Some limitations to ventilation/air distribution and some novel air distribution methods.

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Topics

-Basic concepts

-Puging flow rate

-Dilution capacity

-Deliver capacity

-Necessary conditions for generating unidirectional flow

-Draft

-Passive chilled beams

-Air distribution by varying flow rates

-Air distribution by colliding jets

-Air distribution as an architectural element

A ventilation system delivers a flow rate of air which is less contaminated than the indoor air

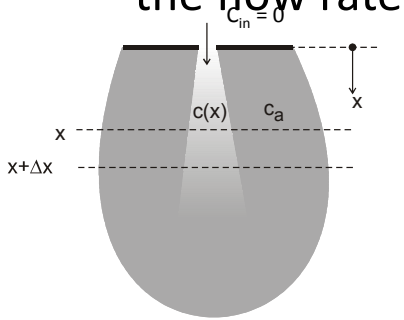
Flow rate is the basic physical property and therfore it is natural to quantify the performance of a ventilation system in terms of a *flow rate.*

A ventilation company deliver a fan which can transport a certain flow rate into a room. Sometimes they say that they deliver a *ventilation capacity*

From the perspective of ventilation this flow rate provides a *dilution capacity* of a contaminant*

* By a contaminant is ment a gas, particles, heat…….

A first introduction to Deliver Capacity Deliver capacity is *not* dependent on the flow rate

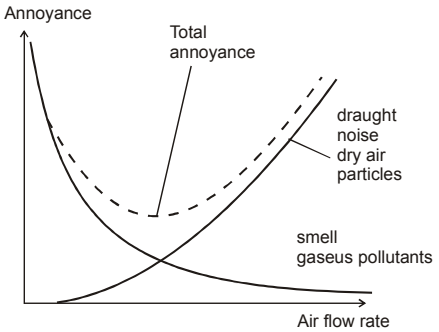


A room is filled with a uniform concentration C_a of a contaminant. Clean air, $C_{in} = 0$, is supplied to the room as a jet.

Question: What is the concentration C(x) in the supplied air at position x in relation to the concentration the ambient?

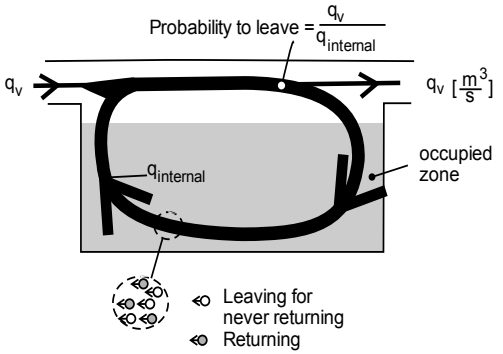
The concentration is dependent on entrainment ambient air into jet

There are side affects related to deliver of a flow rate to a room



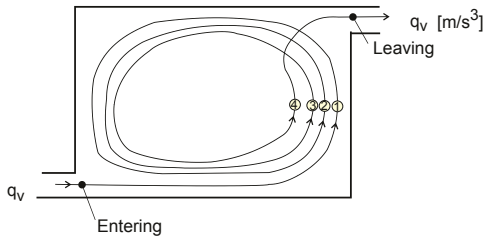
Pros- and cons

Properties of a mixing system



Due to entrainment, q_e, into the air stream generated within the room by the supply of air the ventilation system *itself* generates an internal flow rate, $q_{internal} = q_v + q_e$, which is greater than the ventilation flow rate. Therefore probability to leave is less tnan one. Therefore ……

That the probability to leave is less to one implies….

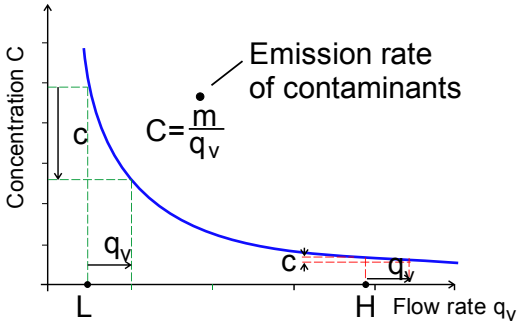


A ”particle” entering the room will make several turns within the room before it leaves the room

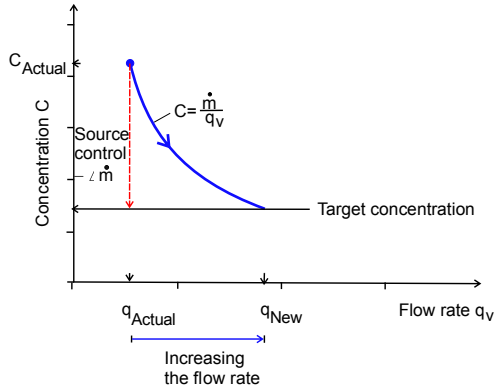
There is a flow of two populations of air in the room. One population leaving the room for never returning, *the purging flow rate,* and one population circulating within the room. It is the purging flow rate that ventilats the room and its maximum value is equal to the ventilation flow rate q_v.

By using tracer gas technique one can discriminate between the two poluations. By employing *tracer gas technique* one obtains the purging flow rate.

Marginal revenue of dilution at different flow rates



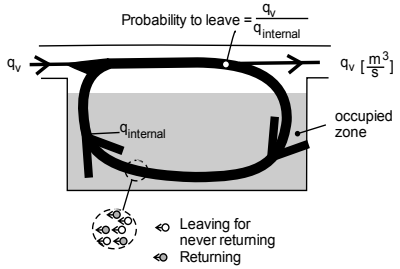
Reduction of concentration
Dilution versus source control



The shortest distance for reduction of concentration is by source control. However the relative cost for reduction by increasing flow rate or by source control must be considered.

How to create an unidirectional flow ?

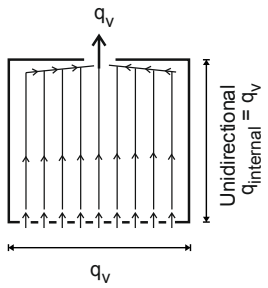
The probability to leave = $\dfrac{1}{1+\dfrac{q_e}{q_v}}$



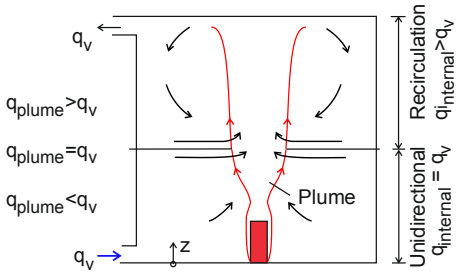
-To avoid recirculation the probability to leave must be equal to 1

-Therefore one has to control the entrainmnet q_e

Solution 1: Make the whole room to a supply duct



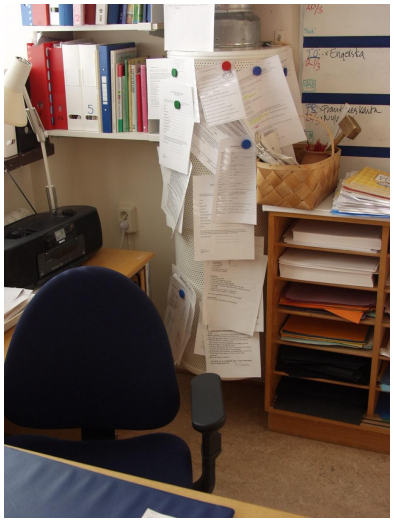
Solution 2
Use the properties of stratified flow



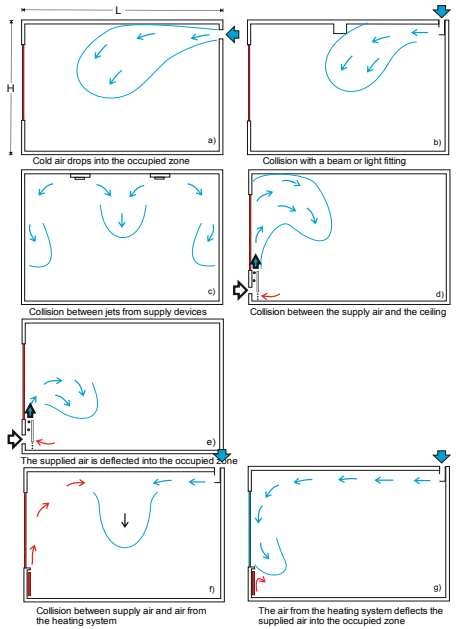
Draft

People cannot stand draft for a longer time period and thefore people take actions if the draft is not eliminated……

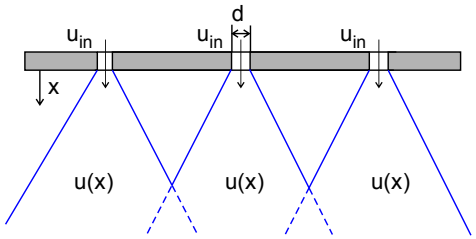
To eliminate draft a supply device has been converted into a notice board !

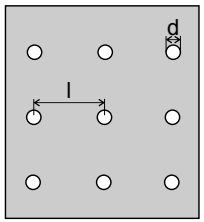


Situations where draft may occur

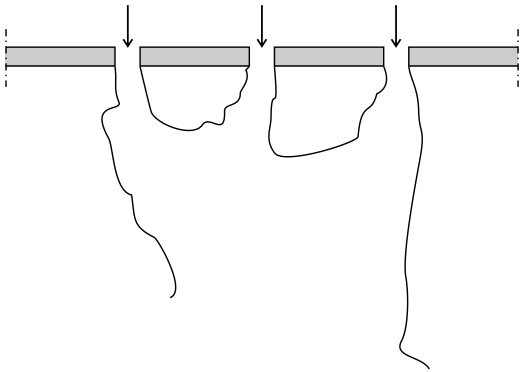


Perforated ceilings



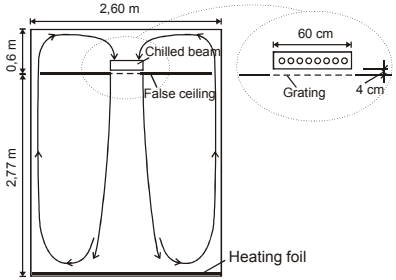


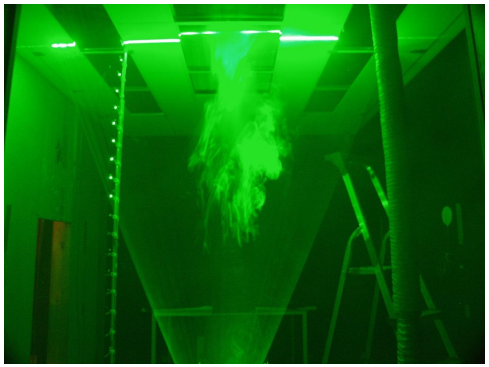
Merging of jets may generate higher velocities in the centre of a perforated plate

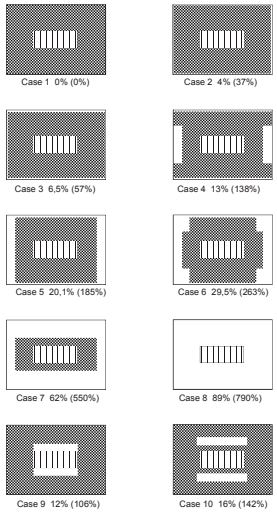


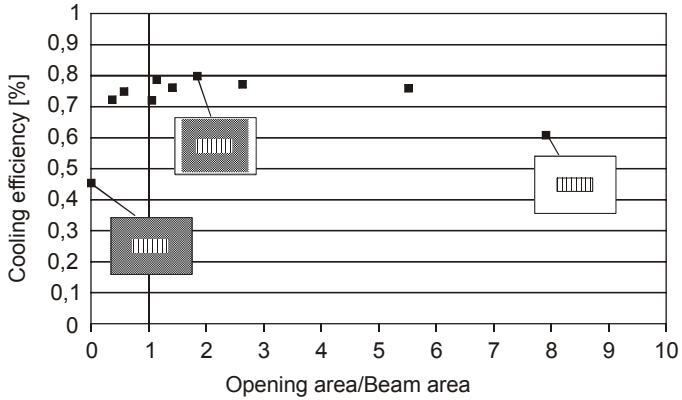
Passive chilled beams mounted in ceilings

What opening sizes are required in the ceilings to generate a proper cooiling ?

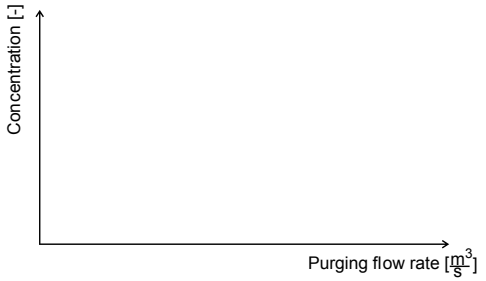




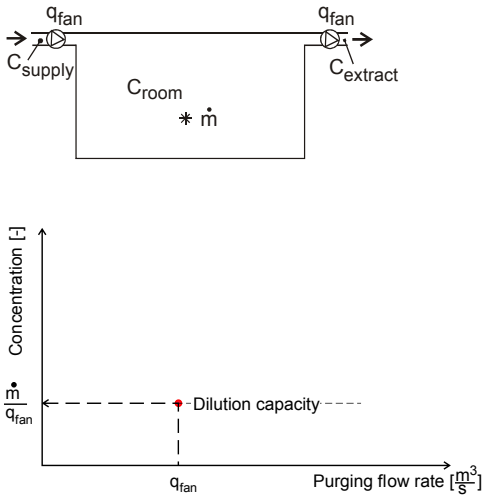


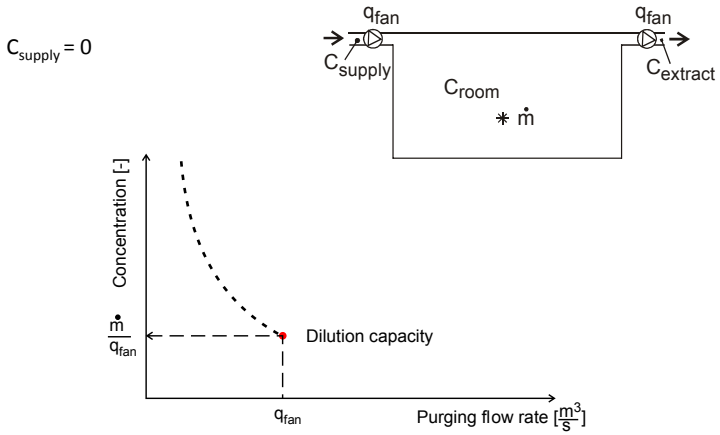


Graph for showing the performance of Mixing ventilation at different conditions

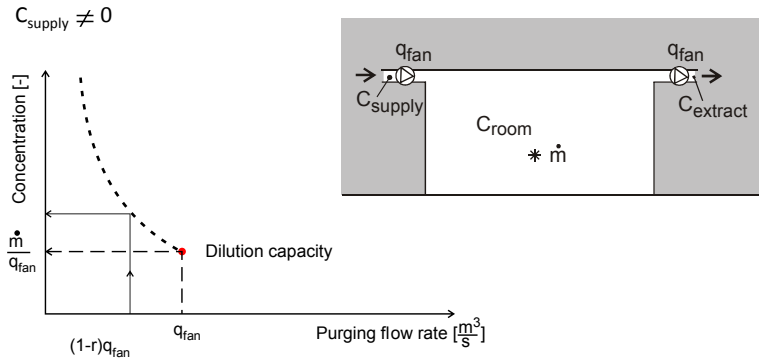


Purging flow rate is the flow rate that ventilates and it is not always equal to the flow rate supplied by the fan bu





Reduction in dilution capacity due to a contaminant in the ambient

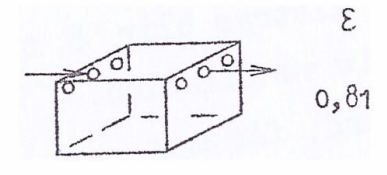


Purging flow rate = $q_{fan}(1-r)$
$0 \leq r \leq 1$

r =

Loss of supplied air

Isothermal supply. Supply terminal located directly opposite to the extetract terminal



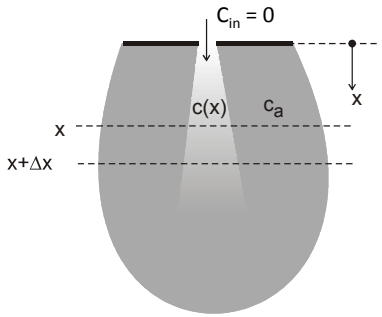
In the figure above about 20 % of the supplied air goes directly from the supply terminal to the extract terminal. I have experinced cases where about 50 % of the the supplied air goes directly from the supply to the extract terminal. When the supplie air is heated it may be worse

Note The figure is from a test made by Professor John Rydberg 1947 .
Prof. John Rydberg worked at the Royal Institute of Technology in Stockholm Sweden

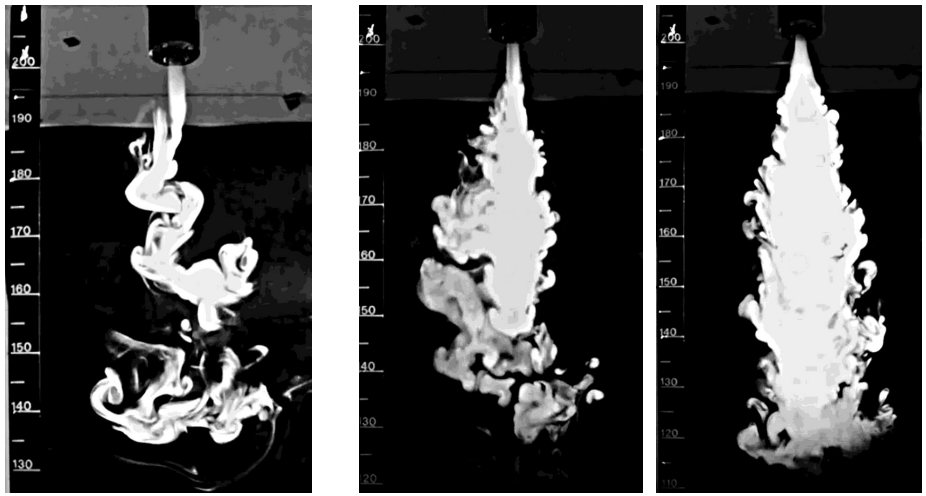
Deliver capacity

1.Generate a stable jet that penetrates to the target region

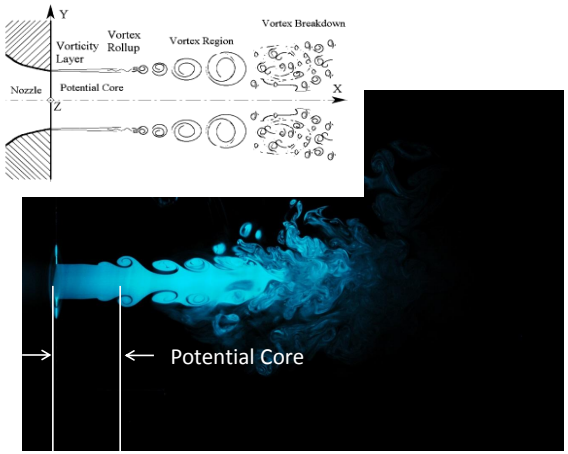
2. Evolution of the concentration in the jet relative to the ambient



Exampel of unstable and stable jets

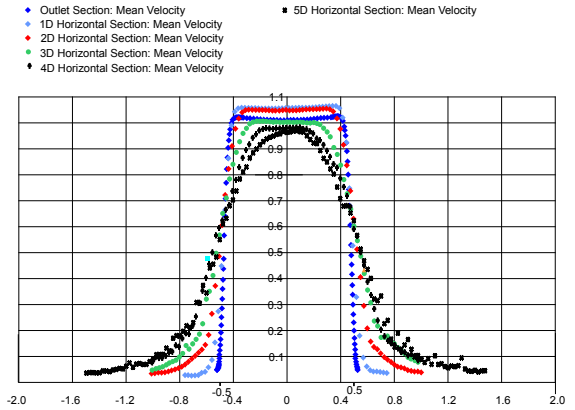


Close up of a jet



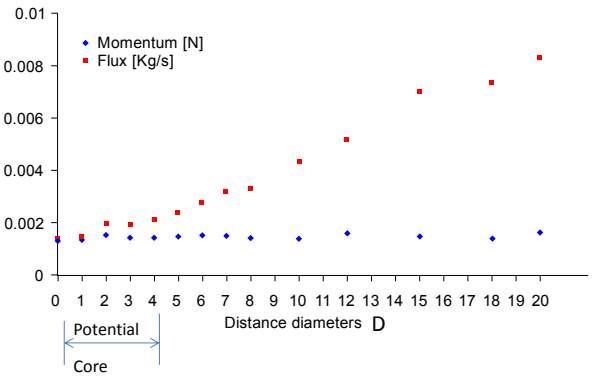
Visualization close to the supply

Mean velocity

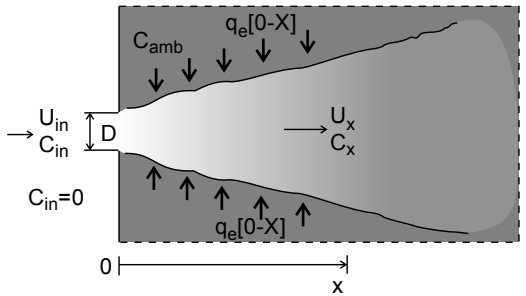


D is the diameter of the nozzle

Force and flow rate along centre line



Concentration in the jet relative to the ambient

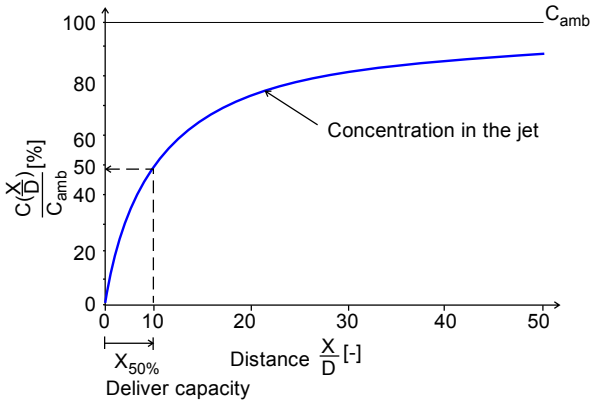


Assuming there is no pressure difference between the positions 0 and x then the momentum and mass balances give the relation

$$\frac{C(x)}{C_{amb}} == (1 - \frac{U(x)}{U_{in}})$$

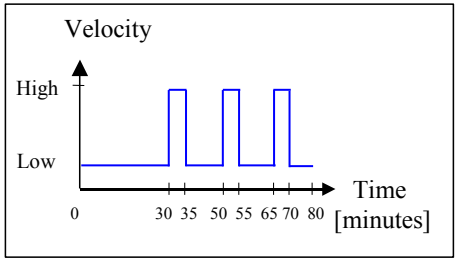
$q_e[0 - X]$ is the inflow from the ambient, entrainment, into the jet during the diststance from 0 to X.

An example of a defintion of a deliver capacity



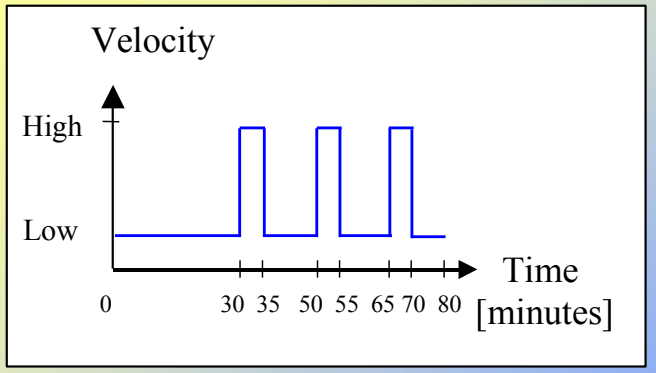
Varying ventilation flow rate

Intermittent cooling



Oscillating flow

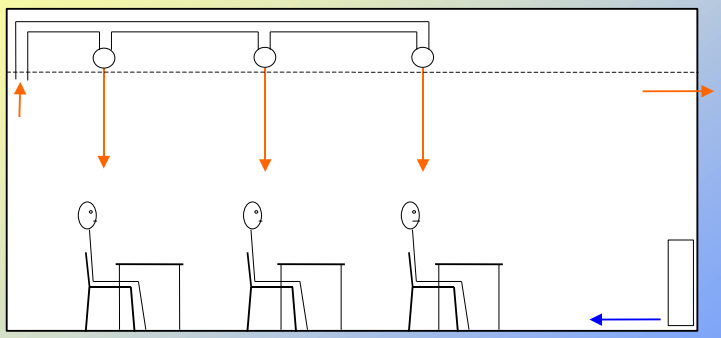
Intermittent cooling



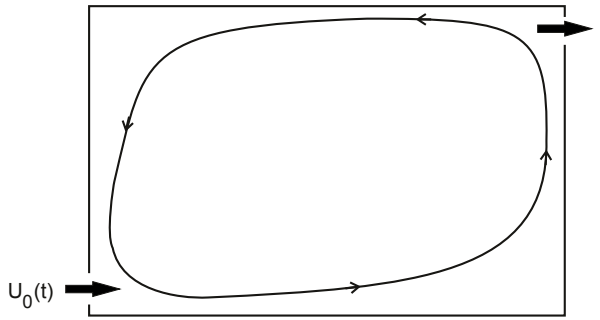
- cool without causing draught

- influence affect and cognitive performance

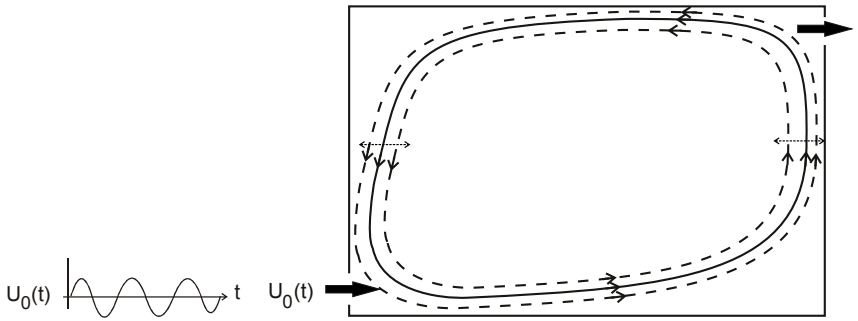
High velocity system III



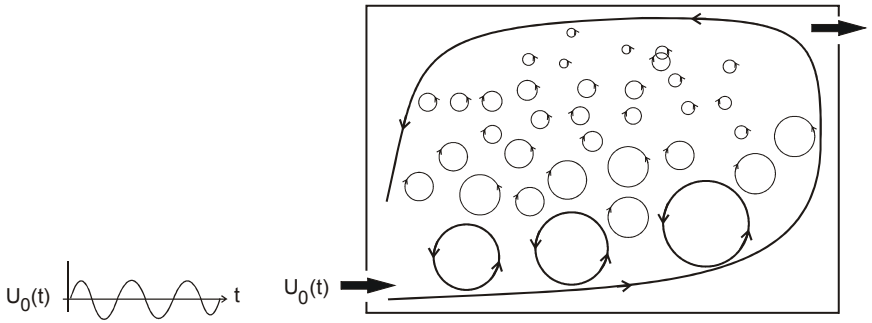
Steady ventilation flow rate
A Convection loop is generated



Large scale effect of oscillating flow
The convection loop oscillates



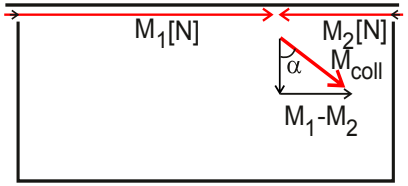
Small scale effect of oscillating ventilation flow
Vortices are generated which penetrate into the occupied zone



The stagnation disappears!

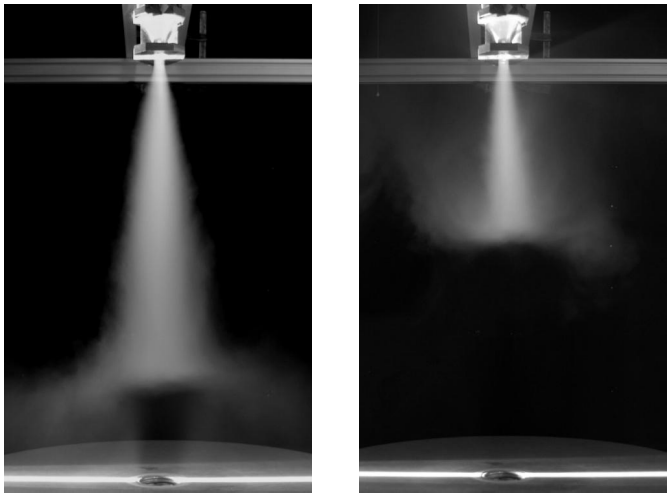
Air distribution by means of colliding jets and air distribution as an architectural element

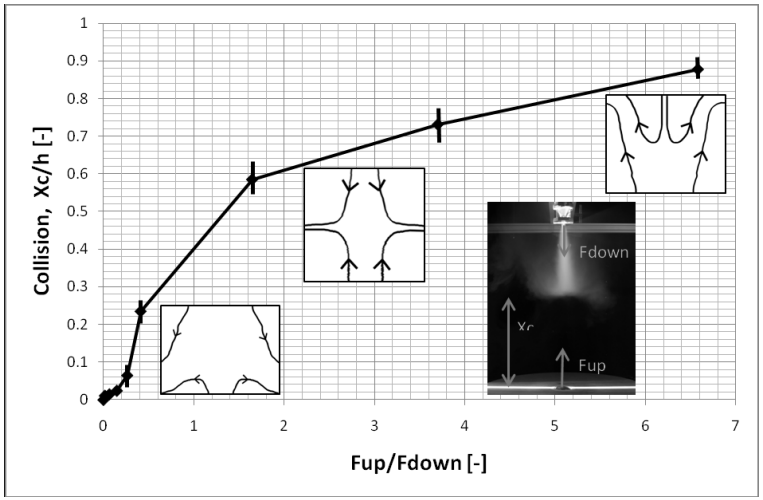
Two dimensional jets
One can control the direction of the jet genrated by a collision



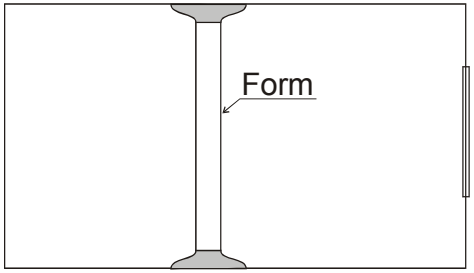
$$M_{coll}=M_1+M_2.\ \sin\ =\frac{M_1-M_2}{M_1+M_2}$$

Two round jets blown against each other

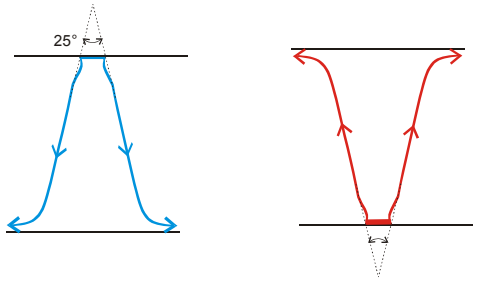




A pillar can both be a support for a construction or an element in forming a passage



Why not form a passage of pillars of jets



Colliding jets can generate air fountains!

Thank you for your attention!