

## Air Motion and Emissions

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## Related Issues

- **Can we estimate emission from a surface with contamination sources?  
What are the challenges?**
- **pH, TAN, T, V...?**



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# Fundamentals

- **Characteristics of ventilation in Livestock Buildings**
- **Inlet air momentum, velocity decay and air speed at floor level**



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## Inlet air momentum, velocity decay and air speed at floor level



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## Isothermal Jet in air space

A surprising similarity among the shape of jets exists at a short distance from the inlet face, whether the inlet is round, rectangular, grille-like or a perforated panel.

Angle of Divergence: 20-24 deg

Free jet:  $X \leq 1.5 A_R^{0.5}$

Four zones in jet expansion:

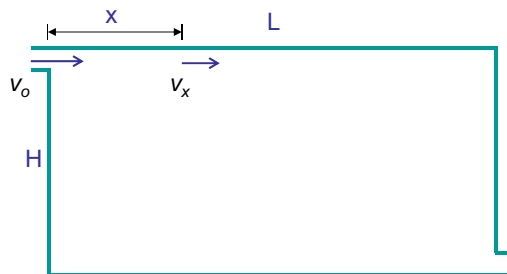
1. A short corne zone:  $x \leq 4d(h)$ ;  $v_x = v_o$
2. A transition zone:  $x \leq 8d(h)$ ;
3. A long zone: of full established turbulent flow;
4. A terminal zone



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## Jet velocity decay in a ventilated space



Axis symmetric jet

$$\frac{v_x}{v_o} = K_a \sqrt{\frac{A_o}{2x}}$$

Free wall jet

$$\frac{v_x}{v_o} = K_p \sqrt{\frac{h}{2x}}$$

Plan wall jet

$$\frac{v_x}{v_o} = K_p \sqrt{\frac{h}{x}}$$

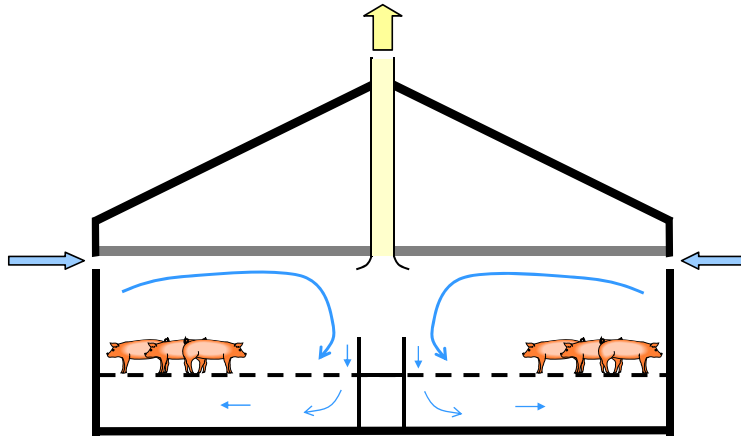


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## In systems with side wall inlet

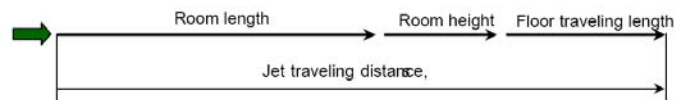
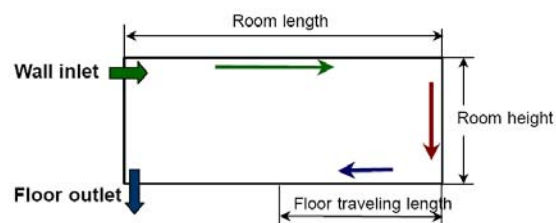
How to estimate floor air speed?



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## Estimate floor air speed based on inlet air velocity



Linearization of jet traveling distance



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### Estimate floor air speed based on inlet air velocity

$$u_s = u_o \cdot C_p \cdot \sqrt{\frac{h_e}{s + s_o}}$$

$$u_s = \frac{Re \mu}{\rho} \cdot C_p \cdot \sqrt{\frac{1}{h_e (s + s_o)}}$$

#### Estimate floor air speed using jet decay theory

- $C_p$  : velocity decay constant
- $Re$  :  $\rho u_o h_e \mu$



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### Estimate floor air speed based on inlet jet momentum

Hypothesis: Floor air velocity is function of

- Inlet air jet momentum and
- Floor area
- Numbers of animals in room

$$J = \frac{U \cdot u_o}{g \cdot V}$$

#### Definition of Jet momentum number

- $U$  is the supply airflow rate
- $V$  is the room volume

Floor air velocity can be expressed in terms of the jet momentum number or the inlet height and the pressure difference



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## Inlet air momentum, velocity decay and air speed at floor level

### References:

12. Morsing, S., J. S. Strøm, and G. Zhang. 1996. Make space for the return air in ventilated rooms. AgEng Paper: 96B-057. Ref ID: 279

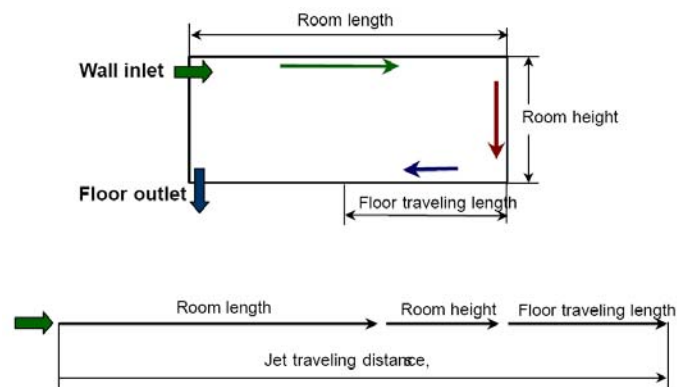
Nielsen, P. V. 1981. Ventilation of working areas (in Danish: Luftstrømning i ventilerede arbejdslokaler). SBI Report No. 128. Hørsholm, Denmark: Danish Building Research Institute.



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**Something for thinking: If the room length is much larger than room height – e.g.,  $L \gg 3H$ , can we use the jet velocity decay method? And why?**



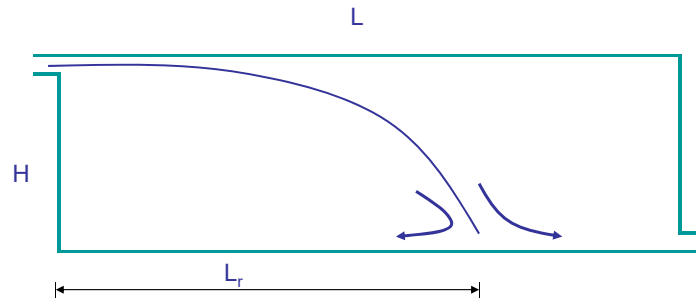
Linearization of jet traveling distance



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## Jet travel distance in a ventilated room



if  $L \gg H$ ;  $L_r/H = 3-5$ ;  $L_r/A^{0.5} = 2.5-3$ ;

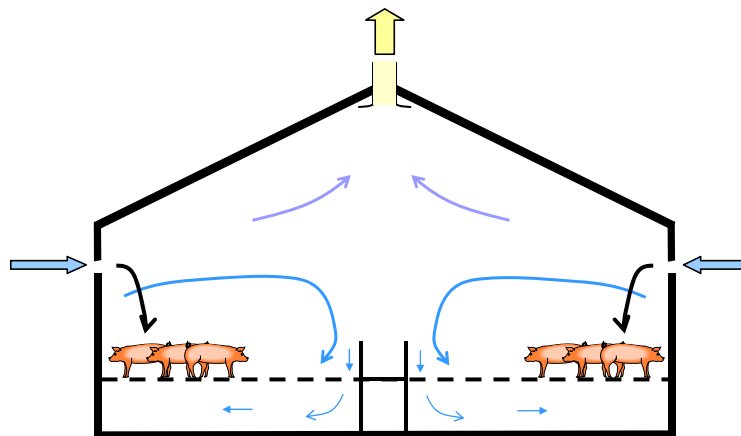


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## In a naturally ventilated livestock building

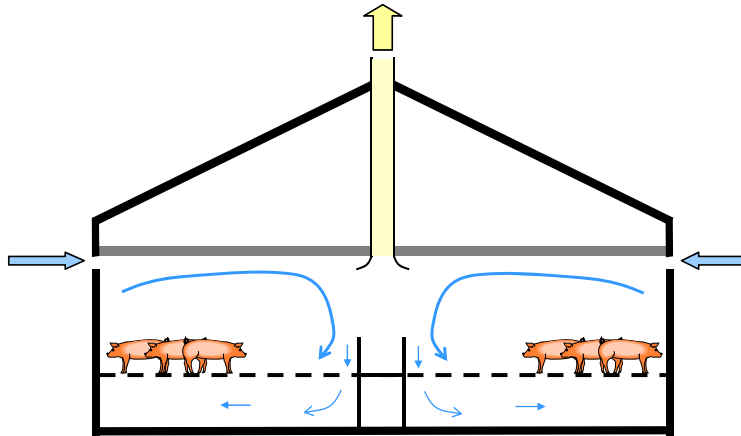
What will happen for inlet air jet if  $T_o$  very low?



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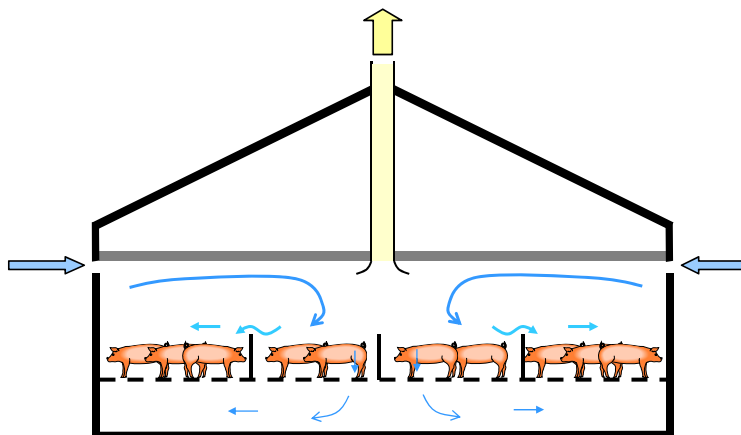
## A general airflow pattern in systems with side wall inlet



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## Internal structure effects (1)



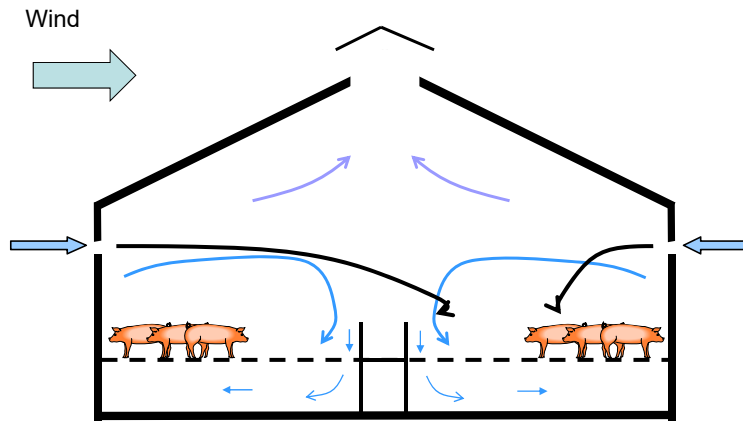
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## In a naturally ventilated livestock building

wind driven effects

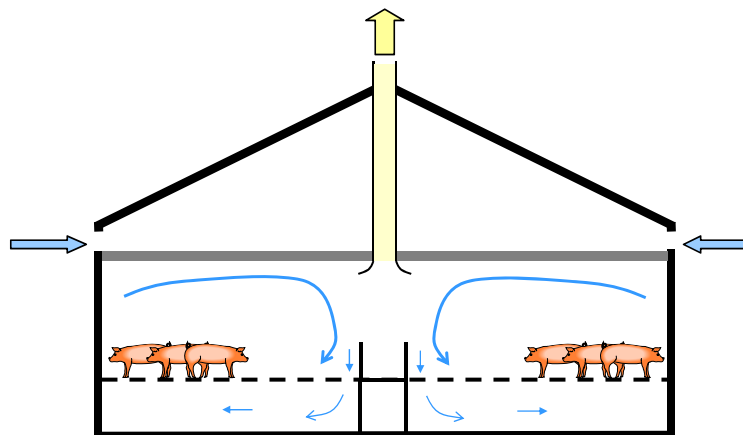


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## What about the air motion?

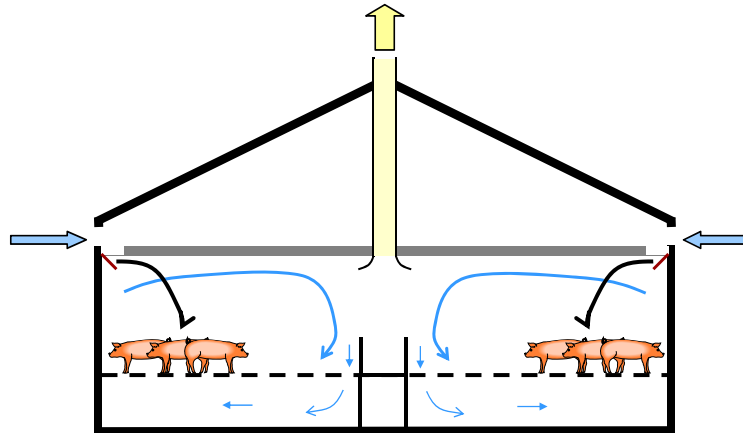
### in systems with ceiling diffusion inlet



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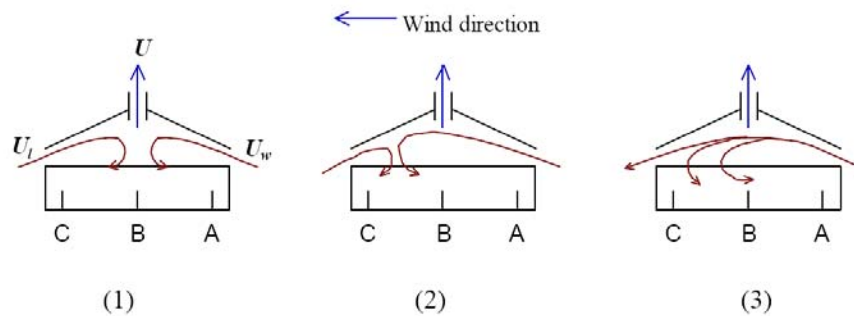
## Increase floor air speed in systems with ceiling diffusion inlet



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## How to avoid side wind effects in systems with side wall inlet



The variation of the penetration depth of the inlet airflow according to increase outside wind velocity. (1)  $h_w = h_p$ ,  $U > U_w = U_i$ ; (2)  $U > U_w > U_i$  and (3)  $U < U_w$



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## Secondary Thermal Zone

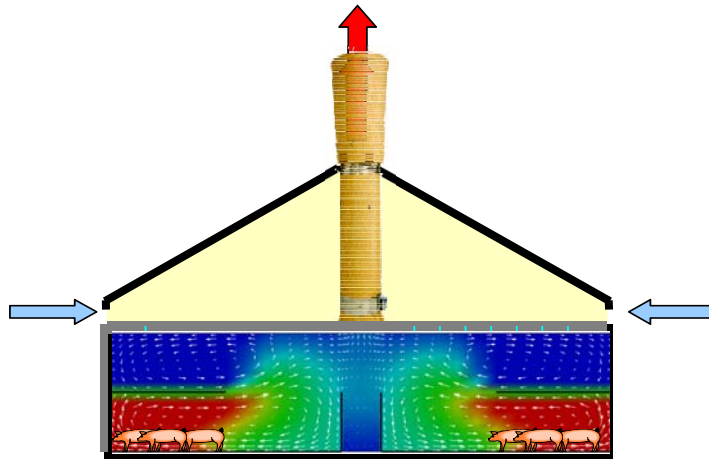
- Creep – Design & Control
- Temperature & Air motion in creeps
- Heating control in creeps
- ....



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## Stabilised condition with pen coverings



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## Creep for growing pigs

Straw and automatic cover



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## Take home questions

- **Modelling Floor/Pit air speed in a system with**
  - MV?
  - NV?
  - With different farm animals?
  - In different building designs?
- ....



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