ETiC
Laboratoire Commun de Recherche pour
l'**ET**ude des **I**ncendies en milieu **C**onfiné

Ecoulement de fumée entre deux pièces ventilées mécaniquement et reliées par une trémie

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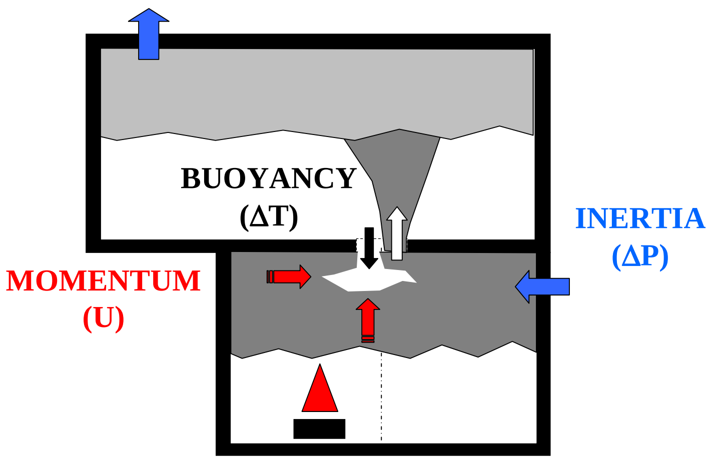
Objective

Effect of ventilation flow rate on the vent flow

Coupling effects of buoyancy, inertia and local momentum

Compartment fire scenario

Closed rooms mechanically ventilated

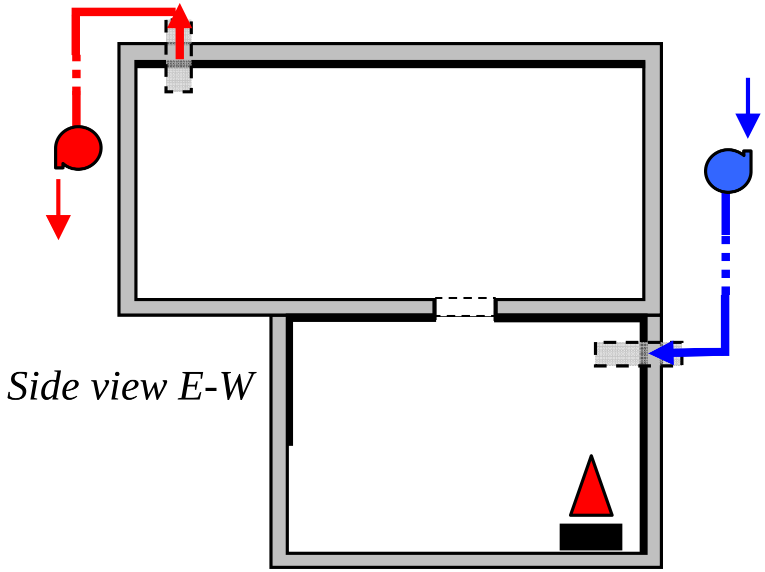


Fire test

Fire source

Gas propane fire (97kW)

Off-centre



Ventilation

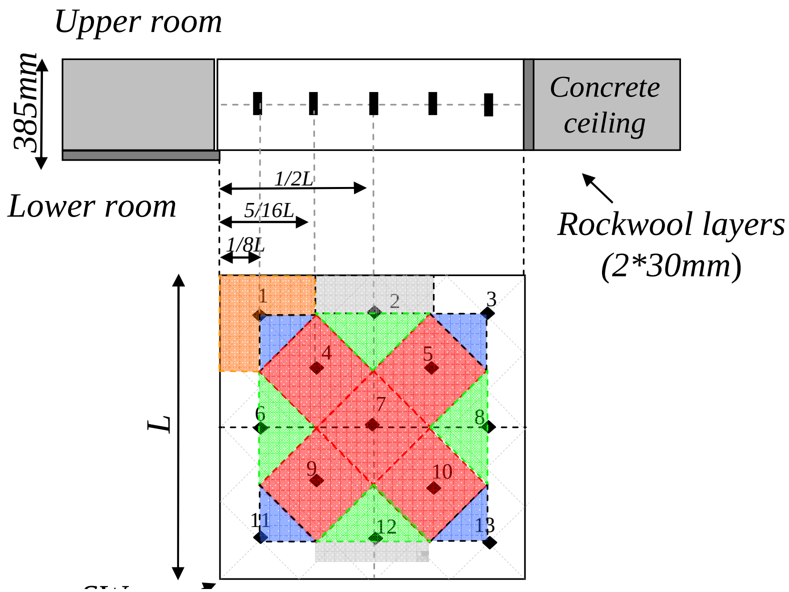
One inlet in the fire room and one outlet in the upper room

Various ventilation rates qv

Test matrix

Test	Q17	Q13	Q16	Q12
HRR (kW)	97	97	97	97
TR (h^{-1})	2.3	4	6.2	8
Qv (m^3/h)	621	1080	1674	2160

Vent opening



Dimension

Rectangular : 1.03*1.03=1.06m2

Depth=0.39m

Vent flow calculation

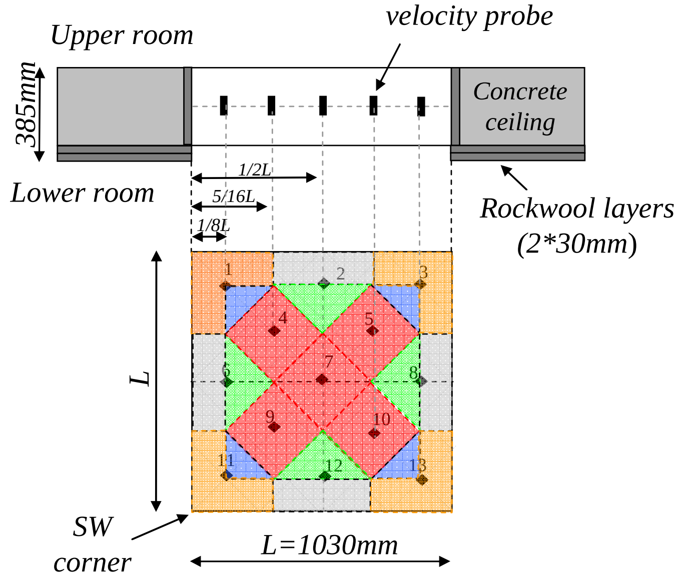
Flow rate

$$\dot{m}_{vent} = \int_S U\rho(T)ds$$

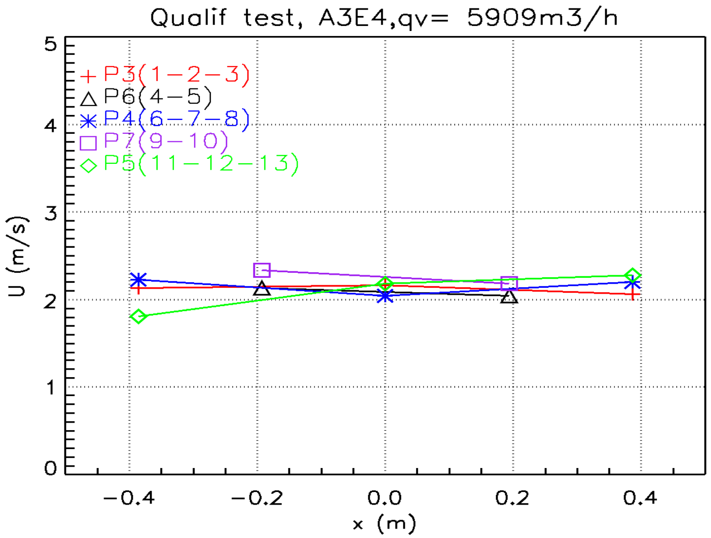
$$\int_S U\rho(T)ds = C\frac{PM}{R}\sum_S\left(\frac{U_i}{T_i}ds_i\right) = \sum_{i=4,5,7,9,10}\left(\frac{U_i}{T_i}ds_i\right) + \sum_{\substack{i=2,6,8,12\\1,3,11,13}}\left(\frac{U_i}{T_i}ds_i^1 + \frac{1}{2}\frac{U_i}{T_i}ds_i^2\right)$$

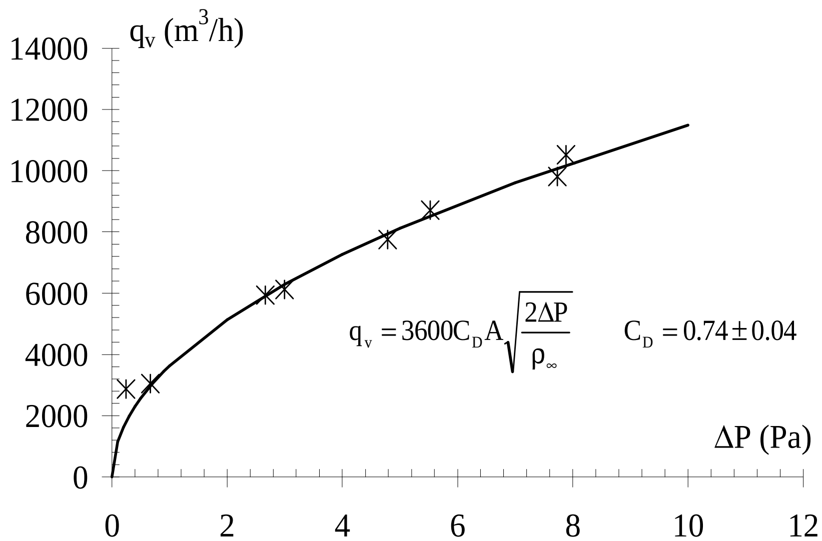
$$\dot{m}_v^{up} = \frac{1}{2}\left(\int_S U\rho(T)ds + \int_S |U|\rho(T)ds\right)$$

$$\dot{m}_v^{down} = -\frac{1}{2}\left(\int_S U\rho(T)ds - \int_S |U|\rho(T)ds\right)$$



Vent flow at ambient conditions





Only forced convection

Relationship q_v=f(ΔP)

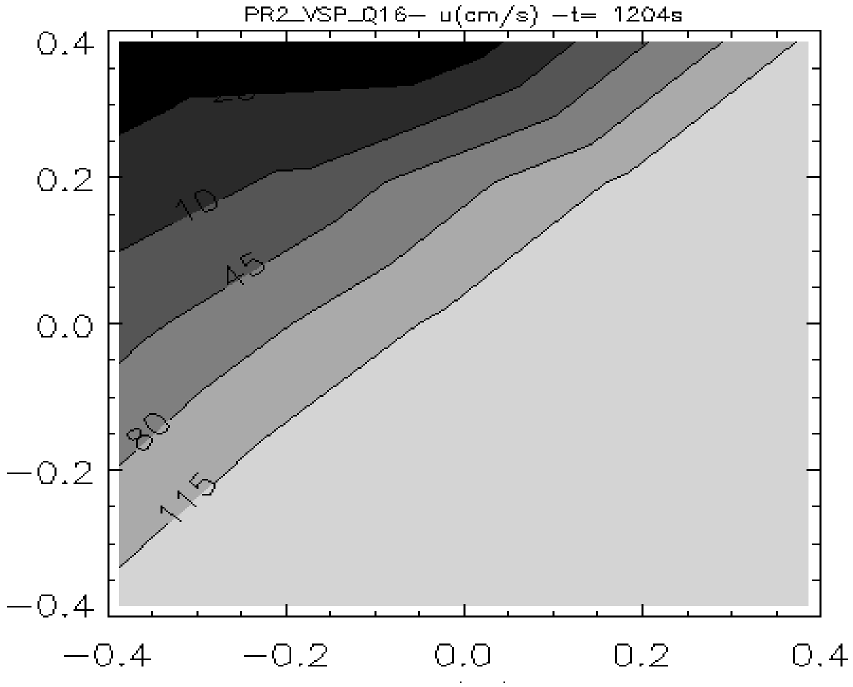
Discharge coefficient

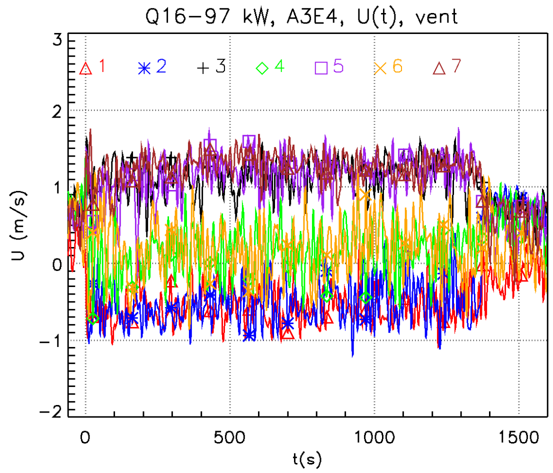
$$q_v = C_D A \sqrt{\frac{2\Delta P}{\rho(T)}}$$

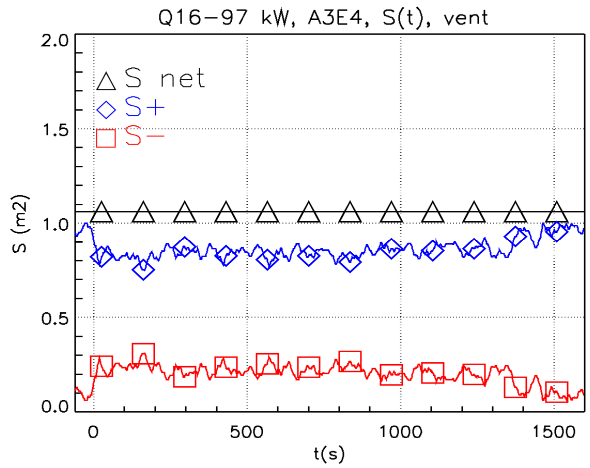
Typical velocity field at the vent

Bi-directional flow

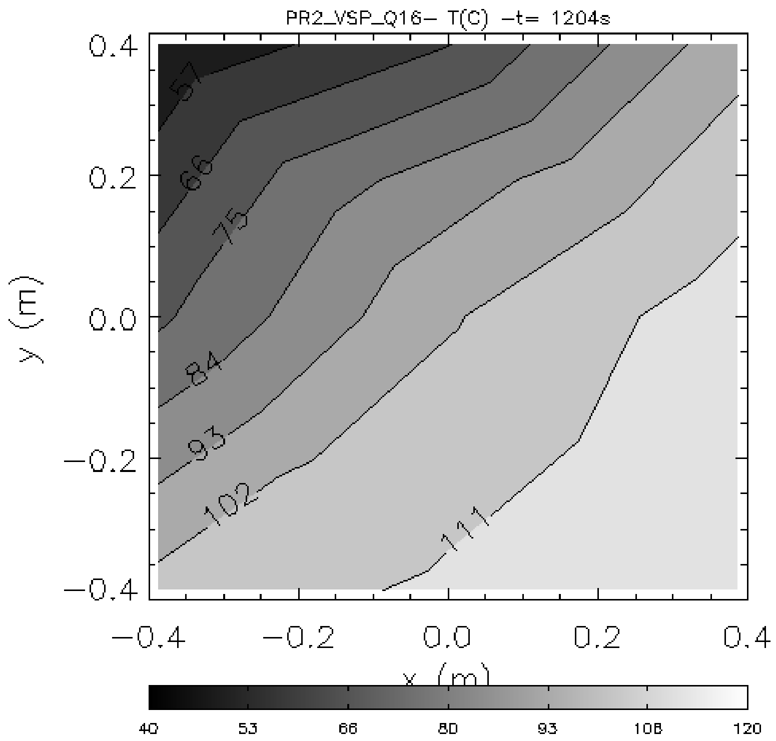
Negative velocity in one corner

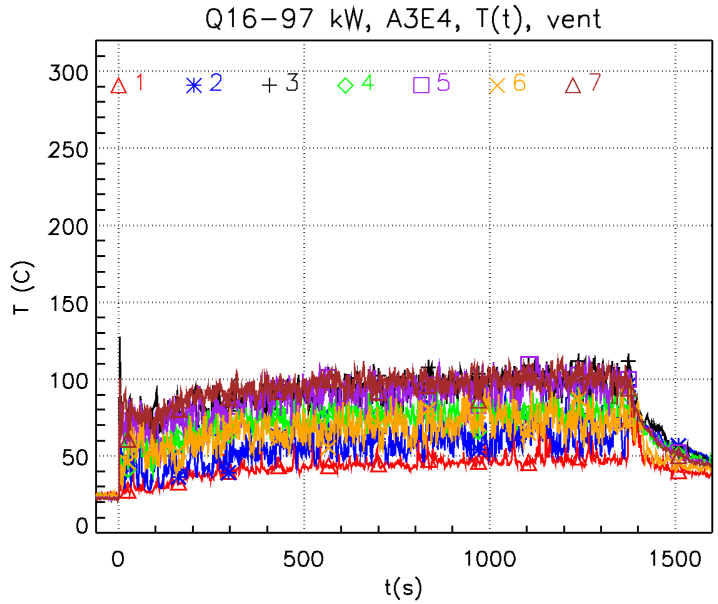






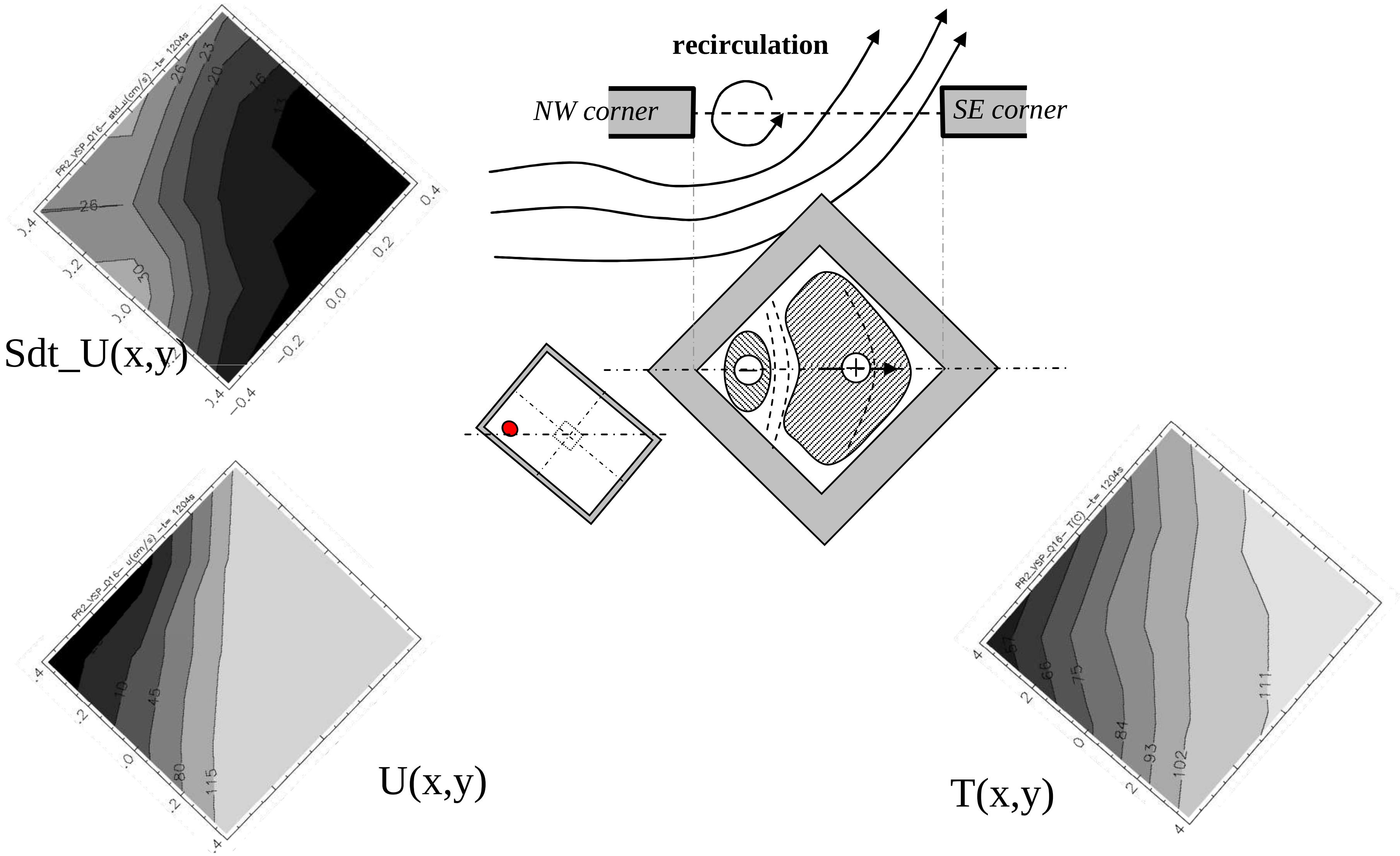
Typical Temperature field at the vent



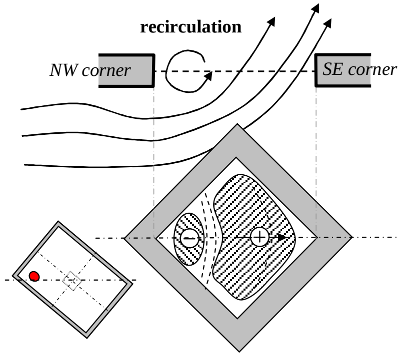


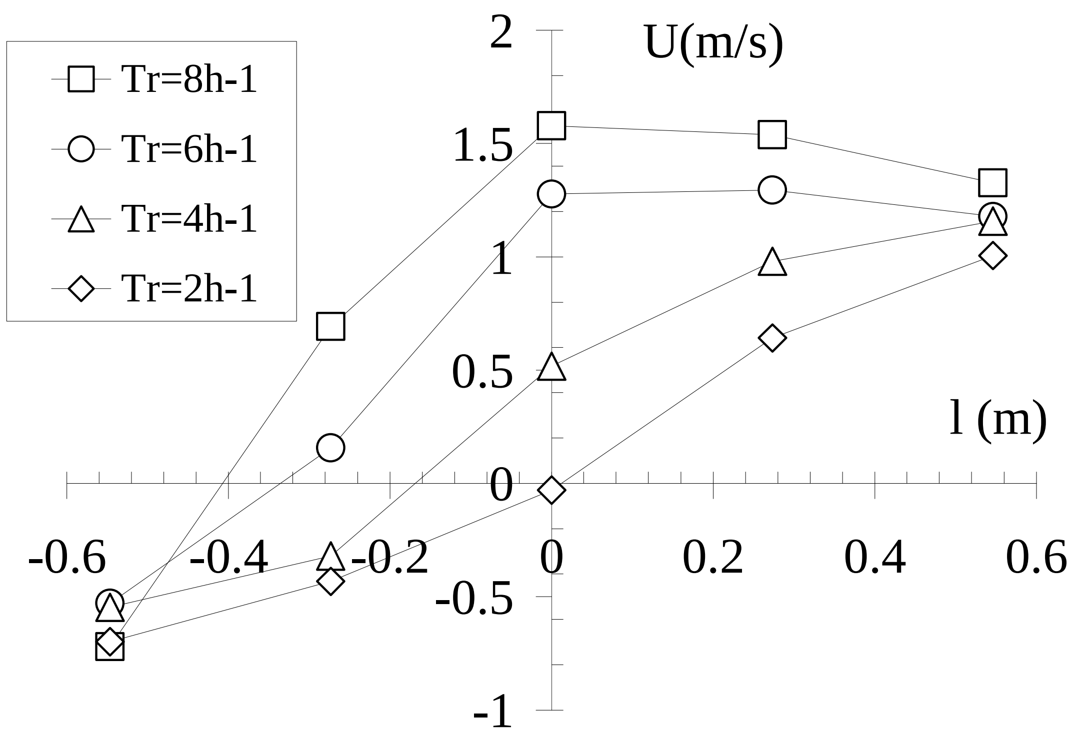
Highest temperature level in the corner of highest velocity level

Typical flow field at the vent



Effect of the ventilation flow rate (1)



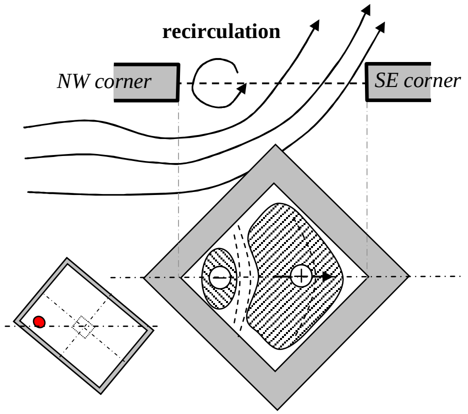


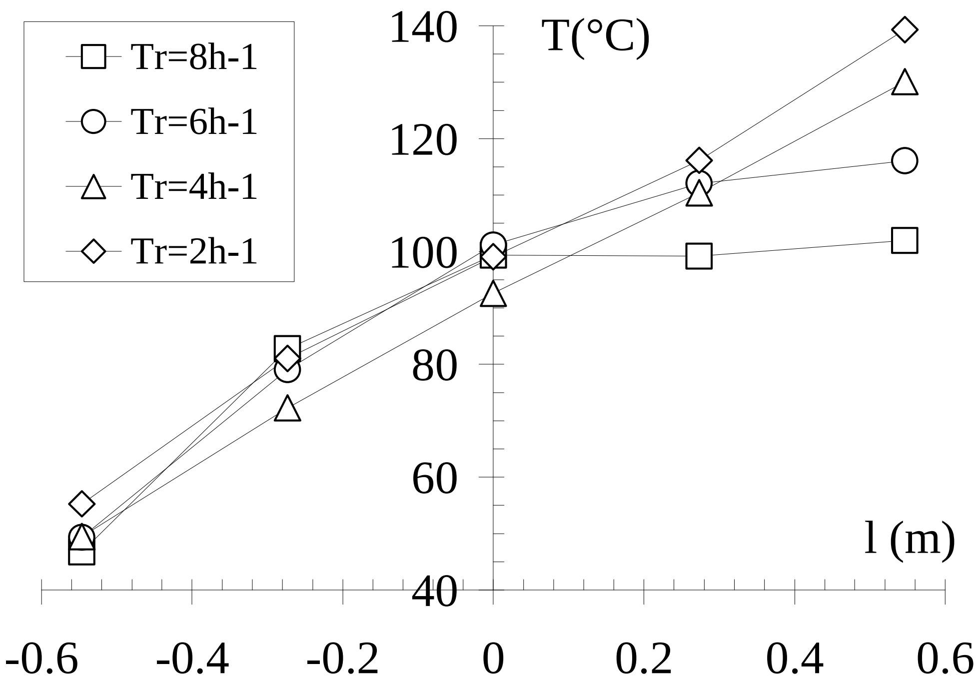
The increase of the ventilation flow rate

Increases the velocity at the centre of the vent

Reduces the area relative to the downward flow

Effect of the ventilation flow rate (2)



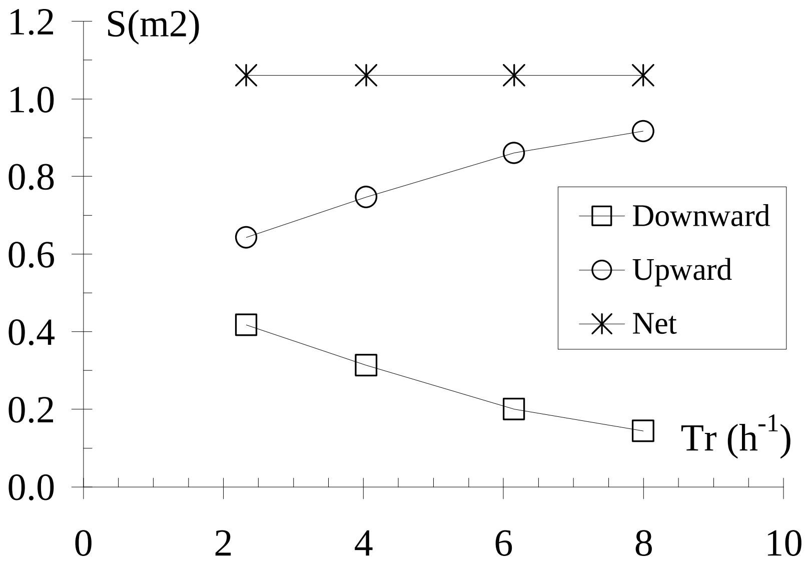


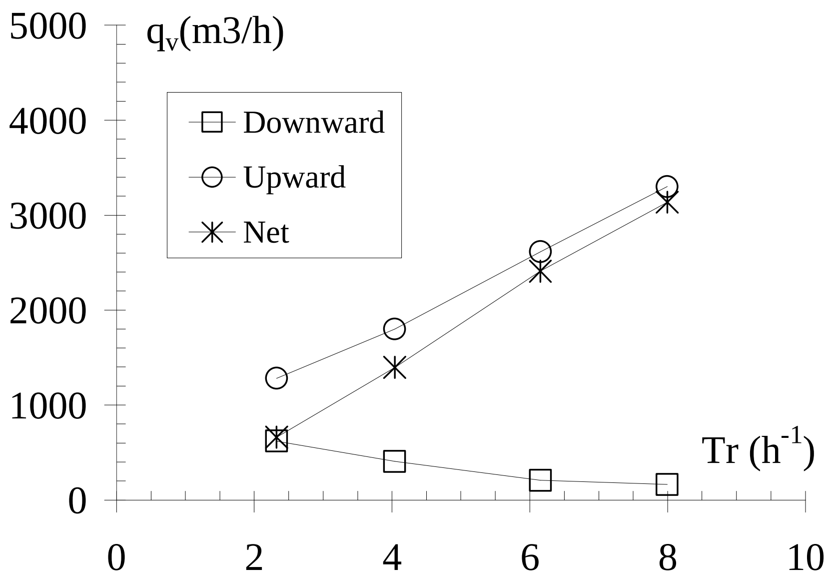
The increase of the ventilation flow rate

Reduces the temperature of the upward flow

Has nearly no impact on the downward flow

Effect of the ventilation flow rate (3)





The increase of the ventilation flow rate

Reduces the downward flow

Correlative approach of the vent flow (Cooper)

Two contributions

Standard (inertia)

Exchange (buoyancy)

$$\dot{v}^U = \dot{v}^U_{st} + \left|\dot{v}_{ex}\right|$$

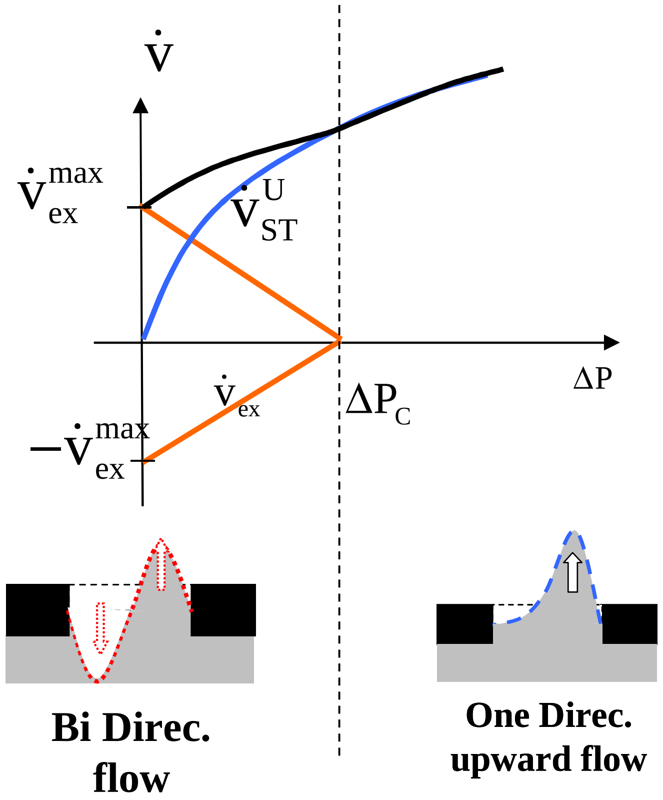
$$\dot{v}^D = \dot{v}^D_{st} + \left|\dot{v}_{ex}\right|$$

Standard term

$$\dot{v}_{st} = C_d A \sqrt{\frac{2\Delta P}{\rho}}$$

Exchange term

$$\dot{v}_{ex} = \dot{v}^{max}_{ex} f(\Delta P/\Delta Pc)$$



Cooper's correlation (V89)

Standard term

$$\dot{v}_{st}^{U} = C_d A \sqrt{\frac{2\Delta P}{\rho_B}} \quad \text{and} \quad \dot{v}_{st}^{D} = 0 \quad \text{for} \quad \Delta P > 0$$

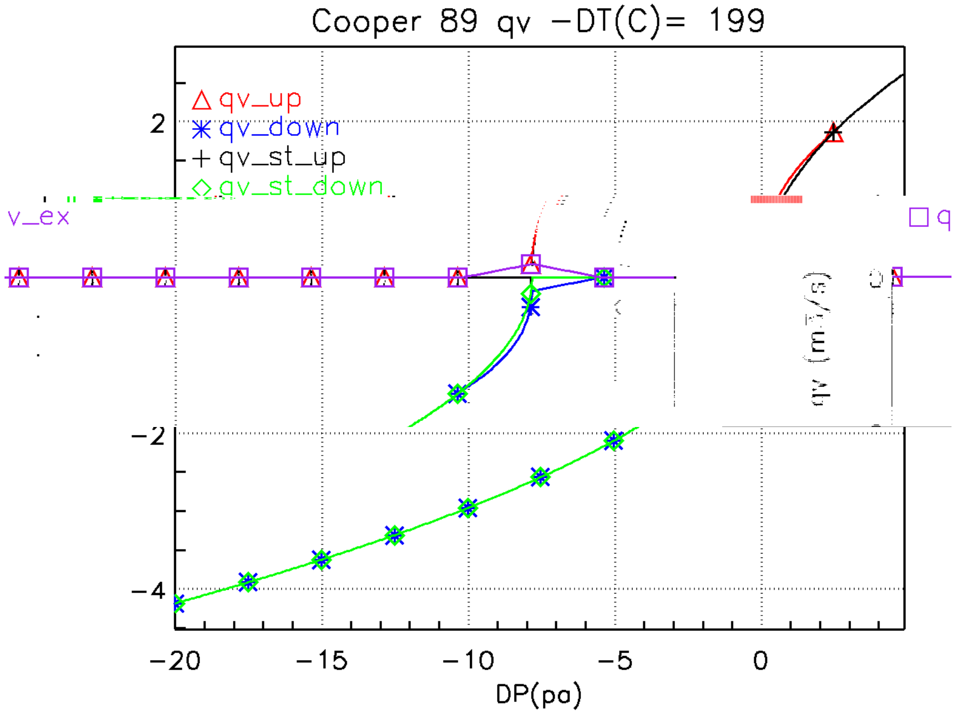
$$\dot{v}_{st}^{U} = 0 \quad \text{and} \quad \dot{v}_{st}^{D} = C_d A \sqrt{\frac{2\Delta P}{\rho_U}} \quad \text{for} \quad \Delta P < 0$$

Exchange term

$$\dot{v}_{ex} = \dot{v}_{ex}^{max}\left(1 - \left|\Delta P^{*}\right|\right)$$

$$\dot{v}_{ex}^{max} = 0.055 D^{2} \sqrt{\frac{\Delta \rho g D}{(\rho_L + \rho_U)/2}}$$

$$\Delta P_c = \left(C^{2} \frac{D^{4}}{8A^{2}}\right) 4 \Delta \rho g D = \left(C^{2} \frac{8}{\pi^{2}}\right) \Delta \rho g D$$



Cooper's correlation (V94)

Standard term

$$\dot{v}_{st}^{U} = C_D(\Delta P^*)A\sqrt{\frac{2\Delta\rho g D}{(\rho_L+\rho_U)/2}}Fr \quad \text{and} \quad \dot{v}_{st}^{D} = 0 \quad \text{for} \quad \Delta P > 0$$

$$\dot{v}_{st}^{U} = 0 \quad \text{and} \quad \dot{v}_{st}^{D} = C_D(\Delta P^*)A\sqrt{\frac{2\Delta\rho g D}{(\rho_L+\rho_U)/2}}Fr \quad \text{for} \quad \Delta P < 0$$

$$C_D(\Delta P^*) = 1 - C_2{}^2 + \sqrt{C_2{}^4 + C_1{}^2(\Delta P^* - 1)}. \quad \text{for} \quad \Delta P^* > 1$$

$$= \frac{C - \sqrt{1 + (C^2-1)(1-\Delta P^*)}}{C-1} \quad \text{for} \quad \Delta P^* < 1$$

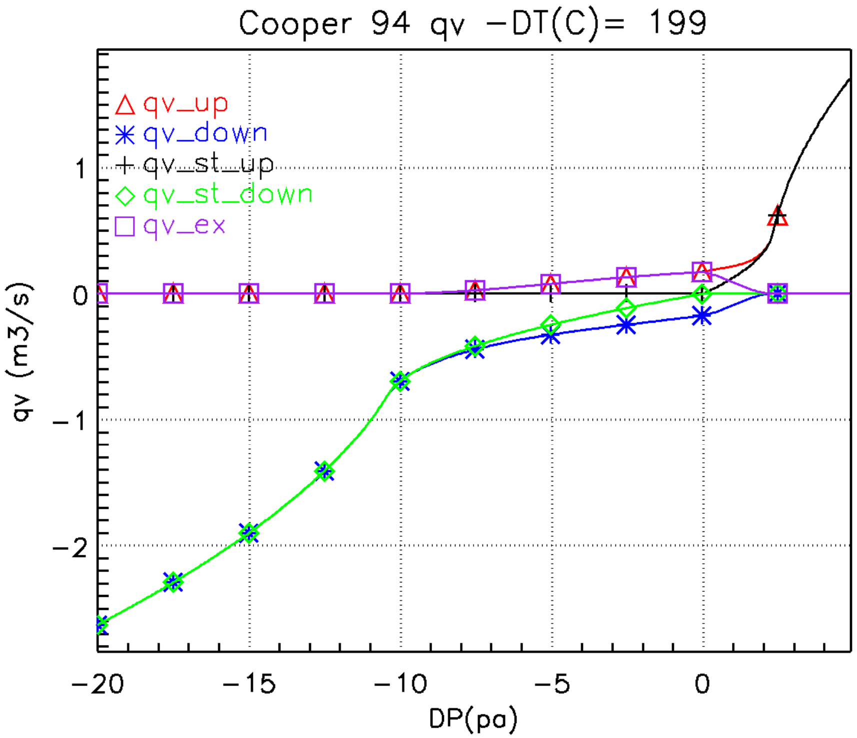
Exchange term

$$\dot{v}_{ex} = \dot{v}_{ex}^{max} H(\Delta P^*)$$

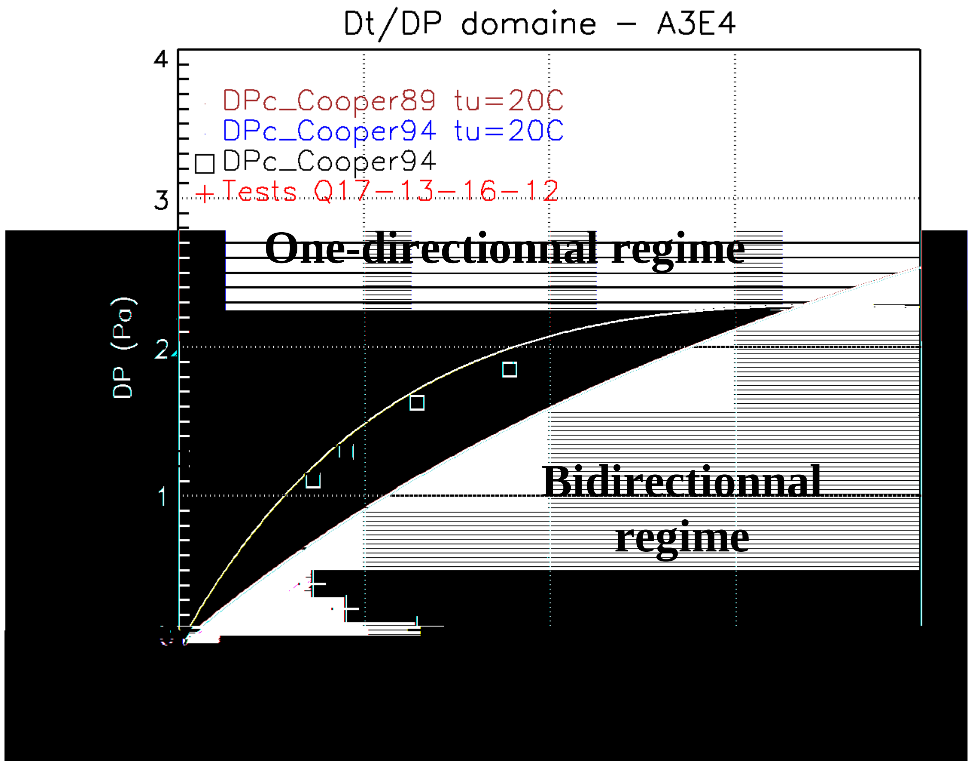
$$\dot{v}_{ex}^{max} = 0.055\frac{4}{\pi}A\sqrt{\frac{\Delta\rho g D}{(\rho_L+\rho_U)/2}}$$

$$H(\Delta P^*) = \left[(1+C_3/2)(1-\Delta P^*)^2 - (2+C_3/2)(1-\Delta P^*)\right]^2$$

$$\Delta P_c = \left(0.2427\left(1 \pm \frac{\varepsilon}{2}\right)\exp[1.1072(\pm\varepsilon)]\right)4\Delta\rho g D$$



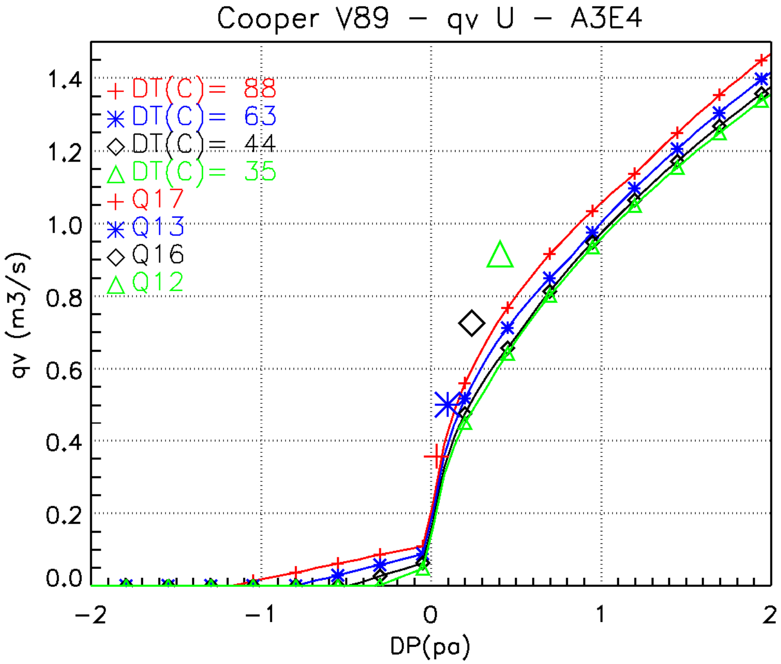
Comparison : critical pressure

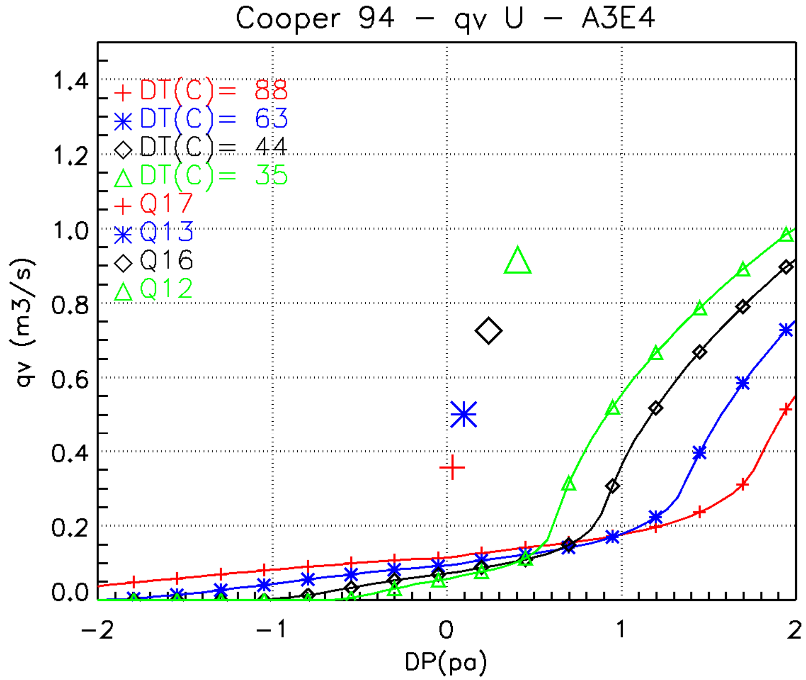


Agreement in the determination of the regime

Fire test = bi-directionnal regime

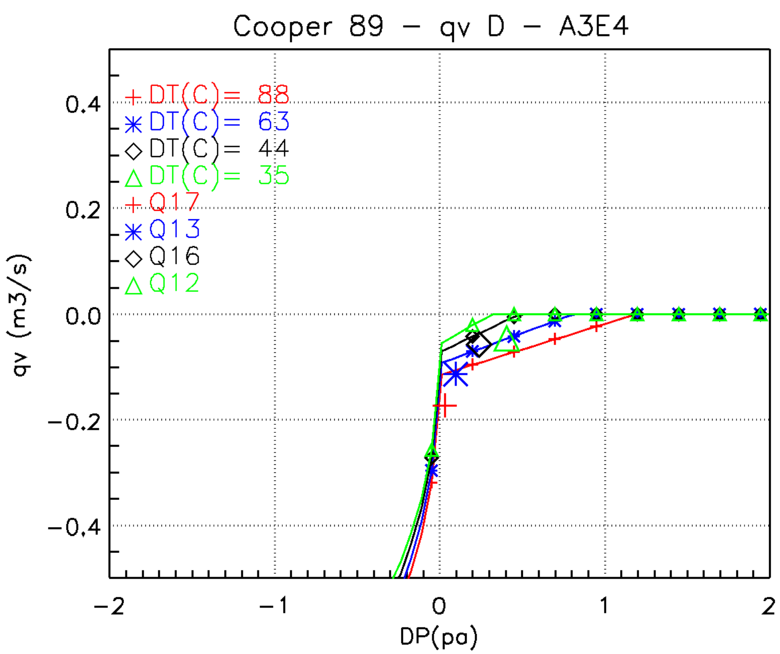
Comparison : upward flow

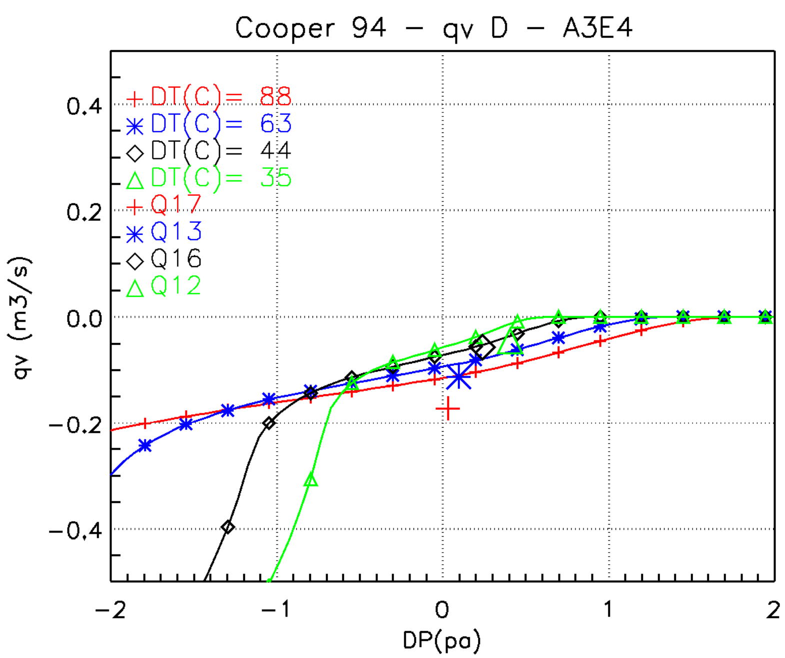




Good agreement with version 1

Comparison : downward flow





Good agreement with the two versions

Conclusions

- Bi-directionnal flow at the vent
- Significant influence of the location of the fire
- Effect of the ventilation flow rate
  - Reduction of the downward flow
  - Critical pressure never obtained with $Tr=8h^{-1}$
- Tentative of comparison with Cooper correlation
  - Two versions
  - Good agreement with one approach
  - Large difference between the two approaches
  - Need of going further in the validation of the correlations