The Characteristics of Wall Confluent Jets for Ventilated Enclosures

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PORTUGAL

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Introduction

- The method of supplying conditioned air to a room or a zone in a building has a direct impaction on:

  - The thermal comfort in the zone
  - The air quality in the zone
  - The energy consumption of the HVAC system
 - The facility management schedules

Definition

- **In ventilation, a confluent jet is formed, when circular jets issuing from different apertures in the same plane flow in parallel directions, and at a certain distance downstream they coalesce and move as a single jet .**

- **Two type of configurations: (a) Ceiling level (b) floor level (blowing to the wall)**
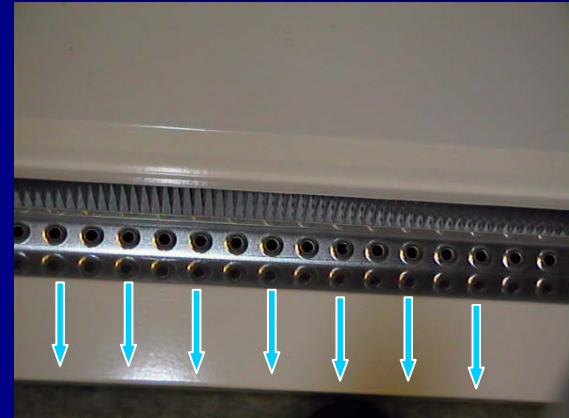
Spacing: Confluent Jets

- The distance from the outlets at which the jets merge depends on the distance between and the area of the outlets.

(a)   (b)   (c)
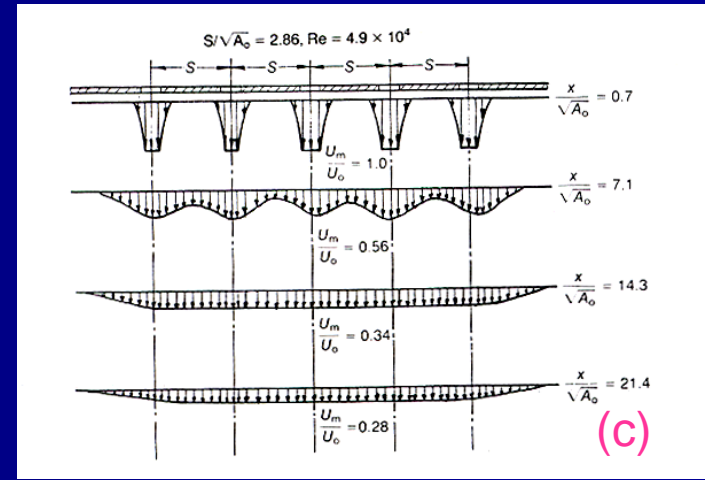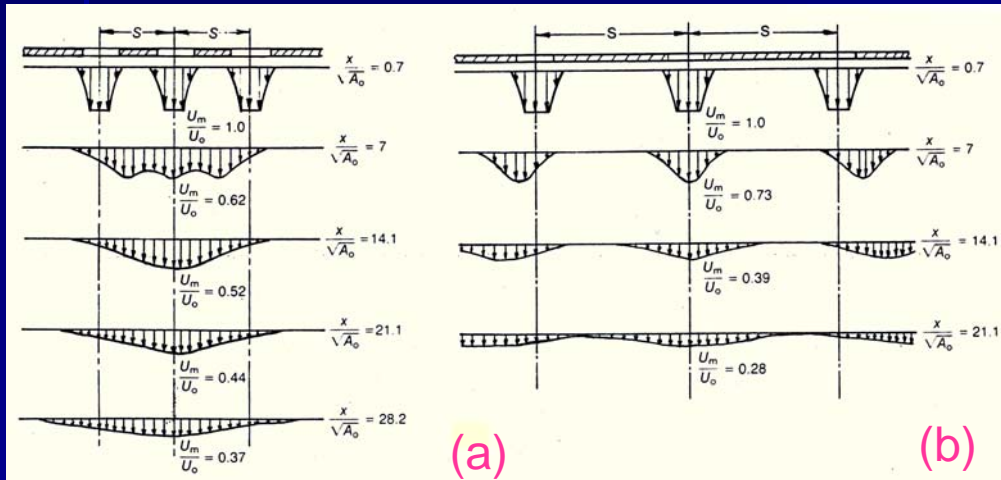
Velocity profiles for confluent circular jets. (a) Closely-spaced $S/\sqrt{A_o} = 2.8, \ \text{Re}=8\times10^4$

(b) widely-spaced $S/\sqrt{A_o} = 5.6, \ \text{Re}=5.8\times10^4$ Awbi (2003)
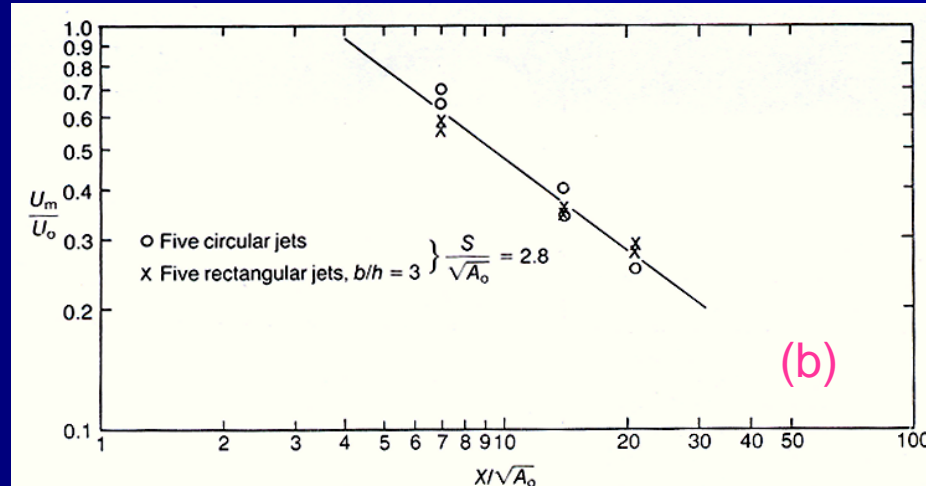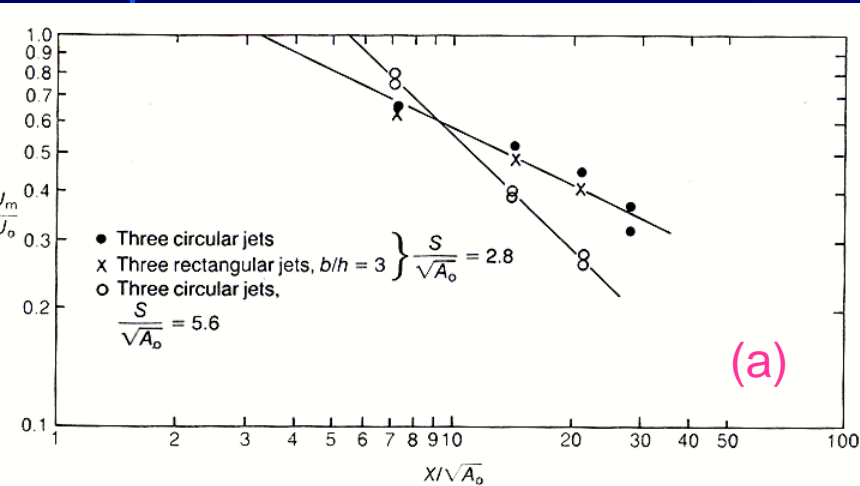
(c) Velocity profiles for five confluent circular jets $S/\sqrt{A_o} = 2.86, \ \text{Re}=4.9\times10^4$.

Definition: Confluent Jets /Con...

Awbi (2003)

(a)

(b)

(a) Velocity decay for three confluent jets (circular & rectangular openings).

(b) Velocity decay for five confluent jets (circular & rectangular openings).

MECHANICAL VENTILATION

Mixing Air Distribution

A mixing ventilation system aims to dilute the indoor pollutants by mixing fresh air with room air. Usually, an air jet is supplied at high level to achieve the mixing and provide acceptable velocities at low level. Ventilation effectiveness < 100% (<50% in SI system).

Displacement Ventilation

Here, air is usually supplied directly into the occupied zone at low velocity and heat and indoor pollutants are displaced upwards due to the plumes rising above heat sources in the room. The ventilation effectiveness is usually >>100% (>> 50% in SI system).
Wall DV units are only suitable for small cooling loads (<40W/m^2) and for higher loads chilled ceiling panels or chilled beams are used to supplement the cooling.

MECHANICAL VENTILATION /Cont..

Confluent Jets Ventilation

- Here a jet of air is supplied downward on to the floor with quite a high momentum (i.e. resembling mixing ventilation) but the velocity decays very rapidly away from the point of impact on the floor. These method is suitable for cooling and heating. The ventilation

- Effectiveness is usually >>100% (>> 50% in SI system).

- Confluent jets units are suitable for high cooling loads (>40W/m^2 Up to 67W/m^2 was tested in Reading climate chamber).

Confluent jets – Benefits

- It is known that for example wall-mounted displacement ventilation systems are more efficient than mixing ventilation systems but have their own limitations, e.g. not suitable for heating. The confluent jet systems have the potential of low energy air distribution and at the same time do not have the limitations of the displacement systems.

- The reason is controlled balance between thermal forces and momentum forces.

Experiments

- **The experiments were carried out at a fixed air flow rate and fixed temperature difference between the supply and room air in the cooling mode.**

- **The aim of the velocity measurements was to establish a basis for dimensioning physical parameters for the use in the design of confluent jets ventilation systems.**

OBJECTIVES

- **The overall objective of this project is to evaluate the above system for HVAC applications and to improve existing designs using results from laboratory tests.**
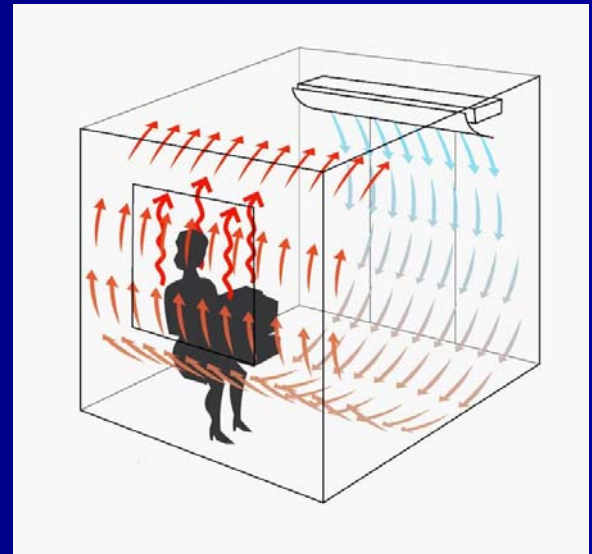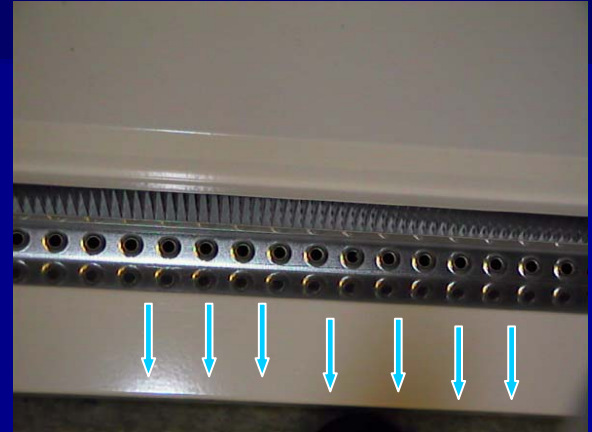
Procedure

- Test room (2.78m x 2.78m x2.3m height)
- The aim of the velocity measurements was to establish a basis for dimensioning physical parameters for the use in the design of confluent jets ventilation systems.
- During the tests, a flow rate of 25 l/s, supply temperature of 18°C and an average room temperature of 22°C were used.

The jet configuration

Fig.1. Schematic of wall confluent jets
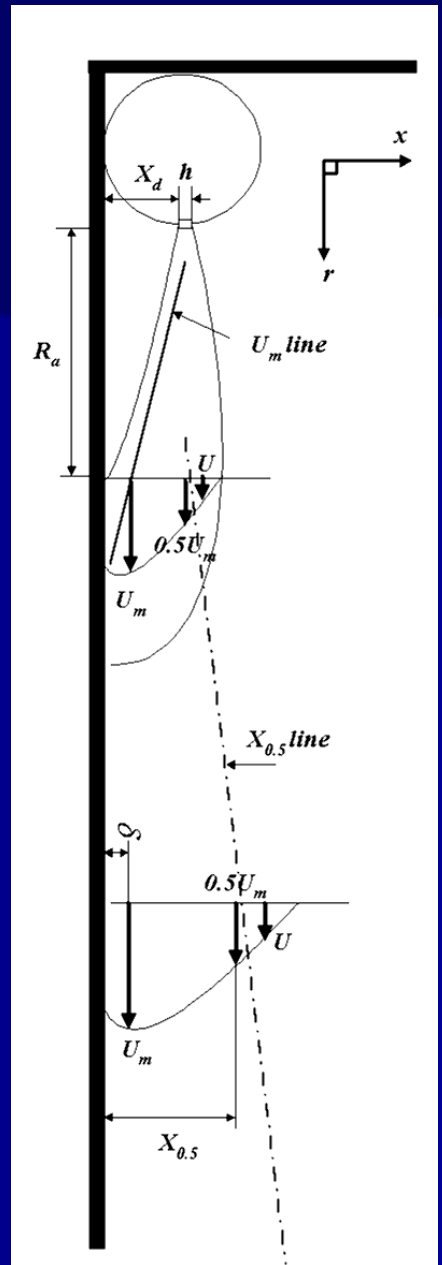
Measuring points
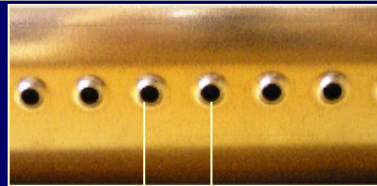
$S = 2h$

(a) Horizontal measurement   (b) Vertical measurement

Fig. 2. The measurement configuration of confluent jets

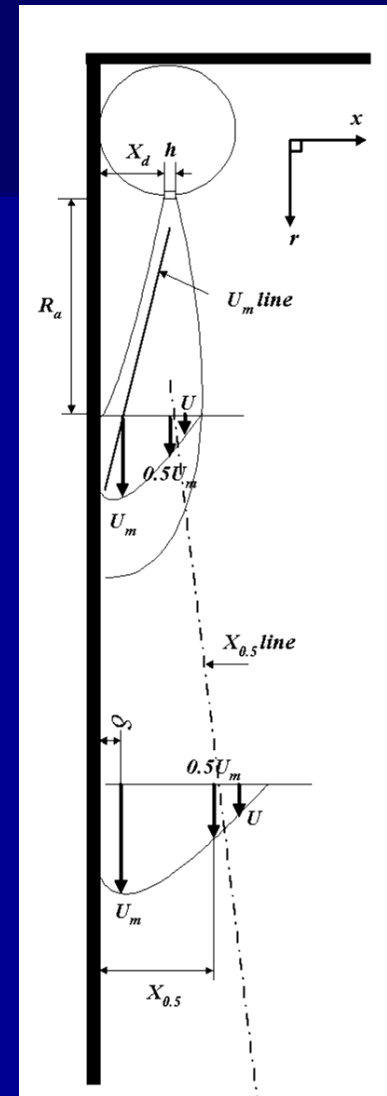# Fig. 3. Velocity profiles for confluent circular jets

(a) Near wall $(\sqrt{x/h} = 1.6)$ **(b) Centerline** $(\sqrt{x/h} = 2.9)$

$\dfrac{U_m}{U_o}$

$\sqrt{\dfrac{r}{h}}$

$\dfrac{U_m}{U_o}$

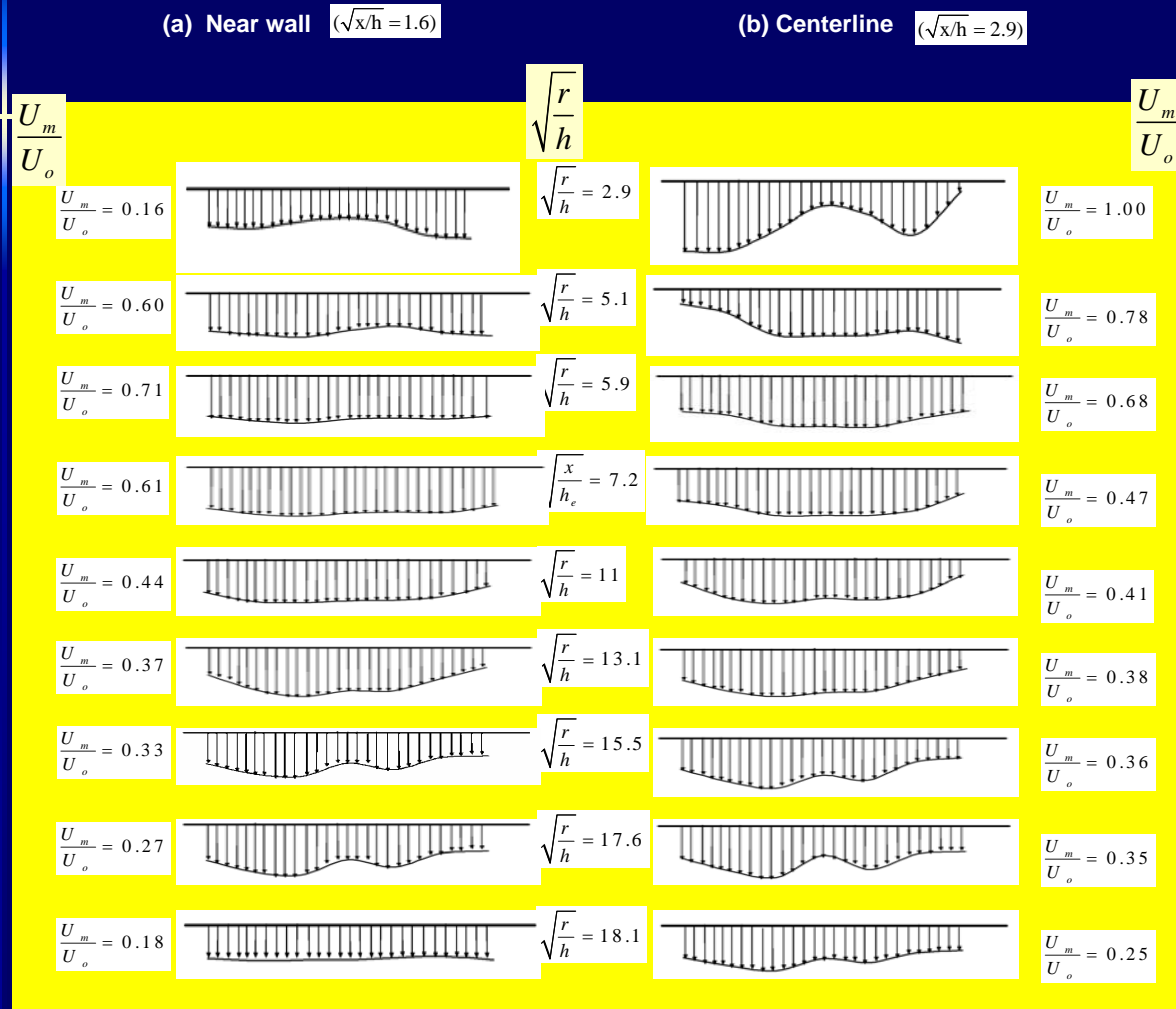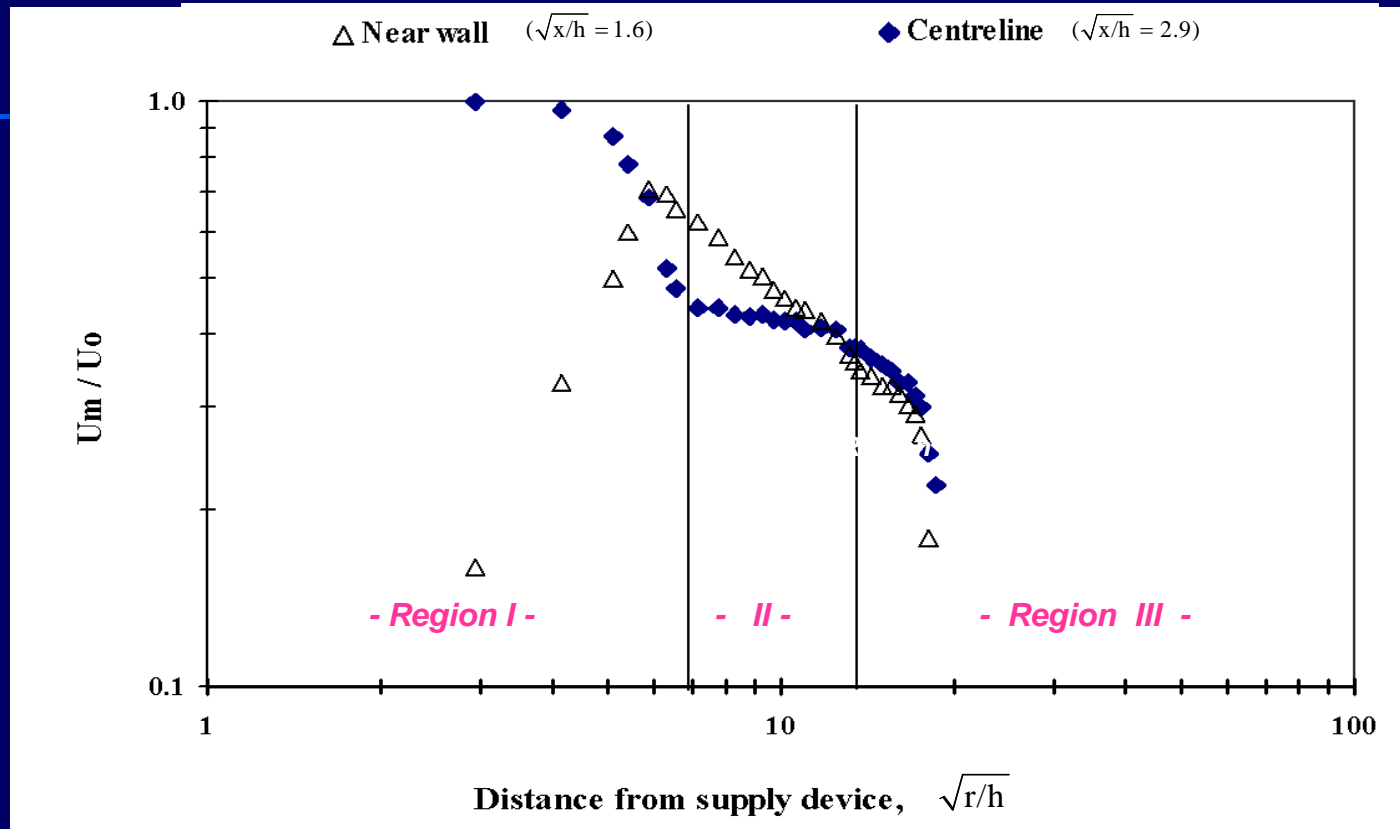| $\dfrac{U_m}{U_o}$			$\dfrac{U_m}{U_o}$
$\dfrac{U_m}{U_o} = 0.16$		$\sqrt{\dfrac{r}{h}} = 2.9$	$\dfrac{U_m}{U_o} = 1.00$
$\dfrac{U_m}{U_o} = 0.60$		$\sqrt{\dfrac{r}{h}} = 5.1$	$\dfrac{U_m}{U_o} = 0.78$
$\dfrac{U_m}{U_o} = 0.71$		$\sqrt{\dfrac{r}{h}} = 5.9$	$\dfrac{U_m}{U_o} = 0.68$
$\dfrac{U_m}{U_o} = 0.61$		$\sqrt{\dfrac{x}{h_e}} = 7.2$	$\dfrac{U_m}{U_o} = 0.47$
$\dfrac{U_m}{U_o} = 0.44$		$\sqrt{\dfrac{r}{h}} = 11$	$\dfrac{U_m}{U_o} = 0.41$
$\dfrac{U_m}{U_o} = 0.37$		$\sqrt{\dfrac{r}{h}} = 13.1$	$\dfrac{U_m}{U_o} = 0.38$
$\dfrac{U_m}{U_o} = 0.33$		$\sqrt{\dfrac{r}{h}} = 15.5$	$\dfrac{U_m}{U_o} = 0.36$
$\dfrac{U_m}{U_o} = 0.27$		$\sqrt{\dfrac{r}{h}} = 17.6$	$\dfrac{U_m}{U_o} = 0.35$
$\dfrac{U_m}{U_o} = 0.18$		$\sqrt{\dfrac{r}{h}} = 18.1$	$\dfrac{U_m}{U_o} = 0.25$

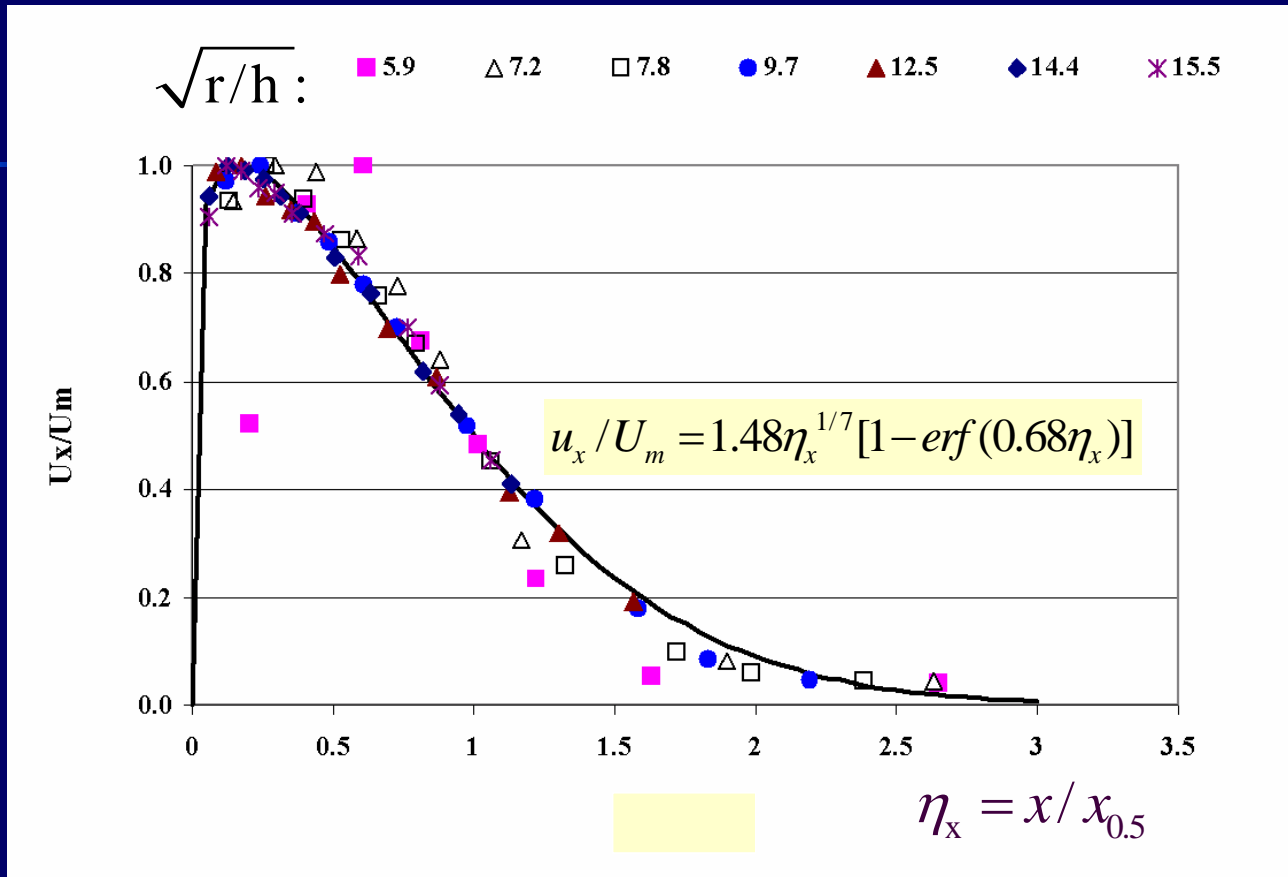# Fig.4. Three regions of wall confluent jets

The flow within these jets may be classified into three regions:
Region I : Free Jet Region
Region II: Coanda Effect Region
Region III: Wall Jet Region.

Fig. 5. Non - dimensional velocity profiles of wall confluent jets

The empirical equation for the non- dimensional velocity profile of a plane wall jet is expressed as above and there x is the distance form the wall and x0.5 is the distance where the jet velocity is a half of maximum velocity.

Fig. 6. Spreading rate of the wall confluent jet
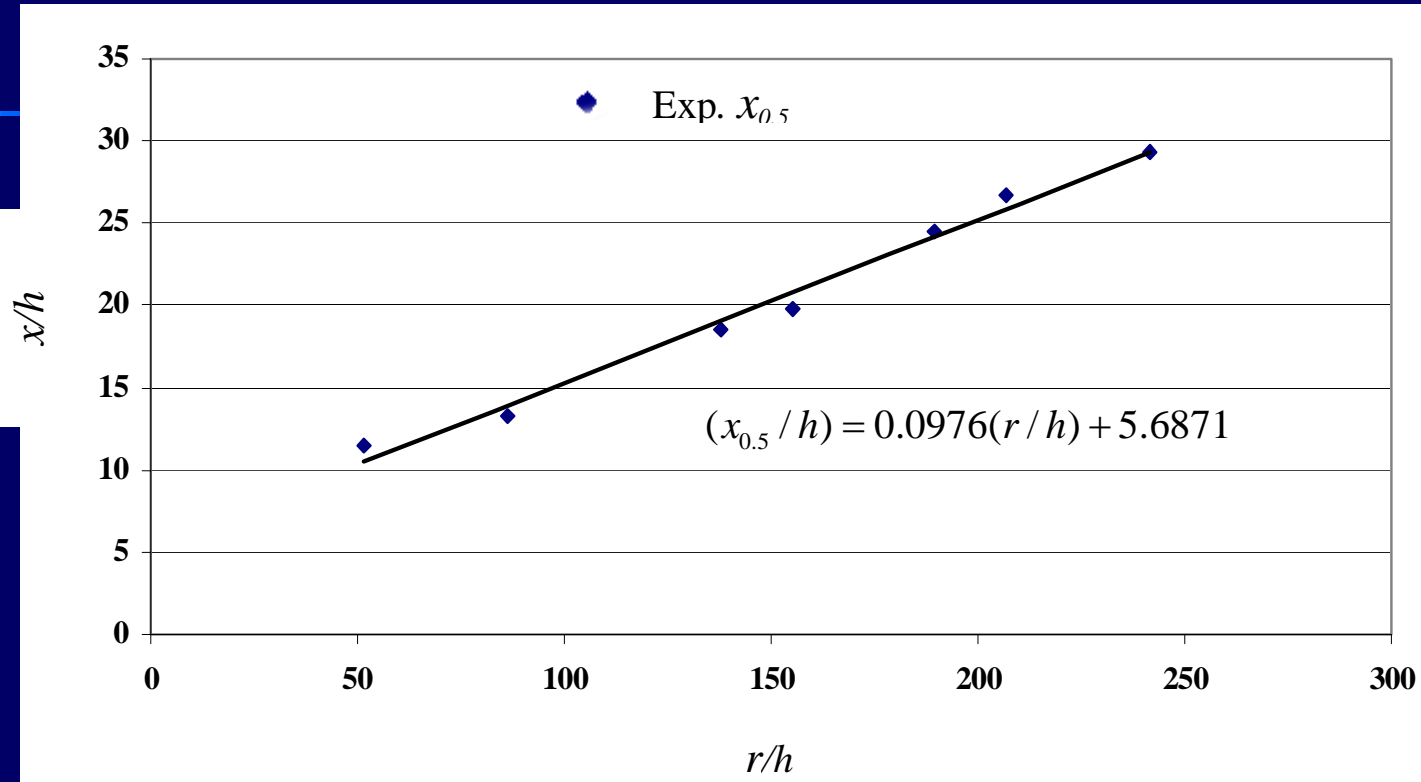
The spreading rate of the wall confluent jets is 0.0976 which is similar to that of the radial wall jet, i.e. given in Launder and Rodi (1983):

$$dx_{0.5} / dr = 0.09 \pm 0.005$$
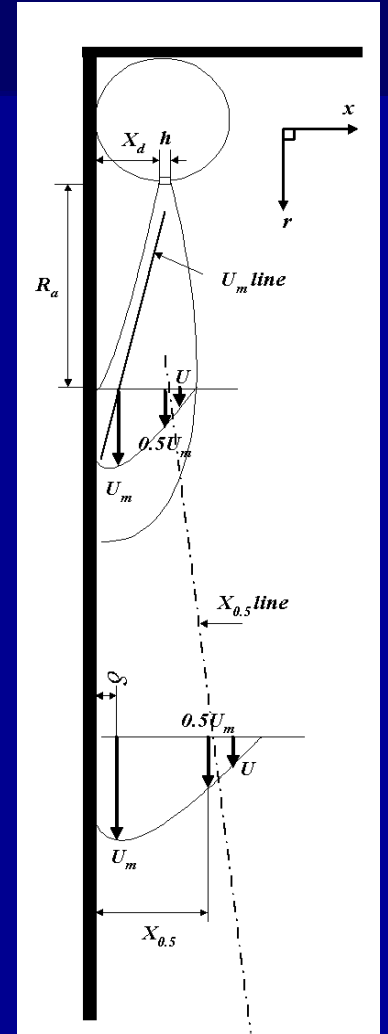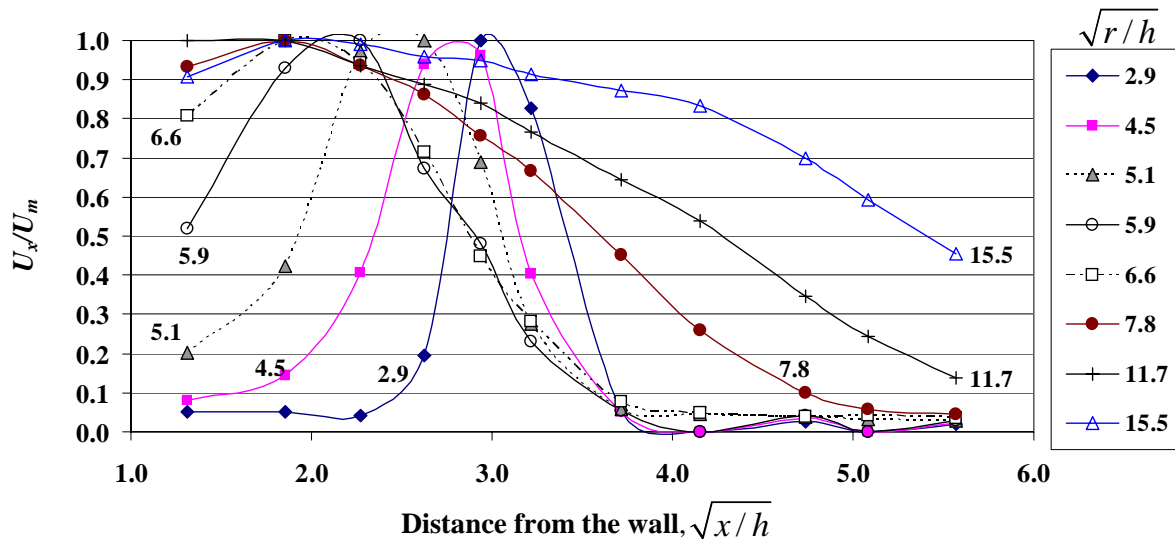
Comparison of wall confluent jets with other jets
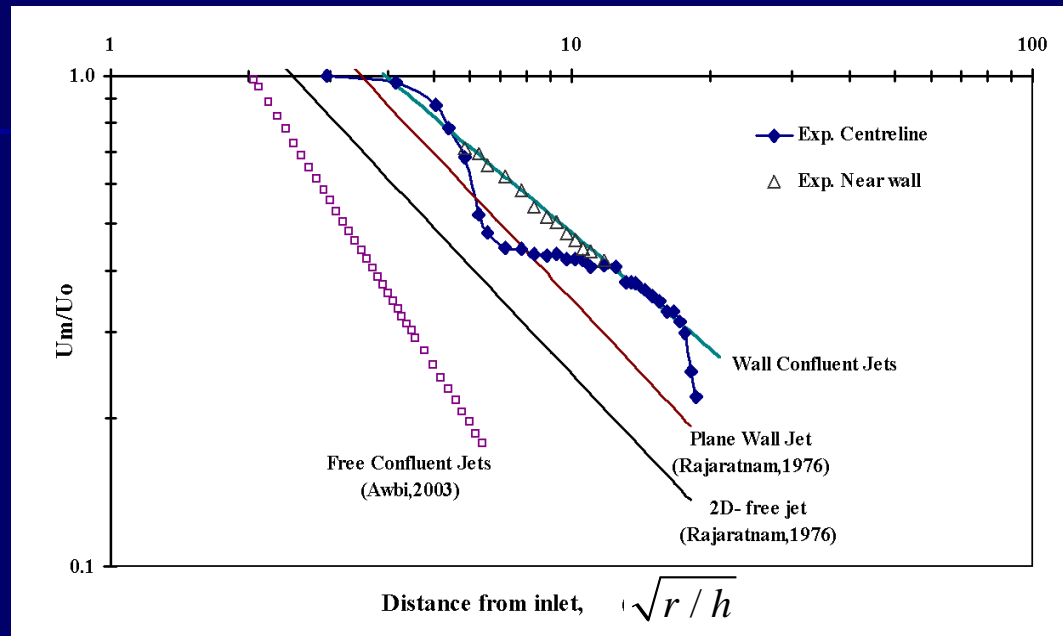
For a plane free jet : $U_m/U_o = 2.47/l_c$

For a plane wall jet : $U_m/U_o = 3.50/l_c$

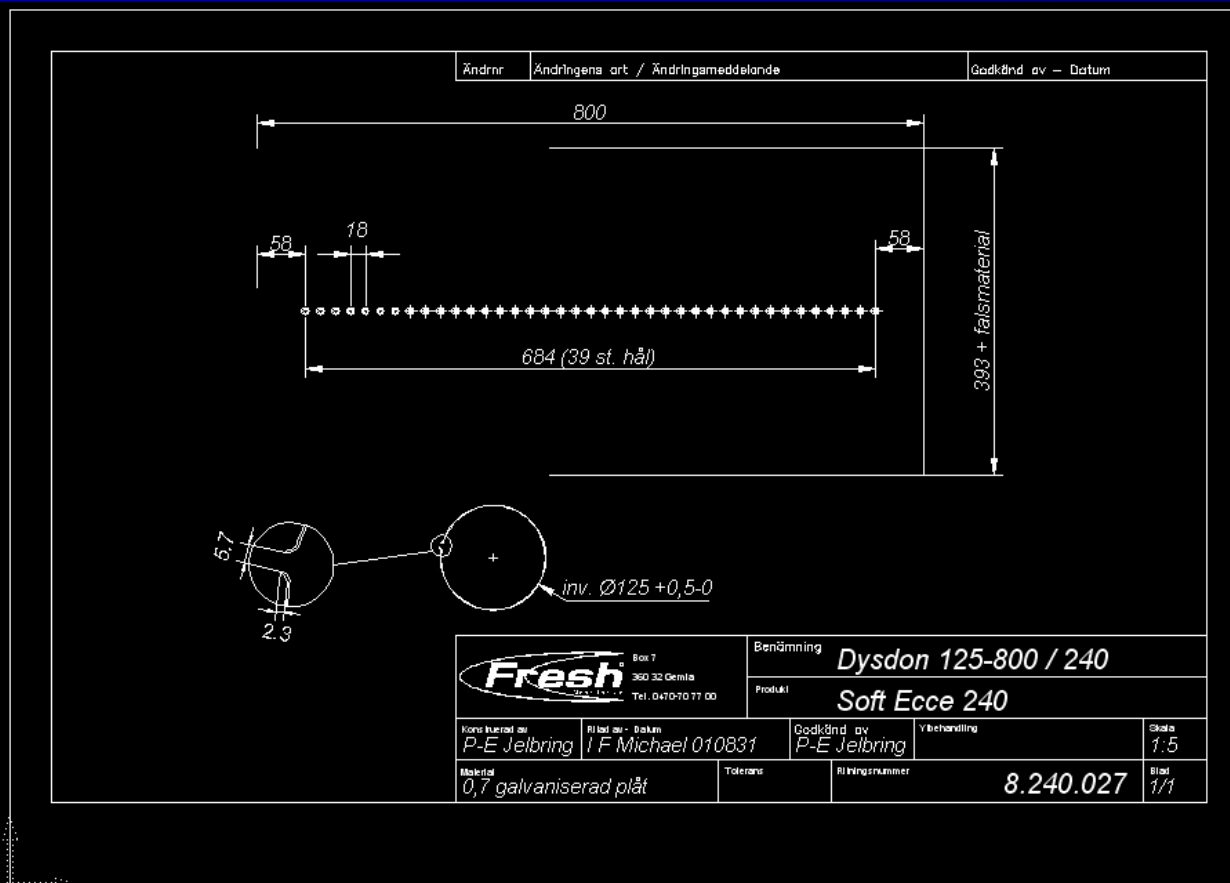For free confluent jets: $U_m/U_o = 2.887 l_c^{-1.5}$ where $l_c = \sqrt{r/h}$

For wall confluent jets: $U_m/U_o = 2.96(l_c)^{-0.79}$ For $\sqrt{r/h}$ >4

Fig. 7. The variation in horizontal velocity profiles at different distances from supply $\sqrt{r/h}$

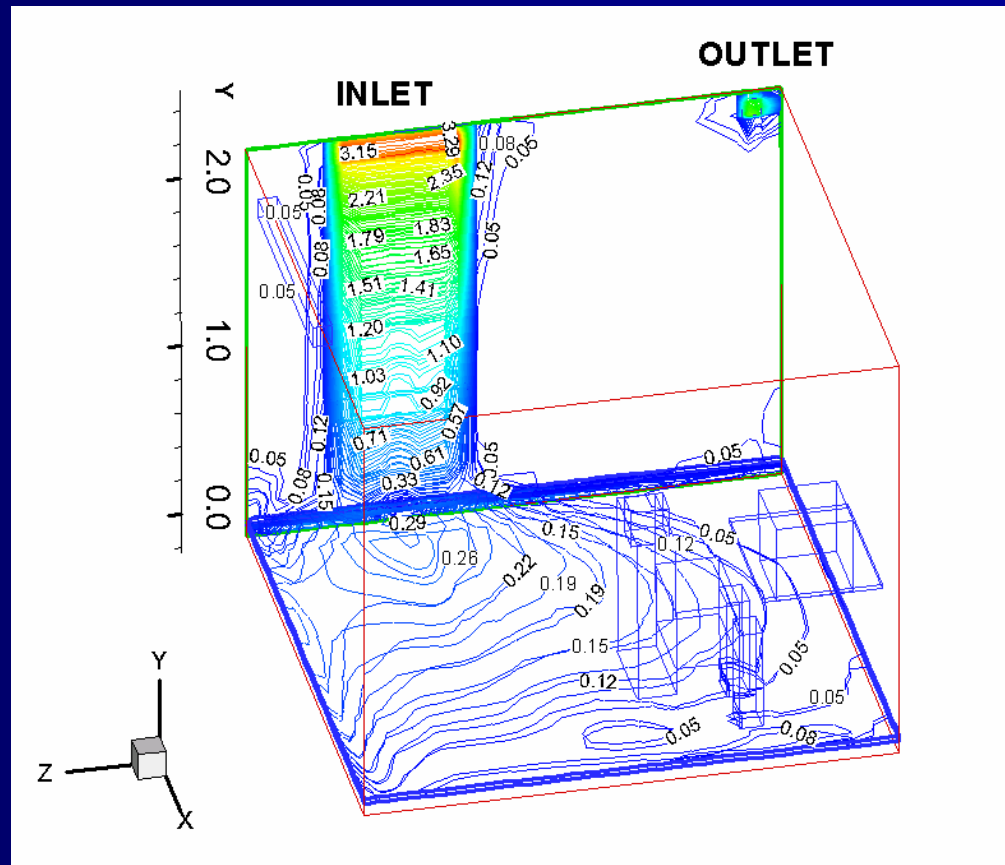# Experimental set-up & CFD modelling:

Confluent Jets

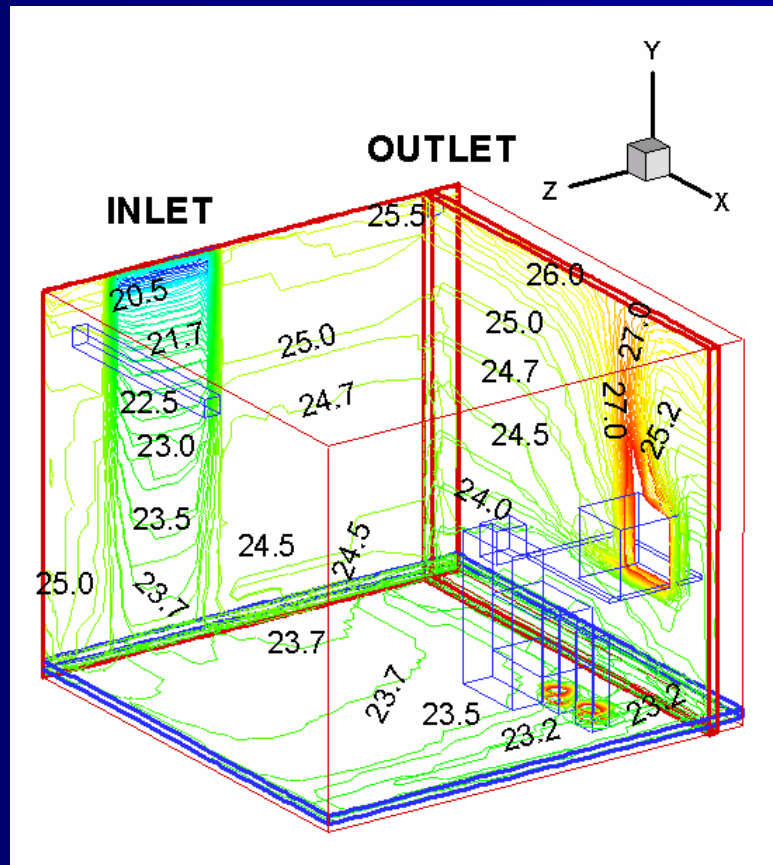# Experimental set-up & CFD modelling:

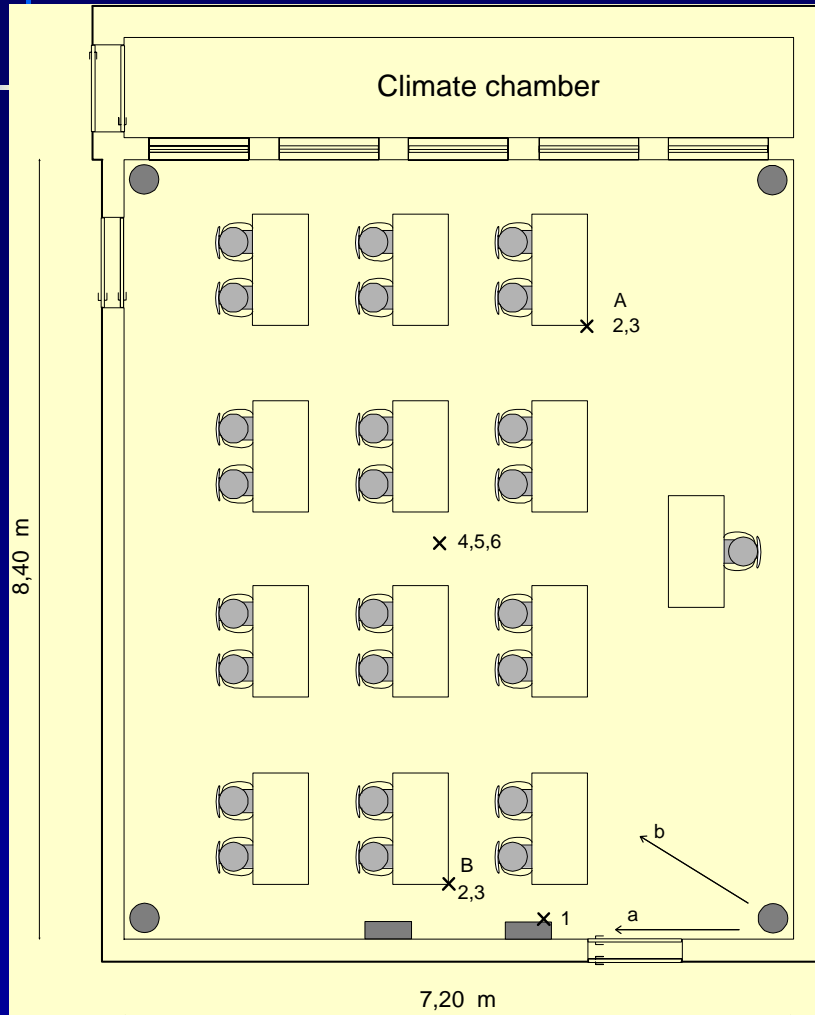## Confluent Jets / Con ...

Mannequin - Computer box & heated plate

Velocities, CFD

Temperatures , CFD

Measurements in BMG classroom, Gävle

Measurements in BMG classroom, Gävle

Air Exchange Efficiency [%]
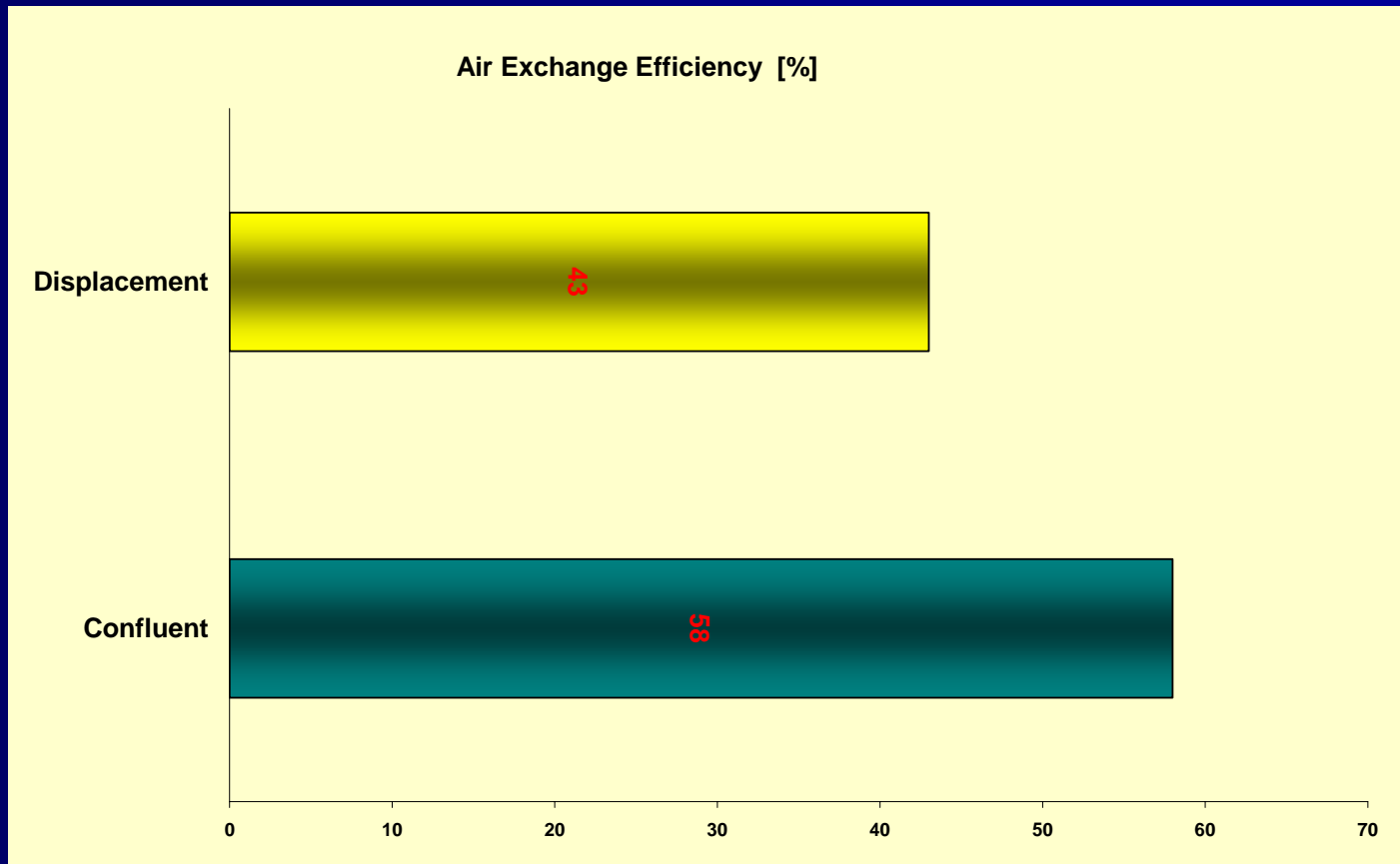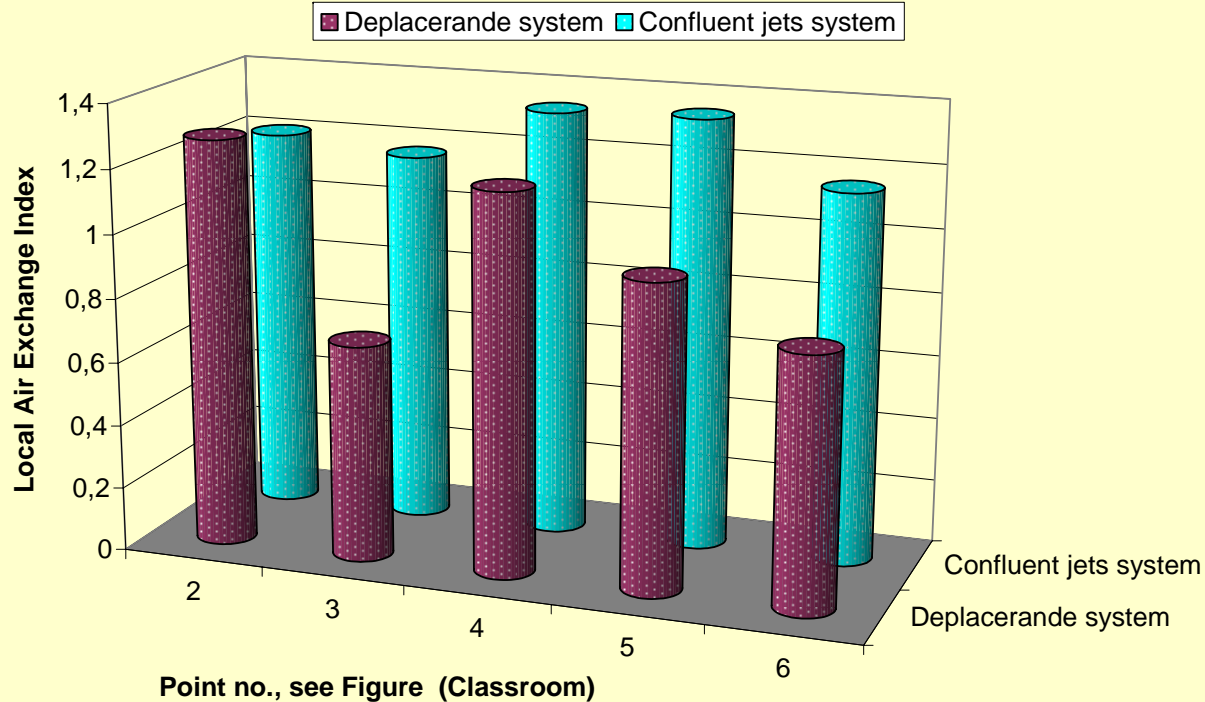
Measurements in BMG classroom, Gävle

Comparison between Displacement system and Confluent jets system in classroom with 4 supply terminals (one in each corner with 50 l/s)

Local Air Exchange >1

Good Air Exchange

Conclusions

- The flow field of the wall confluent jet is classified into three regions: Free jet region, Coanda effect region, Wall jet region.

- The wall confluent jets have a better self preservation characteristics than other types of air jets.

  - Overall, through comparison with the throw constant of the other jets, the slow diffusion of the wall confluent jet is due to the lower velocity decay. In other words, the jet momentum of the wall confluent jets can be more conserved than other jets.

- Wall confluent jets can successfully be used for both heating and cooling – a combined effect of mixing and displacement systems .