CFD Study of ACC Airflow and Performance Improvement Potential

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Your Guard Against the Elements

Outline

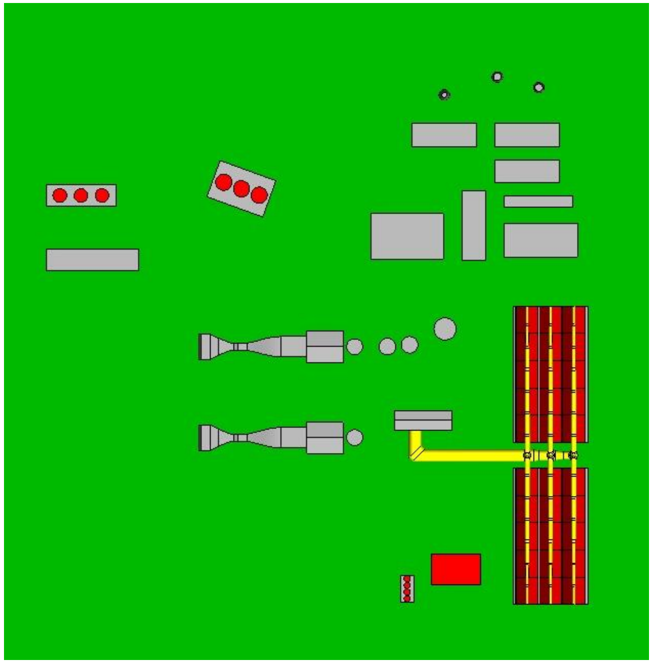
- **Background and Geometry**
- Setup
- Results
  - Characterization of Wind Losses
  - Effects of Windscreens
  - Optimal Solution

Background

- Combined Cycle Unit 2 on 1
- Power Plant Nameplate: 578MW
- Steam Turbine Design Output: 295MW
- Commercial Operation 2008
- Goal is to increase back pressure trip limits
- Part of larger upgrade to the C.C Unit. Increase the CT output and ACC heat rejection. Mitigate wind effects on ACC performance.

Background

Plant

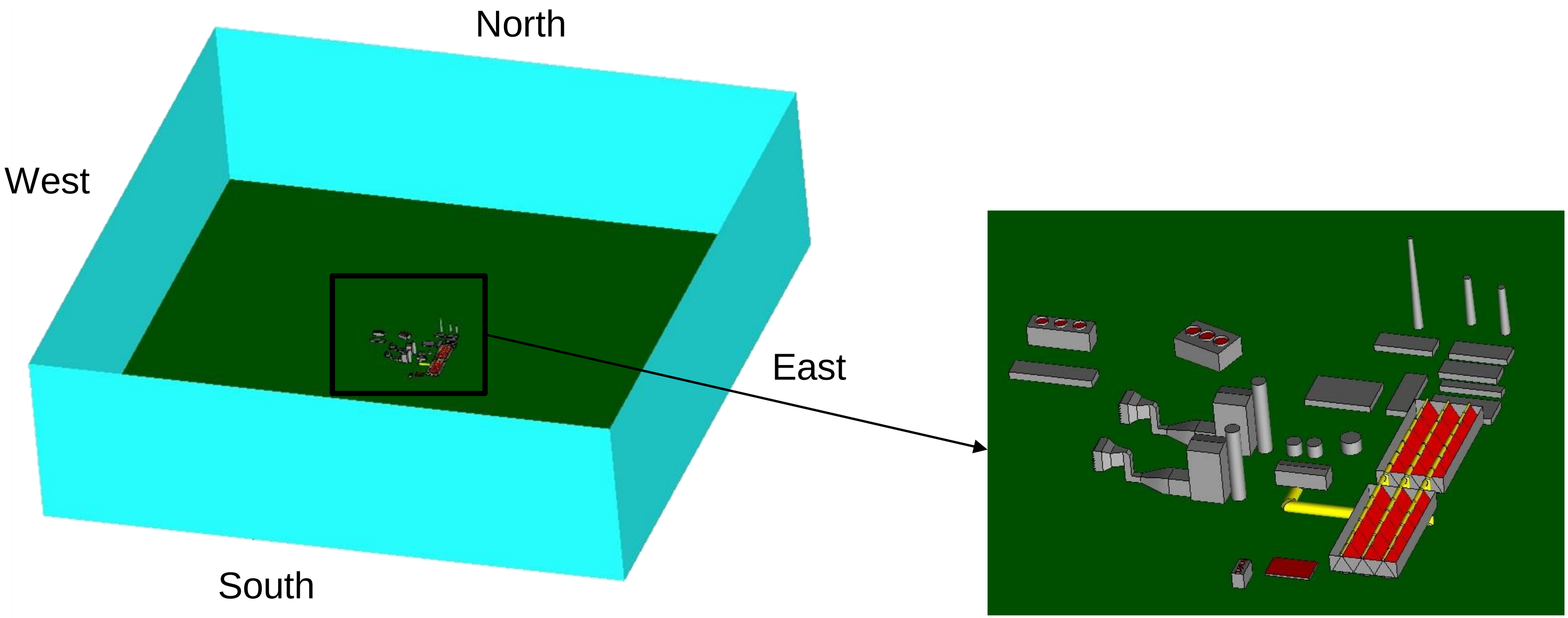


3D Model

Background

Geometry

- 3D drawing of the plant
  - ACC (2 units 3x5 modules)
  - Buildings



Geometry

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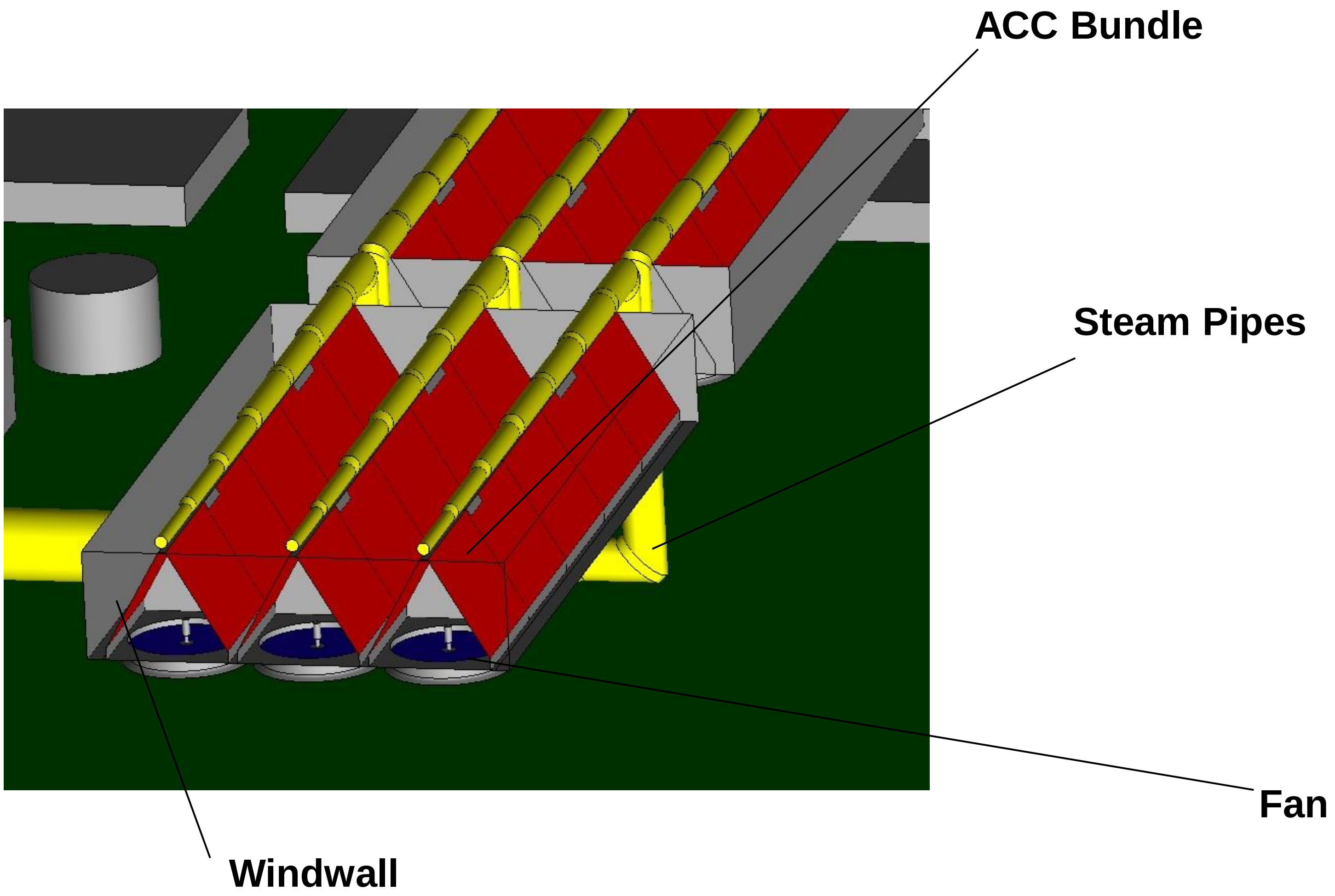

Geometry

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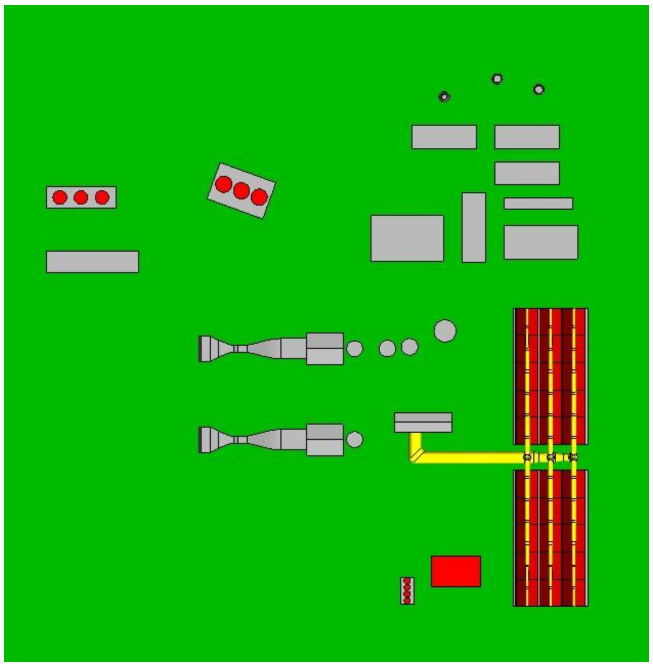
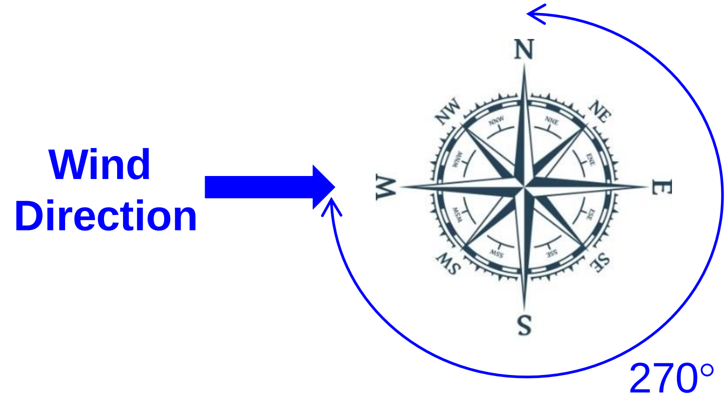


Plant North ≡ North



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- Results:
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  - Effects of Windscreens
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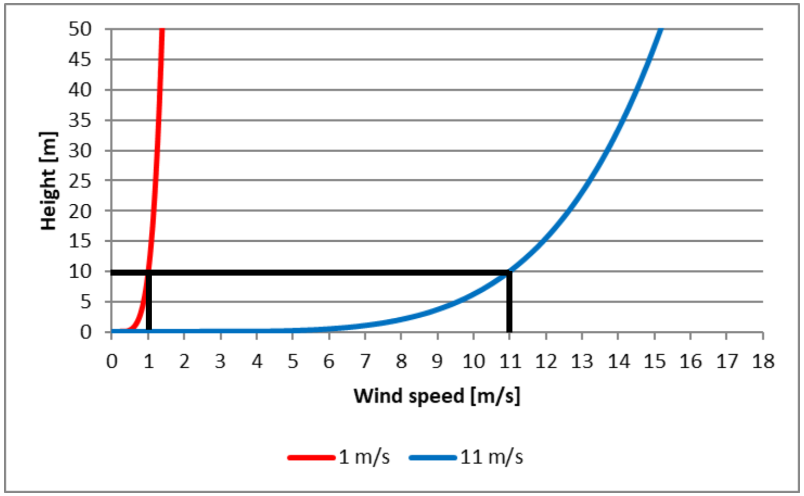
Setup

- Ambient conditions:
  - Ambient temperature = Design temperature = 35 °C = 308.15 K
  - Wind directions = 270 deg (W)
  - Wind speed = 1 and 11 m/s, 10m above the ground

- Numerical modelling based on our practice
  - Ansys Fluent v222 CFD code
  - Steady-state
  - Coupled solver
  - Ideal gas: air
  - Buoyancy forces activated
  - Turbulence Model: Standard k-e with Buoyancy effects

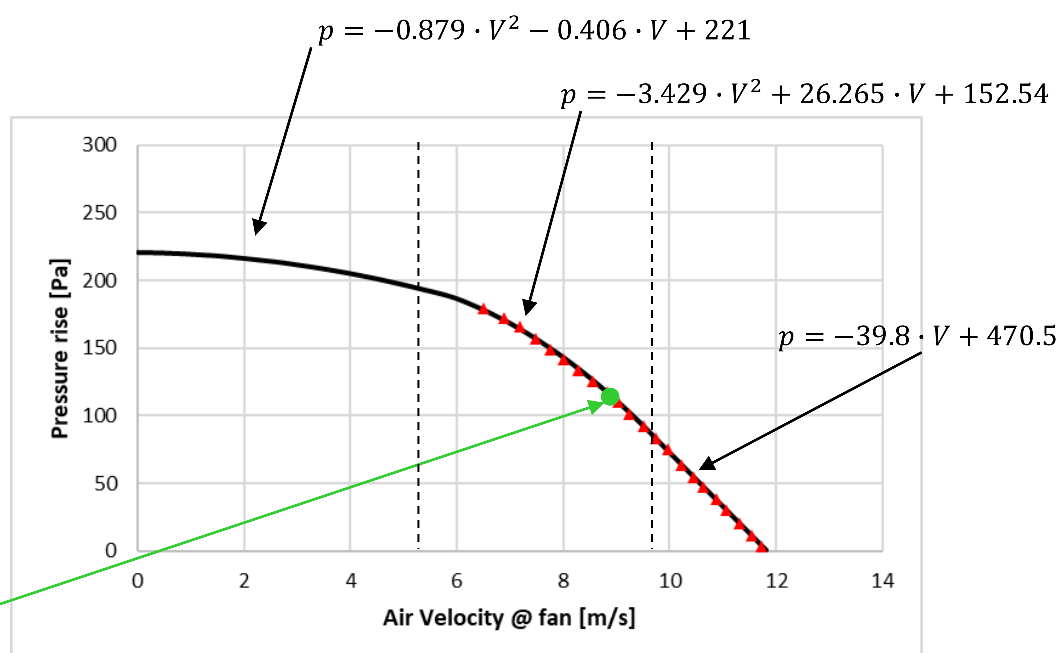
Modeling Details

- Wind profile:
  - Far field boundary layer: $V(y) = V_{ref} \times \left(\frac{y}{H_{ref}}\right)^{a}$ $\begin{cases} V_{ref} \\ H_{ref} \\ a \end{cases}$
  - V_{ref} = 1 and 11 m/s
  - Wind readings are assumed at H_{ref} = 10m
  - Power law exponent *a* is a function of ground roughness and BL stability (and of H_{ref})
    → Irwin 1979 suggested a value of 0.2 for stable BL over rough surfaces (http://www.webmet.com)



Modelling Details

- ACC fan model
  - Fan model implements a sudden pressure rise (p) as a function of normal air velocity (V)
  - Fan curve is extrapolated from duty point in terms of analytical functions p=f(V)
  - Fan curve is extended towards low flow rates to cover the full range of velocities



● Curve from datasheet

▬ Fan “ as it is”

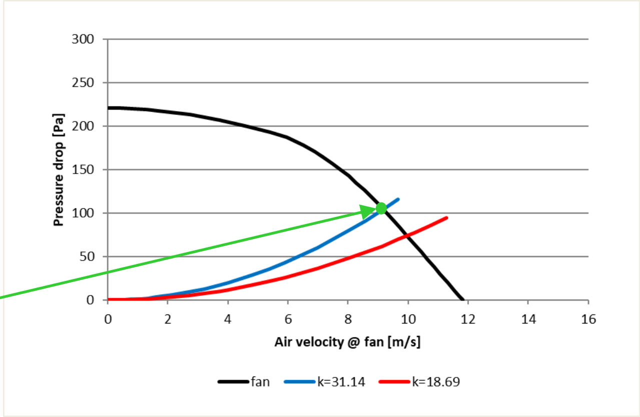
Duty point:
Flow rate = 868.08 m^3/s
Pressure rise = 108 Pa

Modelling Details

- ACC bundle model
  - Bundle is modelled as a thin surface and implements:
    - → A sudden pressure (p) drop
    - → A sudden temperature (T) rise
  - Pressure drop can be expressed as a function of normal air velocity (V) through a pressure drop coefficient (k):
    - ΔP = pressure drop
    - ρ = air density
    - V = air velocity @bundle

$$k = \frac{\Delta P}{\frac{1}{2}\rho V^2}$$

  - Bundle k coefficient can be estimated using duty point data
    - → Overall pressure drop corresponds to a K_{total} = 31.14 (based on estimated bundle surface = 9755 m^2)
    - → Usually, only part of the losses at duty point occurs on the bundle
      - K bundle is normally estimated as 60% of the total losses
        - » $K_{bundle} = 0.6\ K_{total} = 18.69$



Duty point:
Flow rate = 868.08 m^3/s
Pressure rise = 108 Pa

Modelling Details

- ACC bundle model
  - Thermal behavior is modelled with a sudden temperature rise
  - Outlet air temperature is maintained fixed at:

$$T_b = T_{amb} + \Delta T = 308.15\ K + 10.85\ K = 319\ K$$

  - Thermal power exchanged is:

→ $\dot{Q} = mfr \cdot C_p \cdot (T_b - T_{amb}) = 276.61\ MW$

→ Where:

  - MFR = 25342 kg/s
  - C_p = 1006 J/kg/K

Outline

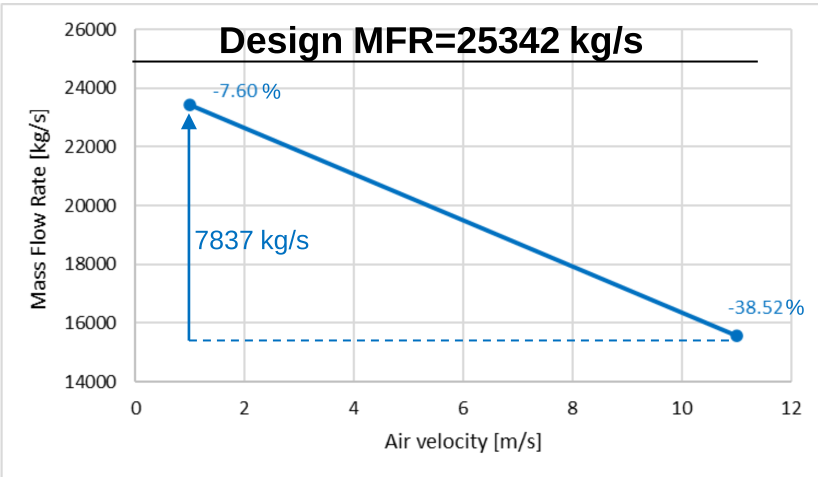
- Background and Geometry:

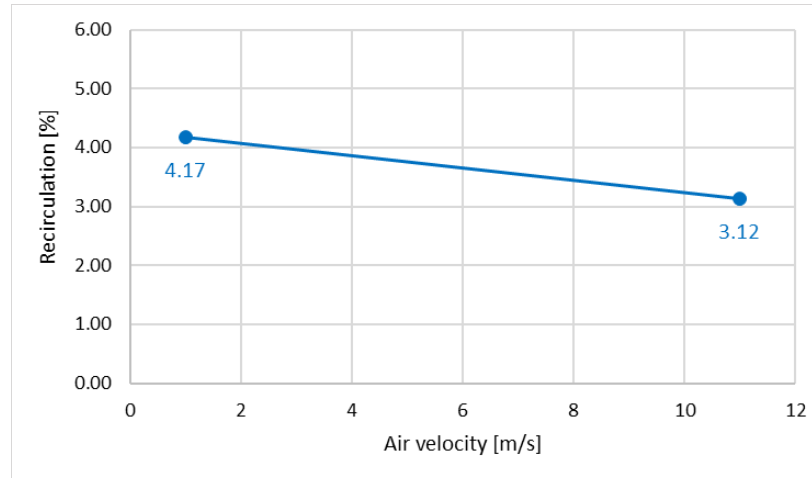
- Setup:

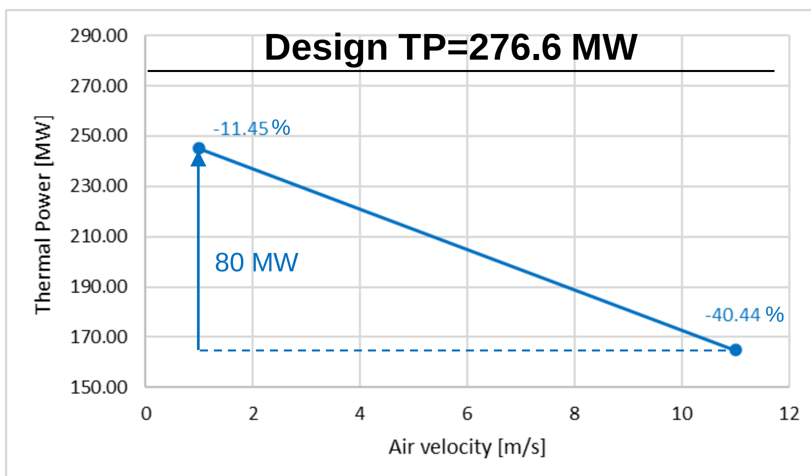
- **Results:**
  - **Chacterization of Wind Losses**
  - Effects of Windscreens
  - Optimal Solution

Characterization of Wind Losses (**WS**=1 m/s and 11 m/s,**WD**=270deg)

- Global performance derating in terms of mass flow rate, recirculation and thermal power

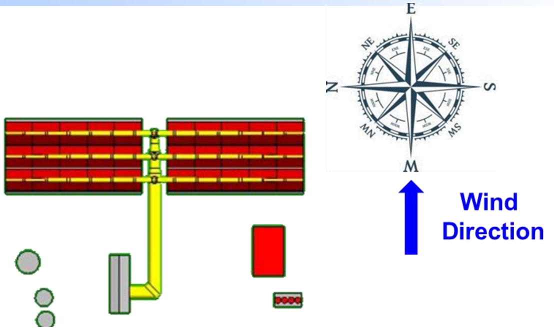






Characterization of Wind Losses (**WS**=1 and 11 m/s,**WD**=270deg)

- Performance in terms of thermal power



Thermal Power [%]

min	70%
mean	85%
max	100%

1 m/s

fan id	5	4	3	2	1
3	97%	102%	101%	99%	97%
2	95%	99%	96%	96%	82%
1	84%	74%	60%	62%	67%

fan id	1	2	3	4	5
6	98%	100%	101%	101%	95%
5	82%	98%	95%	99%	95%
4	72%	74%	76%	76%	85%

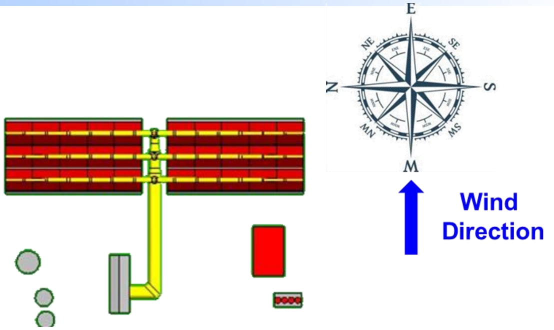
11 m/s

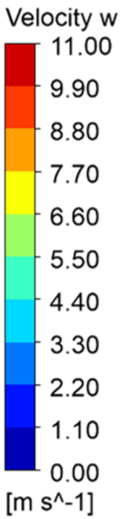
fan id	5	4	3	2	1
3	89%	92%	90%	88%	66%
2	80%	81%	73%	81%	75%
1	37%	17%	9%	12%	44%

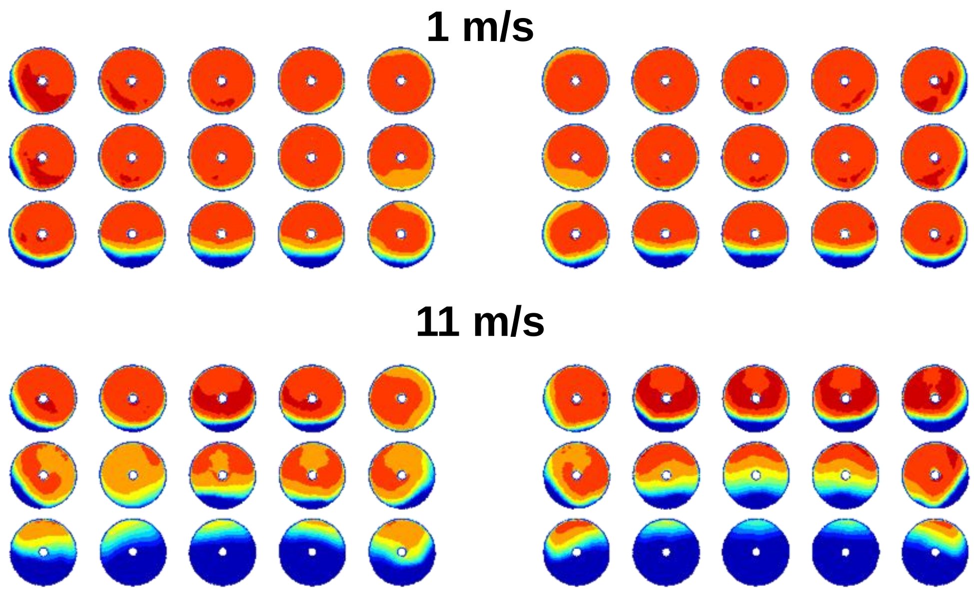
fan id	1	2	3	4	5
6	74%	87%	86%	86%	80%
5	79%	67%	82%	64%	82%
4	31%	5%	3%	3%	23%

Characterization of Wind Losses(**WS**=1 and 11m/s,**WD**=270deg)

- Vertical velocity contours on fans

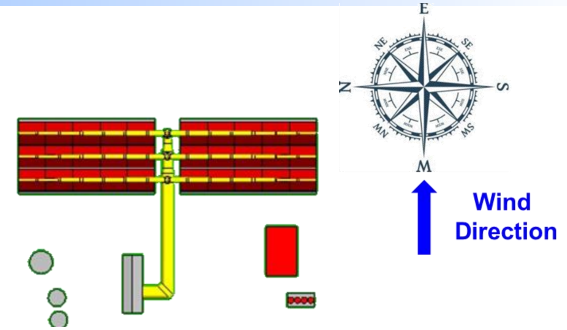


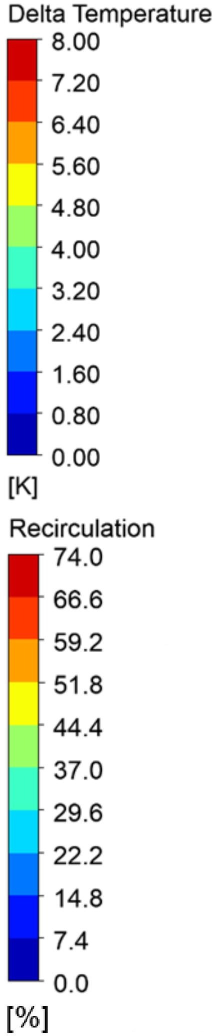


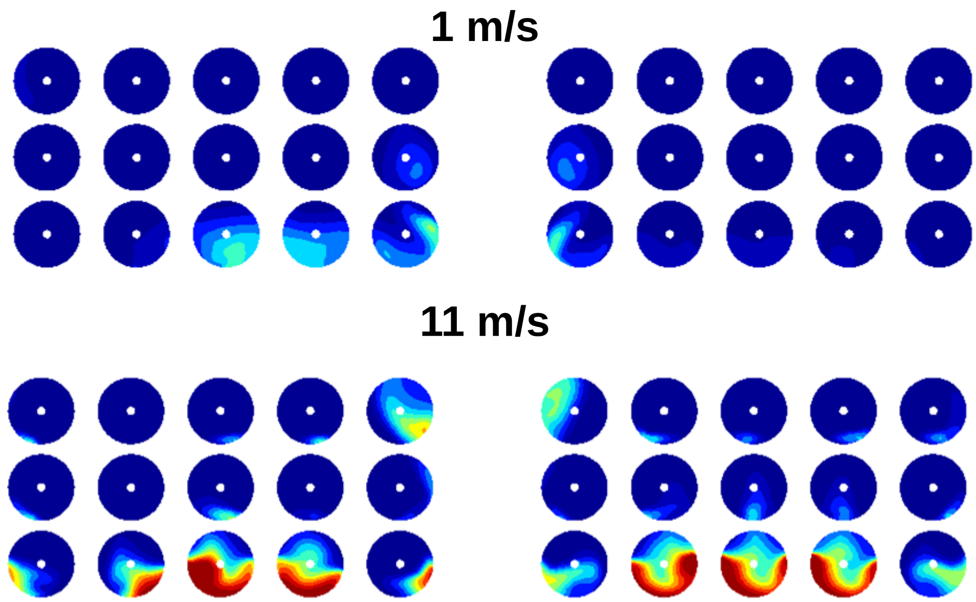


Characterization of Wind Losses(**WS**=1 and 11m/s,**WD**=270deg)

- Temperature contours on fans





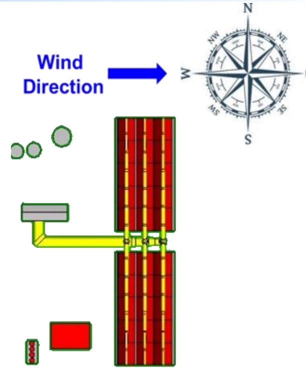


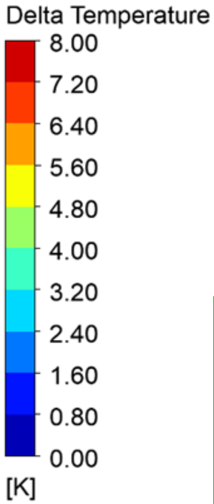
$$DeltaTemperature = T - T_{amb}$$

$$Recirculation = 100 \cdot \frac{T - T_{amb}}{T_{bundle} - T_{amb}}$$

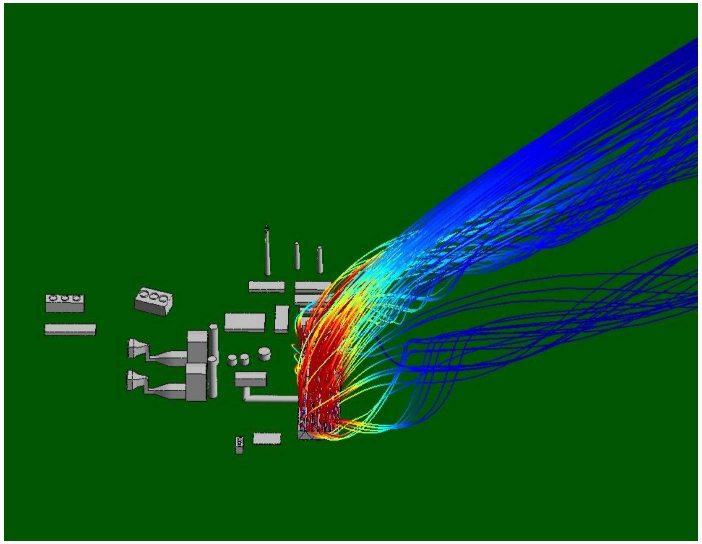
Characterization of Wind Losses(**WS**=1 and 11m/s,**WD**=270deg)

- Forward Streamlines from ACC fans colored with delta temperature

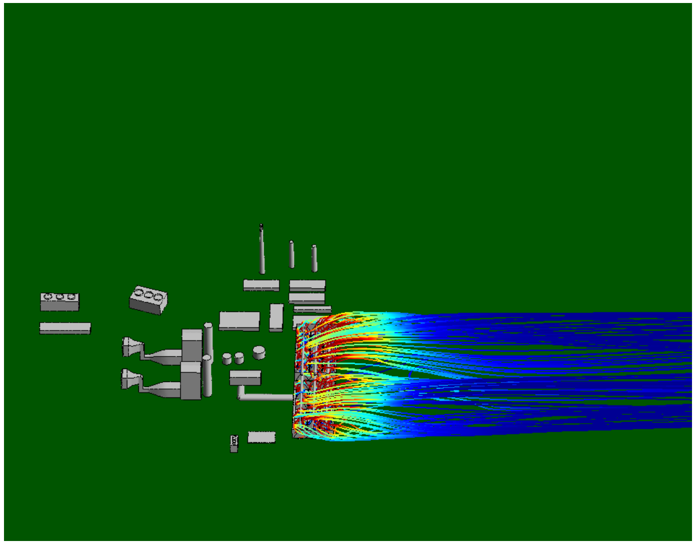




1 m/s



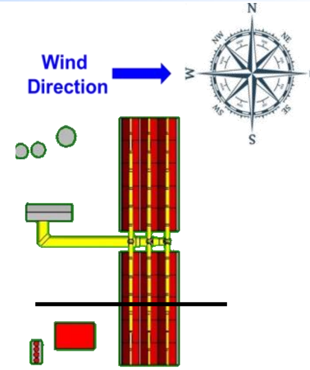
11 m/s

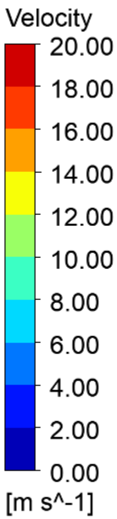


$$DeltaTemperature = T - T_{amb}$$

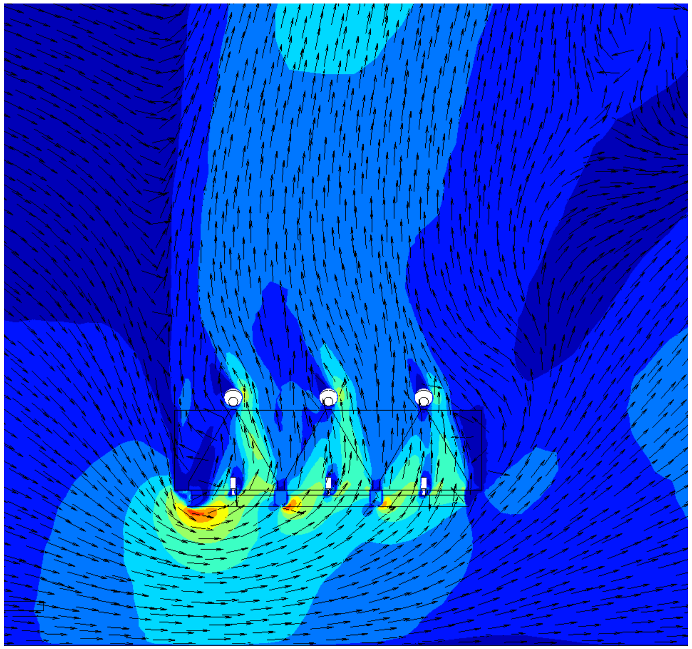
Characterization of Wind Losses (**WS**=1 and 11/s, **WD**=270deg)

- Velocity Contour on a central plane

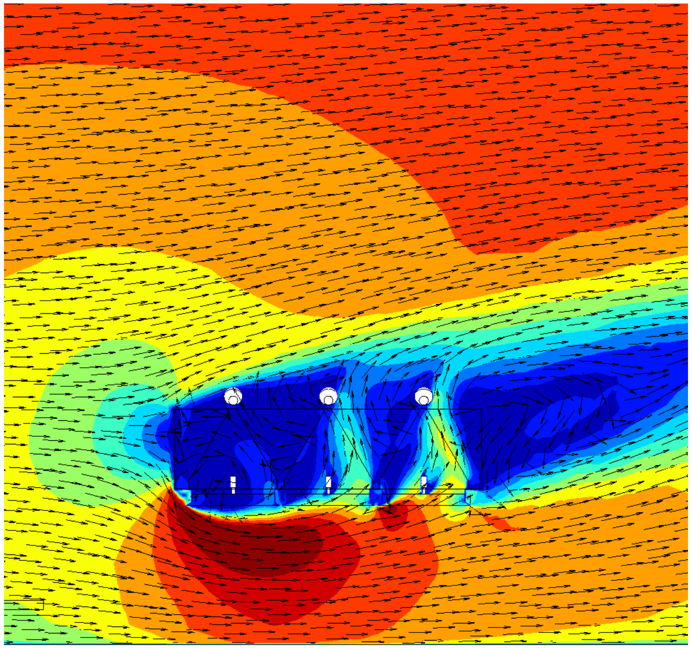




1 m/s

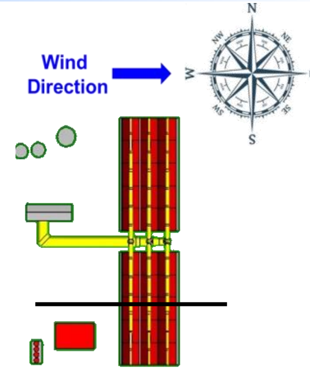


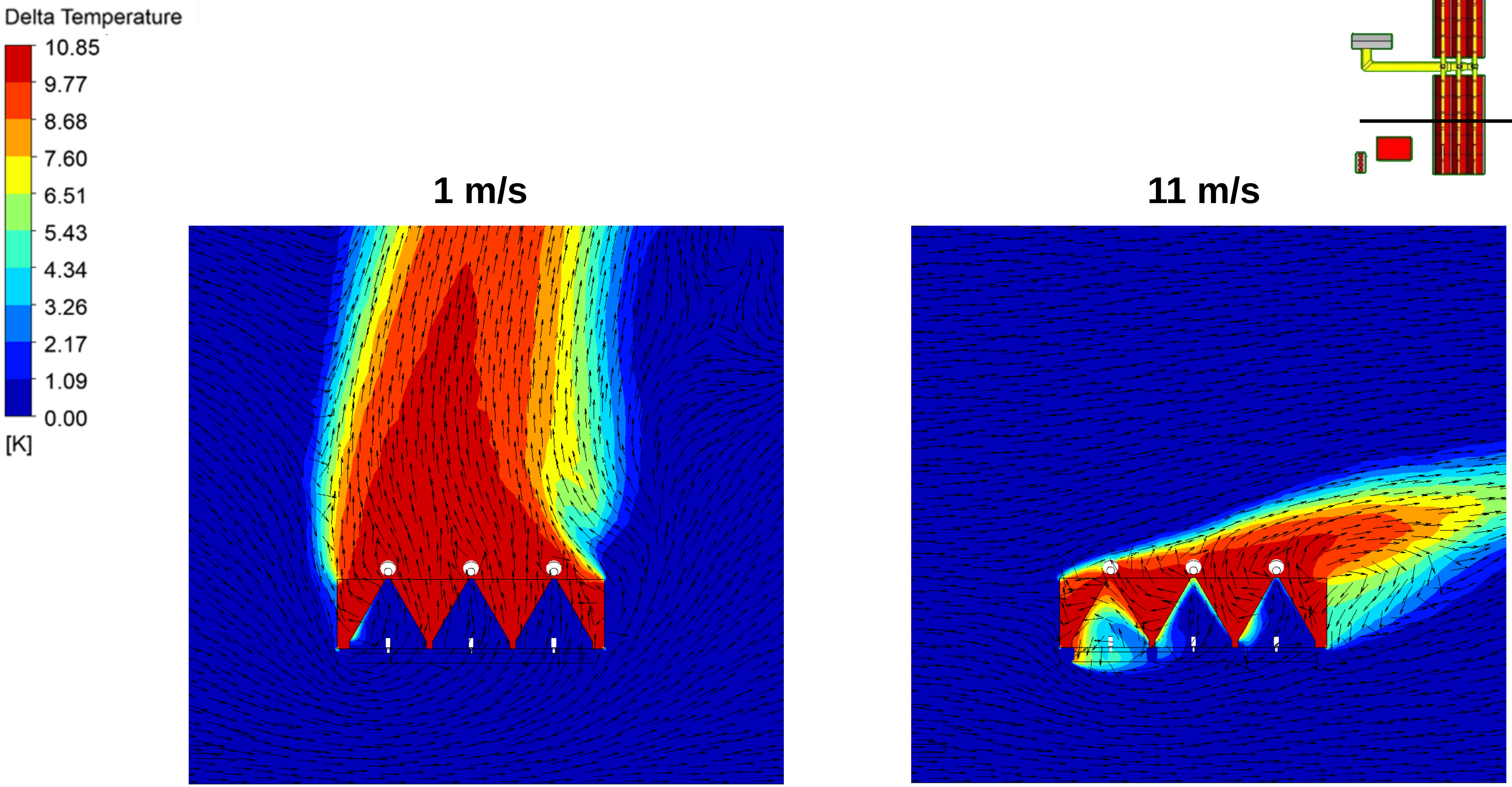
11 m/s



Characterization of Wind Losses(**WS**=1 and 11m/s,**WD**=270deg)

- Delta Temperature Contour on a Centrl Plane





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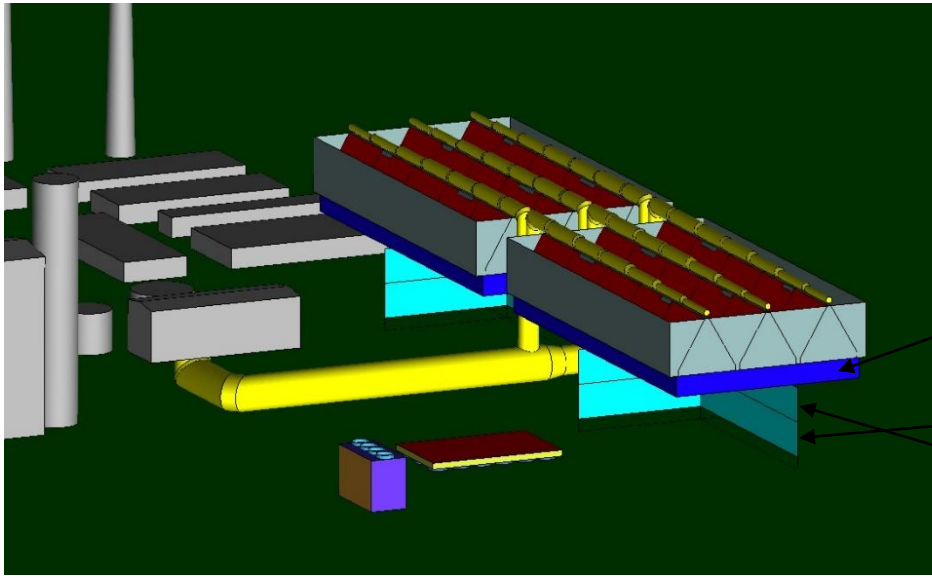
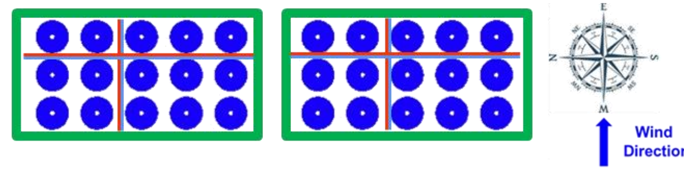
Effects of Windscreen Configurations Tested (**WS**=11 m/s, **D**=270deg)

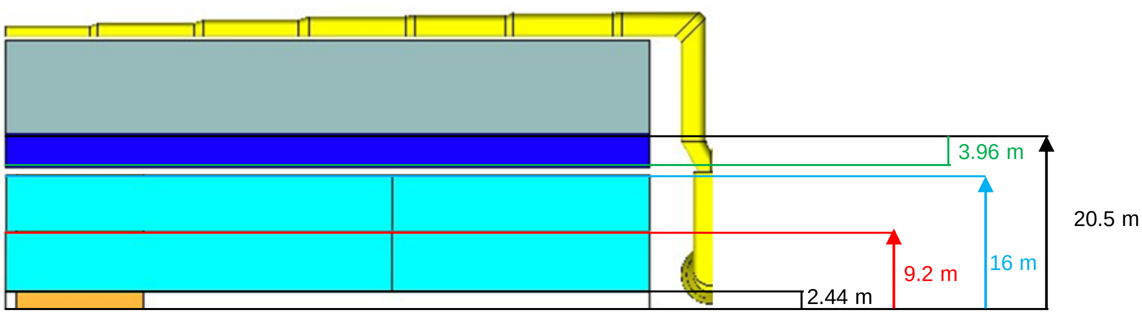




L01: Perimeter M50

L02: Cruciform M75 Short

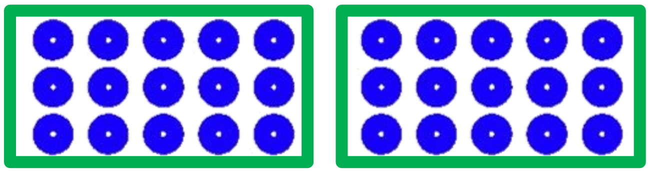
L03: Cruciform M75 Tall



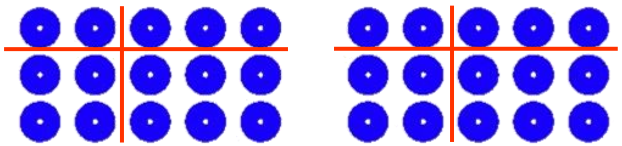
The position of the short side
of cruciform windscreen is not relevant
for the ccurrent wind direction, but it would
be important for southerly winds

Effects of Windscreen (**WS**=11 m/s, **WD**=270deg)

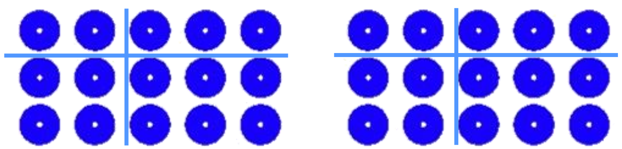
L01: Perimeter M50



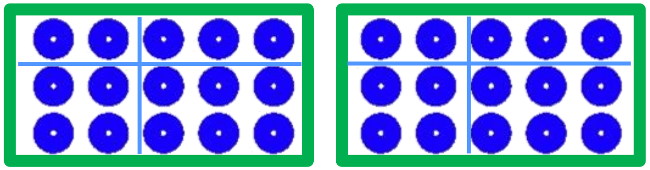
L02: Cruciform M75 Short

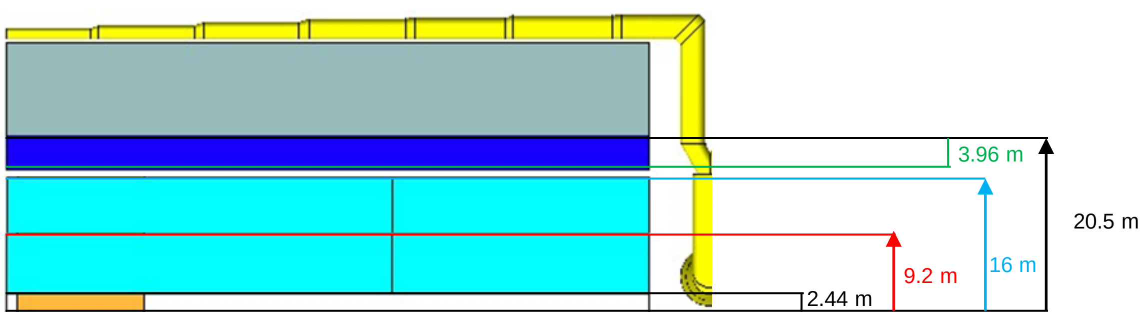


L03: Cruciform M75 Tall



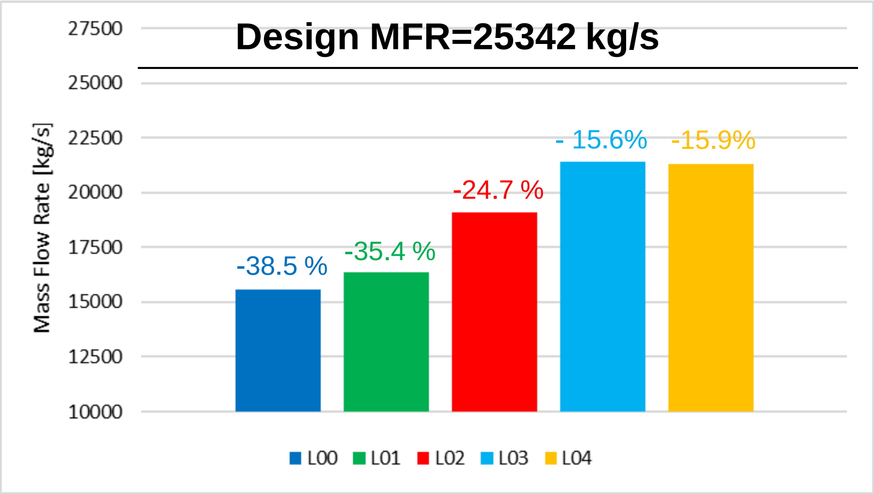
L04: Combined (L01+L03)

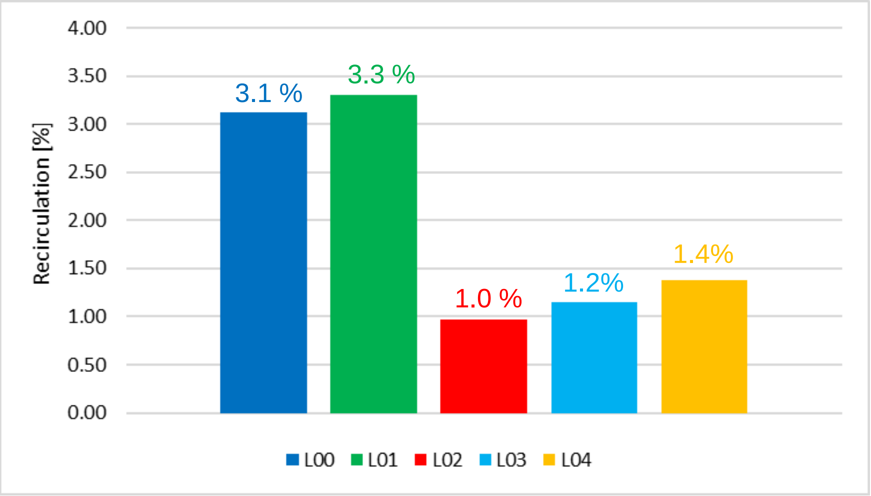


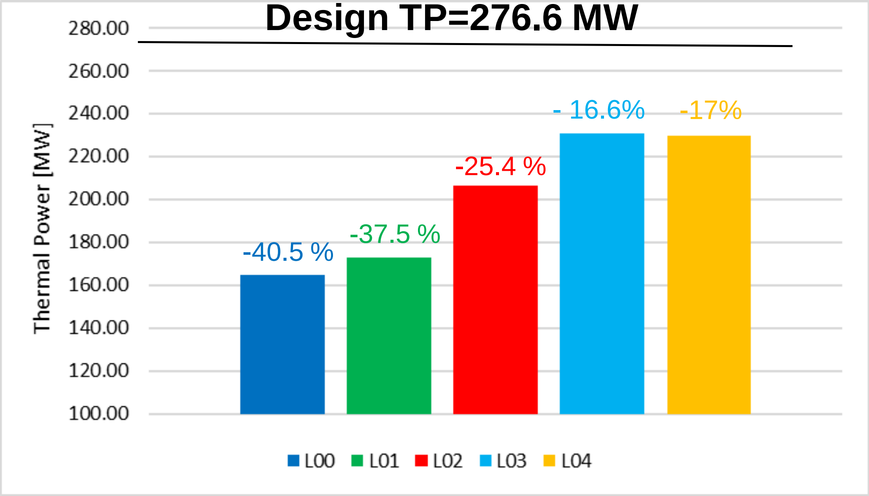


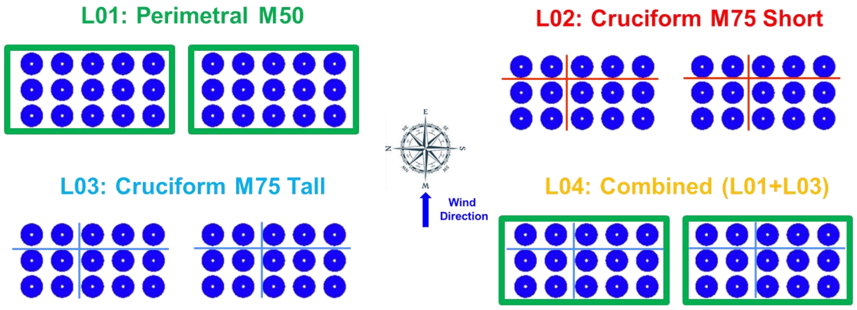
Effects of Windscreen (**WS**=11 m/s, **WD**=270deg)

- Global performance derating in terms of mass flow rate, recirculation and thermal power



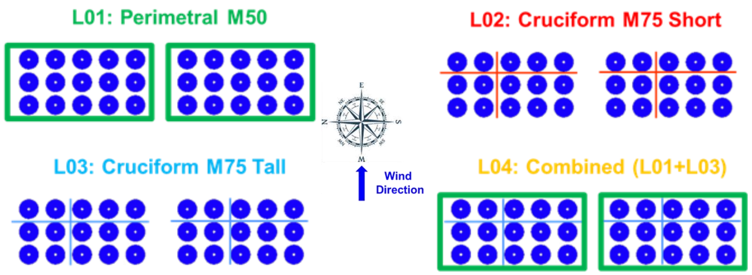


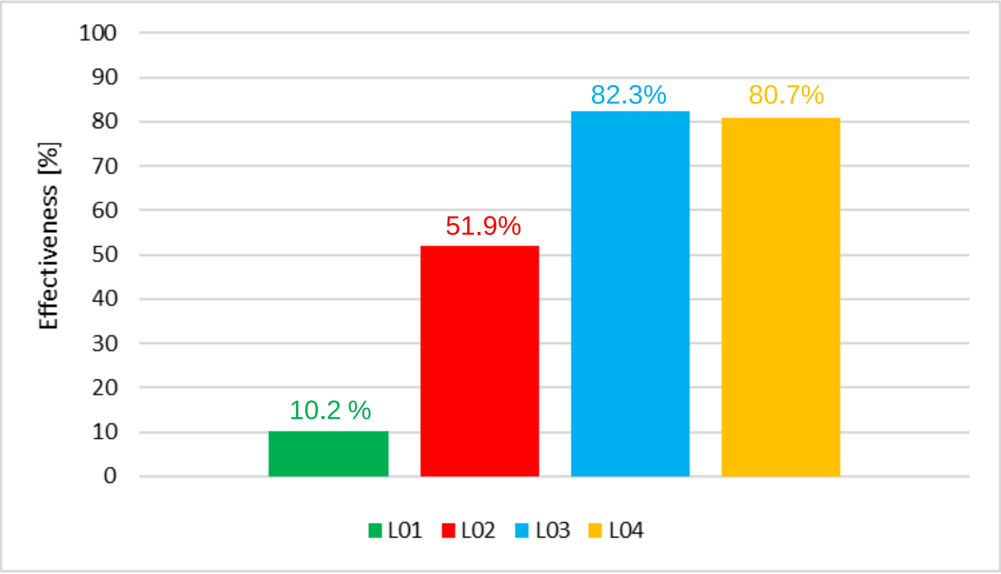




Windscreen Effectiveness (**WS**=11 m/s, **WD**=270deg)

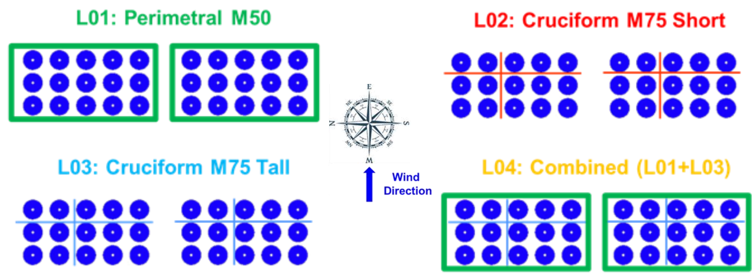
$$Effectiveness = \frac{TP_{WS11,L0X} - TP_{WS11,L00}}{TP_{WS01,L00} - TP_{WS11,L00}}\ x\ 100$$





Windscreen Effectiveness (**WS**=11 m/s, **WD**=270deg)

- Performance in terms of thermal power



Thermal Power [%]

min	70%
mean	85%
max	100%

L00

89%	93%	90%	88%	66%
80%	81%	73%	81%	75%
37%	17%	9%	12%	44%

74%	88%	86%	86%	80%
79%	67%	82%	64%	82%
31%	5%	3%	3%	23%

L01

93%	95%	96%	92%	66%
80%	79%	72%	80%	76%
40%	19%	16%	17%	44%

73%	95%	94%	96%	89%
79%	61%	78%	58%	78%
35%	15%	13%	13%	30%

L02

97%	96%	90%	93%	82%
94%	94%	92%	92%	87%
59%	39%	31%	39%	60%

94%	89%	89%	92%	95%
91%	93%	96%	95%	96%
49%	26%	24%	24%	42%

L03

91%	90%	91%	89%	86%
100%	101%	102%	99%	95%
71%	54%	55%	64%	74%

89%	89%	89%	90%	91%
104%	104%	106%	105%	106%
65%	50%	48%	48%	57%

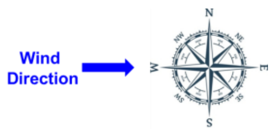
L04

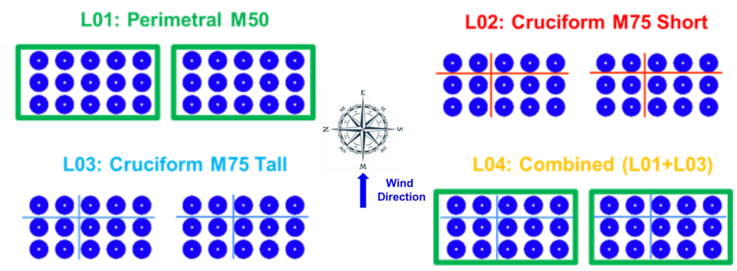
91%	89%	90%	89%	86%
100%	101%	103%	99%	95%
72%	53%	51%	61%	74%

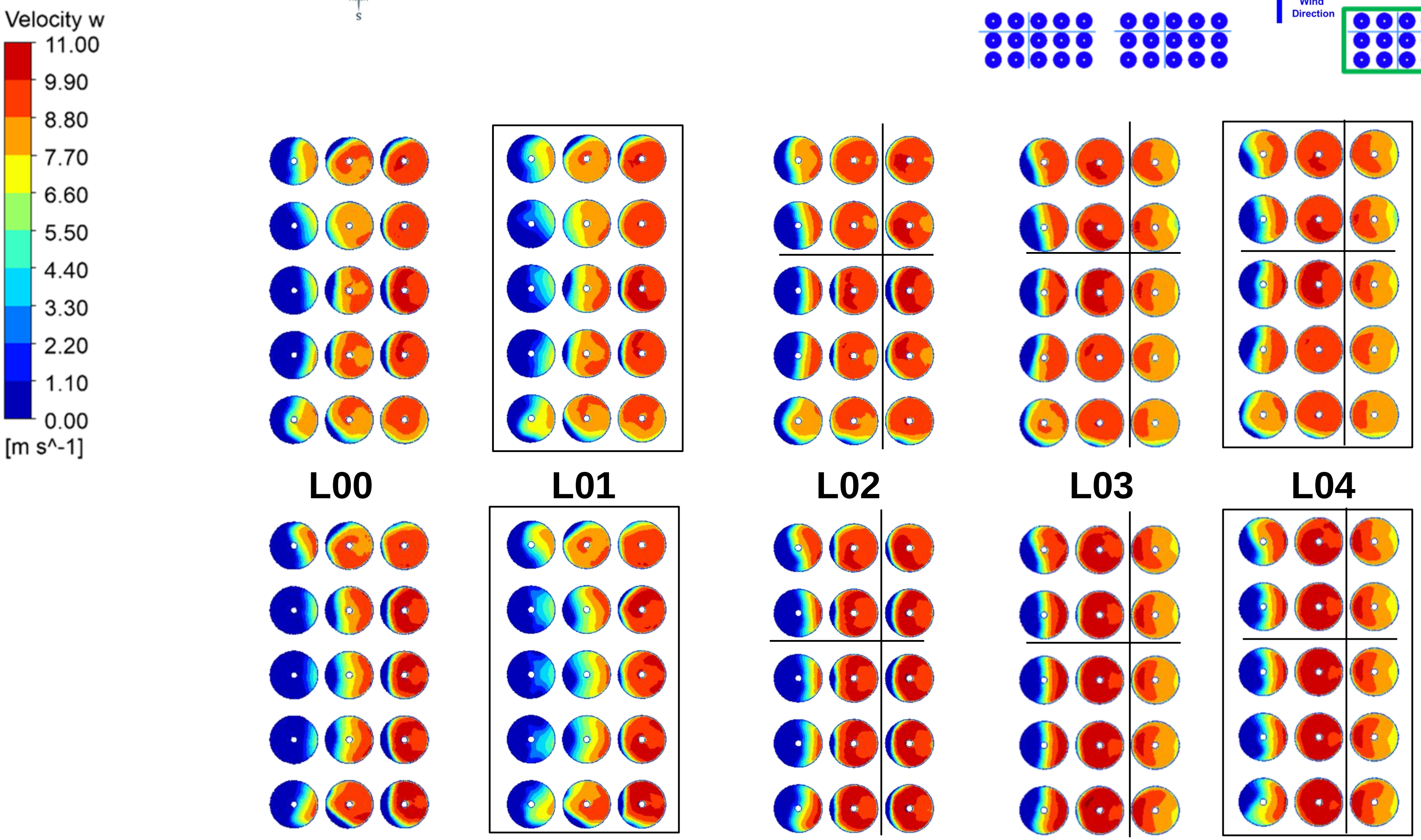
89%	88%	89%	89%	90%
105%	106%	108%	107%	108%
64%	46%	44%	44%	59%

Windscreen Effectiveness (**WS**=11 m/s, **WD**=270deg)

- Vertical velocity contours on fans

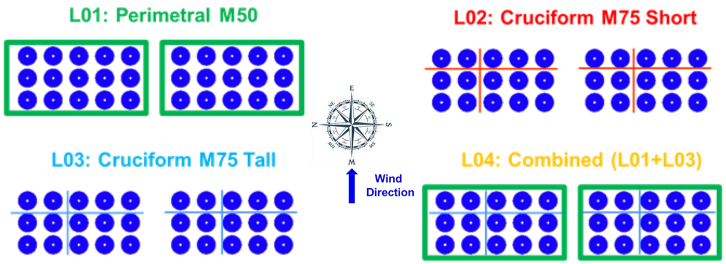


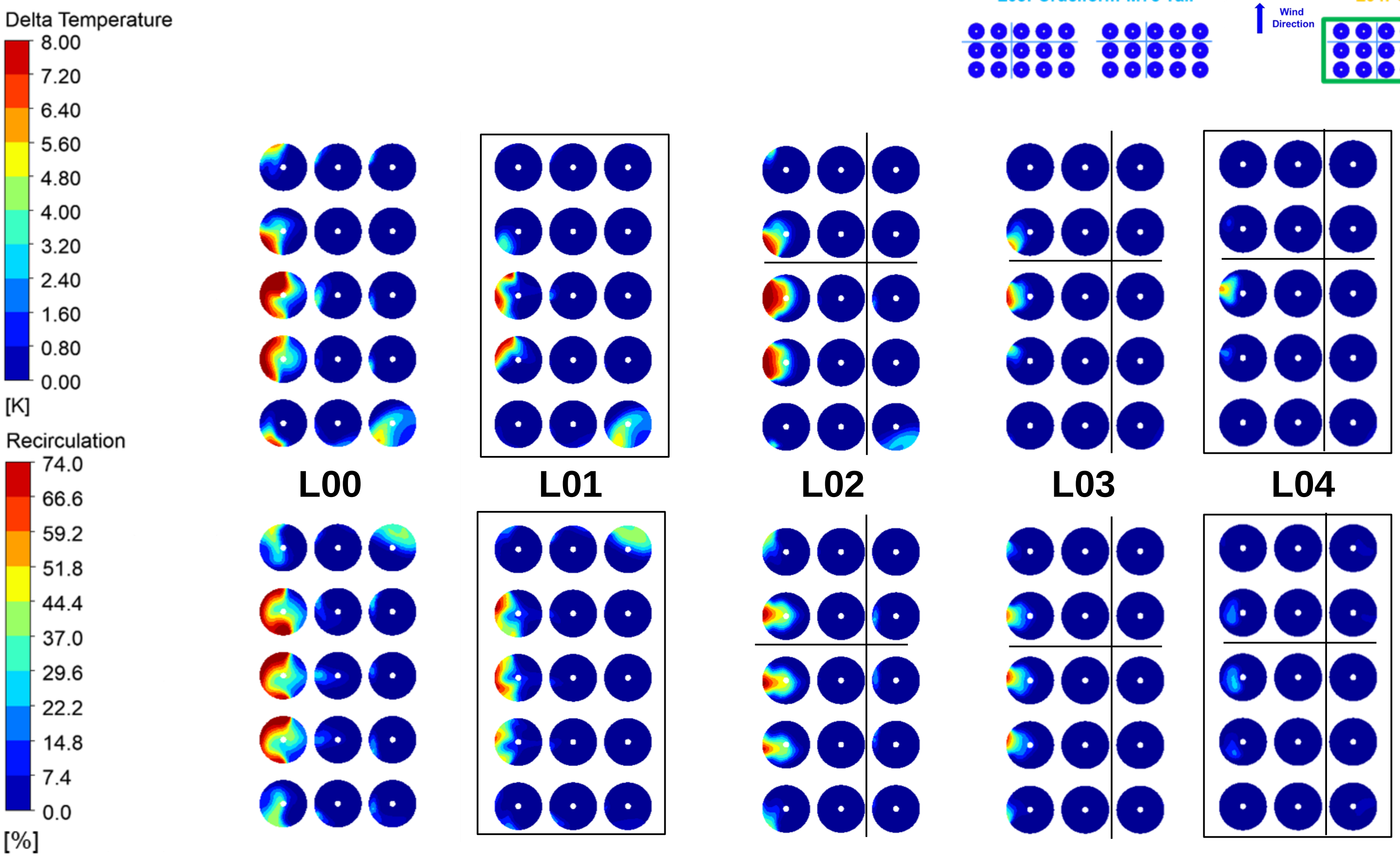




Windscreen Effectiveness (**WS**=11 m/s, **WD**=270deg)

- Temperature contours on fans





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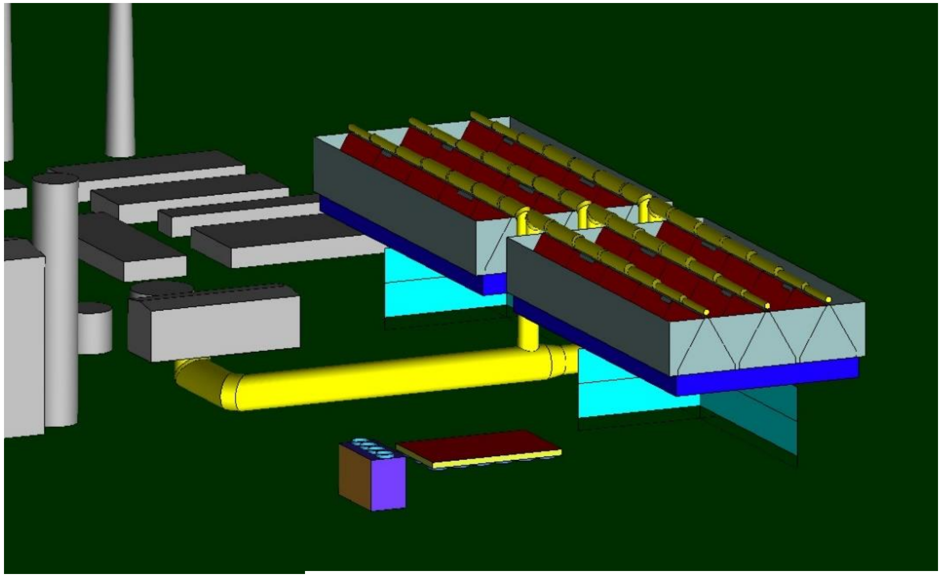
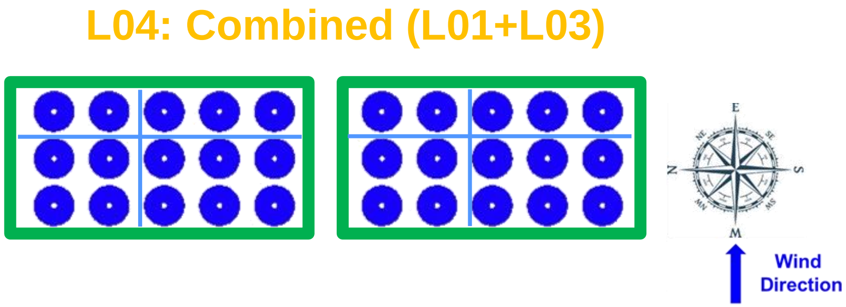
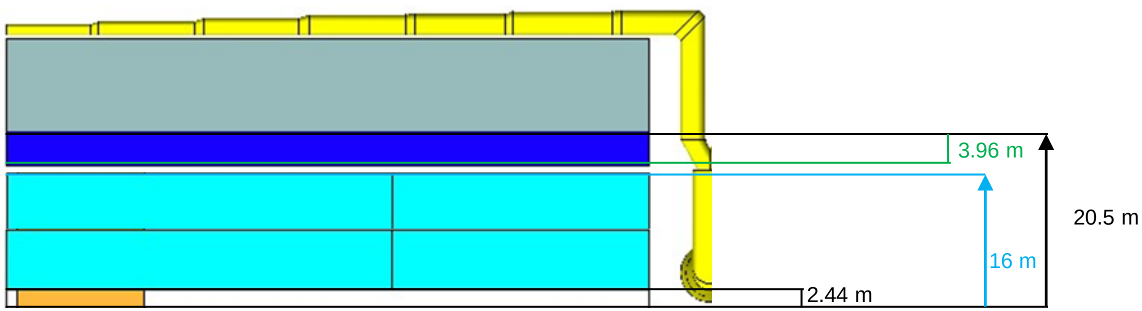
  - **Optimal Solution**

Optimal solution

Windscreen layout L04: Combined (L01+L03)

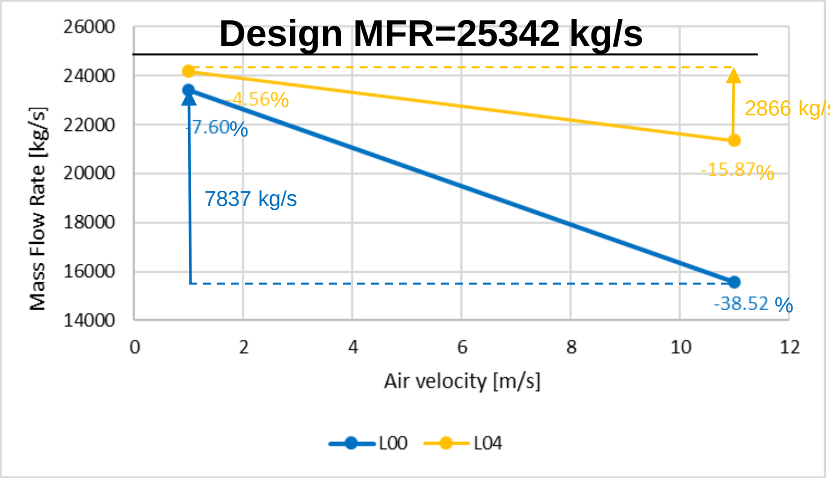


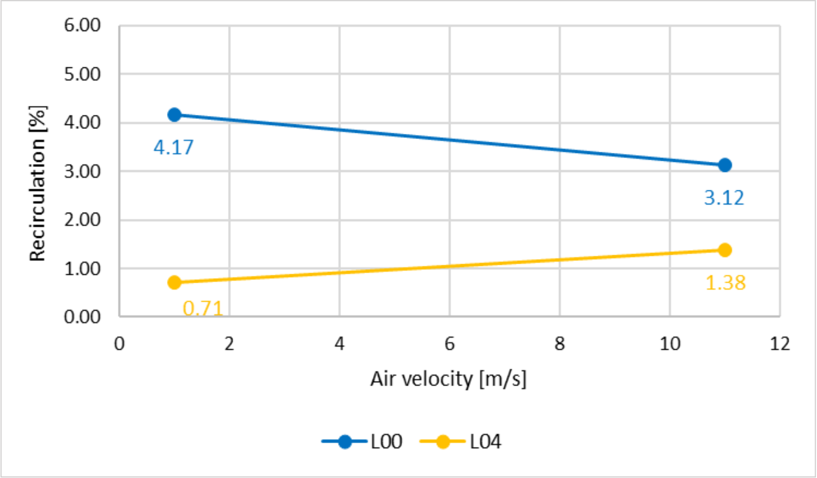


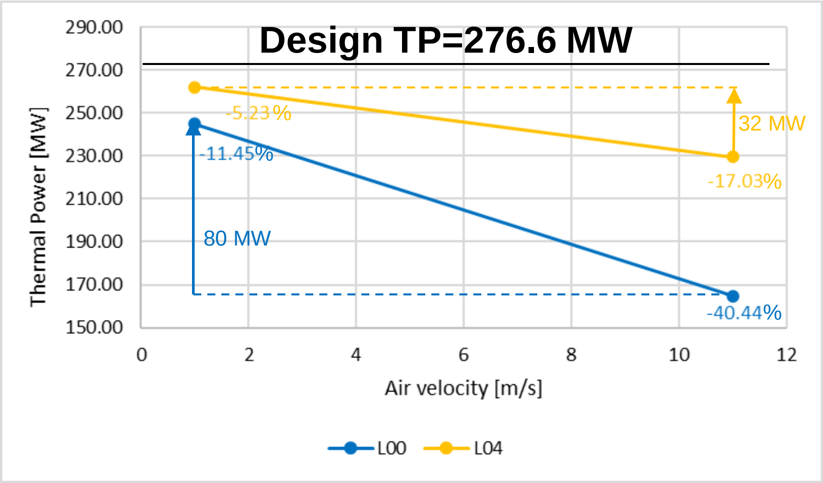


Optimal Solution (**WS**=1 and 11 m/s,**WD**=270deg)

- Global performance derating in terms of mass flow rate, recirculation and thermal power







Conclusions

- A CFD model was implemented and proved to be predictive
- Asses the wind losses
- Windscreens
    - L04 is preferred to L03 because of higher protection for oscillating blade loading and resistance to the wind gusts and minor reduction in effectiveness.

Next steps

- Couple the CFD results with a thermodynamic model of the steam cycle to get the actual power output improvements
- Study the effects of wind on the oscillating blade load
- Quantify the benefits of the windscreens on the fluctuating stresses

- **Any Questions ??**