List of symbols and basic concept

RRA Duct diffuser, Cegep of Granby, Granby, Canada

“ Our challenge is to establish an equal
balance between performance and savings
to improve our users’ life quality,
while also enhancing excellence standards
in our products. ”

Today, NAD Klima manufactures and distributes throughout North America.
The product range offer redefines standards of quality,
efficiency, energy savings and construction costs.

As a leader in diffusers for LEED projects, the objective is always improvement
of comfort, air quality and energy savings.

NAD Klima is constantly innovating and is proud of
its numerous achievements, which have been realised in collaboration
with contractors, engineers and architects.

We are NAD Klima.

MADE IN
CANADA

The information contained in this catalogue is subject to change.
Refer to the digital version on **www. nadklima.com**

2024 Version

DRS diffuser, Thibault/GM Sports complex, Sherbrooke, Canada

List of symbols and basic concept

Symbols

Symbole	Description	Unit
A	Surface	m^2
A_{eff}	Geometrically free cross-section of stream	m^2
B	Width	mm
C	Induction correction factor for an angle of opening "a"	-
D, d	Diameter	mm
D_{min}	Distance from the grid ceiling	m
F	Power	N
f	Correction factor for the vertical stream speed	-
f_m	Average frequency	Hz
g	Gravity	ms^{-2}
H, h	Height	m, mm
i	Induction Ratio	-
K	v_{eff} correction factor for an angle b of strips β	-
k	Height of roughness	mm
L, l	Length (of the room), length of the stream course	m, mm
L_W	Sound power level	dB
L_{WA}	Sound-intensity level weighted A	dB (A)
L_p	Sound pressure level	dB
L_{PA}	Sound Pressure Level weighted A	dB (A)
ΔL	Room attenuation	dB
$\Delta L_{Oct.}$	Sound power level per octave	dB/Okt.
m	Mass	kg
$\dot{m}$	Mass Water Flow Rate	kg/s
n	Number (quantity)	-
P	Sound power	W
p	Sound pressure	Pa
p_d	Dynamic pressure	Pa
p_0	External pressure (air pressure)	Pa
p_{st}	Static pressure	Pa
p_t	Total pressure	Pa
Δ_p	Pressure difference	Pa
Δp_R	Pressure drop through friction	Pa

Symbol	Description	Unit
Δp_t	Total pressure difference	Pa
R, r	Radius	m, mm
T	Thermodynamic temperature	K
T_A	Thermodynamic temperature of the room	K
T_{ae}	Thermodynamic temperature of outgoing air	K
T_{as}	Thermodynamic temperature of supply air	K
t	Time	s
t_0, t_A	Supply air temp. / Room air temperature	°C
$t_{x\,max}$	Maximum temperature in the course section after blowing	°C
ΔT_0, Δt_0	Temperature difference between supply air and room air	K
ΔT_{xy}	Temperature difference between stream and room air after point x or x+y	K
$\Delta t_{x\,max}$	Max. temperature difference between stream and room air	K
V, V_{geo}	Room volume	m^3
$\dot{V}$	Air Flow Volume	m^3/h
$\dot{V}_x$	Total volume flow at coordinate x	m^3/h
$\dot{V}_0$	Volume flow of supply air	m^3/h $m^3(h/m)$
v	Velocity	m/s
v_{eff}	Blowing rate	m/s
vβ	Blowing rate with an inclination angle β	m/s
v_{max}	Maximum average velocity after point x or x+y in a stream's course length	m/s
X, x	Length of a stream's course	m
x_{crit}	Critical airflow distance	m
y	Vertical length of a stream's course after the blast	m
y_{max}	Vertical penetration depth	m
Y, y	Vertical deflection of a nonisothermal stream	m
$Y_{0,2}$, $y_{0,2}$	Distance from the jet axis for which v = 0.2 m/s	m
α, β, γ, δ	Angles, angle of flow expansion	°
ζ	Resistance coefficient	-
λ	Friction coefficient	-
ρ	Density	kg/m^3

List of symbols and basic concept

Airflow technique reminders

Coanda Effect
The Coanda effect is the property of flowing mediums, where they are flowing in parallel or divergent directions and align themselves with level surfaces or other streams, or are attracted to such streams.

Critical airflow distance
Airflow will rise or fall when ambient temperature is higher or lower than airflow temperature. If an air stream is blown into a room horizontally, the airstream will follow a course that immediately curves downwards. With ceiling streams (or wall streams), the Coanda effect will cause the stream to cling to the ceiling for a certain distance in spite of a lower temperature; the stream will not start to curve downwards until a later time. This distance, from the air diffuser to the point where the colder air unsticks from the ceiling, is called the “critical airflow distance”.

Temperature ratio
The temperature ratio is the ratio of temperature differences between a point **“x“** and the air diffuser. The temperature ratio is a dimensionless quantity. The smaller the temperature ratio is, after a certain length of a stream’s course, the faster the temperature difference will be reduced, and the greater the airflow induction will be.

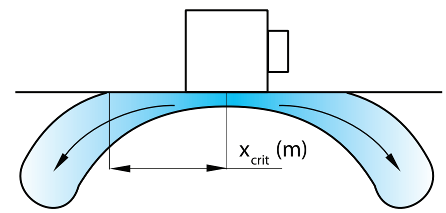
Induction ratio
The induction ratio is the ratio between the total airflow volume in motion at a point **“x“** and the volume when the airflow leaves the diffuser. As the induction ratio cannot be determined experimentally, it is calculated indirectly from the temperature ratio.

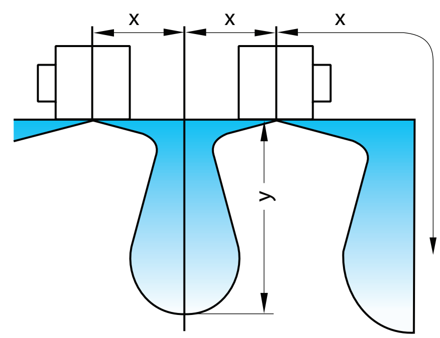
Airflow distance x and y
Airflow distance **x** is:
- The distance from the geometric center of a diffuser to a junction with an airstream or where two jets meet.
- The course length of an airstream from the diffuser’s geometric center along a horizontal (or vertical) wall, to a point for which the parameters relevant to the stream are to be determined.

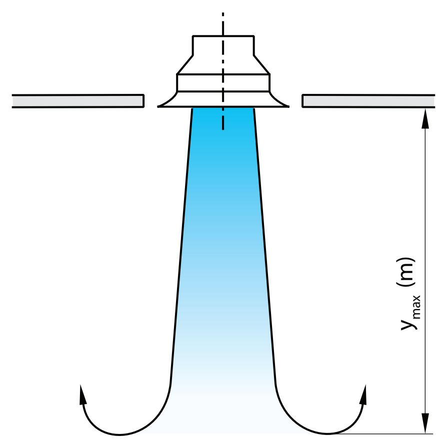
Airflow distance **y** is:
- The vertical distance of an airstream created by the meeting of two horizontal streams flowing one towards another, from their joining point to the point for which the parameters relevant to the stream are to be determined.

The definitions for **x** and **y** also apply when, owing to their placement, diffusers are not flush with the ceiling or are suspended. In those cases one must take into account the fact that after the airflow distance (**x** + **y**), the following relationship between the velocities applies, with or without any ceiling influence:
In this case the air speed can be calculated using the formula:
$\mathbf{v}_{max}$ (with ceiling) = 1.4 x $\mathbf{v}_{max}$ (without a ceiling)
$\mathbf{v}_{max}$ (without ceiling) = 0.71 x $\mathbf{v}_{max}$ (with a ceiling)

Vertical penetration depth
Vertical penetration depth, $\mathbf{y}_{max}$, defines the vertical distance of an airstream at a higher airflow temperature than ambient air. It corresponds to distance between the diffuser’s exit point and the point where the jet tends to go upwards.







Unit conversion table

Length	Pressure	Speed	Flow	Capacity
inch x 25.4 = mm	in/H_2O x 249 = Pa	m/s x 200 = ft/min	L/s x 2.12 = cfm	Btu/h x 0.2931 = Watt
ft x 0.305 = m	Pa x 0.004 = in/H_2O	ft/min x 0.005 = m/s	cfm x 1.7 = m^3/h	1 ton = 12 000 Btu/h
m x 3.281 = ft			L/s x 3.6 = m^3/h	1 ton = 400 cfm

Ratio for the maximum variation of temperature in the air stream zone $\frac{\Delta Txy}{\Delta To} \leq 0.1$

Airflow technique reminders (suite)

Air distribution efficiency: Ez

In order to calculate the quantity of fresh air required, the **ANSI/ASHRAE 62.1-2016** standard takes into account the air distribution efficiency in the room through the **Ez factor.**

To calculate the total amount of fresh air to be treated by a unizone V_{oz} system, follow the following steps:

1. Calculate the input of fresh air necessary in the breathable zone V_{bz}:

The ANSI / ASHRAE 62.1-2016 standard recommends an input of fresh air based on the number of occupants in a room and the surface area according to accepted values. These values vary according to the type of room studied (office, kitchen, etc.).

$$V_{bz} = R_p * P_z + R_a * A_z$$

With:

R_p: Exterior air flow per person (cfm / person)
P_z: Number of occupants in the zone
R_a: Exterior air flow per zone (cfm / ft^2)
A_z: Zone Area (ft^2)

2. Using table 6.2.2.2 (ASHRAE 129) *(Measuring Air-Change Effectiveness)* select the value of air diffusion efficiency.

- In the case of air distribution through the ceiling with returns in the ceiling, the value according to table 6.2.2.2 is Ez = 0.8.
- The DAL 358 and DAL 359 of NAD Klima have been tested according to the ASHRAE 129 protocol.

The DAL 358 obtained an Ez value = 1.1 and the DAL 359 an Ez value = 1.0.
These results indicate that NAD diffusers have an efficiency rating superior to standard diffusers.

3. Calculate the total exterior air airflow:
$$V_{ox} = V_{bz} / Ez$$
For unizone systems, the following advantages have been defined:

DAL 358: 27% less fresh air input than a standard diffuser.

DAL 359: 20% less fresh air input than a standard diffuser.

Acoustic technique reminders

Sound causes vibrations in the air, which alternately compress and expand. These changes in pressure overlay the existing air pressure and reproduce in sine waves in the air. If these pressure variations reach the human ear, the air pressure waves are converted into mechanical vibrations by the ear drum.

The hearing process has begun.
The human ear is able to distinguish a sound depending on the two following parameters:

a. Sound pressure
b. Frequency

1. Acoustic pressure
Acoustic pressure is the pressure change in the air, generated by an acoustic source. These variations in pressure are measured in Pa or N/m^2 and identified with the letter "p".

Acoustic pressure represents an indicator for volume. It depends on the distance between the acoustic source and the measurement point, as well as the characteristics (shape, obstructions, etc.) of the room.

Acoustic pressure as the sole parameter is not suitable for calculating the spread of sound in an area. The source's level of acoustic pressure is also required.

2. Acoustic power
Acoustic power is energy emitted from an acoustic source and transformed into sound. Acoustic power is fed into the air in the form of pressure fluctuations. Acoustic power is a parameter that cannot be measured directly. It is determined from the sum of the air pressures surrounding the acoustic source.

Therefore, acoustic power is not dependent upon a room's properties or distance. It will be used in all of the following calculations. Acoustic power is measured and expressed in watts (W).
For practical reasons, non-dimensional operational figures are adopted, which go back to A.G. Bell.

3. Acoustic pressure level
The level of acoustic pressure is defined as the logarithmic ratio between acoustic pressure "p" and pressure "p_0".
It is expressed in decibels (dB).

$$Lp = 10 \log (p^2 / p_0)^2$$

The reference value $p_0 = 2 \times 10^{-5}$ N/m^2 is the minimum acoustic pressure perceivable by humans. It is identified as the auditory threshold. The acoustic range (auditory threshold – pain threshold) therefore lies between 0 dB and 120 dB.

4. Acoustic power level
The level of acoustic power is defined as the logarithmic ratio between acoustic power (W) and power (W_o).
The ratio is expressed in decibels (dB).

$L_W = 10 \log W / W_0$
When $W_0 = 10^{-12}$ W

Although the sound pressure level and sound power levels are both expressed in decibels (dB), they are two very different things. The acoustic power level is the sound generated at the source and the acoustic pressure level is a sound perceived at a certain distance from the source. Thus, the acoustic power level is generally higher than the acoustic pressure level.

5. Frequency weighting
As frequencies vary, humans perceive equal acoustic pressure levels differently. Generally, an acoustic pressure level at a low frequency is perceived softer and less disruptive than the same pressure level at a higher frequency. In order to accommodate these sensory perceptions, pressure levels are weighted in specific ways.

Lower frequency acoustic pressure levels are lowered while higher frequency acoustic pressure levels are increased.

Many weighting types exist but the most used is a-weighting. This weighting provides acoustic pressure and acoustic power expressed in decibels dB(A).

Acoustic technique reminders

6. Acoustic level addition

If there are several acoustic sources, respective energy (acoustic power) and sound intensity (acoustic pressure) levels must be added together to find the total acoustic level. The same principles are valid for both acoustic power and acoustic pressure levels.

For multiple sources of same acoustic level (dB), the following formula applies :
$L_{gl} = L_l + 10 * \log n$ where " n " is the number of acoustic sources.

The function is illustrated in graphic 1.

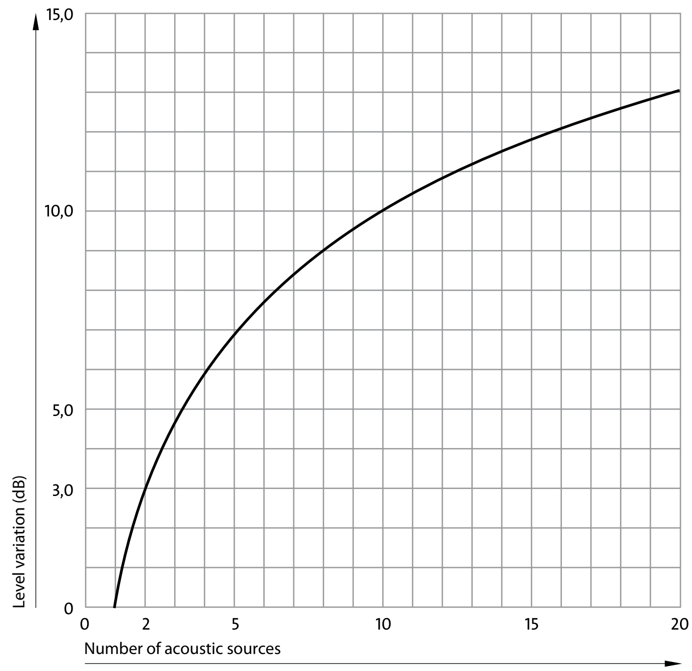
If there are acoustic sources with varying acoustic levels, the highest acoustic level is given the additional value AL. This value is obtained from the difference in acoustic levels using the following formula:
$AL = 10 * \log (1 + 10^{(L1-L2/10)})$
This correlation is also valid for $L_2 > L_1$ and illustrated in graphic 2.

If there are several acoustic sources with varying levels, the addition should be made in steps. First, the level sum should be calculated from two levels. The level sum is then added to a third and so on. Each individual addition is made according to the equation stated above. Calculation order is not important, as the result is always the same.

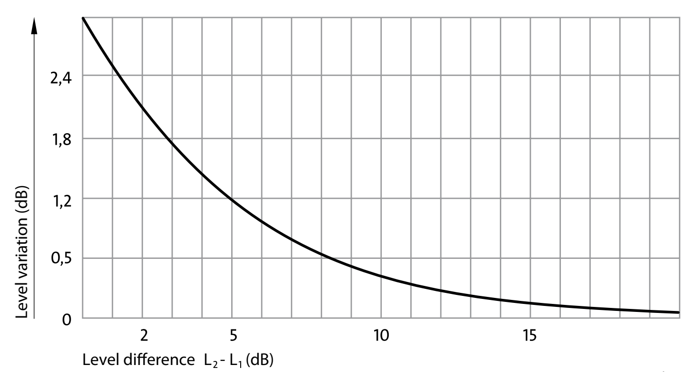
As a result, the following conclusion can be drawn, the addition of two acoustic sources with the same level results in an increase of 3 dB.

If the level difference is greater than 10 dB, the increase is almost non-existent. In reality, there is an increase of 0.4 dB. Although, this is not taken into consideration because the human ear can only perceive changes of at least 3 dB.

Graphic 1
Variation in level with equally loud acoustic sources



Graphic 2
Variation in level with unequally loud acoustic sources



Acoustic technique reminders

7. Determining the acoustic pressure level in a space

The acoustic sources and their level of acoustic power must be known to determine the level of acoustic pressure in a room. The acoustic power emitted by an acoustic source generates an acoustic pressure at a certain point of the room. That acoustic pressure is indicated by the distance between the point and the acoustic source, the room's directivity and the room's absorption factor.

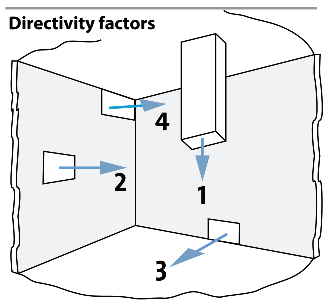
The level of pressure, in dB, is the sum of the two (2) components, direct and indirect.

$L_p = L_W + 10 \log (Q \div 4(\pi r^2) + (4 \div A)$

Q: is the directivity factor.
R: is the distance by ratio from the source (in meters).
A: is the total absorption surface (expressed in m^2 Sabin).

The following directivity factors are considered according to the acoustic source's position.

1. In the middle of a room
2. In the wall
3. In the middle of a baseboard
4. At an angle



To simplify, in practical situations, the value can be considered equal to eight (8) when the airflow travels without deviation in a single direction and equal to four (4) in all other situations.
The total absorption surface can be obtained from the reverberation time.

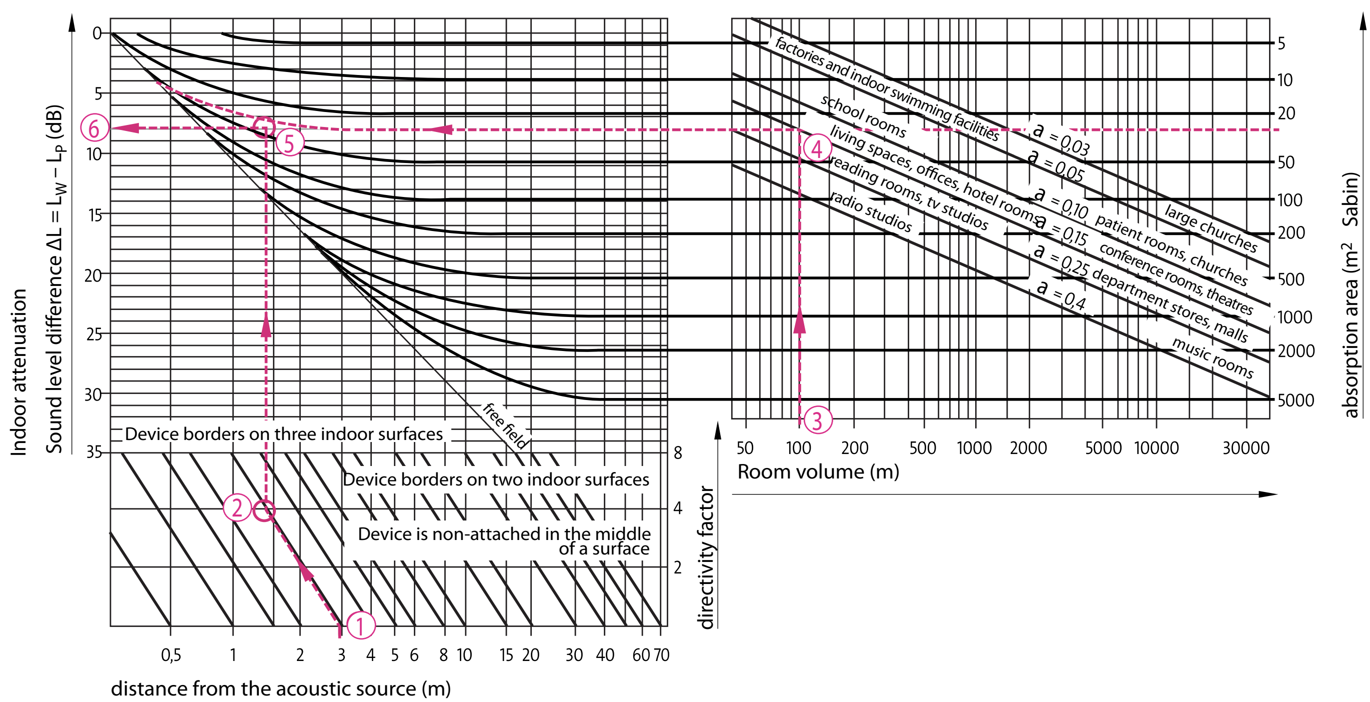
A: 0.163 V/T in m^2
V: Volume in m^3
T: Reverberation time in s

Reverberation time can be obtained through experimentation. During a planning phase, its value can be determined by following the VDI 281 from the table below.

Chart: Reverberation time

Type of room	Example	Average reverberation time (s)
Work	Individual office	0.5
	Shared office	0.5
	Workshop	1.5
Shared spaces	Opera hall	1.5
	Theatre / cinema	1.0
	Conference room	1.0
Living spaces	Hotel room	0.5
Rest areas	Break room	0.5
Education	Reading room	1.0
	Classroom	1.0
	Meeting room / Seminar room	1.0
Hospital	Operating theatre	2.0
	Room	1.0
	Bathroom	2.0
Public places	Museum	1.5
	Restaurant	1.0
	Retail store	1.0
Sport	Gym	2.0
Other locations	TV / Radio studio	0.5
	Computer room	1.5

Relation between sound power level and sound pressure level



Acoustic attenuation, determined by the absorption area, directivity factor and distance from the acoustic source, can be seen in the graph above.

Absorption factor

A surface absorbing all sounds has an absorption factor = 1.

The factors above (m) represent an average value corresponding to the ratio between the actual absorption and the ideal absorption.

The total area of absorption in m^2 Sabine is the sum of absorption surfaces in a space.

A = ∑ S

This area is not equal to the total area of the room's walls.

Acoustic example:

Situation:

A diffuser device with an acoustic power level of 40 dB (A) is situated in a conference room with an area of 100 m^3.

Question:

What is the acoustic pressure level at a distance of 3 m from the device?

Assumptions for the study:

Directivity factor = 4

1. From point (1) (distance is 3 m) follow the horizontal axis to the intersection (2) with the directivity factor.

2. Follow the vertical axis.

3. Start on the second graph at point (3) (room volume = 100 m^3) and follow the vertical line upwards to point (4), which intersects the absorption factor line of a conference room.

4. From point (4) follow the parallel attenuation curves to the intersection point. (5)

5. From point (6), read the space attenuation value = 8 dB(A) on the y axis.
The level of acoustic pressure at 3 m is therefore: $L_{PA} = L_{WA} - \Delta L$ = 40 dB(A) – 8 dB (A) = 32 dB(A).

DAL 358 diffuser, CIMA +, Sherbrooke, Canada

www.nadklima.com

NAD Klima
144, rue Léger,
Sherbrooke (Québec), Canada J1L 1L9
819 780-0111 • 1 866 531-1739

info@nadklima.com

MADE IN CANADA