PHOENICS Case Study: HVAC - Ventilation of the Spanish Parliament Building
A PHOENICS/Flair application undertaken on behalf of Tayra SL by Krantz GmbH

El Congreso de los Diputados


Image from Gallery

Image of the deputies' hall during a parliamentary plenary session

The Congreso de los Diputados (Congress of Deputies of Spain) is the seat of the lower house of the Spanish Parliament located in the Palacio de las Cortes de España. Built in 1843, it represents one of the finest examples of late-neoclassical architecture to be found in Madrid.

This case study describes the use of PHOENICS/Flair on behalf of a Spanish company, Soluciones de Agua Y Aire Tayra SL, concerning the ventilation of the main chamber of the parliament building.

The air diffusion equipment was supplied by Krantz GmbH following laboratory tests in Aachen coupled with CFD simulation. The CFD and laboratory tests were compared to validate the accuracy and convergence of the CFD simulations.

Tayra SL designed the system layout, supervised the installation and undertook experimental field tests in situ to validate the CFD results. These physical measurements showed that, in operation, the performance of the ventilation system met and even exceeded expectation. The seating allows for roughly one person per square metre, each having a monitor in front of the seat.

The ventilation system for the Congreso de los Diputados combines three types of diffuser:-

1. Whirl diffusers for the "Hemiciclo" (the main semicircular part of the chamber).
2. Slot diffusers for the "Galeria" (the rear upper colonnade area).
3. Krantz Opticlean diffusers for local ventilation in the seating beneath the Galeria.

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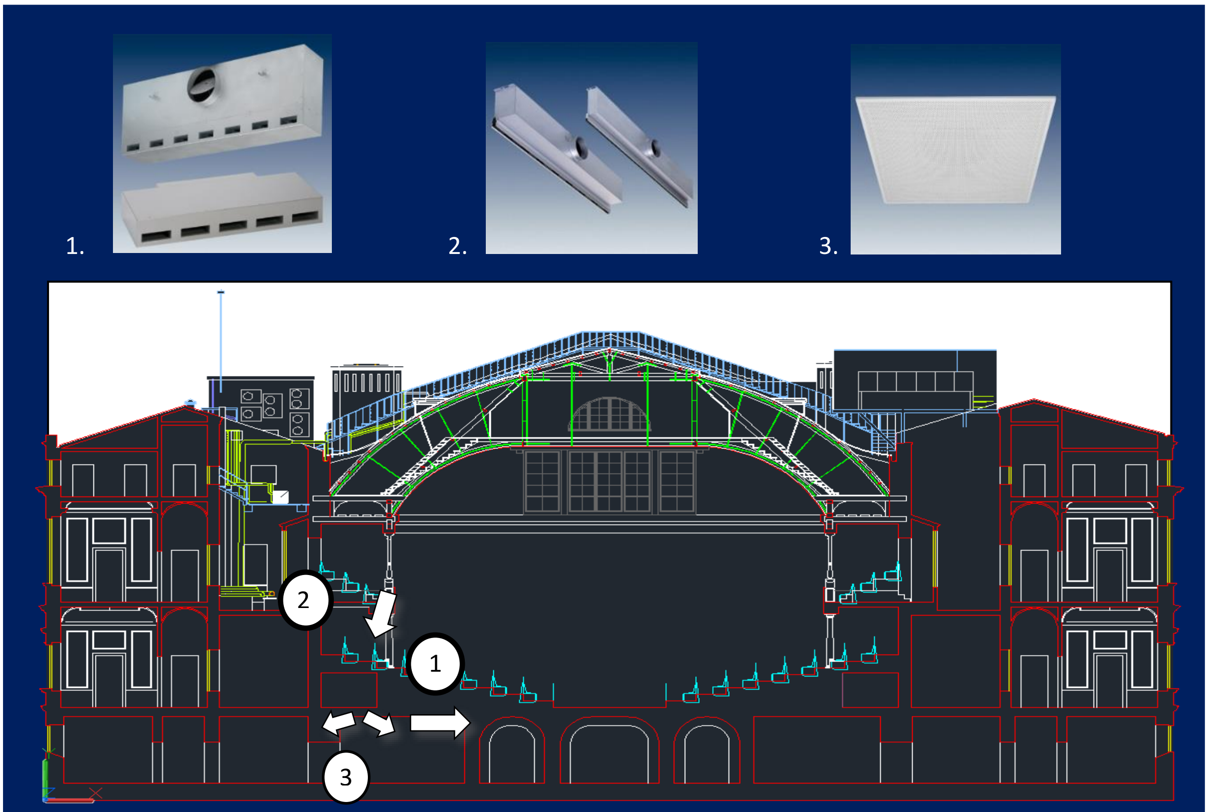


Cross-section of the 'Congreso de los Diputados', the semicircular Parliament chamber

Boundary Conditions - Air flow rates and heat load definition

Diffusers

Whirl diffuser WL3	V1 = 16 x 1559 m³/h (1100mm + 660mm) = 24.944 m³/h
INV slot diffuser	V2 = 17 x 580 m³/h (387 m³/h x ML) = 9.860 m3/h
Opticlean diffuser	V3 = 17 x 500 m³/h = 8500 m³/h
Total supply air	Vsupp = 24.944 + 8.500+9.860 = 43.304 m3/h
Total Exhaust air	Vexh = 34.643 m³/h

Heat loads

Persons in Hemiciclo	Q1 = 360 persons x 65W = 23.4 kW
Persons in Galeria	Q2 = 230 persons x 65W = 14.95 kW
Computer	Q3 = 350 x 29W (voting) + 18 PC´s @ 94 W + 350x29W = 19.895 kW
Lights	Q4 = 32 kW = 19 kW above and 13 kW below
PCs, computer, galerias	Q5 = 30W/m2 x 170.5 m2 = 5,115 kW
Total load	Q_{total} = Q1+ Q2+Q3+Q4+Q5 =95.4 kW
Supply temperature	$T_{supp,min}$ = 18°C (14°C under summer conditions)
Temperature rise	$\Delta T = Q_{total} / (\rho * cp * V_{supp}) = 6.7K$
Exhaust temperature	T_{EX} = ~ 26°C

Areas

Floor area	A0 = 556.1 m² (Hemiciclo)

A1 = 170.5 m² (Galeria)

Modelling the WL3 Whirl Diffusers

Substitution model

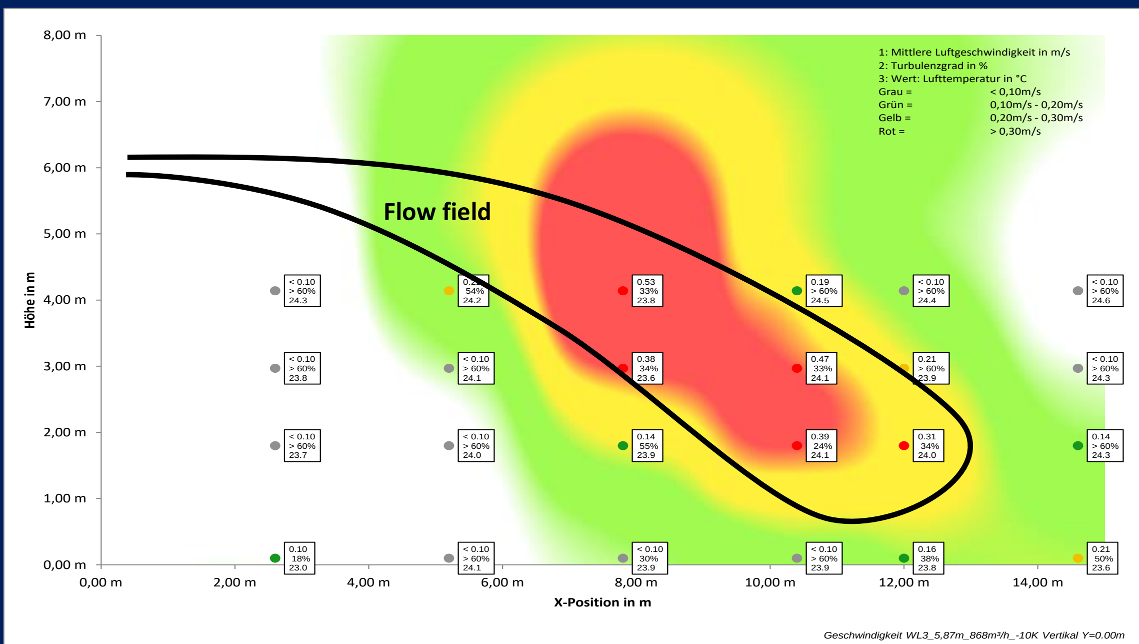
Numerical simulation systems have a limited spatial resolution. For a large scale model, the size of an individual diffuser nozzle may be very small; details of the jet development cannot be properly represented in the model. Therefore it is not practical to set up realistic diffuser models in detail within the context of a large-scale simulation. A simpler "substitution model" has to be found that gives the same flow characteristics as the physical diffusers; for example by using a simple jet nozzle with different diameter, and compensating for this by choosing an appropriate flow rate and temperature to get a similar flow field.

The whirl diffusers employed for the Hemiciclo use a special technology to produce a highly turbulent air flow with increased induction rate. A substitution model was used to simulate the performance of the whirl diffuser. It was validated using the laboratory tests at a temperature difference of 10°C.

Laboratory tests for WL3 whirl diffuser

Laboratory tests were used to calibrate the substitution model. The diffuser jet may be broadly characterized by its throw and its droop, the latter being an effect of buoyancy based on temperature difference between supply air and ambient air within the space. The laboratory tests were based on a temperature difference of 10°C.

This plot shows the laboratory test results for the whirl diffuser WL3.



WL3 at V0 = 868 m³/h and ΔT = 10 °C

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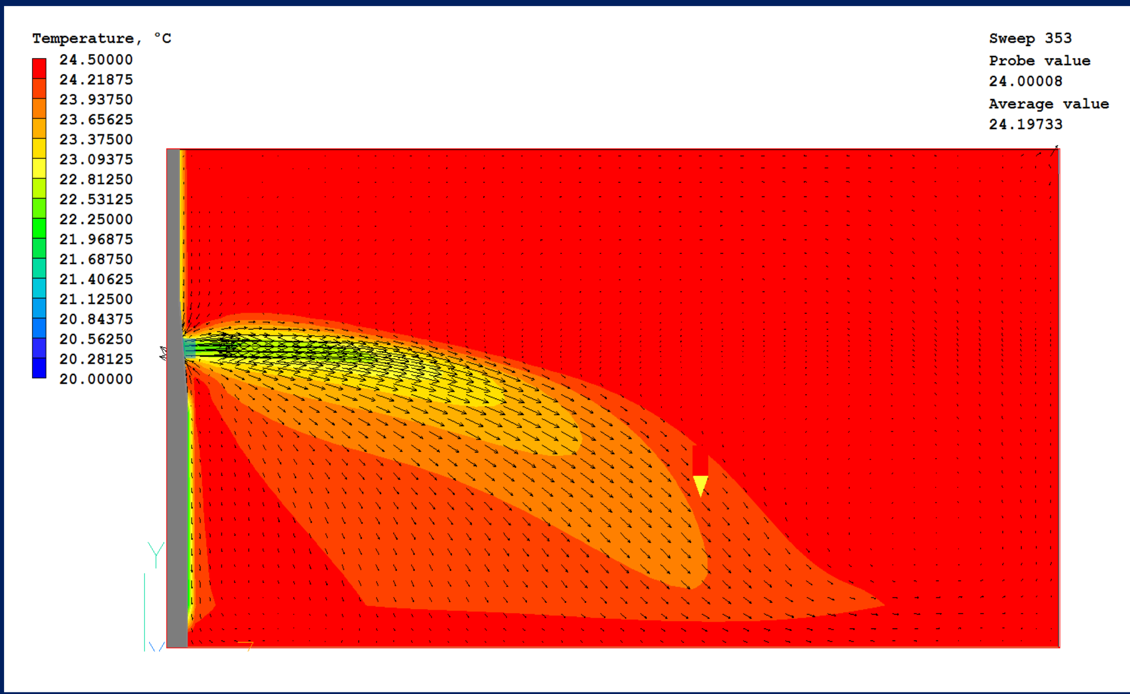
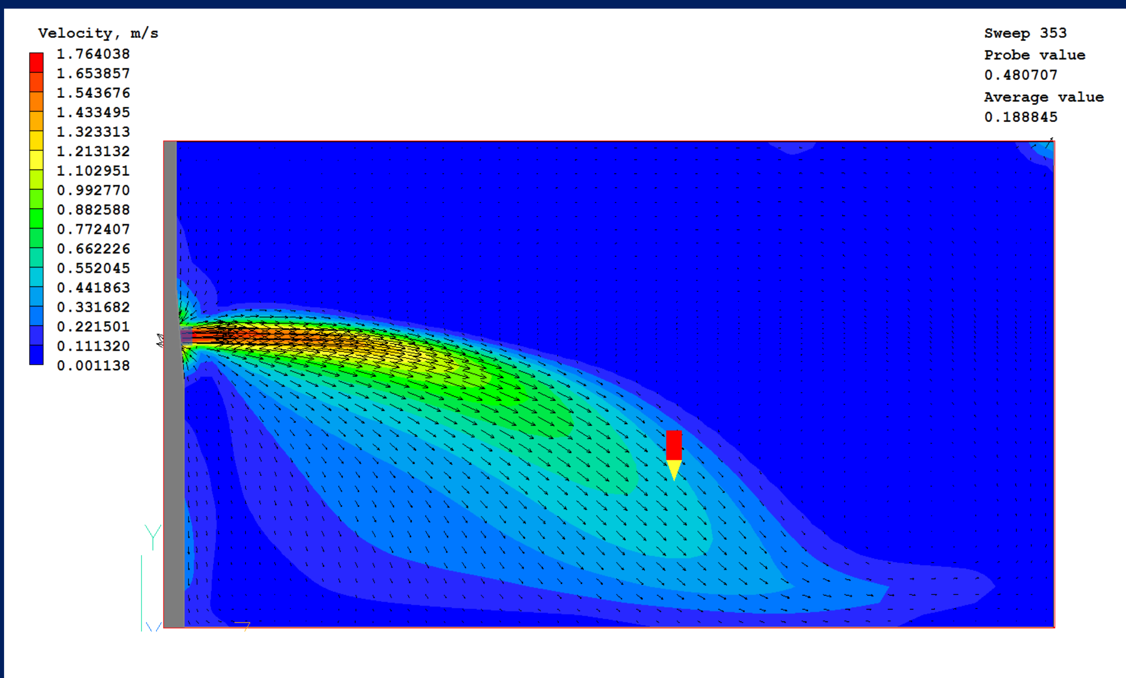
Substitution model for WL3 – temperature field



PHOENICS-2019

Substitution model for WL3 – velocity field



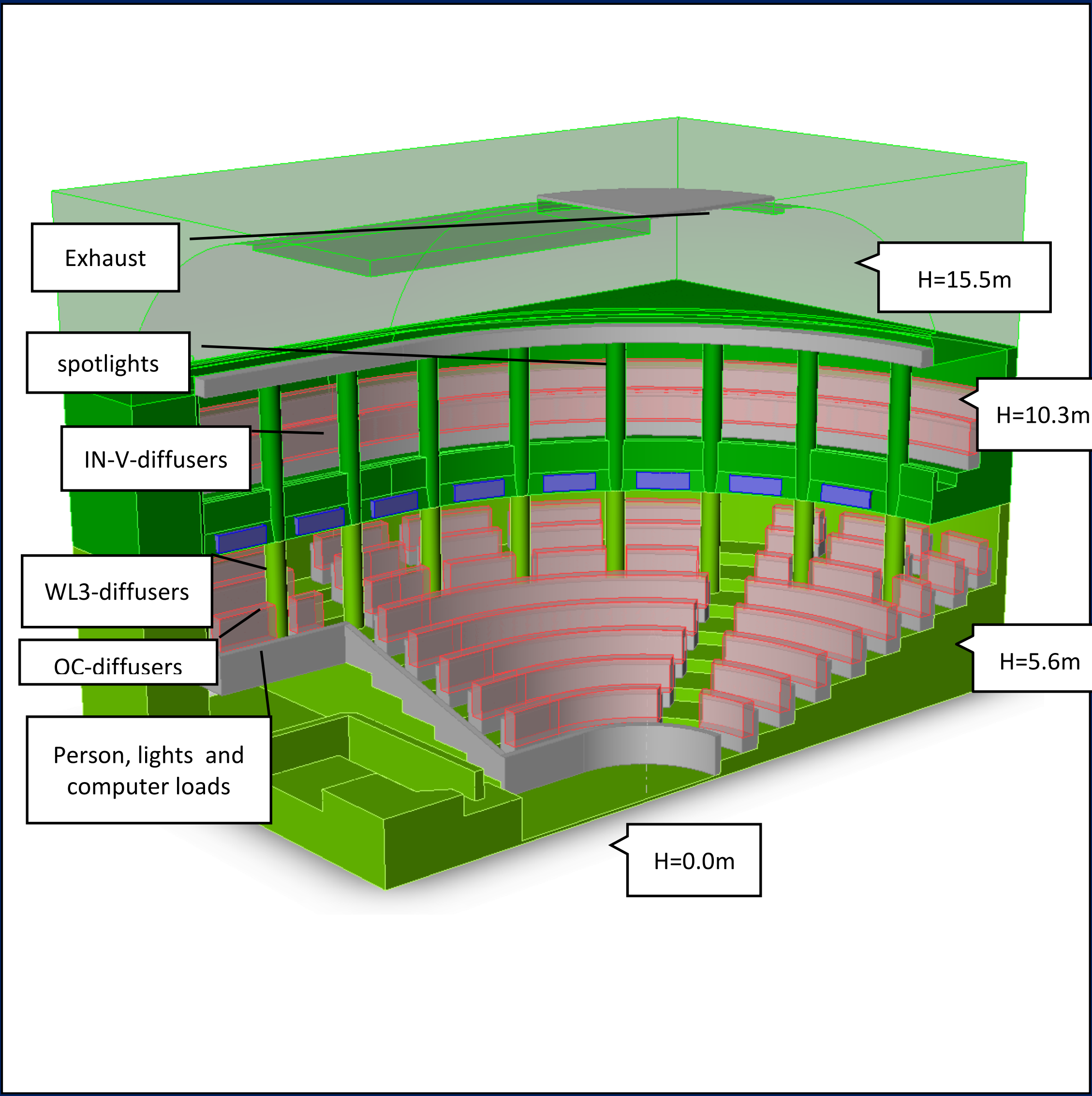
Substitution model for WL3 – comparison

Comparison at a selected location (x = 10.3 m, H=3 m) shows the following values:

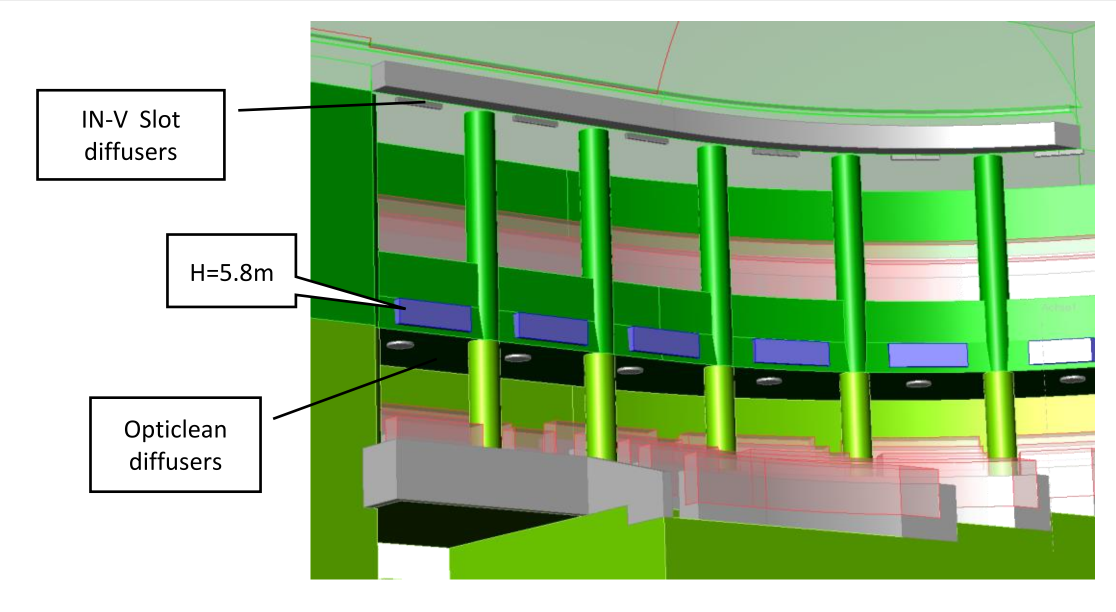
	Lab test	*Simulation model*
Velocity	u = 0.47 m/s	u = 0.48 m/s
Temperature	T = 24.1°C	T = 24.0°C

The model predicts the effects of the highly-turbulent induction system very well. It slightly overestimates the resulting velocity.

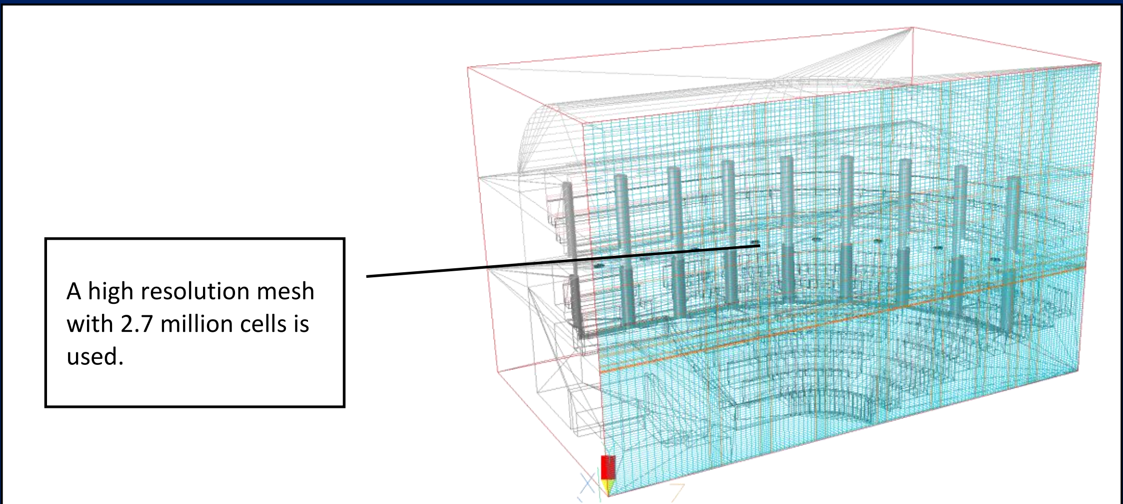
3D Geometry model



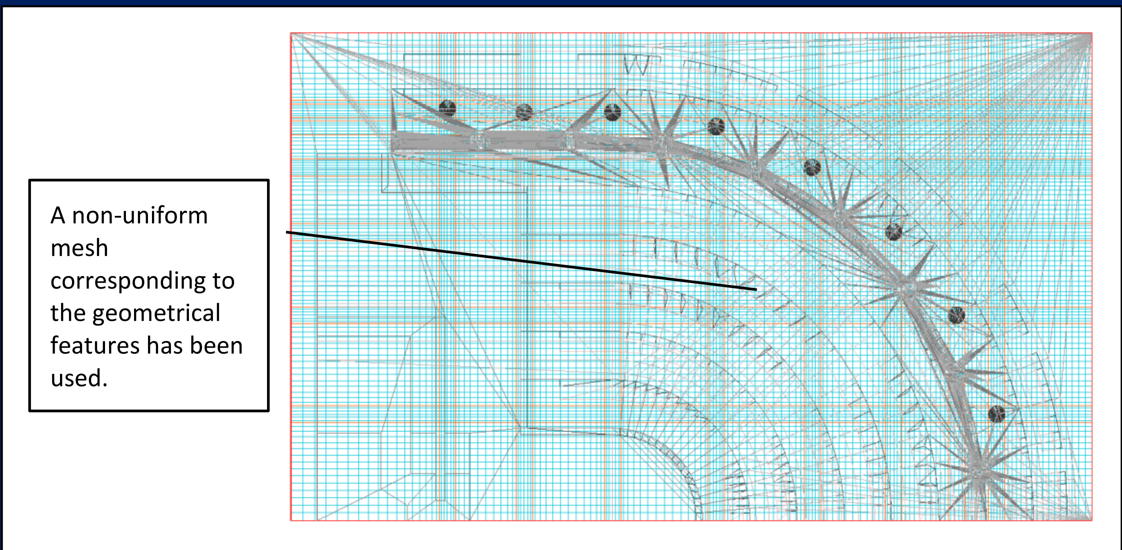
3D Geometry model



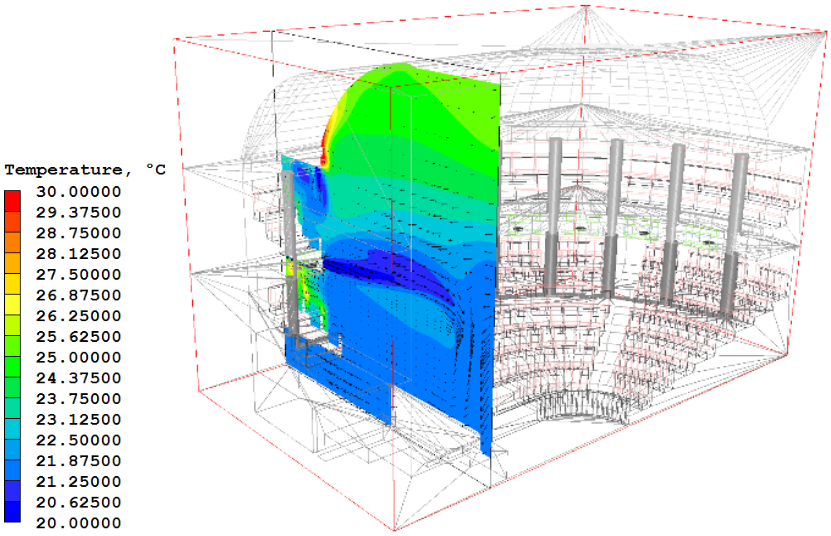
Computational mesh

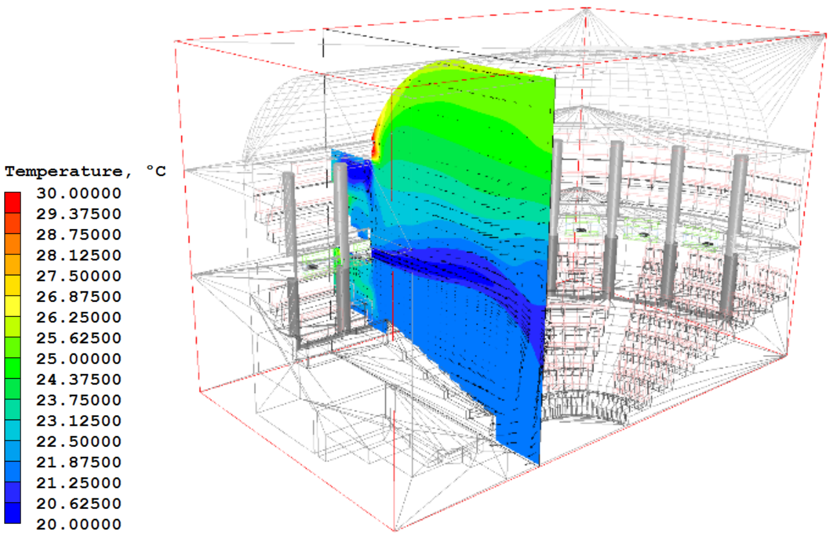


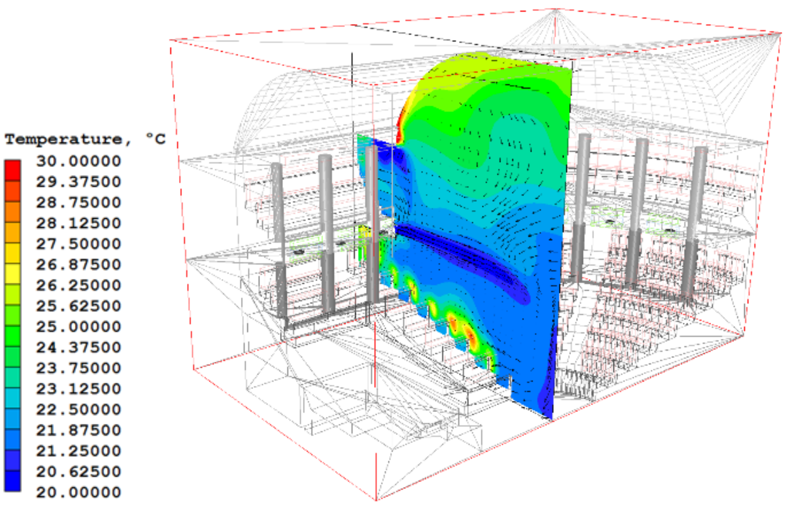
Computational mesh

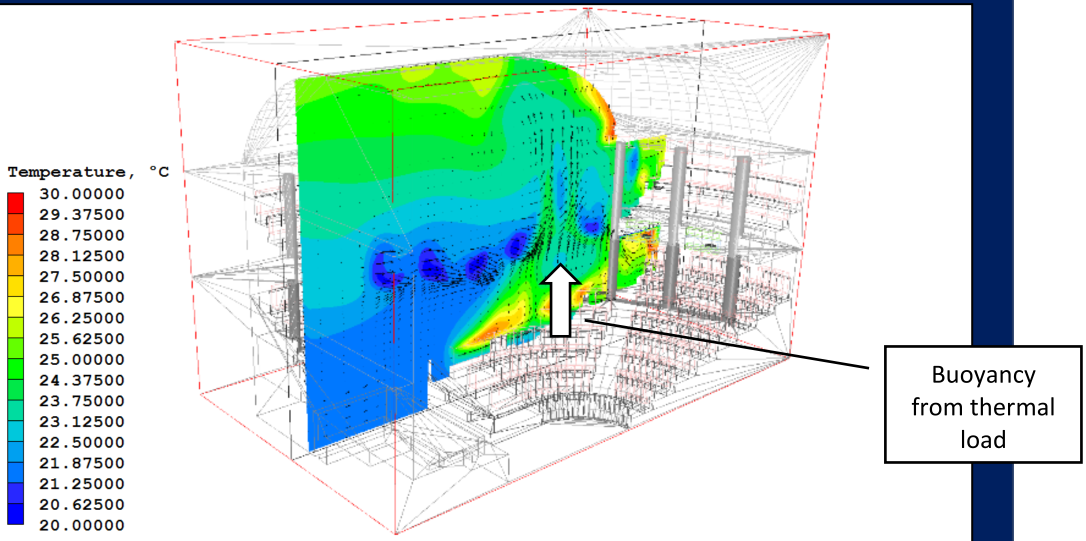


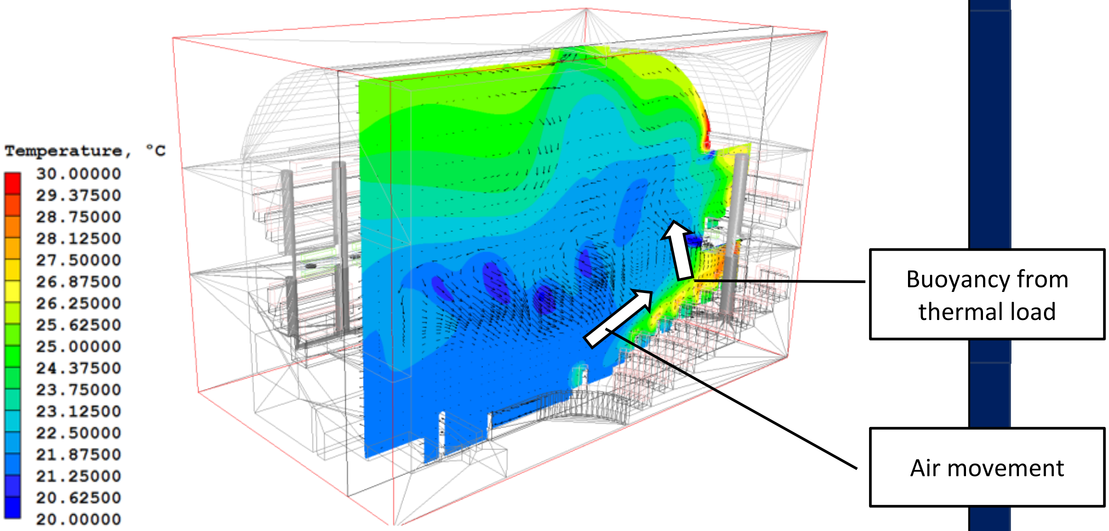
Results - Temperature profiles



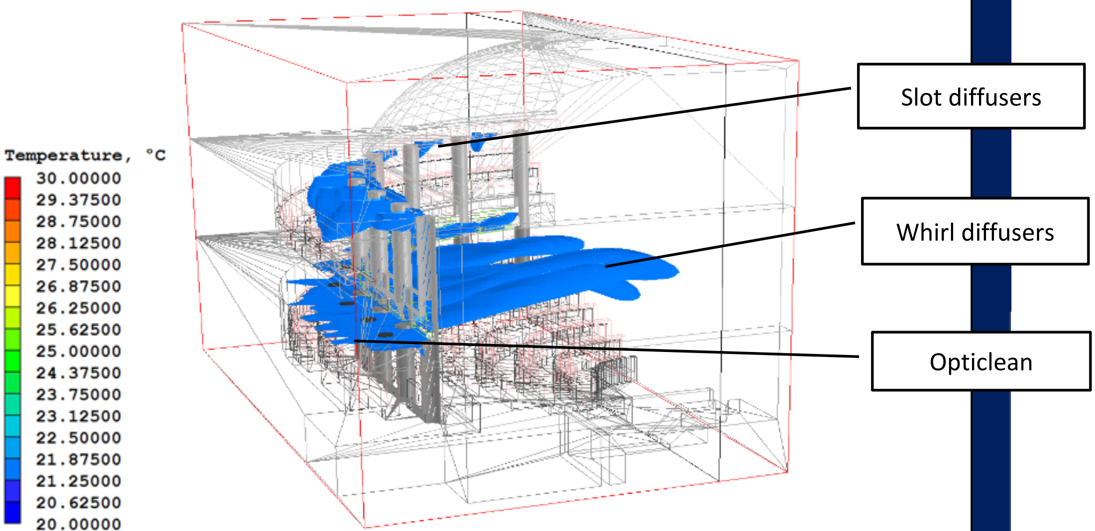




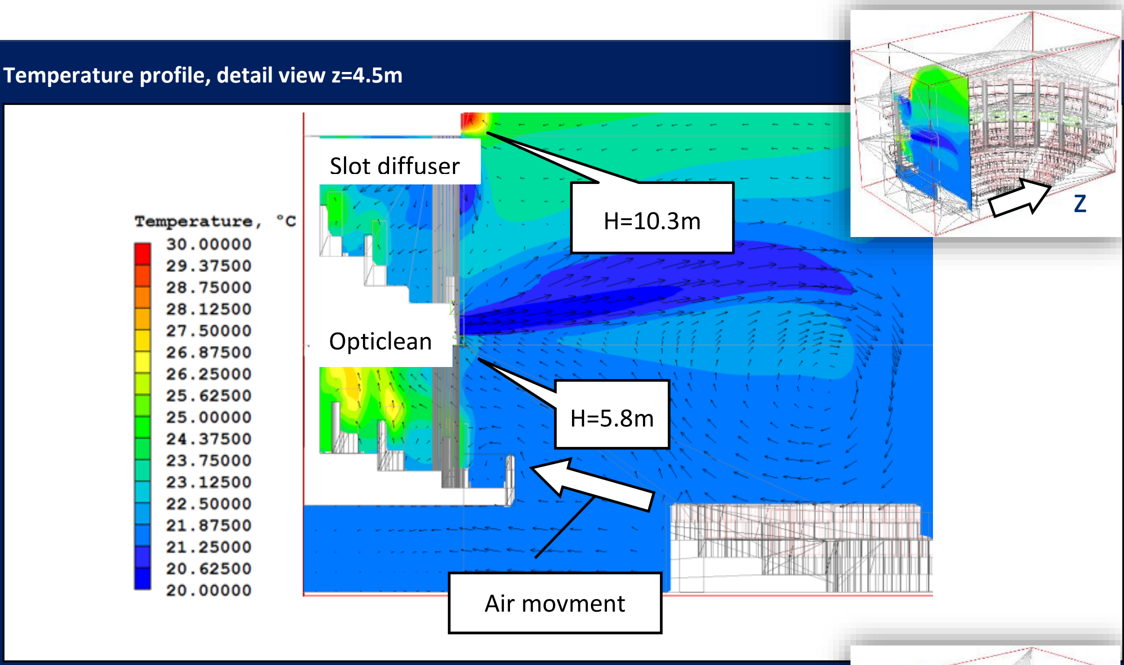




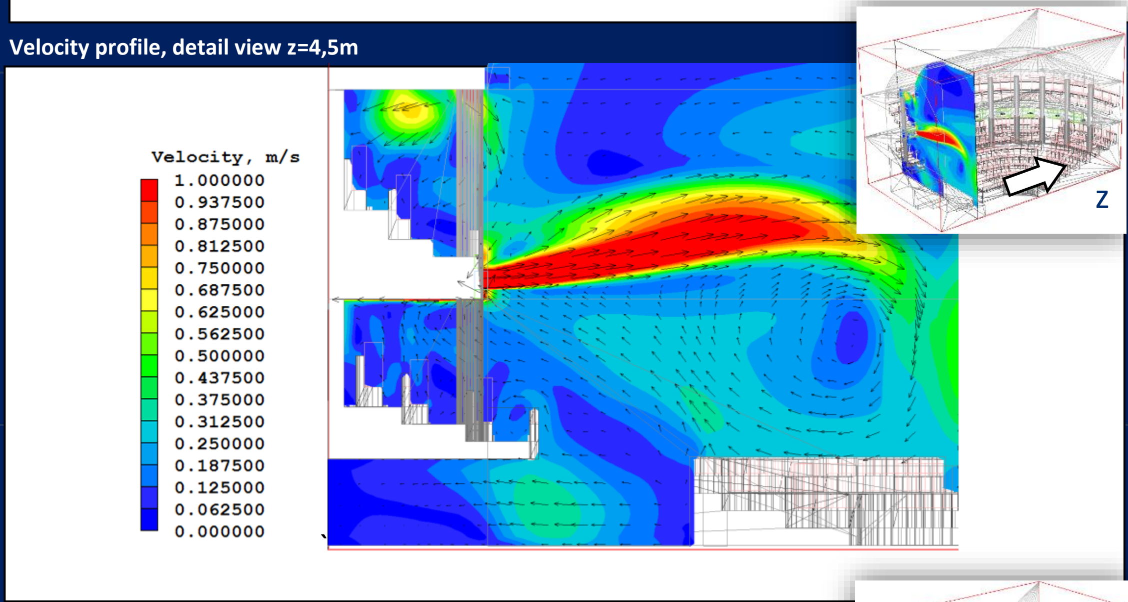
Temperature iso-surfaces at 22°C



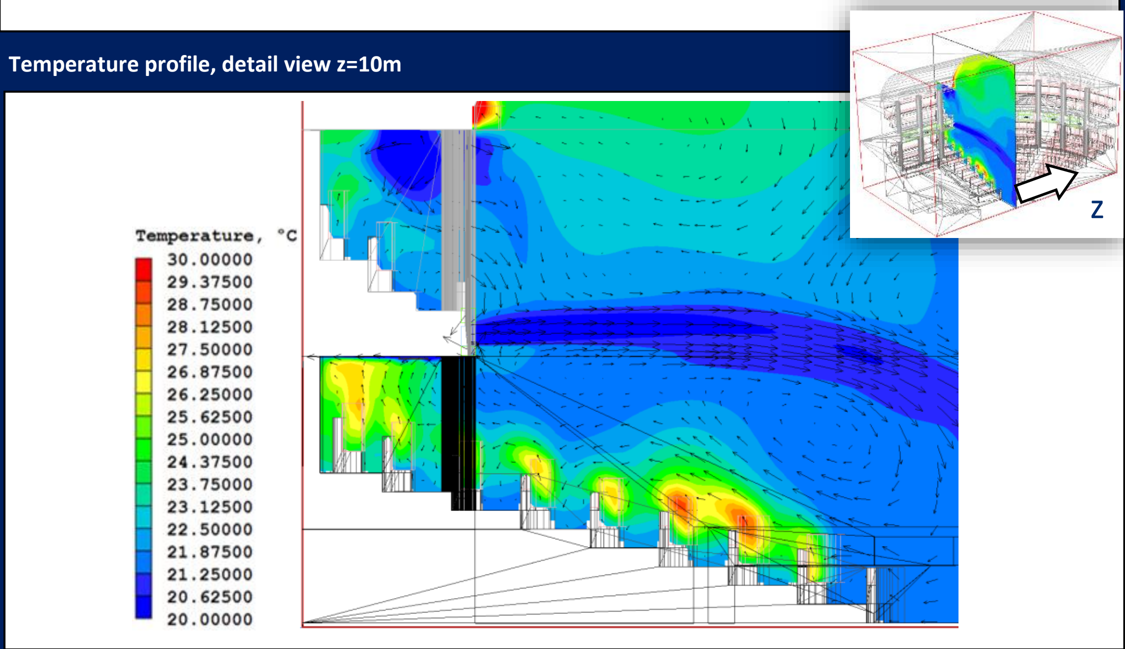
Temperature profile, detail view z=4.5m



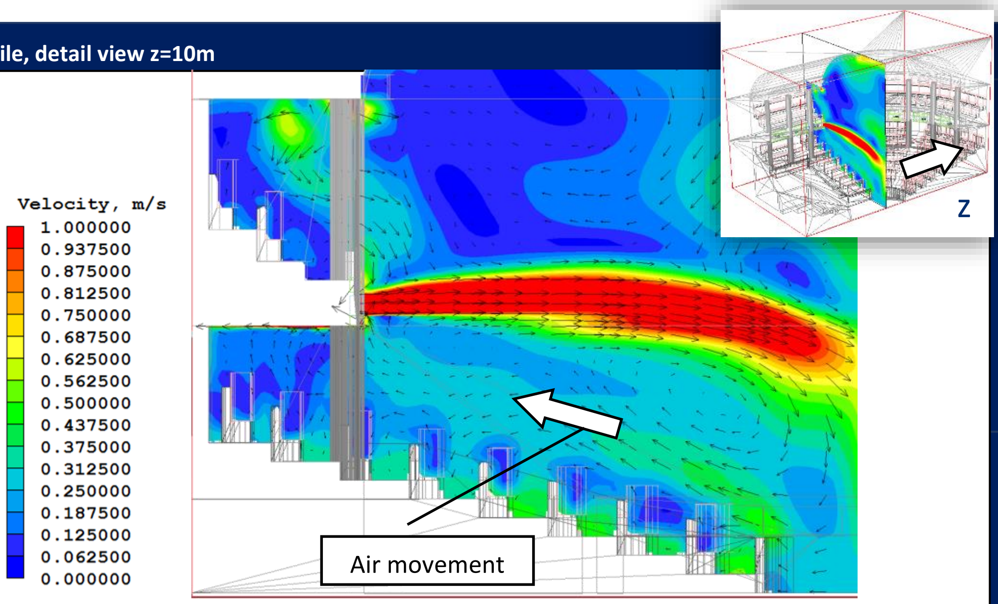
Velocity profile, detail view z=4,5m



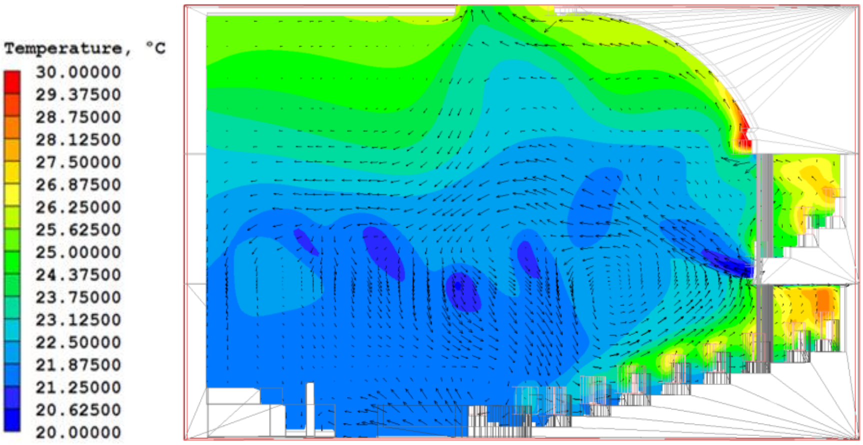
Temperature profile, detail view z=10m



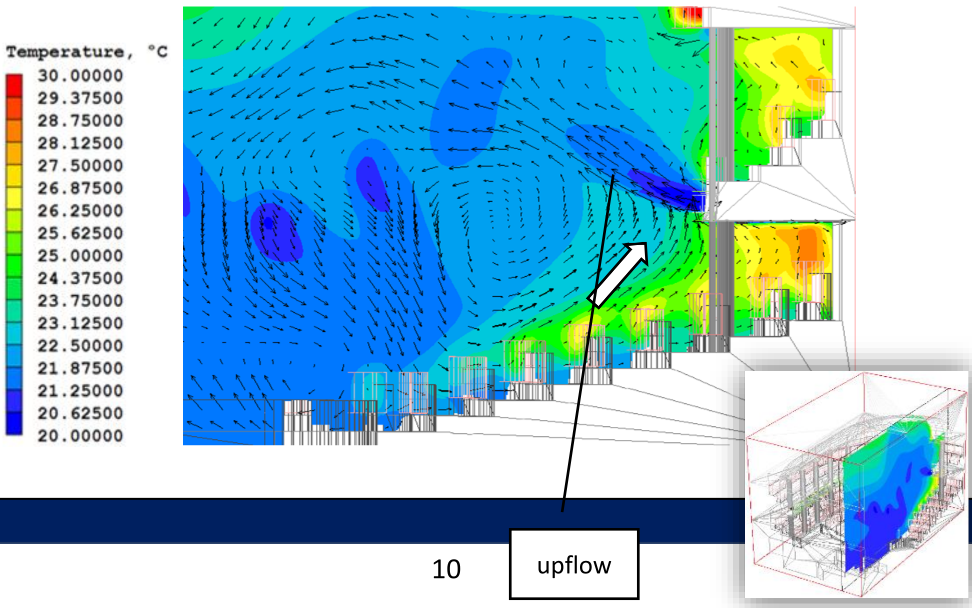
Velocity profile, detail view z=10m



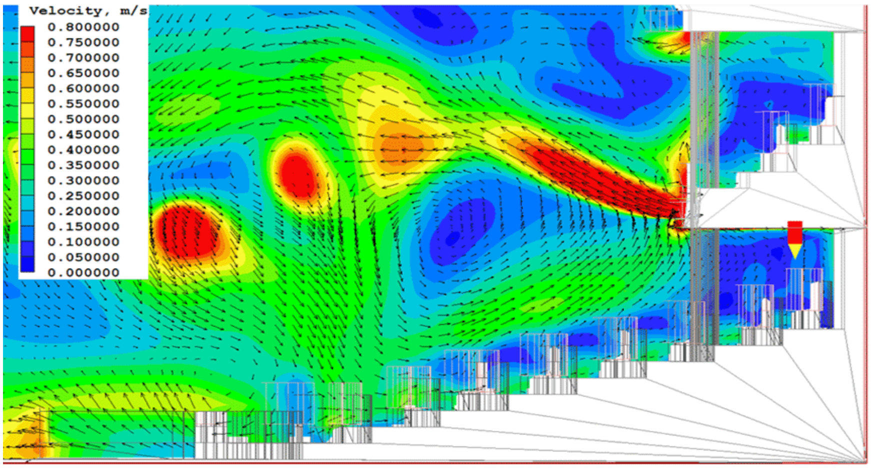
Temperature profile, longitudinal section



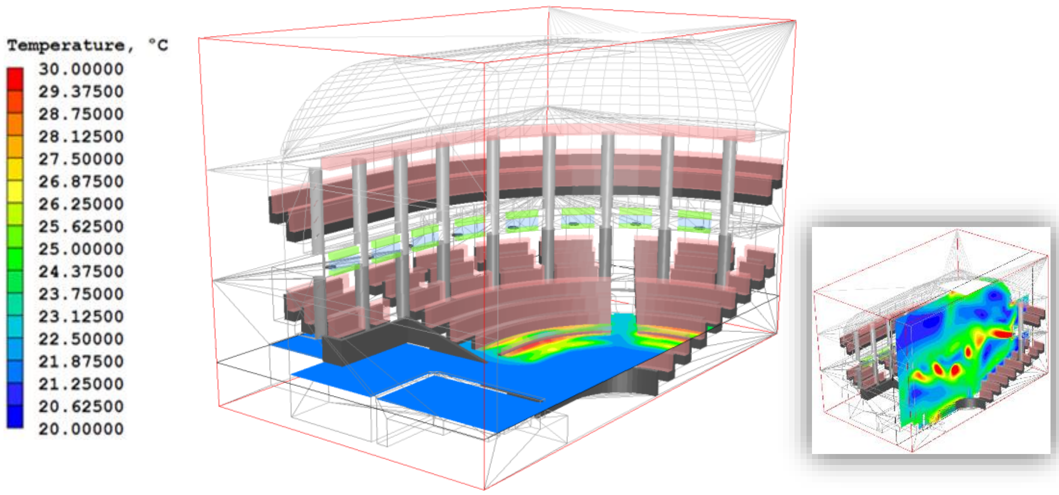
Temperature profile, detail view longitudinal section



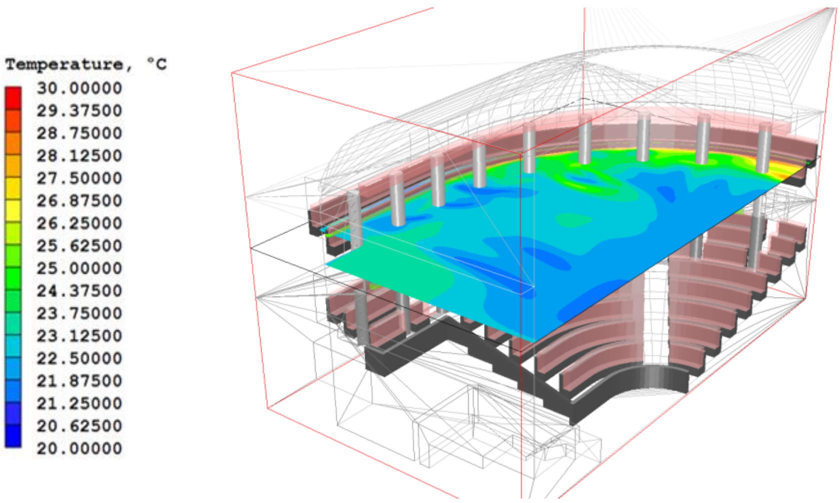
Velocity profiles, detail view longitudinal section



Temperature profile on horizontal plane at h = 2m

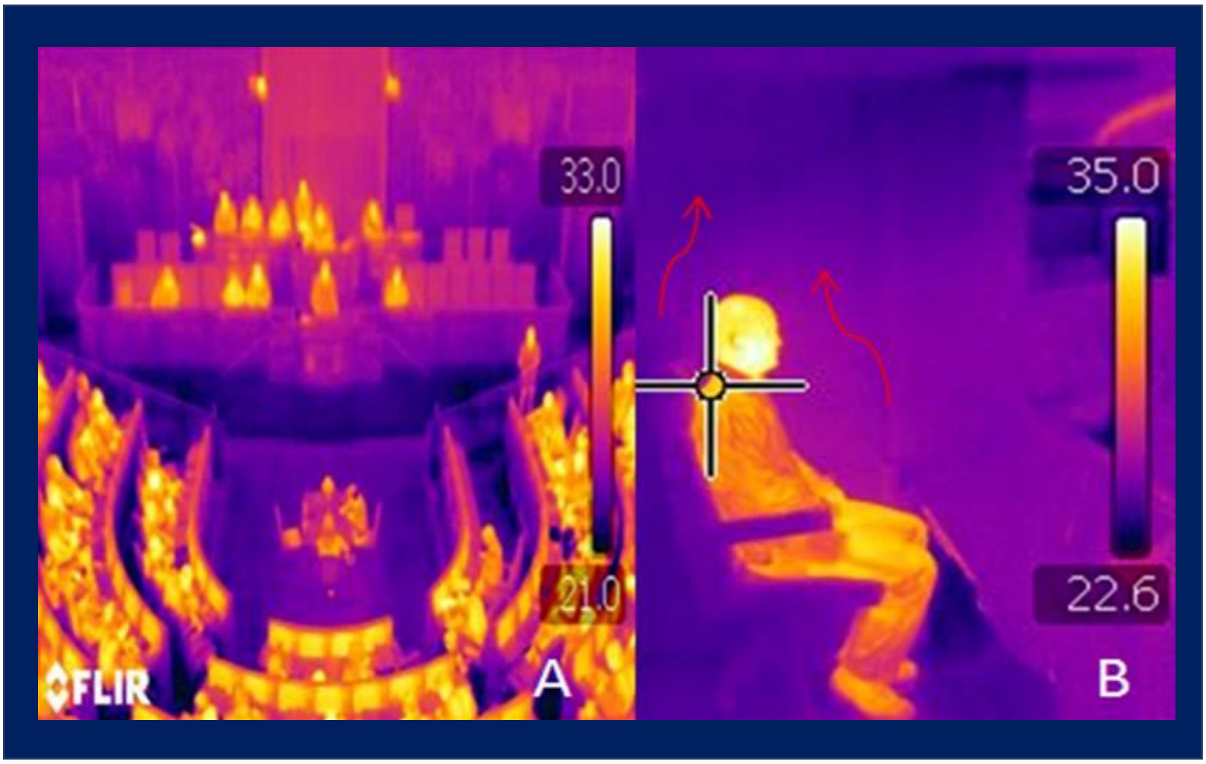


Temperature profile on horizontal plane at h = 8m

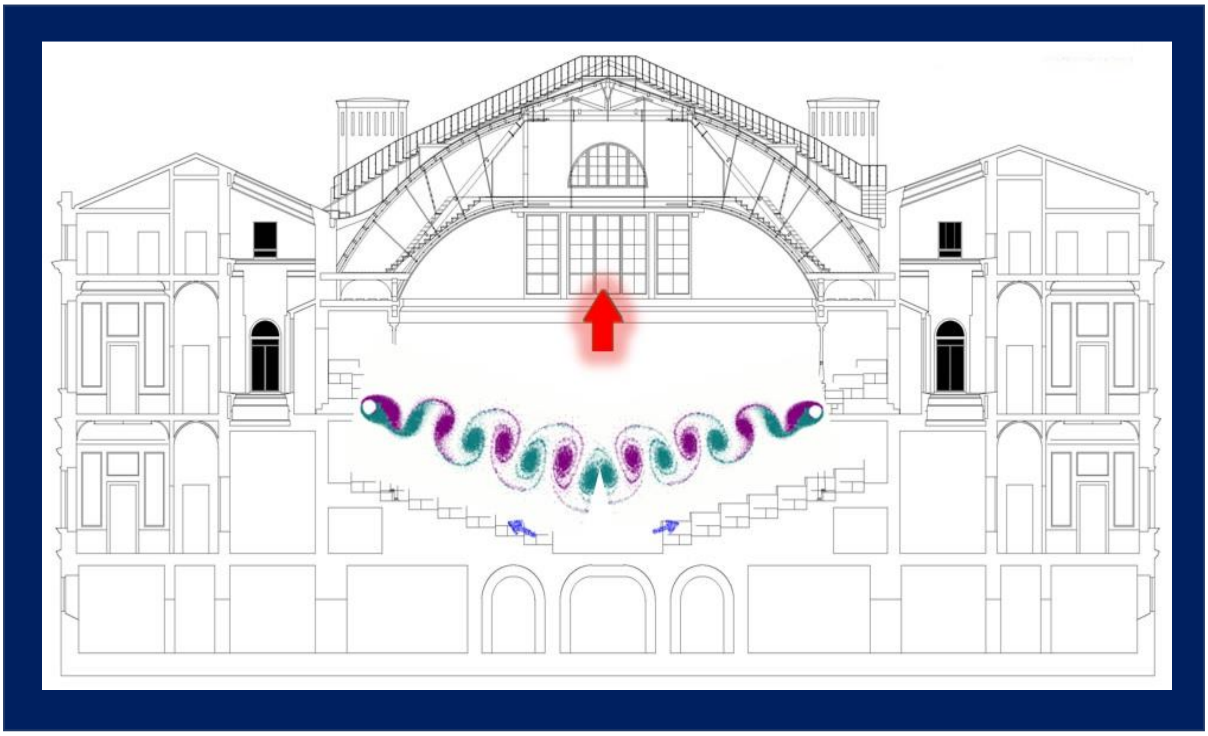


Field Test Results

There follows some photographs taken of the inside of the parliament building showing thermography visualisation in full-load steady-state working conditions. These again confirmed the similarity between the excellent CFD analysis output from Krantz and the field results.



Click here to view a video of the smoke test confirming the same pattern as predicted by the CFD.



Visualization of the on-site smoke test. Its pattern is very similar to the results produced by PHOENICS/Flair.

Conclusion

The ventilation system works well as a displacement system in "Galeria" (the upper colonnade area), and a mixing system in the rear seating area beneath it. This provides excellent heat extraction.

In the main semicircular "Hemiciclo" area, it is clear from the results that jets from the whirl diffusers do not penetrate significantly into the seating to cause draughts; air velocities are generally low on all seats. Increased air velocity was observed in the central part of the semi-circular chamber, caused by buoyancy from the thermal load. Under extreme thermal load this may reach a local velocity of 0.35m/s.

The area beneath the Galeria, i.e. at the rear of the main seating, may reach a temperature of 28°C under extreme load conditions (600 persons + computers in the "Hemiciclo"). The air flow rate is sufficient to cover the heat load of about 250 persons beneath the Galeria.

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