected are not to suffer from damages such as abrasion and extrusion. The pressure loss incurred by the particle collection device is not to affect the proceeding of the collection efficiency test. The volume of the collection device is not to be smaller than 2,380 cm^3.

7.3.3 Measurement instrument

(1) The measurement instrument is to consist of at least the following equipment:

— a sound level meter with octave and 1/3 octave filters;

— an instrument (instruments) measuring the air flow velocity in the duct: Pitot tube and pressure gauge in the case of Pitot tube method and flowmeter in the case of flowmeter method;

— a pressure gauge measuring the air flow pressure in the duct.

(2) The sound level meter with octave and 1/3 octave filters, including the microphone and the cable, are to comply with the specification on Level 1 sound level meter in GB/T 3785.1, and corresponding filters are to comply with GB/T 3241.

(3) Before and after each test, the sound calibrator of accuracy higher than ±0.5 dB is to be used to calibrate the sound level meter, and the difference between two calibration values in a row is not to exceed 1.0 dB.

(4) The straight part of the upstream duct and downstream duct of the flowmeter is to meet the flowmeter installation requirements as well as the relative error listed in Table 7.3.3 (1). The flowmeter is to be installed such that the sound wave transmission of the noise source is not affected. The supersonic wave flowmeter, if used, may be installed on the upstream side of the noise source.

Relative error of flowmeters **Table 7.3.3(1)**

Volumetric flow q_v m^3/s	Relative error %
$0.07 < q_v \leq 7$	± 2.5
$0.007 < q_v \leq 0.07$	± 5.0

(5) The maximum scale interval and permissible error of the pressure gauge are shown in Tables 7.3.3 (2) and 7.3.3 (3) respectively.

Maximum scale interval of pressure gauges **Table 7.3.3(2)**

Pressure scope p Pa	Scale interval Δp Pa
P ≤ 25	1.0
25 <p≤ 250	2.5
250 < p ≤ 500	5.0
P > 500	25

Permissible error of pressure gauges **Table 7.3.3(3)**

Pressure scope	Permissible error
≤ 100 Pa	± 1.0 Pa
> 100 Pa	± 1%

(6) The sensibility of the weighing equipment is not to be greater than 0.1 g and its range is not to be smaller than 1 kg. Electric scale is recommended, provided that its accuracy is to comply with accuracy level Ⅱ specified in GB/T 7724-2008.

(7) The measurement instrument is to be calibrated as specified and be within the period of calibration validity.

7.4 Measurement of silencer insertion loss

7.4.1 General

(1) During the measurement of silencer insertion loss, the empty duct test is to be performed (the substitution duct is to be substituted for the silencer) before the installation of the silencer to measure at each given test point the 1/3 octave band sound pressure level radiating noise downstream and to obtain the sound power level from them. After that, the silencer is to be substituted for the substitution duct for the rest of the test. To keep the noise source conditions the same as that in the empty duct test, the air flow source system is to be regulated appropriately to make the air flow velocity in the main duct be the same as that in the empty duct test. Since the sound power levels corresponding to each frequency band are known now, the insertion loss at each frequency band is to be obtained from the difference between two sound power levels in a row.

(2) The low-noise flow test is to be carried out under each working conditions: measurements are to be made with the noise source turned off, and each measured band sound pressure level is to be regarded as the background noise level. Next, the correction value *K* is to be obtained in accordance with Table 7.3.1 (2) from the difference between the sound pressure level measured previously and the background noise level.

(3) If multiple test points are selected, the band sound pressure levels at each test point are to be averaged by the energy method, and the correction value K is to be obtained in accordance with Table 7.3.1 (2) from the difference between the average sound pressure level and the average background noise level. During the calculation process, all values are better to be rounded to one decimal place, and the calculated band insertion loss is to be rounded to an integer.

(4) For the silencer insertion loss determination, the reverberation room method is generally preferred. However, the semi-anechoic room method or the duct method may be used based on the necessity and feasibility.

7.4.2 Reverberation room method

(1) If the reverberation room is used as the receiving room, the sound power level radiated from the duct mouth to the receiving room is to be determined according to GB 6881.1. For the insertion loss, the relative change to sound power level may be determined only.

(2) During the test, the microphone is to be fixed on the support, and test points are to be able to determine the position repeatedly and correctly. In general, the microphone is connected to the analyzer with the extension cables for outdoor operation.

(3) The empty duct test and corresponding low-noise air flow test are to be performed to determine the band sound pressure level and background noise level at each test point. Then, the averaged band sound level $\overline{L_{p1}}$ and corresponding correction value K_1 are to be calculated in accordance with 7.4.1 (2) and (3).

(4) The silencer is substituted for the substitution duct to continue the test, and corresponding low-noise air flow test is to be performed to determine the band sound pressure level and background noise level at each test point. Then, the averaged band sound level $\overline{L_{p2}}$ and corresponding correction value K_2 are to be calculated in accordance with 7.4.1 (2) and (3).

(5) The silencer insertion loss at each frequency band is to be calculated as per:

$$D = \overline{L_{p1}} - \overline{L_{p2}} + K_2 - K_1 \quad \text{dB}$$

where: $\overline{L_{p1}}$ — average band sound pressure level in the substitution duct test, in dB;

K_1 — background noise correction value of average band sound pressure level in the substitution duct test, in dB;

$\overline{L_{p2}}$ — average band sound pressure level in the silencer test, in dB;

K_2 — background noise correction value of average band sound pressure level in the silencer test, in dB.

(6) Based on the sound power frequency spectrum of the noise source, A-weighted insertion loss is to be obtained from the measured insertion loss at each frequency band (test frequency range: 1/3 octave frequency band at the center frequency of 50 ~ 10000 Hz).

7.4.3 Semi-anechoic room method

(1) If the semi-anechoic room is used as the receiving room, the sound power level radiated from the duct mouth to the receiving room is to be determined according to GB 6882. For the insertion loss, the relative change of sound power level may be determined only.

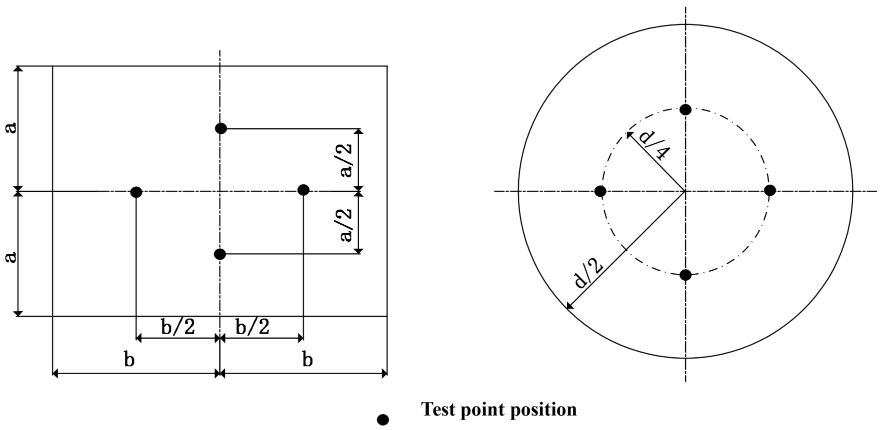
(2) During the test, the wind shield is to be furnished (such as nose cone and sponge) the installation conditions of which are to comply with the requirements in 7.4.2 (2).

(3) The insertion loss is to be determined in accordance with 7.4.2 (3) ~ (6).

7.4.4 Duct method

(1) If the duct method is used for insertion loss determination, the test points are to be in the middle of the straight part of downstream duct at the silencer outlet where required anechoic termination specified in 7.3.1(4) ④ is to be available.

(2) If the equivalent duct diameter is not greater than 300 mm, the selection of only one test point is allowed. The test position is better to be on the duct axis, or on the rigid side wall. If the equivalent duct diameter is greater than 300 mm, multiple (generally four) test points are to be selected along the duct cross section. The test point position is better to be as shown in Fig. 7.4.4 (1).



a Rectangular section b Circular section

Fig. 7.4.4 (1) Typical positions of four test points

(3) The microphone may be directly fixed at the test point during the test, or a probe may be

used for measurement. If the test position is selected to be in the duct, a diversion device is to be mounted in the direction of the microphone or probe against the air flow. The maximum cross section area of the measurement device is not to exceed 5% of the duct section area.

(4) If the air flow velocity in the main duct is greater than 15 m/s, and the test position is better to be on the rigid side wall in which a sound transmission hole is to be made and outside of which a microphone or a probe is to be installed, and such flow diversion and sound transmission layer as a fine mesh or micro-perforated panel is to be installed inside. Proper vibration insulation measures are to be taken to the fixing device on the duct wall. The typical arrangement is as shown in Fig. 7.4.4 (2).

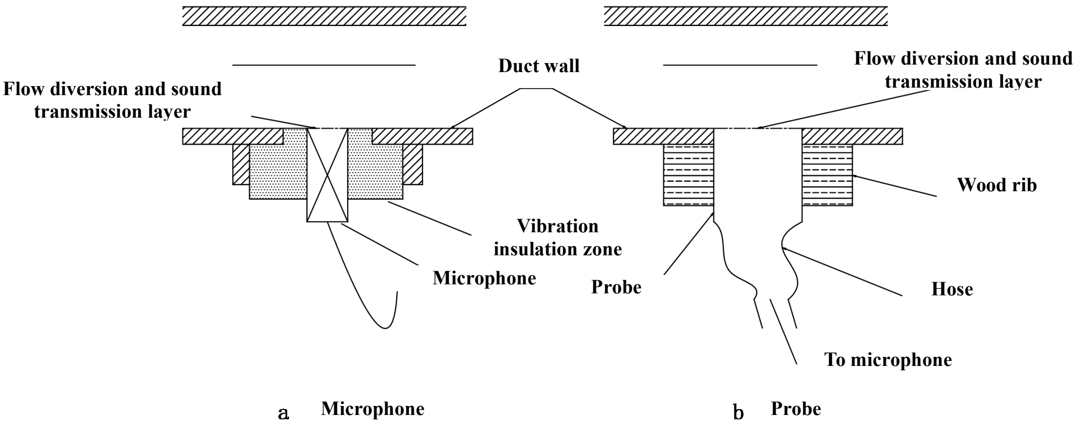


Fig. 7.4.4(2) Typical arrangement of test points on flexible side wall

(5) The insertion loss is to be determined according to 7.4.2 (3) ~ (6).

7.4.5 Air flow velocity requirement in insertion loss determination

In the insertion loss test, it is to be made sure that for the exhaust system to be used in the silencer, the flow velocity in the main duct is not slower than that specified in Table 7.3.1(1).

7.5 Determination of Silencer Pressure Loss and its Coefficient

7.5.1 General

(1) A measurement section is to be selected in the middle of the straight part of the silencer duct at both inlet end and outlet end. The average kinetic pressure and static pressure on the two sections are to be measured respectively at given flow velocity to calculate the average total pressure. Then, the pressure loss is to be obtained from the decrease of the average total pressure at both ends of the silencer, and the drag coefficient is to be calculated from the ratio of the pressure loss to the average kinetic pressure. If the duct section area at both ends of the silencer is the same, the pressure loss is equal to the difference between the static pressure at the two ends.

(2) In general, the kinetic pressure and velocity of air flow is better to be determined with Pitot tube and the static pressure with static tube. The pressure difference is to be determined with

calibrated micromanometer.

7.5.2 Flow velocity determination

(1) To determine the average flow velocity in the duct, the measurement section is to be selected at the straight part of the duct to arrange the test points. On principle, the number of test points is to be no less than 8, and they are to be distributed evenly on the whole section according to the area. However, this number may be added or subtracted when necessary, based on the duct section area.

(2) The Pitot tube is to be placed such as to make its end be at the test point and against the flow direction. The kinetic pressure readings p_v at each test point is to be read with the micromanometer. The flow velocity at each test point is to be calculated as per:

$$v = \left(1 + \frac{t-20}{293}\right)^{1/2} \times \left(\frac{2p_v}{\rho}\right)^{1/2} \quad \text{m/s}$$

where: v — flow velocity, in m/s;

t — flow temperature, in °C;

ρ — flow density, in kg/m^3;

p_v — kinetic pressure of air flow, namely the difference between the total pressure and the static pressure, in Pa;

(3) In actual measurement, the average velocity of the air flow is to be calculated as per:

$$\bar{v} = \alpha v_m \quad \text{m/s}$$

where: v_m — flow velocity at the section center, in m/s;

α — correction factor: it is related to the duct section shape and the flow velocity, but it varies little and may be calculated as per the following equation based on the results measured according to 7.5.2(1) and (2):

$$\alpha = \left(\frac{1}{N}\sum_{i=1}^{N} v_i\right) \div v_m$$

(4) In the case of flowmeter method, the average air flow velocity is to be calculated as per:

$$\bar{v} = U/S \quad \text{m/s}$$

where: U — volumetric flow, in m^3/s;

S — section area, in m^2.

7.5.3 Static pressure and total pressure determination

(1) To determine the static pressure p_s in the duct, one test point may be selected only, and the static tube may be divided from the Pitot tube or come out of the tube wall through a hole;

(2) The average kinetic flow pressure $\overline{p_v}$ along the given section may be calculated on an approximate basis as per:

$$\overline{p_v} = \alpha^2 p_{vm} \quad \text{Pa}$$

where: p_{vm} — kinetic pressure at the section center, in Pa;

α — correction factor, determined by 7.5.2(3).

(3) The average total flow pressure along the given section may be calculated as per:

$$\overline{p_t} = \overline{p_v} + p_s \quad \text{Pa}$$

$\overline{p_v}$ — average kinetic flow pressure, in Pa;

p_s —static flow pressure, in Pa.

7.5.4 Pressure loss determination

(1) The silencer pressure loss is to be calculated as per:

$$\Delta p = \overline{p_{t1}} - \overline{p_{t2}} \quad \text{Pa}$$

where: $\overline{p_{t1}}$ — average total pressure at the inlet, in Pa;

$\overline{p_{t2}}$ — average total pressure at the outlet, in Pa.

(2) If the section area of the silencer duct at both ends is the same, the pressure loss may be calculated as per;

$$\Delta p = p_{s1} - p_{s2} \quad \text{Pa}$$

where: p_{s1} — static pressure at the inlet, in Pa;

p_{s2} — static pressure at the outlet, in Pa.

7.5.5 Pressure loss coefficient determination

The silencer pressure loss coefficient is to be calculated as per:

$$\xi = \Delta p / \overline{p_v}$$

where: Δp — pressure loss, in Pa;

$\overline{p_v}$ — average kinetic flow pressure, in Pa.

7.5.6 The silencer pressure loss under the rated working conditions of burning equipment is to be calculated as per:

$$\Delta P_t = \xi \times \frac{1}{2} \rho v^2 \quad \text{Pa}$$

where: ξ — pressure loss coefficient;

ρ — exhaust density at corresponding exhaust temperature under rated working conditions, in kg/m^3;

v — exhaust flow velocity under rated working conditions, in m/s.

7.5.7 Flow velocity requirement in pressure loss measurement

In the pressure loss test, it is to be made sure that for the exhaust system to be used in the silencer, the flow velocity in the main duct is not slower than that specified in Table 7.3.1(1).

7.6 Particle collection efficiency determination

7.6.1 The activated carbon particles used in the test are to comply with related requirements on coarse and fine particles in SAE J997-2013, and the test is to be performed in accordance with the requirements in 7.6.2 ~ 7.6.6.

7.6.2 The activated carbon of at least 400 g (M_1) in weight is to be weighed and the particles are to be loaded into the loading device.

7.6.3 The fan is to be turned on and then turned up to the flow required by the test. At least five flow points are to be selected within the spark arrester flow scope, one as 100% rated flow point, the rest as evenly distributed as possible between 30% and 100% of rated flow. The weight of the particles entered and collected are to be accurate to 0.1 g.

7.6.4 When the fan operates stably, the particle loading device is to be turned on, and all of the activated carbon particles in it are to be loaded into the air flow at uniform rate within 15 ± 5 min.

7.6.5 After the activated carbon particles are loaded, the fan is to continue working for no less than two minutes before being stopped.

7.6.6 After the activated carbon particles in the particle collection device are taken out, a No.30 (600 μm) screen complying with ASTM E11 is to be used to weigh the rest of the particles and obtain M_2.

7.6.7 Collection efficiency calculation

The spark arrester collection efficiency is to be calculated as per:

$$\eta = \frac{M_1 - M_2}{M_1} \times 100\%$$

where: η — collection efficiency;

M_1 — mass of loaded activated carbon particles, in g.

M_2 — total mass of uncollected activated carbon particles, in g.

7.7 Back pressure determination

To measure the spark arrester back pressure, the particle collection device is to be removed. Or, the pressure loss measured by methods in 7.5 may be regarded as the back pressure.

7.8 Measurement report

The measurement report is to include:

(1) name, address, contact and qualification of the measurement agency;

(2) measurement time and personnel;

(3) manufacturer, model, S/N, outline dimensions and other information of the tested product;

(4) schematic diagrams of measurement devices and layout;

(5) measurement instrument;

(6) measurement conditions;

(7) collection efficiency of activated carbon in two different groups of particles and the diagram of relationship among the back pressure, collection efficiency and flow;

(8) noise attenuation test data and the insertion loss spectrum diagram at 1/3 octave;

(9) pressure loss test data and the estimated diagram of relationship between the pressure loss and the flow velocity at different temperature;

(10) other content required to be reported.

8 Unit/batch inspection

8.1 Unit/batch inspection of approved products

For those silencers and spark arresters that have passed the type approval by the Society, if the unit/batch inspection is applied for to the Society, the delivery inspection/test is to be carried out as regard to Items 1 ~ 4 listed in Table 7.2. For the inspection of physical dimensions, the test report submitted by the works may be reviewed.

8.2 Unit/batch inspection of unapproved products

For those silencers and spark arresters that have failed the type approval by the Society, if the unit/batch inspection is applied for to the Society, the delivery inspection/test is to be carried out as regard to all items listed in Table 7.2.

9 Miscellaneous

For the spark arresters complying with EN 1834-1:2000E, SAE J350 JAN91, SAE J342 JAN91 or equivalent standards, this Guideline may serve as a reference for the purposes of approval and inspection.

10 Reference standards

For the purpose of this Guideline, relevant content in the following rules and standards is referenced during preparation.

(1) CCS Rules for Classification of Sea-going Steel Ships (2012) and its amendment

(2) GB/T 4760-1995 Acoustics. Measurement procedure for silencers;

(3) ISO 7325: 2003 Acoustics — Laboratory measurement procedures for ducted silencers and air — Terminal units — Insertion loss, flow noise and total pressure loss.

(4) SAE J342 JAN91 Spark Arrester Test Procedure For Large Size Engines.