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“Tozeret Haretz” Building. Air Drying Distribution System Simulation

By Alon Ashkenazi
Optunity Ltd.

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Mutual project

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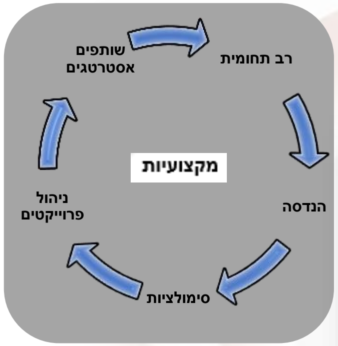
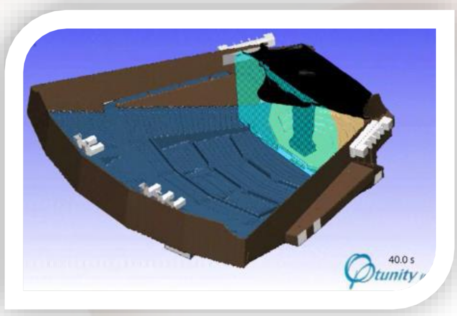
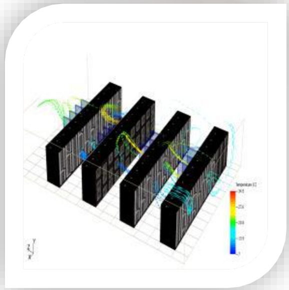
- ❑ Aluminum construction.
- ❑ Optunity.
- ❑ Asulin Compressors.

אופטיוניטי: תחומי פעילות





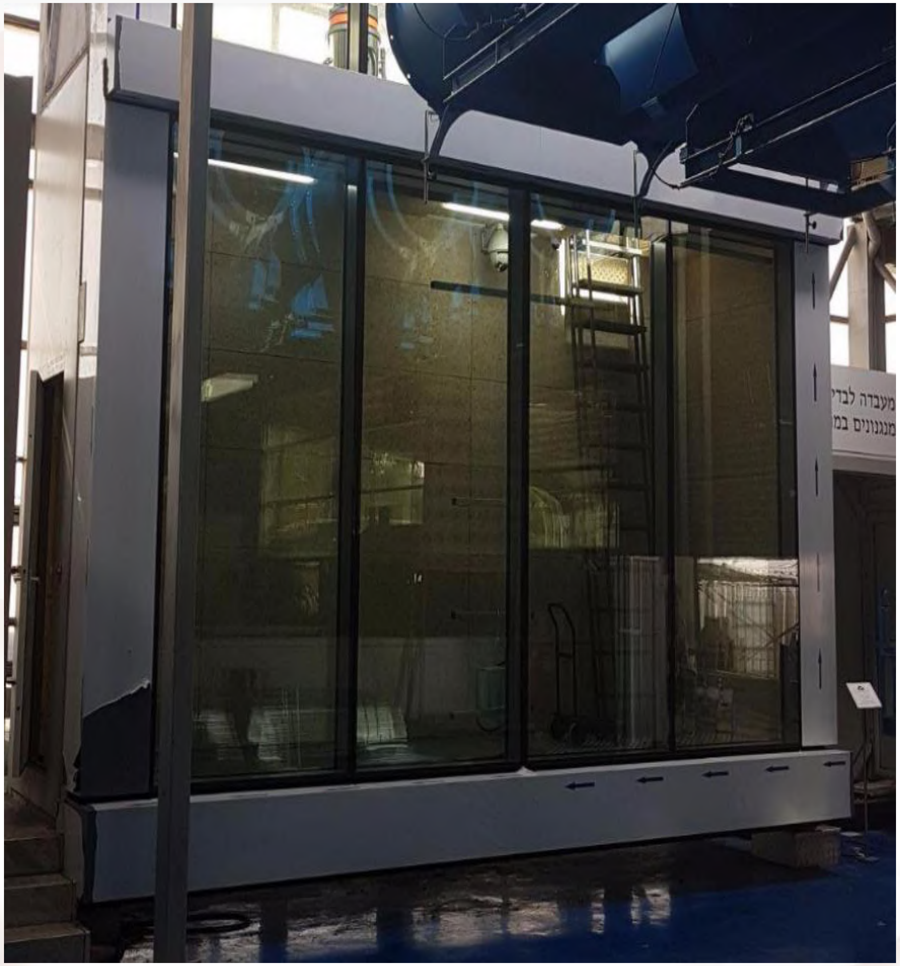


- בטיחות
  - √ פיזור עשן.
  - √ הימלטות.
- ניהול אנרגטי:
  - √ בקרת אקלים (+מערכות מחשוב)
  - √ קרינת שמש (סולארי).
  - √ אופטיקה (Ray tracing, ציפויים).
  - √ חיסכון באנרגיה.
- מקורות אנרגיה מתחדשים
  - √ סולארי (IP בתחום מערכות חימום).
  - √ שיווק כלי התכנון והסימולציה בלבד.
    - פוטו וולטאי.
    - רוח.
    - אגירת אנרגיה.
- הנדסת אנוש
  - √ מציאות מדומה.
  - √ אקוסטיקה.

Problem Definition

The challenge

To dry 6750 double sided windows, along 27 floors , each floor can have 250 windows, with internal void of 3.2m length x 1.35m width x 0.16m thick (682.5L/window) from 4.4gr/m3 water content to 0.325 gr/m3 water content, in less than 12 hours ?



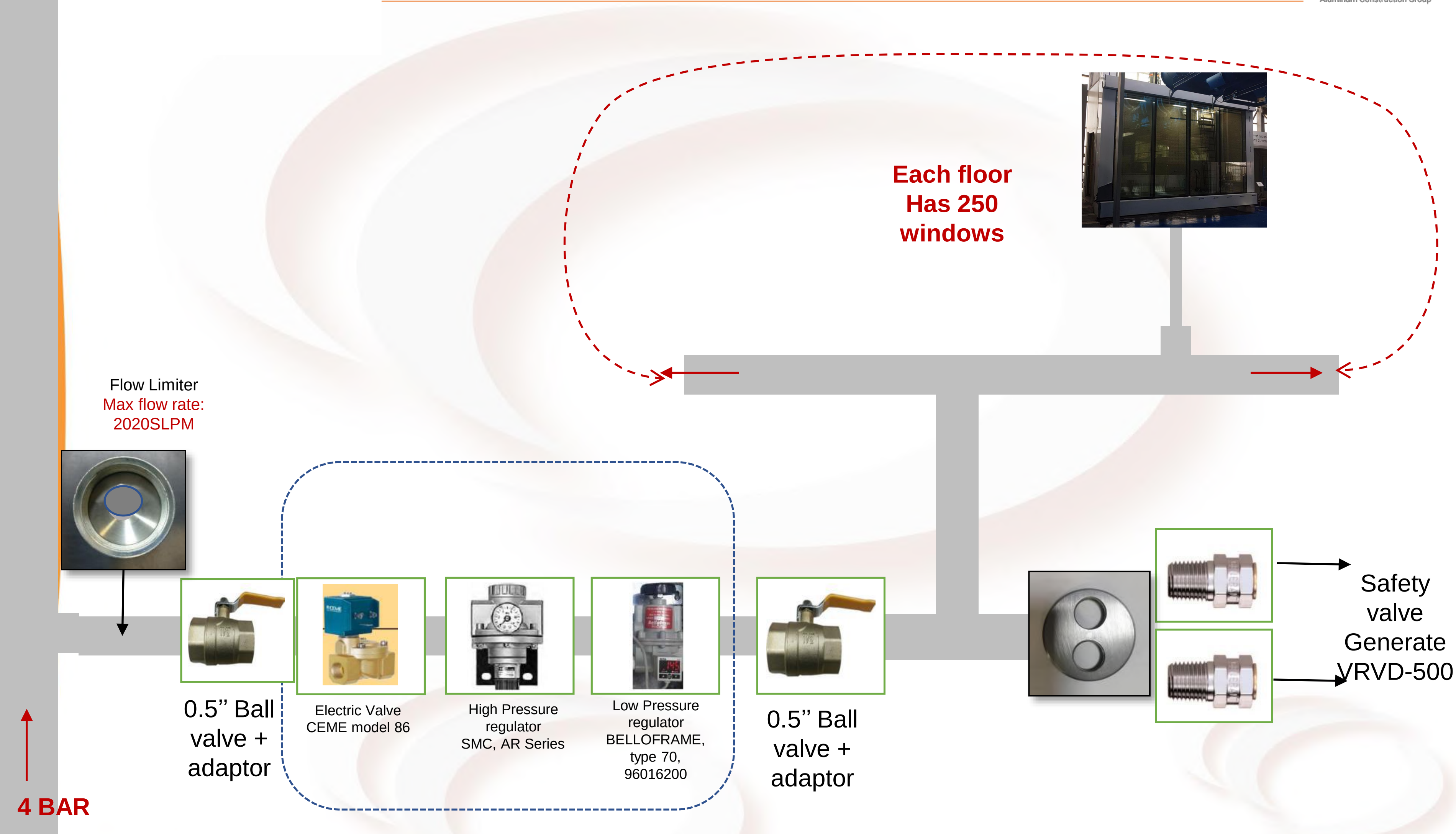
Simulation Tools

- ESI's Multiphysics CFD-ACE+ for the , CFD & Mechanics parts:
  - CFD part: Finite volume.
  - Mechanical (Stress/ Deformation/Thermal Conduction) part: Finite Element
- ESI's Multiphysics SimulationX for the Building's Flow Rate and Pressure Loss calculations.
- Scilab code, for large models empirical calculations.

Simulation Products

- Required Flow.
- Piping diameter .
- Piping pressure drop.
- Recommended piping structure.
- Safety Valve Recommended position.

Summary - Floor level Diagram



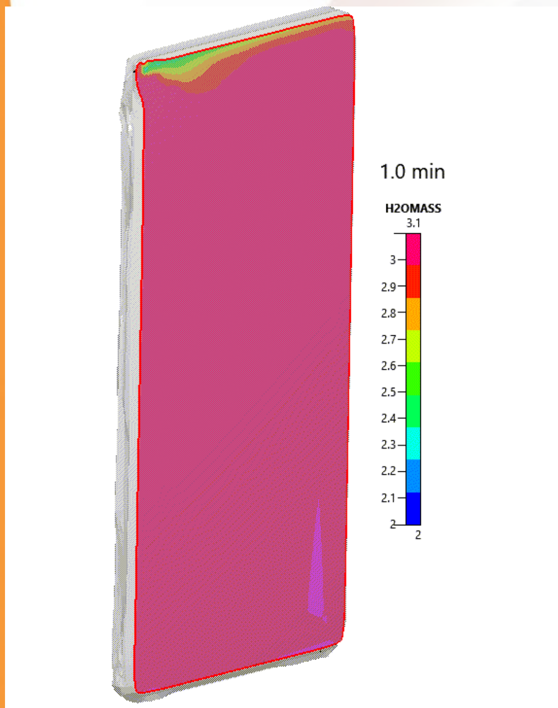
The Solution

From Down to Top Approach

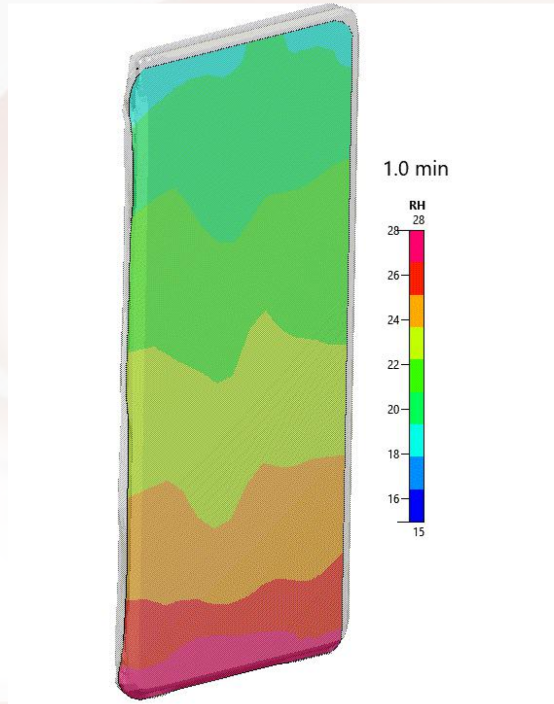
1. Conducting **Single Window Transient Simulation** (Unstructured CFD-ACE+) to calculate the required flow rate and pressure drop.
2. Developing a **Lumped Body transient Model**, (100% mixing , Scilab), change the mixing factor to match the previous Single Window CFD results,
3. **Compare Alternate Series to Parallel solutions**
4. **Finding resistance curves of system elements**
   Run CFD simulations, (S.S, unstructured CFD-ACE+) for system elements : Fasteners, Piping, Junctions, and field testing, building and empirical flow/pressure model for each component.
5. Run **Floor level Simulation** (S.S , empirical, Scilab).
6. Run **Building Level Simulation** (S.S, SimulationX)

Single Window Transient Simulation (1)

Window Drying CFD simulation



Water Vapor Mass Movie



RH Movie

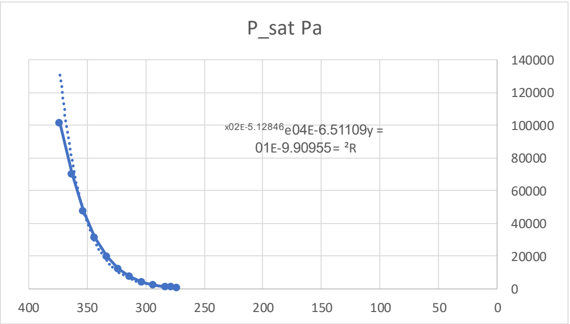
- Initial condition is air with 4.4 gr/m^3 water @ 4 °C (68.2% RH)
- Dry air is injected at the top left entrance.
- The time step is 20 minutes
- It takes 12.2 hours to dry the system to 0.325 gr/m^3 water @ 4°C (5% RH)

RH Calculator

m_w	0.00315	kg
V	1	m3
M_w	0.018	kg/mol
R	8.134	kg m2 s−2 K−1 mol−1
T	4	oC
	277	oK
Pw	394.29565	Pa
P_tot	100000	Pa
P_a	99605.70435	Pa
M_a	0.029	kg/mol
m_a	1.282030247	kg
m_tot	1.285180247	kg
X_w	0.00245102	kg/kg
X_a	0.99754898	kg/kg
P_sat	961.9867767	Pa
M_tot	44.38293955	mol
XM_w	0.00394296	mol/mol
XM_a	0.99605704	mol/mol

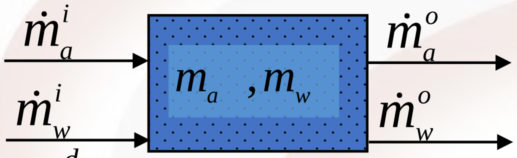
	Dry air mass fraction	Humid Air mass fraction
O2	0.2321	0.231531119
N2	0.7551	0.753249236
Ar	0.0128	0.012768627
H2O	0	0.0024510
	1.00000000	0.99754898

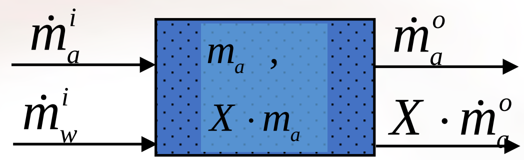
RH	41%



T oK	P_sat Pa
273	610.5
278	872.2
283	1228
293	2338
303	4243
313	7376
323	12330
333	19920
343	31160
353	47340
363	70100
373	101300

Lumped Body Transient Modeling (2)





$a) \quad \frac{d}{dt} m_w = m'_w = \dot m_w^i - \dot m_w^o = \dot m_w^i - X \cdot \dot m_a^o$

$b) \quad m'_a = \dot m_a^i - \dot m_a^o$

$c) \quad m_w = X \cdot m_a => \quad m'_w = X' \cdot m_a + X \cdot m'_a$

$a, c => d)$

$X' \cdot m_a + X \cdot m'_a = \dot m_w^i - X \cdot \dot m_a^o$

$d, b => e)$

$X' \cdot m_a + X \cdot (\dot m_a^i - \dot m_a^o) = \dot m_w^i - X \cdot \dot m_a^o$

$X' \cdot m_a + X \cdot (\dot m_a^i - \dot m_a^o + \dot m_a^o) - \dot m_w^i = 0$

$X' \cdot m_a + X \cdot \dot m_a^i - \dot m_w^i = 0$

$e) \ X' \cdot m_a + X \cdot \dot m_a^i - \dot m_w^i = 0$

$X \equiv k_1 \cdot e^{\alpha t} + k_2, \quad \alpha = -\frac{\dot m_a^i}{m_a(t)},$

$k_2 = -\frac{\dot m_w^i}{\dot m_a^i}, \quad k_1 = X_0 - k_2$

$f) \ X \equiv k_1 \cdot e^{\alpha t} + k_2$

$e, f \Rightarrow$

$g) \ (\alpha \cdot k_1 \cdot e^{\alpha t}) \cdot m_a + (k_1 \cdot e^{\alpha t} + k_2) \cdot \dot m_a^i - \dot m_w^i = 0$

parameters seperation $\Rightarrow$

$h) k_1 \cdot e^{\alpha t} (\alpha \cdot m_a + \cdot \dot m_a^i) = 0$

$(\alpha \cdot m_a + \dot m_a^i) = 0$

$\alpha = -\frac{\dot m_a^i}{m_a}$

$i) k_2 \cdot \dot m_a^i - \dot m_w^i = 0$

$k_2 = -\frac{\dot m_w^i}{\dot m_a^i}$

$k) t = 0 \Rightarrow, X = X_0$

$X_0 = k_1 \cdot e^{\alpha 0} + k_2 = k_1 + k_2$

$\Rightarrow k_1 = X_0 - k_2$

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$$e)\ X'\cdot m_a + X\cdot \dot{m}_a^i - \dot{m}_w^i = 0$$

$$l)\ V = \frac{m_a(t)}{\rho_a} + \frac{m_w(t)}{\rho_w} =$$

$$m_a(t)\left(\frac{1}{\rho_a} + \frac{X(t)}{\rho_w}\right)$$

$$m)\ m_a(t) = \frac{V\cdot\rho_a\cdot\rho_w}{\rho_w + X(t)\cdot\rho_a}$$

$$m)\ m_a(t) = \frac{V\cdot\rho_a\cdot\rho_w}{\rho_w + X(t)\cdot\rho_a}$$

$e, m \Rightarrow n)$

$$X'\cdot\frac{V\cdot\rho_a\cdot\rho_w}{\rho_w + X\cdot\rho_a} + X\cdot\dot{m}_a^i - \dot{m}_w^i = 0$$

$$X' = \frac{(\dot{m}_w^i - X\cdot\dot{m}_a^i)(\rho_w + X\cdot\rho_a)}{V\cdot\rho_a\cdot\rho_w} =$$

$$\frac{\dot{m}_w^i\cdot\rho_w + (\rho_a\cdot\dot{m}_w^i - \dot{m}_a^i\cdot\rho_w)X - \dot{m}_a^i\cdot\rho_a\cdot X^2}{V\cdot\rho_a\cdot\rho_w} =$$

$$\frac{1}{V}\left(\frac{\dot{m}_w^i}{\rho_a} + \left(\frac{\dot{m}_w^i}{\rho_w} - \frac{-\dot{m}_a^i}{\rho_a}\right)X + \frac{\dot{m}_a^i}{\rho_w}X^2\right)$$

$n)$

$$X' = \frac{(\dot{m}_w^i - X\cdot\dot{m}_a^i)(\rho_w + X\cdot\rho_a)}{V\cdot\rho_a\cdot\rho_w} =$$

$$\frac{\dot{m}_w^i\cdot\rho_w + (\rho_a\cdot\dot{m}_w^i - \dot{m}_a^i\cdot\rho_w)X - \dot{m}_a^i\cdot\rho_a\cdot X^2}{V\cdot\rho_a\cdot\rho_w} =$$

$$\frac{1}{V}\left(\frac{\dot{m}_w^i}{\rho_a} + \left(\frac{\dot{m}_w^i}{\rho_w} - \frac{-\dot{m}_a^i}{\rho_a}\right)X + \frac{\dot{m}_a^i}{\rho_w}X^2\right)$$

שימור מסה

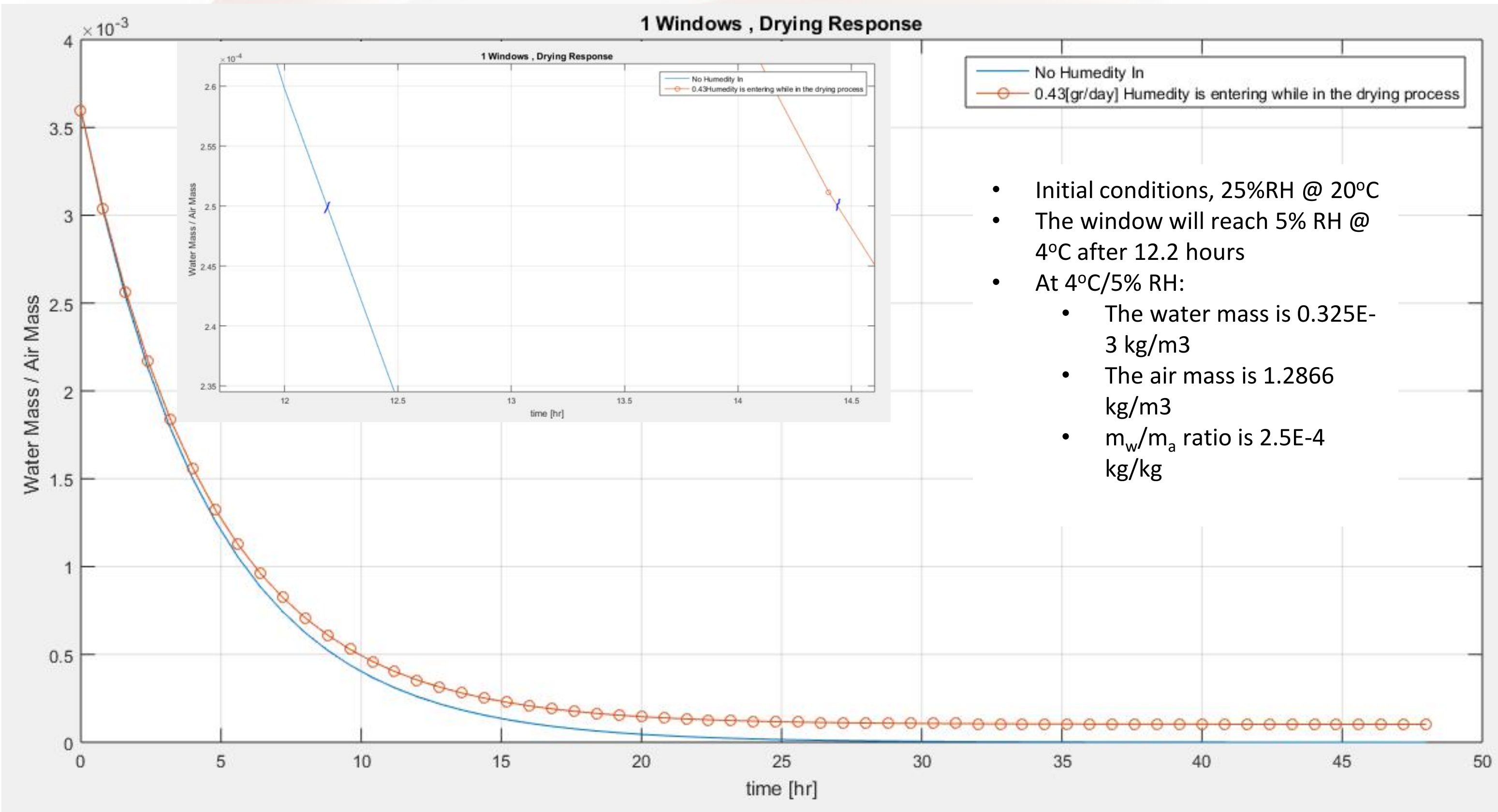
$o)$

$$\dot{m}^{i}(i+1)=\dot{m}^{o}(i)=\dot{m}^{i}(i)=\dot{m}_{a}^{o}(i)(1+X(i))$$

$$\dot{m}_{a}^{i}(i+1)=\frac{\dot{m}^{i}(i)}{(1+X(i))}=\frac{\dot{m}_{a}^{i}(i)+\dot{m}_{w}^{i}(i)}{(1+X(i))}$$

$$\dot{m}_{w}^{i}(i+1)=\dot{m}^{i}(i)\frac{X(i)}{(1+X(i))}=(\dot{m}_{a}^{i}(i)+\dot{m}_{w}^{i}(i))\frac{X(i)}{(1+X(i))}$$

Drying Response - hour

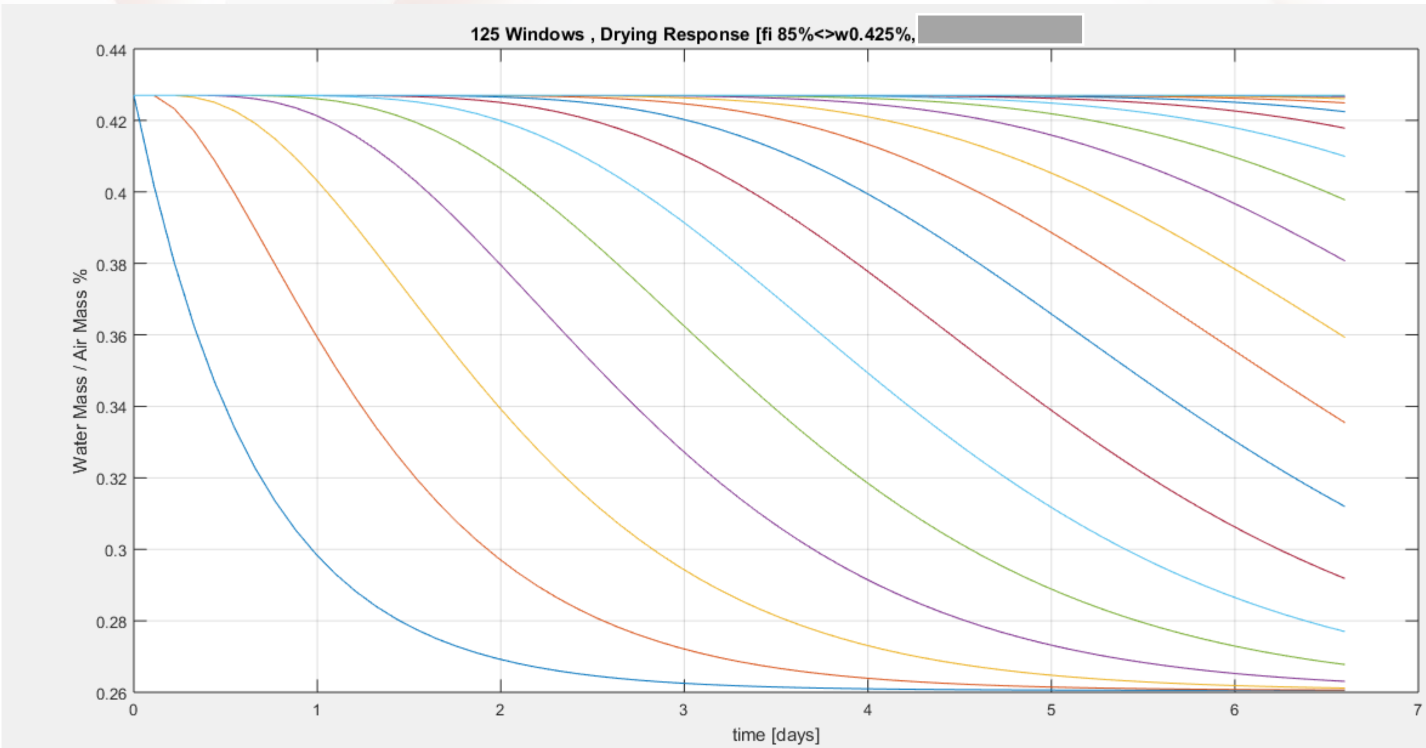


- Initial conditions, 25%RH @ 20°C
- The window will reach 5% RH @ 4°C after 12.2 hours
- At 4°C/5% RH:
  - The water mass is 0.325E-3 kg/m3
  - The air mass is 1.2866 kg/m3
  - m_w/m_a ratio is 2.5E-4 kg/kg

Comparing Alternate Series to Parallel solutions (3)

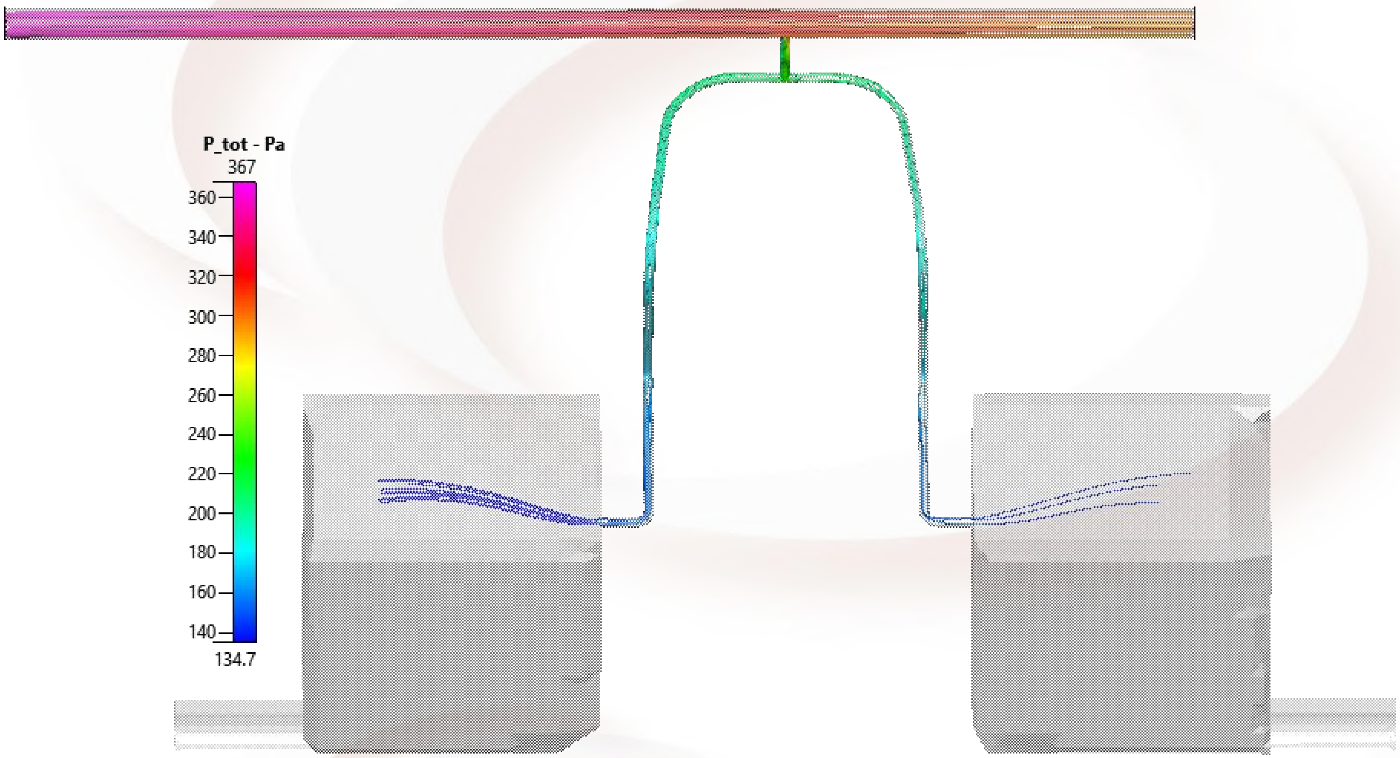
Series of Windows Drying Response

- Series of windows.
- Lumped body Transient Calculation.
- Water to Air mass ration in (%)
- At a single flow rate

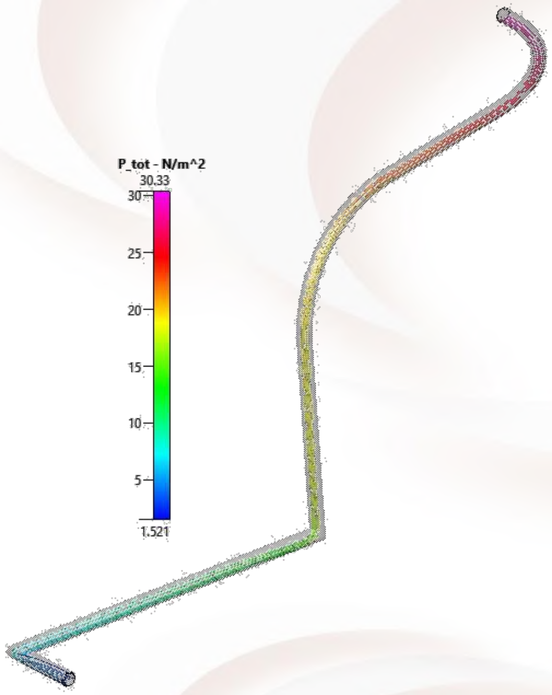


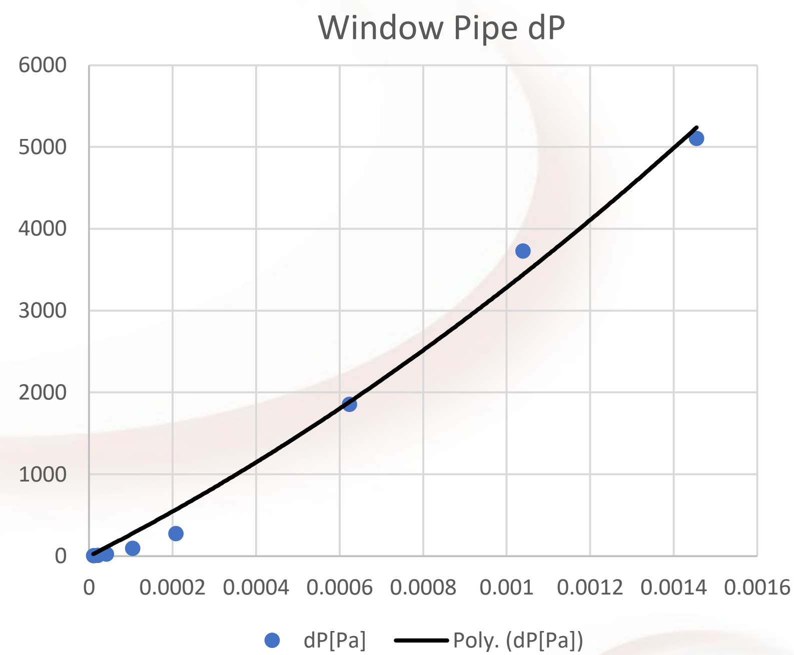
Finding resistance curves of system elements using CFD Simulations (4)

2 Windows CFD simulation

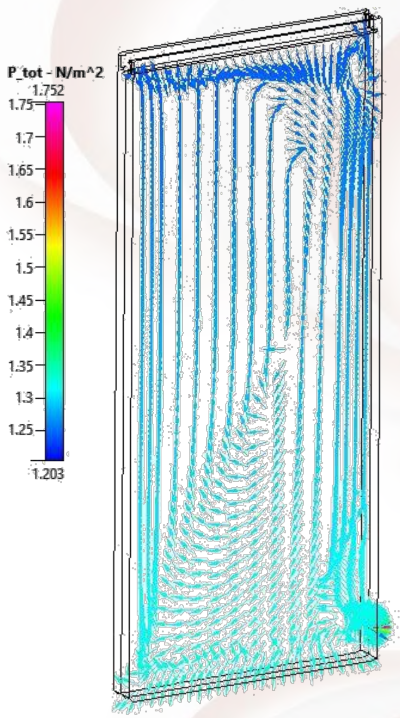


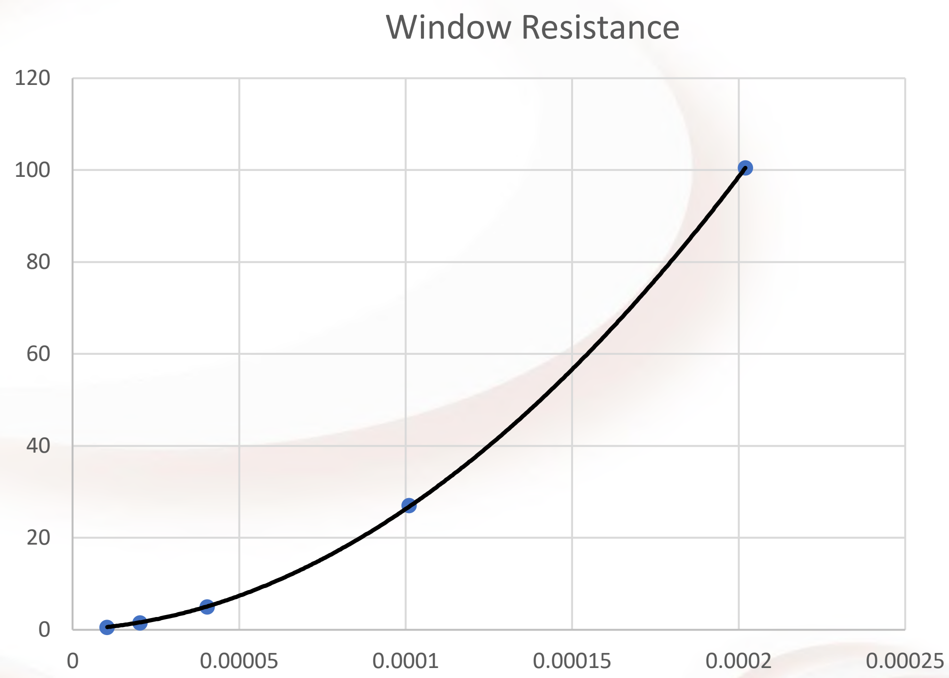
Single Window entry pipe resistance curve



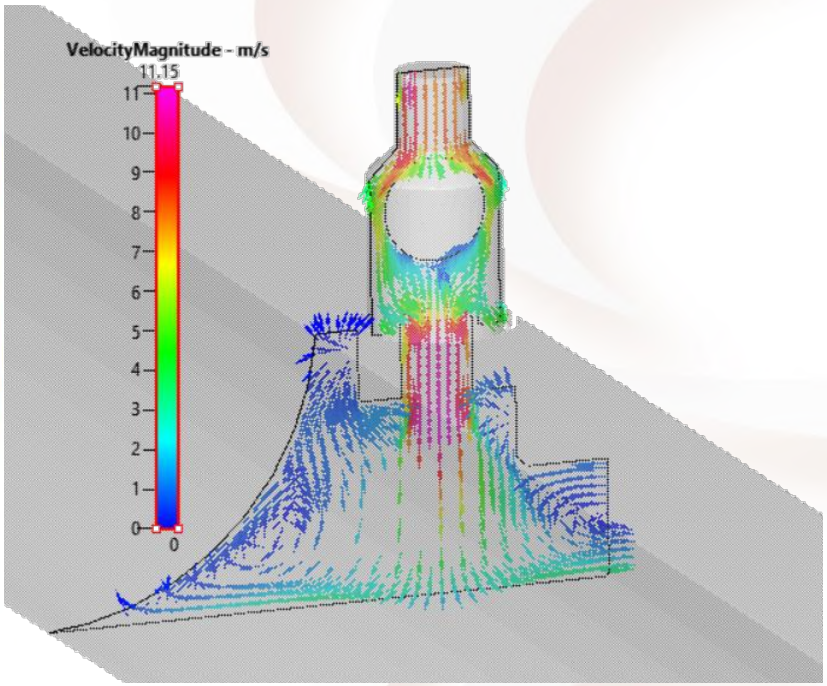


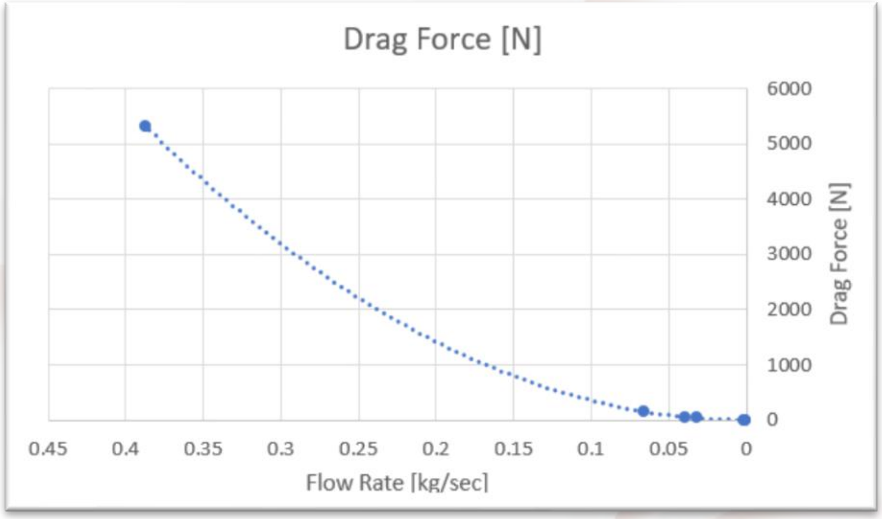
Window resistance curve





Flow through pressure relief valve

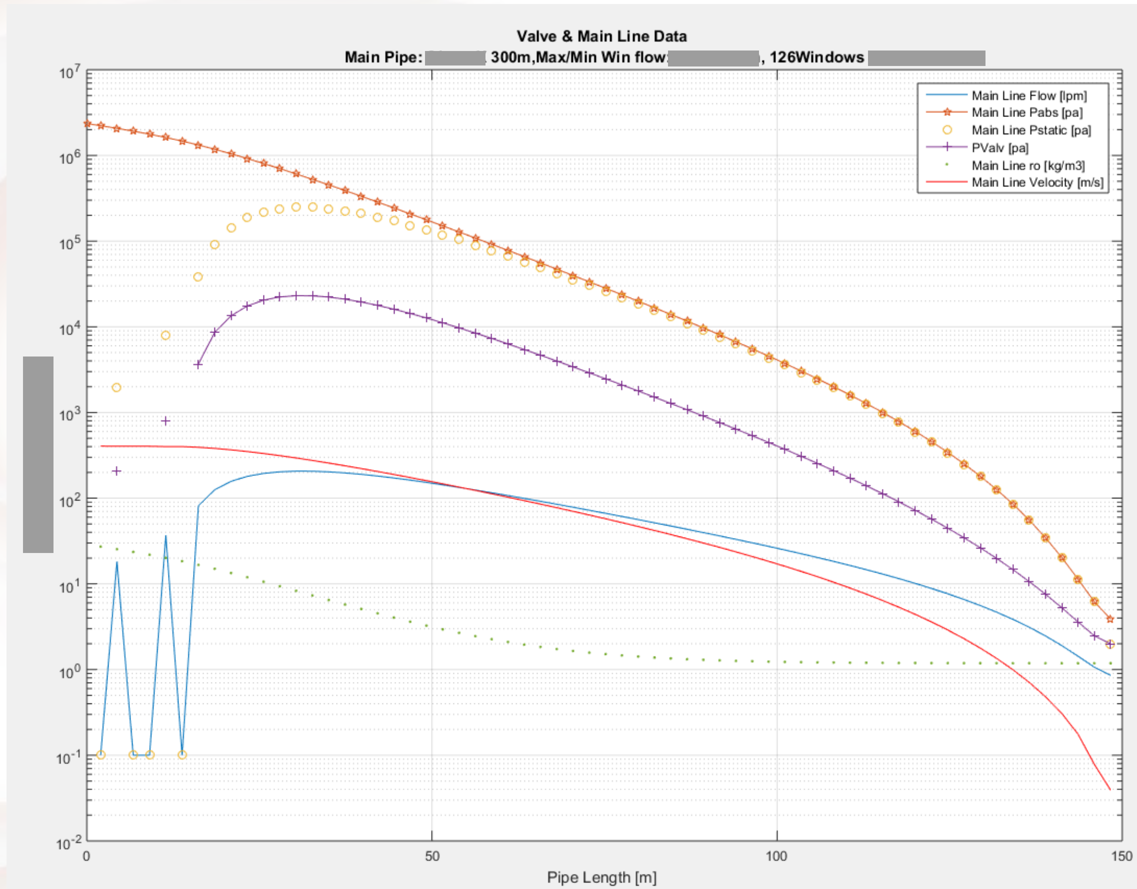




Floor Level Simulation (6)

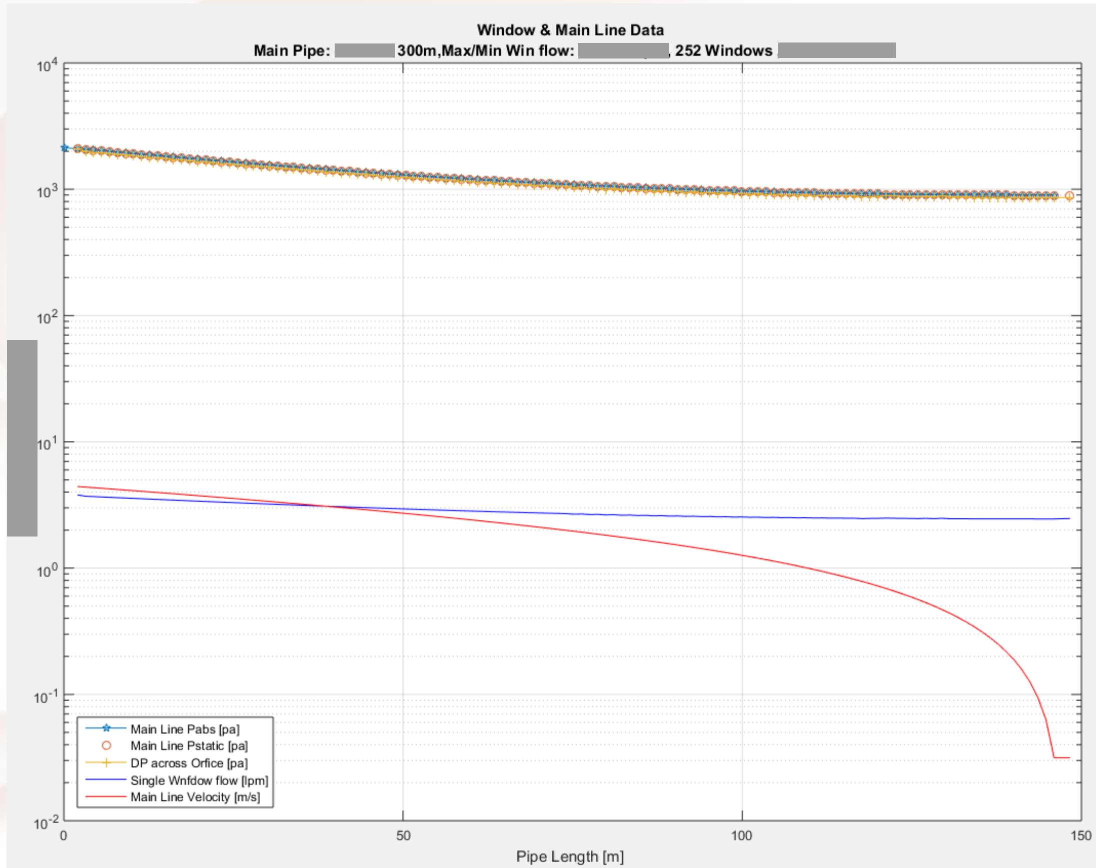
Original Solution

- 250 windows.
- 300m pipe.
- One can see that the pipe diameter is two small, and cause a suck force at pipe entrance.



Pressure in main line & Flow rate in each window

- Line is 150m long (equivalent to 300m circular)
- Minimum Flow Rate is 64% from the maximum.



Building level Simulation (6)

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Main Building Transmission Line.

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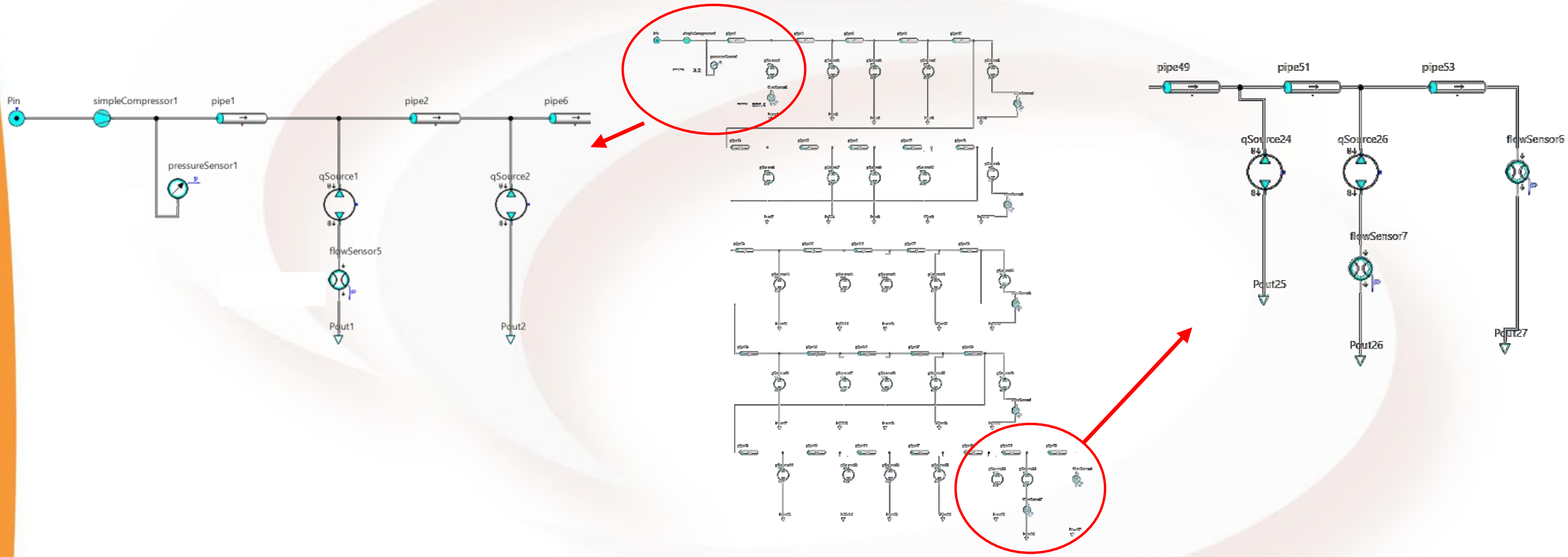

From the main transportation line , 2” line with 27 floors and less than 150m length , we found that the absolute pressure would range about 4Bar.

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Thank You!

alon@Optunity.co.il