WELCOME TO Galebreaker®

Wind Effects on an ACC at a Geothermal Power Station

Co-authors- Jeff Ebert, Gary Mirsky – Galebreaker LTD and Cosimo Bianchini – Ergon Research

EST. 1984 Galebreaker® INDUSTRIAL

Agenda

- Geothermal Power basics
- Geothermal power in the US
- Videos – smoke test, dry ice
- CFD study of wind effect at a small geothermal power plant
- Mitigation strategies

Geothermal Basics

- Three types of geothermal power plants
- Dry steam- steam direct from an underground reservoir to turn the generator turbines
- Flash Steam- high pressure hot water from very deep wells flashed into steam to drive the turbines. Steam condenses and water injected back into the ground for another cycle.
- Binary-cycle- Geothermal hot water used to convert another liquid like isobutane (via a heat exchanger) into a gas (steam) that drives the turbine. The water is reinjected back into the well.

Geothermal in the US

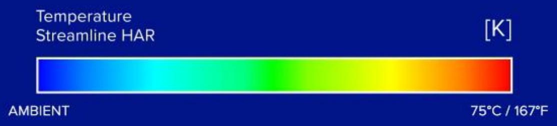
- 3.9 GW as of 2023
- Only 4%
- The Geysers, commissioned in 1960, probably still the largest geothermal field in the world, 1500MW. 22 units
- Geothermal; capacity factor of 65%. Much higher than solar or wind.
- Big Beautifull Bill- controversial, extends tax credits for geothermal, others expire.
- Huge growth potential, new technologies in drilling, monitoring well production.

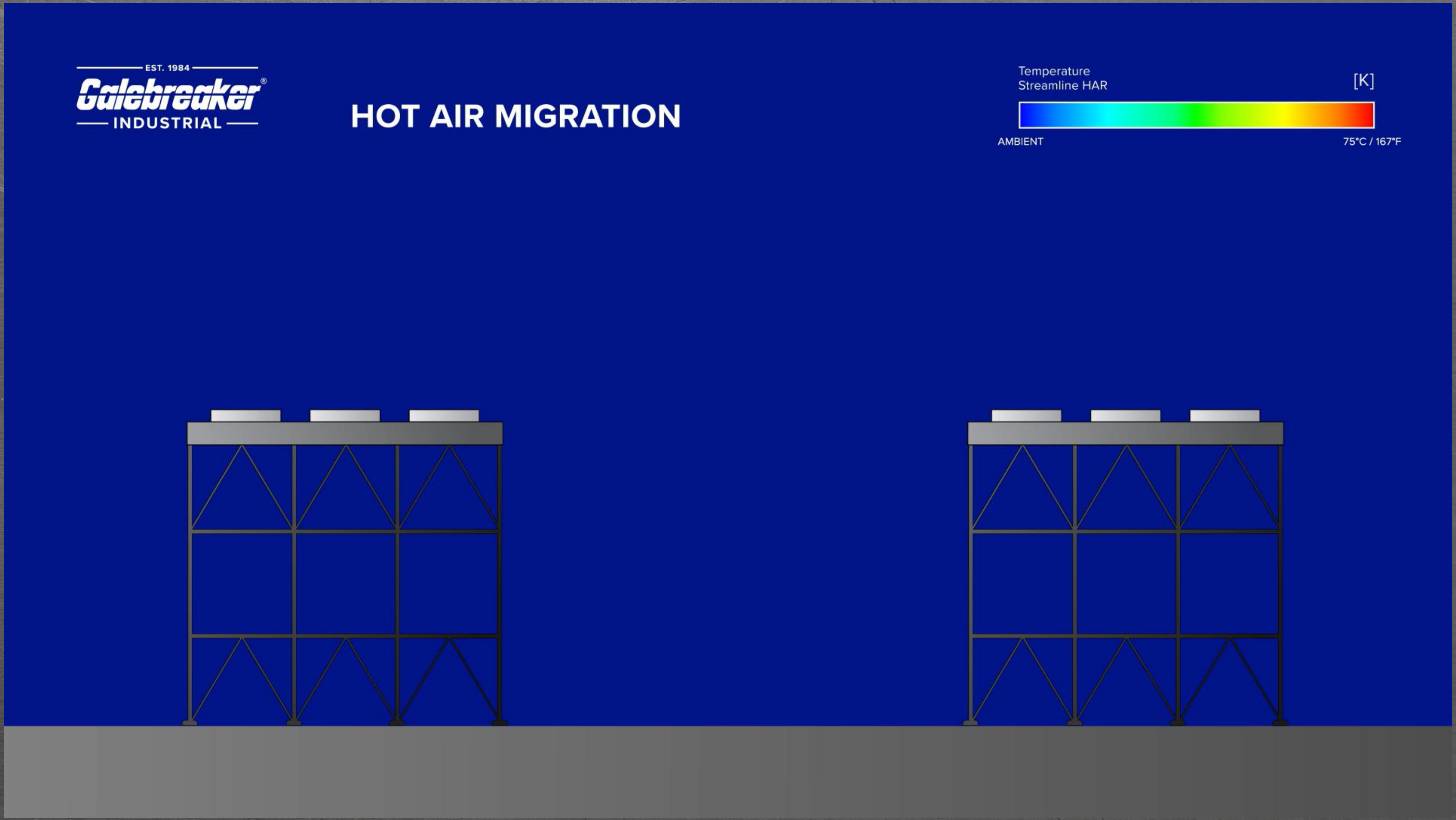
Geothermal in the US

- For Galebreaker, similar wind effects to what we see on out LNG projects
- Large ACHE close to each other; reduce expensive pipework
- Geothermal- typically in desert locations with very high seasonal prevailing winds.
- Growing market

EST. 1984
Galebreaker®
INDUSTRIAL

HOT AIR RECIRCULATION





EST. 1984
Galebreaker
INDUSTRIAL
HOT AIR MIGRATION
Temperature
Streamline HAR
[K]
AMBIENT
75°C / 167°F

Wind Tunnel and Smoke Testing in the Field

EST. 1984
Galebreaker®
INDUSTRIAL

Video of Wind Tunnel Testing at the U.C. Davis ABL Wind Tunnel Showing Smoke Testing At a 9 m/s Wind Speed with and without wind screens under the ACC (video provided upon request)

Video of Field Testing Using Dry Ice to Demonstrate Recirculation between Modules On An ACHE (Video Provided Upon Request)

Video of Smoke Testing on an Operating ACC with and without Windscreens
(Video Provided Upon Request)

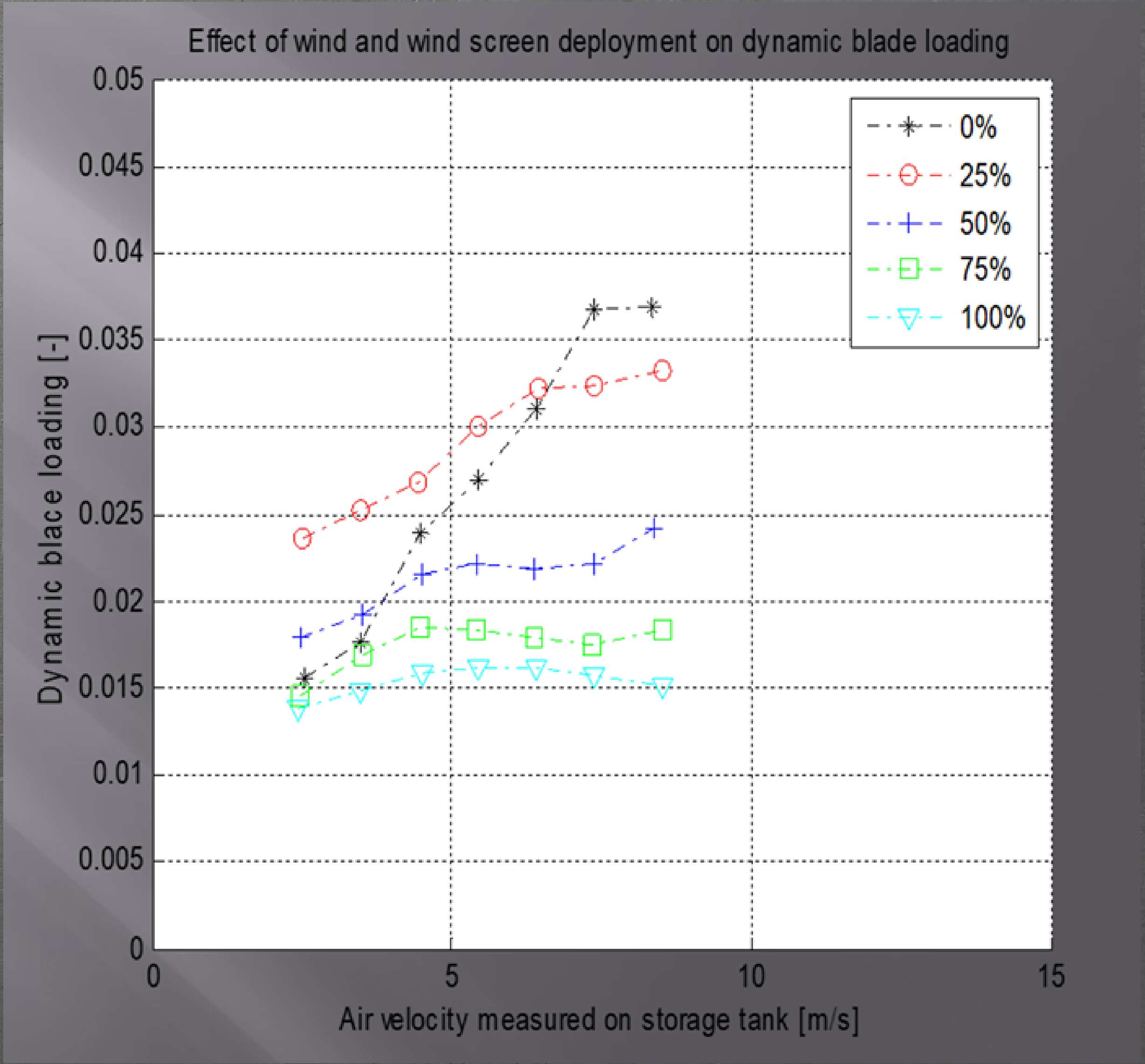
Dynamic Blade Loading Fan 3.4

Loading Increases at Higher Wind Speeds

Significant Influence of Wind Screen

Screen Deployment Reduces Loading

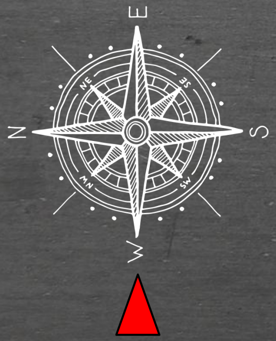
Fully Deployed Dynamic Blade Load Reduced by a Factor 2-3



An existing solution for mitigating hot-air recirculation

Analysis Via CFD

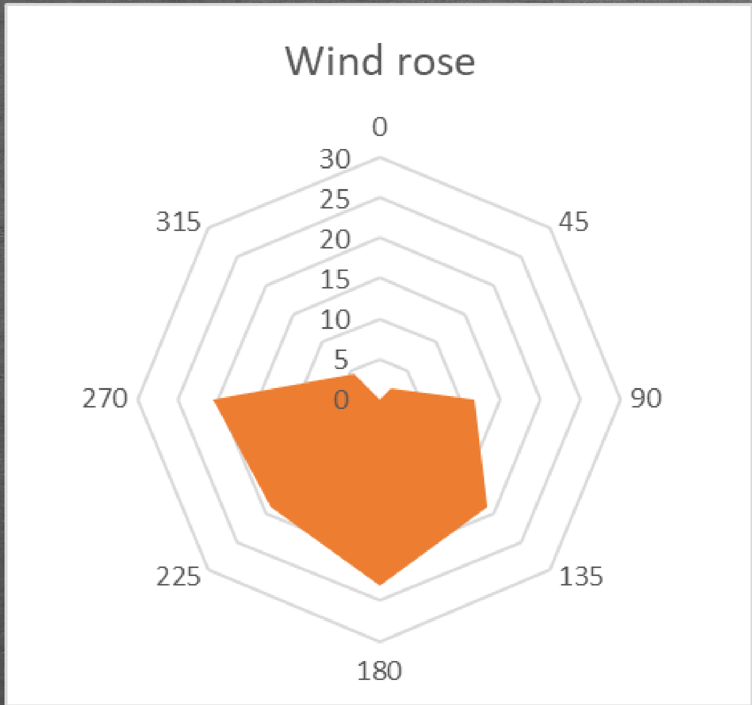
Energia e Meccanica
Ergon
research
info@ergonresearch.it
www.ergonresearch.it
Ergon Research
Via Campani50 Firenze



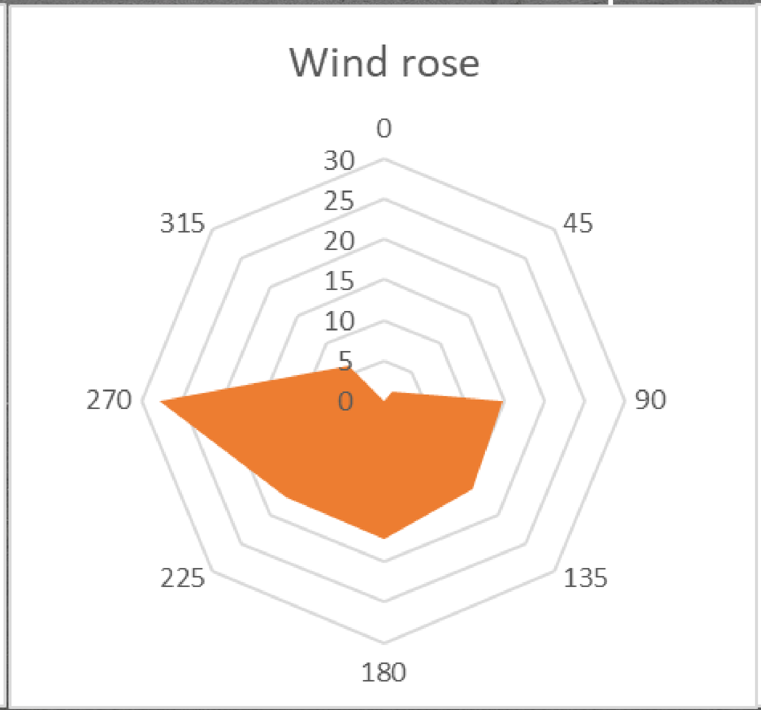
Wind direction

Site Wind Rose

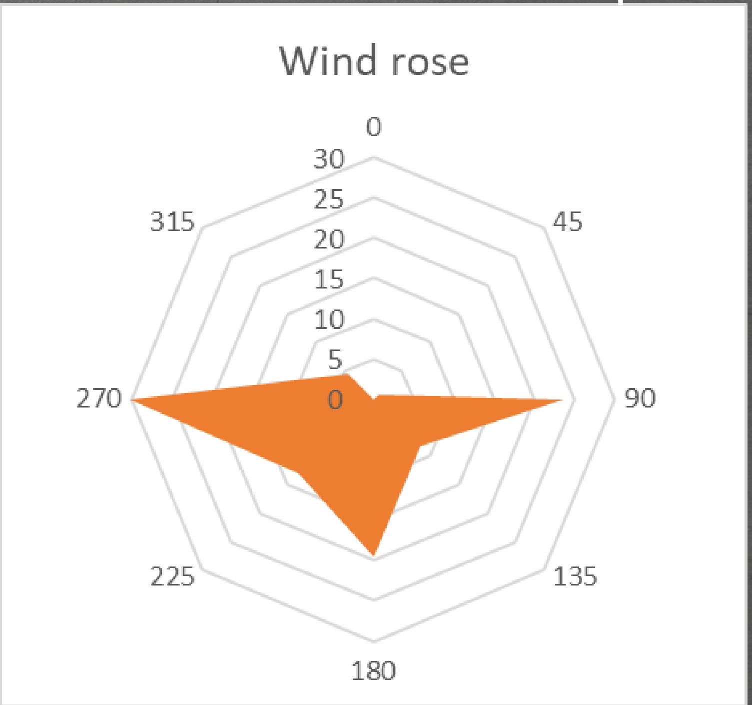
All events



Filtered for WS > 5 mph



Filtered for WS > 14 mph

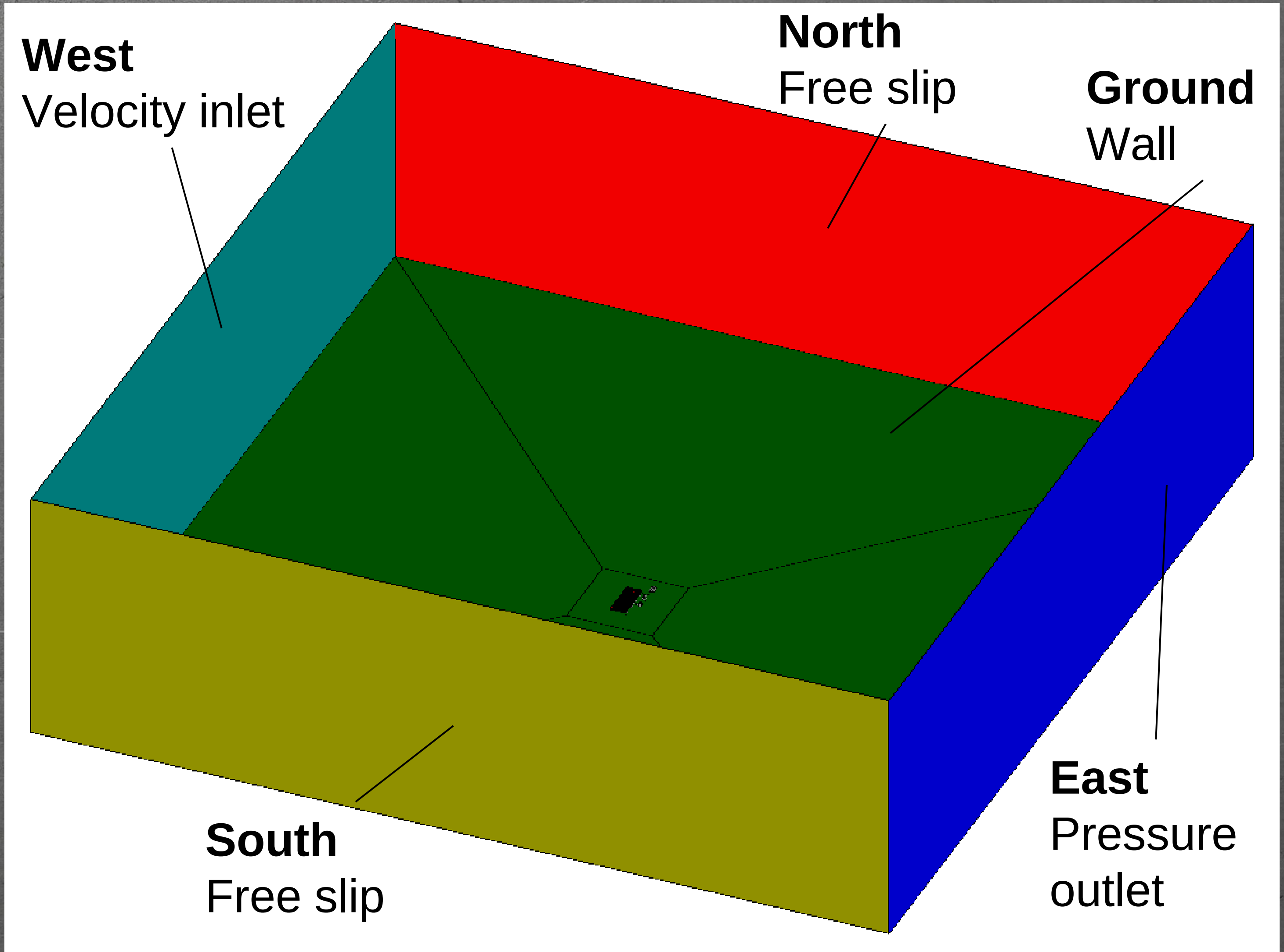


EST. 1984
Galebreaker®
INDUSTRIAL

Modelling details

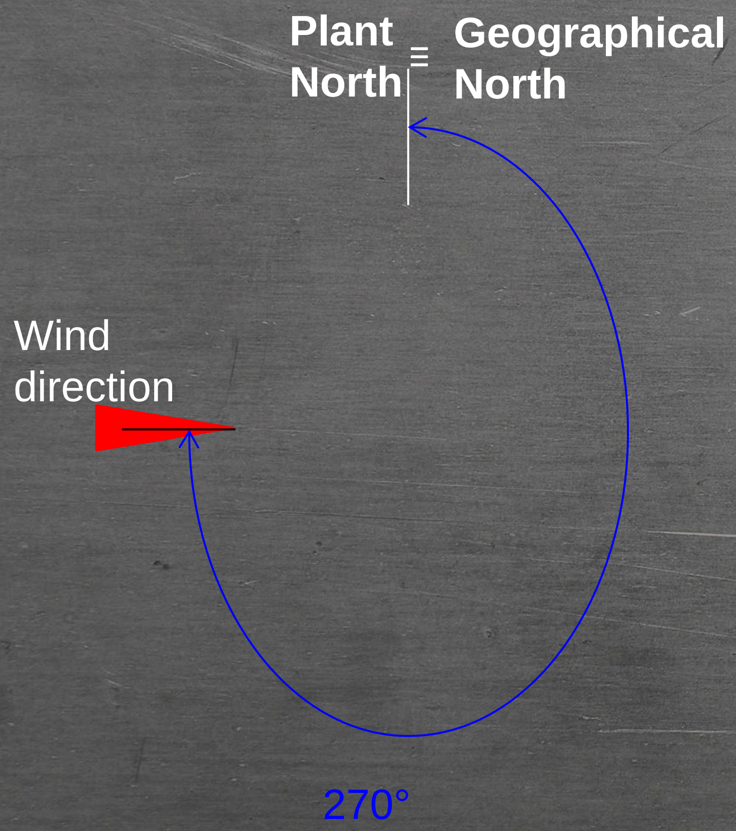
Domain definition

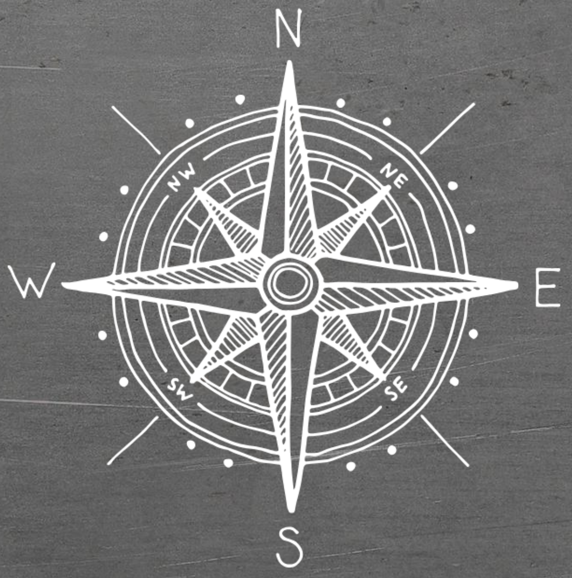
2km x 2km x 600m height

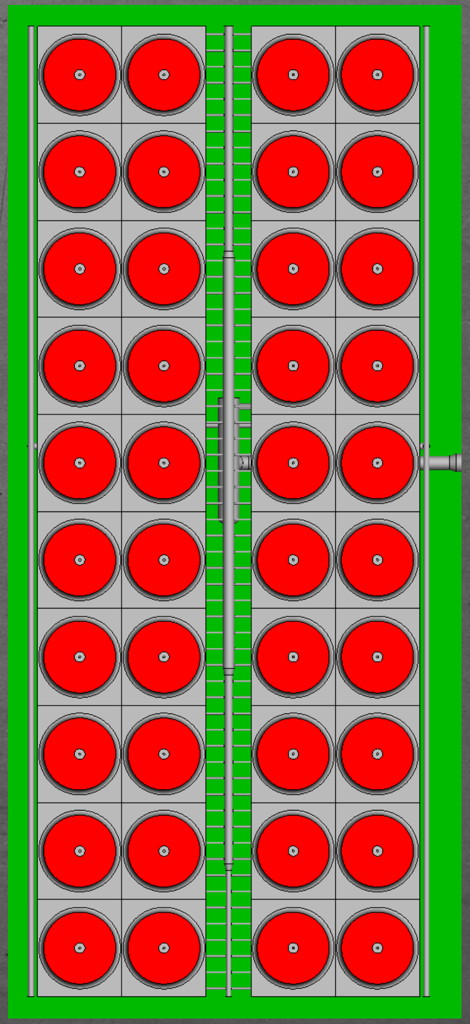


Modelling details

ACC geometry

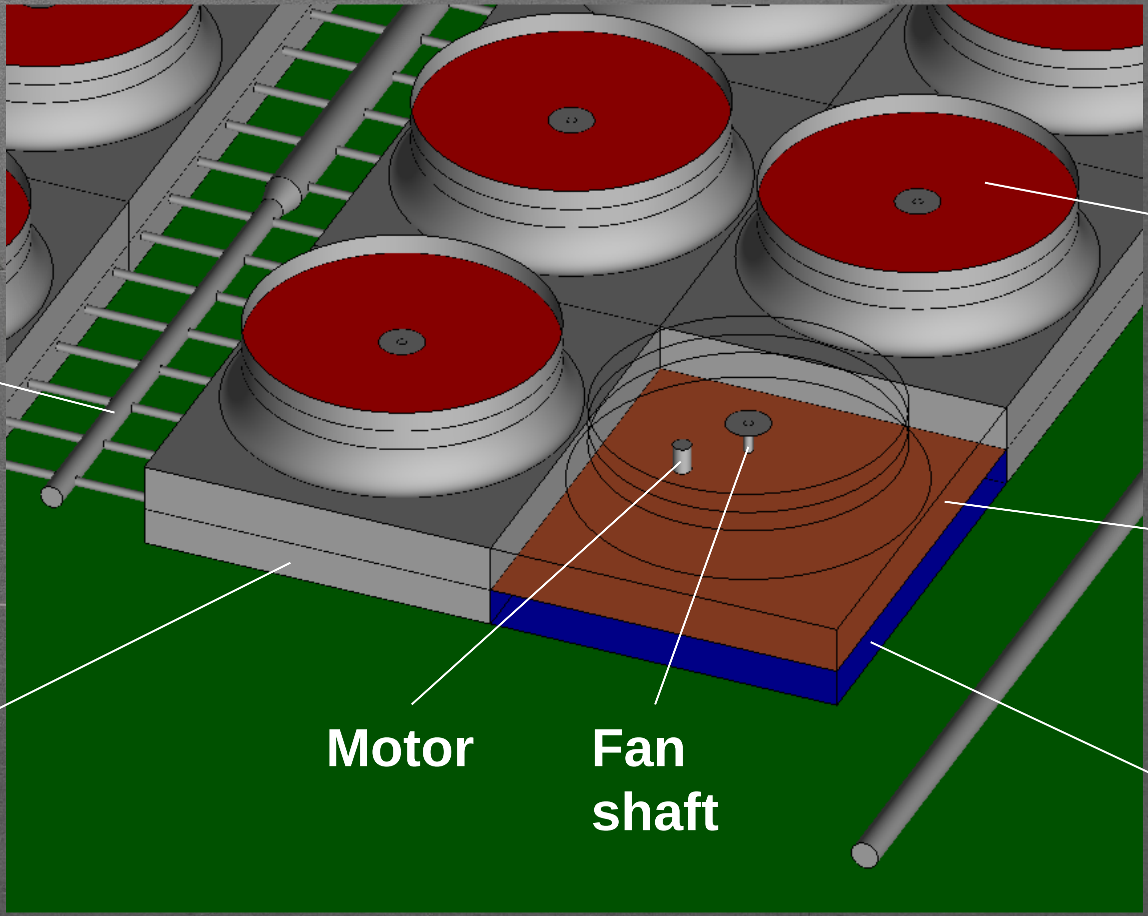






Modelling details

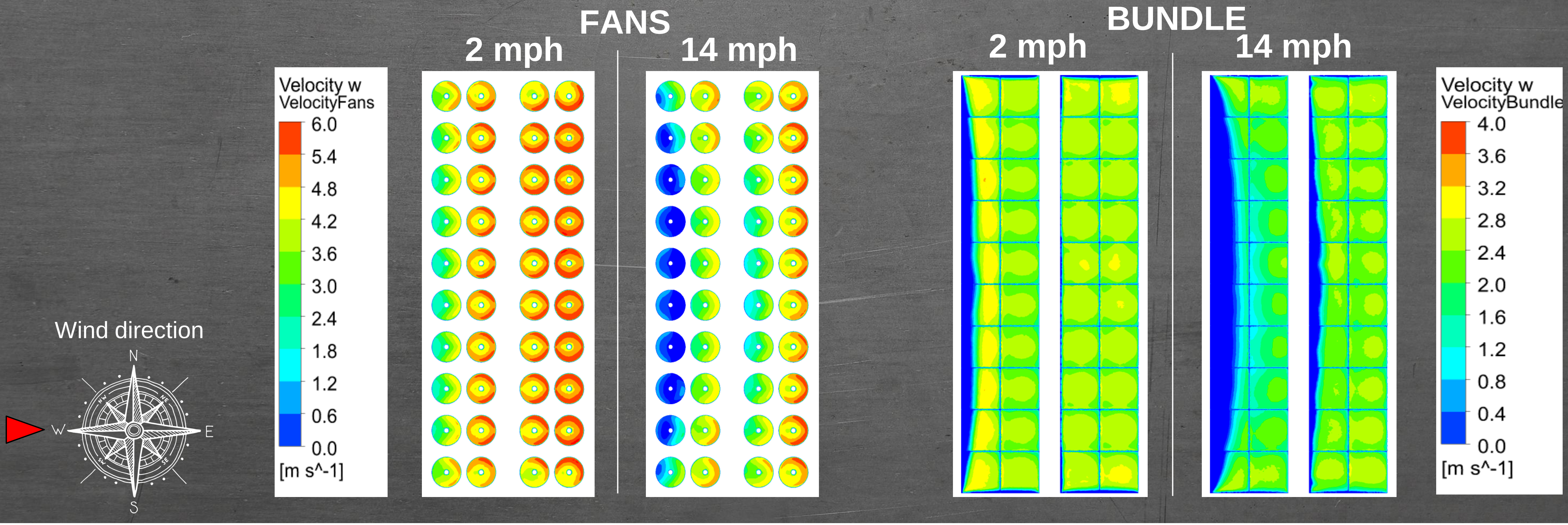
ACC geometry



EST. 1984 Galebreaker® INDUSTRIAL

Baseline results

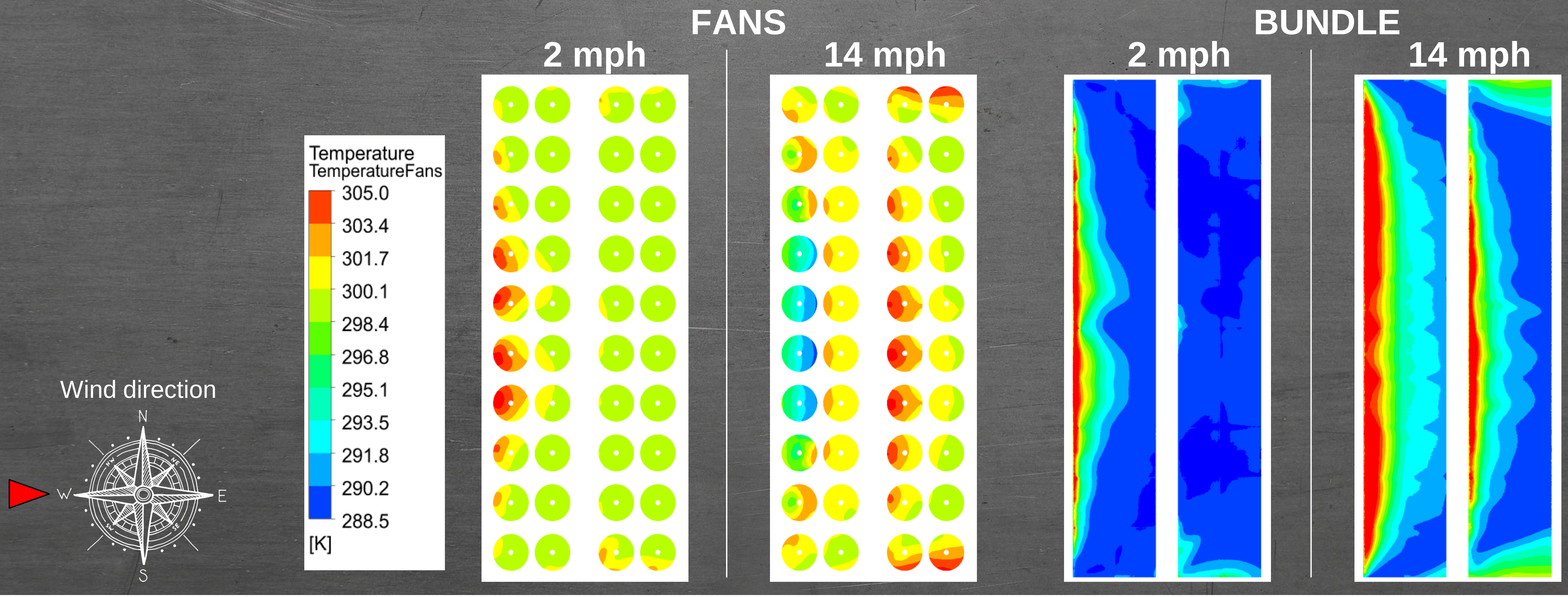
Vertical velocity on fans and bundle inlet - The misbalance of airflow generates an overall reduction of the flow



EST. 1984
Galebreaker®
INDUSTRIAL

Baseline results

Temperature on fans and bundle as a result of recirculation and backflow



Baseline results

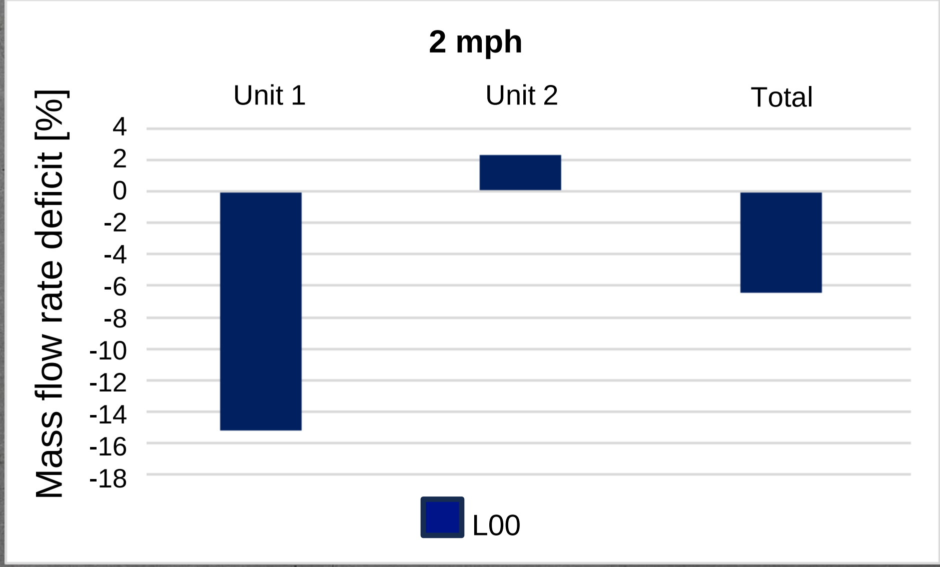
Mass flow rate

At both wind speeds the baseline configuration (L00) shows a deficit if compared to design condition

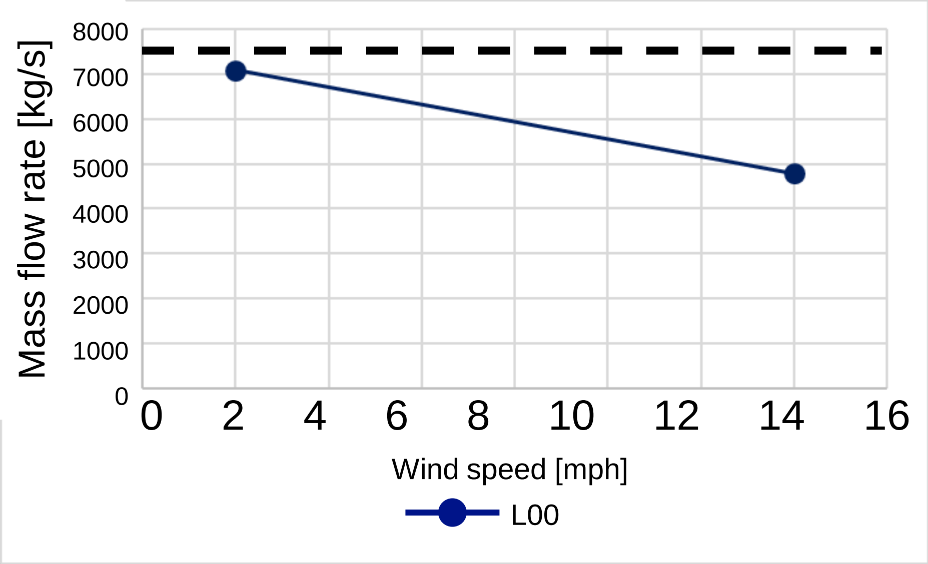
- @**2** mph the deficit is **-6.44%**
- @**14** mph the deficit is **-36.87%**

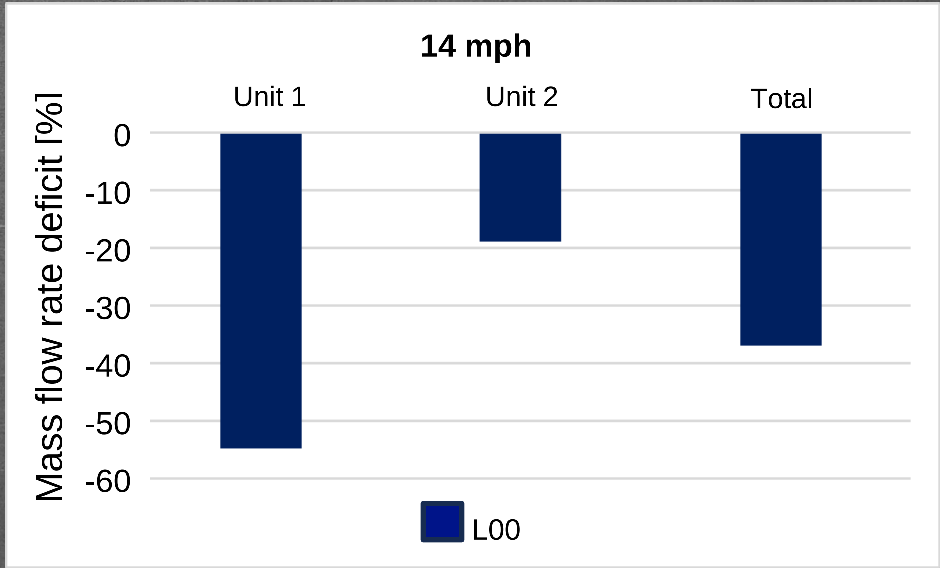
$$m_{deficit} = \frac{m - m_{design}}{m_{design}}$$

Downstream unit is delivering more than design air flow



Design flow rate = 7570 kg/s





EST. 1984 Galebreaker® INDUSTRIAL

Baseline results - L00

Recirculation

Recirculation is a measure of the quantity of spent air ingested at the fan

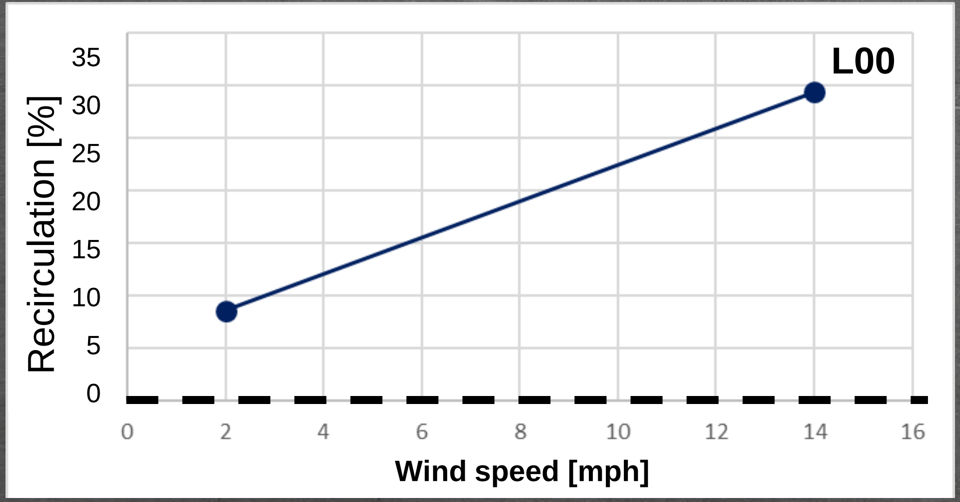
It is defined based on the temperature level at the fan

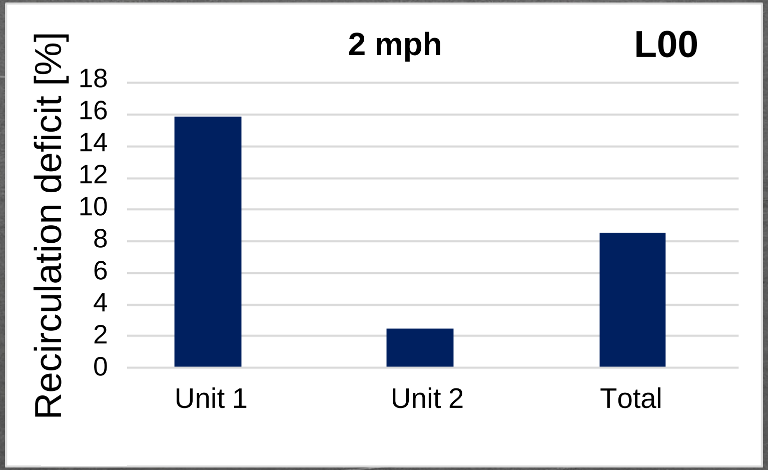
$$R = 100 \cdot \frac{T_{fan} - T_{amb}}{T_{bundle} - T_{amb}}$$

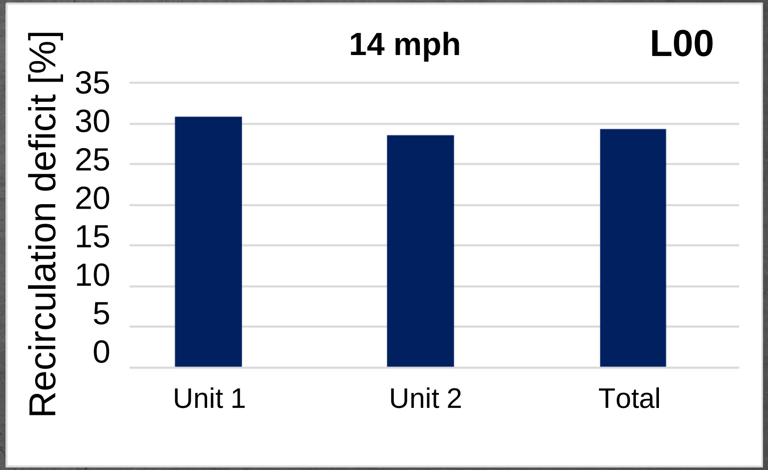
L00 shows a considerable recirculation at both wind speeds:

@**2** mph the deficit is **8.55%**

@**14** mph the deficit is **29.36%**







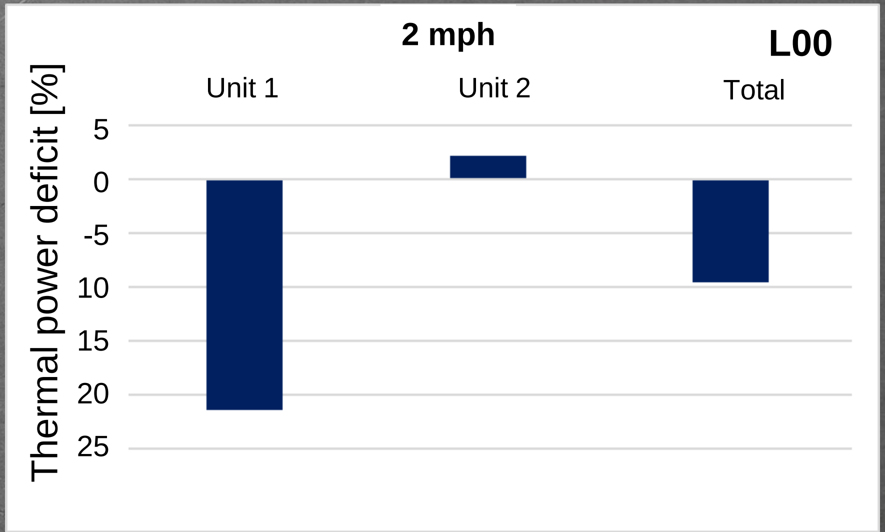
Baseline results - L00

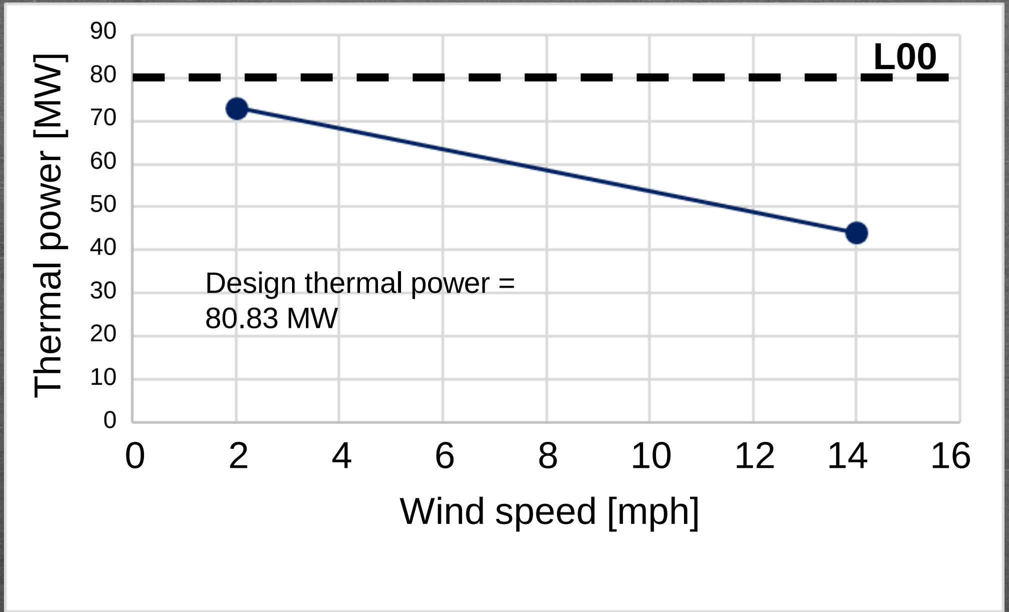
Thermal power

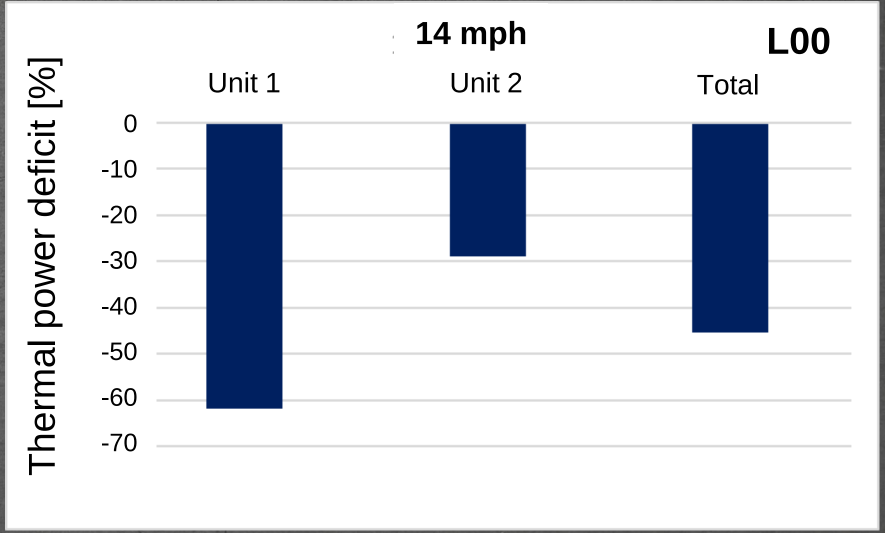
At both wind speeds L00 configuration shows a deficit if compared to design condition

- @**2** mph the deficit is **-9.59%**
- @**14** mph the deficit is **-45.37%**

$$\dot{Q}_{deficit} = \frac{\dot{Q}-\dot{Q}_{design}}{\dot{Q}_{design}}$$





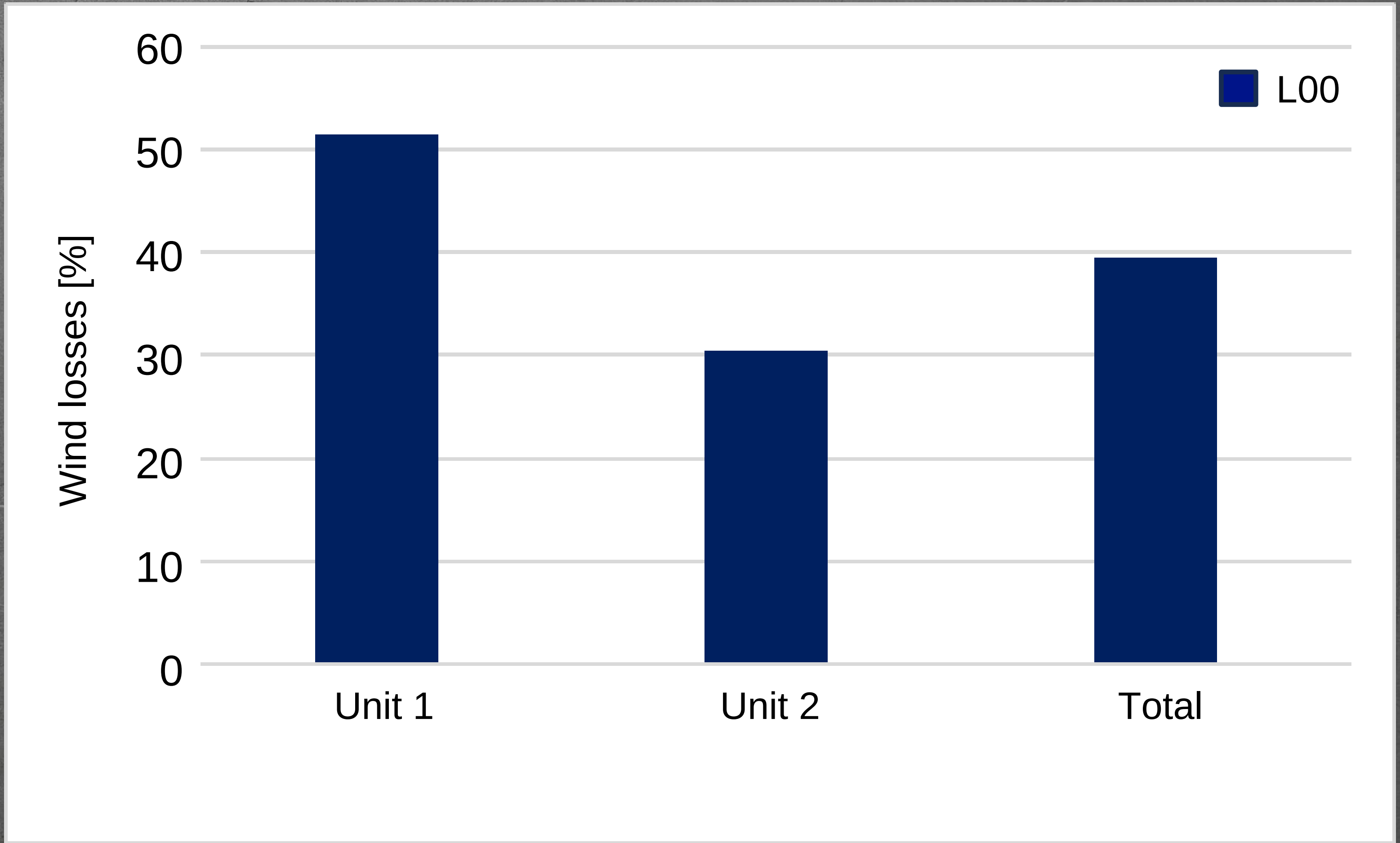


Baseline results - L00

Wind loss

@**14** mph the wind loss for the L00 configuration is **39.57%**

$$Wind\ losses = \frac{\dot{Q}_{2mph} - \dot{Q}_{14mph}}{\dot{Q}_{2mph}}$$



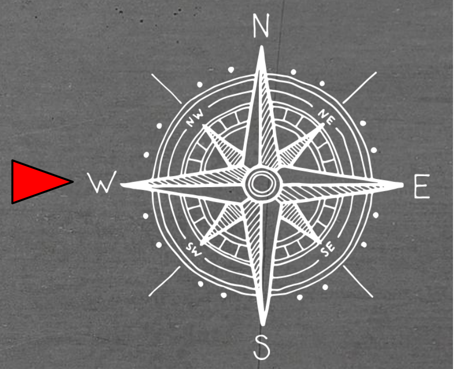
EST. 1984
Galebreaker®
INDUSTRIAL

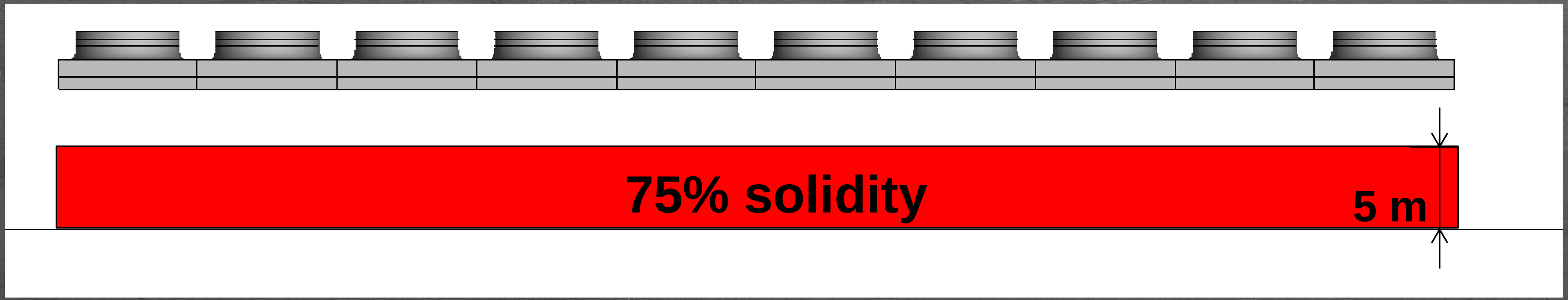
Proposed windscreens configurations

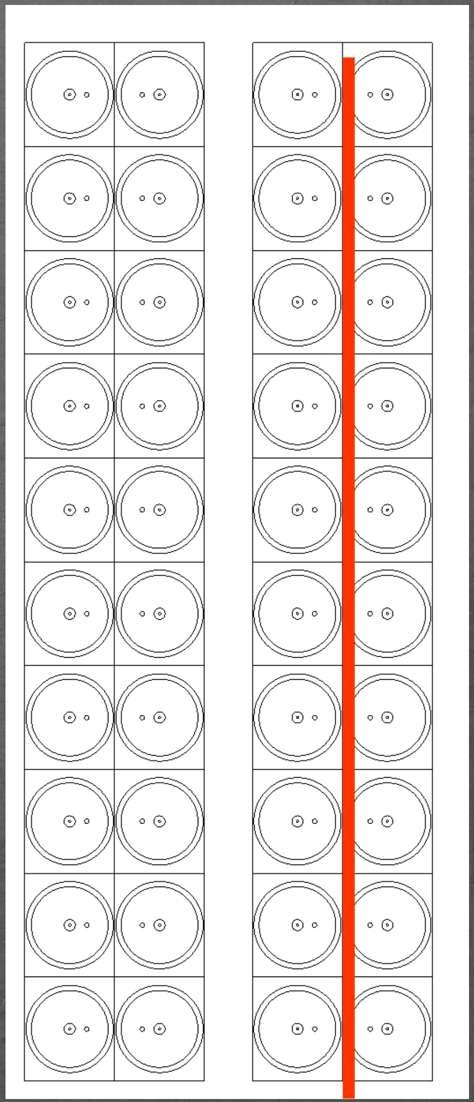
To increase the ACC performance the following windsceens configuration are proposed:

- L01 Wind wall

Wind direction





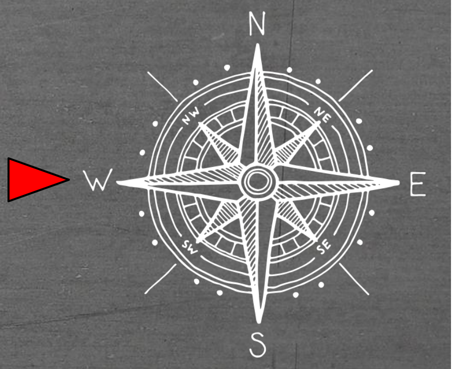


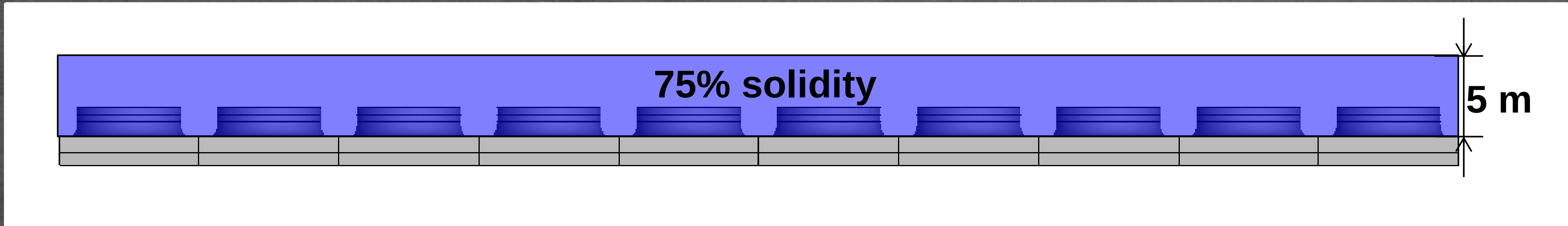
Proposed windscreens configurations

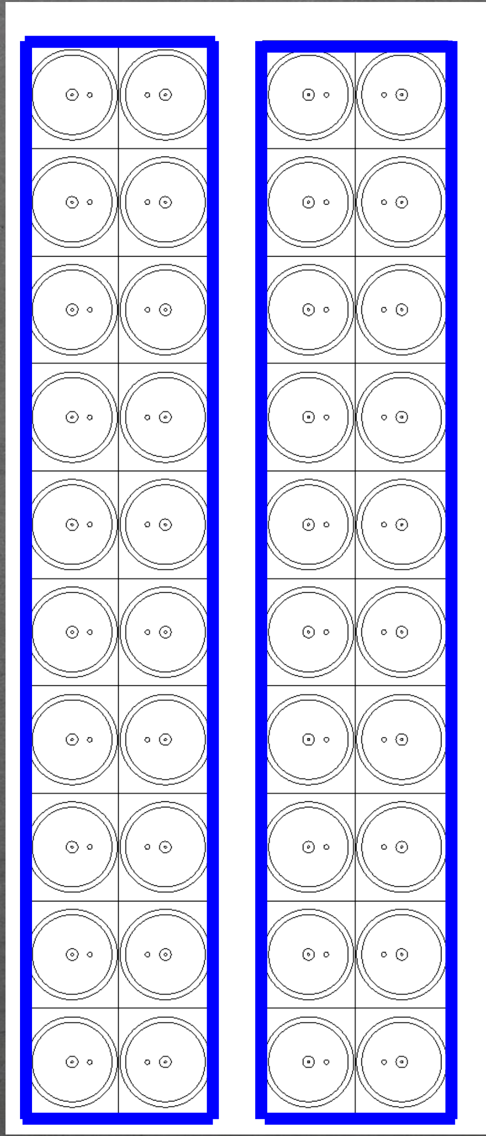
To increase the ACC performance the following windscreens configuration are proposed:

- L02 Chimney

Wind direction







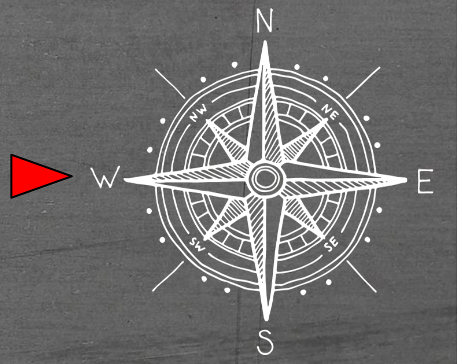
EST. 1984
Galebreaker®
INDUSTRIAL

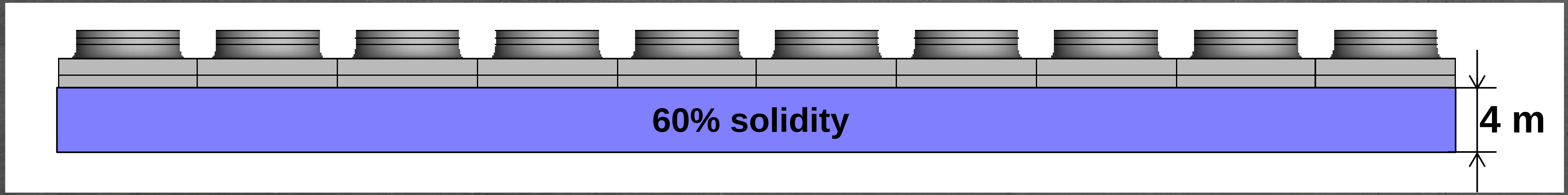
Proposed windscreens configurations

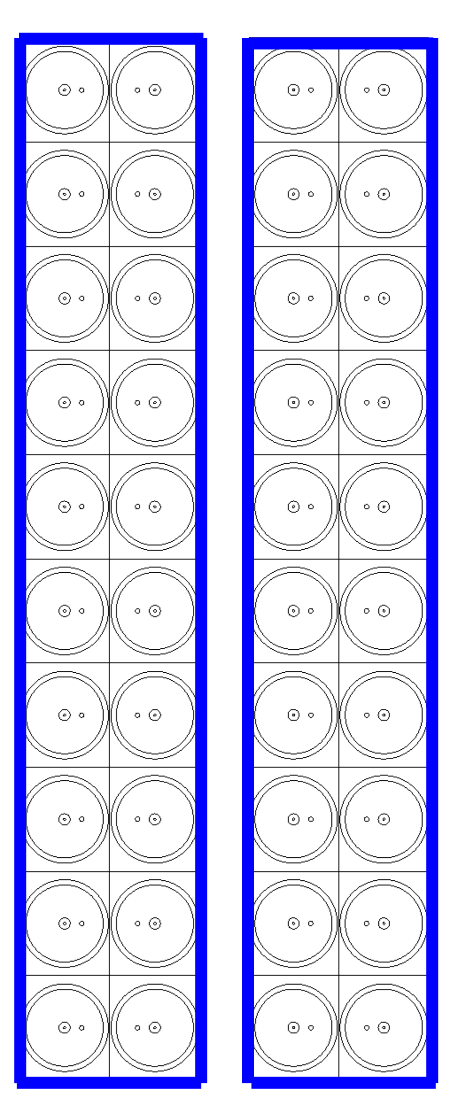
To increase the ACC performance the following windscreens configuration are proposed:

- L03 Perimeter

Wind direction



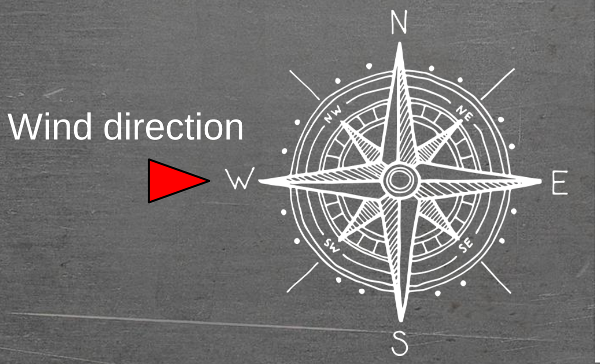


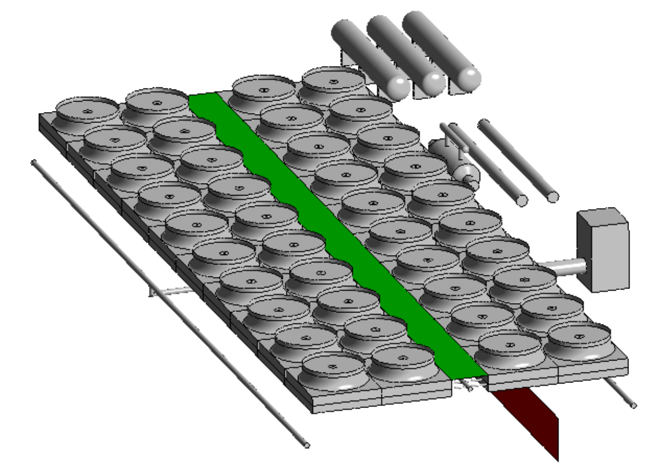


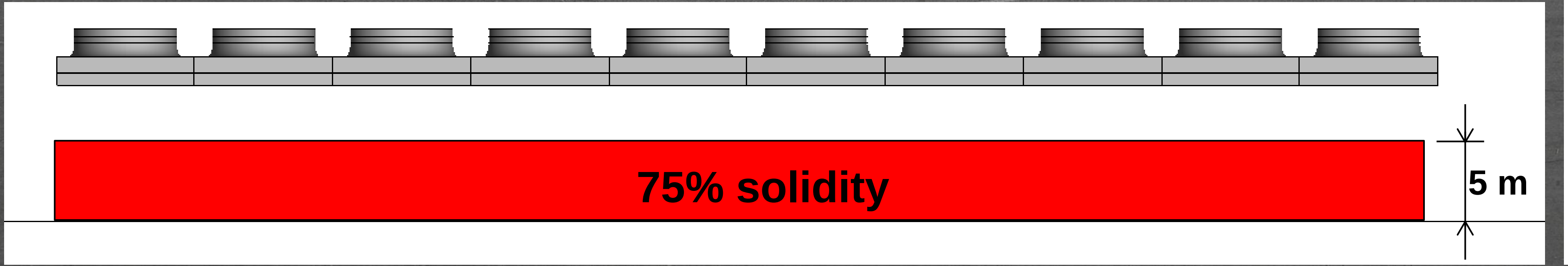
Proposed windscreens configurations

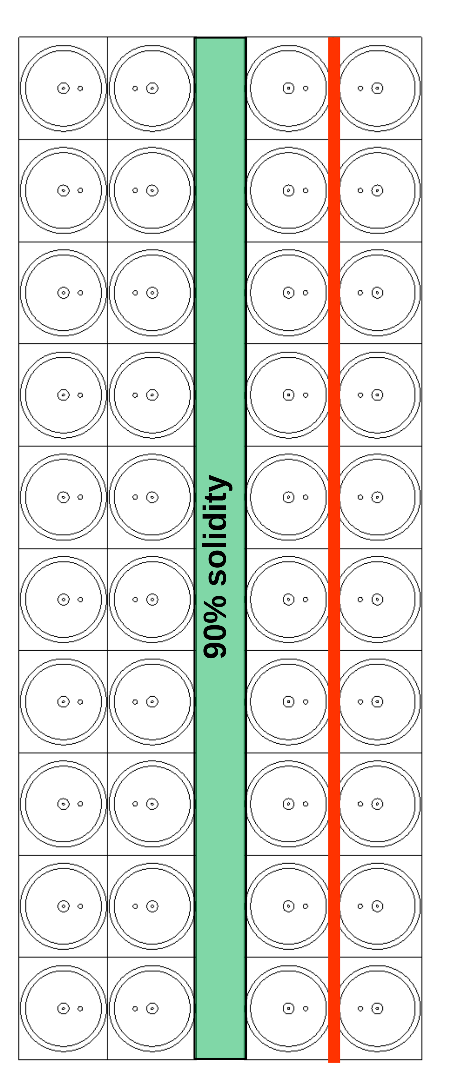
To increase the ACC performance the following windscreens configuration are proposed:

- L04 Wind wall and gap closure

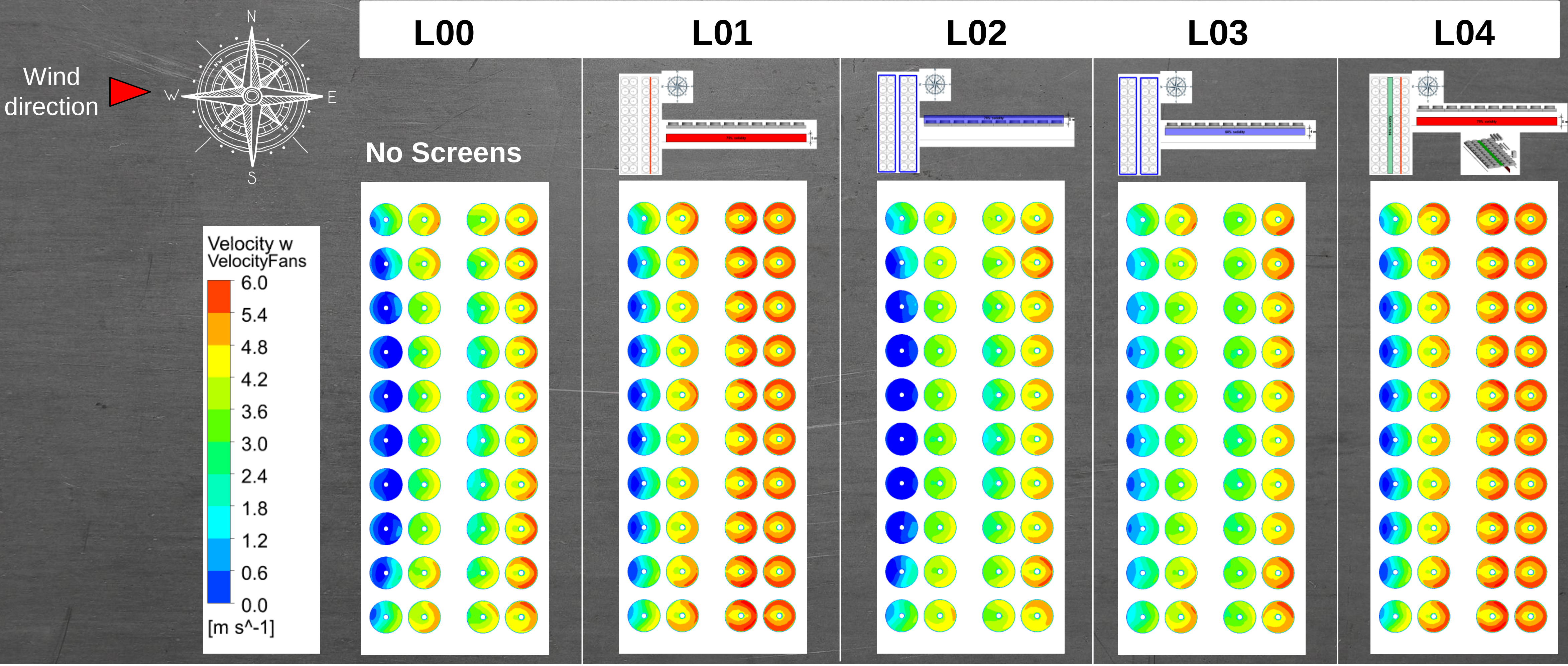








Results – High wind speed



Galebreaker INDUSTRIAL EST. 1984

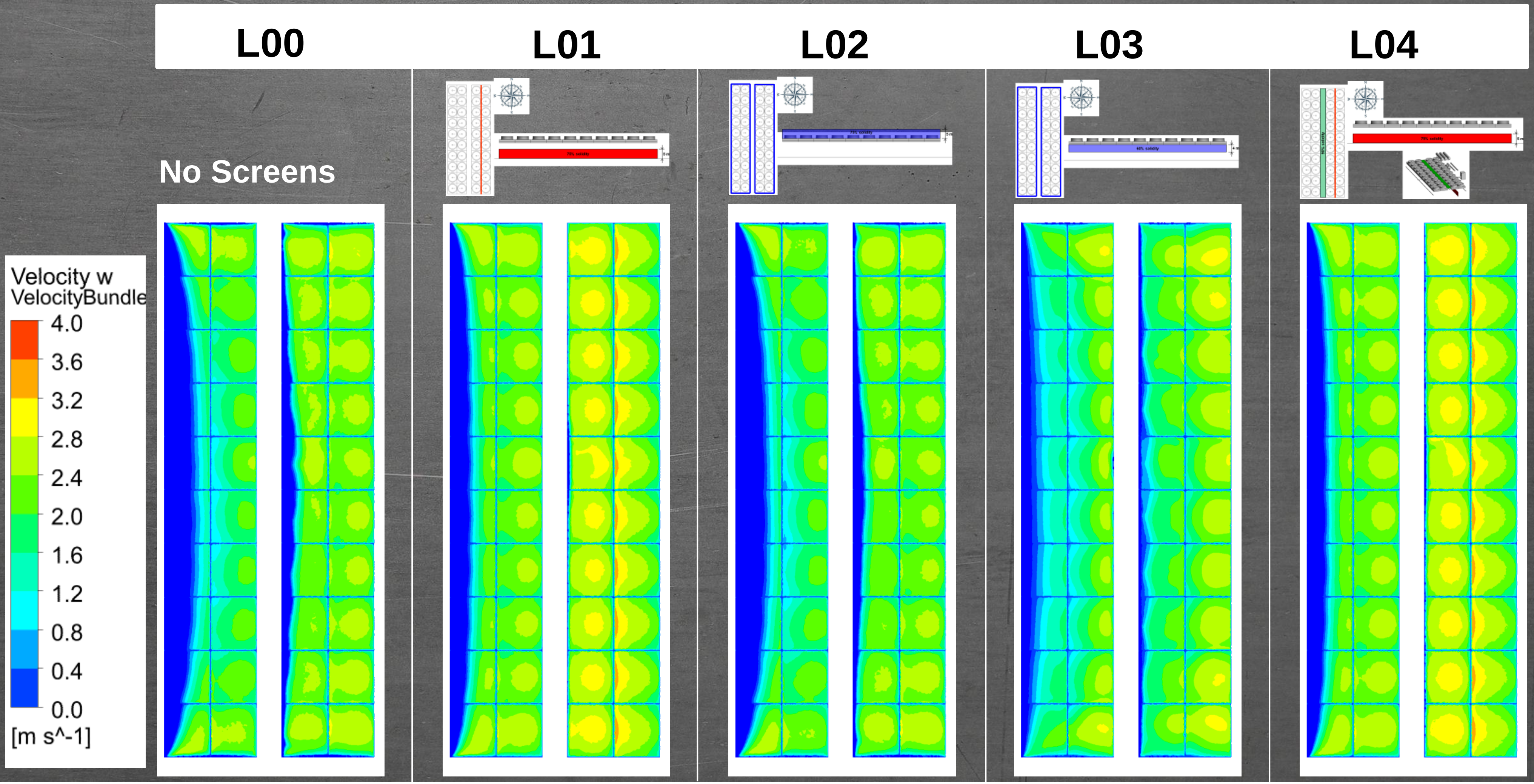
Results – High wind speed

Vertical velocity on bundle inlet

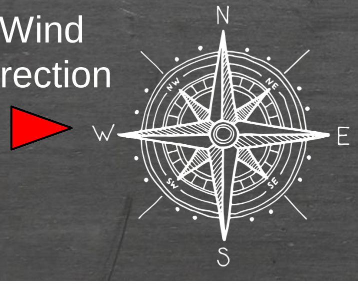
Red areas indicate high velocity (i.e. high flow rate)

Blue areas indicate low air velocity (i.e. low airflow or reversed flow)

The misbalance of airflow generates an overall reduction of the flow and creates fan imbalance



Wind direction



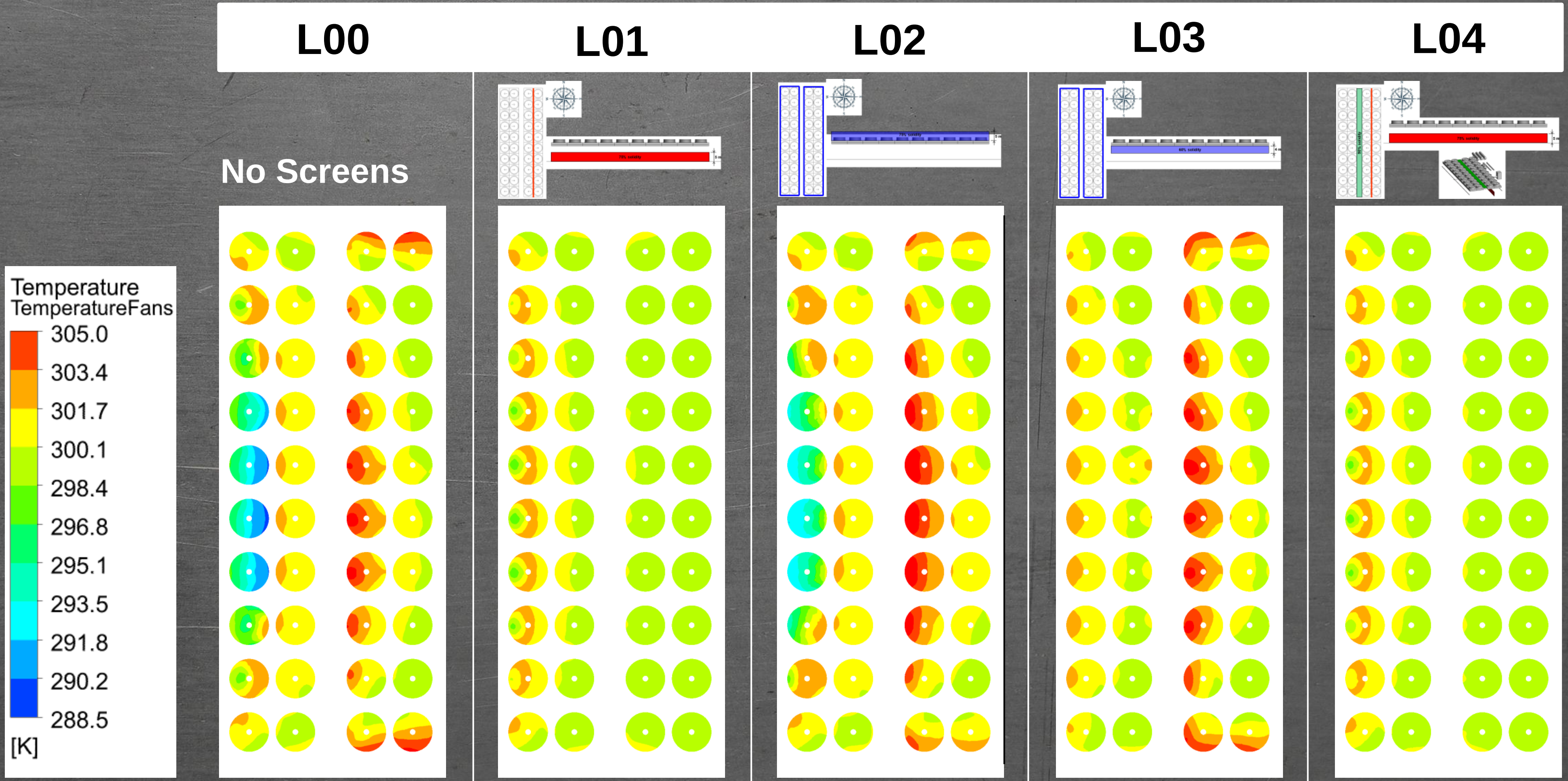
Results – High wind speed

Temperature on fans as a result of recirculation and backflow

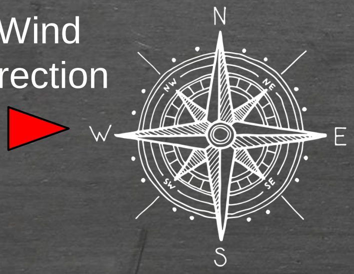
Design temperature is 299.16 K

Low temperature means backflow on fans

High temperature means low air flow rate (higher temperature increase)



Wind direction

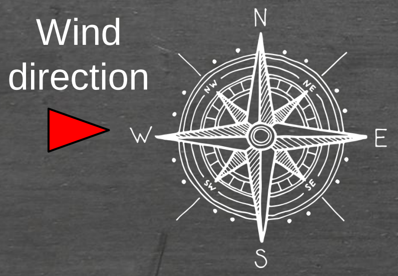


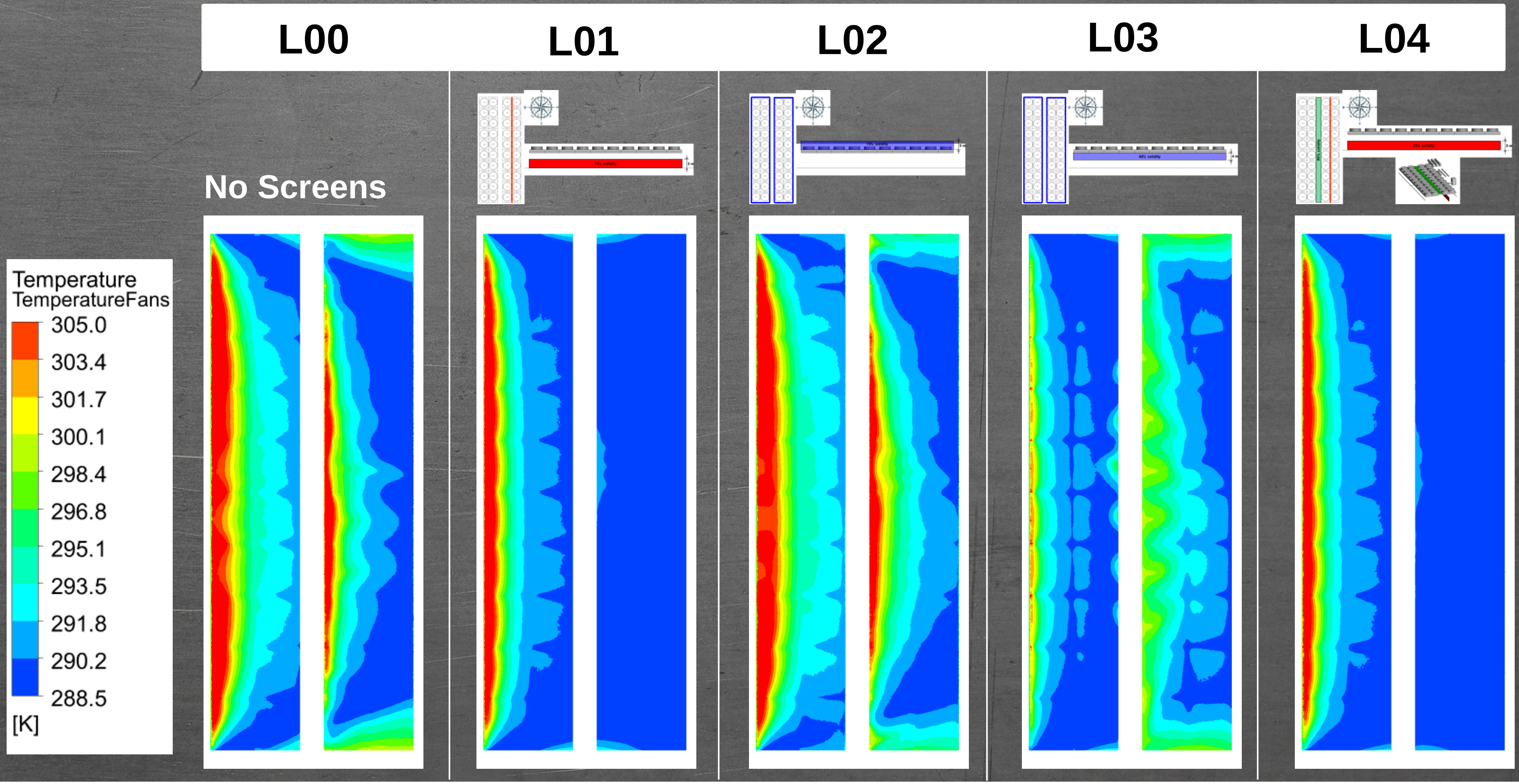
Results – High wind speed

Temperature on bundles inlet as a result of recirculation and backflow

Ambient temperature is 288.55 K

Any temperature higher than this reflect either a recirculation of spent air from the exterior or a backflow

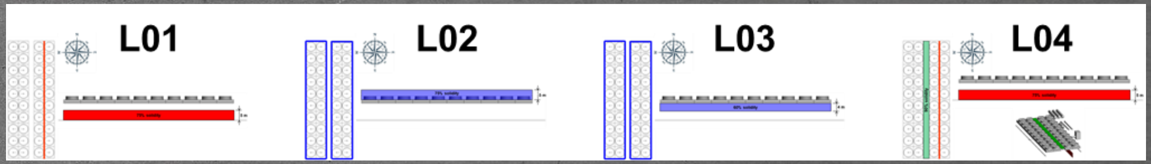




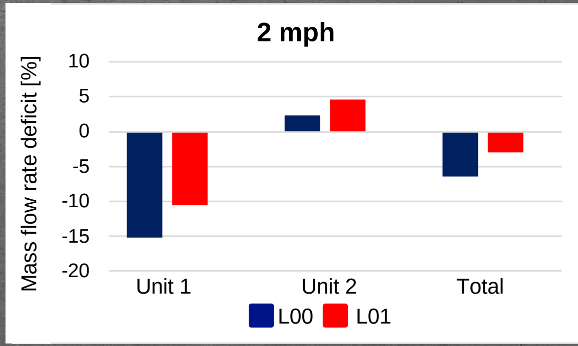
Baseline results

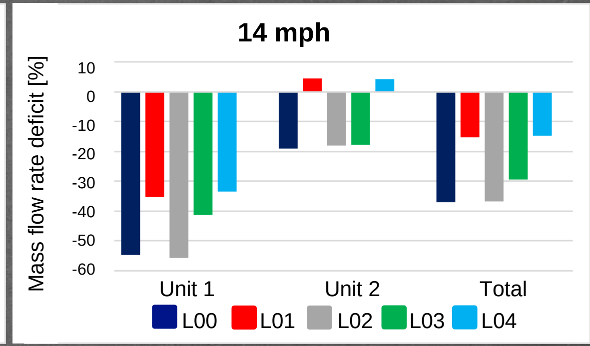
Mass flow rate

- At low wind speed, wind losses are minimal
- Nevertheless, L01 (and L04) generates an additional benefits resulting in 3.69% gain
- At high wind speed, wind wall based screens outperform the other layouts
- The gain is high on both units with higher benefits on unit 1
- **L04 shows the best results: @14 mph the gain is 35.27%**
- L03 is also showing some improvements

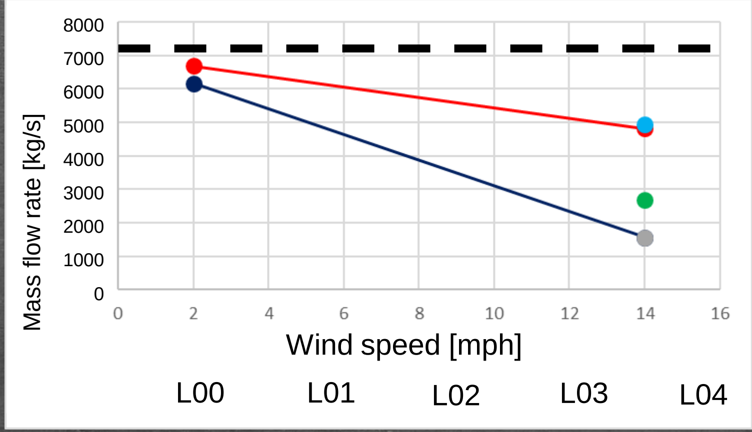


$$m_{deficit} = \frac{m - m_{design}}{m_{design}}$$

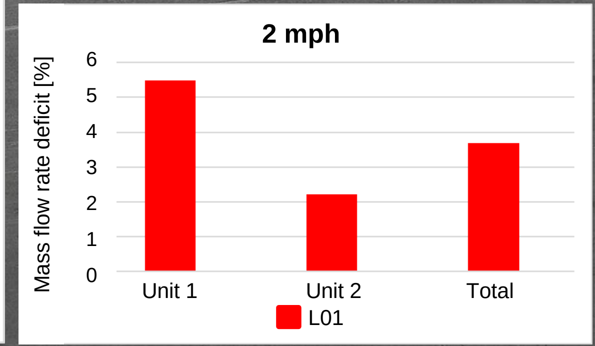


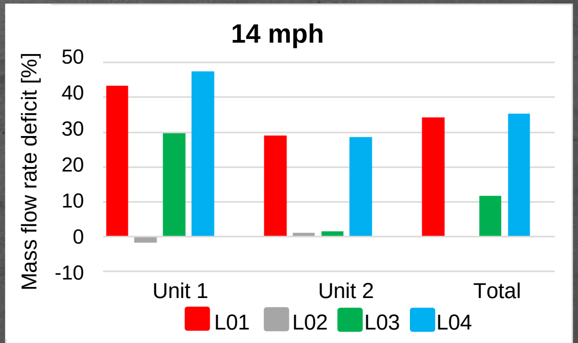


Design flow rate = 7570 kg/s



$$m_{gain} = \frac{m_{L0x} - m_{L00}}{m_{L00}}$$



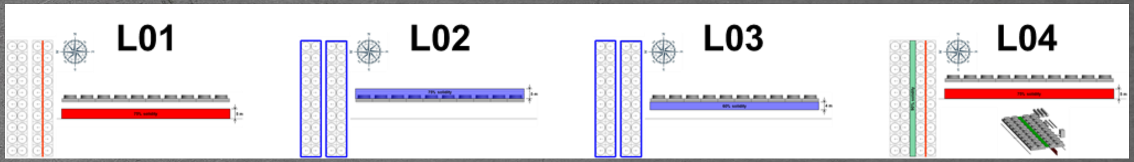


EST. 1984 Galebreaker® INDUSTRIAL

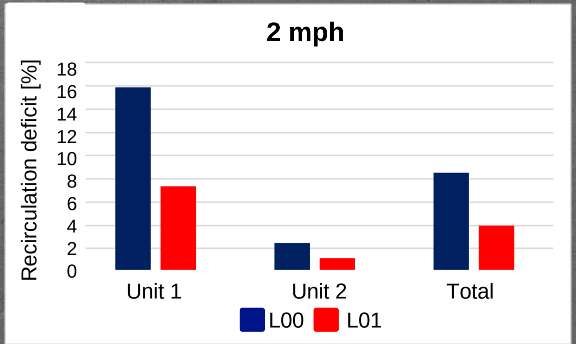
Baseline results

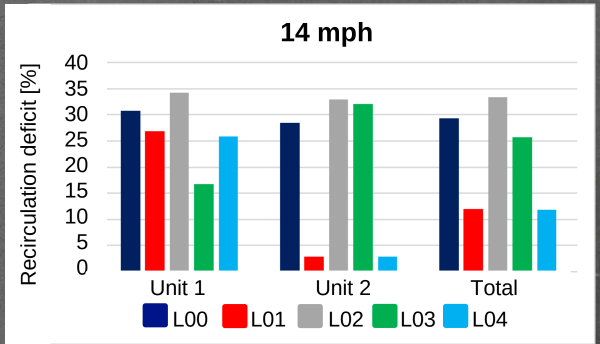
Recirculation

- Recirculation is a measure of the quantity of spent air ingested at the bundle
- At low wind speed, L00 recirculation is not dramatic but is still significant
- L01 (and L04) is able to halve the recirculation with a net gain of -4.54%
- At high wind speed, recirculation without windscreens increase up to 30%
- **L04 shows at the lowest recirculation: @14 mph the gain is -17.49%**

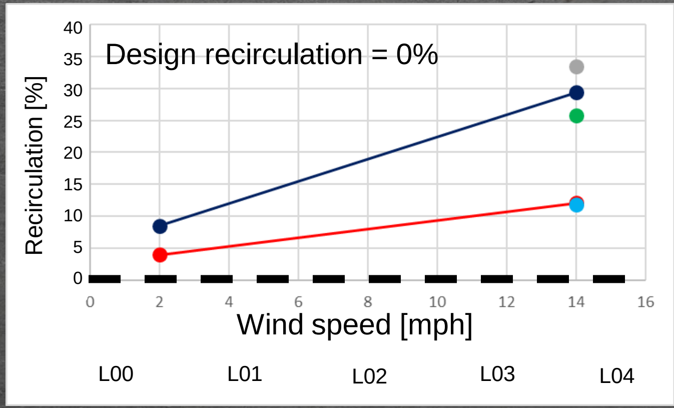


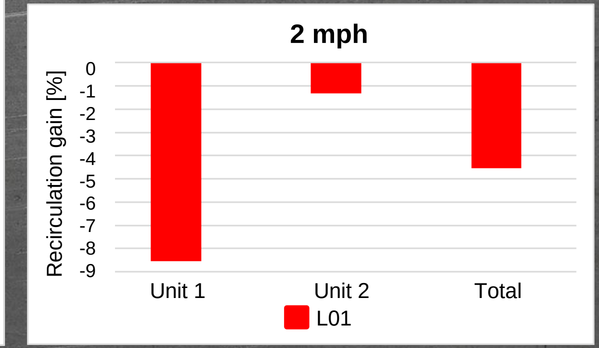
$$R_{deficit} = R - R_{design}$$

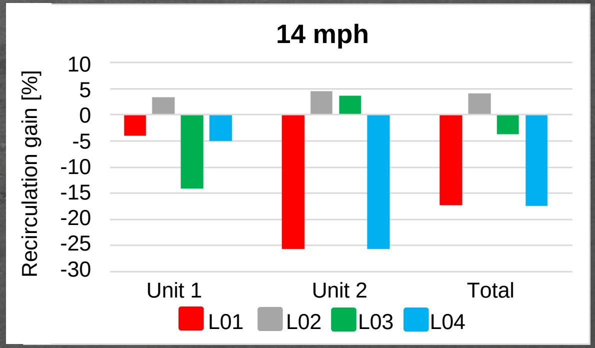




$$R_{gain} = R_{L0x} - R_{L00}$$





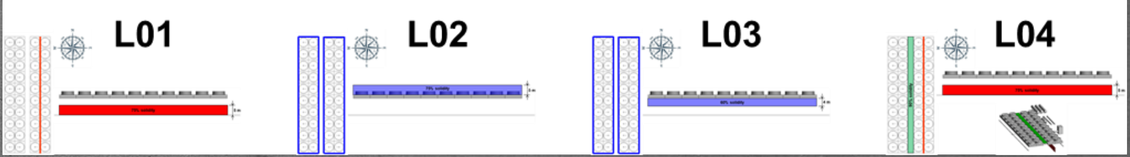


$$R = 100 \cdot \frac{T_{fan} - T_{amb}}{T_{bundle} - T_{amb}}$$

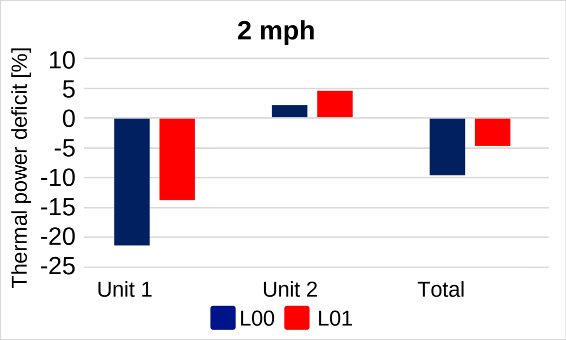
Baseline results

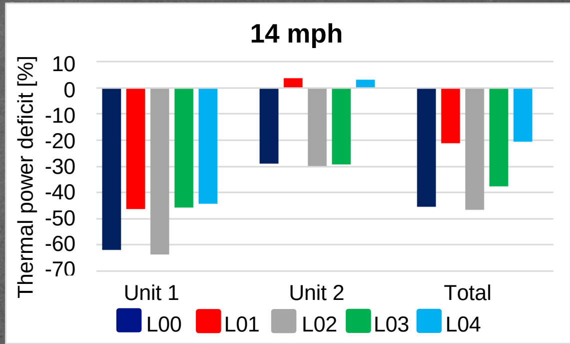
Thermal power

- At low wind speed, thermal power deficit is about 10% mostly due to deficiency on unit 1
- L01 (and L04) is able to further improve the power obtaining a 5.52% gain
- At high wind speed, wind wall based screens outperform the other layouts
- The gain is high on both units with higher benefits on unit 1
- **L04 shows the best results: @14 mph the gain is 45.42%**
- L03 is also showing some improvements

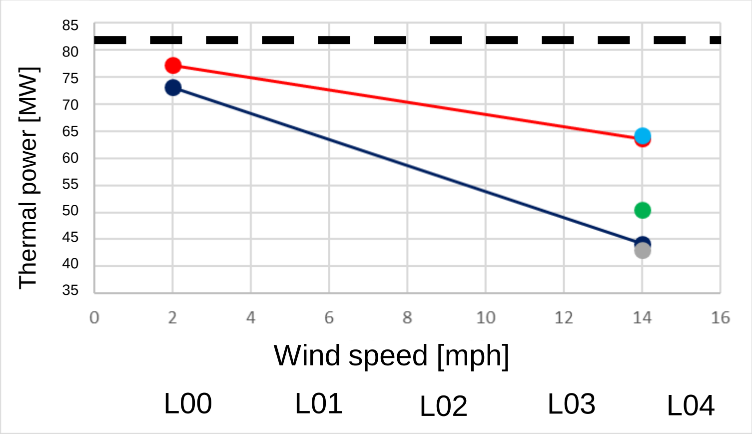


$$\dot{Q}_{deficit} = \frac{\dot{Q} - \dot{Q}_{design}}{\dot{Q}_{design}}$$

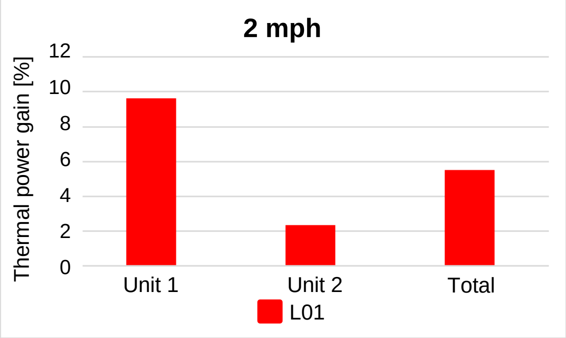


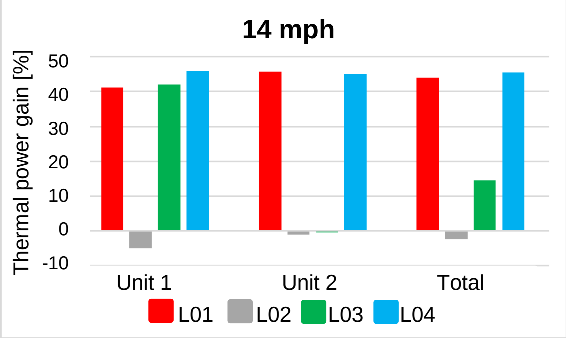


$$\dot{Q}_{gain} = \frac{\dot{Q}_{L01x} - \dot{Q}_{L00}}{\dot{Q}_{L00}}$$



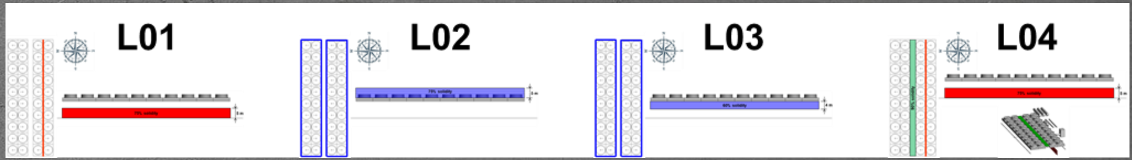
Design thermal power = 80.83 MW





EST. 1984 Galebreaker® INDUSTRIAL

Baseline results

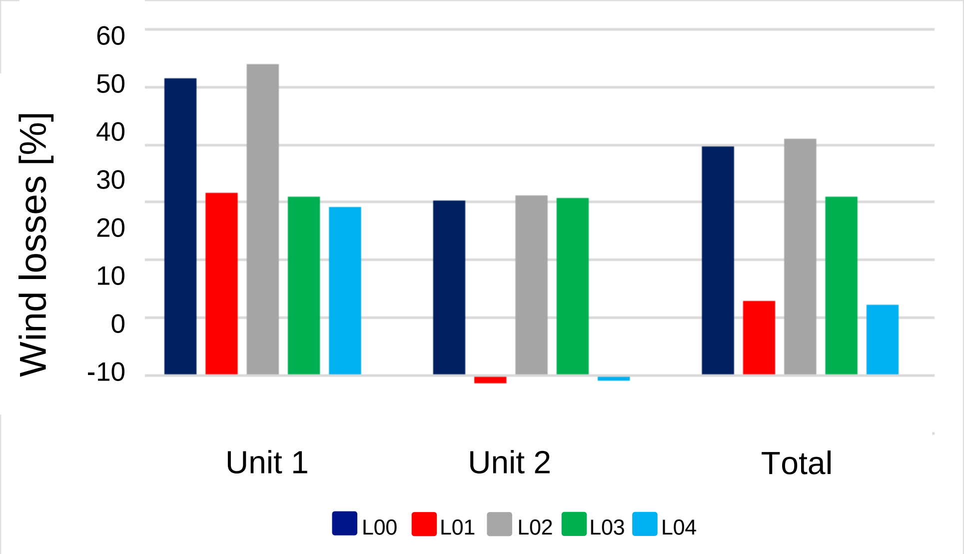


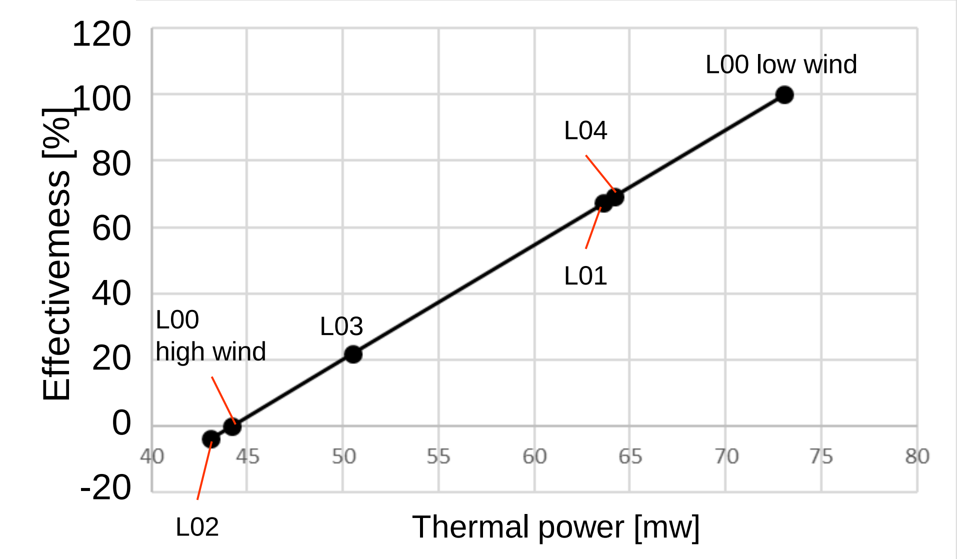
Effectiveness

The effectiveness is a measure of the thermal power gained due to the windscreens
Such gain actually corresponds to a reduction of the wind losses
Wind losses with no windscreens are 39.57% @14 mph
At 14 mph such losses are reduced to 12.12% implementing L04
Corresponding effectiveness is **69.37%**

$$\eta_{L0x} = 100 \cdot \frac{\dot{Q}_{L0x\ 14mph} - \dot{Q}_{L00\ 14mph}}{\dot{Q}_{L00\ 2mph} - \dot{Q}_{L00\ 14mph}}$$

$$Wind\ losses = \frac{\dot{Q}_{L00\ 2mph} - \dot{Q}_{L0x\ 14mph}}{\dot{Q}_{L00\ 2mph}}$$





Conclusions

- The implemented CFD modelling is able to accurately reproduce expected cooler performance
  - At low wind speed, the predicted thermal power is within 10% uncertainty respect to the design spec
  - Such gap is mainly due to considerable recirculation predicted even at 2 mph
  - @**14** mph wind speed, the wind losses grows up to **40%**

- The suggested wind screen layouts are able to mitigate such wind losses significantly
  - Wind wall based solutions obtain wind losses close to 12%
  - Corresponding effectiveness is **70%**
  - Perimeter screens are also able to provide some benefits
  - Interesting could be to verify the combined benefits of wind wall and perimeter screens

References

~ *US Department of Energy- Geothermal Technologies Office*

~ *Wikipedia- List of Geothermal power stations*

~ *Geothermal Rising*

~ *Wind Barriers to Mitigate Wind Effects on Air-Cooled Condensers, Prepared For: The California Energy Commission, Public Interest Energy Research Program , Prepared By:John S. Maulbetsch and Michael N. DiFilippo, Consultant, 2016*

~ *Study into the effectiveness of wind screening to mitigate wind effects on ACC fans , Sander Venema, 2015*

~ *UC Davis Wind Tunnel Testing in the ABL Wind Tunnel, Ryan Parker – PHD, 2015.*

~ *Smoke Testing at Ferrybridge , Tim Dazeley, Galebreaker*

~ *Airflow Testing using dry ice, GE Power*

~ *CFD Analysis of ACC at Geothermal Power Station, Cosimo Bianchini, Ergon Research , 2021*

EST. 1984
Galebreaker®
INDUSTRIAL