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Recommended verification method for calibration conditions in multi-channel simultaneous acoustical noise measurement system

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Japan Business Machine and Information System Industries Association
Sub-working group 2 of working group for investigations
of acoustical noise standards and specifications,
Environmental committee

Sub-working group 2 for improving calibration work of measurement system of working group for investigations of acoustical noise standards and specifications, Environmental Committee

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Introduction

For sound power level determinations of information technology and telecommunications equipment (ITT equipment) according to the noise test codes (ISO 7779, ECMA-74, JIS X 7779 etc.), 9 or more microphone positions are required in a hemi-anechoic chamber (HAC). In this measurement, a multi-channel simultaneous acoustical noise measurement system is indispensable not only for the efficiency of workload savings, but also for the improvement of measurement accuracy (repeatability), especially for the noise sources emitting time-varying noise, such as multifunctional devices, printers, copy machines, personal computers (PCs) and hard disk drives.

ISO 7779 requires the verification for the calibration conditions of measurement systems by applying a sound calibrator to each microphone, once during each series of measurement as daily check. It is true that the daily calibration work is one of key activities of the measurement routines; however it is a very time-consuming process due to the nature of multi-channel systems.

On the other hand, as long as no significant fluctuation of meteorological condition would occur and all the measurement systems maintain the wire connection from a microphone to analyzer, it is known that an impact to the sensitivity of microphones would be negligibly small. And also, this verification operation may have an influence on measurement results by causing an overload to diaphragm of microphone depending on the way of inserting microphone to a sound calibrator. Therefore, the verification must be done as less frequent as possible. For these reasons, frequent verification of calibration conditions increases not only the workload of operators, but also a risk of damaging microphones, particularly for the testing laboratories adopting multi-channel simultaneous acoustical noise measurement system

This time, the Environmental committee of Japan Business Machine and Information System Industries Association (JBMIA) has organized SWG 2 under the Noise WG (working group for investigation of acoustical noise standards and specifications) in January 2012, and has studied for improving the efficiency of verification of calibration condition not only from the standpoint of manufacturers of ITT equipment, but also from that of the testing laboratories and the manufacturers of the measurement systems. The verification method from this study uses a reference sound source satisfying the requirements of ISO 6926 for verification instead of a sound calibrator. This new method could improve time efficiency and verify more than one microphone safely and appropriately, because it does not touch directly the microphones. This JBMIA-TR reports the method.

1 Scope

This technical report gives information of recommended verification method for the calibration conditions in a multi-channel simultaneous measurement system to measure sound power level of acoustical noise from ITT equipment according to noise test codes such as ISO 7779.

2 Terms and definitions

For the purposes of this technical report, the terms and definitions given in ISO 7779 and the following apply.

2.1
reference sound source (RSS)
device which is intended for use as a stable source of sound, and which has a known broad-band sound power spectrum calibrated in accordance with ISO 6926 over the frequency range of interest

2.2
sound calibrator
device generating one or more known sound pressure levels at one or more frequencies in accordance with IEC 60942, and of which intended use is to apply to the microphones of specific model and configuration

2.3
multi-channel simultaneous acoustical noise measurement system
system for measuring acoustical noise with more than one microphone simultaneously especially for the measurement of time-varying noise such as printers, copiers, personal computers and hard disks for improving the measurement efficiency and repeatability

2.4
automatic microphone positioning system,
automatic microphone traversing system
system for positioning one or more microphones automatically, which adjusts the microphones precisely and efficiently to the designated positions depending on the size of the noise source under test

3 Noise test codes for ITT equipment and their trend in revisions

3.1 Requirements in the current noise test codes

For the measurement of acoustical noise emitted from ITT equipment, there are several parallel noise test codes such as global ISO 7779, industry wide ECMA-74, nation-wide JIS X 7779 for Japan; ANSI/ASA S12.10 Part 1 for USA; GB/T 18313 for PRC, etc. (See Table 1.)

Table 1 — Noise test codes for ITT equipment

Coverage	Organization (Nation)	Standard number
Global	ISO	ISO 7779:2010 3rd edition
Industry wide	Ecma International (Europe basis, but actually global)	ECMA-74:2012 12th edition [a]
	JBMIA (Japan)	JBMS-74 series [b]
Nation wide	JISC (Japan)	JIS X 7779:2012 2nd edition [c]
	ANSI/ASA (USA)	ANSI/ASA S12.10-2010 Part 1 [d]
	GB (PRC)	GB/T 18313:2001 1st edition [e]
	KS (Korea)	KS I ISO 7779:2002 1st edition [f]
	AS (Australia)	AS 3755-1990 1st edition [g]

a Equivalent to ISO 7779:2010, 3rd edition + Normative Annex C for specifying operating/installation conditions for many equipment categories.

b Supplement to ECMA-74, for specific needs of JBMIA

c Japanese translation of ISO 7779:2010, 3rd edition

d Equivalent to ISO 7779:2010, 3rd edition

e Chinese translation of ISO 7779:1999, 2nd edition

f Korean translation of ISO 7779:1999, 2nd edition

g Equivalent to ISO 7779:1988, 1st edition

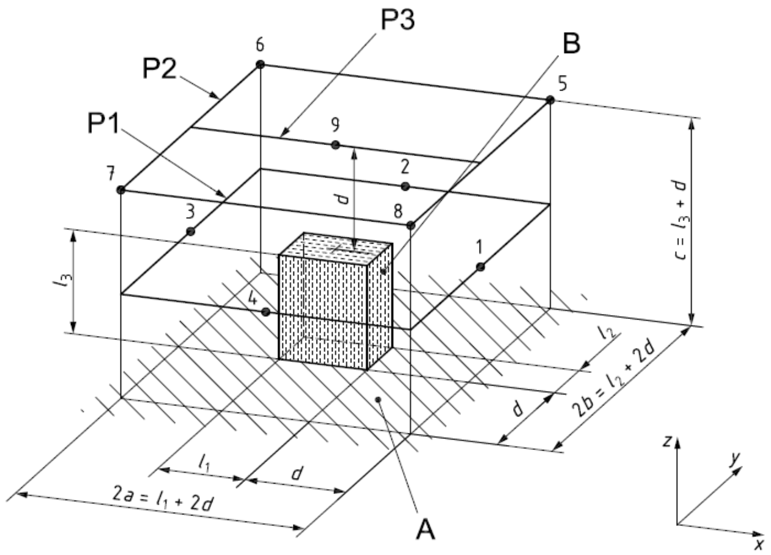
These noise test codes commonly state alternative test methods for each testing environment; “Method for determination of sound power level of equipment in reverberation test rooms” and “Method for determination of sound power levels of equipment under essentially free-field conditions over a reflecting plane". The former is so called a reverberation chamber method (RC method), and the latter is so called a hemi-anechoic chamber method (HAC method). For RC method, 6 microphone positions are required according to ISO 3741, and for HAC method, 9 or more microphone positions are required according to ISO 3744. (Typical example of microphone arrays on a parallelepiped measurement surface is shown in Figure 1.) Many testing laboratories (particularly those testing ITT equipments such as printers, copy machines, PCs and hard disk drives) adopt a multi-channel simultaneous acoustical noise measurement system and an automatic microphone positioning system for the following reasons:

- Since the most of ITT equipment emit time-varying noise, it is difficult to synchronize the measurement timing in case that the acoustical noises are to be measured more than once with repositioning the microphones.

- Because the manual positioning of microphones may increase human errors depending on the operators' proficiency levels.

- To improve the efficiency in positioning the microphones because parallelepiped measurement surface shall always be adjusted depending on the dimensions of the noise source under test.

- To ease the quantification of measurement uncertainty by referring the specifications of the automatic microphone positioning system.



Key	
●	key microphone positions
A	reflecting plane
B	reference box
$2a$	measurement surface length
$2b$	measurement surface width
c	measurement surface height
d	measurement distance
l_1	reference box length
l_2	reference box width
l_3	reference box height
P1 to P3	path 1 to path 3

Figure 1 — Example of Microphone arrays on parallelepiped measurement surface (excerpted from ISO 3744:2010)

On the other hand, the existing noise test codes such as ISO 7779 commonly requires the verification of the entire measurement system by physical contact with applying sound calibrator to microphones once during each series of measurements as follows.

> **7.4.6 Calibration**
> During each series of measurements, a sound calibrator as specified in IEC 60942, class 1, shall be applied to the microphone to verify the calibration of the entire measurement system at one or more frequencies over the frequency range of interest.

Therefore, according to such noise test codes, the testing laboratories are required to verify calibration conditions as one of the key routine activities of every measurement day, although such verification operations consume a lot of time and may have a risk of damaging microphones.

3.2 Recent trend in standard revision for verifying calibration condition requirements in measurement system

When the noise test codes such as ISO 7779 is revised, Guide 1 of ISO/TC43/SC1 is the most influential document on it. At the time of development of this JBMIA-TR, the requirement of "calibration" in the document is as follows.

> **X.1.2 Calibration**
> At the beginning and at the end of every measurement session and at least at the beginning and the end of each measurement day the entire sound pressure level measuring system shall be checked at one or more frequencies by means of a sound calibrator meeting the requirements for a class X instrument according to IEC 60942. Without any further adjustment the difference between the readings of two consecutive checks shall be less or equal to 0,5 dB. If this value is exceeded the results of measurements obtained after the previous satisfactory check shall be discarded.

NOTE 1 In "class X", "class 1" or "class 2" is inserted accommodating noise test code applying this requirement.

NOTE 2 In this excerpt, "," is used for decimal point according to Guide 1.

Thus, Guide 1 requires testing laboratories to verify calibration condition of the entire measurement system "at the beginning and at the end of every measurement session". Though the present noise test codes such as ISO 7779 requires "once during each series of measurements," the testing laboratories having multi-channel simultaneous measurement system will have to verify, at least, 6 microphones for RC method and 9 or more microphones for HAC method twice a day, if the requirements of Guide 1 are adapted to the noise test code such as ISO 7779. This means that the microphones shall be verified 18 times or more every measurement day for HAC method. Such a time-consuming daily operation does not look practical.

4 Study for variation in sensitivity of microphone by JBMIA SWG2

4.1 Specifications of measurement microphone

JBMIA has organized SWG 2 under the Noise WG, and has studied for improving the efficiency of verification of calibration condition from various standpoints not only from the manufacturers of ITT equipment, but also the testing laboratories and the manufacturers of measurement systems. SWG2 inquired the manufacturers of microphones and sound calibrators about their specifications related to verification regardless that if they are a member of SWG2 or not. As the results, SWG2 has noticed some common issues as follows:

- Verification operation may have an influence on the measurement results because it may cause an overload to the microphone diaphragm depending on the way of inserting a microphone to a sound calibrator. Therefore, the insertion must be done carefully as less frequent as possible.

- The manufacturers of the sound calibrator assume that a microphone is inserted vertically to a sound calibrator which is placed on a stable place such as on a desk. Thus, it is not assumed and has difficulty in that the microphone fastened to the manipulator of the automatic microphone positioning system.

- As long as all the measurement systems maintain the wire connection from microphone to analyzer, an impact to the sensitivity of microphones should be very small or negligible.

From the above, provided that there are no significant fluctuation of meteorological conditions (temperature, humidity and atmospheric pressure) and the wire connection from microphone to analyzer are maintained, two times of the verification operations, i.e., both before and after a measurement session, would not be necessary.

If the two verifications before and after a measurement are applied to noise test codes such as ISO 7779 for the testing laboratories adopting multi-channel simultaneous acoustical noise measurement system, not only the daily verification workload will be increased twice but also the failure risks will be increased by the number of microphones.

4.2 Verification experiment using a reference sound source

SWG2 have conducted an experiment inspecting the fluctuation of the measurement results for 5 consecutive days in order to demonstrate that the sensitivity of microphone would fluctuate little or be negligible as long as the entire measurement systems maintain wire connection, even though long time would be passed.

A reference sound source (RSS) was used as the test sound source of this experiment. The technical requirements of a RSS are specified in ISO 6926 and it is usually designed and calibrated to satisfy the standard deviation of repeatability of 0.2 dB for one-third-octave band sound power level of 1 kHz (see Table 2). From measurement experiences of the members of SWG2, it was known that a RSS also has good repeatability for sound pressure level (measured) at every microphone position.

Table 2 — Maximum value of the standard deviation of the sound power level under repeatability conditions for reference sound source according to ISO 6926 (excerpt)

Frequency range Hz	**Standard deviation** dB
50 to 80	0,8
100 to 160	0,4
200 to 20 000	0,2

Other conditions were as follows:

- The RSS was measured once a day with the entire measurement systems maintaining the wire connections from microphone to analyzer for the entire test days, but the systems were electrically powered on and off every day.
- According to ISO 3744, the microphones were positioned over the parallelepiped measurement surface with the reference box of the RSS, 30 cm × 30 cm × 30 cm and the measurement distance, d = 1.0 m.
- All the microphones were verified with a sound calibrator only before the measurement of the first day and after the measurement of the last day.
- A CVCF (Constant Voltage – Constant Frequency unit) was used for the main power supply to the RSS. The RSS was operated for 5 min before its daily sound power level determination, and the time-averaged sound pressure level of 30 s was measured at each microphone position. This RSS has been checked its conformance to **ISO 6926** once a year.
- Microphones were re-positioned by the automatic microphone positioning system every day and the RSS was also re-positioned every day.
- The measurement results were shown as those of 1 kHz one-third-octave band because the sound calibrator with 1 kHz nominal frequency was used.
- Corrections due to the reference meteorological conditions were not applied.

Fluctuation of the sound pressure levels on each microphone is shown in Figure 2. Figure 3 shows the sound power level calculated from the sound pressure levels of all the 9 measurement points to demonstrate the stability of the RSS.

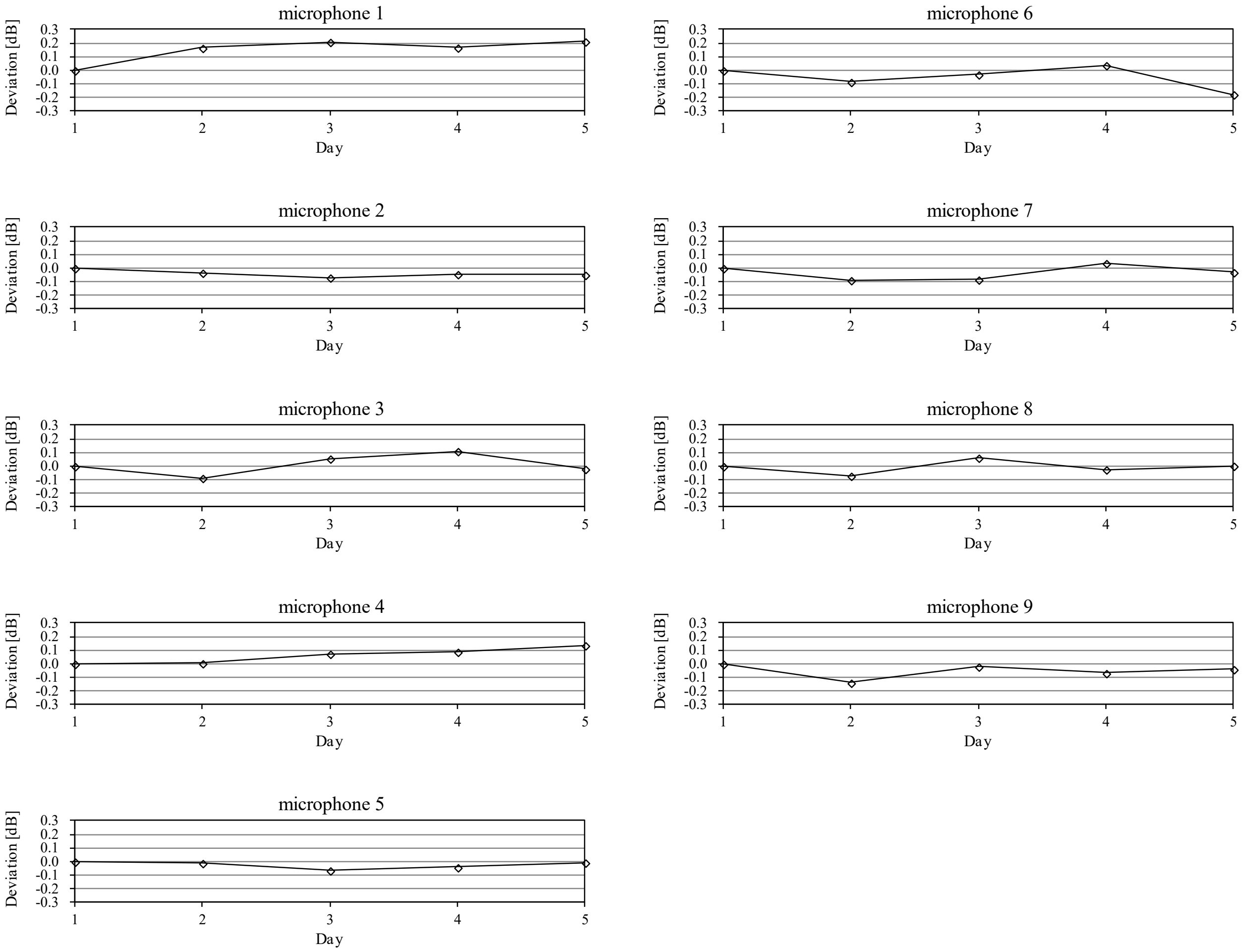


Figure 2 — Fluctuation of 1 kHz one-third-octave band sound pressure level on each microphone, reference to day 1 (The microphone numbers correspond to Figure 1.)

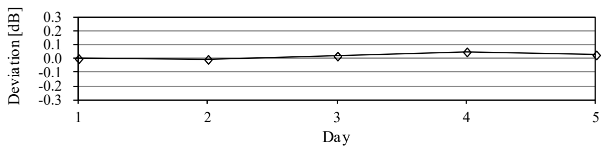


Figure 3 — Fluctuation of 1 kHz one-third-octave band sound power level (reference to day 1)

As shown in Figure 2, the maximum fluctuation of sound pressure levels on each microphone was 0.21 dB and every microphone has good stability.

4.3 Reference sound source as verification method

The RSS could be used as a tool for verifying the calibration conditions by comparing the measurement results of validation of 4.2, instead of a sound calibrator. This would also be verification of the compliance to the requirement of Guide 1 that “the difference between the readings of two consecutive checks shall be less or equal to 0.5 dB.” However, it requires the verification of sound pressure level, not sound power level, per microphone.

This method has the following advantages:

- This method allows verification without any physical contact to a microphone; which would prevent microphones from being damaged.
- This method allows verification with any one-third-octave band; while the existing method using a sound calibrator only allows the verification for a single frequency.

5 Recommended verification method for calibration conditions in measurement system using reference sound source

5.1 General

This clause states the recommended verification method for calibration conditions in measurement system on the basis of the above studies.

5.2 Testing environment

The requirements of the noise test codes shall be followed, as applicable. In this measurement, it is recommended to hold the temperature and the humidity stable. And especially if the noise source under test is low noise equipment, it is also recommended to confirm it before or after microphone sensitivity measurement by RSS that the background noise of the testing environment is sufficiently low.

5.3 Instrumentation

In case that the verification method in this JBMIA-TR is used, it is strongly recommended to maintain wire connection of each microphone, pre-amplifier and cables for the entire test period, while the measurement systems do not need maintaining powered on electrically. Additionally, it is also recommended to check the internal noise of the measurement systems before test.

5.4 Recommended verification method for calibration conditions in measurement system

5.4.1 General

Verification method recommended in this JBMIA-TR consists of “pre-test verification” and “mid-test verification” that is verification for calibration conditions during test. “Pre-test verification” is executed before the first measurement after the measurement systems are wire connected. “Mid-test verification” is executed after pre-test verification. It is expected that the specific timing of “mid-test verification” would be stipulated in a noise test code in which this verification method could be introduced.

5.4.2 Pre-test verification

5.4.2.1 Verification using a sound calibrator

A sound calibrator is applied to the microphone to verify the calibration of the entire measuring system at one or more frequencies over the frequency range of interest in accordance with the requirements of noise test code.

5.4.2.2 Verification using reference sound source

After the verification using a sound calibrator is completed, a RSS is positioned in testing environment. If noise source under test could not be put out during a measurement session, a RSS could not be positioned in the center of the test room as long as positional relationship between the noise source under test, microphones and RSS could be duplicated at any timing of test. The RSS is operated in the same manner as those calibrated in accordance with ISO 6926. After the rotating speed becomes stable, one-third-octave band time-averaged sound pressure levels over the frequency range of interest are measured at each microphone (for decision methods of operating time after power-on and averaging time are referred in Annex A). These measurement values become reference of subsequent verification. One-third-octave band frequency which includes the frequency verified in 5.4.2.1 is verified. The other frequency band data could be used to verify that characteristic of every microphone is not changed due to breakage, for example. After recording the information to duplicate the positional relationship, RSS is removed from the test chamber.

5.4.3 Mid-test verification - Verification for calibration conditions during test

Microphones and RSS are positioned at the same locations as in 5.4.2.2. In case that the testing laboratory chose not to change the location of the noise source under test, all positions including the noise sound source should be duplicated. After RSS is operated and rotating speed become stable, the time-averaged sound pressure level same as 5.4.2.2 is measured by every microphone. By comparing these measured values with the reference values measured in 5.4.2.2 and as long as the differences are within 0.5 dB, the microphones are verified that they are functioning correctly at this frequency. From this point onward, testing laboratories can verify their calibration conditions by executing this verification.

5.4.4 Supplemental verification for calibration conditions

If the verification using a RSS is not sufficient since, for example, microphones are damaged by a certain reason during a measurement, the testing laboratories can verify the entire measurement systems by applying a sound calibrator to every microphone as described in 5.4.2.1, as appropriate.

5.4.5 Other points to remember

Since a significant variation of atmospheric pressure affects the measurement values, it can be possible to correct the measurement values according to the referenced meteorological conditions, as appropriate. However, it is limited and supposed that the same method is applied to both 5.4.2.2 and 5.4.3.

Annex A
(informative)

Guideline for deciding the measurement time interval of reference sound source

In the verification method for calibration conditions using a RSS recommended by this JBMIA-TR, it is effective to evaluate the stability of the RSS in advance and to decide proper measurement time interval of it in the individual testing laboratories. This annex presents the evaluation results of the variation of sound pressure level after power-on and the stability of time-averaged sound pressure level depending on the measurement time interval of the calibrated RSS in accordance with ISO 6926.

A.1 Variation of sound pressure level after power-on

Figure A.1 shows an example of time variation of the sound pressure level after the power-on of a RSS. Since the evaluated RSS generated sound by using an AC fan, a CVCF was used for the electrical power supply. Figure A.1 shows the result of 100 Hz – 10 000 Hz at one of the 9 microphones for A-weighted sound pressure level positioned as the same as the sound power level measurement, the results of the other 8 microphones showed the similarity to Figure A.1. Since this result shows that the RSS was operated sufficiently stable when 30 s passed after power-on, the measurement productivity should not be spoiled by applying the recommended verification method in this JBMIA-TR.

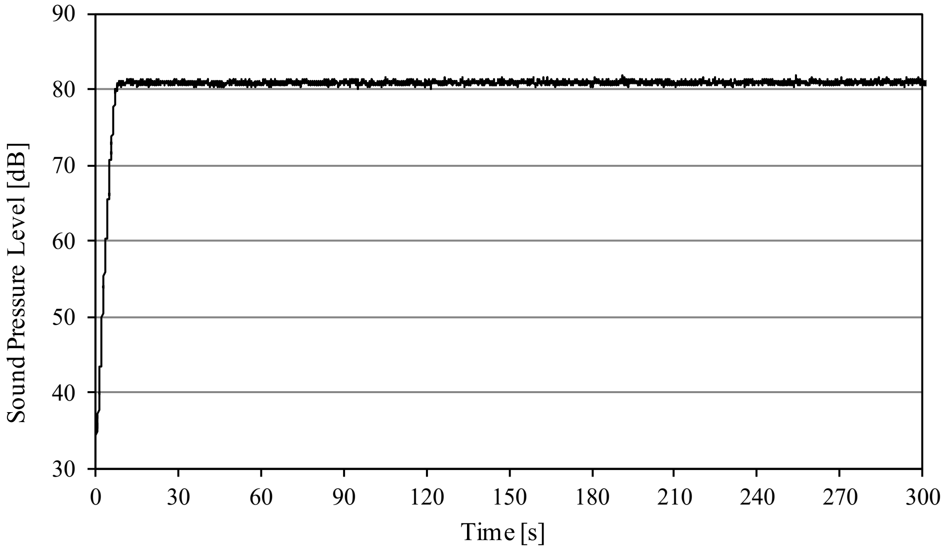


Figure A.1 — Variation of sound pressure level after power-on (A-weighted level)

A.2 Stability of time-averaged sound pressure level depending on measurement time interval

Figure A.2 shows an example of the standard deviations of sound pressure level which was measured 5 times with different measurement time intervals. The Figure shows the standard deviations of the maximum and the average value of 1 kHz center frequency of one-third-octave band at the 9 microphone positions of sound power level measurement. In order to evaluate the characteristic of the RSS, the RSS had been continuously operated through all the measurements. All the measurements were executed consecutively and the positions between the RSS and the microphones were not changed. From this result, the measurement value was found sufficiently stable at the equal to or more than 30 s, and more stable measurement result could be obtained if longer the measurement time interval becomes.

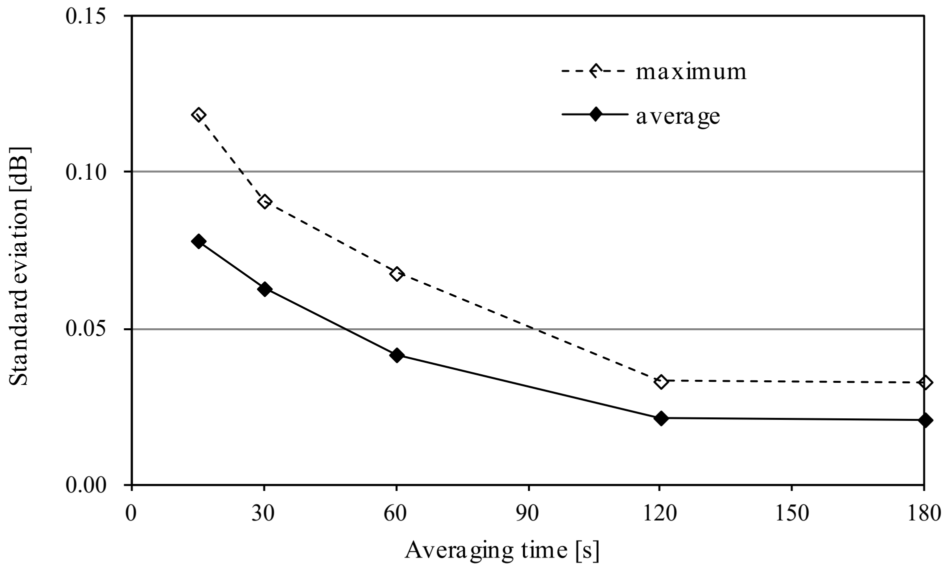


Figure A.2 — Stability of time-averaged sound pressure level depending on measurement time interval (at 1 kHz 1/3 octave band)

NOTE In case of an aerodynamic method type RSS with using fan, the generated sound pressure level should be depending on the rotating speed of the fan that is led by voltage and frequency of the power-supply. The testing laboratories can confirm if or not the RSS is operated as expected and generating the proper sound power level stably with using a contactless (photoelectric) revolution indicator,. This is effective when a question would arise in the sound power level of the RSS or when the setting of power supply voltage is changed on the RSS.

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[3] ISO 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels*

NOTE JIS counterpart, JIS Z 8739:2001 (IDT) exists.

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