Mixing systems technology

Air-movement mixing systems in confined rooms
The selection method used by Solid Air is a simple and quick way to arrive at an accurate and responsible choice of diffuser. However, air distribution as such is a complex matter. The following consideration provides some insight into the influence of ceilings, walls, obstacles and heat sources on the air pattern.

1. Introduction

The purpose of air-distribution systems is to supply the pre-treated air volume required for climate control, without causing nuisance, to a room that is confined by a ceiling, walls and a floor, whilst striving for the most complete possible air refreshment of the room.

On these pages we use a simple calculation model to describe the influence of the ceiling, floor and walls, and we also deal with the impact of heat sources and obstacles.

The most common air distributors for mixing systems work on the principle of: Plane flow, radial flow or a combination of the two, and therefore axial flow is not taken into consideration.

Wall, baffle and louvre ceiling diffusers work on the basis of the plane-flow principle. Perforated, round ceiling diffusers and swirl patterns in a panel work on the basis of the radial-flow principle.

Displacement ventilation works on the basis of a completely different principle. See chapter 3.3 floor and displacement diffusers.

2. Flows limited by a ceiling

a. Plane flow

If air is blown out through an infinitely long baffle, you create a plane flow (fig. 2.1). The air is supplied in the direction of the x-axis.

At a distance x is:
v_x = velocity
t_x = temperature
h_x = jet thickness

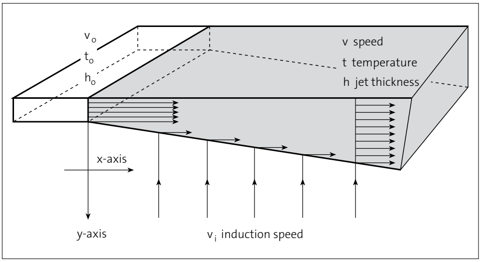

Fig. 2.1 plane flow

b. Radial flow

If the air is blown through a circular baffle, you create a radial flow (fig. 2.2). The air is supplied in the direction of the r-axis.

At a distance r is:
v_r = velocity
t_r = temperature
h_r = jet thickness

The following applies to both flows:
v_o = air-supply velocity
t_o = temperature difference between supply and room air
h_o = baffle height
v_i = induction speed

Observations demonstrate that the air that flows in through the baffle brings the surrounding air into motion and includes it in the jet. This phenomenon is called induction. The velocity of the inflowing air (vi) is directly proportional to the jet velocity **v**:

$$v_i = a * v$$

(where a is a constant)

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If we assume that the jet velocity in the y-direction does not change, that there is no build-up of static pressure in the room, and that the momentum in the jet is maintained, the following applies:

$$v_o^2 * h_o = v^2 * h$$

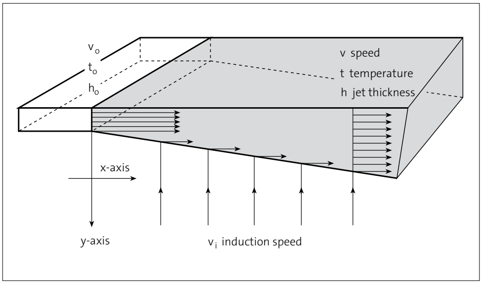


Fig. 2.2 Radial Flow

By using the law of conservation of mass and momentum, it is possible to calculate the jet thickness, velocity and temperature with the applied assumptions (fig. 2.3).

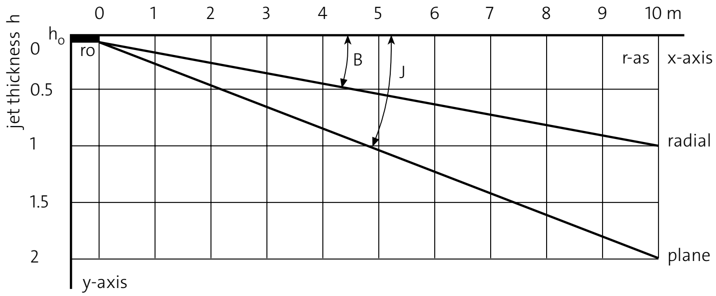
The course of the jet thickness is linear to the distance and increases twice as fast for plane flows as for radial flows.

As the jet induces more, the jet thickness increases faster too. The starting velocity has very little influence on the eventual jet thickness. The calculated course matches observations in practice. The course of the speed for a radial and a plane flow is given in fig. 2.4.

It is clear that the velocity reduces to a lower level with a radial pattern than with a plane pattern. The distance over which the velocity in the jet has a value of 0.25 m/s is called the “throw”. At that distance, you can place a wall without producing uncomfortable air movements. If there is no wall,the jet remains intact until the speed becomes 0.10 to 0.15 m/s and it is not longer possible to detect the difference between jet air and room air. The term throw is not an absolute. It is a practical tool to select an air-outflow device. The course of the jet temperature equals the course of the velocity (fig. 2.5).

Takeaways

- Radial flows reduce velocity and speed quicker than plane flows.
- For plane flows, the jet thickness increases twice as quickly as for radial flows.



tan B = a (induction constant)
tan J = 2a
principles: gap height h_o = 0.02 m
gap radius r_o = 0.3 m
induction factor a = 0.1

Fig. 2.3 Jet thickness

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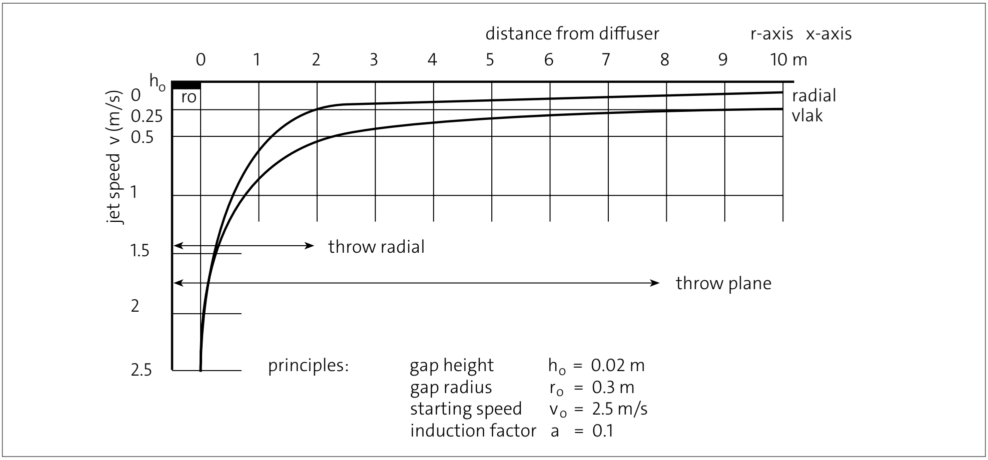

Fig. 2.4 Jet velocity

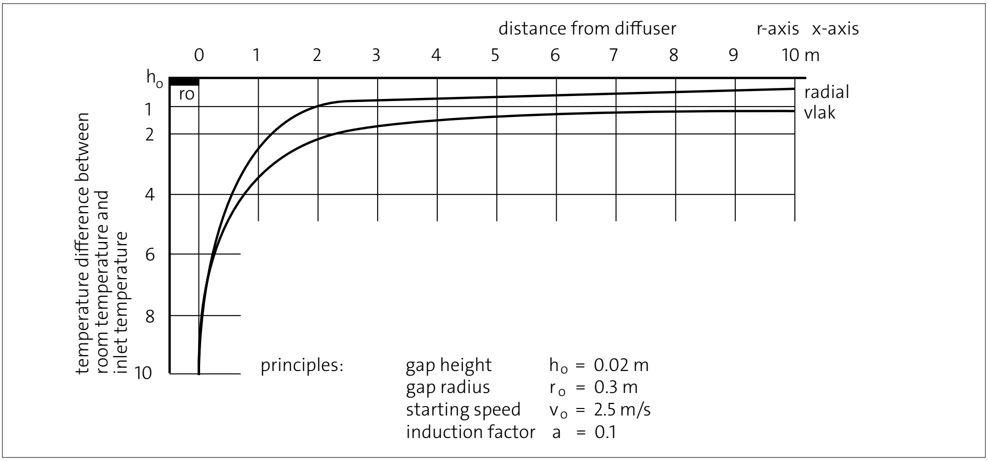

Fig. 2.5 Jet temperature

3. Influence of the floor

If a floor is built under the existing ceiling, the flow from the infinity of induction air to the jet is impeded. However, according to the assumption, the jet will continue to supply air. At this point, an air movement is produced over the floor that goes against the jet direction, which is known as the return vortex. Assuming that the velocity at the jet edge is nil in the x-direction, the velocity will be highest at floor level.

From this assumption, it is possible to calculate the velocity distribution in the return vortex in the x-direction. The sum of the shaded surfaces in fig. 3.1 and 3.4 should be equal to the blocked surface. This velocity course is theoretical.

To give an impression of the actual course, this has been marked with a thin line at r = 5. To describe the complete vortex, the velocity in the y-direction must be calculated too. This is a x v on the jet edge, and will be nil on the floor. Now, it is possible to calculate the y-component (fig. 3.2 and 3.5). A complete picture of the room flow with a radial pattern is given in fig. 3.3. For the plane flow pattern, see fig. 3.6.

Takeaways

For a plane pattern, the velocities in the return vortex are higher and distributed more unevenly.

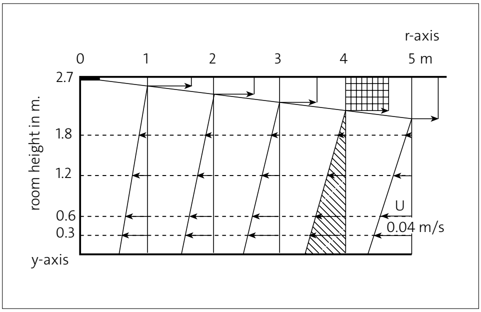

Fig. 3.1 Velocity increase return vortex in the x-direction radial pattern.

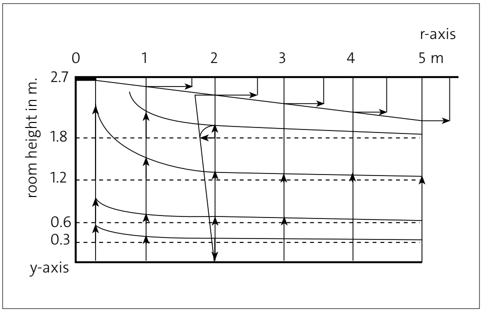

Fig. 3.2 Velocity increase return vortex in the y-direction radial pattern.

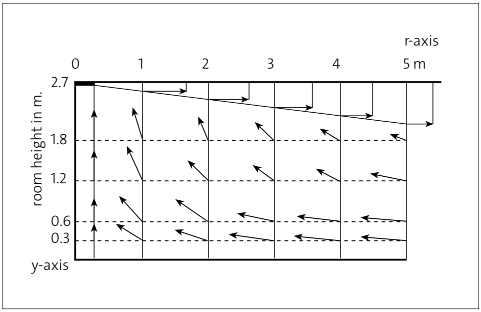

Fig. 3.3 Velocity increase return vortex radial pattern.

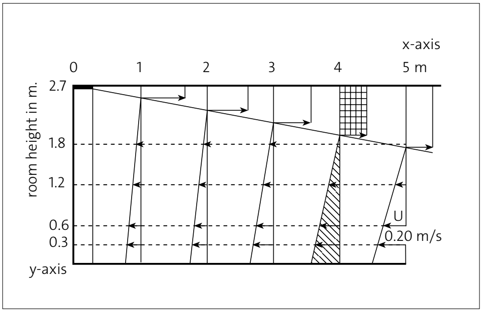

Fig. 3.4 Velocity increase return vortex in the x-direction plane pattern.

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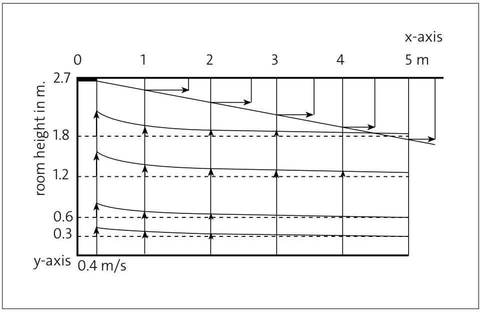

Fig. 3.5 Velocity increase return vortex in the y-direction plane pattern.

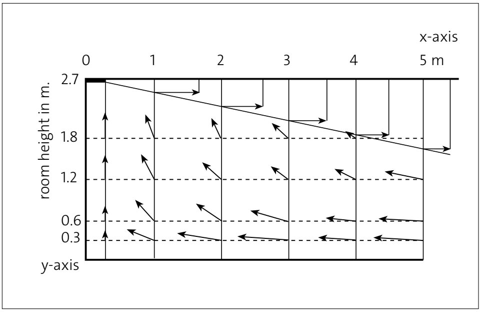

Fig. 3.6 Velocity increase return vortex plane pattern.

4. The influence of walls

The back wall prevents the air jet from going straight on and bends it downwards, whereby the jet expands to the return vortex. This happens with the smallest possible curvature radius, and it creates an eye where the air is motionless. The supply of air from the return vortex is interrupted, and the jet itself becomes a return vortex. In the downward area there is no longer any induction. Therefore, the throw along the back wall may not be made equal to the throw along the ceiling! It is possible to distinguish two separate areas: induction area, downward and expansion area.

The flow patterns for a plane and radial pattern have been given in fig. 4.1 and 4.2. The radial pattern produces an extremely even vortex with a small downward area.

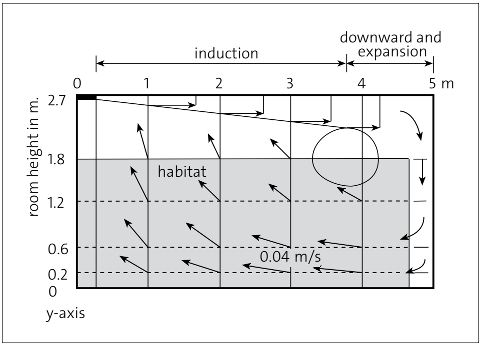

Fig. 4.1 Flow picture radial pattern.

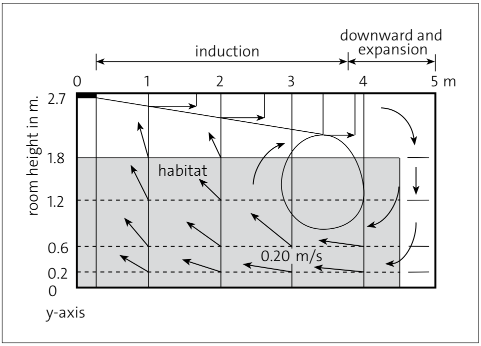

Fig. 4.2 Flow picture plane pattern.

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5. The influence of heat sources

With heat development in a room, air with a lower temperature than the room temperature is blown into the room to control the temperature. If the heat load is divided evenly over the floor surface area, this is taken up in the downward and expansion area which means the temperature of the supplied air rises. This heated air rises to the induction area, where the rest of the heat load is taken up by the moving air. The air heated by the heat load is taken up in the cold jet. If the heat production is concentrated in the discharge area (fig. 5.2) the convection flow that is produced will be taken up by the jet without any difficulties, but the temperature gradient of the room will go up.

However, if the heat development is concentrated in the downward area, you have a completely different situation. At that point the convection flow of the heat source is directed against the forced air flow.

With relatively low heat loads, the source is unable to build up its own vortex. In that case, the flow picture does not change (fig. 5.3). If there is a strong source, such as aradiator, there is a problem. The warm convection vortexand the cold return vortex will exist alongside each other. There will be a cold zone, often with high air velocities, alongside a warm area (fig. 5.4).

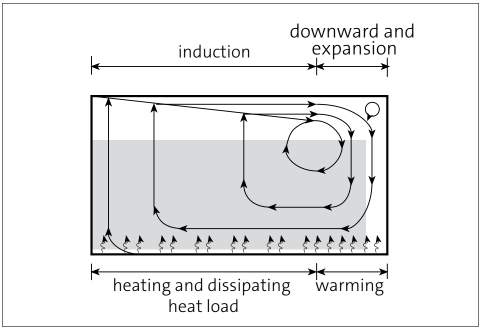

Fig. 5.1 Even heat load.

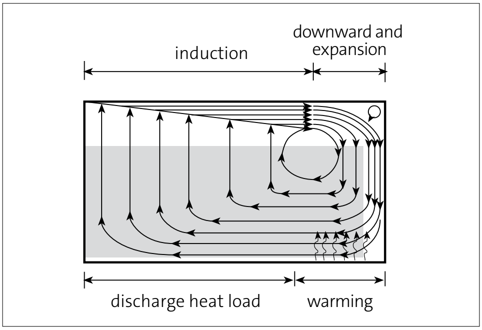

Fig. 5.3 Heat load in the downward area (weak source).

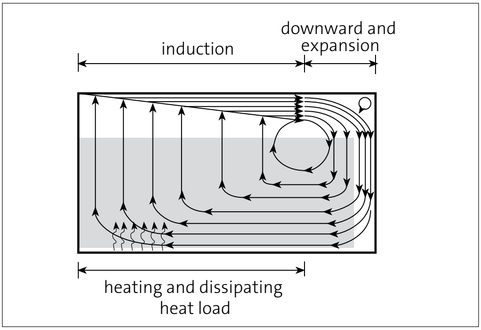

Fig. 5.2 Concentrated heat load.

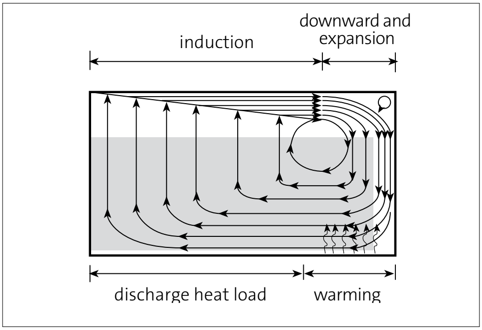

Fig. 5.4 Heat load in the downward area (strong source).

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6. Obstacles

The rooms considered up to now were completely empty. In reality used rooms have all types of obstacles that impact the flow pattern. The effect and the level of impact are very difficult to predict. For two situations, data is known from measurements and observations in practice:

- Beam on the ceiling.
- Large closed obstacles on the floor.

Beams bend the air flow. The part of the jet that flows against the beam (or the surface-mounted strip-light fitting) is bent down. Part of the jet will flow under the beam. As the velocity is constant in the entire jet, the resulting momentum direction can be composed from the geometry (fig. 6.1).

Deflection angle: $\tan c = \dfrac{b}{h - b}$

The influence of an obstacle has to be related to the jet thickness at the location of the obstacle. If large solid obstacles are in the room perpendicular to the floor, the creation of the return vortex often becomes completely impossible (fig. 6.2).

The top of the obstacles will operate as a type of "pseudo floor". Between the obstacles, there is low heat discharge, except when the jet is peeled off as it were and there is too much heat discharge.

These types of problems can occur in bedrooms (closed curtains), laboratories, storage areas, et cetera. By blowing parallel to the obstacles, the flow picture could be better but it is important to be cautious.

As air distributors with a radial outflow are less sensitive to disruption by heat sources or obstacles, they are often preferred over plane patterns for comfort reasons.

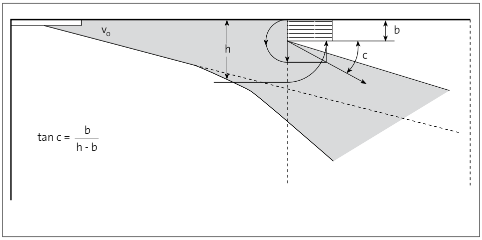

Fig. 6.1 Beam in air flow.

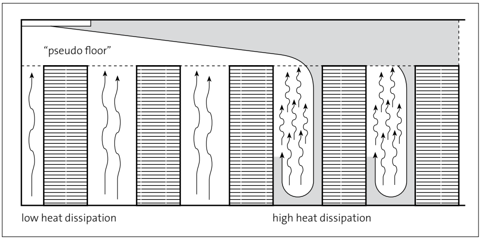

Fig. 6.2 Obstacles perpendicular to the return vortex.

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Appendix I

Assumptions:

1. The momentum of the jet is retained.
2. The jet does not build up static pressure in the room.
3. The induction velocity is directly proportionate to the jet velocity.
4. The jet velocity is an average constant.
5. The velocity in the return vortex is nil on the floor and is linear from the floor to the jet edge.

Appendix II

Overview of formulas:

Plane pattern:
Momentum: $h_o * v_o^2 = h * v^2$
Mass: $d(h * v) = v_i \, d_x$
Induction: $v_i = a * v$

Radial pattern:
Momentum: $h_o * r_o * v_o^2 = h * r * v^2$
Mass: $d(h * r * v) = v_i * r * d_x$
Induction: $v_i = a * v$

Appendix III

Definitions:

Symbol	Quantity	Unit
a	Induction constant	-
x, y	Coordinates	m
r	Radius	m
r_o	Baffle radius	m
h_o	Baffle height	m
v_o	Air velocity in the baffle	m/s
v	Air velocity	m/s
v_i	Induction velocity	m/s
t	Air supply temperature	°C (K)
t	Jet temperature	°C (K)

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Selection method ceiling diffusers

1. Select a diffuser type

Selecting a diffuser is not just an aesthetic choice. The properties of the various diffusers determine their suitability for a particular purpose. Base your choice on the number of air changes with a room height of 2.7 m. For transfer diffusers or overflow diffusers, the pressure loss and the noise level determine the choice. In connection with noticing the pressure difference over doors, we recommend selecting transfer diffusers on a pressure loss of approximately 10 Pa.

Usual noise levels selection chart

		type	number of air changes															
			2	3	4	5	6	8	10	15	20	25	30	40	50	60	80	100
ceiling	with ceiling influence	perforated																
		louvre																
		slot																
		baffle plate																
		downflow																
		swirl																
	without ceiling influence	swirl																
		round perforated																

2. Determine the location of the diffusers on the plan

Ensure a symmetrical distribution where possible. Do not blow towards the external wall, but preferably from the external wall towards the internal area. Do not blow towards strong heat sources, such as radiators, but with the natural convection flows.

3. Take account of obstacles

The ceiling is preferably flat and closed. Remember that beams, surface-mounted light fittings etc are not in the throw range of the diffusers.

4. Determine the permitted level

The data in the table can be used as guide values.

type of room		db(A)									
		15	20	25	30	35	40	45	50	55	60
bank											
library											
cinema											
lecture theatre											
concert hall											
factory hall											
sports hall											
halls and corridors											
hotel room											
office	board										
	private										
	several pers										
	room										
laboratory											
operating theatre											
post office											
radio studio											
restaurant											
class room											
sports centre											
theatre											
hospital room											

5. Determine the air volume per diffuser

Divide the supply-air volume per hour in the room by the number of diffusers.

6. Measure the maximum permissible throw on the drawing

The maximum permissible throw refers to the distance from the centre of the diffuser to a wall or an opposing air flow. Only the horizontally measured distance may be considered permissible throw up to a room height of approximately 3.5 m. The exceptions are noted in the product details.

7. Select the diffuser from the table that complies with all the requirements

- The throw produced by the tables may not exceed the maximum permissible throw; a lower value is permissible.
- The sound pressure Lp is given in dB(A) with an assumed room attenuation of 10. The difference with the actual room attenuation must be corrected.
- Select a diffuser approx. 5 dB below the permissible value.
- When you select a diffuser, take account of the sound addition as a result of there being several diffusers in the room.

8. The tables assume the following details

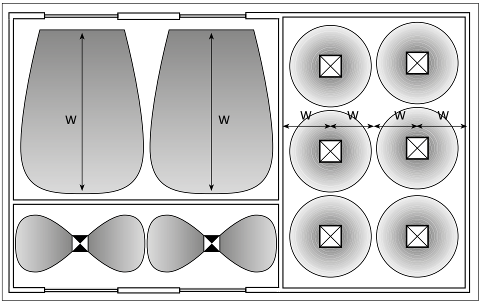
- The tables have an upper limit based on pressure loss and sound values. The lower limit is determined by the minimum required exit speed when discharging cooled air.
- It is permitted to interpolate the interim values.
- The supply-air temperature may be no more than 10 K below or 15 K above the average room temperature.
- However, we do not recommend diffusers in all-air or air-heating systems as such.
- All throw data are given with a ceiling effect.

9. Check the selected throw

The throw may not exceed the maximum permissible Wmax with the given ceiling height H because of the increasing radius thickness.

10. Important for All-Air technology

All Solid Air diffusers are also suitable for supplying heated air with an overtemperature up to approximately 15 K. The use of diffusers in an All-Air or air-heating systems is risky in principle and requires more provisions. Please consult our technical experts.



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Correction table for several diffusers in 1 room with similar sound level:

number of diffusers in 1 room	1	2	3	4	5	6	7	8
addition in dB	0	+ 3	+ 4.8	+ 6	+ 7	+ 7.8	+ 8.5	+ 9

Note

The addition applies for a noise observation for all the diffusers at an equal distance. In practice, this is generally not the case and the distance to the observer always varies. That justifies a reasonable maximum addition of 5 dB.

radial patterns
(perforated and flat swirl diffusers) • W_{max} = 10 x (H - 2)
linear patterns
(line diffusers and louvre diffusers) • W_{max} = 7.5 x (H - 2)

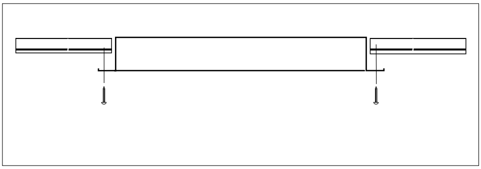
Fitting instructions

Fitting method

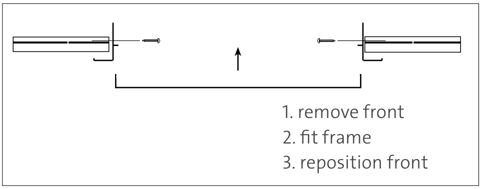
model	A	B	C	D	E
HRE	X	-	X	X	-
LRVD	X	-	X	-	-
LRVM	-	-	-	X	-
LTVD	X	-	X	-	-
LTVM	-	-	-	X	-
PDVM	-	-	X	X	-
PRVD	X	X	X	-	-
PRVM	-	-	-	X	-
PTVD	X	X	X	-	-
PTVM	-	-	-	X	-
PTVS	-	-	-	X	-
RRBC	X	-	X	-	-
RRBD	X	-	X	-	-
RRBM	-	-	X	X	-
RRGC	-	-	X	-	-
RRGD	-	-	X	-	-
RRSV	-	-	X	x	-
RRVO	-	X	-	-	X
RTBC	X	-	X	-	-
RTBD	X	-	X	-	-
RTBM	-	-	X	X	-
RTDO	-	-	X	-	X
RTFO	X	-	X	-	-
RTFM	-	-	X	X	-
RTGC	-	-	X	-	-
RTGD		-	X	-	-
RTLD	X	-	X	-	X
RTWK	X	-	X	X	X
SROD	X	-	X	X1*	-
STAD	X	-	X	X1*	-
STBL	-	-	-	X	-
STBR	-	-	-	X1*	-
TTHA	X	X	X	X1*	-

*X1 not standard (additional cost).

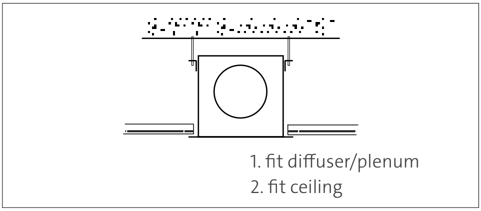
A. Fitting from the front



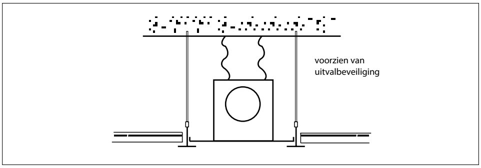
B. Blind fitting from the front



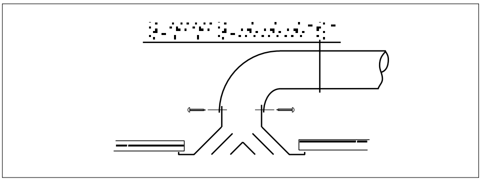
C. Fitting via the plenum box



D. T-bar mounted in modular ceiling



E. Directly in a duct



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