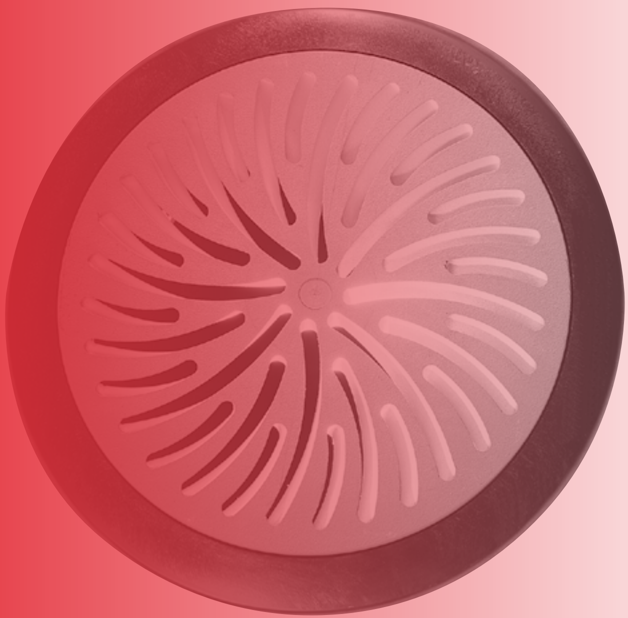

Good climate, better performance!

CHAPTER 3.3

FLOOR AND DISPLACEMENT DIFFUSERS

Chapter 3.3 - Floor and displacement diffusers

Available diffusers, information and prices on request:

Comfort

Round	LKO	LDO		
Half-round	LKH	LDH	LHI	
Quarter-round	LKV	LDV		
Arc	LKB	LKB-L		
Surface-mounted	LDR	LXR	LGR	
Built-in	LDI	LXI	LOI	LGI
	BPK	BPP	GIK	
Plinth	GIR	GRR	GSO	

Industry

Round	LDO	LSO	
Half-round	LDH	LSH	
Surface-mounted	LDR	LXR	LGR
Built-in	LGI	LXI	

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:
$\mathbf{v_x}$ = velocity
$\mathbf{t_x}$ = temperature
$\mathbf{h_x}$ = jet thickness

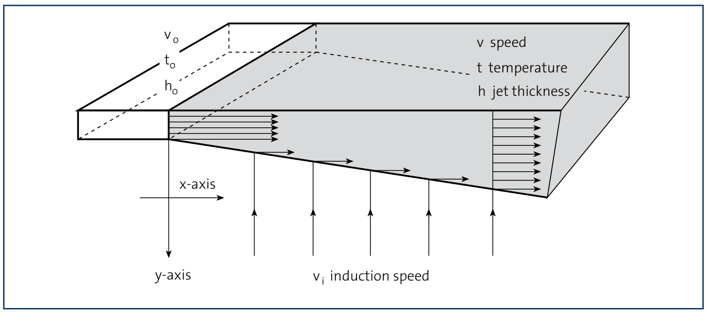

Fig. 2.1 plane flow

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:
$\mathbf{v_r}$ = velocity
$\mathbf{t_r}$ = temperature
$\mathbf{h_r}$ = jet thickness

The following applies to both flows:
$\mathbf{v_o}$ = air-supply velocity
$\mathbf{t_o}$ = temperature difference between supply and room air
$\mathbf{h_o}$ = baffle height
$\mathbf{v_i}$ = 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 ($\mathbf{v_i}$) is directly proportional to the jet velocity **v**:

$$\mathbf{v_i = a * v}$$

(where **a** is a constant)

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:

$$\mathbf{v_o^2 * h_o = v^2 * h}$$

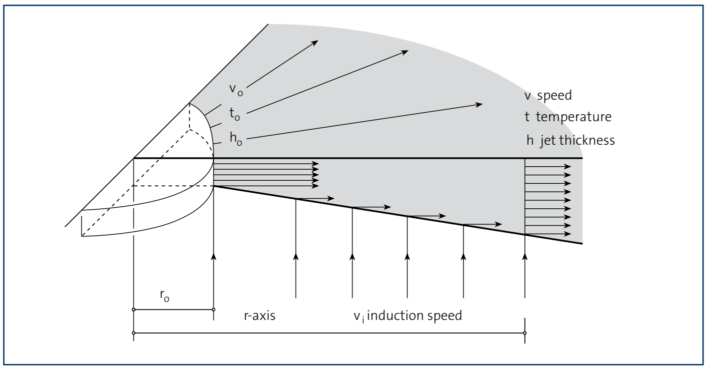

Fig. 2.2 radiale stroming

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.

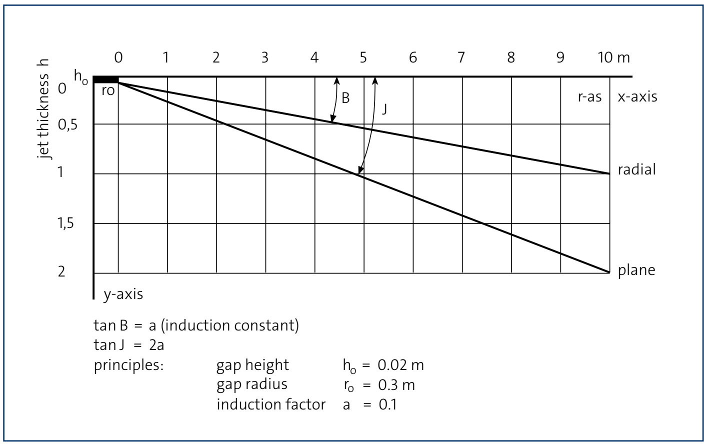

Fig. 2.3 Jet thickness

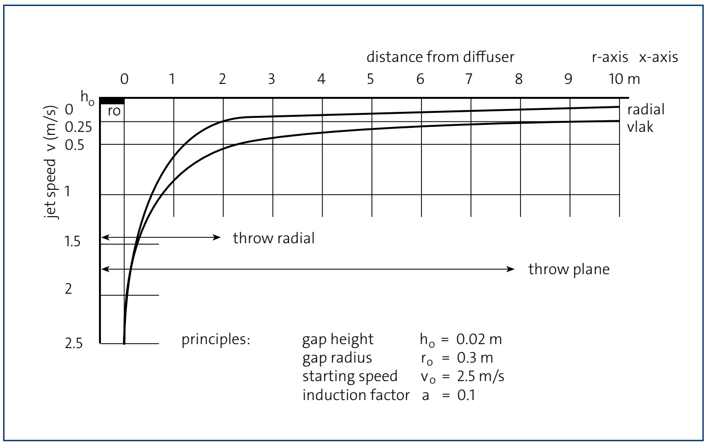

Fig. 2.4 Jet velocity

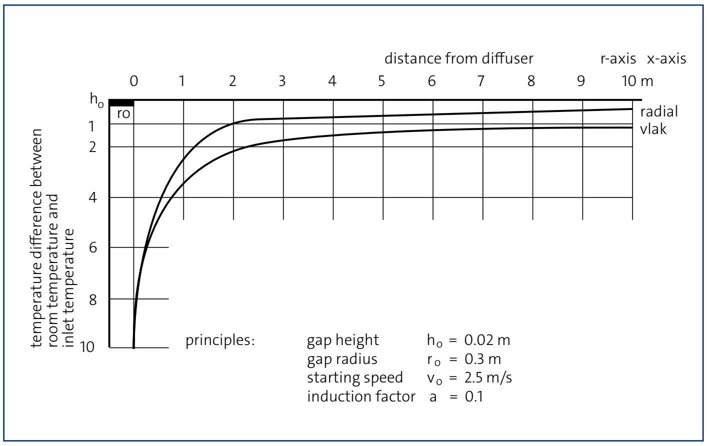

Fig. 2.5 Jet temperature

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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.

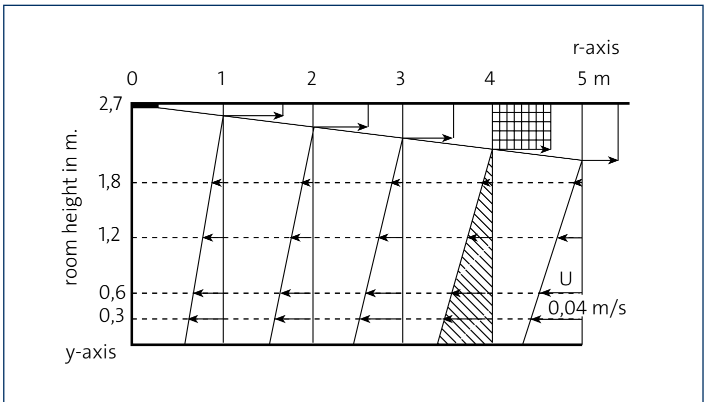

Fig. 3.1 Velocity increase return vortex in the x-direction radial pattern

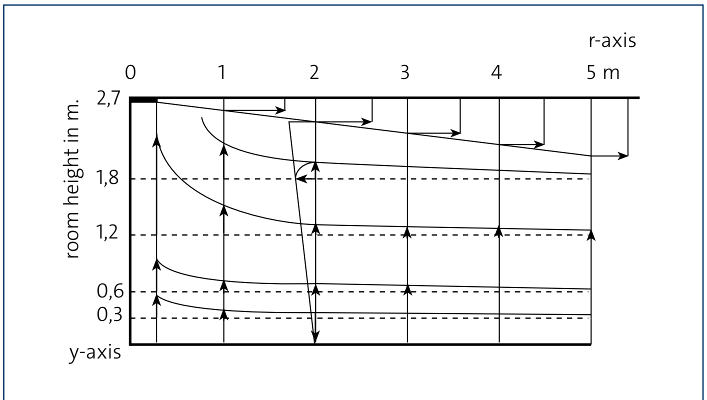

Fig. 3.2 Velocity increase return vortex in the y-direction radial pattern

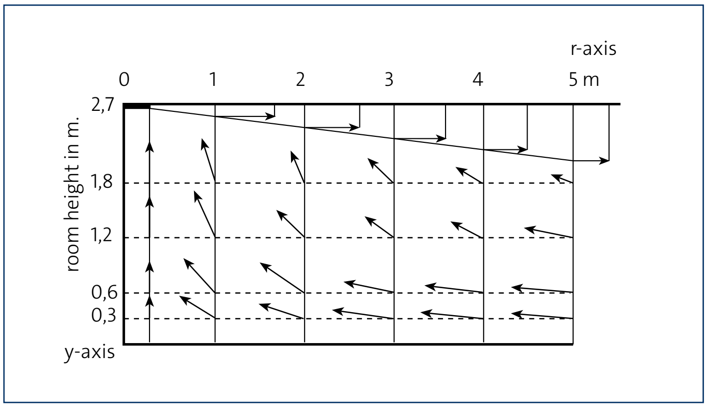

Fig. 3.3 Velocity increase return vortex radial pattern

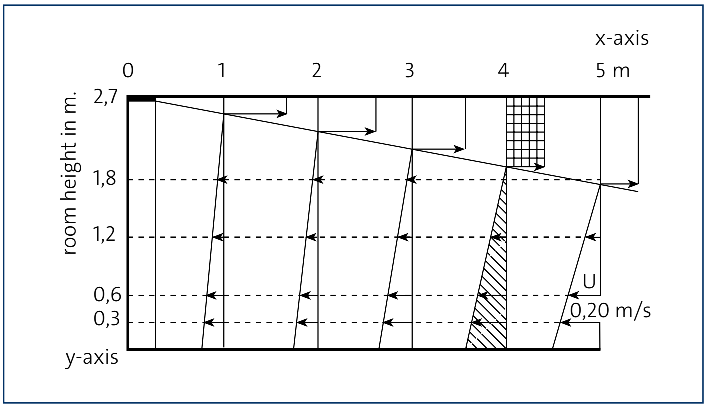

Fig. 3.4 Velocity increase return vortex in the x-direction plane pattern

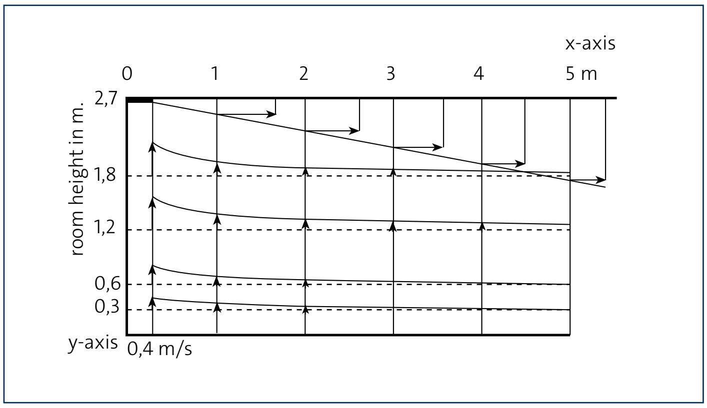

Fig. 3.5 Velocity increase return vortex in the y-direction plane pattern

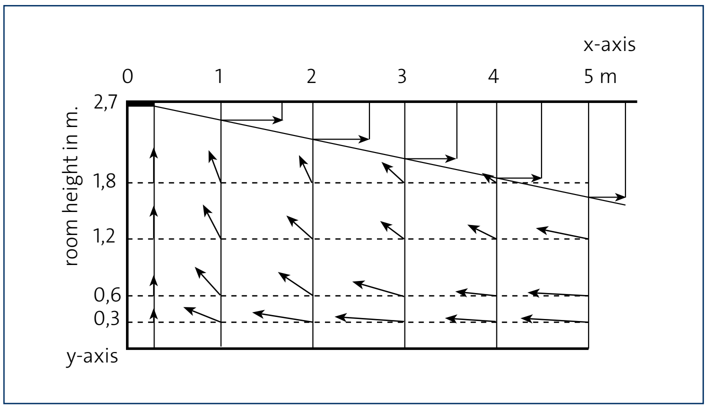

Fig. 3.6 Velocity increase return vortex plane pattern

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.

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.

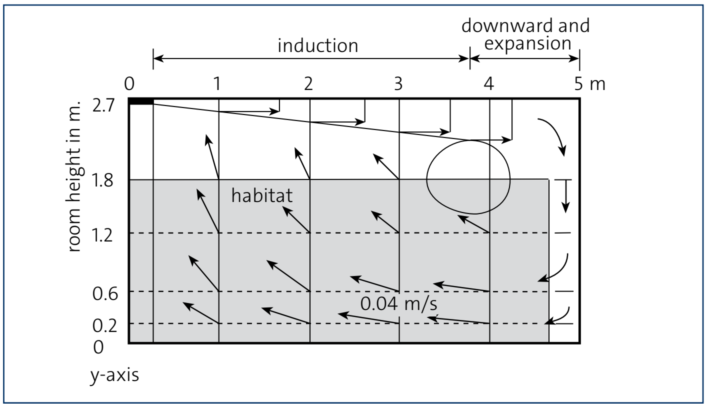

Fig. 4.1 Flow picture radial pattern

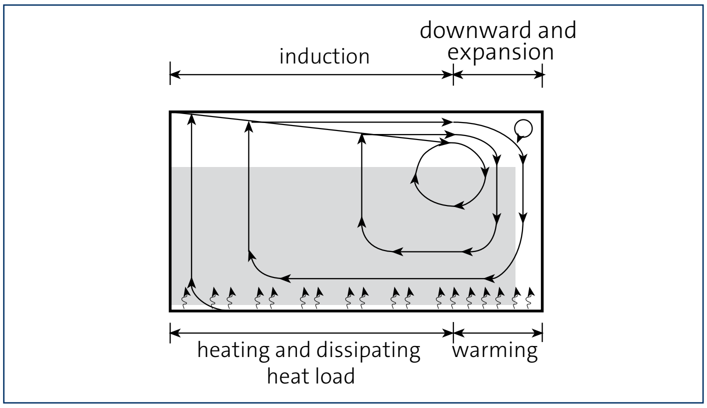

Fig. 5.1 Even heat load

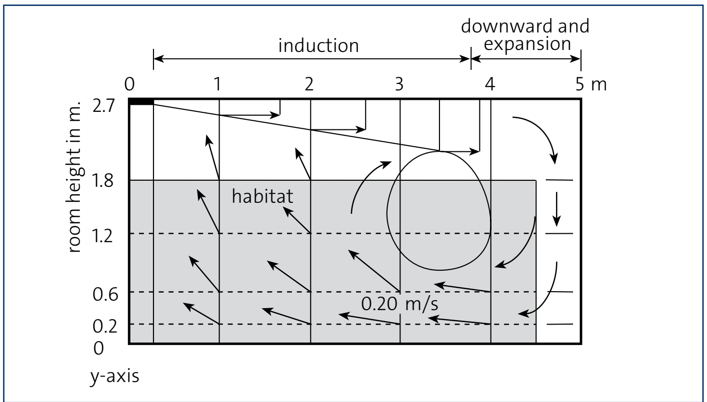

Fig. 4.2 Flow picture plane pattern

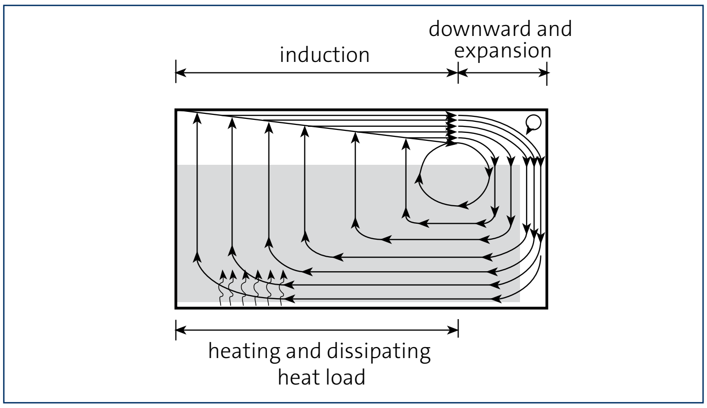

Fig. 5.2 Concentrated heat load

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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).

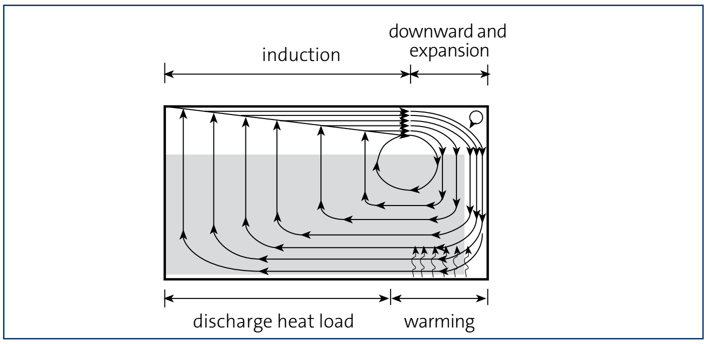


Fig. 5.3 Heat load in the downward area (weak source)

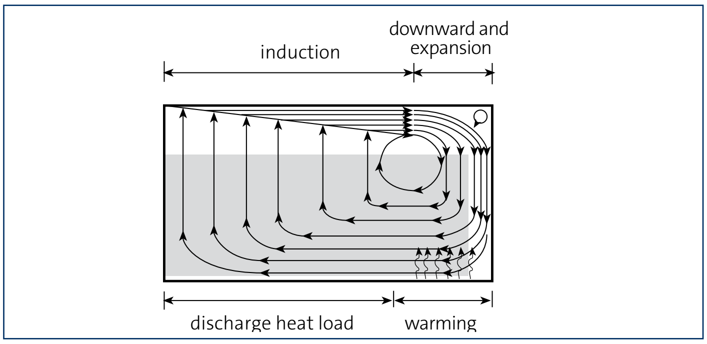


Fig. 5.4 Heat load in the downward area (strong source)

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.

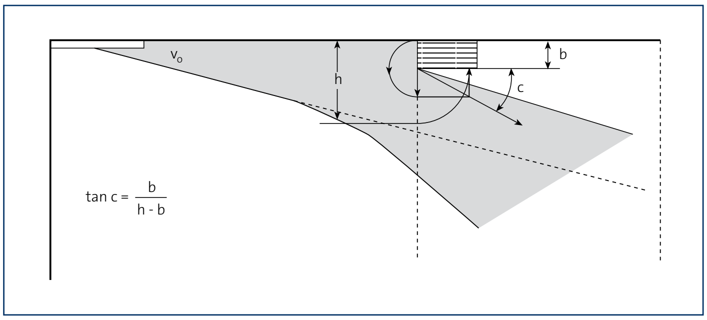


Fig. 6.1 Beam in air flow

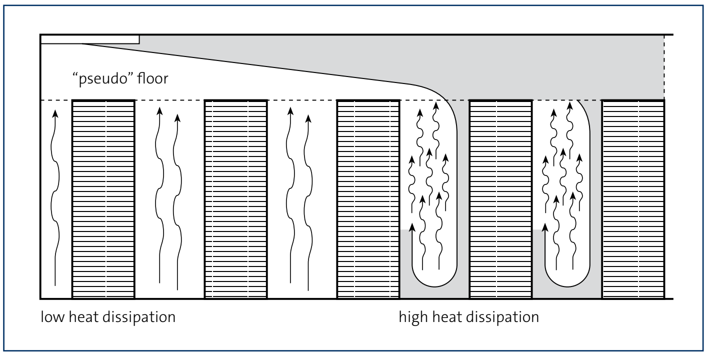


Fig. 6.2 Obstacles perpendicular to the return vortex

3

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: $h_o * v_o2 = h * v^2$

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)

3

DISPLACEMENT VENTILATION

General

1. Introduction

In climate technology, there is a major interest in an air-supply system that matches natural ventilation. With natural ventilation, fresh air enters a building through gaps and cracks. The thermal sources inside the building determine the air-flow pattern in the room. Such a system in a building matches people's experiences at home. For that reason alone, such a system counts with greater acceptance.

A problem with natural ventilation is that little air can be supplied without causing uncomfortable air movements and the temperature of the ventilation air cannot be controlled. In rooms with a moderate load, that quickly produces unacceptably high temperatures.

With displacement ventilation, the air is drawn in at floor level at low speed and at a temperature that is below the room temperature. This produces a system that moves fully in line with the natural flows in the room. It also prevents air velocities in the room becoming too high. The temperature in the room has become controllable, whilst the discharge of dirty air takes place efficiently.

2. Operating principle

In a displacement system, air is supplied at floor level at low velocities with an undertemperature and this is heated up at the top of the room and the dirty air is discharged. The supply air spreads across the floor. The heat sources in the room cause rising convection flows. This air is extracted from the cold supply air on the floor. This continues until there no longer is any supply air available to have the convection flow increase in mass and from that point, the increase of the convection air volume will have to come from its own swirling return air.

This creates three zones. On the floor there is a supply of cool air, at the top a mass of warm air that circulates itself is created, and in between there is an area with extremely low air velocities without a clear flow direction.

The pollutants in the room, dust, skin flakes and smoke particles, will be taken upwards by the room flow. These pollutants are stored in the warm air layer at the top of the room and are then discharged with the return air. When air is dirty due to gases or vapours that are heavier than air, the discharge to the top layer is not complete. The air below is “clean”. The area below the warm layer is suitable as the occupied zone for the occupants.

In principle, this system is only suitable for cooling. If heating is required, a separate system, such as radiators or radiant panels, is required.

3. Use

Displacement systems can be used in extremely wide-ranging situations. Their ability to discharge pollutants quickly and efficiently, together with optimum use of the cooling capacity by only treating the occupied zone, make the systems attractive. In rooms with relatively high ceilings, the benefits come to the fore most strongly. Consequently, displacement systems are often used in industrial settings but also in theatres, conference rooms, and offices.

4. Design

In the central system, a displacement systems does not differ from other systems. This does not apply to determining the cooling load of the room or determining the required air-supply volume.

Comfort requirements
The ultimate purpose of the system is to create optimum comfort for the occupants. Therefore, it has to comply with the usual standards and requirements. However, there is an additional element and that is the vertical temperature gradient. Due to the nature of the system, the temperature rises going up. The difference between the temperature at foot height and head height may not be too great. Comprehensive studies have demonstrated that a maximum difference of 2 - 3 K between head and ankle height is permissible.

It is recommended to set the difference between head and ankle height at 1.8 m so that sitting and standing activities can be carried out in the room.

Room temperature
The vertical temperature gradient means it is useful to agree where the room temperature will be measured. The choice is for a height of 1.2 m. Any further references to room temperature refer to a room temperature measured at a height of 1.2 m.

Inflow temperature
In office systems, the inflow temperature may not be more than 3 K below the room temperature.
In industrial systems, lower temperatures may be permitted. It is recommended to work with an undertemperature of up to 6 K.

5. Air-volume calculation

The cooling-load calculation provides the load that needs to be cooled. The air volume that is required to achieve that can be calculated with the following formula.

$Q = cp \times @ \times q_v \times (t_u - t_i)$

Whereby:

Q	load	W
cp	specific heat capacity	1000 J/kg/K
@	specific gravity	1.2 kg/m³
q_v	flow rate	m³/s
t_u	return-air temperature	°C
t_i	supply-air temperature	°C

The return temperature is higher than the room temperature $t_{1.2}$. The question is now how much air needs to be supplied to achieve the room temperature. That requires further insight into the temperature profile of the room.

6. Temperature profile of the room

The figure shows a simplified representation of the temperature profile of the room.

Whereby:

t_i	supply-air temperature	°C
t_o	temperature just above the floor	°C
$t_{1.2}$	temperature at 1.2 m height	°C
$t_{1.8}$	temperature at 1.8 m height	°C
t_u	return-air temperature	°C
H	room height	m

The profile sketch is a good approximation of the reality for a room where the load is distributed normally.

When the temperatures t_i, t_o and t_u are known, the entire temperature distribution is known.

The return temperature only depends on the load in the room and the supply-air volume in combination with the supply temperature and NOT on the room height. If the supply-air volume and the supply temperature have been selected, the temperature difference between the return temperature and the supply temperature has been determined unequivocally.

The return temperature follows from:

$Q = cp \times @\ qv \times (t_u - t_i)$

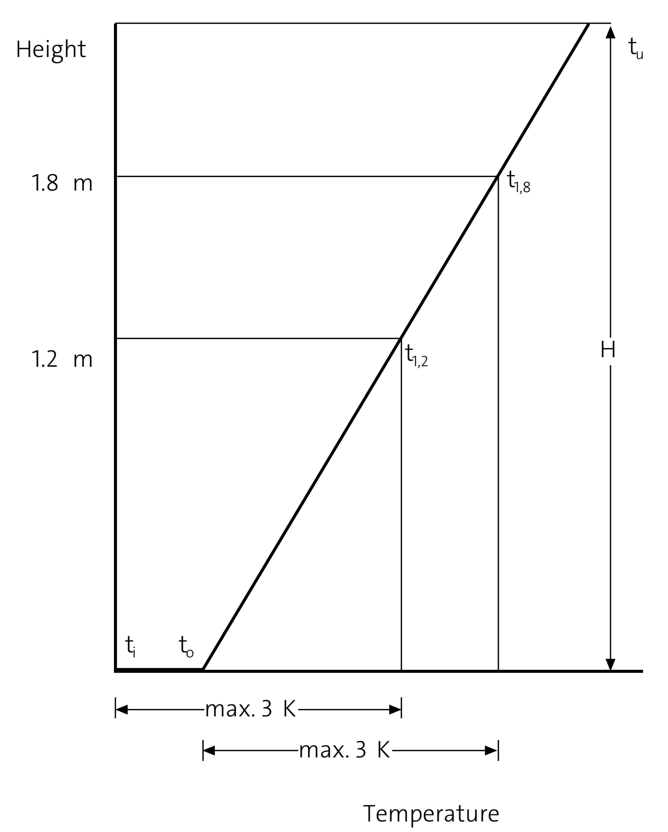
The floor temperature can be approximated with the following formula:

$$to = \frac{(2.15 \times t_u + 1200 \times q_v \times t_i)}{(1200 \times q_v + 2.15)}$$

Whereby:

Q	load	W
c_p	specific heat	1000J/kg/K
@	specific gravity	1.2 kg/m³
q_v	flow rate	m³/s
t_u	return-air temperature	°C
t_i	supply-air temperature	°C
t_o	temperature just above the floor	°C

The following table can be created by using these formulas. To ensure the table has universal application, the load and the supply-air volume are calculated per square metre of building surface. The temperatures t_o and t_u are given as temperature differences compared to the inflow temperature.



RFB

Displacement diffuser

Supply, round

Floor-mounted

Rotating discharge pattern

Use

The RFB displacement diffuser is suitable for supplying cooled air with a low entry velocity.
The diffuser is designed to be built into raised floors. The raised floor operates as the pressure plenum.

Characteristics

Undertemperature:	up to 8 K
Overtemperature:	not applicable
Capacity:	up to approx. 0.055 m³/s

Version

Displacement diffuser

material:	polycarbonate ABS
colour:	black or grey

Available types

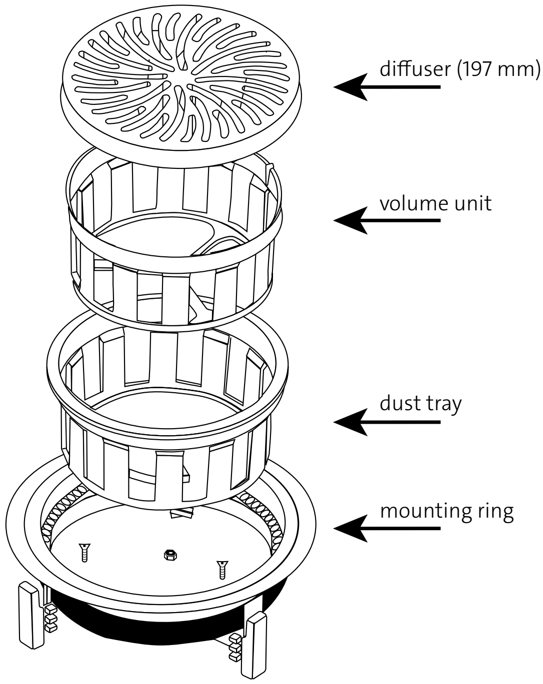
R F B T F C

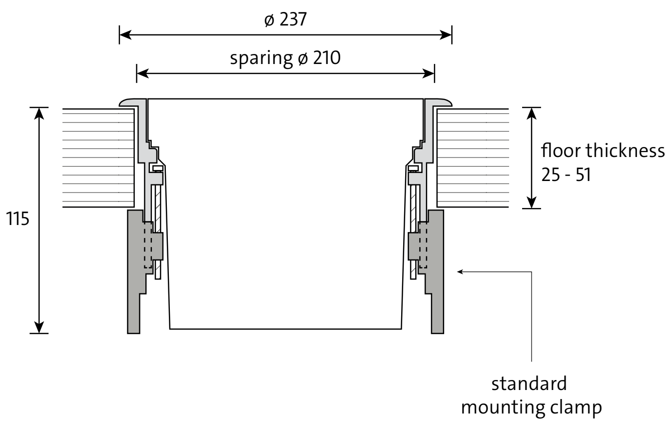
- **R** displacement diffuser
- **F** supply, round, floor-mounted
- **B** rotating discharge pattern
- **T** mounting ring
- **F** fixed volume unit + dust tray
- **C** mounting clip

Note

The listed dimensions are in mm.

Dimensions





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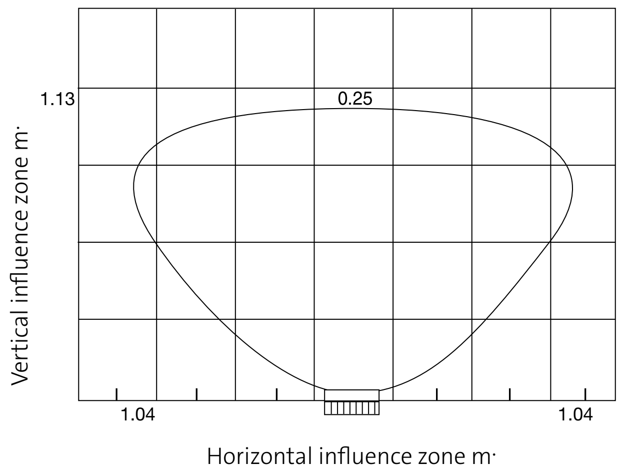
Selection details

PTVI

m³/s	m³/h	velocity isovel m/s	discharge pattern vertical m	horizontal m	p_s	L_p
0.030	**108**	**0.75**	0.33	-	9	-
		0.50	0.43	-	9	-
		0.25	0.86	0.64	9	-
0.035	**126**	**0.75**	0.40	-	12	-
		0.50	0.52	-	12	-
		0.25	1.07	0.95	12	-
0.040	**144**	**0.75**	0.43	-	15	18
		0.50	0.55	-	15	18
		0.25	1.13	1.04	15	18
0.045	**162**	**0.75**	0.49	-	20	20
		0.50	0.64	-	20	20
		0.25	1.34	1.13	20	20
0.050	**180**	**0.75**	0.61	-	25	23
		0.50	0.77	-	25	23
		0.25	1.53	1.22	25	23
0.055	**198**	**0.75**	0.61	-	30	26
		0.50	0.80	-	30	26
		0.25	1.65	1.31	30	26

Velocity profile



The velocity profile is given for an air velocity of 0.25 m/s at 144 m³/h and a Δ T of 5 °C.

General

- The influence zone details are based on a room that is 2.7 m high, with a ΔT of 5 °C between room and supply air.
- The values apply to a diffuser including a fully-opened volume unit and a dust tray.
- Static pressure loss P_S in Pa.
- The assumed room attenuation is 10 dB.
- Sound pressure L_p in dB(A).
- It is permitted to interpolate the interim values.

Correction factor for different ΔT

ΔT	3	4	5	6	7	8
Vertical influence zone	x 1.33	x 1.11	x 1.00	x 0.96	x 0.92	x 0.91
Horizontal influence zone	x 0.87	x 0.94	x 1.00	x 1.06	x 1.11	x 1.16

3