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MIXING SYSTEMS TECHNOLOGY
DIFFUSERS

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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

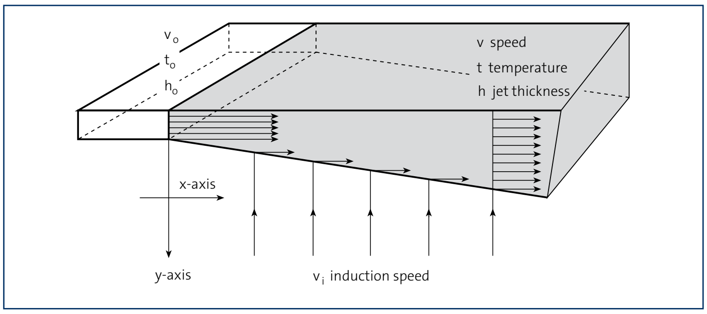

Fig. 2.1 plane flow

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 (v_i) is directly proportional to the jet velocity **v**:

$$v_i = a * v$$

(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:

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

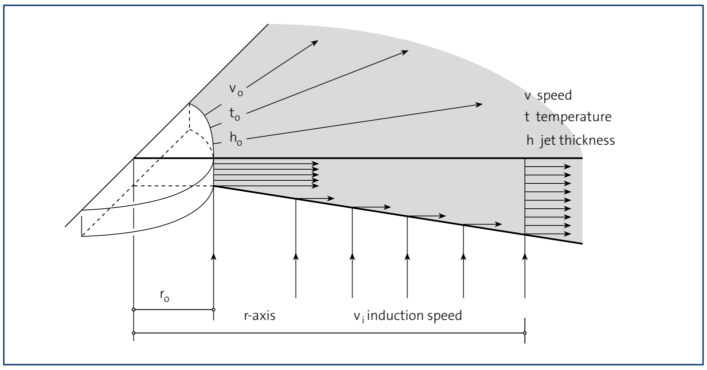

Fig. 2.2 radiale stroming

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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.

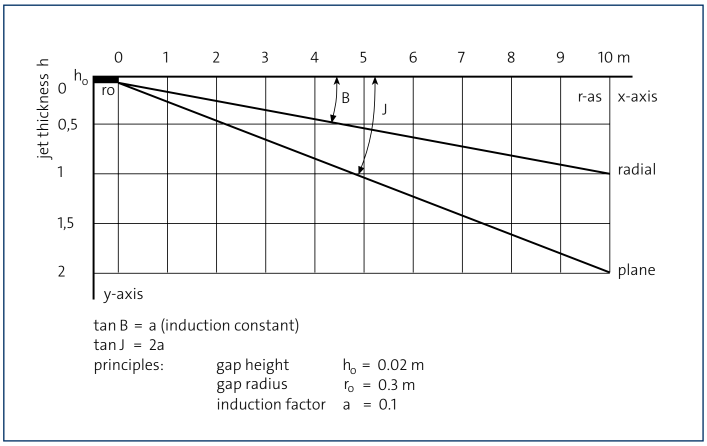

Fig. 2.3 Jet thickness

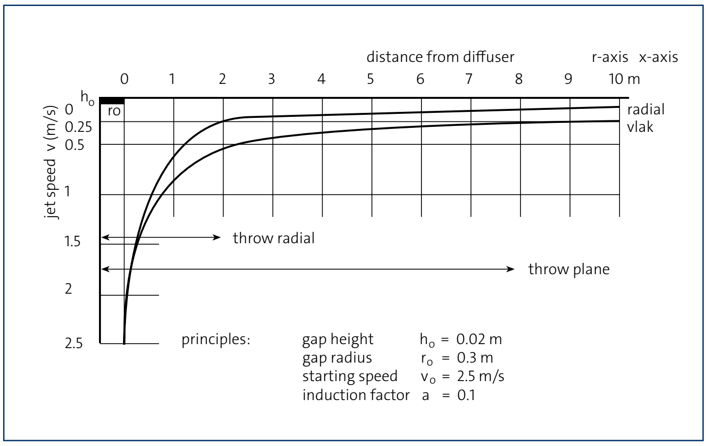

Fig. 2.4 Jet velocity

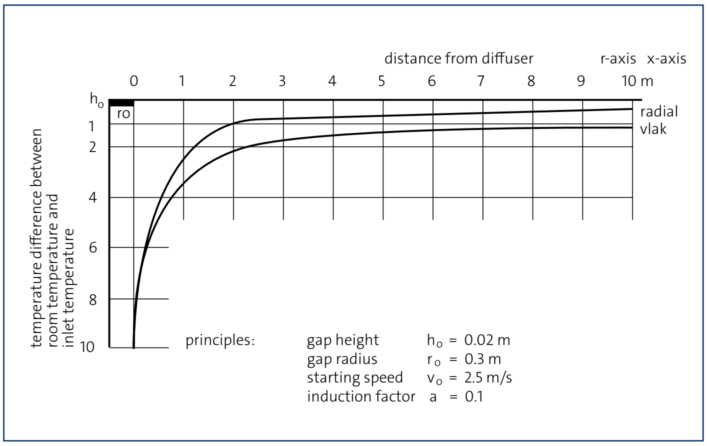

Fig. 2.5 Jet temperature

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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.

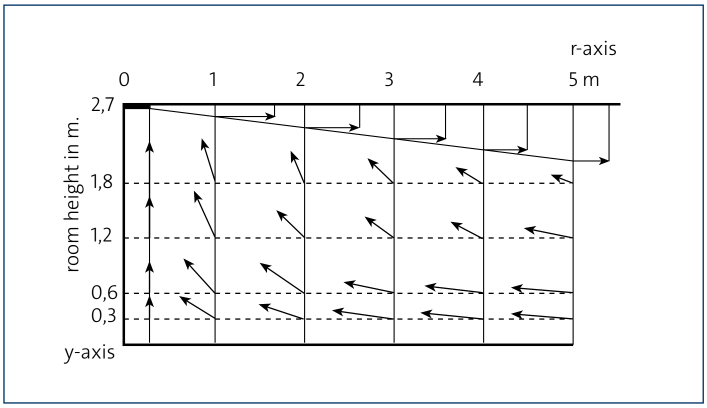

Fig. 3.3 Velocity increase return vortex radial pattern

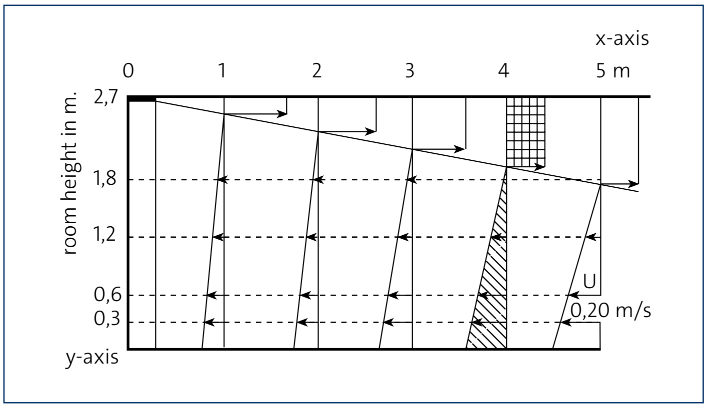

Fig. 3.4 Velocity increase return vortex in the x-direction plane pattern

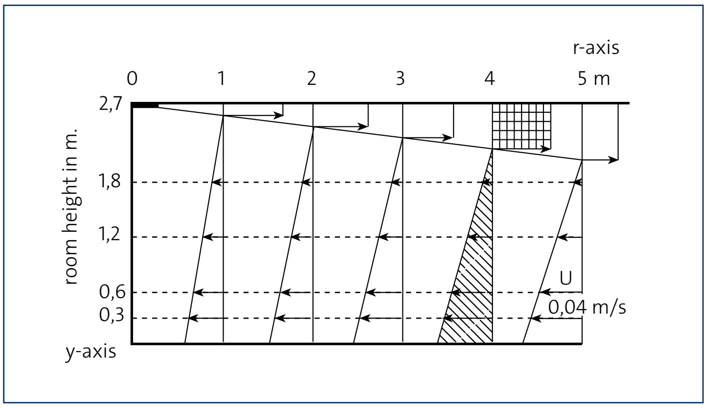

Fig. 3.1 Velocity increase return vortex in the x-direction radial pattern

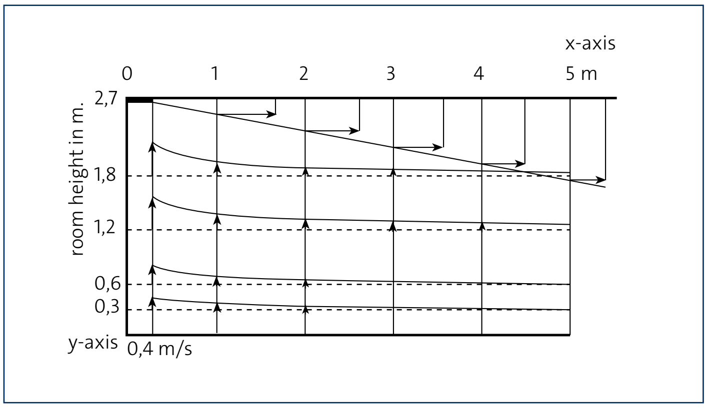

Fig. 3.5 Velocity increase return vortex in the y-direction plane pattern

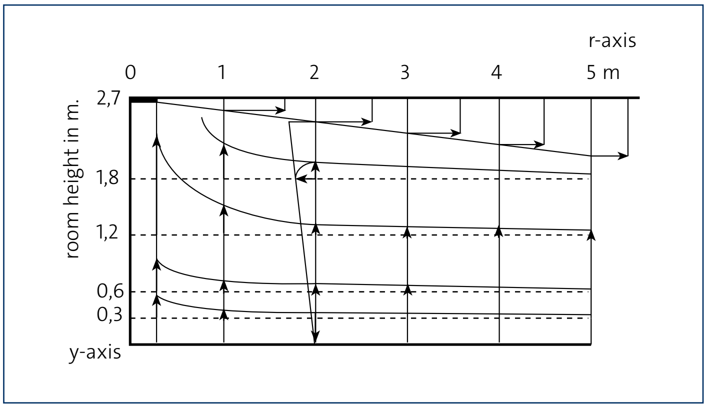

Fig. 3.2 Velocity increase return vortex in the y-direction radial pattern

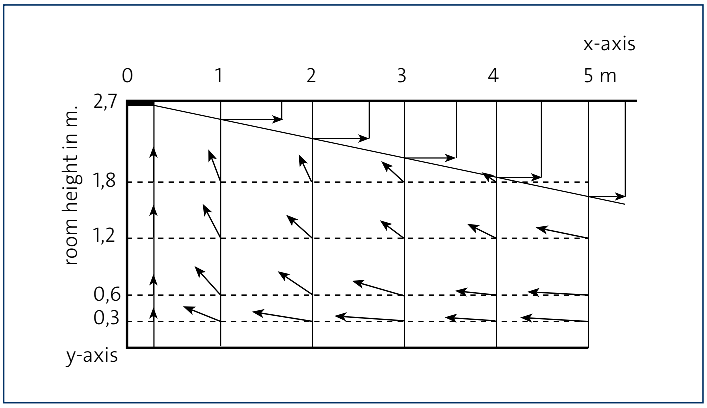

Fig. 3.6 Velocity increase return vortex plane pattern

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.

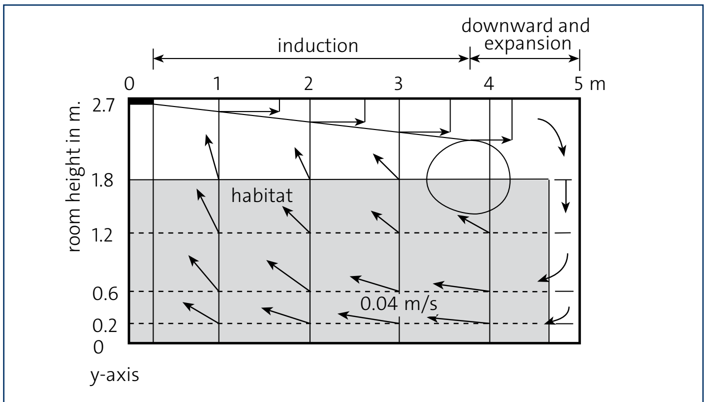

Fig. 4.1 Flow picture radial pattern

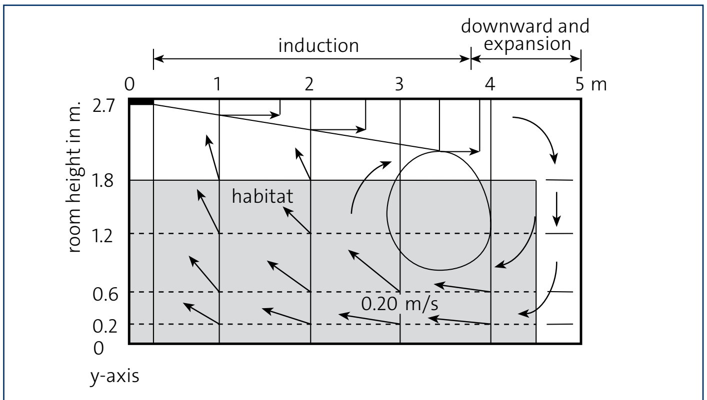

Fig. 4.2 Flow picture plane pattern

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.

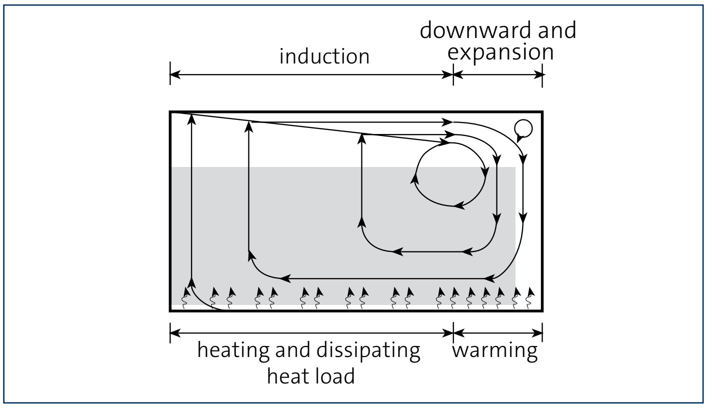

Fig. 5.1 Even heat load

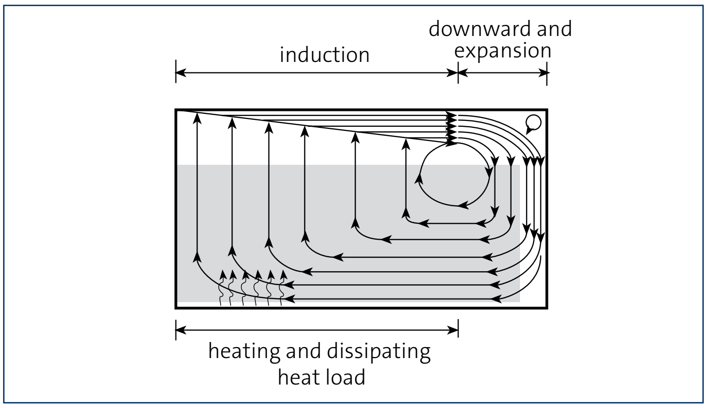

Fig. 5.2 Concentrated heat load

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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).

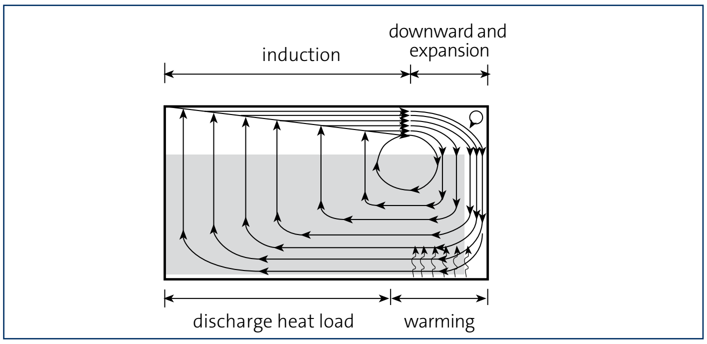

Fig. 5.3 Heat load in the downward area (weak source)

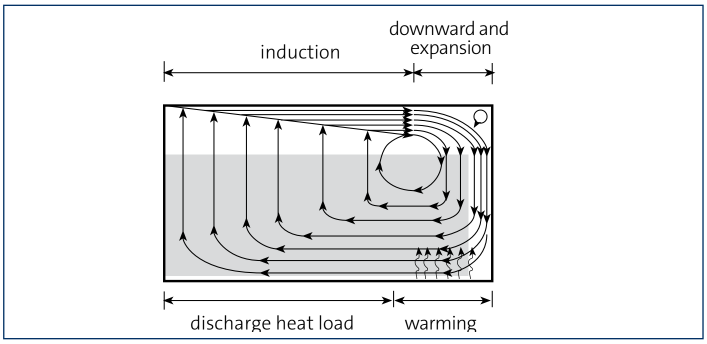

Fig. 5.4 Heat load in the downward area (strong source)

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: $\tan c = \frac{b}{h - b}$

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.

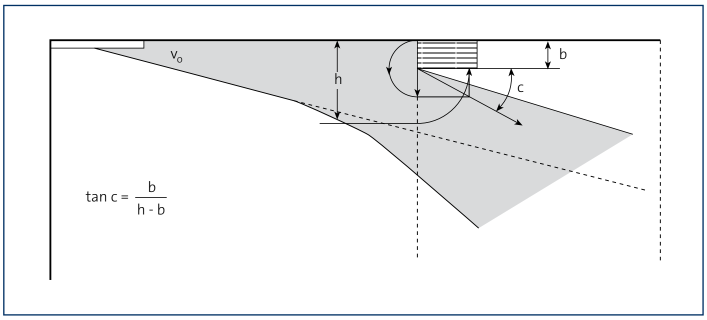

Fig. 6.1 Beam in air flow

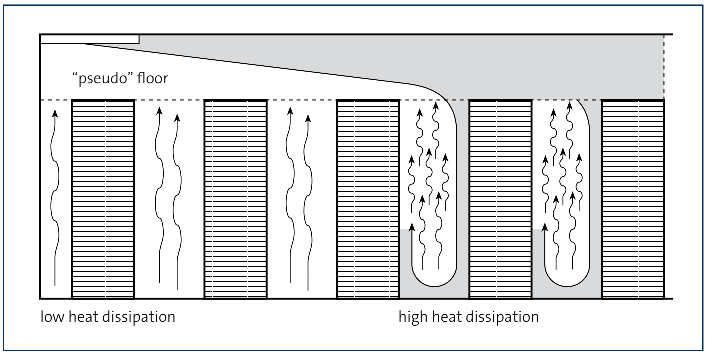

Fig. 6.2 Obstacles perpendicular to the return vortex

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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