ECMA
EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

# METHOD FOR THE PREDICTION OF INSTALLATION NOISE LEVELS

## TR/27

March 1985

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# BRIEF HISTORY

In 1979 ECMA set up its Technical Committee TC26 for Acoustics. As a first task TC26 drafted a standard for determining the noise output of different categories of individual items of computer and business equipment. This Standard ECMA-74, issued in 1981, has been adopted by ISO/TC43 as the basis for International Standard ISO 7779.

Standard ECMA-74 allows one to assess the NOISE EMISSION of a given piece of equipment, viz. the level of noise emitted by this equipment when measured under standard test conditions. In contrast, when several pieces of equipment are installed and operated in a room, the resulting noise level is called INSTALLATION NOISE LEVEL that depends not only on the noise emitted by the installed equipment, but also on its arrangement in the room, on the acoustical properties of the room, and the location of interest.

Knowledge of the installation noise level is required in order to assess the NOISE IMMISSION level at workplaces in the room, that is the personal exposure to noise of people working in an installation. This personal exposure, the so-called RATING LEVEL, depends on the installation noise level and on the exposure duration of the individual person. Limits for the rating level have been set in a number of countries by law or regulation.

When planning an installation it is therefore important to be able to predict the likely installation noise level. This ECMA Technical Report describes a method for such prediction. It is based on mathematical models developed by KRAAK and JOVICIC (see Appendix C). For the purposes of this Technical Report applying to computer and business equipment, the method has been simplified to provide a practical tool for those concerned with machine and system installation as well as early installation planning.

Whilst actual calculations and measurements by members of TC26 have generally shown that the difference between the predicted and the actual measured levels is within 3 dB, users are cautioned that conditions unique to each installation may result in the measured values being more than 3 dB different from the predicted values. The principal reasons for this situation are as follows:

- In a given installation it is possible that the operation conditions are for a certain time more stringent than the standard operating conditions specified in ECMA-74.
- The predicted noise levels include steady background noise but do not include the additive effects of personal communication (speech, telephone, etc.).

It is the intention of TC26 to consider the experience made when applying the method described in this Technical Report with a view to issuing a second improved edition. Readers of this Technical Report are therefore invited to communicate their views to ECMA.

Adopted as an ECMA Technical Report at the General Assembly of Dec. 14, 1984.

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## 1. SCOPE

This ECMA Technical Report specifies a method for the prediction of installation noise levels. This method takes into account the acoustical properties of the room in which computer and business equipment is installed, the location(s) of the noise emitting equipment and their noise emission level(s), determined according to Standard ECMA-74, and the location(s) of interest.

## 2. REFERENCES

ECMA-74 : Measurement of Airborne Noise emitted by Computers and Business Equipment

ISO 7779 : Acoustics - Measurement of Airborne Noise emitted by Computer and Business Equipment.
*Status in 1984: Draft International Standard.*

ISO 3741 : Acoustics - Determination of sound power levels of noise sources - Precision methods for broadband sources in reverberation rooms.

ISO 3742 : Acoustics - Determination of sound power levels of noise sources - Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.

ISO 3744 : Acoustics - Determination of sound power levels of noise sources - Engineering methods for free-field conditions over a reflecting plane.

ISO 3745 : Acoustics - Determination of sound power levels of noise sources - Precision methods for anechoic and semi-anechoic rooms.

ISO 4871 : Acoustics - Noise Classification and Labelling of Equipment and Machinery

ISO 7574 : Acoustics - Statistical Methods for Determining and Verifying the Noise Emission Values of Machinery and Equipment.
*Status in 1984: Draft International Standard*

ISO 6081 : Acoustics - Noise emitted by Machinery and Equipment - Measurements at the Operator's Position.

DIN 45645 : Einheitliche Ermittlung des Beurteilungspegels für Geräuschimmissionen (Standardized determination of the rating level for occupational noise immissions).

IEC 651 : IEC Publication 651, Sound Level Meters.

BERANEK,L. : Acoustics, McGraw-Hill Book Company, New York 1954.

VDI 2720 (Blatt 2) : VDI Richtlinie: Schallschutz in Räumen durch Abschirmung.

DIN : Deutscher Normenausschuss, Schallabsorptionsgrad-Tabelle, Beuth-Vertrieb GmbH Berlin 30, 1968.

## 3. NOISE EMISSION

### 3.1 General

The term "Noise Emission" is used to describe the characteristics of the acoustical output of equipment. It refers always to one functional unit and requires standardized test conditions for the acoustical measurements as well as the installation and operation of the equipment under test; this is illustrated in Figure 1.

Noise emission is preferably expressed in terms of sound power, which, for practical purposes, is one real invariant, independent of the environment. It may also be expressed in terms of sound pressure which however is dependent on the measurement location, the distance from the equipment and the test environment.

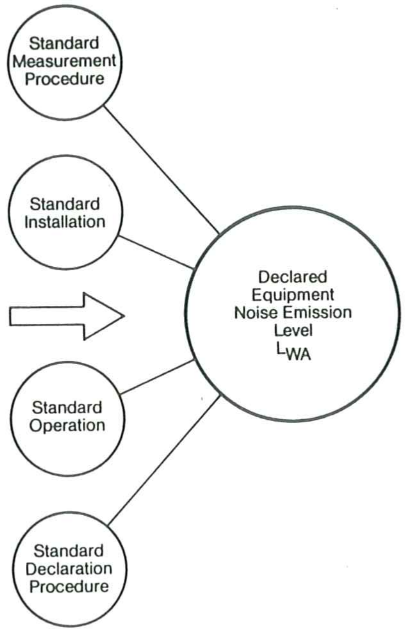

Figure 1. NOISE EMISSION

### 3.2 Measurement of Noise Emission

The basic noise emission quantity is the A-weighted sound power level, $L_{WA}$ in dB re 1 pW (decibels with reference to one picowatt).

For computer and business equipment it is determined according to Standard ECMA-74 (or ISO 7779) that was derived from the basic International Standards ISO 3741 to ISO 3745.

The measurements are performed in either of the two acoustic environments, a semi-anechoic room (providing a free field over a reflecting plane), or a reverberation room (providing diffuse field conditions).

Other noise emission quantities of interest are the sound pressure level, $L_{pA}$ in dB re 20 uPa (decibels with reference to 20 micropascals), measured at the specified equipment operator position(s) or at an otherwise defined position(s), the bystander's position(s). Furthermore the noise spectrum and the directivity of the noise radiation may be useful information when planning an installation.

It should however be clearly understood, that these noise emission quantities are not personal exposure values (rating levels). There exists generally no simple relationship between the (equipment) emission levels and the (personal) rating level. However, the rating level can be determined if all relevant parameters, as indicated in Figure 2, are known.

### 3.3 Use of Noise Emission Values

Product noise emission data may be used in a number of ways:

- to assist in making product development design changes,
- to control product quality in production,
- to provide a declared product noise emission value in accordance with standards and regulations,
- to characterize the state of noise control for that class of product,
- to compare competing products.

Most important for the task described in this Technical Report are the product noise emission levels, which are used for the determination of the installation noise level.

Generally, for mass-produced equipment, the declared noise emission value takes into account production variations and measurement uncertainties (ISO 4871, ISO 7574). The declared value may therefore be 3 dB to 5 dB higher than the value for the average production unit. These factors must be taken into consideration, when using declared values for the determination of the installation noise level; further details are given in 5.3.1.

## 4. NOISE IMMISSION

### 4.1 General

The term "Noise Immission" is used to describe the influence of noise on man. Rating of immission may be performed with respect to hearing impairment, annoyance or interference with speech or work. For rating the noise immission at a workplace with respect to its influence on an individual person, the rating level is to be determined, which is always valid for a typical 8-hour workshift.

Immission in general depends on the noise level of the installed equipment, the actual operation of each unit, the acoustical properties of the room and the background noise (due to air conditioning systems, road, rail and air traffic, etc.). Furthermore, a person's location(s) in the room as well as the actual exposure durations during the workshift are of importance. In some countries criteria are applied for the presence of discrete tones and/or impulsive noise. The installation noise level determined from this Technical Report is not necessarily identical to the (personal) rating level, because there may be differences in the equipment operation and in the exposure time of an individual person; Figure 2 shows this relationship.

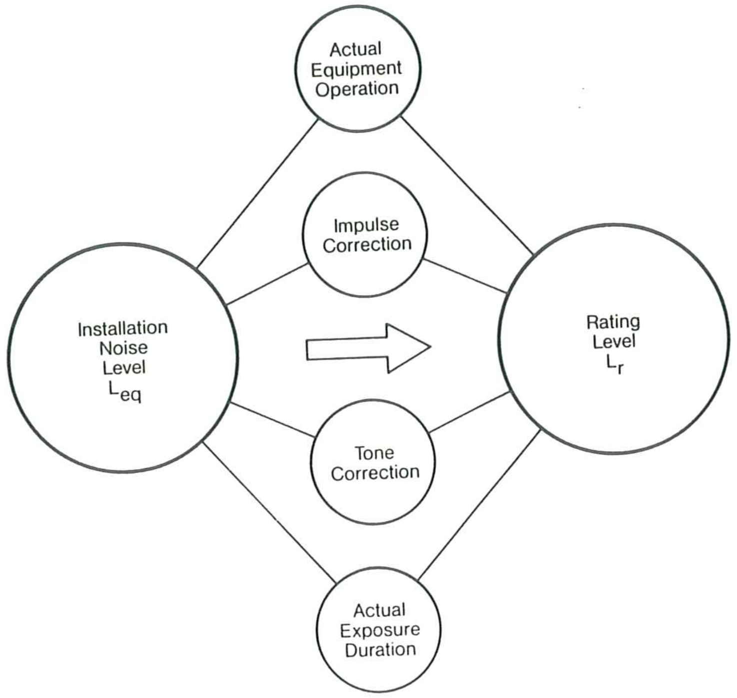

Figure 2. Relationship between Installation Noise Level and the (personal) Rating Level at a specific location.

## 4.2 Measurement of Noise Immission

Noise immission can be measured according to standardized procedures. The basic quantity for noise immission is the rating level $L_r$. This is an A-weighted sound pressure level $L_{pA}$ in dB, averaged over a typical 8-hour workshift (other averaging periods may be used for interpretations other than the daily work). This average level is also known as the equivalent continuous sound pressure level, $L_{eq}$ (ISO 6081). Finally, the rating level is basically an $L_{eq}$.

If national regulations prescribe corrections for the annoyance due to impulsive noise and/or discrete tone(s), these corrections are to be added to the equivalent continuous sound pressure level, to obtain the rating level (DIN 45645).

Due to the 8-hour averaging, equipment that is not in continuous operation during the day contributes less to the rating level than might be expected from the equipment noise emission level.

A daily exposure time of less than 8 hours (or less than 40 hours per week) has the same influence. Typical cases are the part-time operation of just one or only a few units during the day or if the person concerned has different workplaces at which the noise immission is different. In both cases a number of decibels are to be subtracted from the equivalent continuous sound pressure level.

The decibel value to be subtracted is determined from equation I or read from Figure 3. Alternatively, the equivalent continuous sound pressure level can directly be calculated from equation II.

$$\Delta L = 10 \log \frac{t_i}{t_0} \qquad \mathrm{I}$$

$$L_{eq} = 10 \log \left[ \frac{1}{t_0} \sum_{i=1}^{n} t_i 10^{0,1 L_i} \right] \qquad \mathrm{II}$$

where:

| | |
|---|---|
| $L_{eq}$ | is the total equivalent continuous sound pressure level in dB re 20 uPa, averaged for an 8-hour workshift, |
| $\Delta L$ | is the value to be subtracted from equivalent continuous sound level due to an exposure time of less than 8 hours, |
| $L_i$ | is the measured sound pressure level or calculated installation noise level in dB re 20 uPa, |
| $t_i$ | is the individual exposure time in hours during a typical 8-hour workshift, |
| $t_0$ | is equal to 8 hours. |

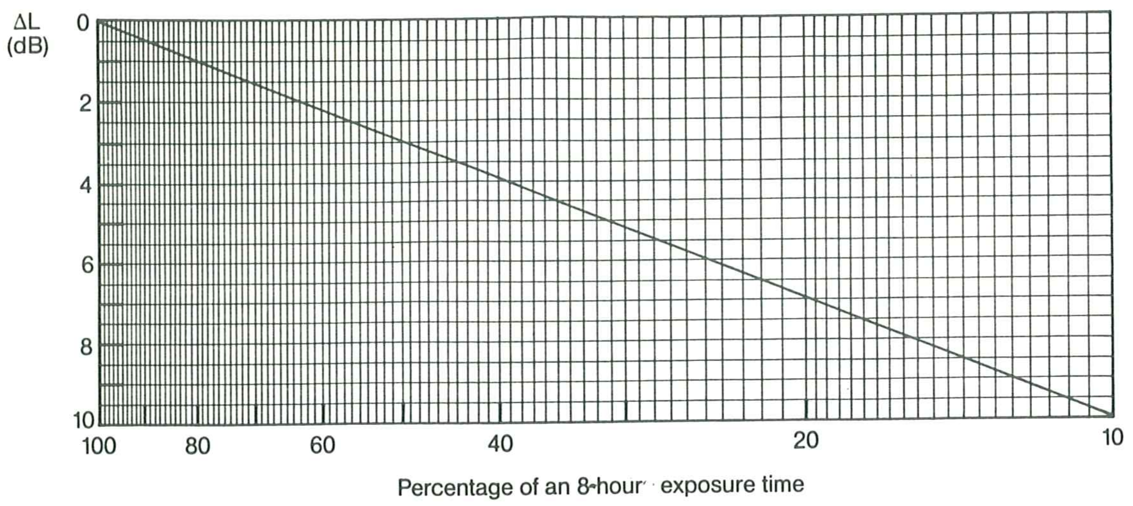

Figure 3. Number of decibels to be subtracted from the equivalent sound level if the daily noise exposure is less than 8 h

### 4.3 Use of Noise Immission Values

The rating level is used to quantify the noise exposure of an individual person or several persons in a given environment and to check compliance with prescribed limits.

## 5. INSTALLATION NOISE

### 5.1 General

The term "Installation Noise" is used in this Technical Report to mean the noise at a specific location in a given environment due to all sources. This quantity is derived from the equipment noise, but allows a direct estimation of noise immission.

The installation noise level is basically an immission level; it differs from the personal rating level, since it does not consider individual personal exposure durations and annoyance criteria for discrete tones and/or impulse noise. Furthermore, it is based on standardized equipment operating conditions, which may differ from the operation under actual use.

The relationship of installation noise to the equipment noise emission level on the one side and to the rating level on the other side is shown in Figure 4.

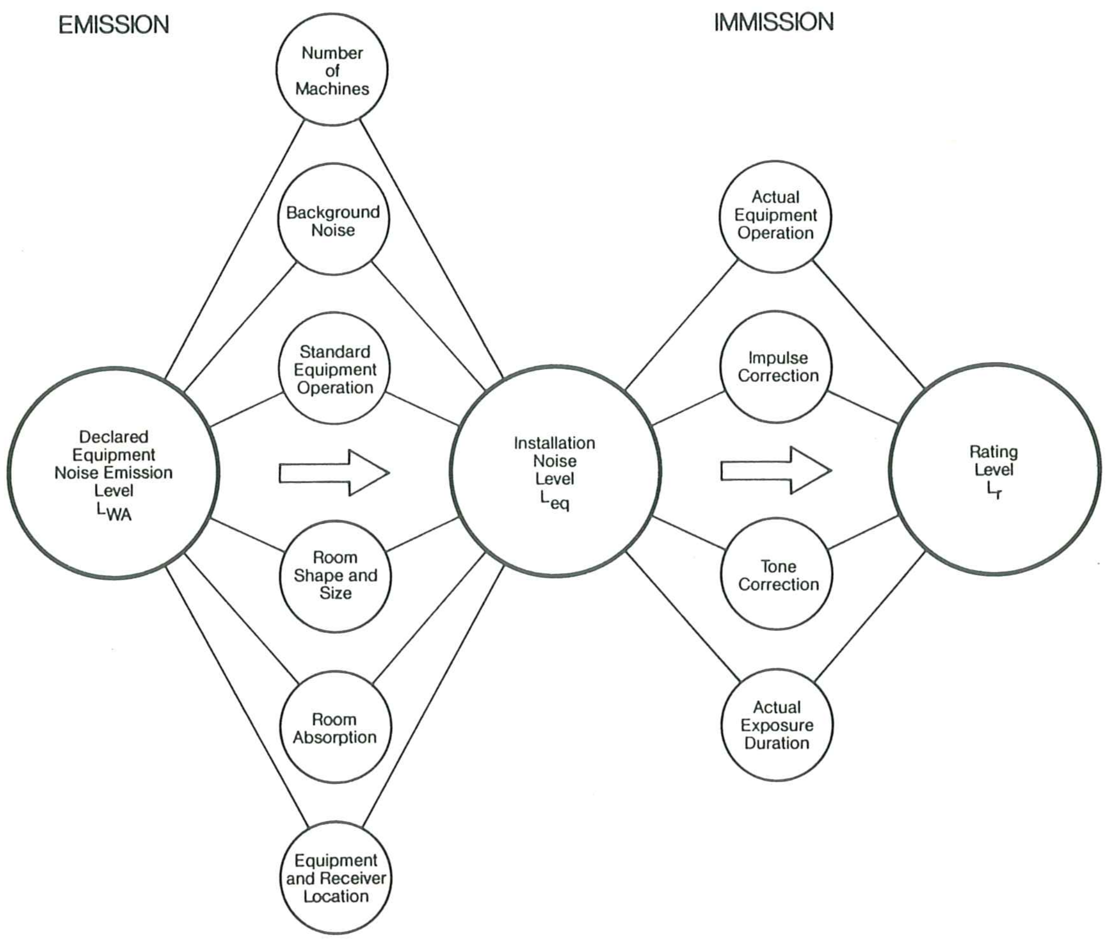

Figure 4. Relationship of Installation Noise Level to Emission and Immission

The installation noise level can either be measured at specific locations within the actual environment, or it can be predicted from known equipment noise emission levels and room acoustical information. The interest in predicting such installation noise levels has increased since some countries have established maximum allowable rating levels for certain types of work. Therefore, a prediction method is of greatest advantage in early installation planning.

### 5.2 Measurement of the Installation Noise Level

The installation noise level at a specific location, $L_{eq}$, is usually the A-weighted sound pressure level in dB; it can directly be measured with a sound level meter that meets the requirements of IEC 651.

For a direct comparison of the measured level with the predicted installation noise level, as defined in this Technical Report, is applicable to a specific location in the environment. Further all the equipment of interest is assumed to be continuously operated at the same time, and in a manner that yields the same noise output as the standardized operating condition specified for the equipment noise emission measurement.

## 5.3 Prediction of the Installation Noise Level

### 5.3.1 Overview and assumptions of the method

The installation noise level is determined from:

- the total noise emitted by the equipment:
  - . the noise received on the direct path,
  - . the noise received due to reflections,
- the background noise.

The installation noise level is an equivalent noise level, Leq, in dB, and is determined for a specific location of interest in the environment. Basically it may be an A-weighted level or a band level, dependent on the type of emission data available for the calculation and required for the prediction. For the purposes of this Technical Report, only the A-weighted level will be considered, which greatly reduced the amount of calculations but will suffice for most practical applications.

Furthermore, the prediction method described in this Technical Report is based on a number of assumptions which should be kept in mind when applying it. These assumptions are:

- the equipment-radiated noise emission is given in terms of sound power level valid for a single unit,
- the radiated noise does not show a strong directivity,
- the radiated noise does not vary greatly during the period of consideration,
- the room length and width are large compared to the wavelength of the radiated noise, usually larger than 5 m,
- the equipment noise does not contain strong discrete tone(s).

Most of these conditions are met by computer and business equipment and are satisfied in rooms where this equipment is installed. In rooms with hard reflecting boundaries the sound field may greatly vary from location to location within the room because of local interferences. In such cases, mainly when low frequencies are involved, this method yields only a spatial average value.

Because of unpredictable variations in the individual equipment noise emission and in the room response, the measured installation noise level may deviate from the calculated level. The range of uncertainty is expected to be within 3 dB.

One should be cautious when using declared noise emission values for the determination of the installation noise level, instead of data which are valid for the individual equipment. Declared values are generally valid as maxima for the whole production series and may include allowances for production variations and for measurement uncertainties. These allowances shall be removed from the declared product noise emission value before determining the installation noise level; if these values are unknown, 3 dB should be subtracted.

### 5.3.2 Guidance through the method

The prediction method described in this Technical Report may be considered as a sequence of steps, outlined briefly in this clause and specified in detail in the referenced clauses.

Step 1: The first step is to decide which of three categories of room shape and size (ordinary, flat or long) best fits to the room under consideration. Guidance on room categories is given in 5.3.3.

Step 2: Next, the sound pressure level at a single location of interest in the room due to a single equipment is calculated. The calculation procedure for ordinary, flat, and long rooms are given in 5.3.4, 5.3.5 and 5.3.6, respectively.

Step 3: Adjustments to the calculated value must be made for added attenuation due to screens, if any, being close to either the equipment or the location of interest. These adjustments are specified in 5.3.7.

Step 4: When more than one equipment is present in the room, Steps 2 and 3 are to be repeated for each source. This is described in 5.3.8. Guidance is also given on mathematically combining several sources to minimize these repetitive calculations.

Step 5: Further adjustments to the calculated value may be required for the influence of background noise, such as noise from air conditioning equipment. These corrections are determined according to 5.3.9, and are to be added to the total noise due to the equipment.

Step 6: If there is more than one location of interest in the room, Steps 2 to 5 are to be repeated for each of these locations, as stated in 5.3.10.

As offices and DP installations are equipped and furnished, the sound distribution within the environment may be considerably influenced by such "obstacles", which are usually called "scatterers" in acoustical terminology. This term applies also to pillars within the room and to other elements attached to walls or the ceiling and which cause additional sound scattering.

Scatterers reflect and/or absorb sound energy which results in lower levels at remote locations. This influence is considered in flat and in long rooms by the density factor q (equation VIII), and the average absorption coefficient $\alpha_s$ of the scatterers.

### 5.3.3 Room categories

The noise level in the installation is greatly infleunced by the room size and shape as well as its acoustical properties. Furthermore the density and orientation of the installed equipment or furniture influence the installation noise level.

Because of the numerous possibilities of room sizes on the one hand, and the requirement to determine the installation noise level with a high degree of confidence on the other hand, it is necessary to categorize the rooms in three broad classes. If a certain room does not fit exactly into one category, the category which is closest may be applied.

- Ordinary rooms

  Ordinary rooms are rooms having similar dimensions in all three directions, but having a length L and a width W smaller than three times the height H.

  $$L < 3\ H$$
  $$\text{and } W < 3\ H$$

  The prediction procedure for ordinary rooms is described in 5.3.4; equation V shall be used to calculate the installation noise level.

- Flat rooms

  Flat rooms are rooms having a length L and a width W of at least three times the height H.

  $$L > 3\ H$$
  $$\text{and } W > 3\ H$$

  The prediction procedure for flat rooms is described in 5.3.5; equation VI or VII shall be used to calculate the installation noise level.

- Long rooms

  Long rooms are rooms having a length L of at least three times the height H, and at least two times the width W, where W should be smaller than three times the height H.

  $$L > 3\ H$$
  $$\text{and } L > 2\ W$$
  $$\text{and } W < 3\ H$$

  The prediction procedure for long rooms is described in 5.3.6; equation X shall be used to calculate the installation noise level.

### 5.3.4 Prediction method - ordinary rooms

In ordinary rooms with a volume of less than 2000 $m^3$ the sound pressure level in the room decreases when the distance from the noise emitting equipment increases. In the vicinity of the equipment the sound pressure level decay closely follows the decay which exists in an ideal free space over a reflecting plane following the equation:

$$L_{pf} = L_W + 10 \log \frac{1}{2\pi d^2} \qquad \text{III}$$

where:

$L_{pf}$ is the noise level in dB re 20 uPa at distance d from the equipment due to direct sound transmission (free-field propagation),

$L_W$ is the Equipment Noise Emission Level (Sound Power Level in dB re 1 pW),

d is the distance of the receiver location from the equipment centre in m.

*NOTE 1*

*The value 1 in the numerator of the equation is a reference area in $m^2$. It must be replaced by the value 2 when the equipment is placed within 1 m of a reflecting wall, and by the value 4 when the equipment is placed in a corner.*

At larger distances the sound pressure level in the room is mainly due to reflections and approaches a constant value which would exist under ideal diffuse field conditions according to the following equation:

$$\left.\begin{aligned} L_{pd} &= L_W + 10 \log \frac{4}{S.\alpha_{sab}} \\ S.\alpha_{sab} &= \sum_{i=1}^{n} S_i \,.\, \alpha_{sab_i} \end{aligned}\right\} \qquad \text{IV}$$

where:

$L_{pd}$ is the noise level in dB re 20 uPa at distance d from the equipment due to reflections (diffuse field portion),

| | |
|---|---|
| $L_W$ | is the Equipment Noise Emission Level (Sound Power Level in dB re 1 pW), |
| $S$ | is the total surface area of room boundaries and furniture in $m^2$, |
| $S_i$ | is the area of individual room surface in $m^2$, |
| $\alpha_{sab}$ | is the Sabine Absorption Coefficient of room and furniture surfaces, |
| $\alpha_{sab,i}$ | is the Sabine Absorption Coefficient of individual room surfaces. |

*NOTE 2*

*The index "sab" refers to Sabine absorption that, in this Technical Report, has been obtained by averaging the absorption coefficients at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. This value is also known as Noise Reduction Coefficient (NRC). See Appendix B for values for some typical materials.*

*NOTE 3*

*The constant value 4 in the numerator of the equation is a reference area in* $m^2$.

The installation noise level in ordinary rooms therefore depends on the distance from the equipment and the room absorption, and is calculated as follows:

$$L_{eq} = L_W + 10 \log\left(\frac{1}{2\pi d^2} + \frac{4}{S.\alpha_{sab}}\right) \qquad \text{V}$$

where:

$L_{eq}$ is the Installation Noise Level in dB re 20 uPa, due to the equipment, and at distance d from the equipment.

### 5.3.5 Prediction method - flat rooms

The propagation of sound in flat rooms may deviate significantly from the conditions described for ordinary rooms, since no diffuse sound field exists. This means that the sound pressure level continuously decreases with distance from the equipment. This is mainly due to the low height of such rooms compared to the other room dimensions. On the other hand a free sound propagation does not exist either. The sound pressure level at remote distances is largely dependent on the room height and scatterers in the room such as furniture and other equipment. These influences have been combined in the following equations:

$$L_{eq} = L_W - 10 \log H . d + \Delta L_F \qquad \text{(Empty rooms)} \qquad \text{VI}$$

$$L_{eq} = L_W - 20 \log H + \Delta L_F \qquad \text{(Furnished rooms)} \qquad \text{VII}$$

where:

| | |
|---|---|
| $L_{eq}$ | is the Installation Noise Level in dB re 20 uPa at distance d from the equipment (Note 4), |
| $L_W$ | is the Equipment Noise Emission Level in dB re 1 pW (Note 5), |
| $\Delta L_F$ | is the correction term for flat rooms in dB (see Appendix A.1), |
| H | is the height of room in m, |
| d | is the distance of the receiver location from the equipment centre in m. |

*NOTE 4*

*In close vicinity of an equipment (normally within 5 m) the sound pressure level cannot be lower than the level which would exist under free-field conditions (equation III). This should be considered when using equation VI and VII.*

*NOTE 5*

*If the equipment is located close to a reflecting wall, i.e. within 1 m, 3 dB should be added to the equipment sound power level; if the receiver location is close to a reflecting wall, 3 dB is to be added to the installation noise level. If the equipment or the receiver location is in a corner, the addition to the installation noise level is 6 dB.*

The correction term $\Delta L_F$ includes several influences on the sound pressure level, such as the distance from the equipment relative to the room height, the average absorption coefficient of the room, the surface area of the scatterers in the room, if any, and their absorption properties. The correction term $\Delta L_F$ is obtained from Appendix A.1, Diagram 1 shall be used for the empty room, and Diagrams 2 to 6 for rooms with various q factors for the density of the scatterers, see also Table 1.

Table 1: FLAT ROOMS - Reference List to Diagrams in Appendix A.1

| | Empty Room<br>q = 0 | Furnished Room with Density q of Scatterers | | | | |
|---|---|---|---|---|---|---|
| | | q = 0,05 | q = 0,1 | q = 0,2 | q = 0,3 | q = 0,4 |
| Diagram No | 1 | 2 | 3 | 4 | 5 | 6 |

Absorption of scatterers is assumed to be $\alpha_S$ = 0,1.

Calculation of the density factor q of reflecting objects:

$$q = \frac{1}{4\,S_F} \sum S_E \qquad \text{VIII}$$

where:

$\Sigma S_E$ is the total surface area of scatterers in $m^2$,

$S_F$ is the surface area of room floor in $m^2$

In the above calculations of the surface area of the scatterers only those surfaces which are exposed to incident sound, and which have dimensions greater than 0,2 m need be considered. An estimate of such surfaces is sufficient. For A-weighted levels, to which this Technical Report is restricted, and for most cases of offices and in low-density DP installations a density factor of q = 0,2 is appropriate. For larger DP installations with closely spaced equipment a density factor of q = 0,4 may be used.

Absorption Coefficient of Scatterers

In many cases of DP installations and office rooms the absorption of the installed equipment and furniture is low. A value of $\alpha_s = 0{,}1$ is appropriate in these cases; a value of $\alpha_s = 0{,}3$ is appropriate if absorbing screens are installed in the room (e.g. landscape office).

Diagrams 2 to 6 in Appendix A.1 are based on $\alpha_s = 0{,}1$. If $0{,}1 < \alpha_s < 0{,}3$ the additional error that may appear at larger distances will be smaller than 1,5 dB for $d/H < 20$.

Average Room Absorption Coefficient

$$\bar{\alpha}_{sab} = \frac{\alpha_{sabC} + \alpha_{sabF}}{2} \qquad \text{IX}$$

where:

$\alpha_{sab\ C}$ is the absorption coefficient of ceiling,

$\alpha_{sab\ f}$ is the absorption coefficient of floor.

NOTE 6

*The average room absorption coefficient should not be determined from reverberation time measurements made in the installation. Instead, measured values for typical materials (Appendix B) should be used.*

### 5.3.6 Prediction method - long rooms

In long rooms the calculation of the installation noise level is similar to that described for the flat room. Accordingly we obtain:

$$L_{eq} = L_W - 10 \log H \,.\, W + \Delta L_L \qquad \text{X}$$

where:

$L_{eq}$ is the Installation Noise Level in dB re 20 uPa at a given location from the equipment (Note 7),

$L_W$ is the Equipment Noise Emission Level in dB re 1 pW (Note 8),

$\Delta L_L$ is the correction term for long rooms in dB (a function of the distance d from the equipment), see Appendix A.2,

H is the height of the room in m,

W is the width of the room in m,

d is the distance of receiver location from the equipment in m.

NOTE 7

*Close to an equipment (within 5 m) the sound pressure level cannot be lower than the level which would exist under free-field conditions over a reflecting plane (equation III). This should be considered when using equation X.*

NOTE 8

*If an equipment is located close to a reflecting wall, 3 dB shall be added to the equipment sound power level; if the receiver location is close to a reflecting wall, 3 dB shall be added to the installation noise level.*

The correction term $\Delta L_L$ considers the same influences as described in 5.3.5 for the flat room, and assuming again an absorption coefficient of $\alpha_s = 0{,}1$ for the scatterers. The correction term $\Delta L_L$ is obtained from Appendix A.2, Diagrams 7 to 24 for different q factors and for different ratios of room height to width, H/W, see Table 2.

Because of the smaller width of such rooms compared to the room length reflections from the side walls may contribute to the noise level at the location of interest. This influence is considered by the ratio H/W.

Table 2: LONG ROOMS - Reference List to Diagrams in Appendix A.2

| H/W | Empty Room q = 0 | Furnished Room with Density q of Scatterers | | | | |
|---|---|---|---|---|---|---|
| | | q = 0,5 | q = 0,1 | q = 0,2 | q = 0,3 | q = 0,4 |
| | Diagram Numbers | | | | | |
| 1/1 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1/2 | 13 | 14 | 15 | 16 | 17 | 18 |
| 1/3 | 19 | 20 | 21 | 22 | 23 | 24 |

Absorption of scatterers assumed to be $\alpha_s = 0{,}1$.

The average room absorption coefficient $\bar{\alpha}_{sab}$ is determined from

$$\bar{\alpha}_{sab} = \frac{H(\alpha_{SW1}+\alpha_{SW2})+W(\alpha_F+\alpha_C)}{2(H+W)} \qquad \text{XI}$$

where:

$\bar{\alpha}_{sab}$ is the average room absorption coefficient,

$\alpha_F$ is the absorption coefficient of floor,

$\alpha_C$ is the absorption coefficient of ceiling,

$\alpha_{SW1}$ is the absorption coefficient of one side wall,

$\alpha_{SW2}$ is the absorption coefficient of the other side wall,

$H$ is the height of the room in m,

$W$ is the width of the room in m.

*NOTE 9*

*The average room absorption coefficient should not be determined from reverberation time measurements made in the installation. Instead, measured values for typical materials (Appendix B) should be used.*

### 5.3.7 Adjustments for screens

In offices and DP installations large equipment may shield certain locations against the noise emitted by other equipment. This may result in a significantly lower installation noise level than calculated from the equations in the previous clauses. The same effect is intentionally wanted when acoustical screens are installed between a workplace and noisy equipment.

The noise attenuation of screens (and large equipment) becomes more effective, the closer the equipment or the receiving location (or both) are to the screen, i.e. the greater the difference is between the direct path (without screen), and the indirect path around the screen, see Figure 5.

This attenuation can be calculated; however a number of parameters must be known which are beyond the scope of this Technical Report.

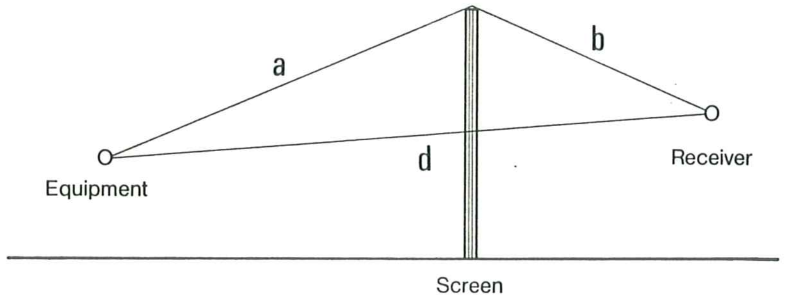

Figure 5. Direct path (d) and indirect path (a+b) around a screen

Detailed information on screens has been published by the Association of German Engineers, VDI. Experimental data for indoor spaces is shown in Table 3 that may be used to estimate the attenuation due to the screen.

The attenuation $\Delta L_c$ is to be subtracted from the calculated installation noise level in equation VII and X respectively.

$$L_{eq,c} = L_{eq} - \Delta L_c \qquad \text{XII}$$

where:

$L_{eq,c}$ is the Installation Noise Level in dB re 20 uPa, corrected for the additional attenuation by a screen,

$L_{eq}$ is the Installation Noise Level in dB re 20 uPa, determined according to equations VII and X,

$\Delta L_c$ is the attenuation in dB from Table 3.

| $\frac{\text{Screen Height}}{\text{Room Height}}$ | $\frac{\text{Distance between Source and Receiver}}{\text{Room Height}} = \frac{c}{H}$ | | |
|---|---|---|---|
| h/H | < 0,3 | 0,3 - 1 | 1 - 3 |
| < 0,3 | 7 dB | 4 dB | no data |
| 0,3 - 0,5 | 10 dB | 7 dB | 4 dB |
| > 0,5 | no data | 9 dB | 6 dB |

Table 3. Attenuation $\Delta L_c$ in dB, due to a screen installed between source and receiver (Reference: VDI 2720, Blatt 2).

### 5.3.8 Multiple equipment in a room

If several units are installed in a room and are operated simultaneously, the total installation noise level at the point of interest is the sum of the influences of all the noise emitting equipment in the room. Therefore the calculation procedure defined in 5.3.4, 5.3.5 and 5.3.6 respectively, is to be applied to each equipment and its corresponding distance to the location of interest. These individually calculated levels are then added by using equation XIII to obtain the total installation noise level.

Alternatively Figure 6 may be used to determine the number of decibels by which the installation noise level increases if two levels are being combined.

$$L_{eq} = 10 \log \sum_{i=1}^{n} 10^{0,1 L_{eq_i}} \qquad \text{XIII}$$

where:

| | |
|---|---|
| Leq | is the total installation noise level in dB re 20 uPa at a specific receiver location in the environment, |
| Leq,i | is the individual installation noise level determined for a single machine, or a single group of machines, |
| n | is the number of individual installation noise levels to be added. |

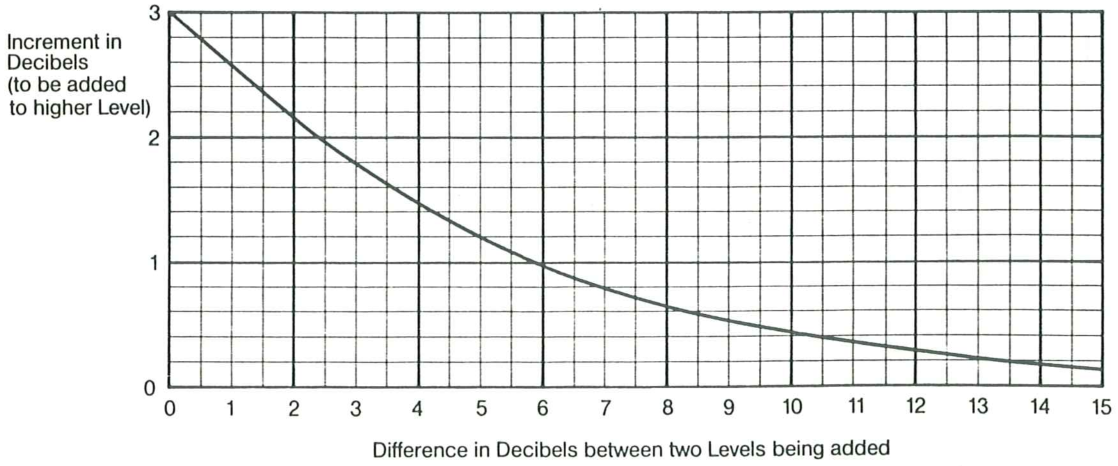

Figure 6. Number of decibels to be added to the larger value if two sound levels are being combined

To reduce the amount of calculations for multiple equipment, several machines may be combined in one group, if either of the following conditions is met:

- the room is an "ordinary room" and has hard, acoustically reflecting surfaces and a room volume of less than 2000 $m^3$, or
- several machines are closely arranged and the receiver location is at least 1,5 times the largest dimension of the group away from the centre of the group.

In all other cases individual calculations are necessary.

The noise emission level for the whole group is obtained by adding the individual equivalent noise emission levels. Equation XIII may be used, where the term installation noise level is to be substituted by machine noise emission level and n is the number of machines.

### 5.3.9 Adjustments for background noise

The noise in a room which remains after the installed equipment has been turned off completely, is the background noise. It may be due to air conditioning, or may originate outside the room (e.g. traffic). Background noise must be treated separately, because in most cases it cannot be described in terms of sound power level. Instead, its sound pressure level, $L_b$, can often be measured or estimated.

The total installation noise level, including steady background noise, may be calculated in either of two equivalent ways.

$$L_{eq,corrected} = 10 \log 10^{(0,1 L_{eq,calculated} + 0,1 L_b)} \qquad \text{XIV}$$

or

$$L_{eq,corrected} = \max\{L_{eq,calculated}; L_b\} + B \qquad \text{XV}$$

where:

| | |
|---|---|
| Leq, calculated | is the total installation noise level at a specific location, in dB re 20 uPa, due to all computer and business equipment, as calculated according to the preceding clauses, |
| Lb | is the steady background noise level at the same location in dB re 20 uPa, |

| | |
|---|---|
| $L_{eq, corrected}$ | is the total installation noise level in dB at a specific location due to all equipment and steady background noise, |
| max {a;b} | is equal to a or b, whichever is larger, |
| B | is the background correction in dB obtained from Table 4 or Figure 6. |

| Absolute value of the difference between the calculated installation noise level $L_{eq, calculated}$ and the background noise level $L_b$ | Increment B in dB to be added to the higher level |
|---|---|
| 0; 1 | 3 |
| 2; 3 | 2 |
| 4; 5; 6; 7; 8; 9 | 1 |
| 10 or greater | 0 |

Table 4. Correction for steady background noise

### 5.3.10 Calculations for several locations of interest

If there is an interest in the installation noise level for several locations within a room, the calculations of 5.3.4 to 5.3.9 must be repeated for each location of interest.

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## APPENDIX A

## CORRECTIONS FOR THE DETERMINATION OF THE INSTALLATION NOISE LEVEL

A.1 CORRECTIONS FOR FLAT ROOMS

Diagrams 1 to 6

A.2 CORRECTIONS FOR LONG ROOMS

Diagrams 7 to 24

## A.1 Corrections for Flat Rooms

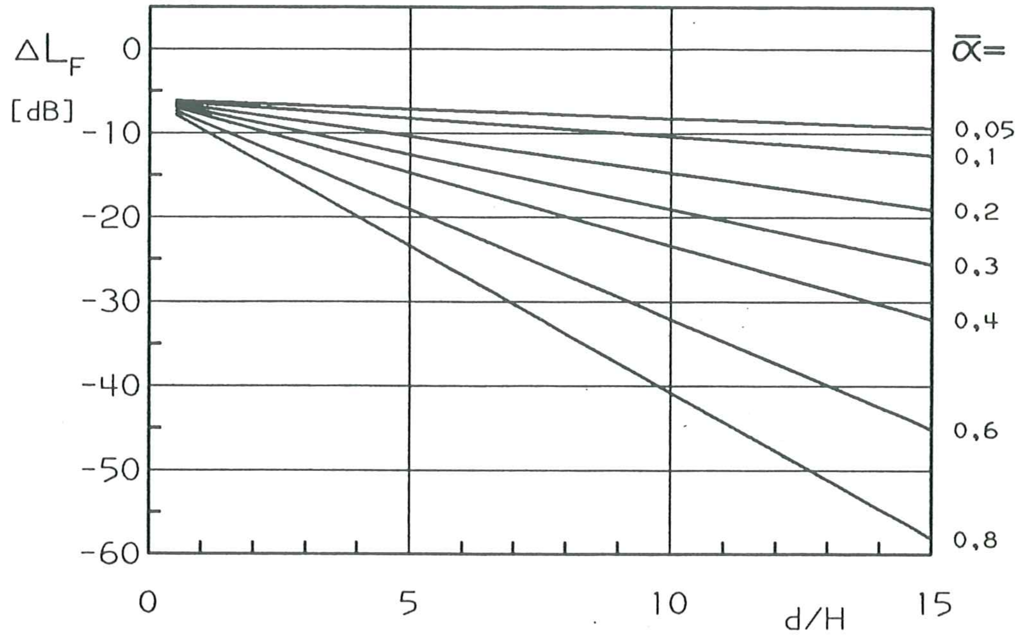

Diagram 1 q = 0

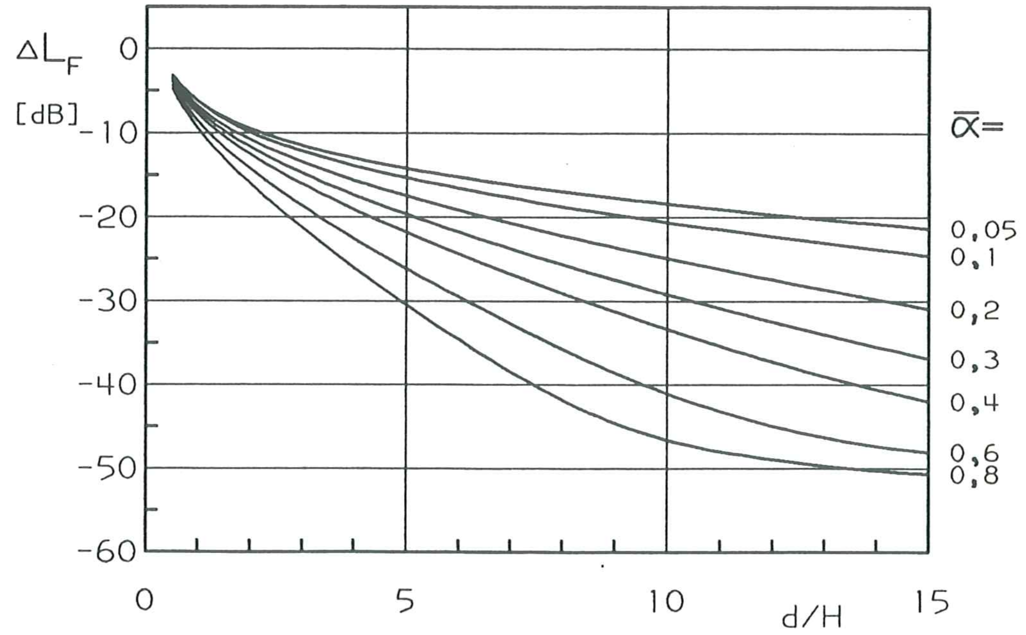

Diagram 2 q = 0,05

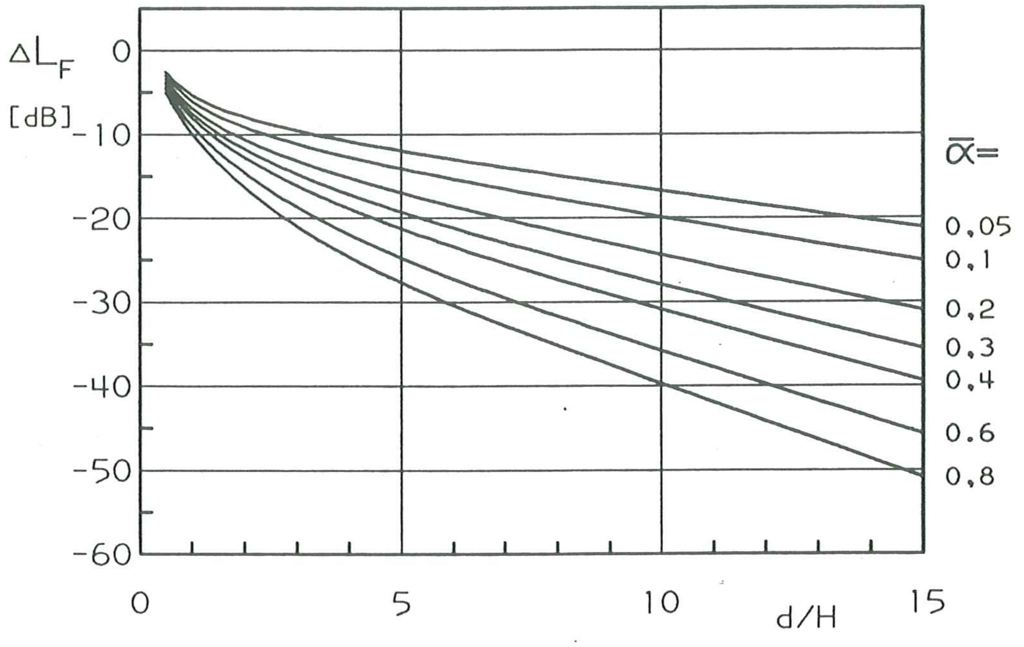

Diagram 3 q = 0,1

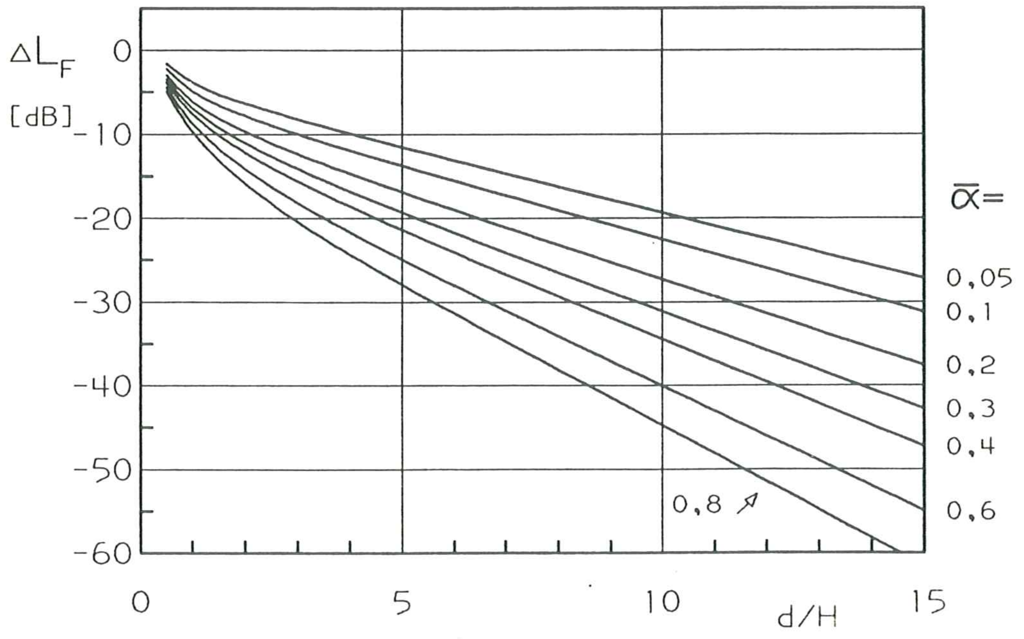

Diagram 4 q = 0,2

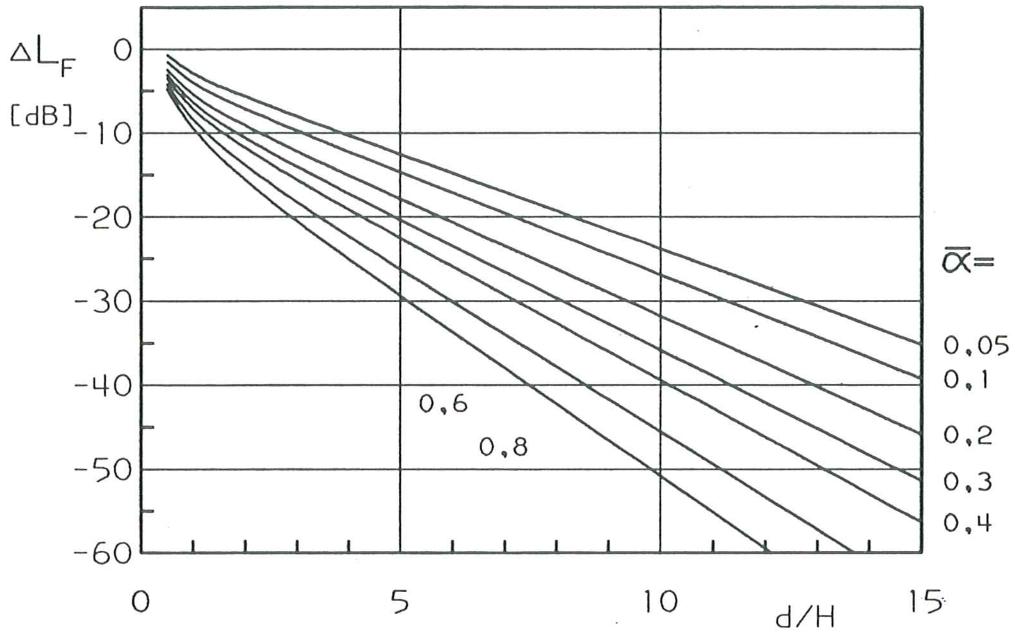

Diagram 5 q = 0,3

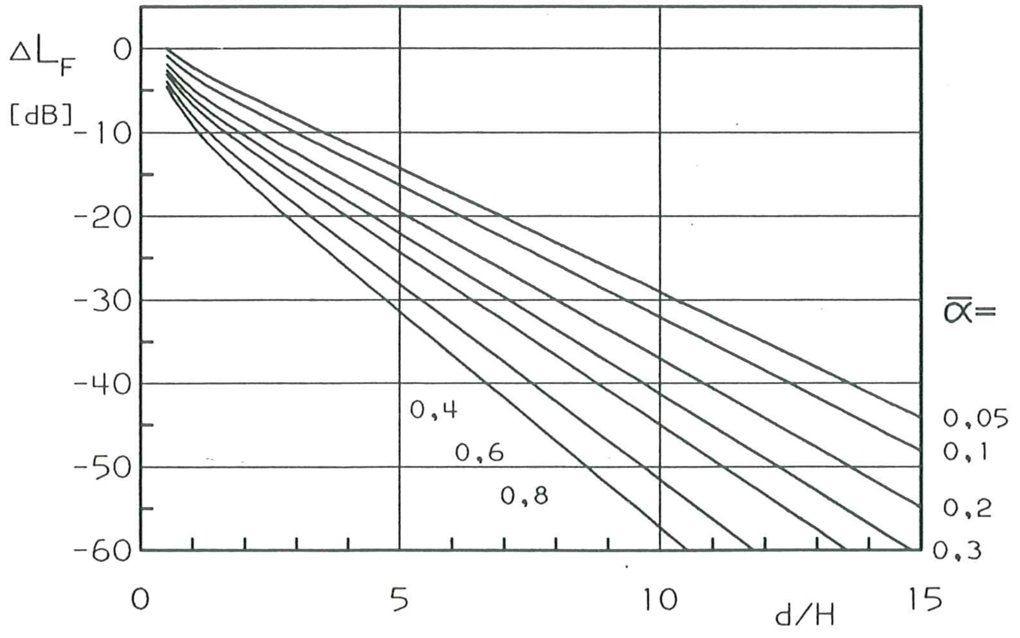

Diagram 6 q = 0,4

## A.2 Corrections for Long Rooms

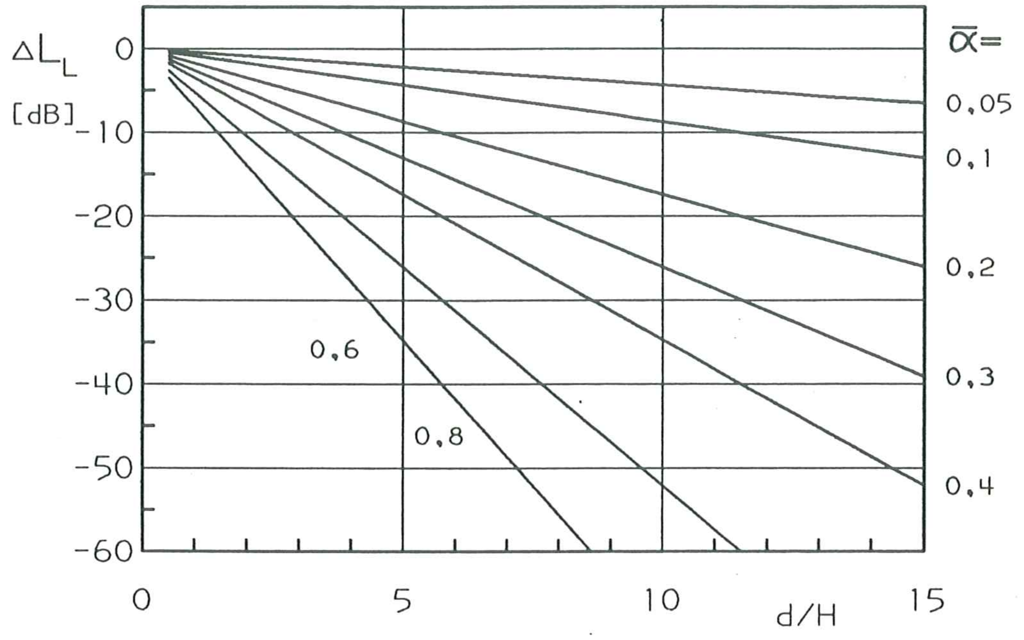

Diagram 7 q = 0 H/W = 1

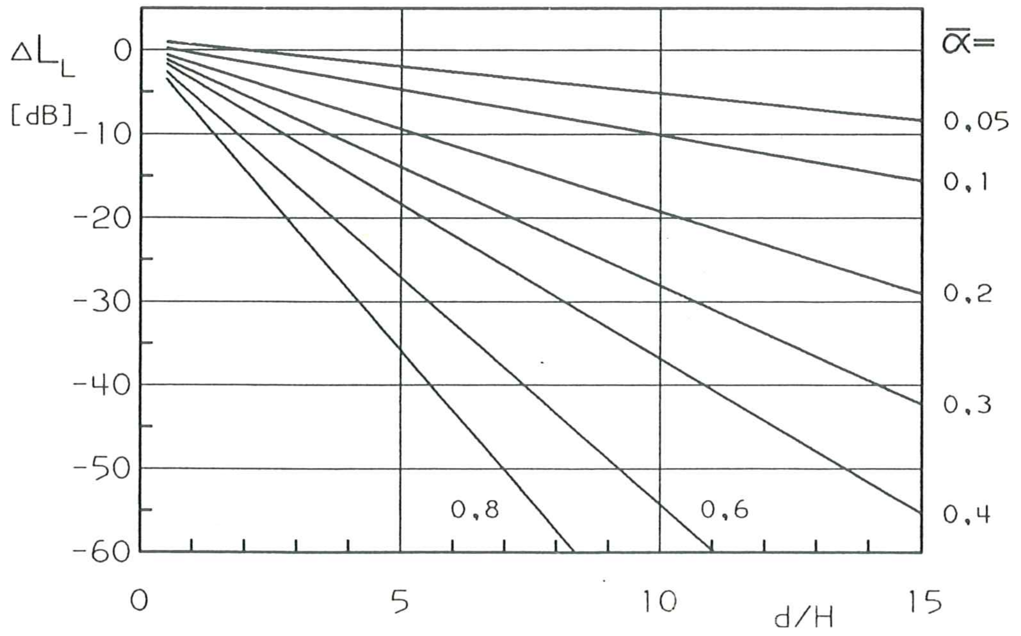

Diagram 8 q = 0,05 H/W = 1

## A.2 Corrections for Long Rooms

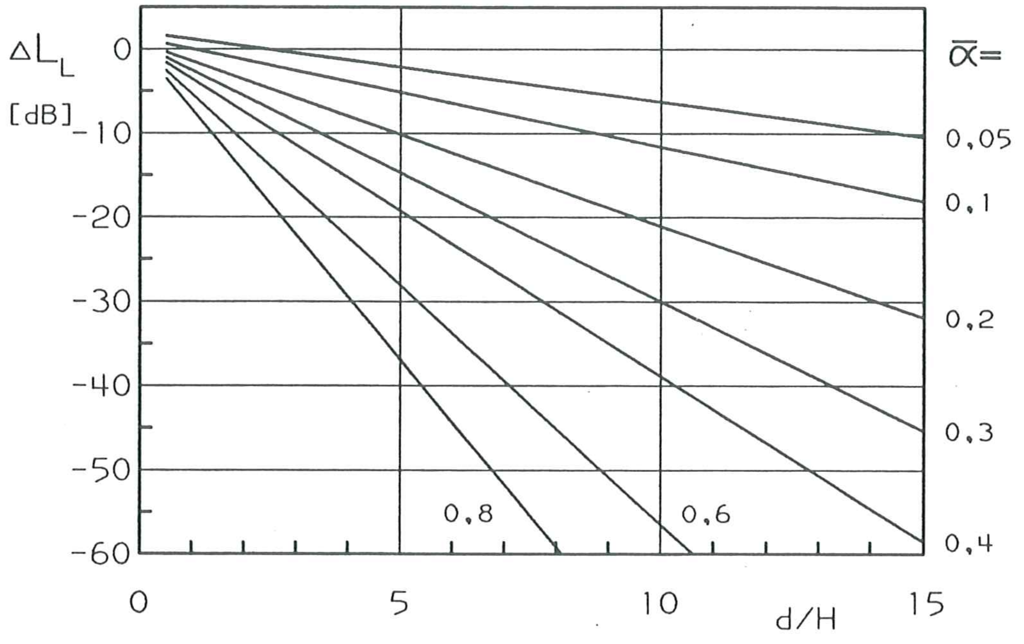

Diagram 9 q = 0,1 H/W = 1

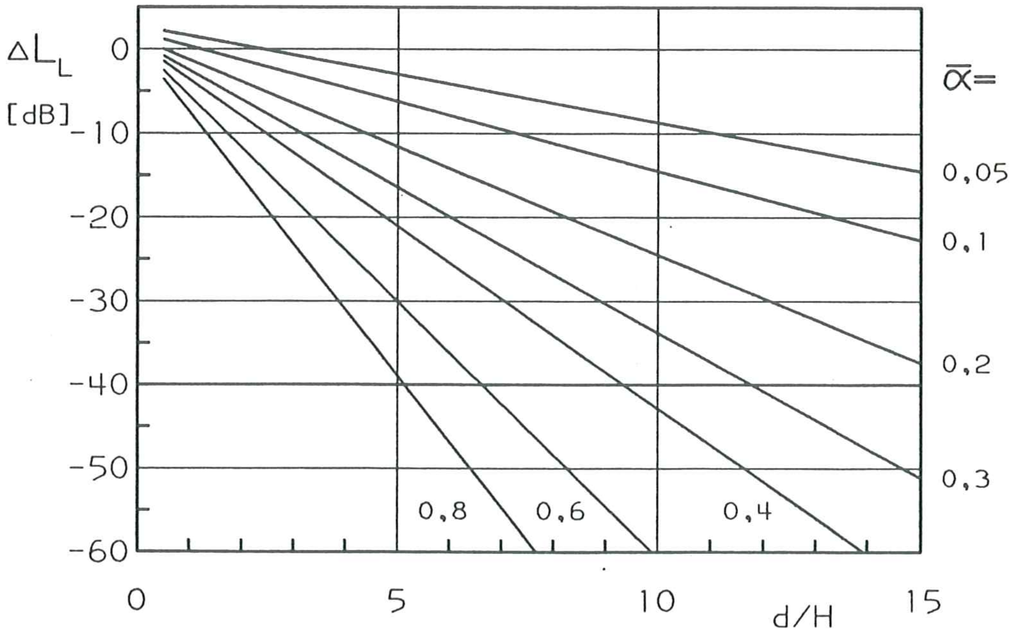

Diagram 10 q = 0,2 H/W = 1

## A.2 Corrections for Long Rooms

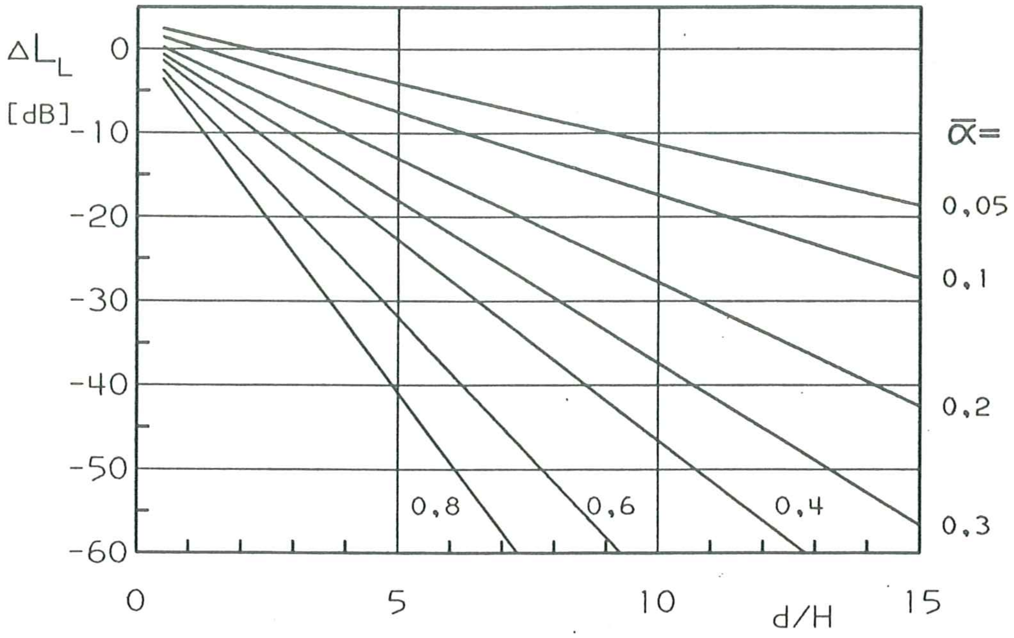

Diagram 11 q = 0,3 H/W = 1

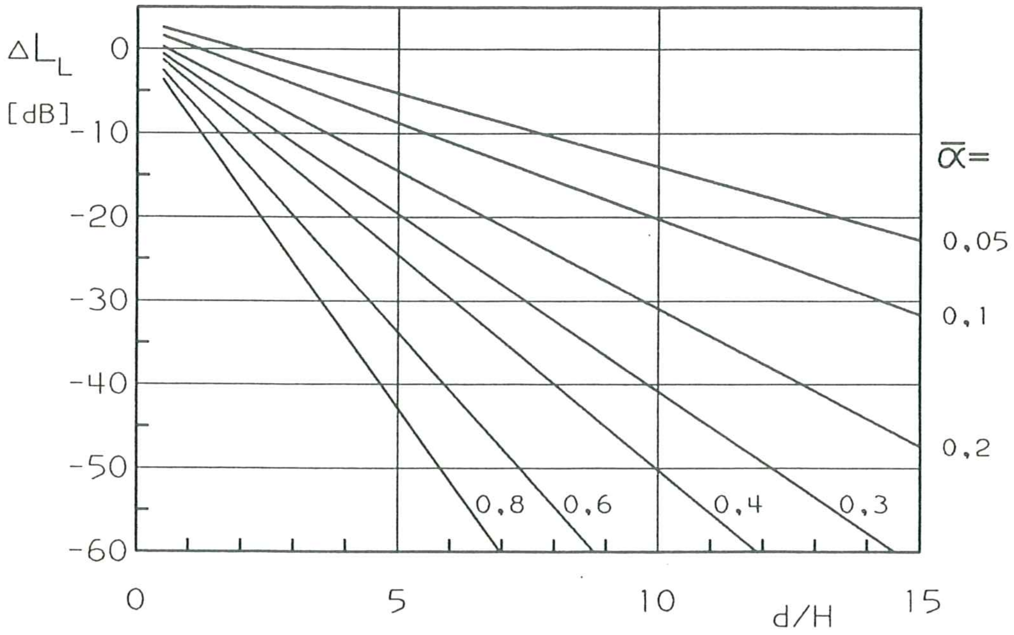

Diagram 12 q = 0,4 H/W = 1

## A.2 Corrections for Long Rooms

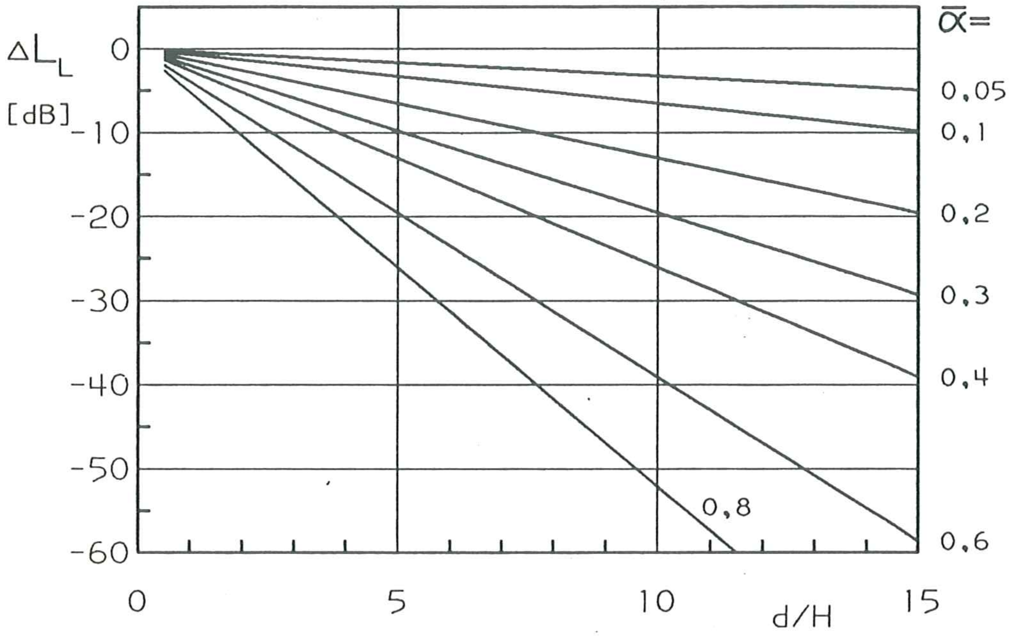

Diagram 13 q = 0 H/W = 1/2

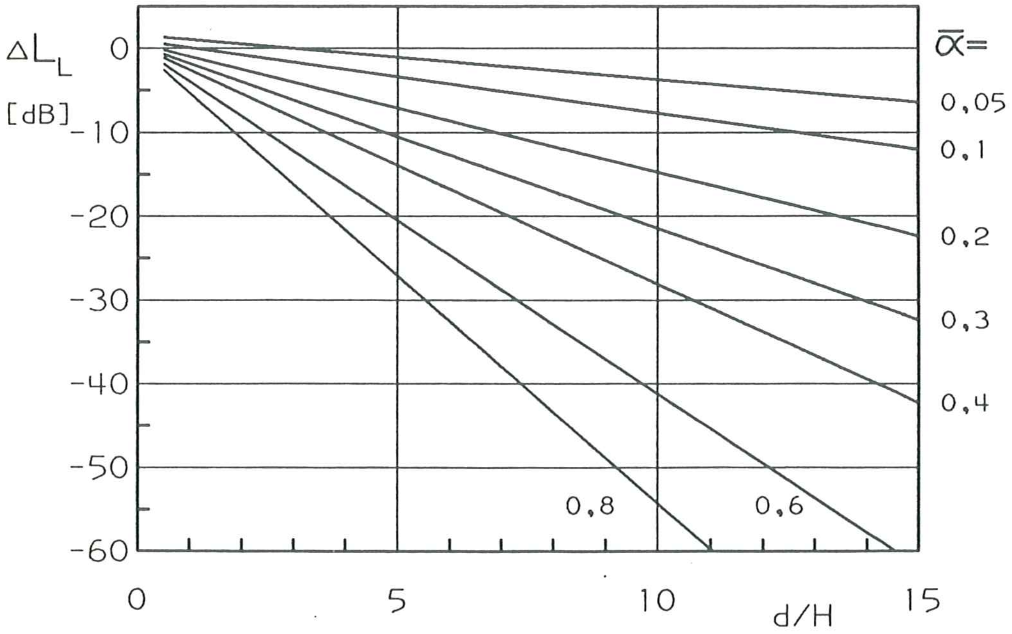

Diagram 14 q = 0,05 H/W =1/2

## A.2 Corrections for Long Rooms

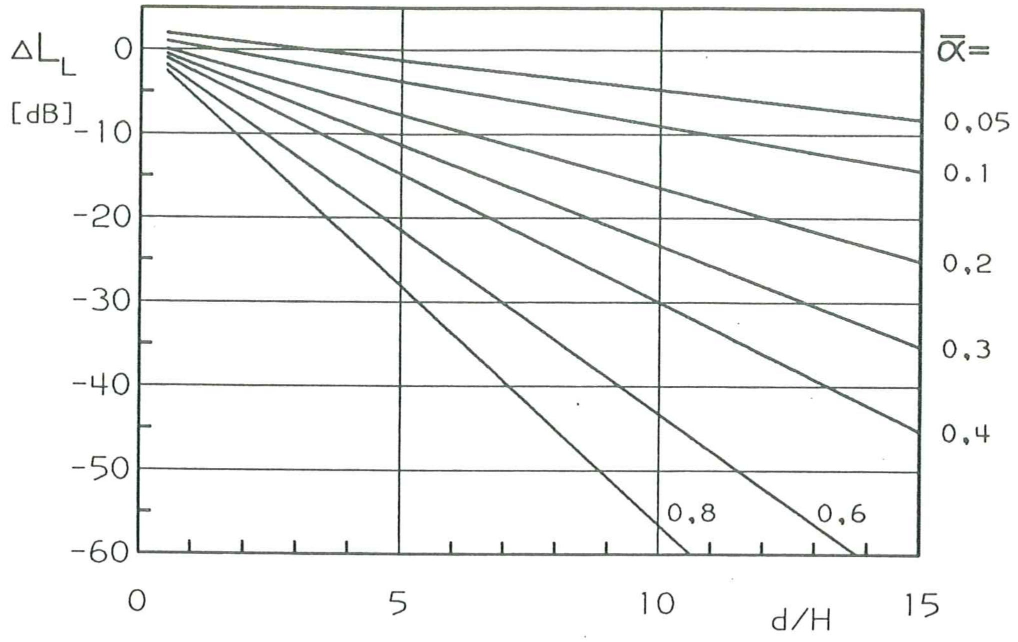

Diagram 15 q = 0,1 H/W = 1/2

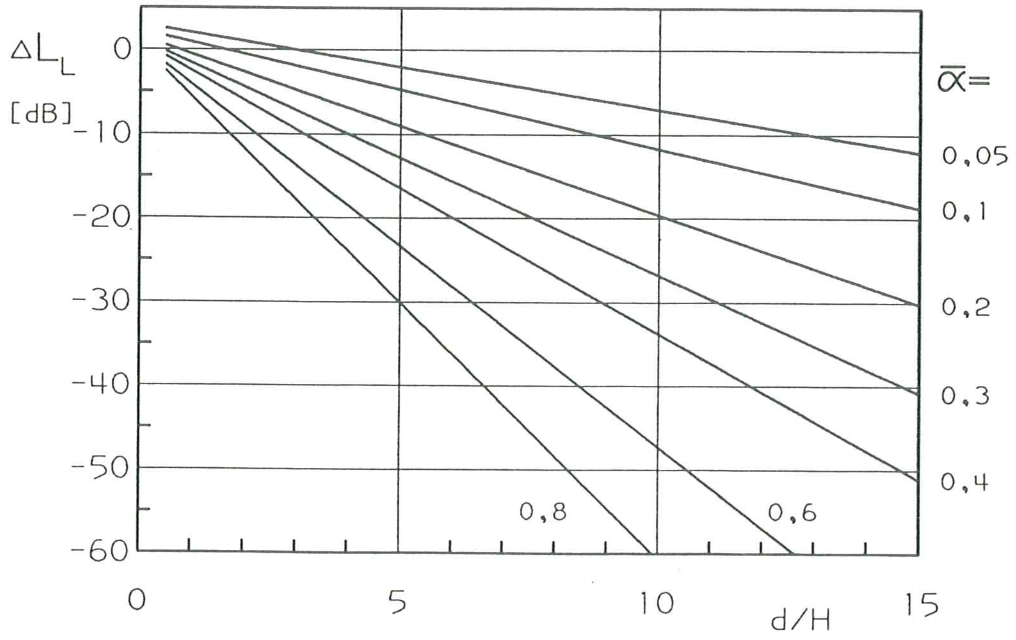

Diagram 16 q = 0,2 H/W = 1/2

## A.2 Corrections for Long Rooms

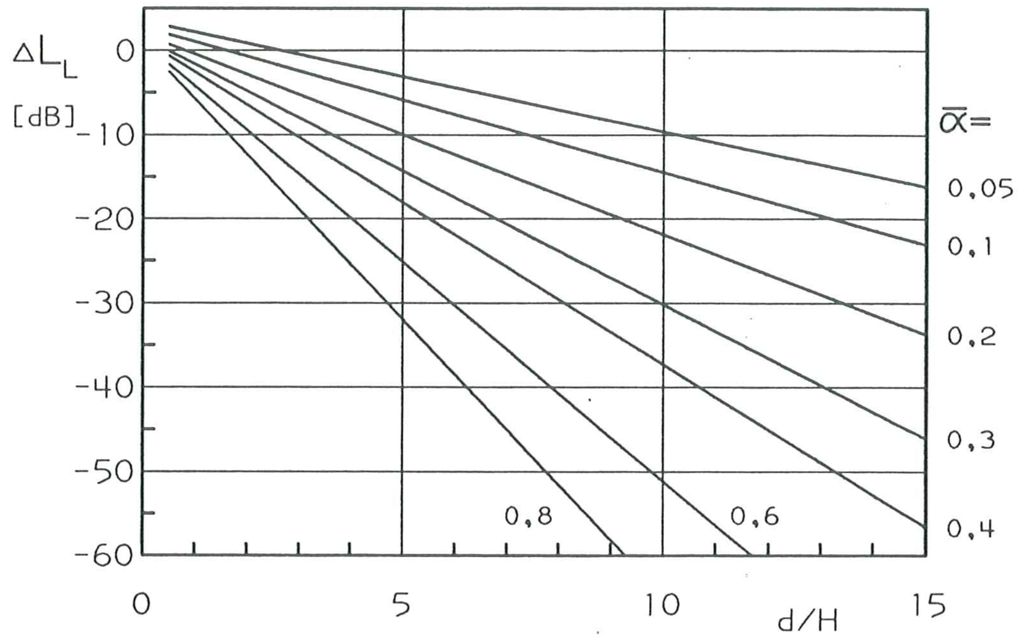

Diagram 17 q = 0,3 H/W = 1/2

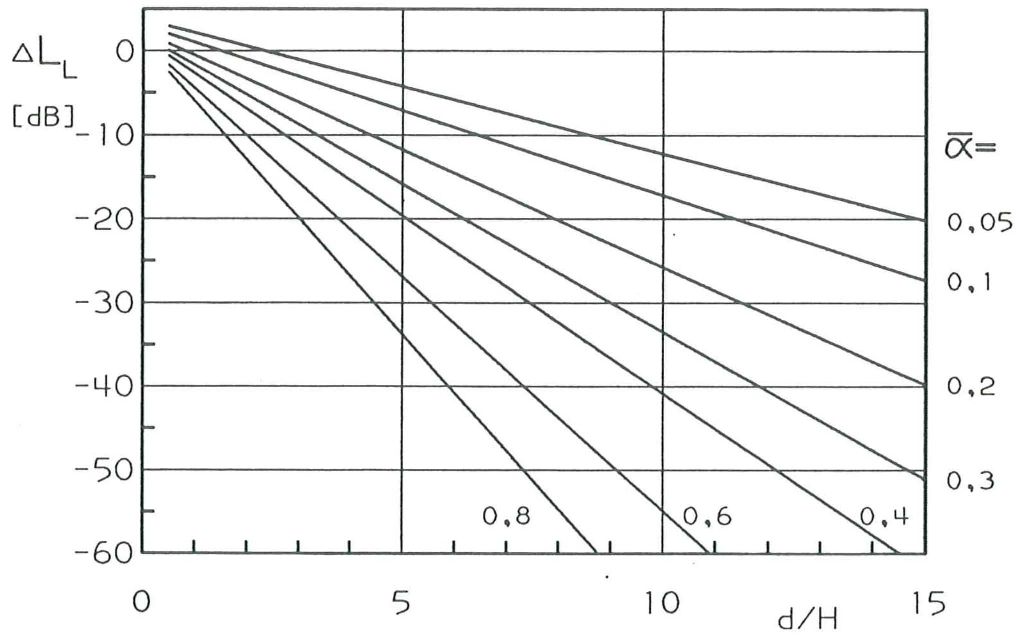

Diagram 18 q = 0,4 H/W = 1/2

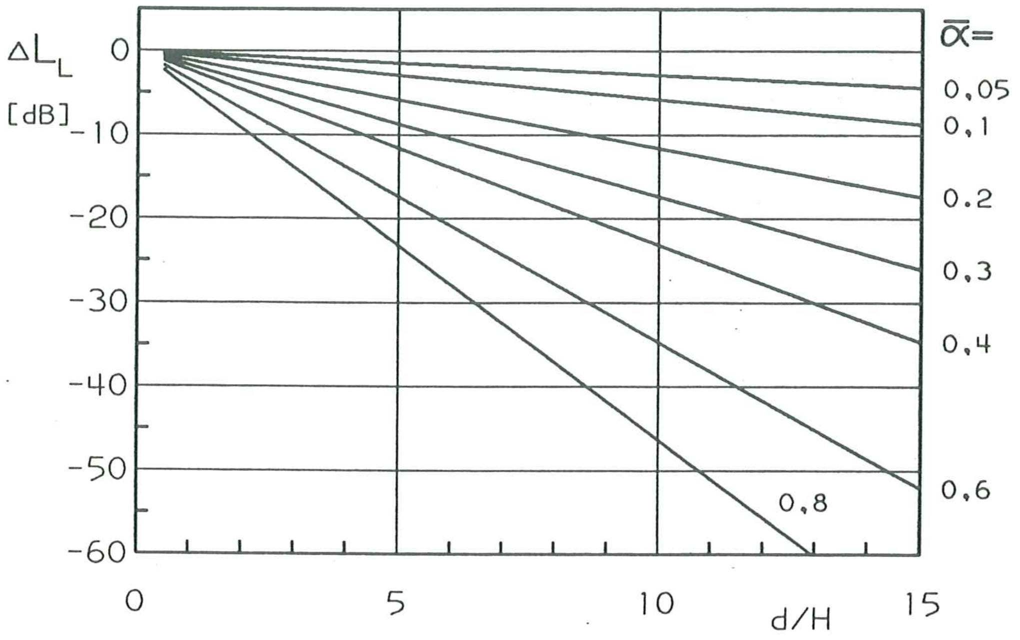

Diagram 19 q = 0 H/W = 1/3

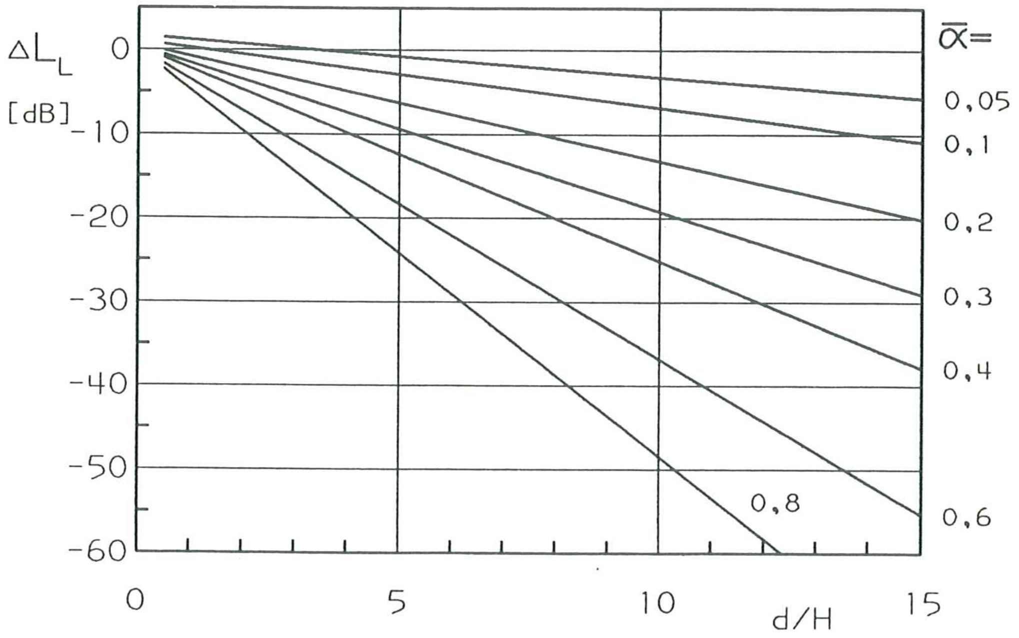

Diagram 20 q = 0,05 H/W = 1/3

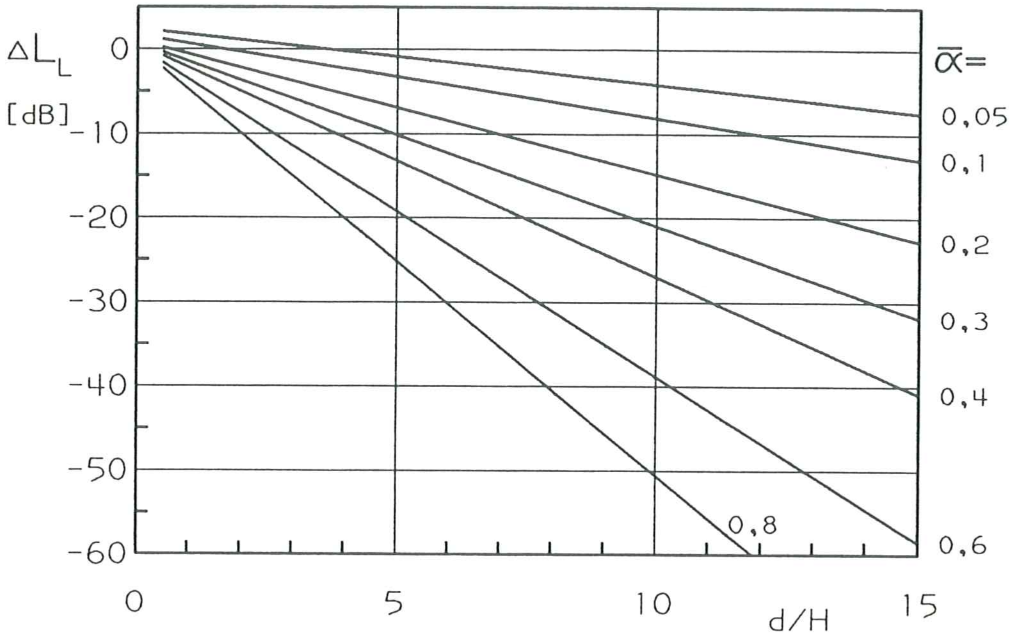

Diagram 21 q = 0,1 H/W = 1/3

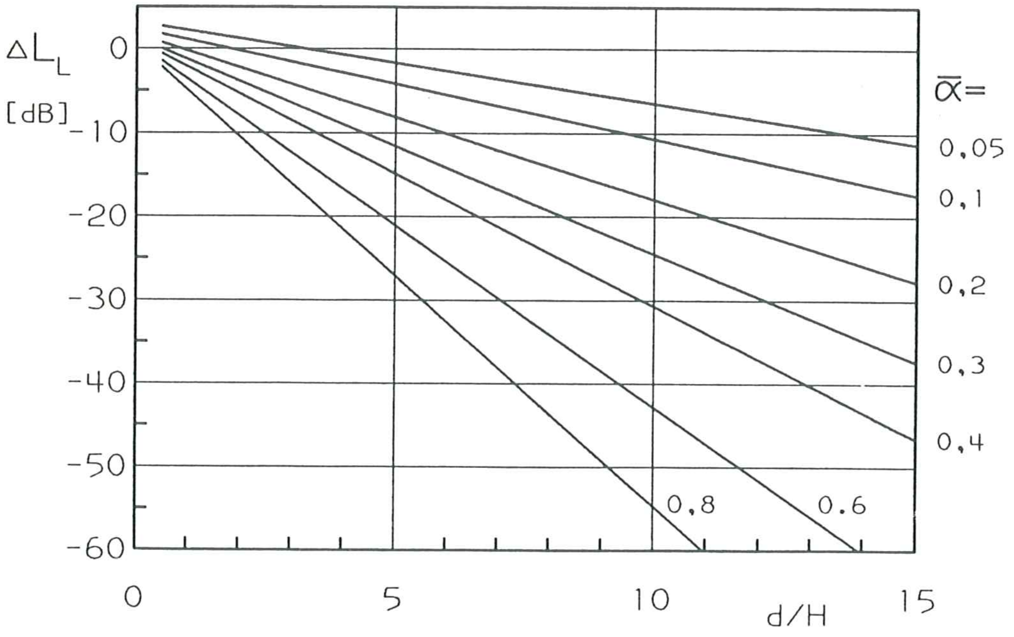

Diagram 22 q = 0,2 H/W = 1/3

### A.2 Corrections for Long Rooms

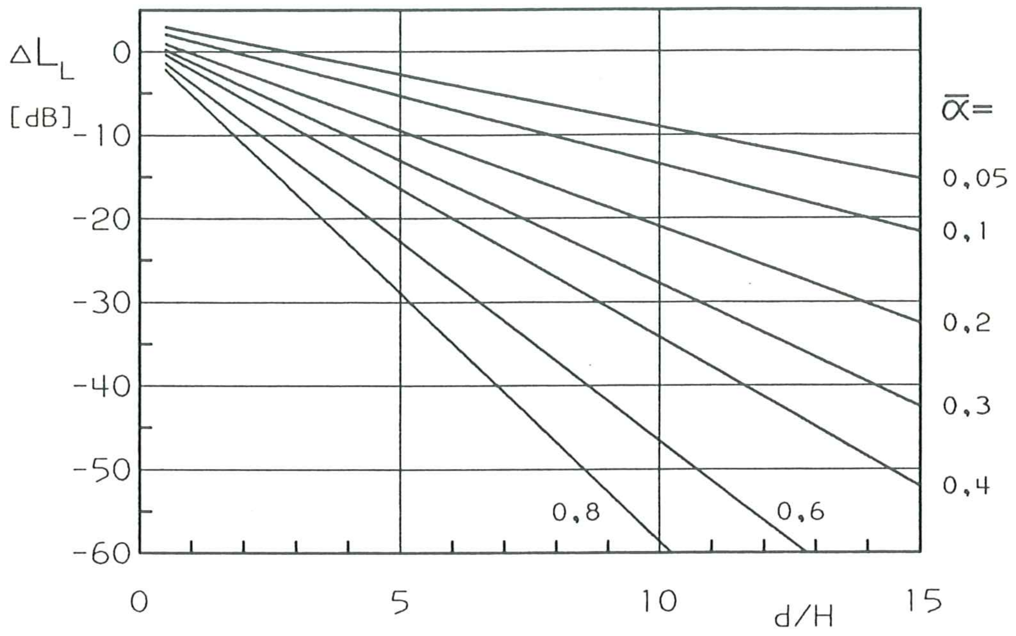

Diagram 23 q = 0,3 H/W = 1/3

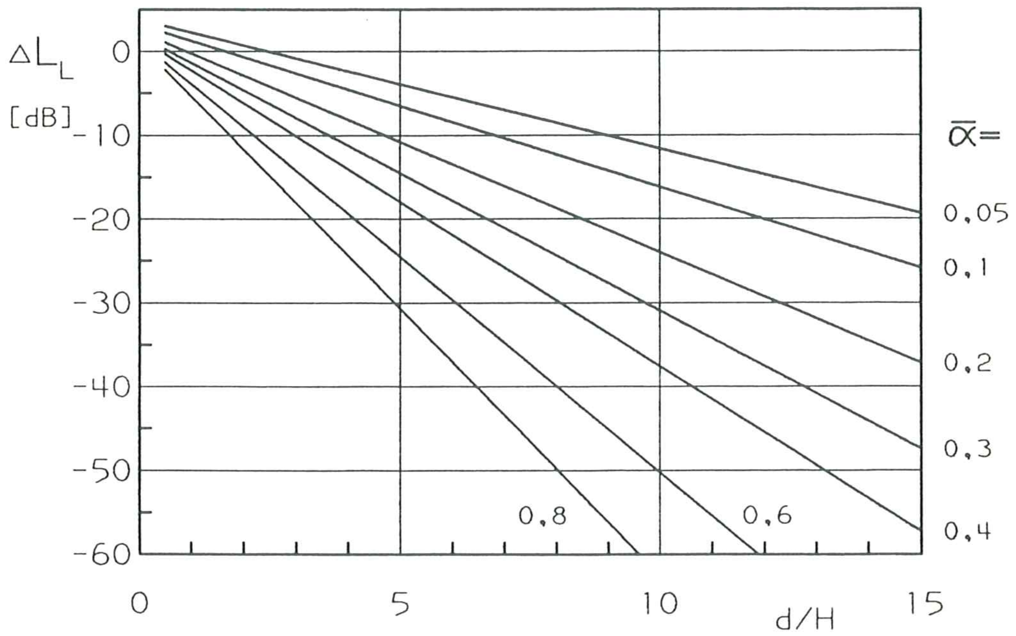

Diagram 24 q = 0,4 H/W = 1/3

## APPENDIX B

### ABSORPTION COEFFICIENTS OF SOME TYPICAL BUILDING MATERIALS

(Beranek and DIN Schallabsorptionsgrad)

| Building Material | Thickness mm | Average Sabine Absorption Coefficient $\alpha_{sab}$ (NRC) |
|---|---|---|
| Floor: | | |
| Wood or asphalt | | 0,05 |
| Linoleum | 5 | 0,05 |
| Carpets | | |
| on hard floor | 5 | 0,10 |
| on 8 mm felt | 13 | 0,50 |
| wool pile on pad | 16 | 0,40 |
| Walls: | | |
| Concrete and Plaster, gypsum | | 0,05 |
| Bricks, untreated | 100 | 0,15 |
| Bricks, open slots | | 0,35 |
| Wooden panels with air space | | 0,20 |
| Glass window | | 0,20 |
| Draperies | | |
| Velour 500 g/m$^2$ straight | | 0,20 |
| draped to half area | | 0,55 |
| Satin, draped 200 mm from hard surface | | 0,80 |
| Ceiling: | | |
| Perforated panels 500 x 500 mm with mineral wood | 200 | 0,60 |
| Laminated metal with 20 mm thick mineral wood and 150 mm air space | 180 | 0,95 |

# APPENDIX C

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