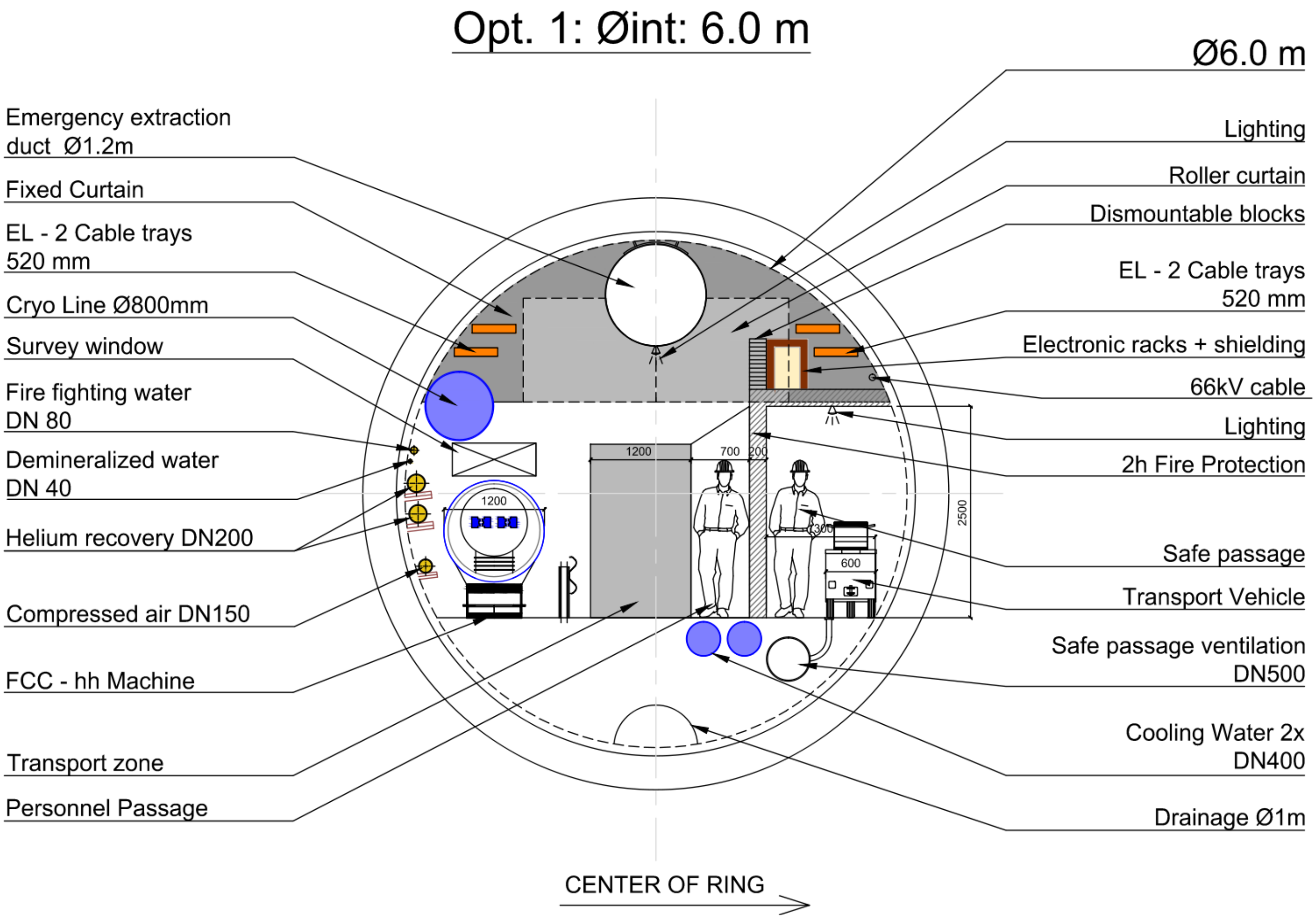
CERN

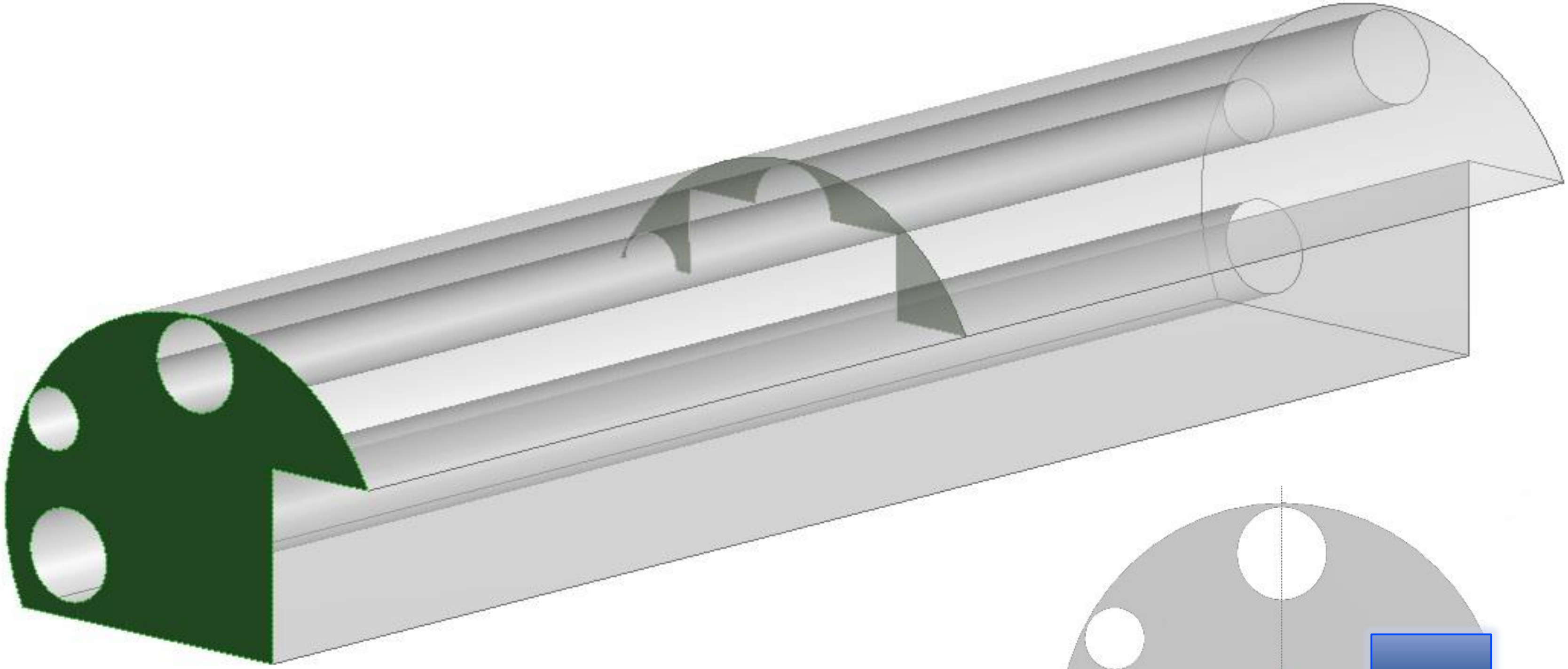
Additional calculations for the FCC (future circular collider) ventilation system

CFD-2016-03-FCC-2
EDMS 1704506

FCC tunnel design



FCC: machine+safety tunnel



Previous part

- CFD project 2015-05-FCC-tunnel
- Final report: EDMS 1523101
- Pressure drop calculations to evaluate the effect of fire curtain, both 1D hydraulic and 3D computational fluid dynamics (CFD) calculations.

Additional calculations

- MathCAD tool for fan choice
- MathCAD tool for thermal behaviour
- Demonstrative CFD case for an ODH situation
- Demonstrative CFD case for air curtain effects

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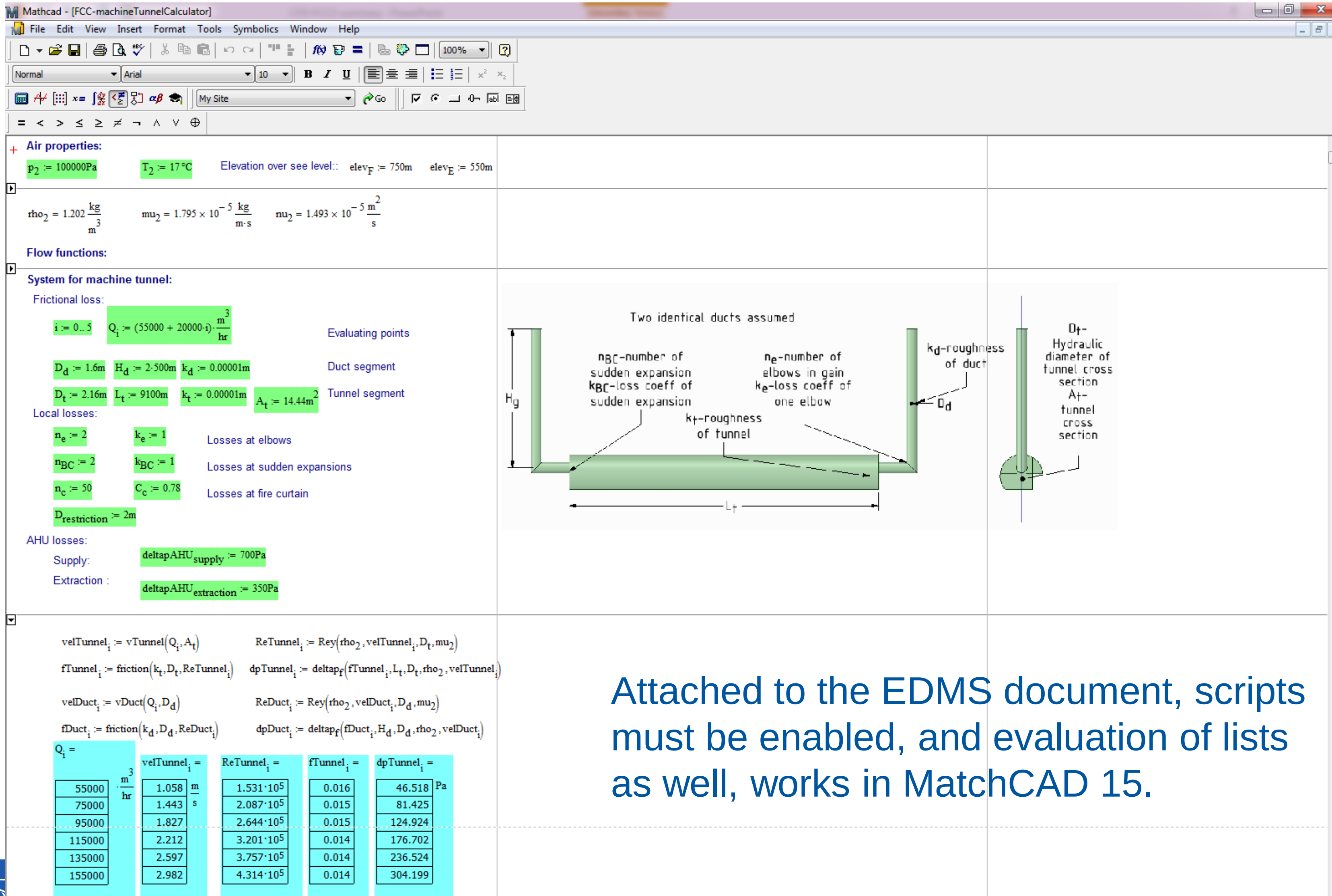
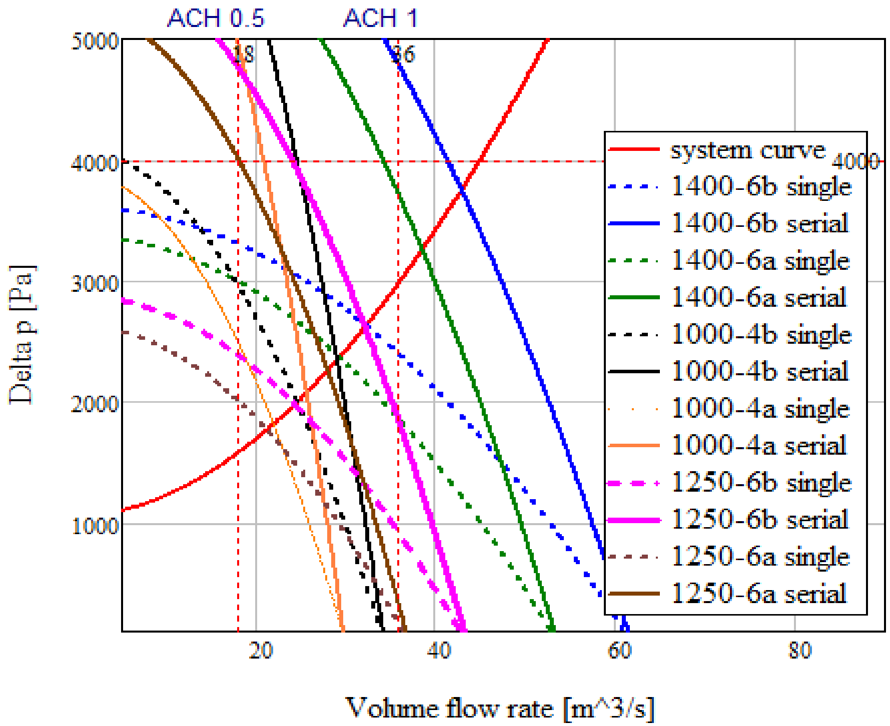
MatchCAD tool for fan choice



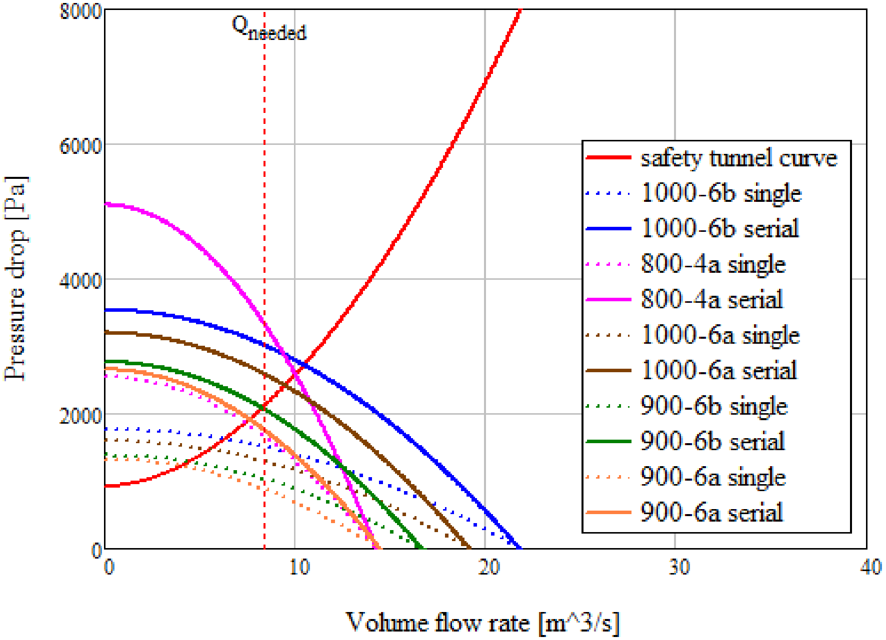
Attached to the EDMS document, scripts must be enabled, and evaluation of lists as well, works in MatchCAD 15.

FCC fan choices

Machine tunnel

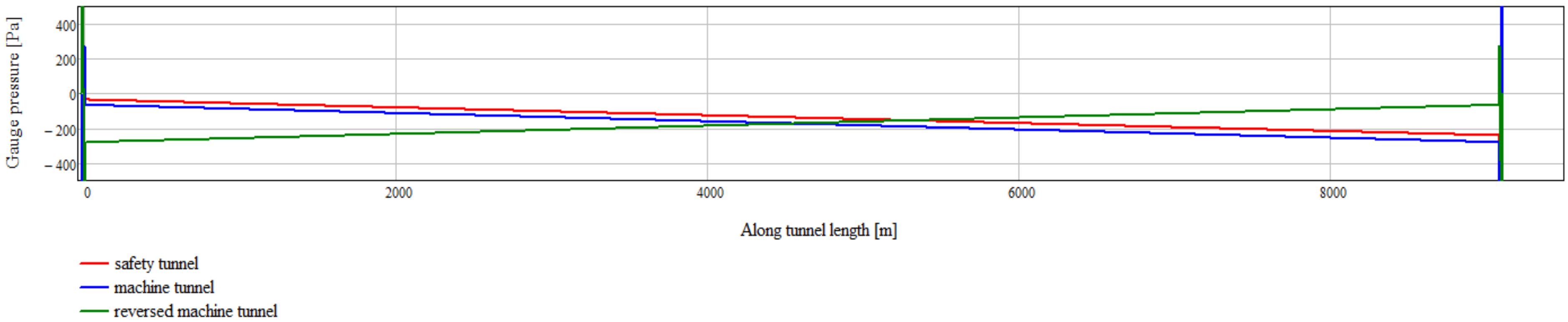


Safety tunnel



Fans taken from a CLICK workshop listing for non standard industrial fans.

FCC pressure in the two tunnel



Max pressure difference between machine and safety tunnel in operation: 40Pa for same direction. In case of reversed direction, the overpressure maintenance is more complicated.

Escape doors

Note that the pressure difference between the machine and safety tunnel has an important effect on the escape door operation, see

Michael Lierau, Marcus Römer, Luigi De Candido from Elkuch Group and Eisenring – Tunnel Escape Doors presented at Swiss Tunnel Conference 2016

Tür Dimension/Door dimensions			Neue Tür/New door		Gealterte Tür/Aged door	
Höhe Height	Breite Width	Fläche Area	Zulässige Öffnungskraft Permissible opening force	Max. Druckdifferenz Max. pressure difference	Zulässige Öffnungskraft Permissible opening force	Max. Druckdifferenz Max. pressure difference
m	m	m^2	N	Pa	N	Pa
Türen nach DIN 18101/Doors according to DIN 18101						
1,985	0,610	1,211	100	83	120	99
1,985	0,735	1,459	100	69	120	82
1,985	0,860	1,707	100	59	120	70
1,985	0,985	1,955	100	51	120	61
1,985	1,110	2,203	100	45	120	54
Fluchttür nach TSI-SRT/Escape door according to TSI-SRT						
2,000	1,400	2,800	100	36	120	43

Quelle/credit: Elkuch Group

Paper attached to EDMS document

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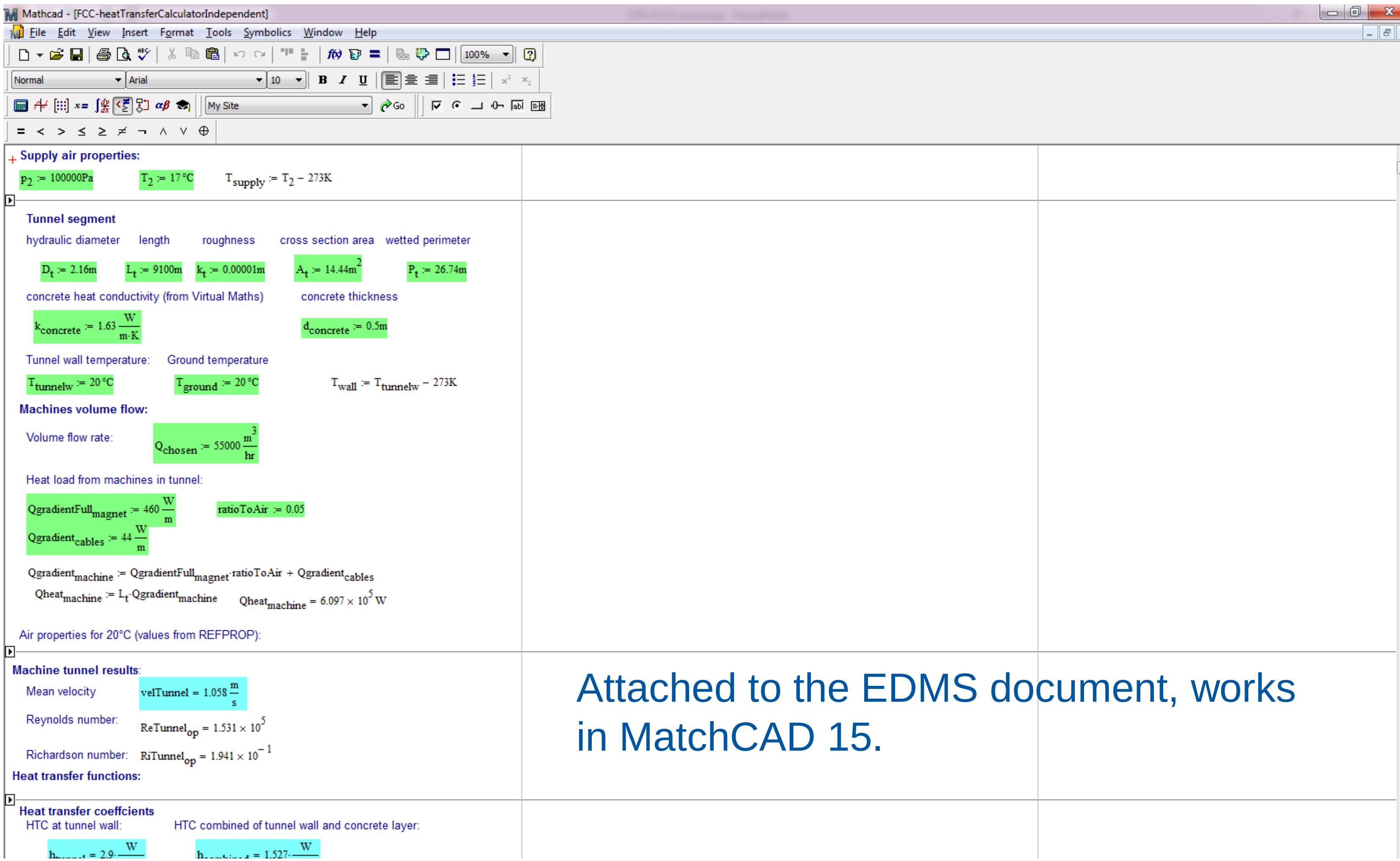
MathCAD tool for thermal behaviour



Attached to the EDMS document, works in MatchCAD 15.

FCC thermal behaviour

Thermal load: 5% of magnets (23 W/m) and cables (55 W/m or 27 W/m)

3 assumptions:

1. All heat load going to air, tunnel adiabatic (ne heat exchange with wall)
2. Heat also leaves by tunnel wall which remains constant temperature (20°C)
3. Tunnel wall resistance included (concrete thermal conductivity:1.28W/(mK), thickness 0.5m), constant ground temperature (20°C)

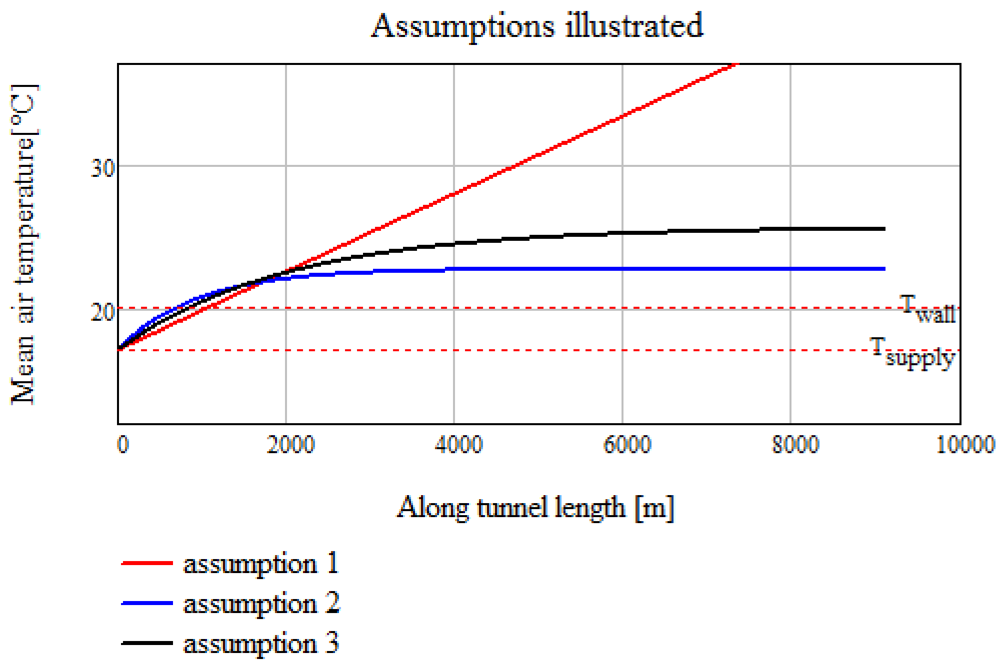


Illustration for 27 W/m cables, 55000 m³/h flow

FCC thermal behaviour

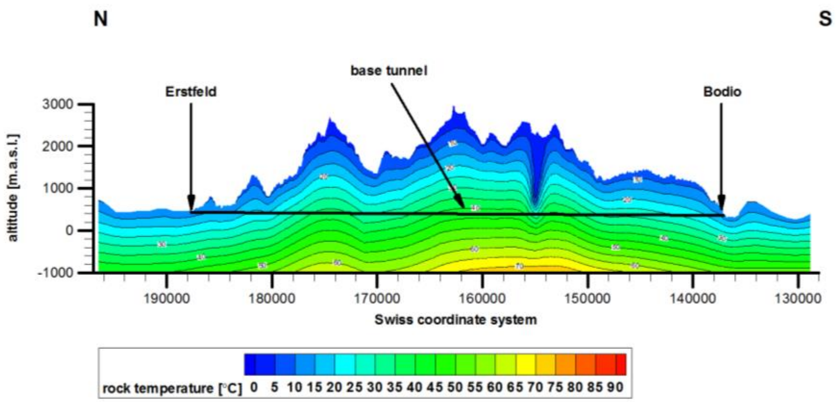
cables 55 W/m									
				Assumption 1		Assumption 2		Assumption 3	
Tunnel volume flow rate	ACH	HTC-tunnel	HTC-combined	exhaust T	Δ T	exhaust T	Δ T	exhaust T	Δ T
m³/h	"-"	W/(m²K)	W/(m²K)	°C	K	°C	K	°C	K
55000	0.42	2.9	1.35	55.4	38.4	24	7	28.4	11.4
75000	0.57	3.7	1.51	45.2	28.2	23.1	6.1	27.3	10.3
95000	0.72	4.5	1.63	39.2	22.2	22.6	5.6	26.6	9.6
115000	0.88	5.2	1.72	35.4	18.4	22.2	5.2	26.1	9.1
135000	1.03	6	1.8	32.6	15.6	21.9	4.9	25.6	8.6
cables 27 W/m									
				Assumption 1		Assumption 2		Assumption 3	
Tunnel volume flow rate	ACH	HTC-tunnel	HTC-combined	exhaust T	Δ T	exhaust T	Δ T	exhaust T	Δ T
m³/h	"-"	W/(m²K)	W/(m²K)	°C	K	°C	K	°C	K
55000	0.42	2.9	1.35	41.6	24.6	22.6	5.6	25.4	8.4
75000	0.57	3.7	1.51	35.1	18.1	22	5	24.7	7.7
95000	0.72	4.5	1.63	31.3	14.3	21.6	4.6	24.2	7.2
115000	0.88	5.2	1.72	28.8	11.8	21.4	4.4	23.8	6.8
135000	1.03	6	1.8	27	10	21.2	4.2	23.5	6.5

As the volume flow rate, and thus the velocity increases, HTC is increasing as well, so more heat can be removed.

Virgin rock temperature issue

- Adiabatic or constant 20°C is most probably not valid for tunnel depths considered
- More expertise is needed, see example:

From Ladislaus Rybach, Institute of Geophysics ETHZ, Zurich, Switzerland and Andreas Busslinger HBI Haerter Consulting Engineers, Bern, Switzerland - **Numerical modelling for rock temperature prediction in deep tunneling** - methodology and verification at Eurock 15, 64th Geomechanics Colloquium



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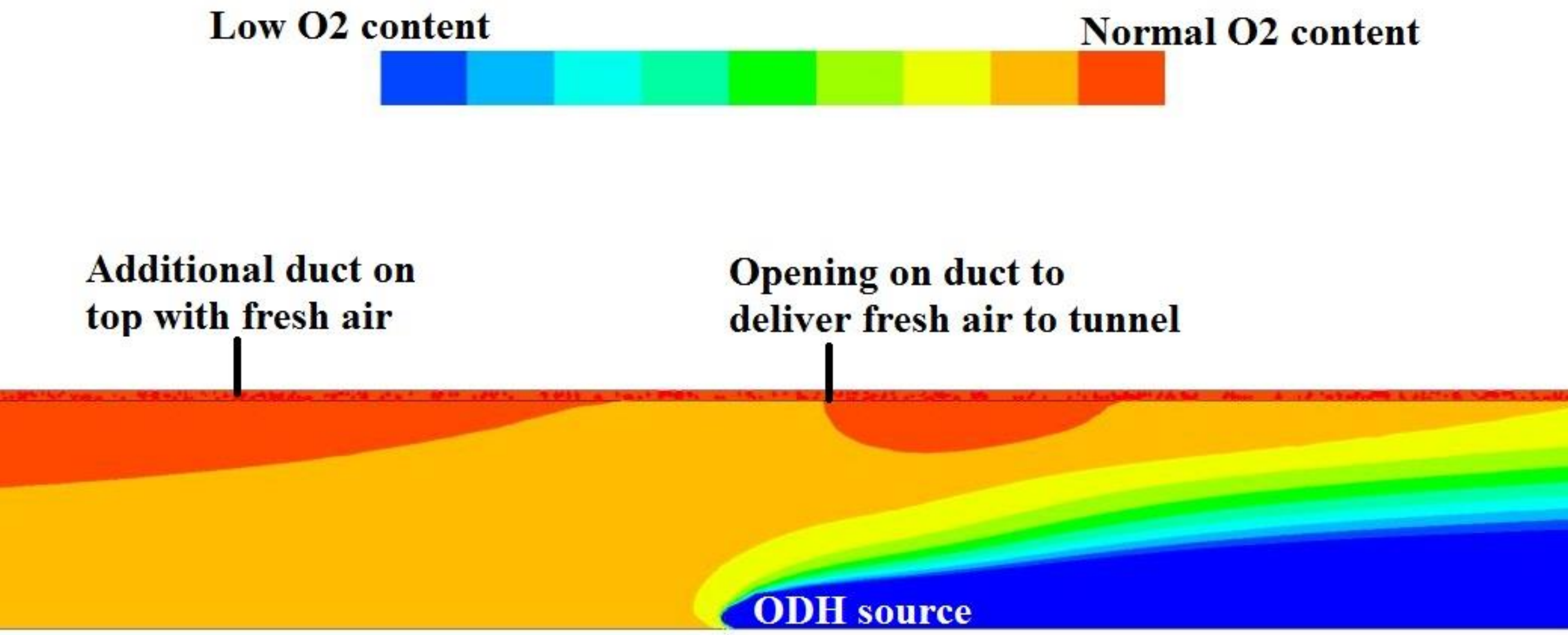
FCC double duct safety tunnel

Fresh air can arrive to the safety tunnel from an additional duct



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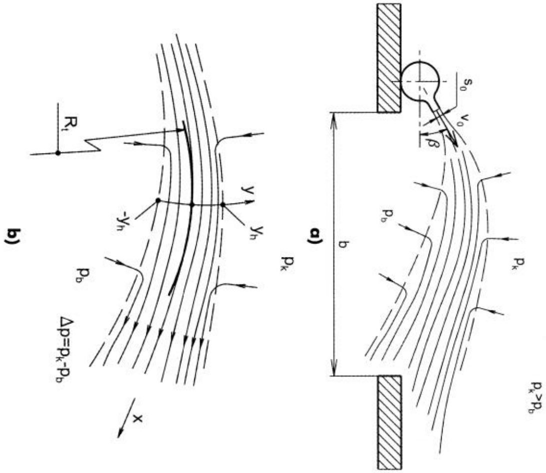
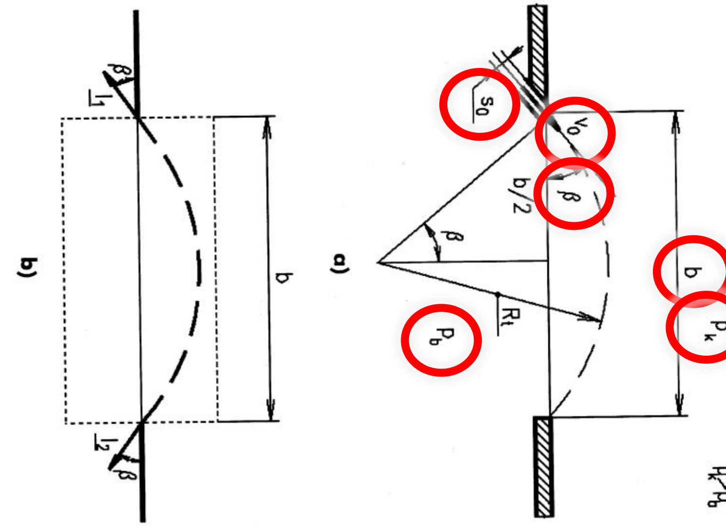
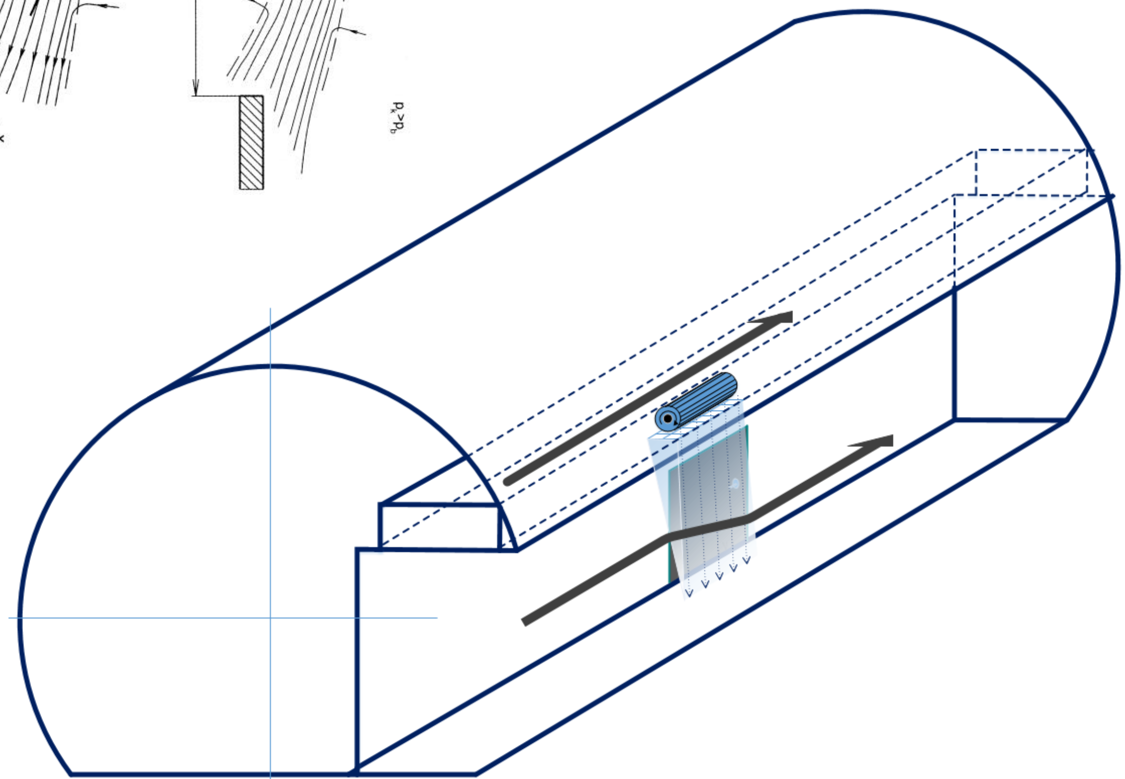
Air curtain basics:





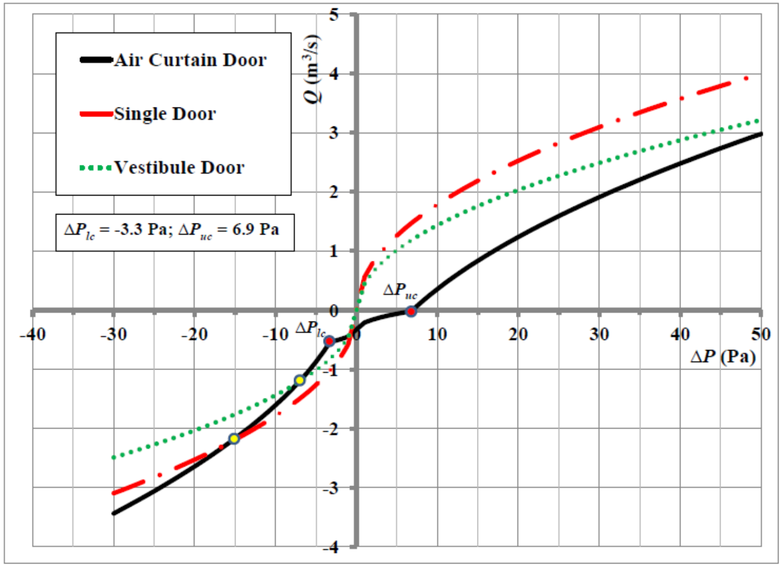


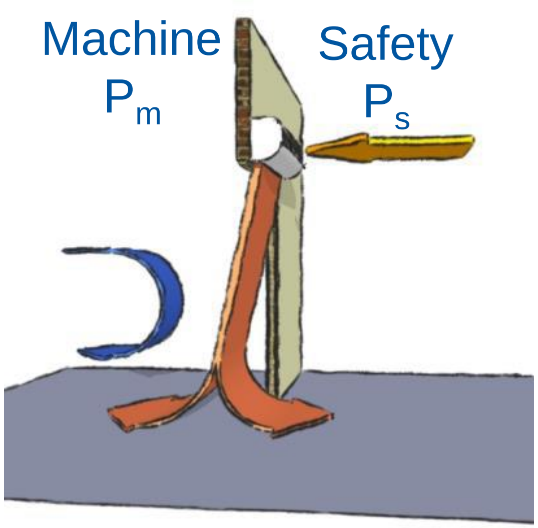
Necessary jet velocity to keep pressure difference:

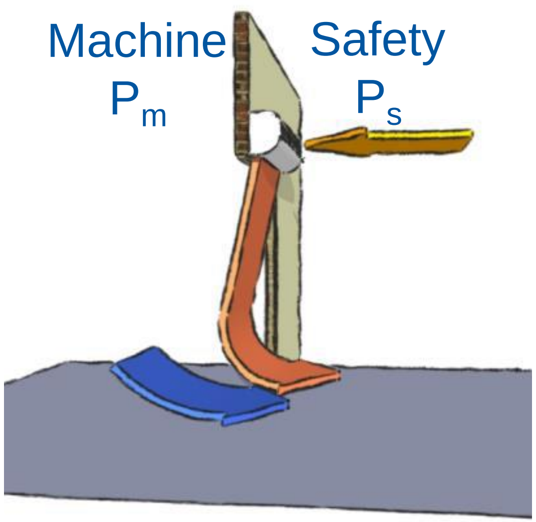
$$v_0 = \sqrt{\frac{\Delta p \cdot b}{2\rho \cdot s_0 \cdot \sin\beta}}$$

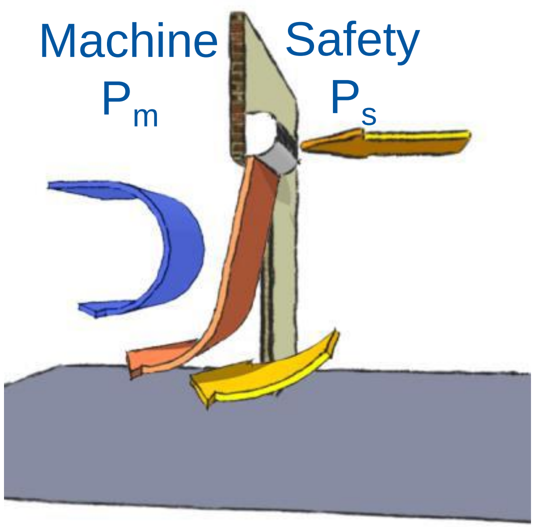
In literature:

Air filtration depending on different pressure ratios from: **L. Wang** – Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use





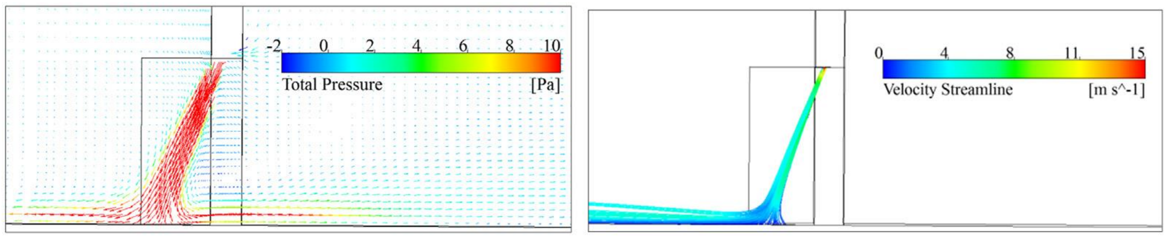




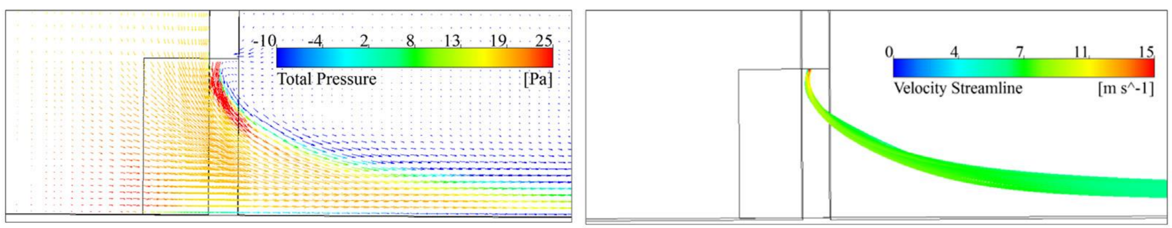
Paper attached to EDMS document

In literature:

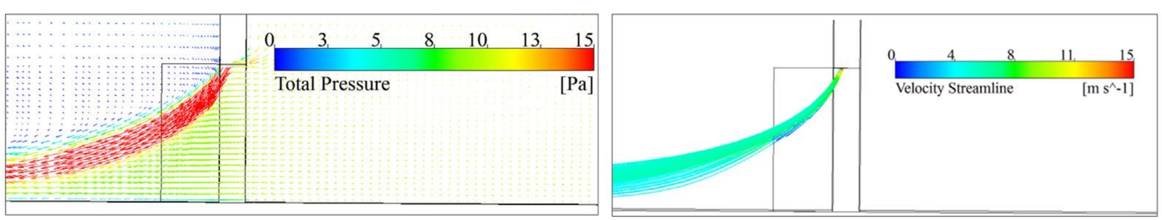
L. Wang –Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use



(a) Optimum condition.



(b) Inflow break-through.

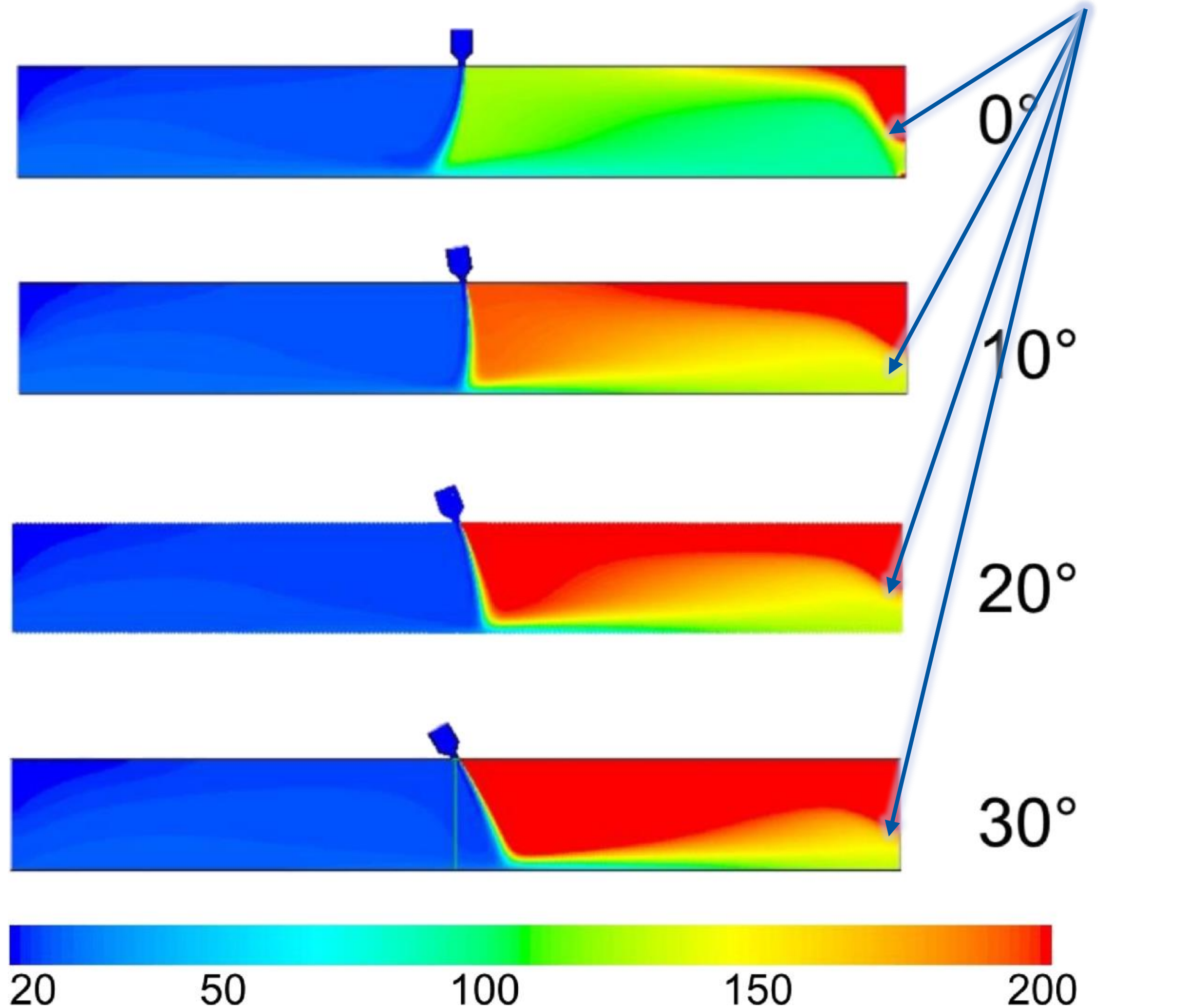


(c) Outflow break-through.

In literature:

KRAJEWSKI and WĘGRZYŃSKI – *Air curtain as a barrier for smoke in case of fire: Numerical modelling*

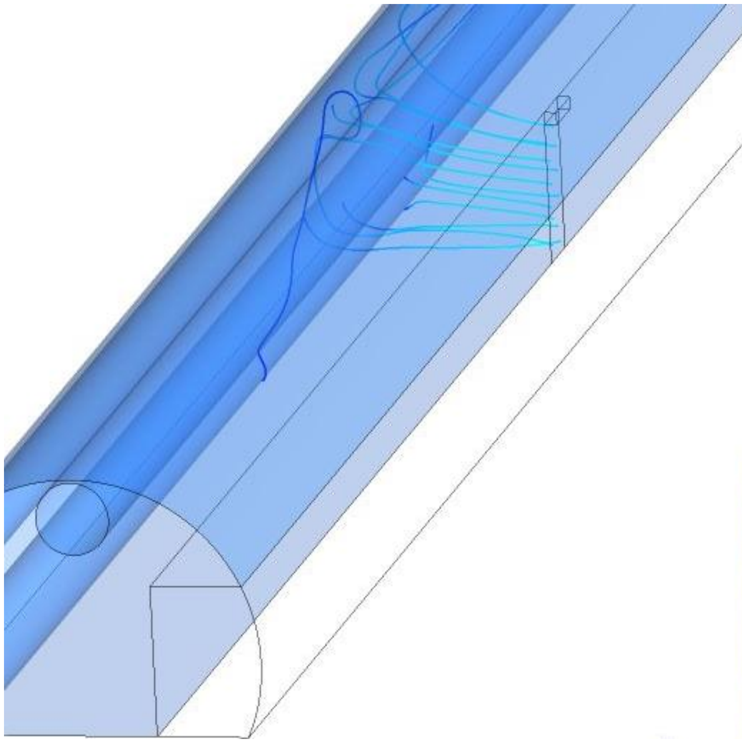
Paper attached to EDMS document



Air curtain FCC simulation:

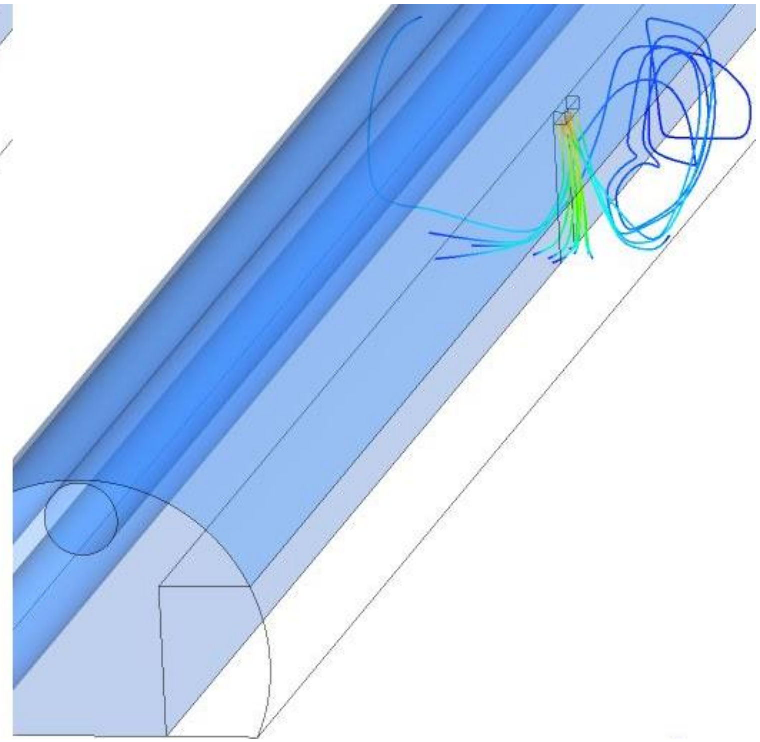
Without air curtain:

- Flow into machine tunnel due to pressure difference when door is open



With air curtain:

- Flow into machine tunnel can be reduced with a well positioned air curtain
- Δp better maintained



Air curtain:

Example:

- Δp = 40 Pa pressure difference
- Door between safety and machine tunnel: 2.3 m x 1 m
- With an air curtain (inlet width 0.2 m, inlet velocity 22 m/s, inlet angle 22.5°) the escape volume flow rate to machine tunnel can be reduced to 25%