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Centrum Klima S.A.

Determination of the insertion loss and pressure loss of circular straight silencers at the test stand of Müller-BBM

Report No. M82 844/3

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1 Situation and task

The company Centrum Klima S.A. is a manufacturer of straight circular silencers for air-conditioning duct systems. This silencers are to be tested according to ISO 7235 in the test stand of the company Müller-BBM in Planegg near Munich.

By means of measurements, the essential characteristic values of the silencers are to be determined, i.e. the insertion loss and the total pressure loss.

Based on the measuring results, the above-mentioned parameters (insertion loss, pressure loss) are to be calculated for other lengths and diameters of silencers.

In this report, only the execution of the measurements and the measuring results will be described. Furthermore, the calculation method for the total pressure loss and the validation of the method will be given.

A complete list of the results of the investigated silencers as well as the calculated intermediate silencer sizes will be given in Müller- BBM Report No. M82 844/4 [5].

2 References

For this task, the following documents were used:

- [1] DIN EN 7235: Acoustics - Laboratory measurement procedures for ducted silencers and air-terminal units - Insertion loss, flow noise and total pressure loss. February 2004
- [2] DIN EN ISO 3741: Acoustics - Determination of sound power levels of noise sources using sound pressure - Precision methods for reverberation rooms. January 2001
- [3] DIN EN ISO 140-4: Acoustics - Measurement of sound insulation in buildings and of components; part 4: Measurement of the airborne sound insulation between rooms. December 1998
- [4] VDI 2081: Noise generation and noise reduction in air-conditioning systems - part 1, July 2001
- [5] Müller-BBM Report No. M82 844/4: Centrum Klima S.A.; Calculation of the insertion loss and the total pressure loss coefficient based on Müller-BBM measuring results; Supplementation to report No. M82 844/3; 2010-01-15

3 Place and date of the measurements

The measurements were carried out in the silencer test stand of the company Müller-BBM by Dipl.-Ing (FH) Michael Haal and MScEng. Andy Péus in November and December 2009.

4 Description of the measured objects

The company Centrum Klima S.A. provided inline silencers (IS) without an inner core, which are briefly listed in the following Table 1.

Table 1. Investigated inline silencers

Description	Inner diameter in mm	Packing thickness in mm	Silencer lengths in mm		
			600	1000	1200
IS 100/50/x	100	50	600	1000	1200
IS 200/50/x	200	50	600	1000	1200
IS 400/50/x	400	50	600	1000	1200
IS 400/100/x	400	100	600	-	1200

5 Measuring equipment

The calibration of the used measuring equipment listed in the following was checked before and after the measurements and its perfect function was determined. In addition, the measuring equipment is also regularly checked within the scope of Müller-BBM's own quality management system.

Table 2 shows the measuring equipment used to determine the insertion loss, and in Table 3 the measuring equipment used to determine the total pressure loss is listed.

Table 2. Instrumentation used to determine the insertion loss

Name	Manufacturer	Type	Serial No.
Sound level meter	Norsonic	121	26342
Power amplifier	Klein + Hummel	MB 140	319
Sound source	Müller-BBM	LS-SDP	-
Microphone rotating beam	Norsonic	231-N-360	16976
Microphone preamplifier	Norsonic	1201	26145
Microphone	Norsonic	1220	25160
Pistonphone	Brüel & Kjaer	4220	1164874
Control and evaluation software	Müller-BBM	Bau 4	Version 1.6

Table 3. Instrumentation used to determine the flow velocity and the total pressure loss

Name	Manufacturer	Type	Serial No.
Micromanometer	Furness Controls GmbH	FC 104	9302130
Handheld pressure meter	Greisinger electronic GmbH	GMH 3151	302901
Digital pressure sensor	Greisinger electronic GmbH	GMSD 25 MR	302903
Digital pressure sensor	Greisinger electronic GmbH	GMSD 2,5 MR	302902
Pressure calibrator	Airflow Lufttechnik GmbH	Kal84	90950129

6 Information on the test stand

According to the requirements stated in [1], in the following information on the test stand used for the measurements can be found.

6.1 Sound source

The sound source is a loudspeaker unit, which is applied at the measuring duct in front of the object to be measured. Pink noise is generated by means of the sound power source listed in Table 2. The pink noise is transmitted into the measuring duct with a sufficiently high sound power by means of the power amplifier and the loudspeaker unit.

6.2 Measuring, substitution and transmission ducts

The measuring ducts of the silencer test stand consist of circular sheet steel pipes with a nominal width of 400 mm and a wall thickness of 2 mm.

In case of the inline silencers with a diameter of 400 mm the substitution duct for the measurements is similar to the above-mentioned measuring duct, i.e. it consists of a circular sheet steel pipe with a nominal width of 400 mm.

The attenuation limit of the test stand for all tested diameters is stated in section 7.1.3.

Behind the measuring object under test, the measuring duct is connected to a reverberation room via a transmission duct. The open end of this transmission duct is located in a lateral wall of the reverberation room. The cross section of this duct, which is circular at first, expands to an elliptical opening of 1.4 x 1.8 m.

The reverberation room is used to determine the sound power according to the standards.

6.3 Adapters

6.4 Transition pieces

In order to bridge the gap from the transmission ducts with a diameter of 400 mm to the silencers with a diameter of 100 mm and 200 mm, on both sides transition pieces with a length of 900 mm and 600 mm each are required. These transition pieces were also provided by Centrum Klima S.A. Therefore, they are also part of the silencer.

6.5 Reverberation room

In the present case, measurements in a reverberation room suitable according to DIN EN ISO 3741 [2] are the preferred method to determine the sound power level. The reverberation room used in this case meets the requirements of [2]. It has a volume of 199.6 m³.

7 Results

In the following, the results of the measurements are listed for the investigated silencers.

7.1 Insertion loss

The insertion loss D_e is the reduction of the sound power level in the duct (behind the measured object) due to the insertion of the measuring object in the substitution duct.

7.1.1 Calculation of the insertion loss

The insertion loss in dB is determined according to the following equation (1):

$$D_e = L_{WII} - L_{WI} \quad (1)$$

with

L_{WI} sound power emitted into the connected reverberation room with inserted measuring object

L_{WII} sound power emitted into the connected reverberation room after replacing the measuring object with the substitution duct

As, according to this definition, only the level difference is of interest, it is sufficient to calculate the difference from the measured sound pressure levels $\overline{L_p}$. These levels were determined in the reverberation room with the rotating microphone boom on identical measuring paths, i.e. spatially and temporally averaged.

7.1.2 Determined insertion losses by measurements

By means of equation (1) the insertion losses D_e of the different types of silencers were determined and listed in Tables 4 and 5 in octave bandwidth. The respective diagrams in octave bandwidth are also stated in the tables and shown in appendix A.

The given insertion losses are valid for the measuring object together with the used transition pieces, as their influence cannot always be neglected.

Table 4 shows the insertion losses for the investigated inline silencers.

Table 4. Insertion loss D_e of the investigated inline silencers

Description	Insertion loss D_e in dB								Diagrams
	63	125	250	500	1000	2000	4000	8000	
IS 100/50/1200	7*	11	23	42	49	50**	50**	36	Fig. 1
IS 100/50/1000	5*	10	18	32	48	50**	50**	30	Fig. 2
IS 100/50/600	5*	8	12	23	35	48	40	21	Fig. 3
IS 200/50/1200	2*	5	12	22	38	35	23	12	Fig. 4
IS 200/50/1000	2*	4	10	18	32	33	21	11	Fig. 5
IS 200/50/600	1*	3	7	14	25	23	16	10	Fig. 6
IS 400/50/1200	0	2	6	15	22	7	7	4	Fig. 7
IS 400/50/1000	0	2	5	14	19	6	5	3	Fig. 7
IS 400/50/600	0	1	3	10	12	5	3	1	Fig. 7
IS 400/100/1200	3	6	15	27	23	8	5	3	Fig. 8
IS 400/100/600	2	3	8	16	11	5	3	1	Fig. 8

*Due to the cross-section change by the transition pieces a correction according to VDI 2081/part 1 [4] was applied in these third-octave frequency bands.

** Insertion losses above 50 dB are not practice-orientated, as there are certain limits e.g. due to flanking path transmissions. Thus, in these cases, a value of 50 dB was stated as maximum insertion loss.

7.1.3 Determined minimum insertion losses

Since the influence of the transition pieces cannot be neglected, in the following the effect of the transition piece (converging nozzle) will be explained and a correction of the insertion loss will be applied.

Due to the transition pieces on the sound source side, the radiated plane sound field by the loudspeaker will be changed in direction by impinging on the walls of the cross-section constriction of the transition piece. These reflections, mainly in the higher frequency ranges, are better attenuated by the silencers than a plane sound field. This yields to higher insertion losses, especially for shorter silencer lengths and larger cross-section ratios.

That means that, if no internals like a converging nozzle or 90° bends are located in front of the silencer, the insertion loss will be less than the measured one with nozzles and bends.

Usually you will not encounter plane sound fields in practice and therefore the determined insertion losses in section 7.1.2 are more realistic. Nevertheless, a correction of the influence of a transition piece must be applied.

These corrected insertion losses then represent the minimum insertion loss of the investigated silencers. These corrections have to be applied in order to make these results of the insertion losses comparable to other silencer test stands according to the ISO 7235.

Since the influence depends on the length and the cross-section ratio of the transition pieces, the frequency range to which the corrections are applied has a lower and an upper frequency limit. The lower frequency limit will be defined as that frequency, where the wavelength of the sound field is equal to the length of the transition pieces. The upper frequency limit is defined by the diameter and is that frequency where the wavelength of the sound field is equal to the inner diameter.

The corrections are applied only on the silencers with a inner diameter of 100 and 200 mm and a length of 1000 and 600 mm. The following Table 5 shows the minimum insertion losses $D_{e,min}$.

Table 5. Minimum insertion loss $D_{e,min}$ of the investigated inline silencers

Description	Insertion loss $D_{e,min}$ in dB								Diagrams
	63	125	250	500	1000	2000	4000	8000	
IS 100/50/1000_C	5	10	18	26	38	45	41	30	Fig. 2
IS 100/50/600_C	5	8	12	21	25	29	26	21	Fig. 3
IS 200/50/1000_C	2	4	10	18	32	30	21	11	Fig. 5
IS 200/50/600_C	1	3	7	14	18	17	16	10	Fig. 6

7.1.4 Limiting insertion loss of the silencer test stand

The limiting insertion loss is the highest insertion loss which can be measured with the given measuring arrangement. In all considered frequency bands, it must be at least 10 dB above the insertion loss to be measured.

The attenuation limit of the used silencer test stand is listed in the following table 6 and is shown in Figure 9 in appendix B.

Table 6. Limiting insertion loss of Müller-BBM's silencer test stand

	Frequency in Hz								Diagram
	63	125	250	500	1000	2000	4000	8000	
Attenuation limit 100 mm diameter in dB	31	48	69	70	59	66	58	57	Fig. 9
Attenuation limit 200 mm diameter in dB	35	44	64	65	55	63	58	58	Fig. 9
Attenuation limit 400 mm diameter in dB	26	43	56	54	45	51	49	57	Fig. 9

8 Calculation of the total pressure loss and the total pressure loss coefficient

8.1 Determination of the total pressure loss and of the pressure loss coefficients

The difference of the total pressure upstream and downstream of the measuring object is described with the total pressure loss Δp_t in Pascals. Since the company Centrum Klima S.A. usually deals with flow velocities of about 4 to 8 m/s the expected total pressure losses of the inline silencers without inner core are negligible.

Nevertheless, for the sake of completeness the total pressure loss for inline silencers with no inner core can be calculated with the following equation (2):

$$\Delta p_t = 0,055 \cdot \frac{l}{D} \cdot \left(\frac{t}{D}\right)^{0,25} \cdot \rho \cdot v^2 \quad (2)$$

with

- ρ density of air upstream of the silencer in kg/m³
- l silencer length in m
- D inner diameter in m
- t perforated steel plate thickness in m
- v flow velocity in m/s

Usually the total pressure loss coefficient ζ is of interest, which can be determined according to the following equation (3):

$$\zeta = \frac{\Delta p_t}{\frac{1}{2} \cdot \rho_1 v^2} \quad (3)$$

with

- Δp_t total pressure loss in Pa
- ρ_1 density of air upstream of the silencer in kg/m³
- v flow velocity in m/s

With the total pressure loss coefficient ζ the total pressure loss Δp_t can be calculated for the flow velocity of interest.

8.2 Validation of the calculated total pressure loss and total pressure loss coefficient

The following Tables 7 and 8 show a comparison of the calculated and measured total pressure loss of the inline silencers with the 100 mm inner diameter, in order to validate equation (2). The comparison was conducted at flow velocities of 14, 19, 24, 29 and 33 m/s. These high flow velocities were selected in order to produce sufficiently high pressure losses.

The measured total pressure loss of the silencer is determined by means of the substitution method. For this, two test series were carried out, one with installed measuring object and another with the substitution duct instead of the measuring object.

Table 7 shows the measured and Table 8 the calculated total pressure loss as well as the total pressure loss coefficient for the inline silencers with an inner diameter of 100 mm.

Table 7. Measured total pressure loss and coefficient calculated with equation (3) of the investigated inline silencers with a inner diameter of 100 mm

Description	Total pressure loss in Pa					Total pressure loss coefficient ζ
	14 m/s	19 m/s	24 m/s	29 m/s	33 m/s	
IS 100/50/1200	47	77	140	219	316	0.43
IS 100/50/1000	34	65	90	166	234	0.32
IS 100/50/600	2	11	27	48	70	0.07

Table 8. Total pressure losses calculated with equation (2) and coefficients calculated with equation (3) of the inline silencers with a inner diameter of 100 mm

Description	Total pressure loss in Pa					Total pressure loss coefficient ζ
	14 m/s	19 m/s	24 m/s	29 m/s	33 m/s	
IS 100/50/1200	45	81	126	181	247	0.39
IS 100/50/1000	38	67	105	151	206	0.32
IS 100/50/600	23	40	63	91	123	0.19

Except for the inline silencer IS 100/50/600 the calculated and the measured total pressure losses and therefore the total pressure loss coefficients are in good accordance.

Based on these results of the comparison, the calculation of the total pressure losses with equation (2) is validated. The perforated steel plate thickness t used in equation (2) was 0.75 mm.

The complete list of the total pressure losses and the pressure loss coefficients are given in Müller-BBM Report No. M82 844/4.

9 Measuring uncertainty

The quality of the measuring method as well as the accuracy that can be achieved mainly depend on the ratio of the geometric dimensions and the sound wavelength, on the insertion loss of the duct walls, the absorption properties of the measuring object and the flow velocity.

The following assessment of the reference standard deviation σ_{RI} of the insertion loss was determined from measurements with the splitter silencers with a length of 1000 mm. As long as no more accurate data is provided, it can be assumed that the extended measuring uncertainty for a confidence level of 95 % is twice the reference standard deviation stated in Table 9.

Table 9. Assessment of the reference standard deviation for the different frequency bands (according to [1], section 7.9)

Third-octave band mid frequencies	Reference standard deviation for the insertion loss
Hz	dB
50 up to 100	1.5
125 up to 500	1
630 up to 1250	2
1600 up to 10000	3

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Appendix A

Insertion losses

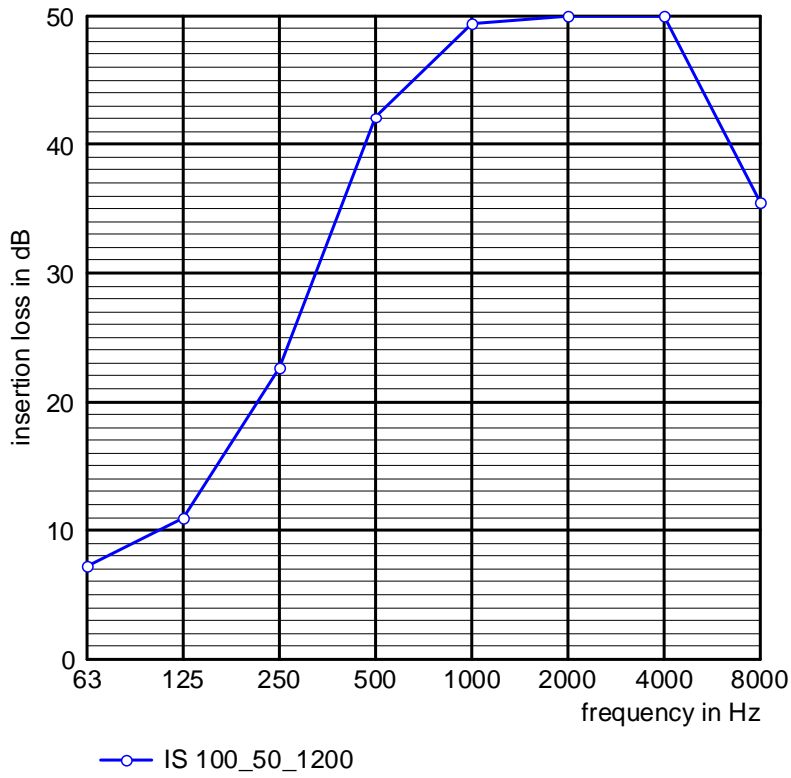


Figure 1. Insertion loss for inline silencer IS 100/50/1200

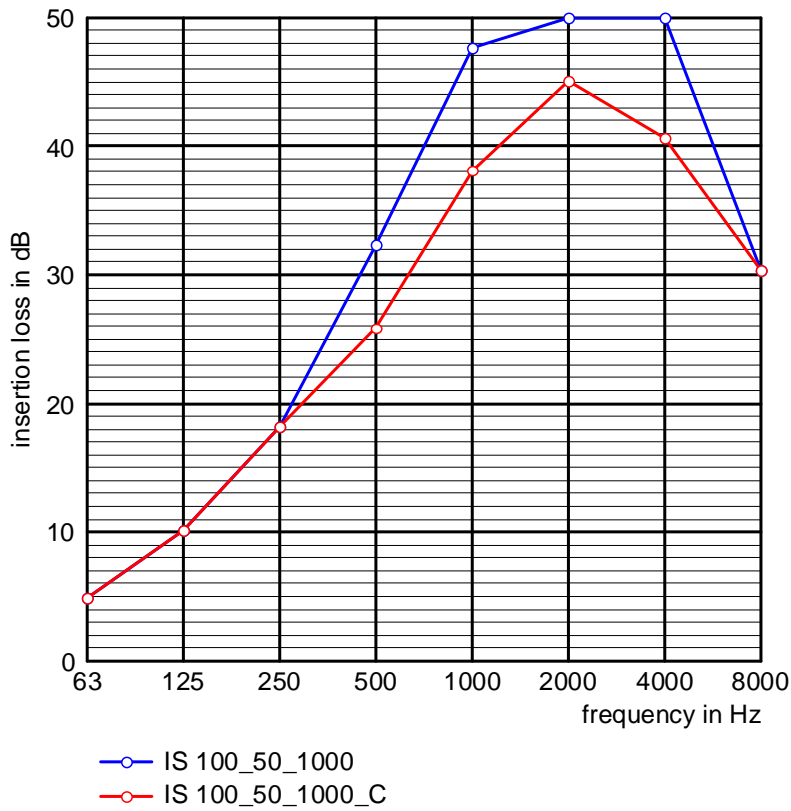


Figure 2. Insertion loss (blue) and minimum insertion loss (red) for inline silencer IS 100/50/1000

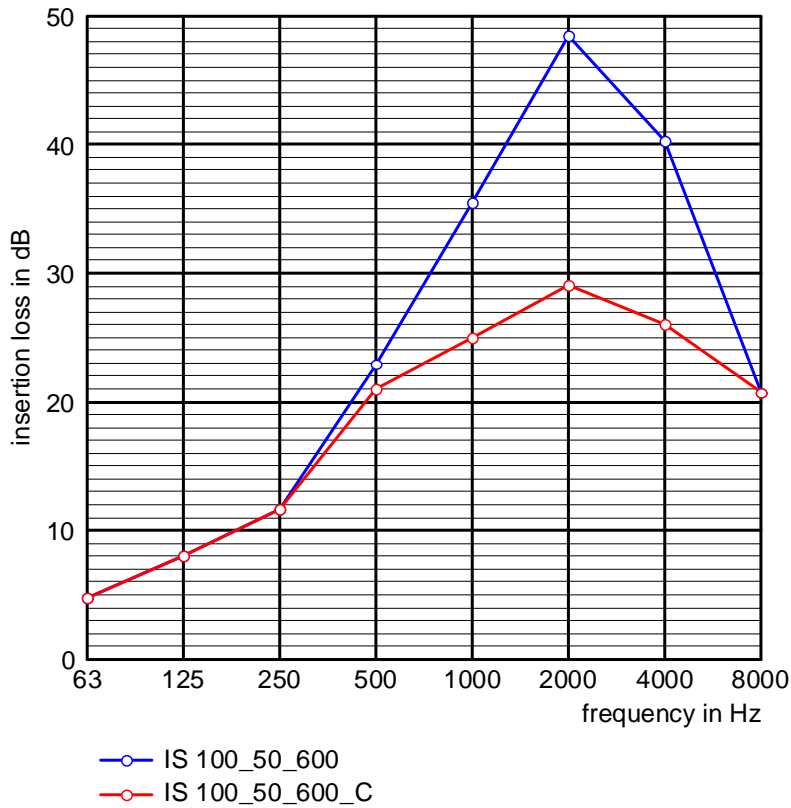


Figure 3. Insertion loss (blue) and minimum insertion loss (red) for inline silencer IS 100/50/600

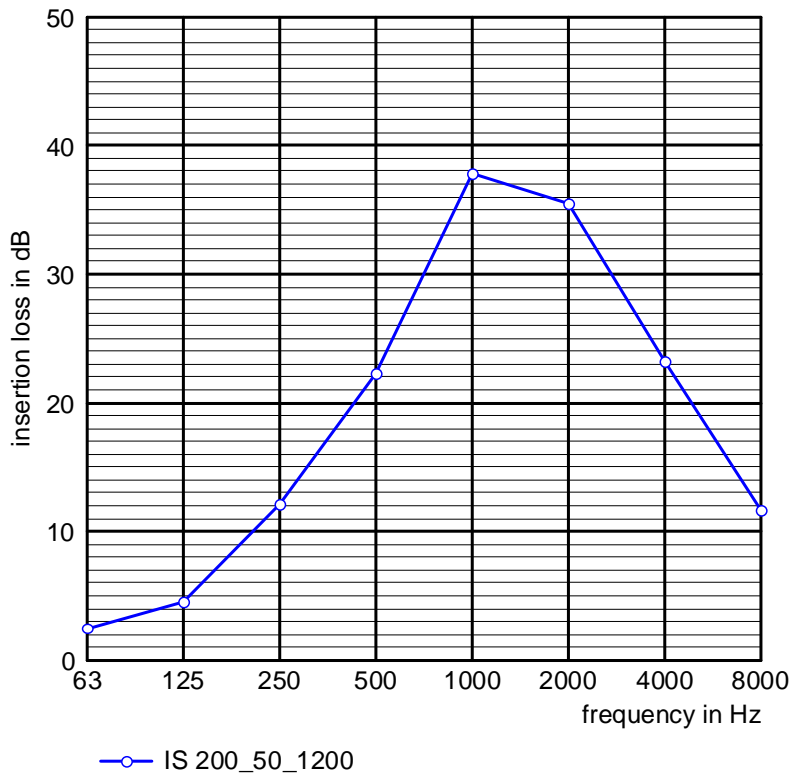


Figure 4. Insertion loss for inline silencer IS 200/50/1200

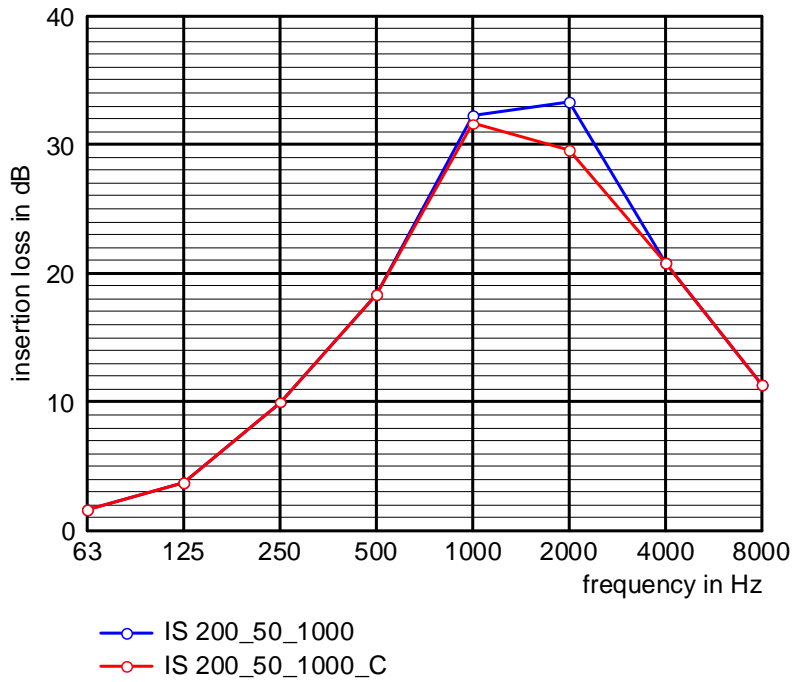


Figure 5. Insertion loss (blue) and minimum insertion loss (red) for inline silencer IS 200/50/1000

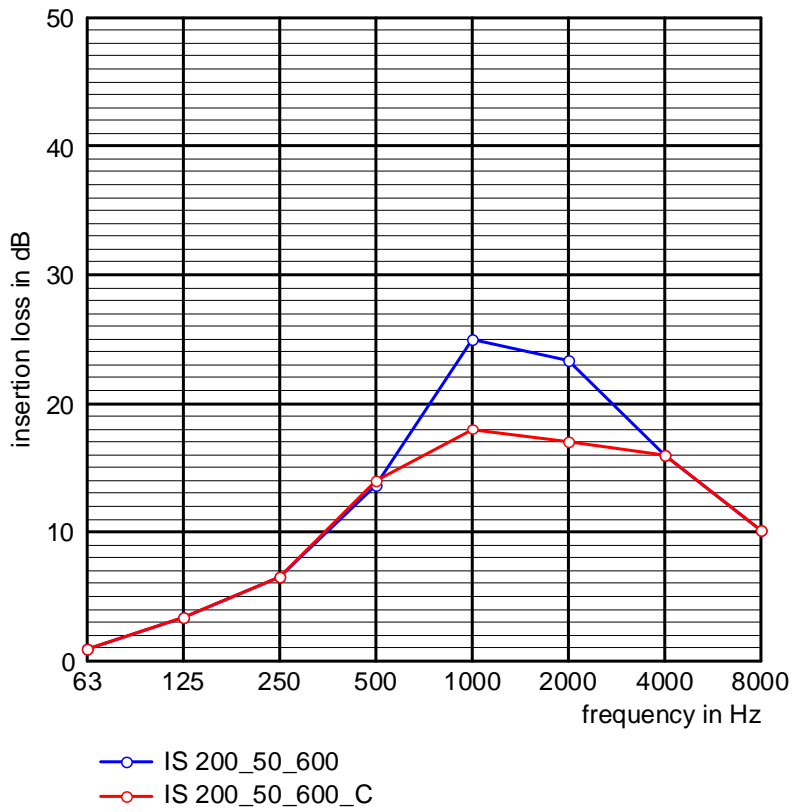


Figure 6. Insertion loss (blue) and minimum insertion loss (red) for inline silencer IS 200/50/600

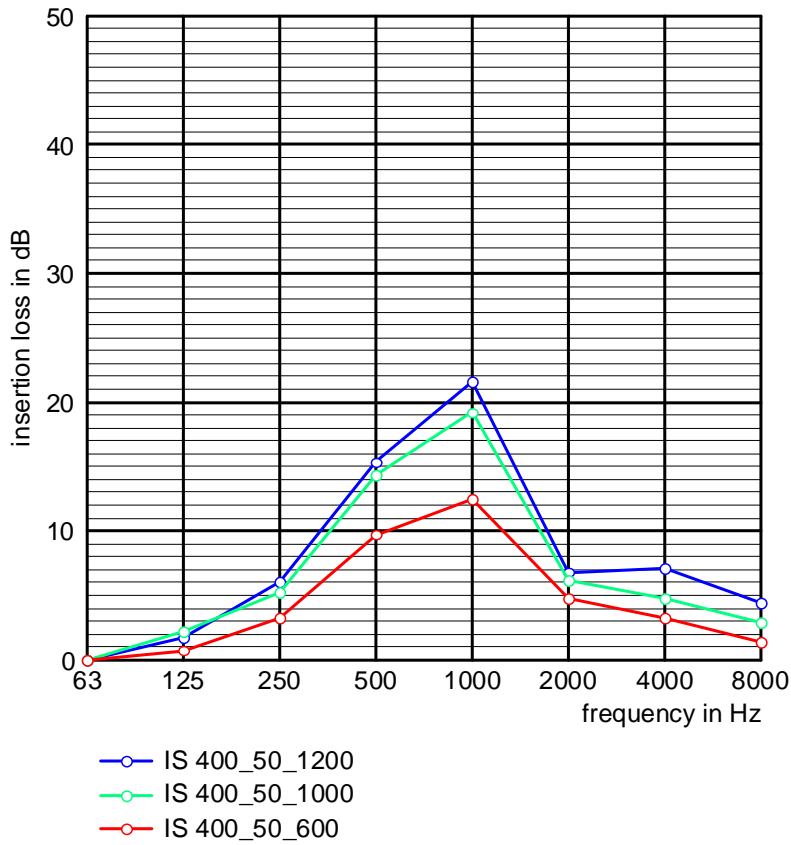


Figure 7. Insertion loss for inline silencer IS 400/50/1200-600

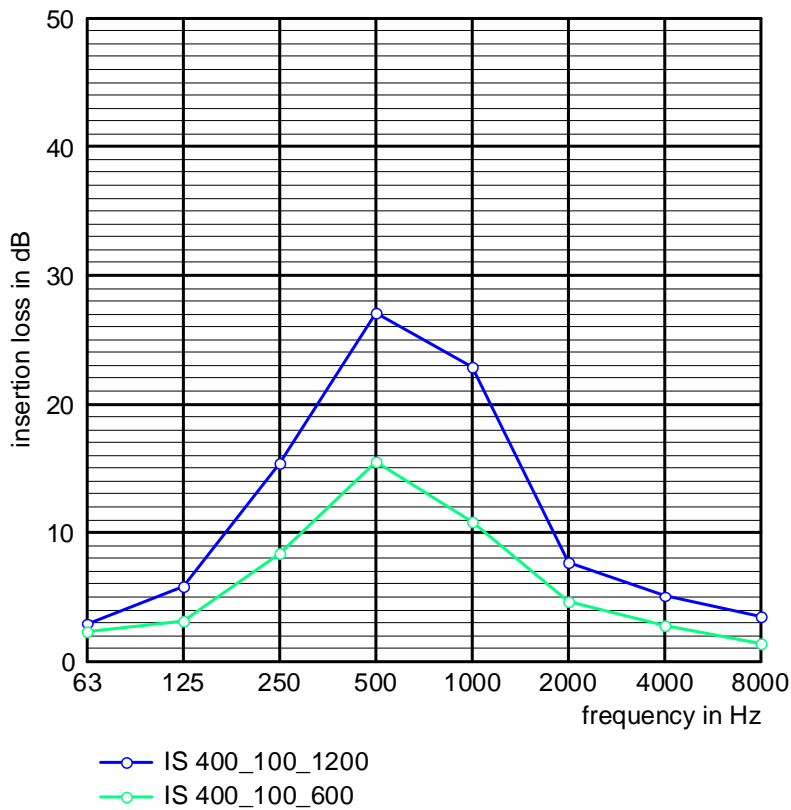


Figure 8. Insertion loss for inline silencer IS 400/100/1200-600

Appendix B

Limiting insertion loss

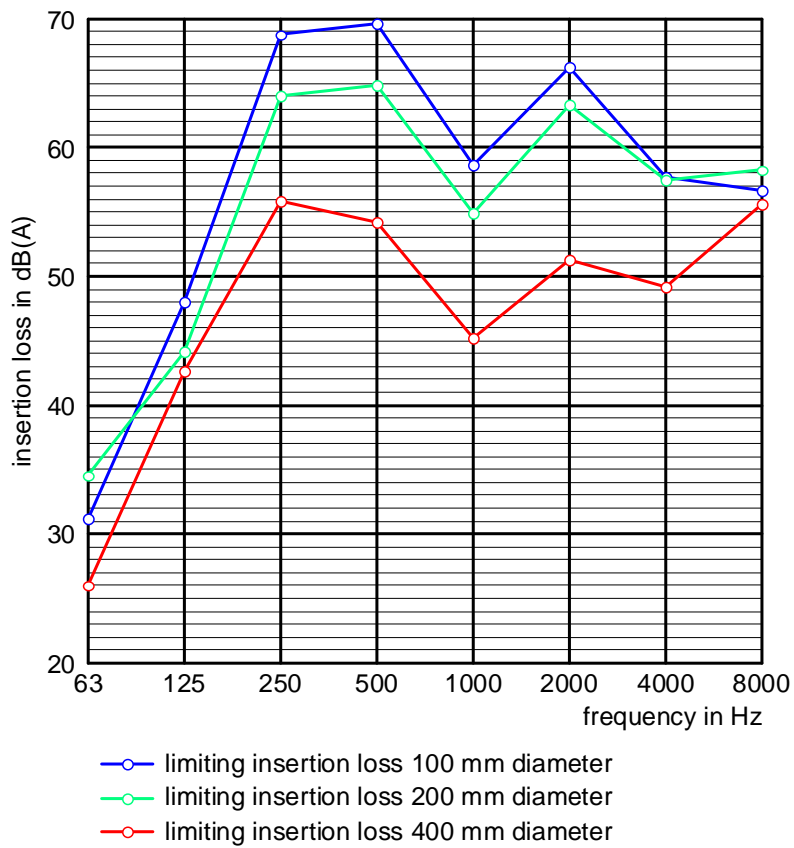


Figure 9. Limiting insertion loss of the silencer test stand for the investigated silencer diameters