

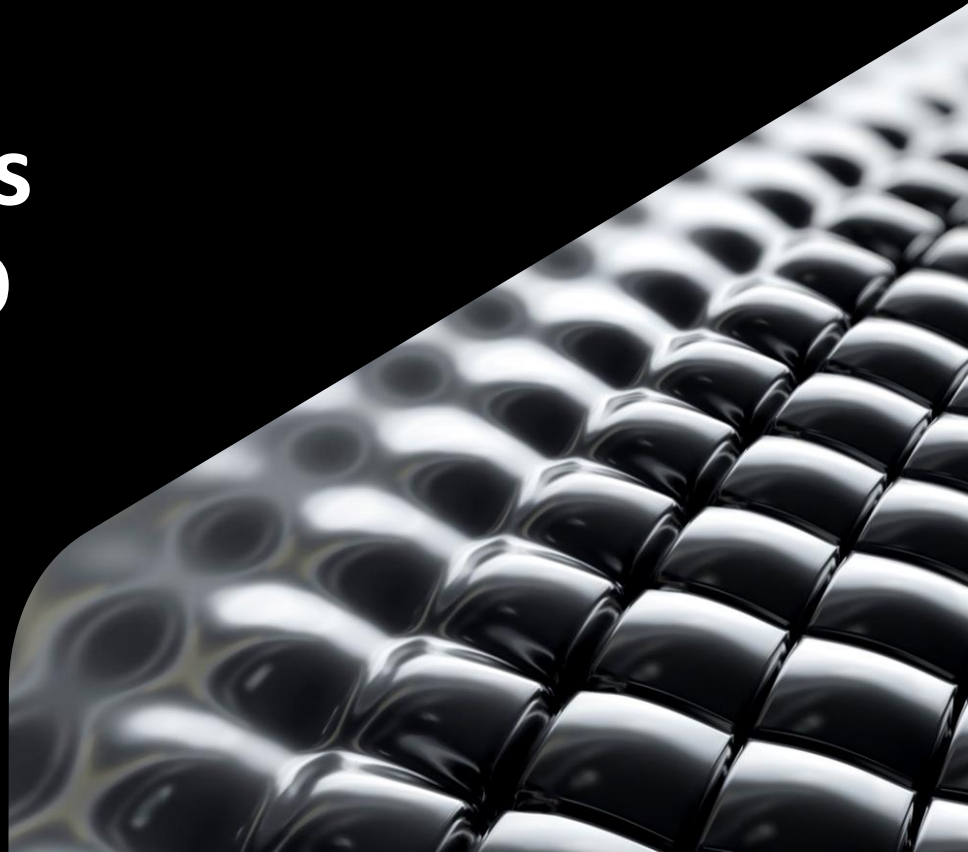
Better HVAC Designs Using Autodesk CFD

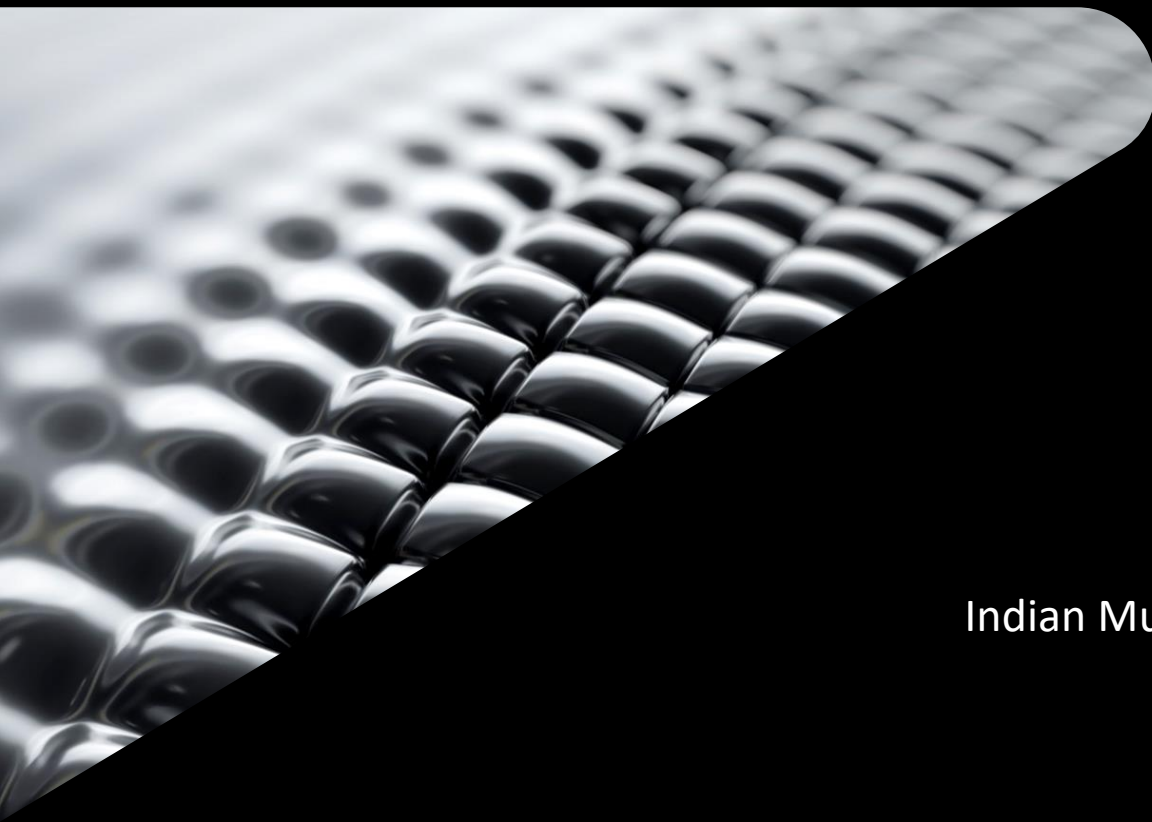
Case Study: Airport Expansion Project

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HEAD - CFD | @m_munirajulu



L&T Construction





L&T Overview

Indian Multinational Conglomerate Company

L&T OVERVIEW



India

USA

Europe

GCC

Africa

South-East Asia



Hydrocarbon

Infrastructure

Power

Process
Industries

Defence



Technology

Engineering

Construction

Manufacturing

Projects

Financial Services

Turnover

USD 21 billion

Order Book

USD 40 billion

Employees

85,000 +

Shareholders

1,000,000 +

L&T's Business Line



Heavy Civil Infra



Transportation Infra



Water, Smart World & Communication



L&T Infotech



Power Transmission & Distribution



Hydrocarbon



Defense & Shipbuilding



L&T Technology Services



Metallurgical & Material Handling



Heavy Engineering



Machinery & Industrial Products



Power



L&T Finance

Business Lines

BUILDINGS & FACTORIES

COMMERCIAL & RESIDENTIAL

IT, OFFICE SPACES & DATACENTER

- IT & Software Parks
- Office Buildings
- Data Centers
- R&D Centers

RESIDENTIAL

- Elite Housing
- Affordable & Mass Housing

HEALTH

- Hospitals
- Medical Colleges

PUBLIC SPACES & AIRPORTS

AIRPORTS

- Passenger Terminal Buildings
- Cargo Terminals

PUBLIC SPACES

- Convention Centers
- Metro Stations
- Shopping Malls
- Stadiums,
- Museums
- Educational Institutions
- Hotels

FACTORIES

- Light & Heavy Factories
- Cement Plants
- Warehouses

TALLEST Statue in the World

182m

Statue of
Unity

L&T's first **FIFA**
Stadium

ITC's first International Hotel Project

ITC Colombo

230m

Al Rayyan Stadium, Qatar

Large & Tall

IICC, Dwarka

Most Sophisticated Convention Centre in
India

Biggest Cricket Stadium in the world

Motera Stadium,
Gujarat

Design Certified – Landmark Data Center

NPCI Data Center – Chennai- UPTIME INSTITUTE Certified for TIER IV Design



International Airports

Bangalore International Airport (T2)



Salalah International Airport



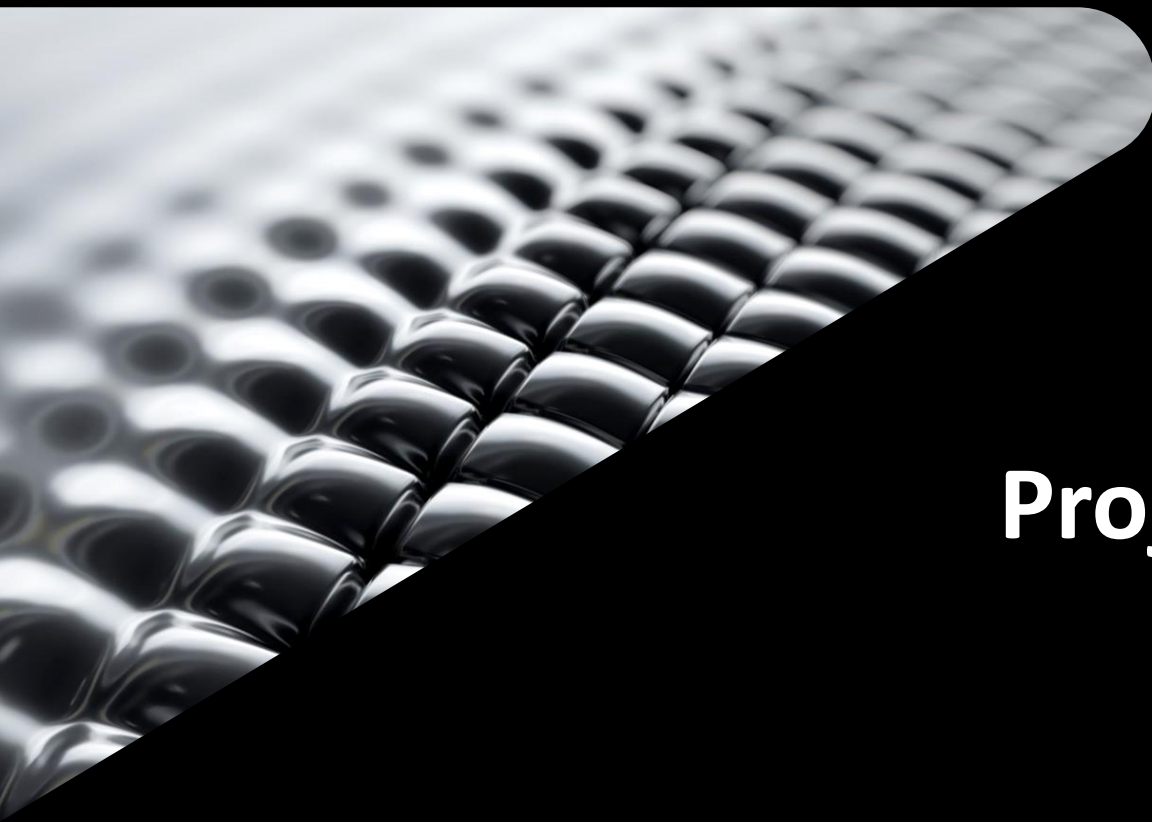
International Airports

Delhi International Airport



Mumbai International Airport



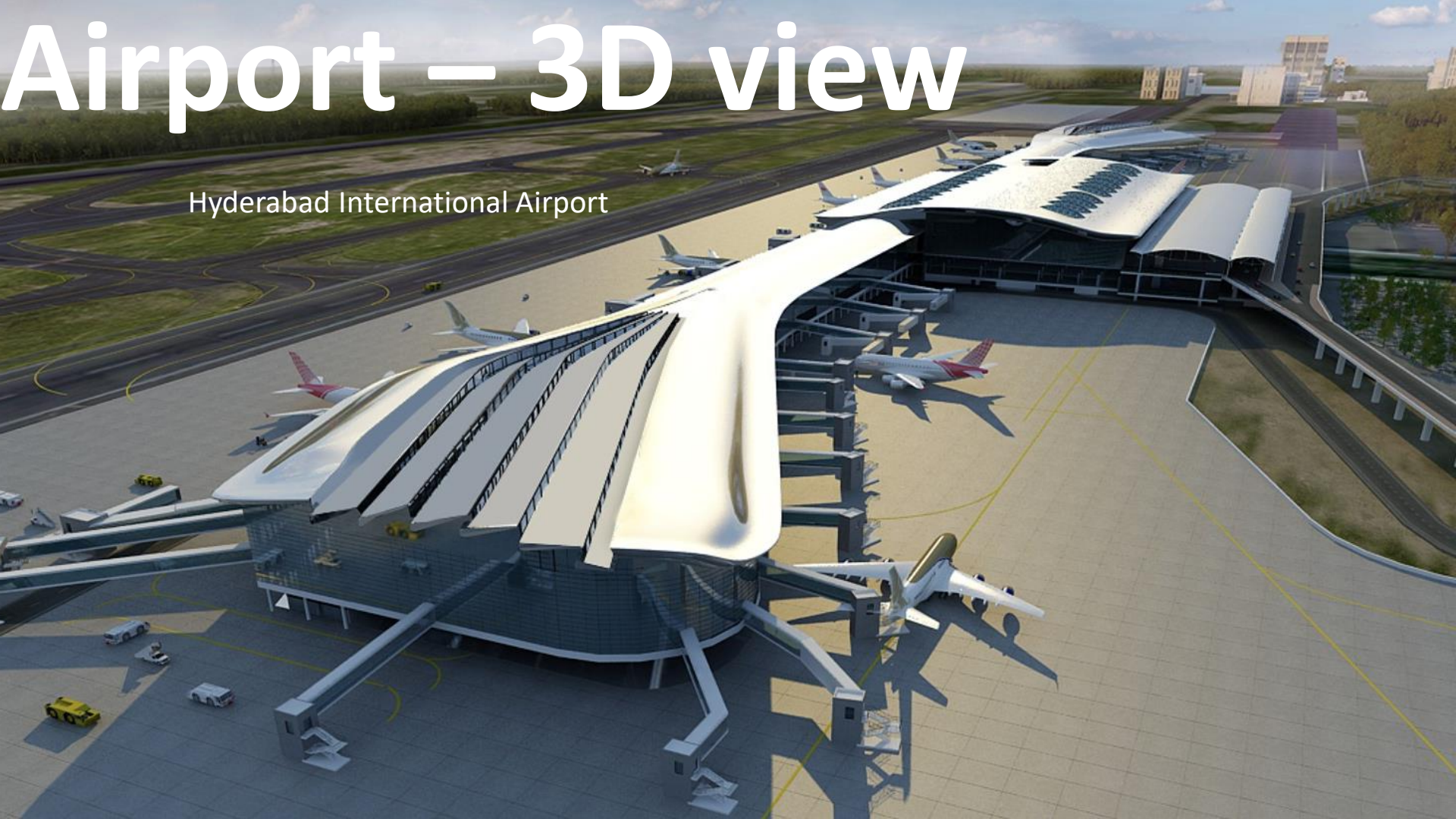


Project Description

International Airport Expansion

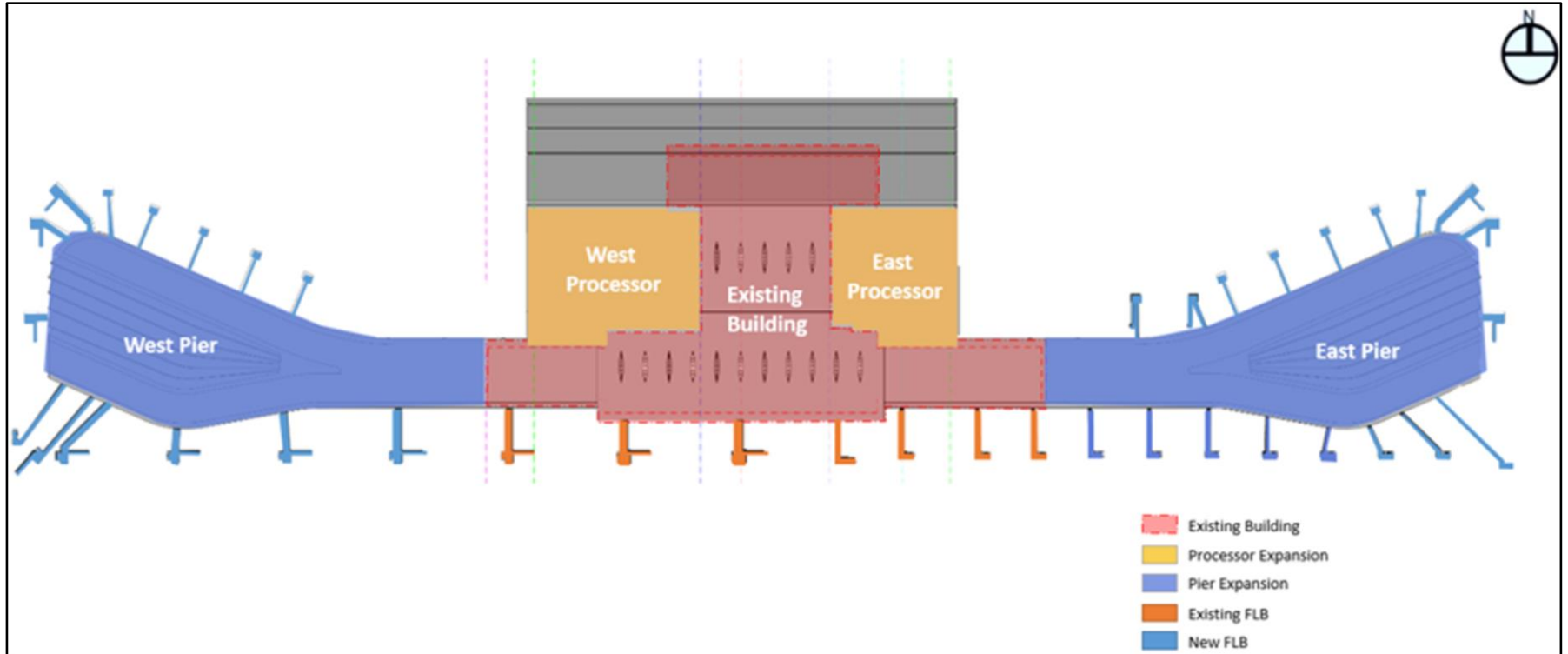
Airport – 3D view

Hyderabad International Airport



Airport expansion

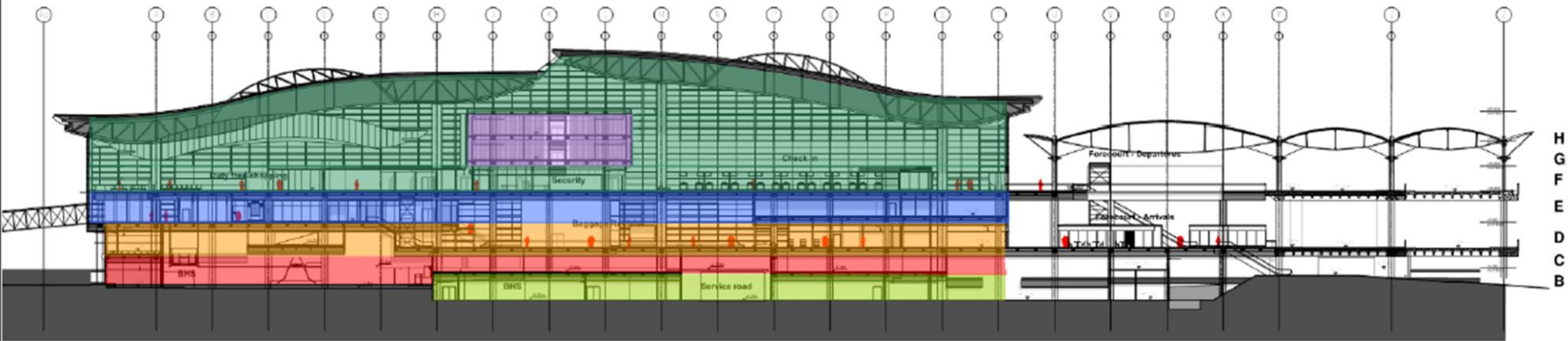
34MPPA from 12 MPPA



Building levels

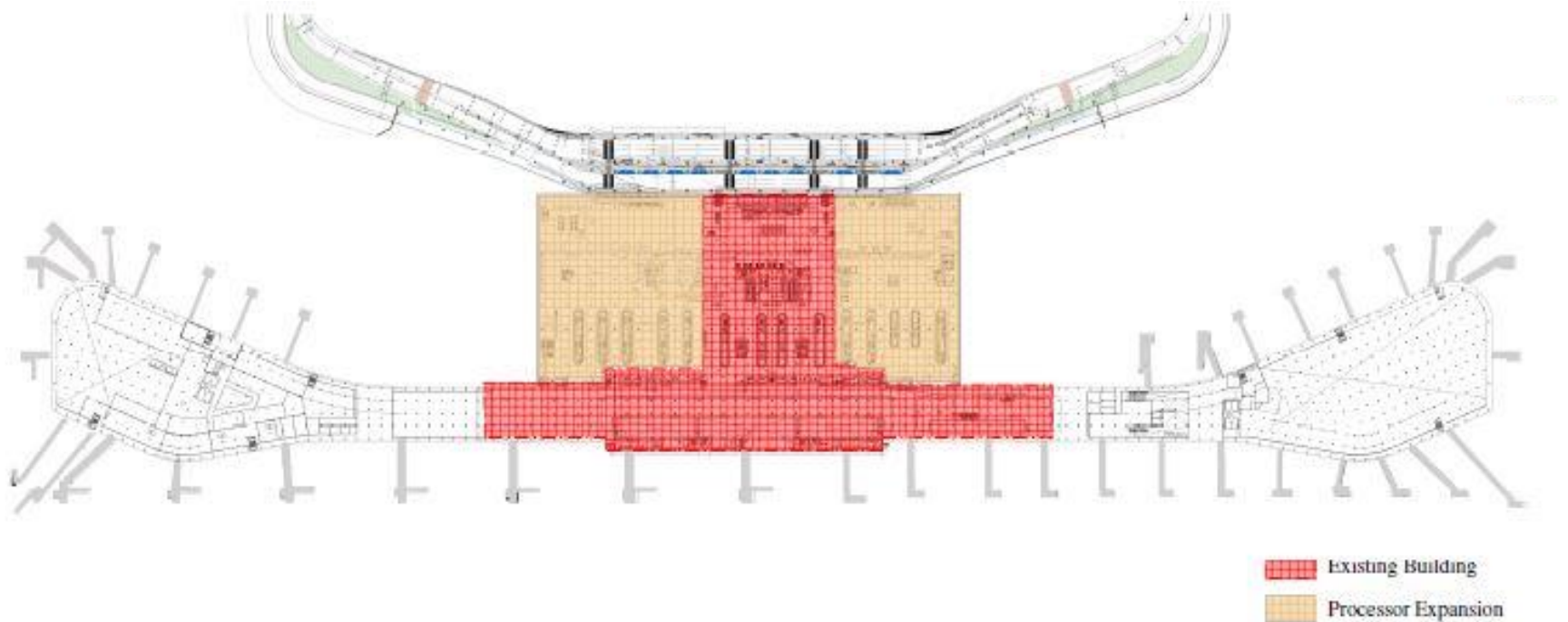
Level B	Staffroom, Plant, Medical rooms and Back of House Storage.
Level C	Ground Services, Plant and Baggage Handling System Bus gates domestic and International departure/arrival Operations Management Office.
Level D	Air Handling Unit Plant, International and domestic baggage claim area, Airport Village.

Level E	International arrivals and immigration concourse, domestic arrivals concourse, retail.
Level F	Check in hall, international and domestic departures concourse, retail.
Level G	Offices(existing–not part of proposed expansion)
Level H	Offices(existing–not part of proposed expansion)



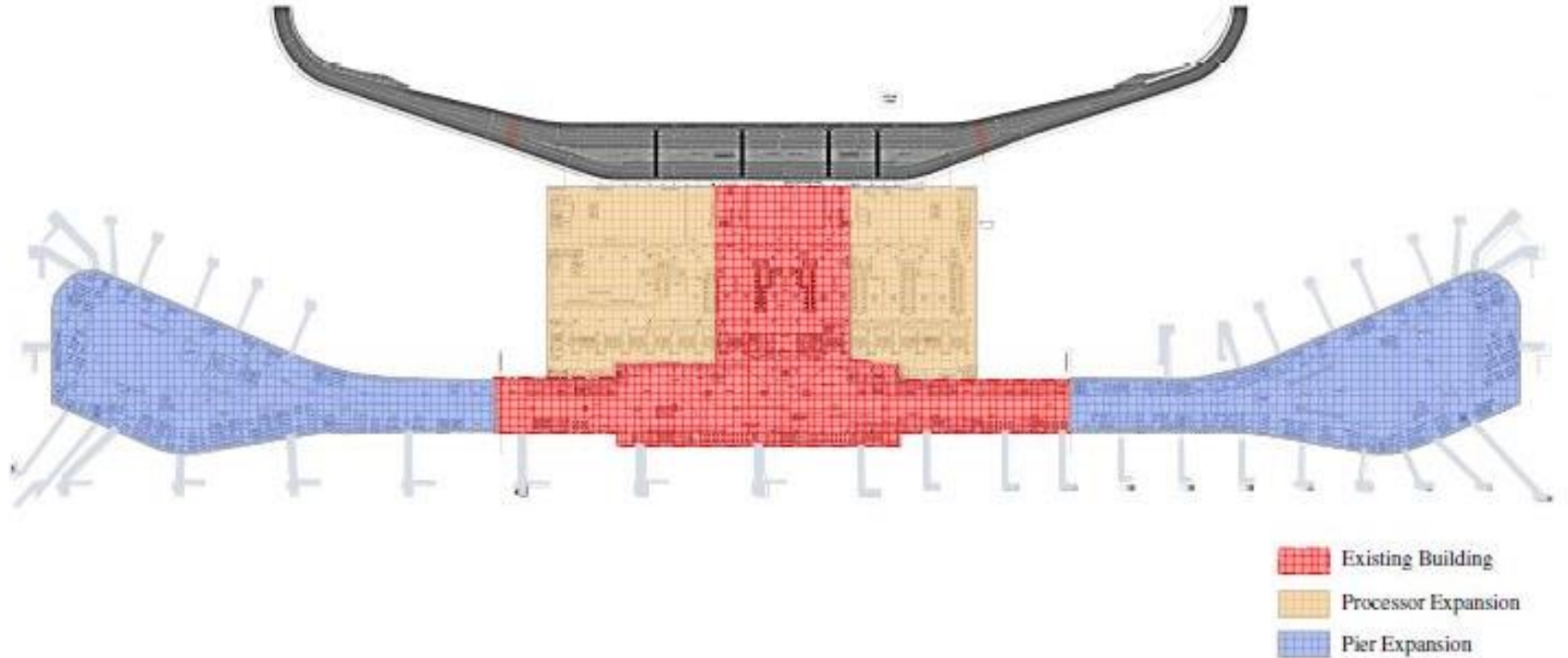
Airport – Arrival –Baggage reclaim expansion-Level D

Built-up area expanded by 21000 sq.m from 9000 sq.m



Airport – Departure–Check-in hall expansion – Level F

Built-up area expanded by 21000sq.m from 9000 sq. m



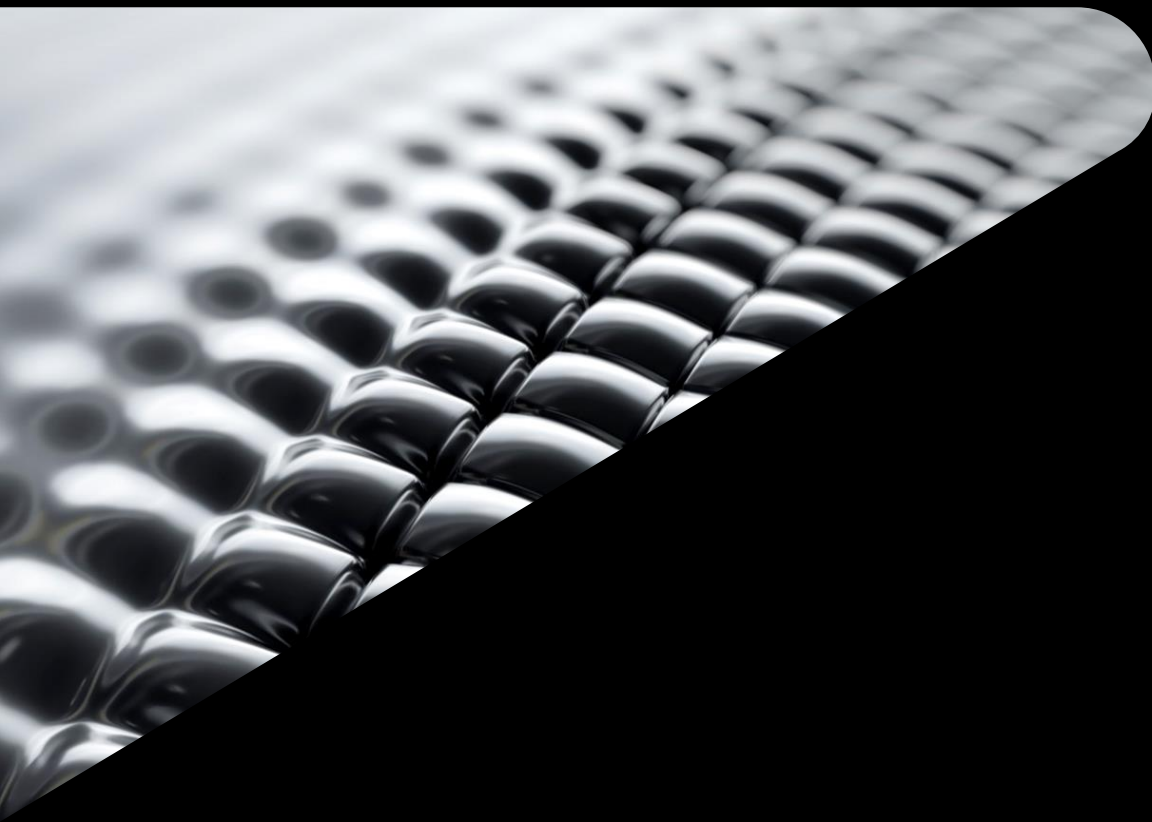
Air-conditioning design basis

- Outdoor design condition:
 - Summer season
 - 41.1 °C DBT
- Indoor design condition:
 - Operating temperature
 - 24±1 °C
- External heat gain :
 - Transmission load (U-values and outdoor temp)
 - solar load
- Internal heat gain: People, equipment and lighting

Air-conditioning system

Chilled water-based system

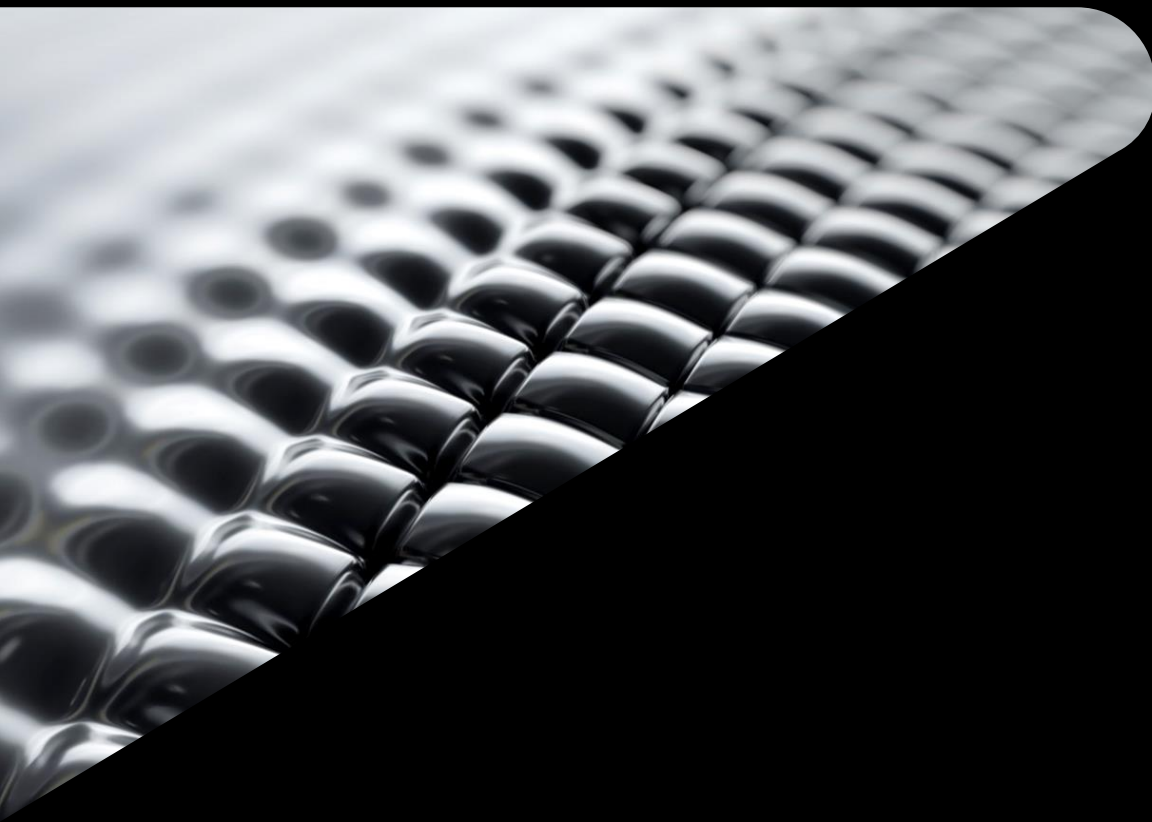
- Centralized chilled water system
 - Chiller plant
 - VFD driven cooling towers
- Air distribution
 - Floor mounted air-handling units
 - Island binnacles
 - Air terminal devices – jet nozzles/drum louvers (drum jet diffusers) /slot diffusers



Key Objectives

Key Learning Objectives

- Simulation best practices in Autodesk CFD
- Modelling strategies
- CFD results
- Opportunities for design optimization



Best Practices

AEC Simulation

Component characterization

Complex features simplified through characterization

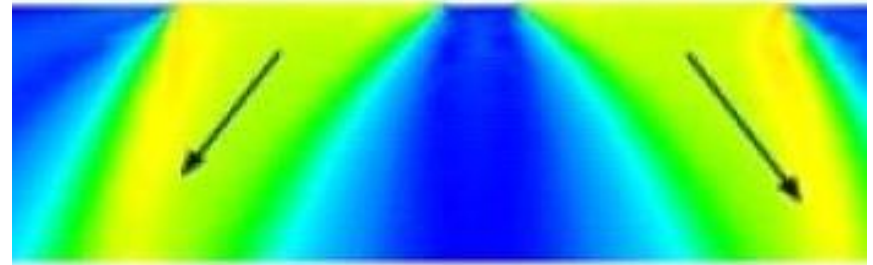
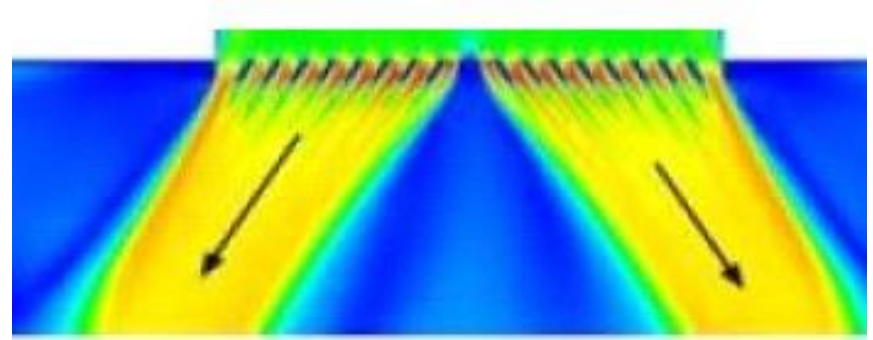
- People
- Slot diffusers/ drum louvers

Important considerations are:

- Insight into physics of the problem
- Manufacturing specifications of the component
- Less detail without losing impact of the component on flow pattern and heat transfer

Component characterization

Diffusers (Image credit: Microgenesis)

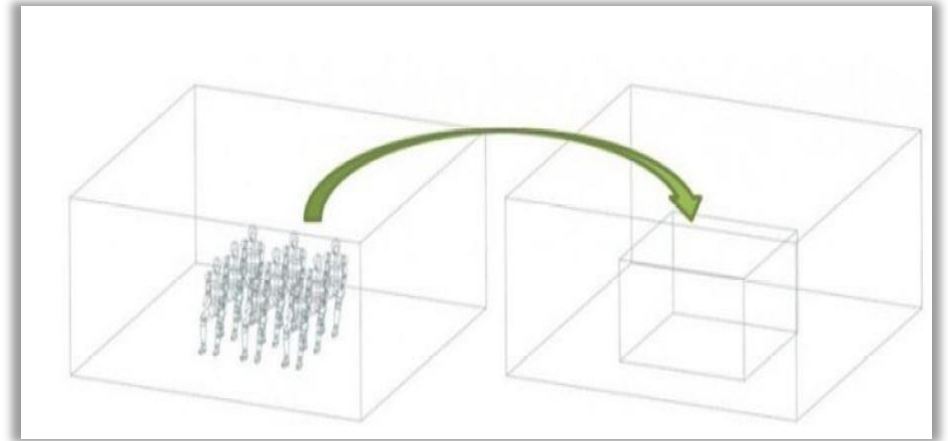


Component characterization

People (Image credit: Microgenesis)

Human occupancy is modeled as :

- Air volume with height of 1.8m from floor
- Air volume assigned heat generated by occupants



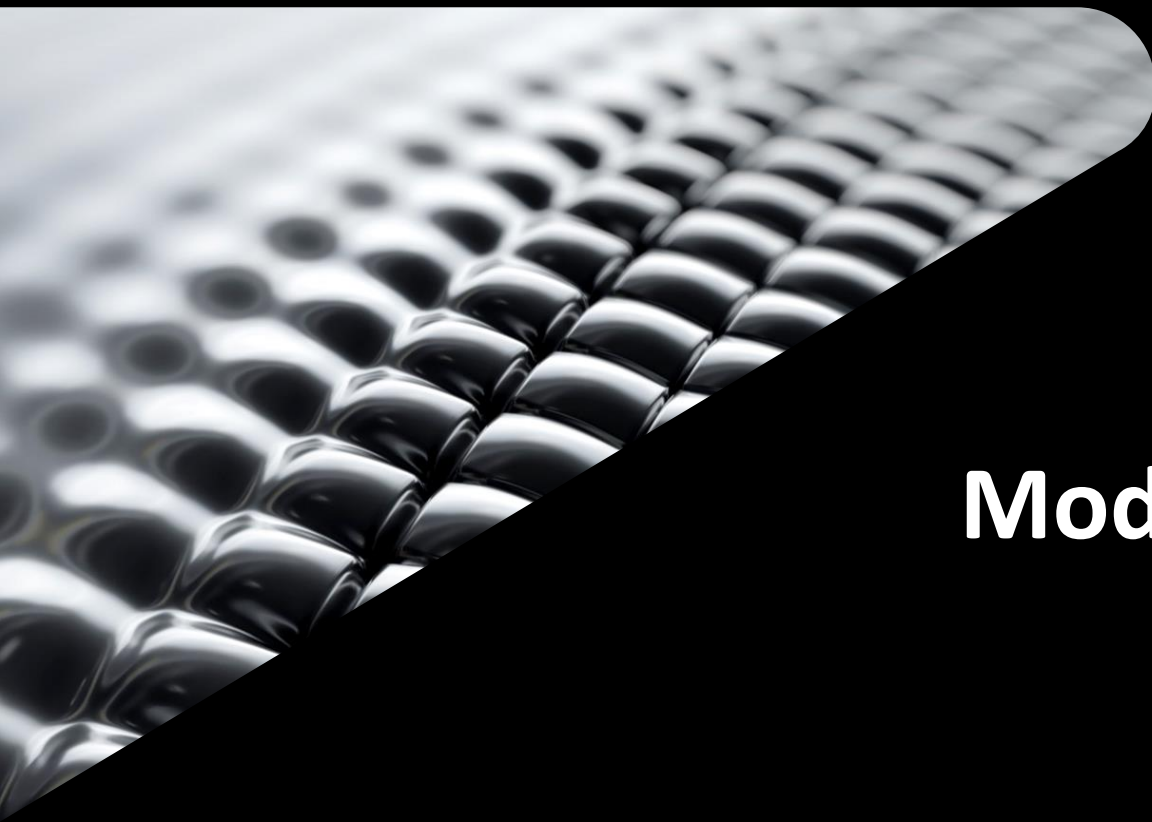
Appropriate Physics

Mixed Convection

- Initially forced convection with “fixed” properties
- Local temperature gradients can lead to appreciable buoyancy effects
- Use “variable” air properties with gravity enabled to account for buoyancy

In this project, mixed convection approach is used to account for buoyancy in check-in hall/ departure hall of airport.

<https://help.autodesk.com/view/SCDSE/2014/ENU/?guid=GUID-7BBB1E45-4469-4F90-8ED7-7756B04CEA80>



Modeling Strategies

Airflow and heat transfer

Modeling strategies for airflow and heat transfer

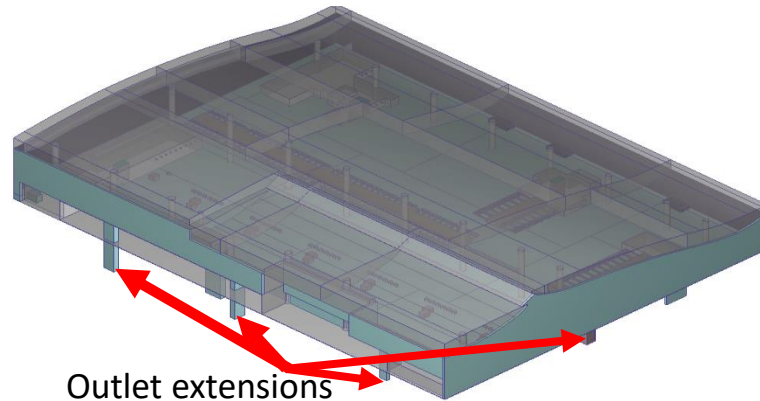
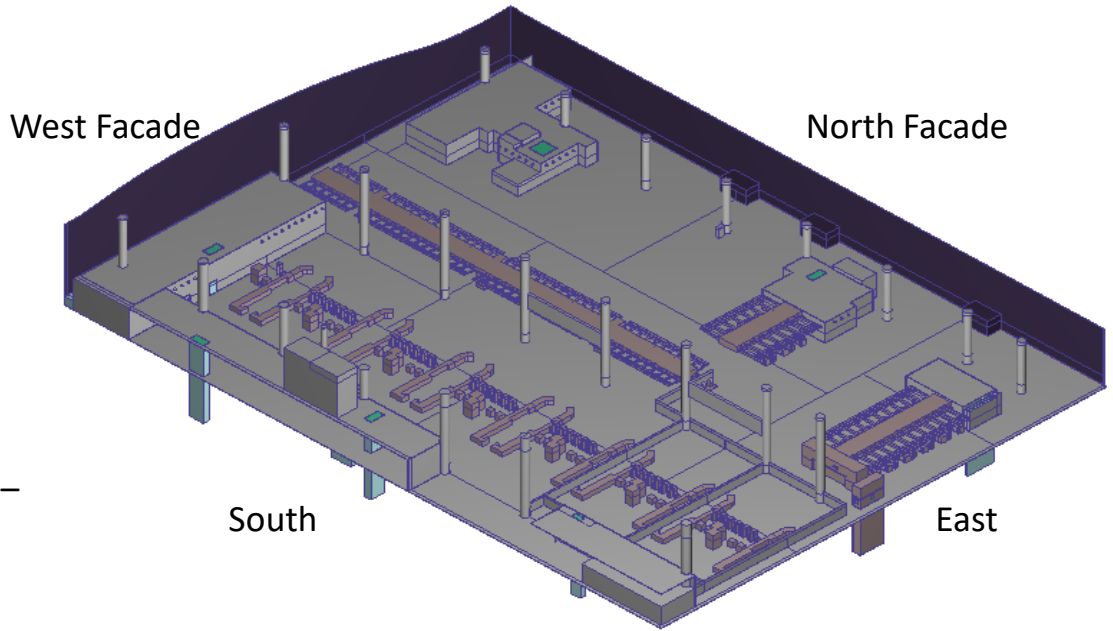
- CAD/CFD model, component characterization
- Materials, boundary conditions
- Meshing
- Solver settings

CAD model

Check-in hall

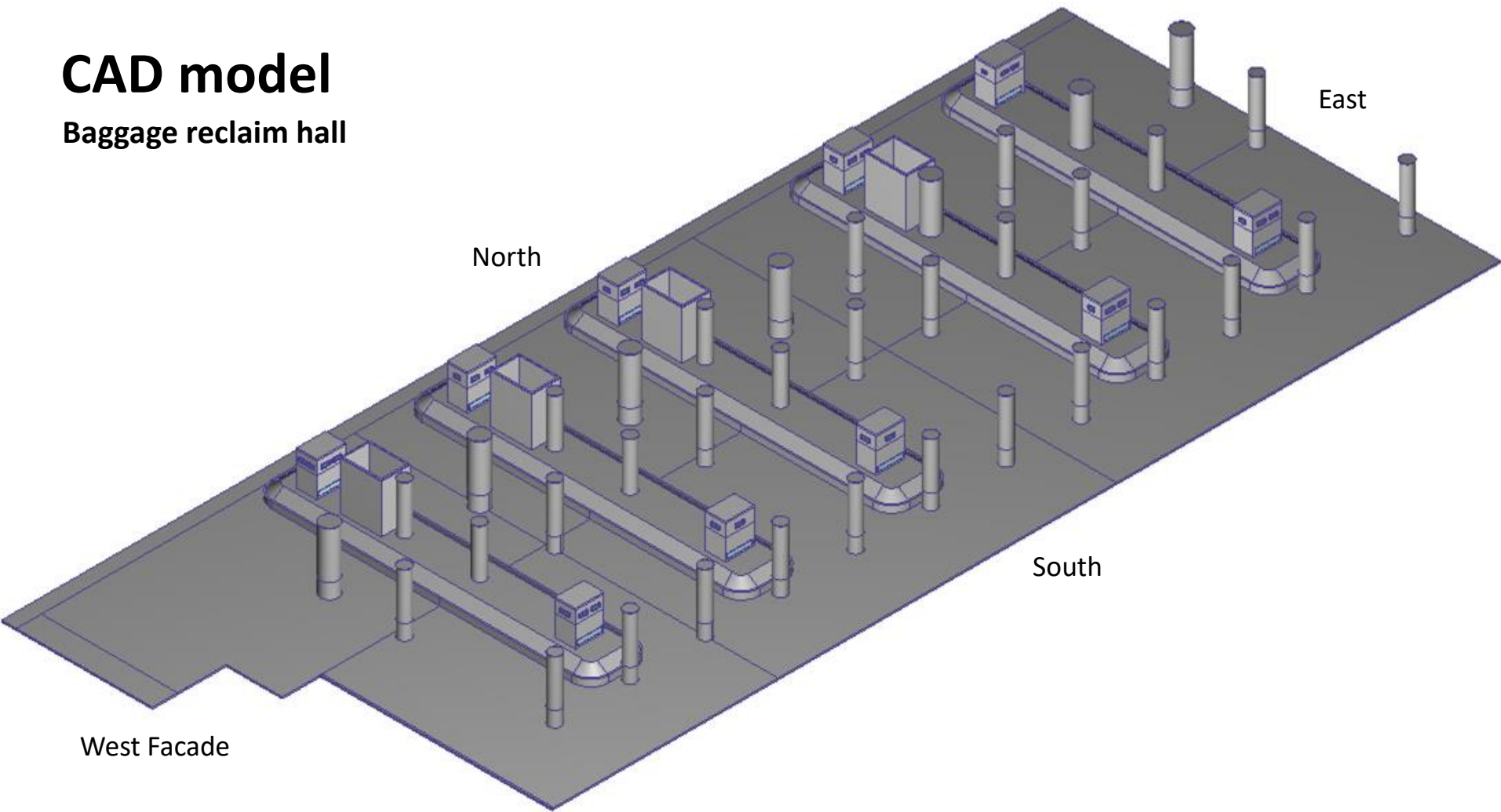
Create CAD model in Revit

- Simplify geometrical details
(include major arch layout and interior –
check-in counters, service counters,
rooms, walls, floor, roof etc.)
- Add inlet and outlet extensions

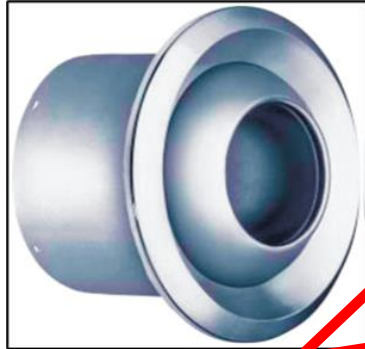


CAD model

Baggage reclaim hall

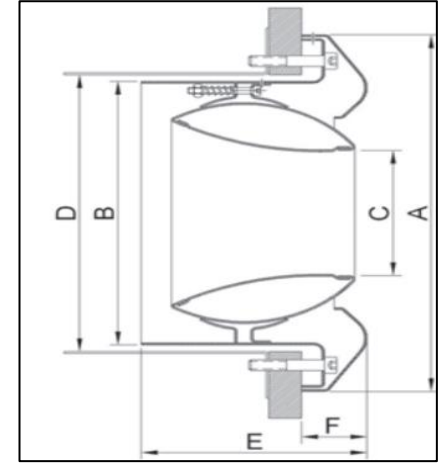


CAD model- Diffusers (Jet/Slot)



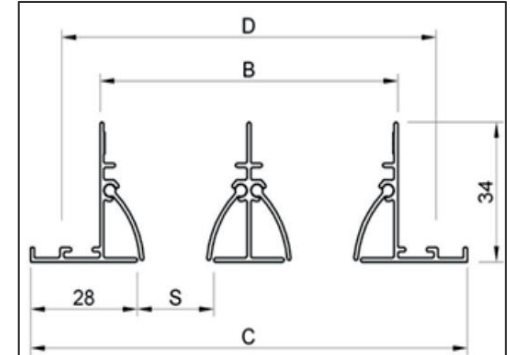
Jet Diffusers

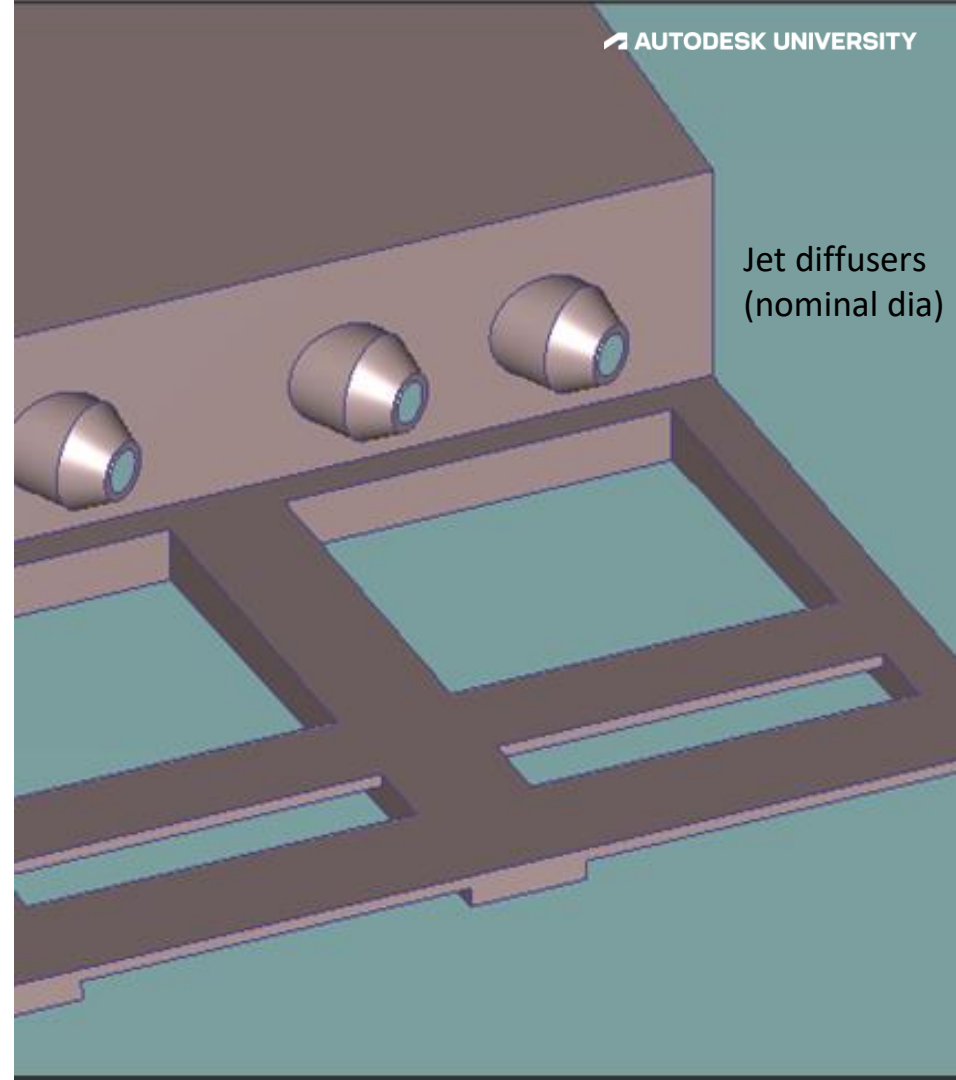
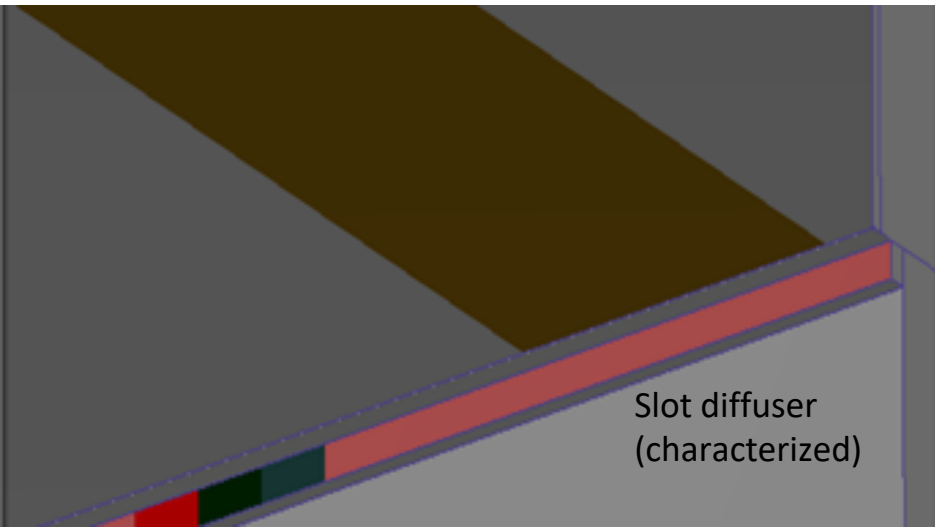
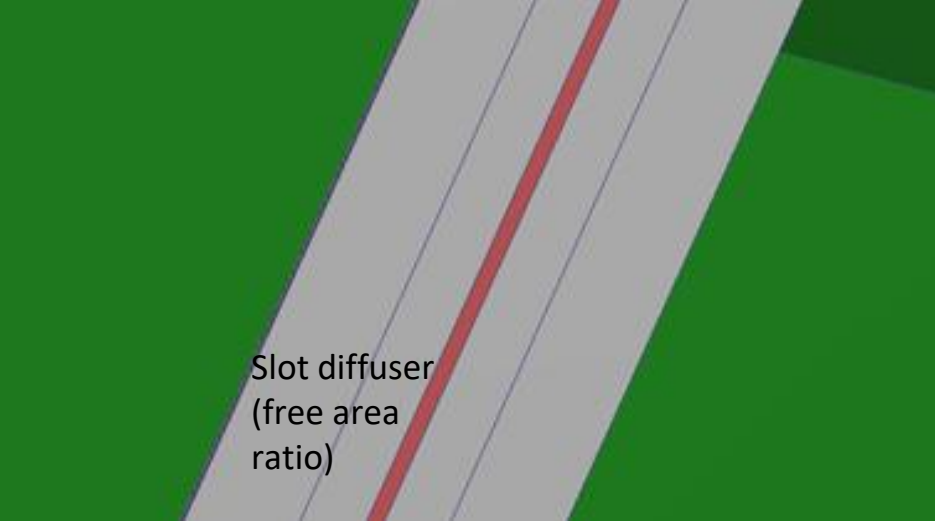
DIMENSION DETAIL						
NOM	A	B	C	D	E	F
200	268	198	94	208	138	40
280	345	275	132	283	140	40
320	395	318	160	328	190	42
400	468	397	224	407	224	46



Slot Diffusers

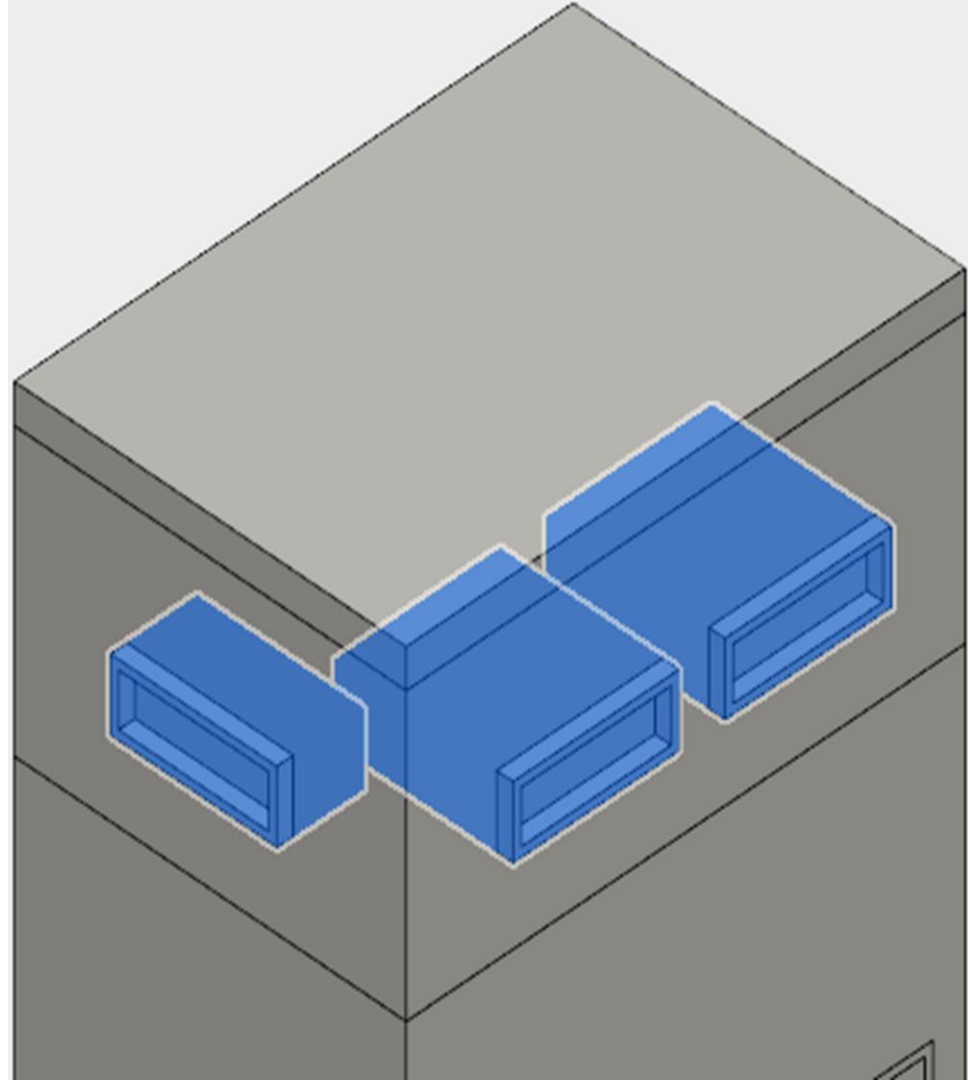
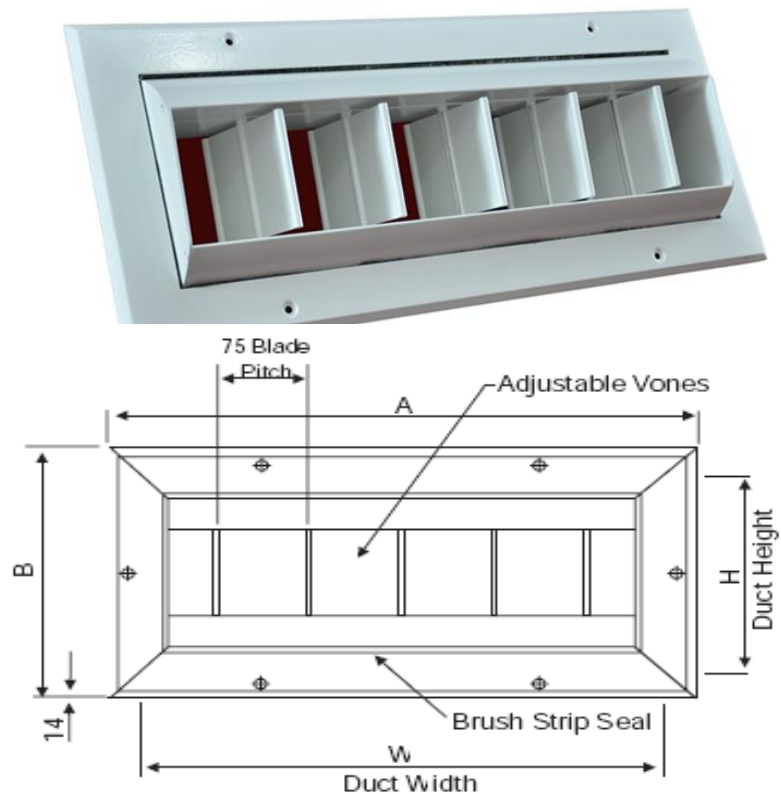
No. of Slots	B	C	D
1	40	76	56
2	48	115	94
3	117	153	133
4	155	192	171
5	194	230	210
6	232	269	248
7	271	307	287
8	309	346	325



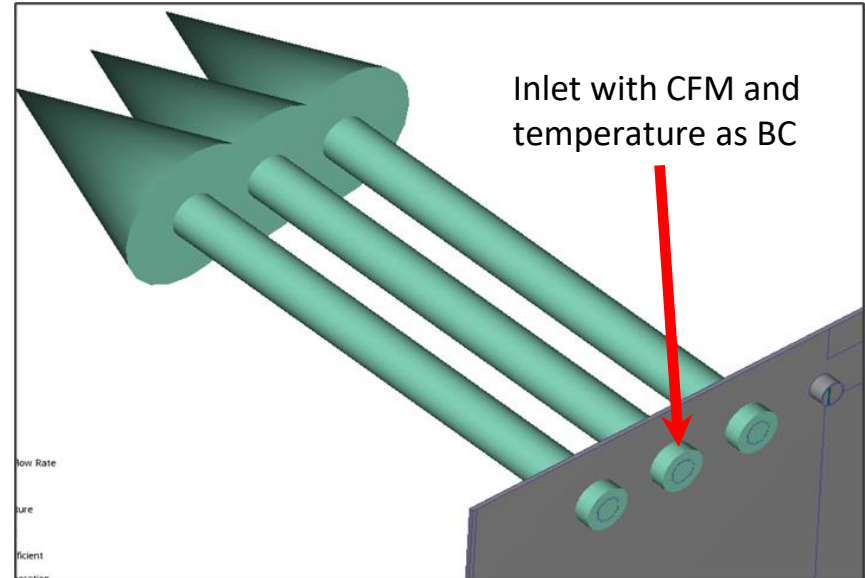
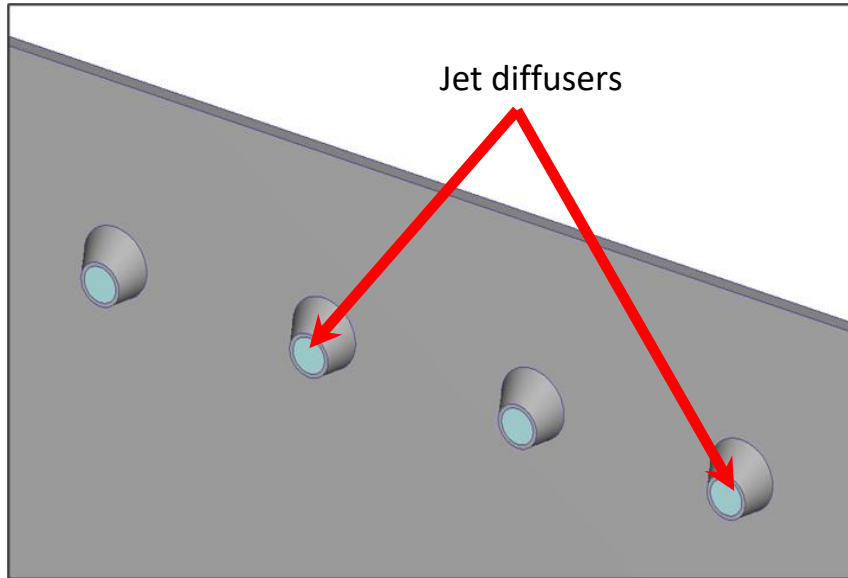


CAD model- Diffusers

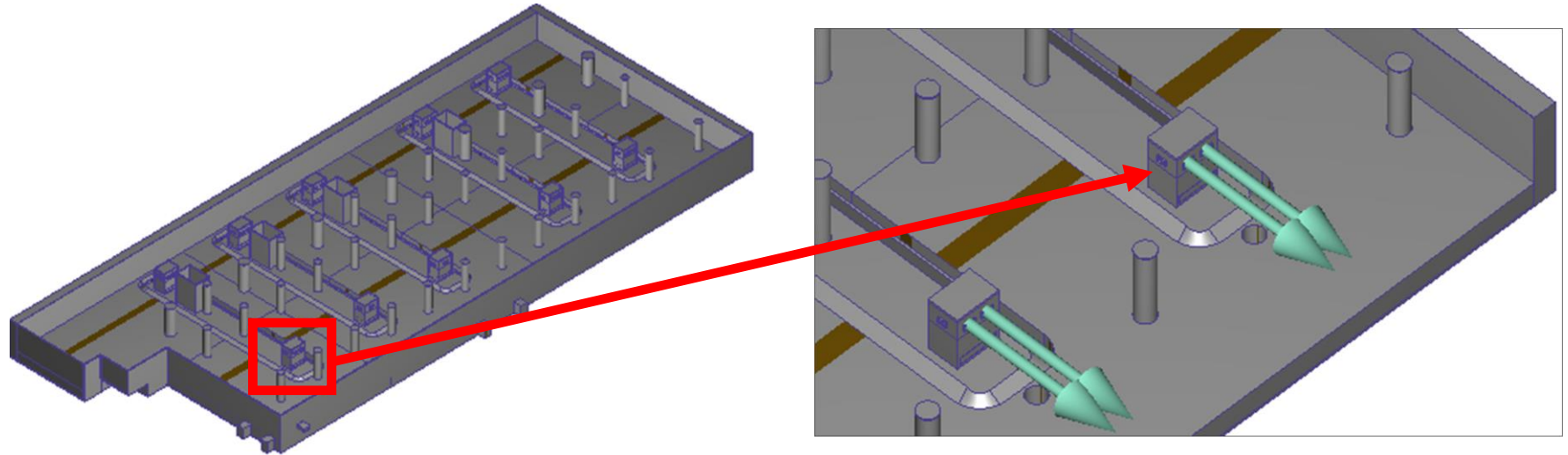
Drum Louvers



CFD model – Diffusers (Jet)



CFD model – Diffusers (Drum louvers)



Fluid volume assigned air material

Air properties - fixed

Material Environment

☒ Fixed ☐ Variable

☒ Use scenario environment

Properties for Air (fixed)
Environment: 101325 Pa, 19.85 Celsius (from scenario)

Property	Value	Units	Underlying variation
Density	1.20473e-06	g/mm3	Equation of State
Viscosity	1.817e-05	Pa-s	Constant
Conductivity	2.563e-05	W/mm-K	Constant
Specific heat	1.004	J/g-K	Constant
Cp/Cv	1.4	none	Constant
Emissivity	1	none	Constant
Wall roughness	0	millimeter	Constant
Phase	0		Vapor Pressure

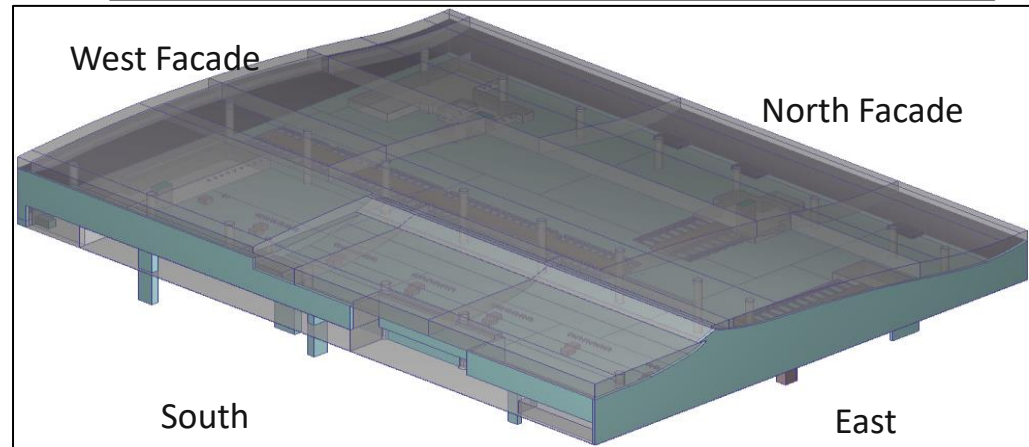
OK Cancel

Materials

Property settings

Material	Edit...
Material DB Name	Default
Type	Fluid
Name	Air
Environment	Set...

Apply Remove Cancel



Fluid volume assigned air material

Air properties - variable

Material Environment

☐ Fixed ☒ Variable

☒ Use scenario environment

Properties for Air (variable)
Environment: 101325 Pa, 19.85 Celsius (from scenario)

Property	Value	Units	Underlying variation
Density	1.20473e-06	g/mm3	Equation of State
Viscosity	1.817e-05	Pa-s	Constant
Conductivity	2.563e-05	W/mm-K	Constant
Specific heat	1.004	J/g-K	Constant
Cp/Cv	1.4	none	Constant
Emissivity	1	none	Constant
Wall roughness	0	millimeter	Constant
Phase	0		Vapor Pressure

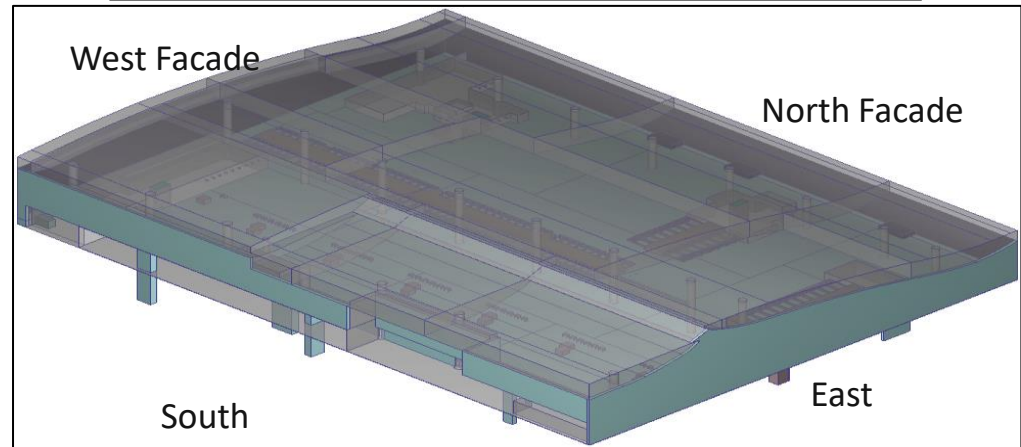
OK **Cancel**

Materials

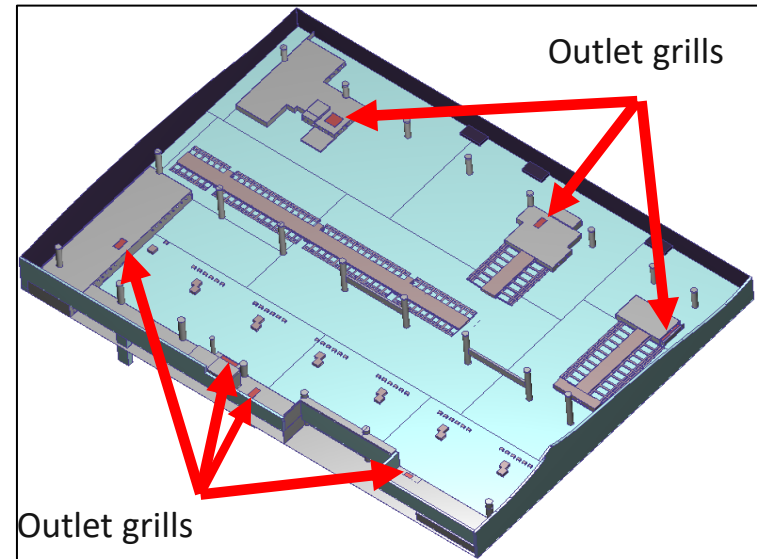
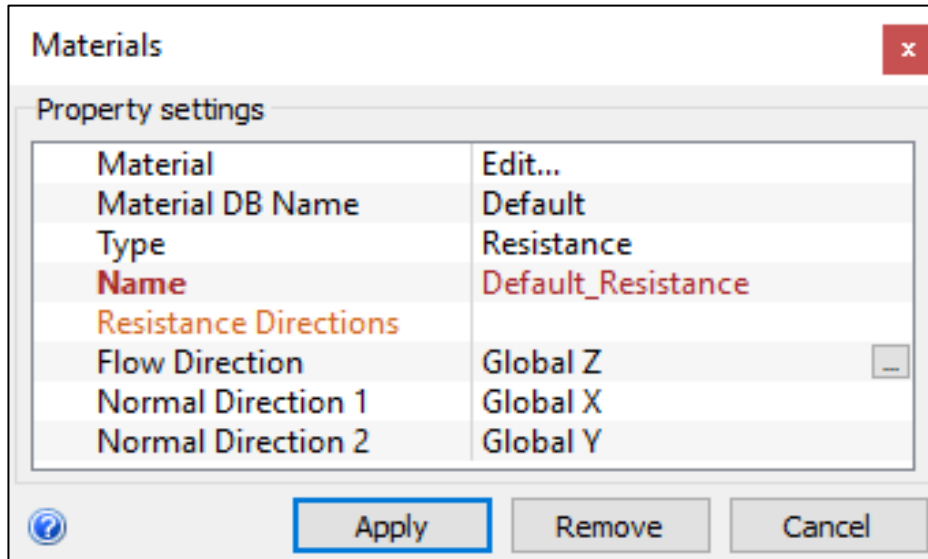
Property settings

Material	Edit...
Material DB Name	Default
Type	Fluid
Name	Air
Environment	Set...

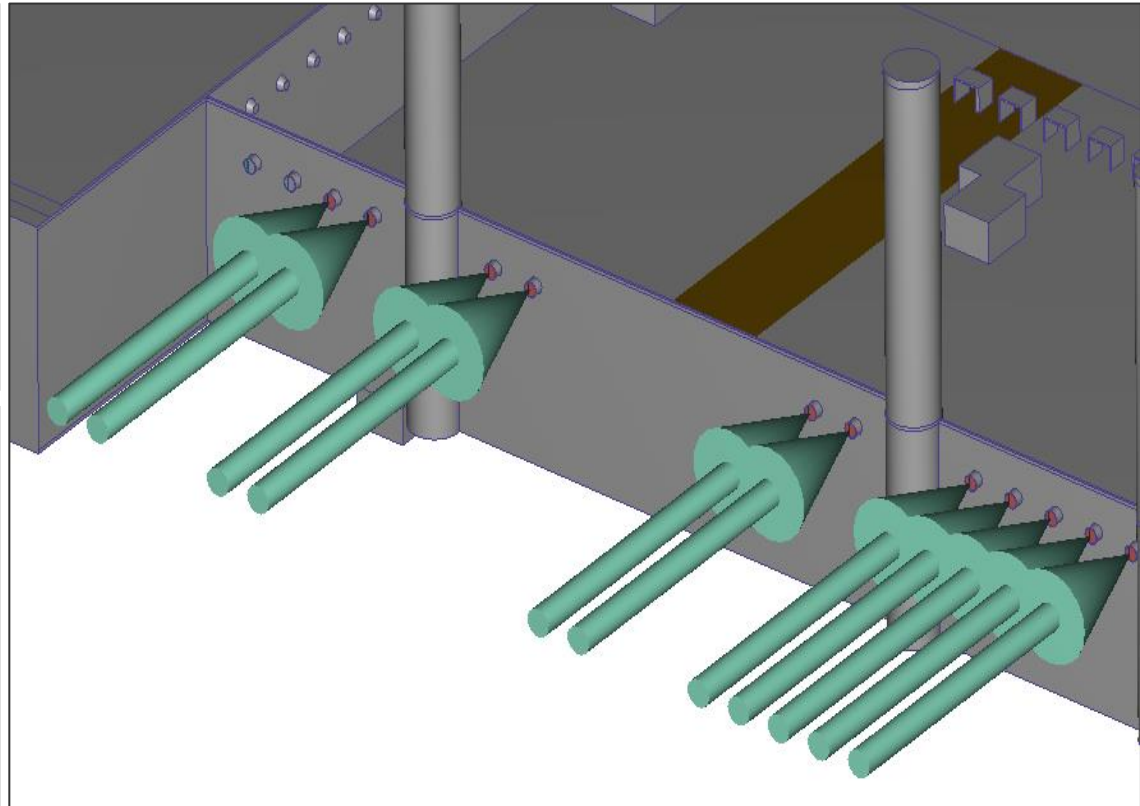
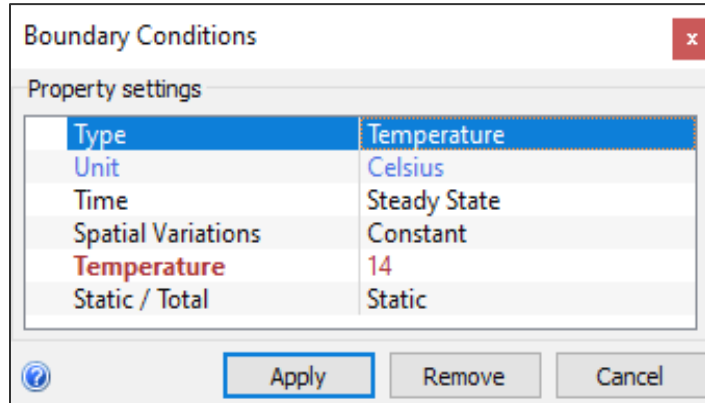
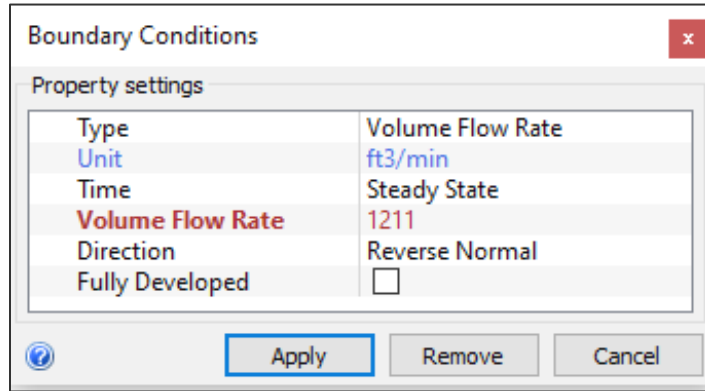
Apply **Remove** **Cancel**



Outlet grill material



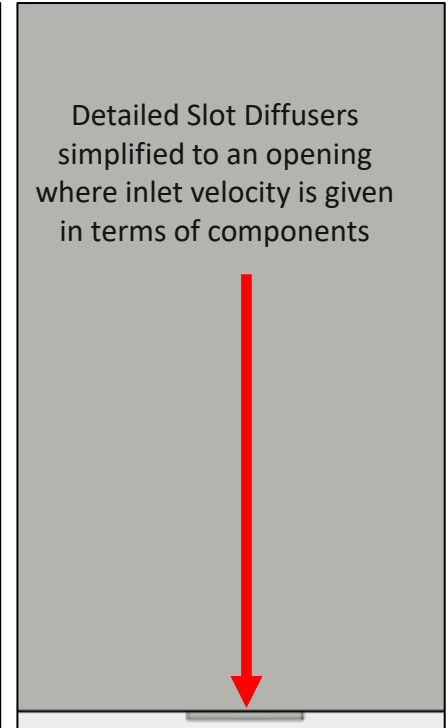
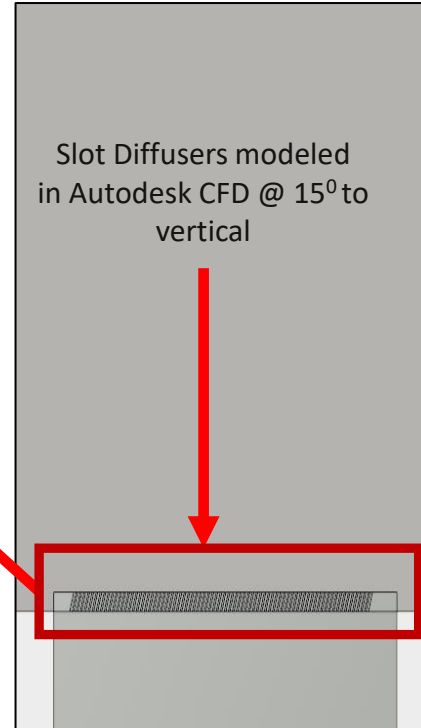
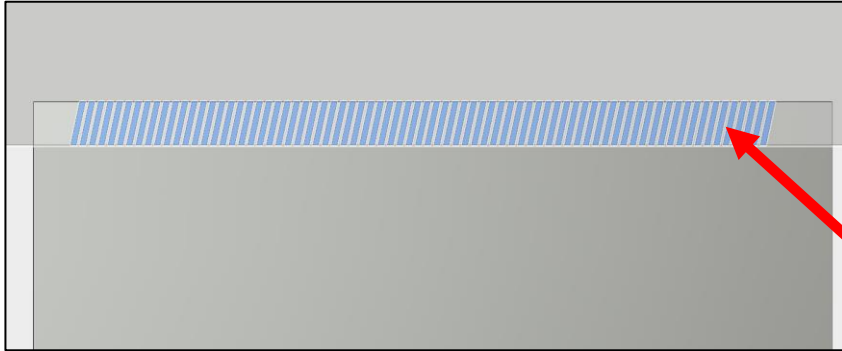
Inlet jet diffusers – Baseline design



Inlet slot diffusers - Characterization

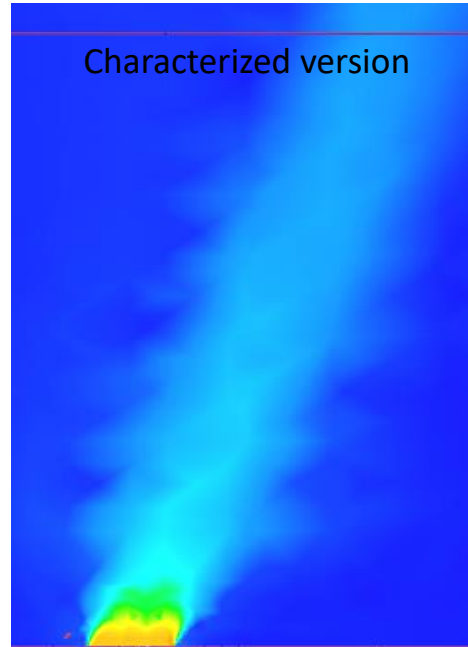
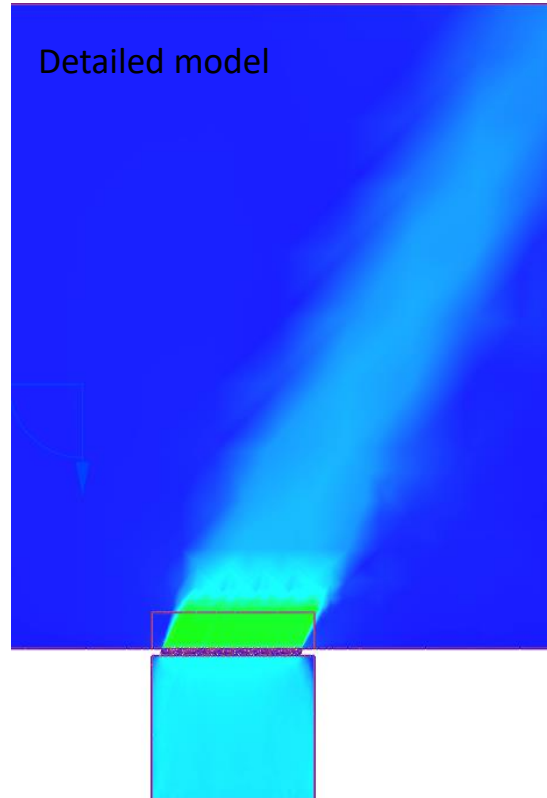
Based on the diffuser performance specifications availability, hand calculations can be used to capture the component velocities given some of the following information:

- Angle of flow leaving diffuser
- Incoming flow rate
- Area that the flow will be coming from



Inlet slot diffusers— Velocity results comparison

Detailed model vs characterized version



Boundary Conditions

Property settings

Type	Velocity
Unit	m/s
Time	Steady State
Method	Component
Vx Enabled	☒
Magnitude	0.66
Vy Enabled	☒
Magnitude	2.454
Vz Enabled	☐

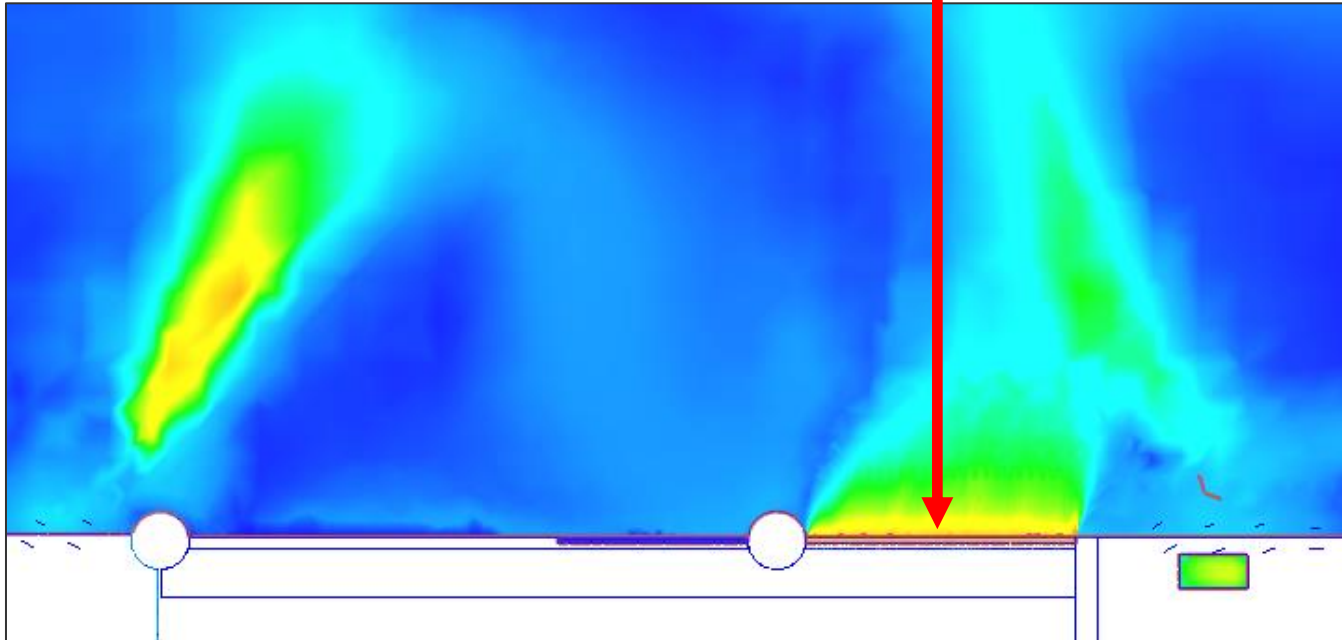
Apply Remove Cancel

Inlet slot diffusers— Use of characterization

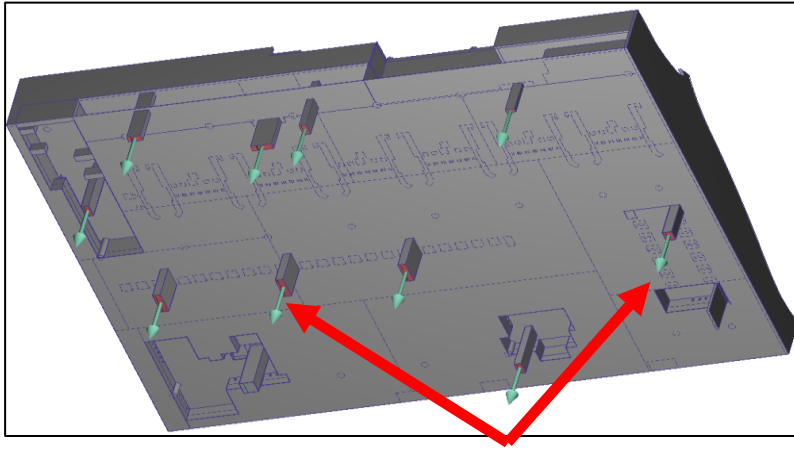
Inlet velocity converted to components based on diffuser angle to get required flow direction and CFM

$$V_x = 0.66 \text{ m/s}$$

$$V_y = 2.454 \text{ m/s}$$



Outlets

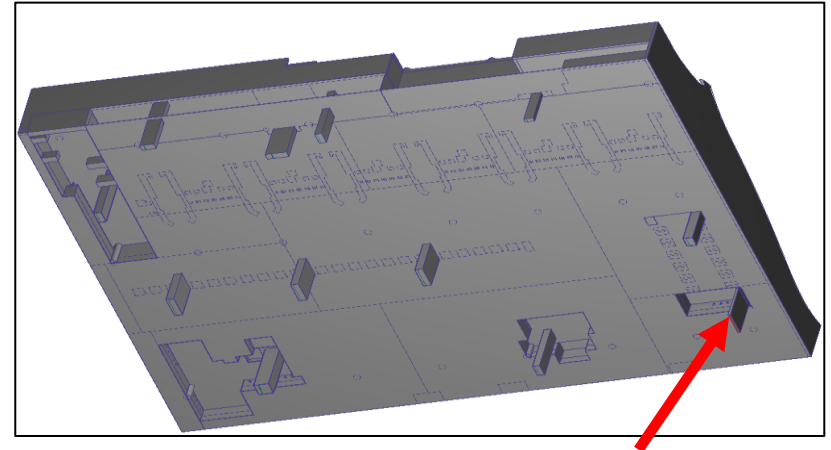


Boundary Conditions

Property settings

Type	Volume Flow Rate
Unit	ft ³ /min
Time	Steady State
Volume Flow Rate	10602
Direction	Reverse Normal
Fully Developed	☐

Apply Remove Cancel



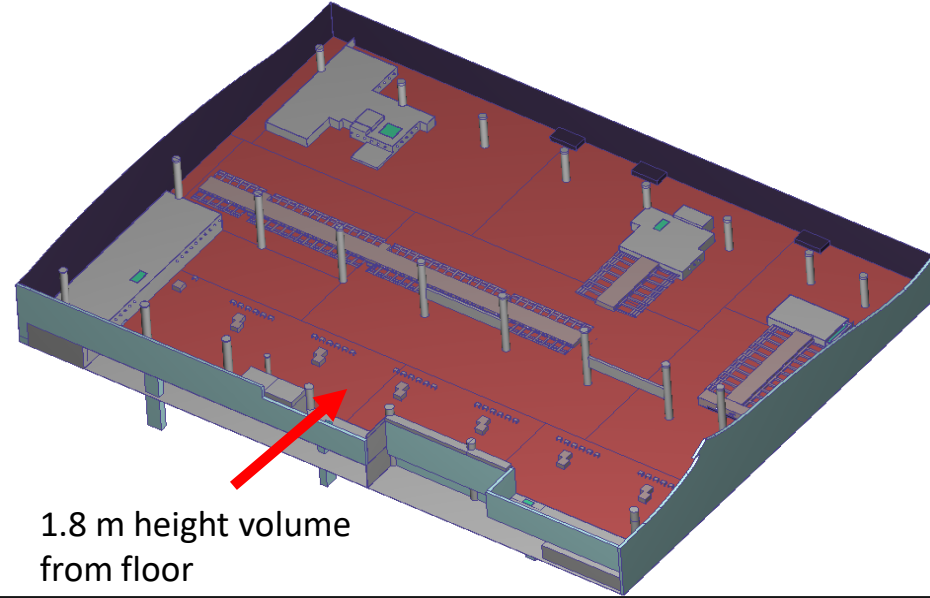
Boundary Conditions

Property settings

Type	Pressure
Unit	Pa
Time	Steady State
Pressure	0
Gage / Absolute	Gage
Static / Total	Static

Apply Remove Cancel

Solar, equipment and occupancy

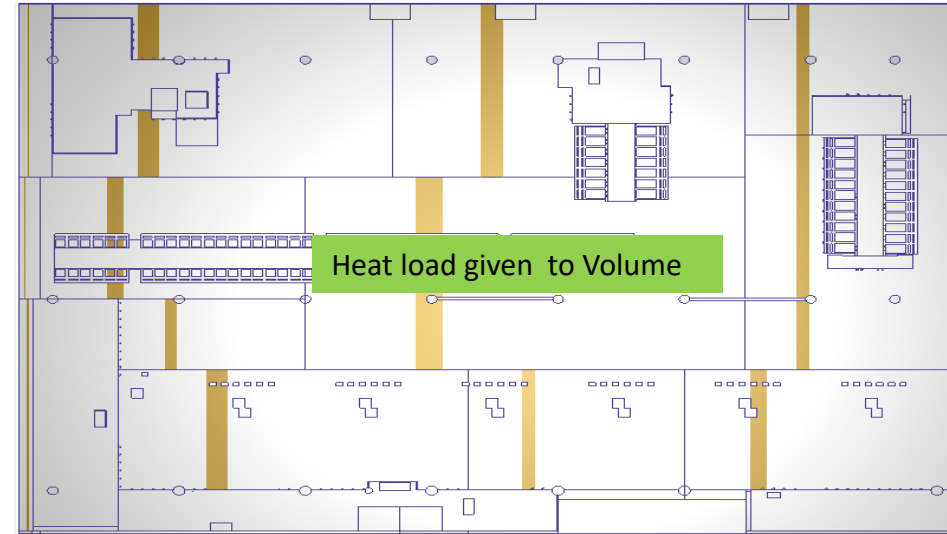


Boundary Conditions

Property settings

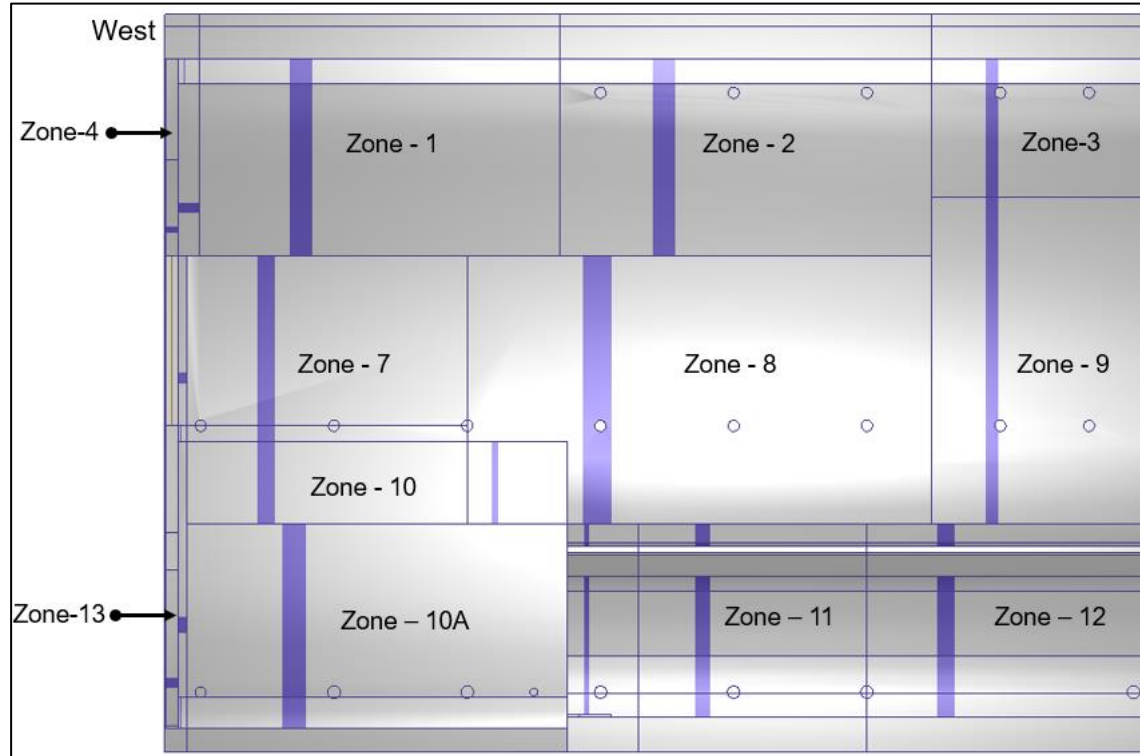
Type	Total Heat Generation
Unit	W
Time	Steady State
Temperature Dependent	Disabled
Total Heat Generation	34767.1

Apply Remove Cancel



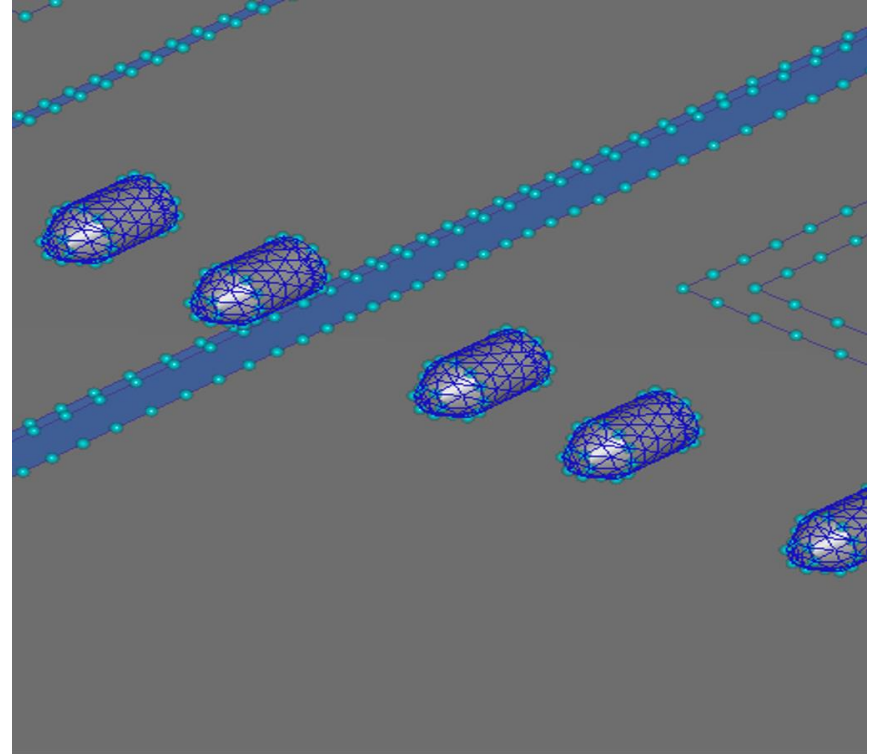
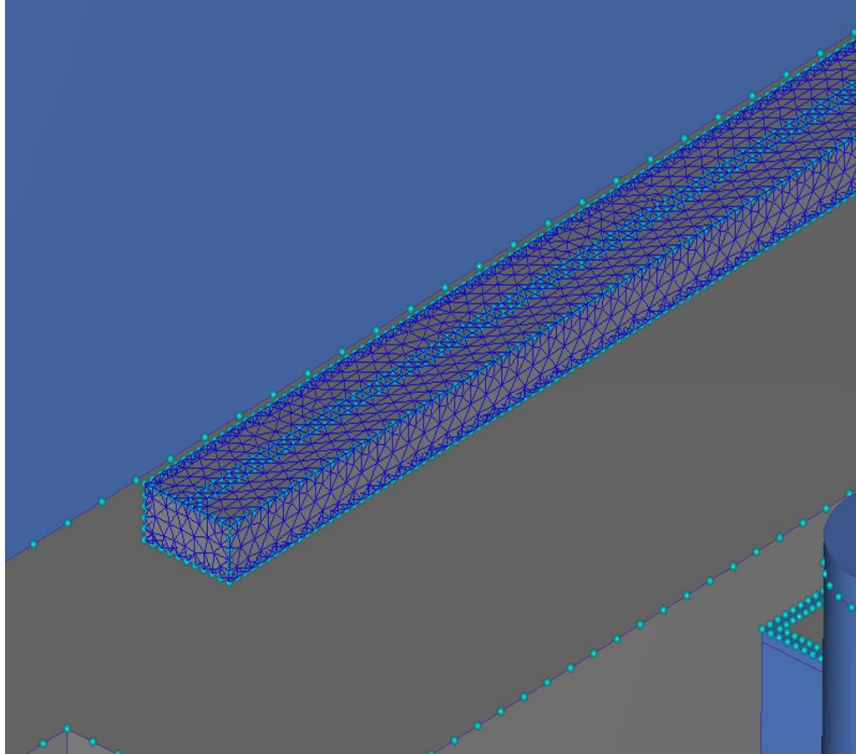
Lighting load

Applied on bottom of ceiling



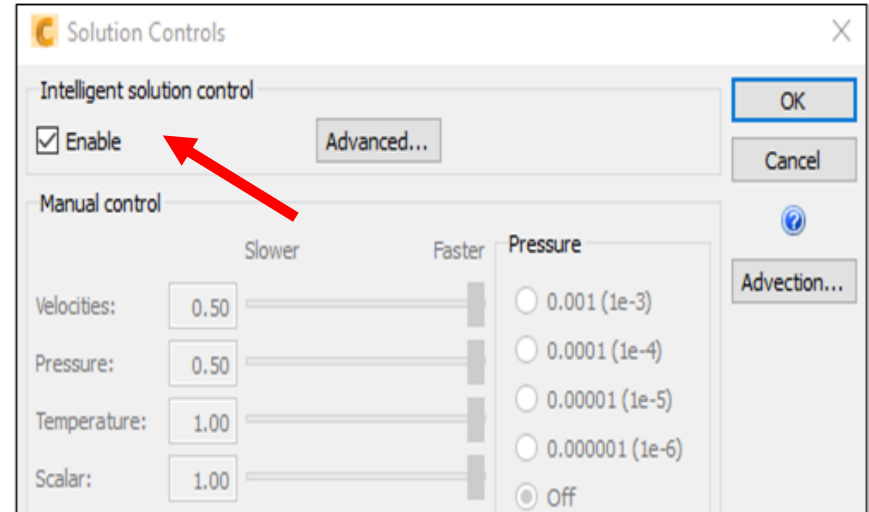
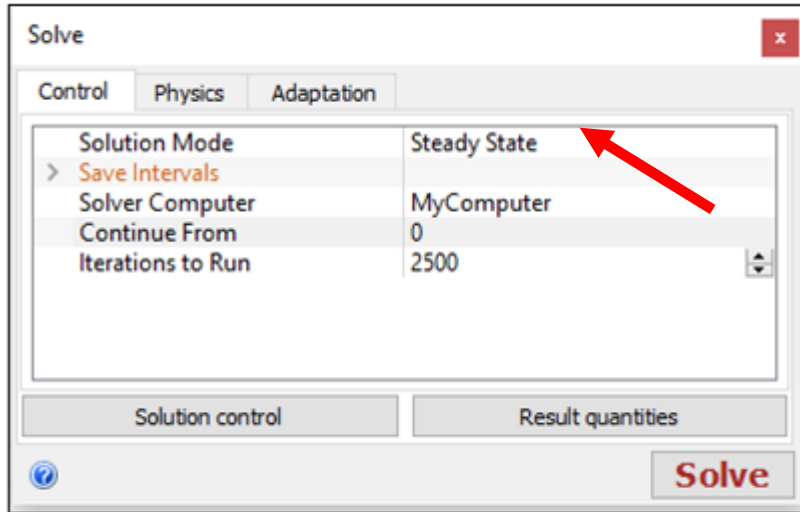
Meshing

Uniform mesh at inlets and fine mesh at jet diffuser inlets



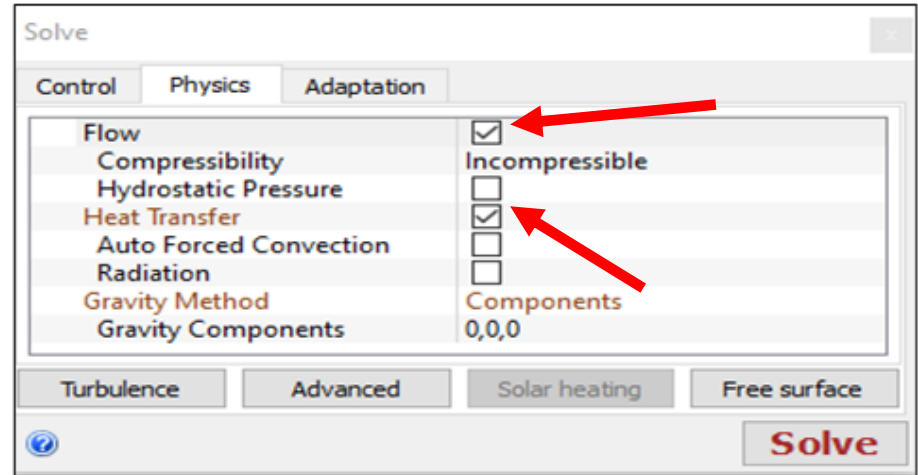
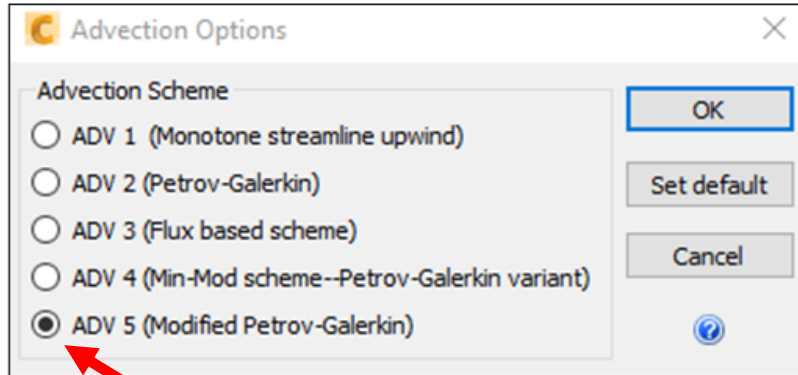
Solver settings— Flow and heat transfer

Air properties – fixed, ISC- on



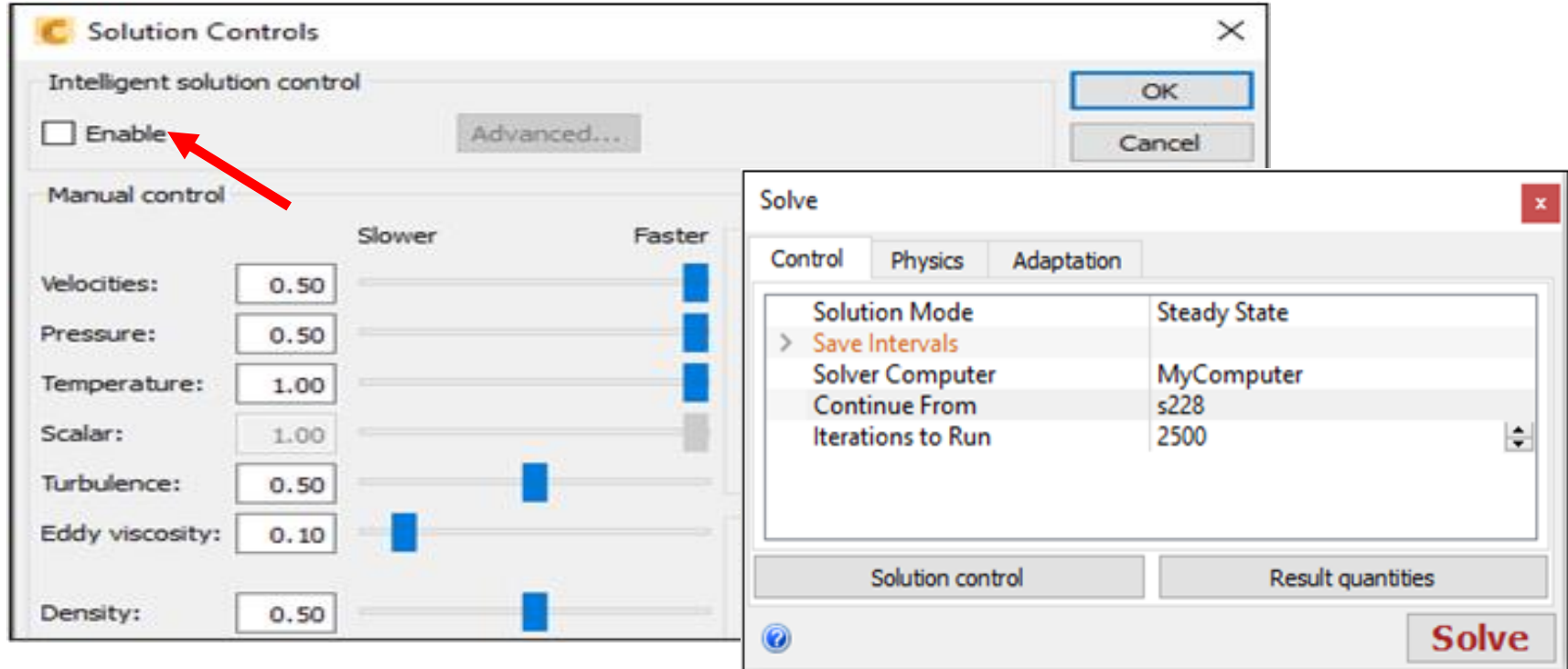
Solver settings— Flow and heat transfer

Advection - 5



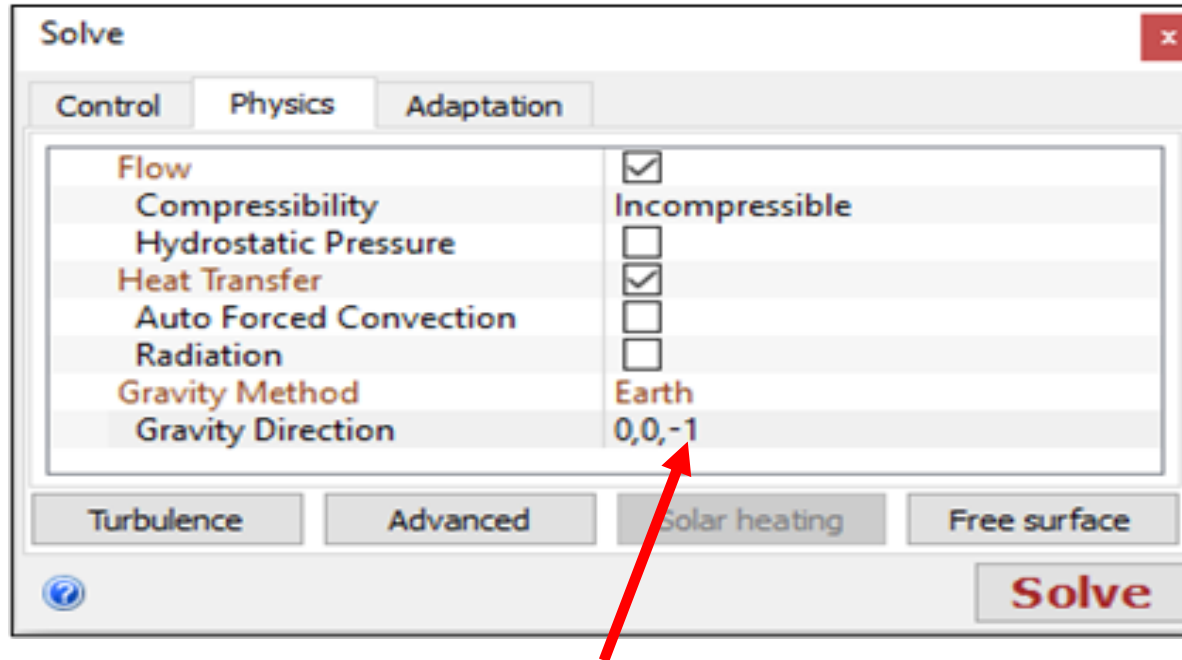
Solver settings— Flow and heat transfer

Air properties – variable, ISC - Off

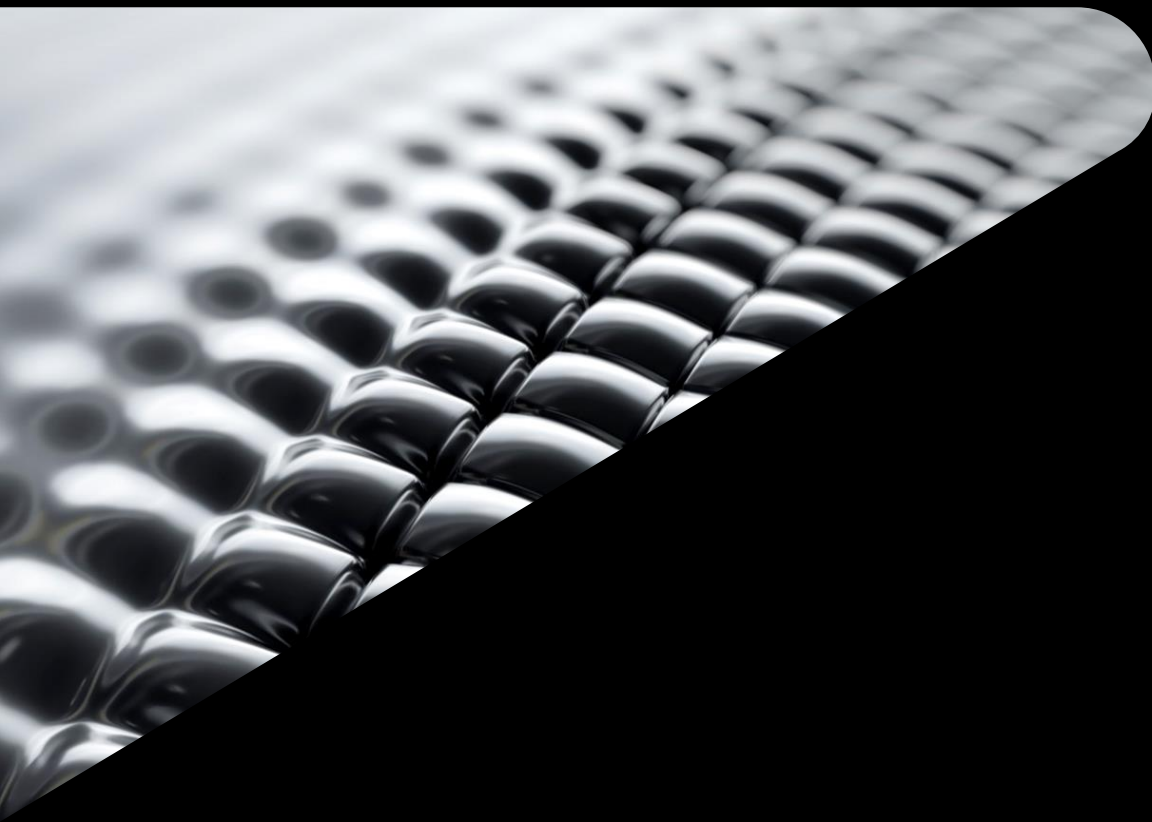


Solver settings— Flow and heat transfer

Gravity – enabled



Gravity enabled to account for buoyancy effects

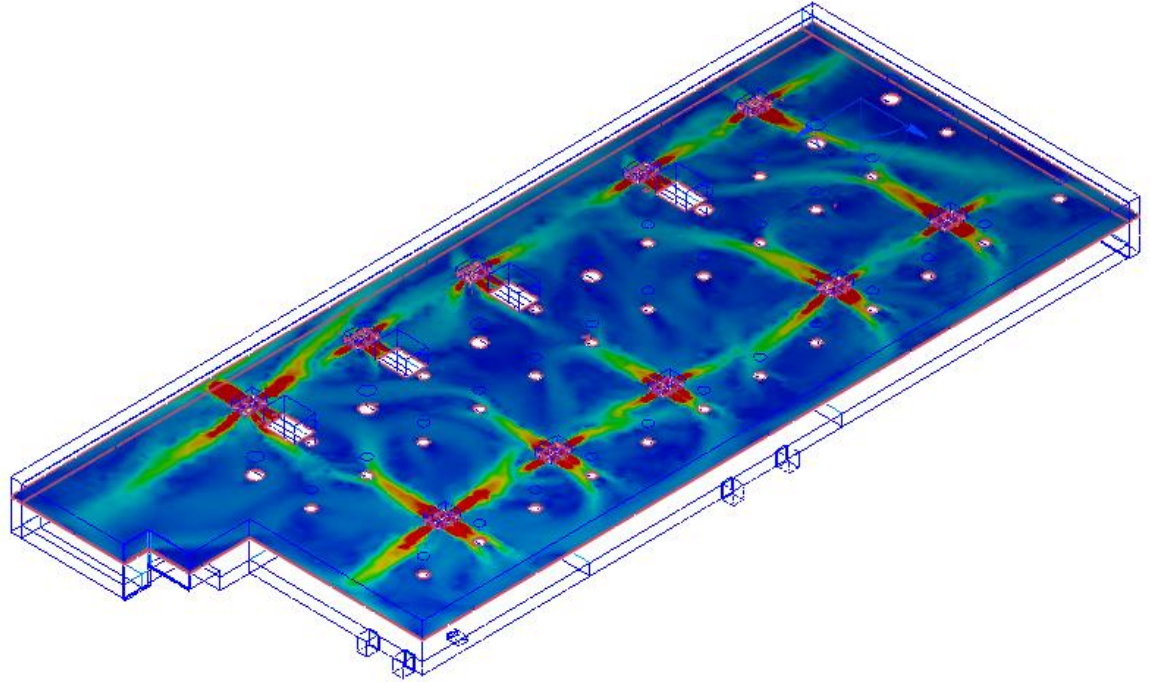
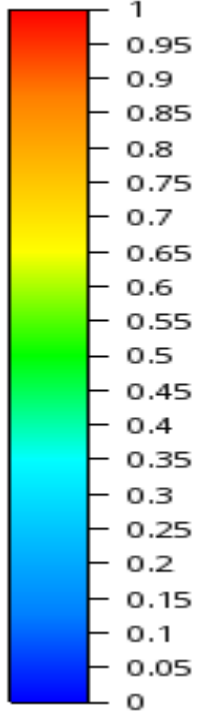


CFD results

Temperature and air flow velocity

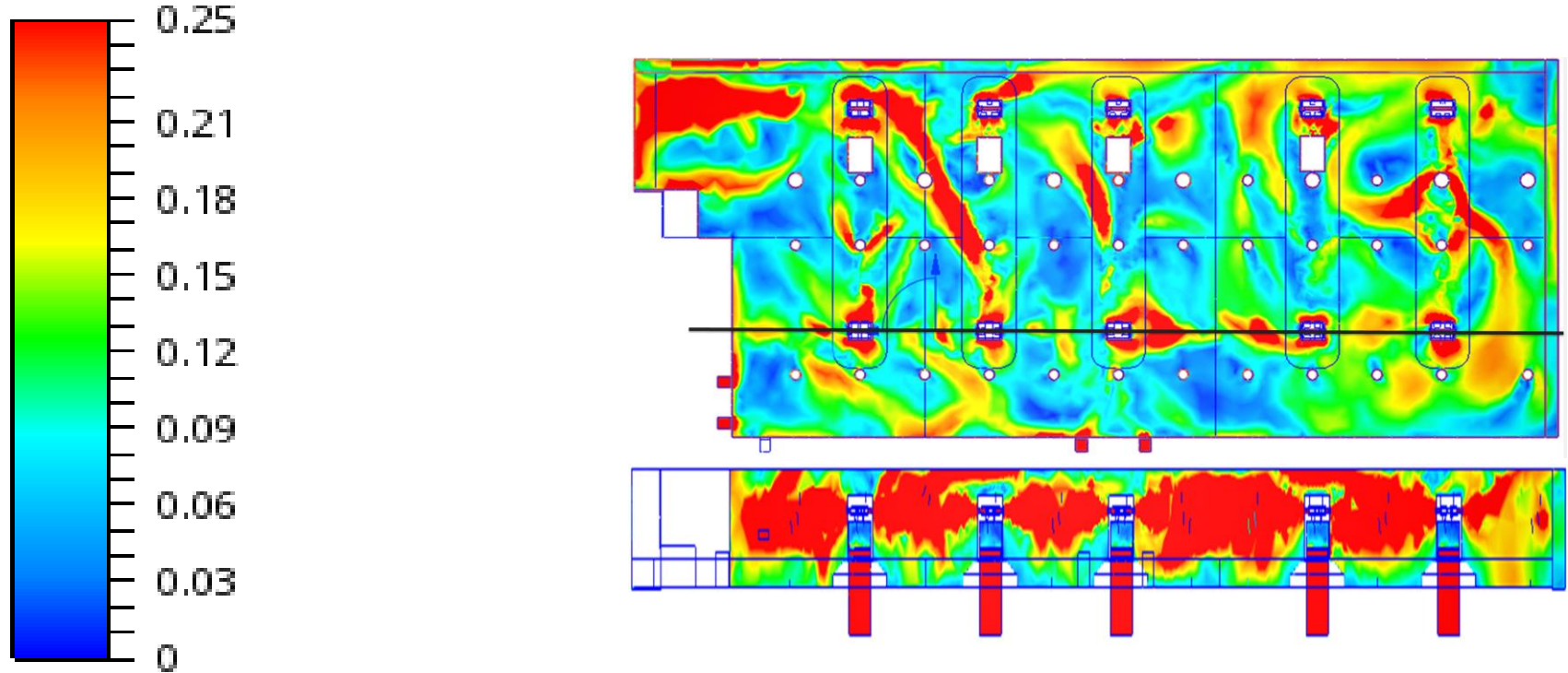
Flow pattern– Drum louvers (Baggage reclaim)

(1) Velocity Magnitude - m/s



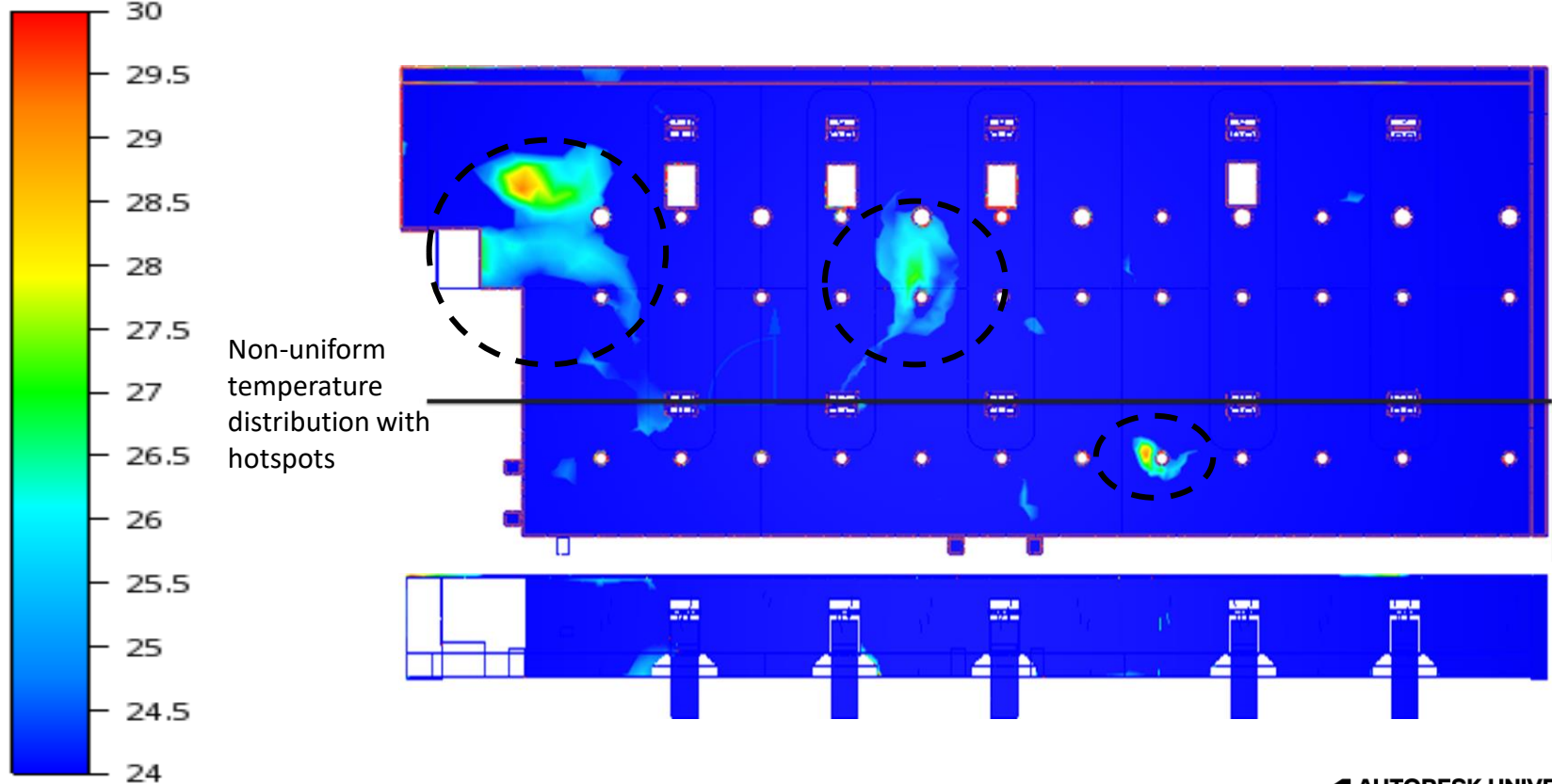
Velocity results – Baseline design (Baggage reclaim)

(1) Velocity Magnitude - m/s



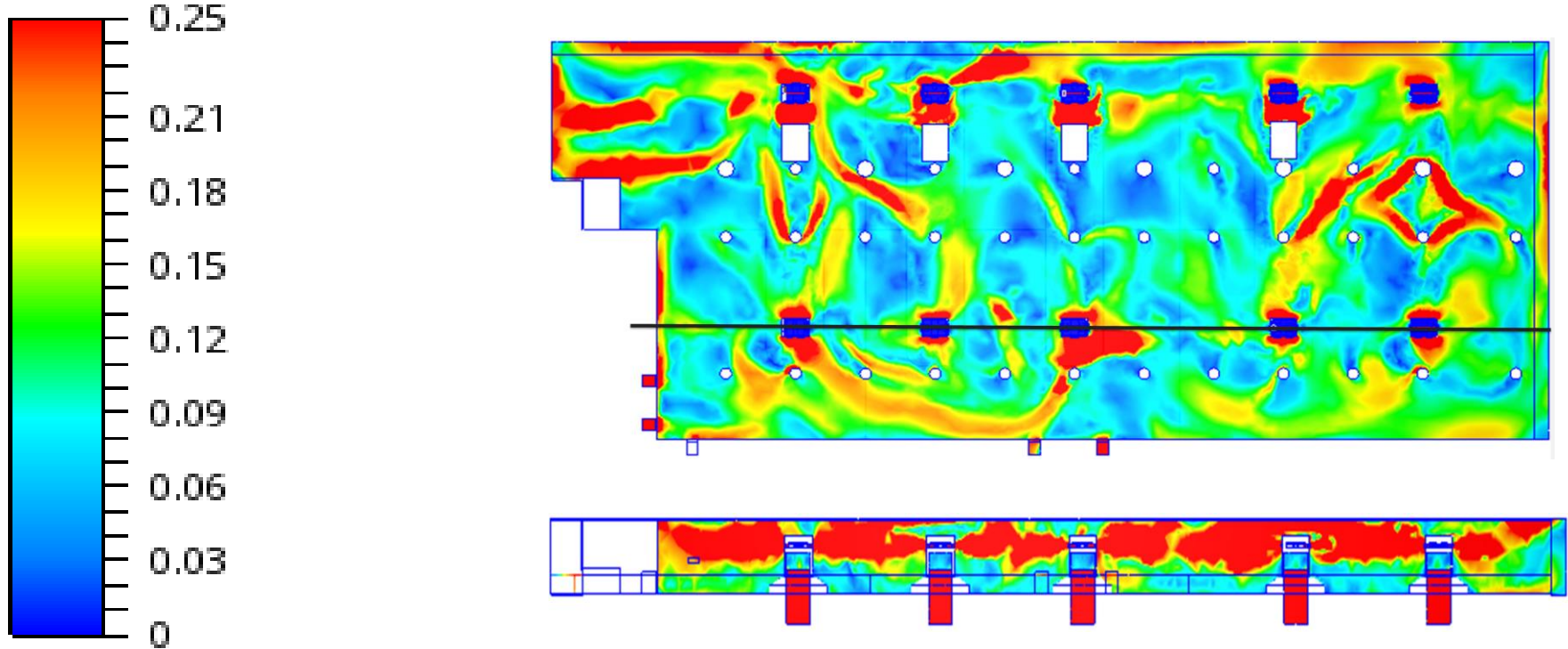
Temperature results – Baseline design (Baggage reclaim)

(6) Temperature - Celsius



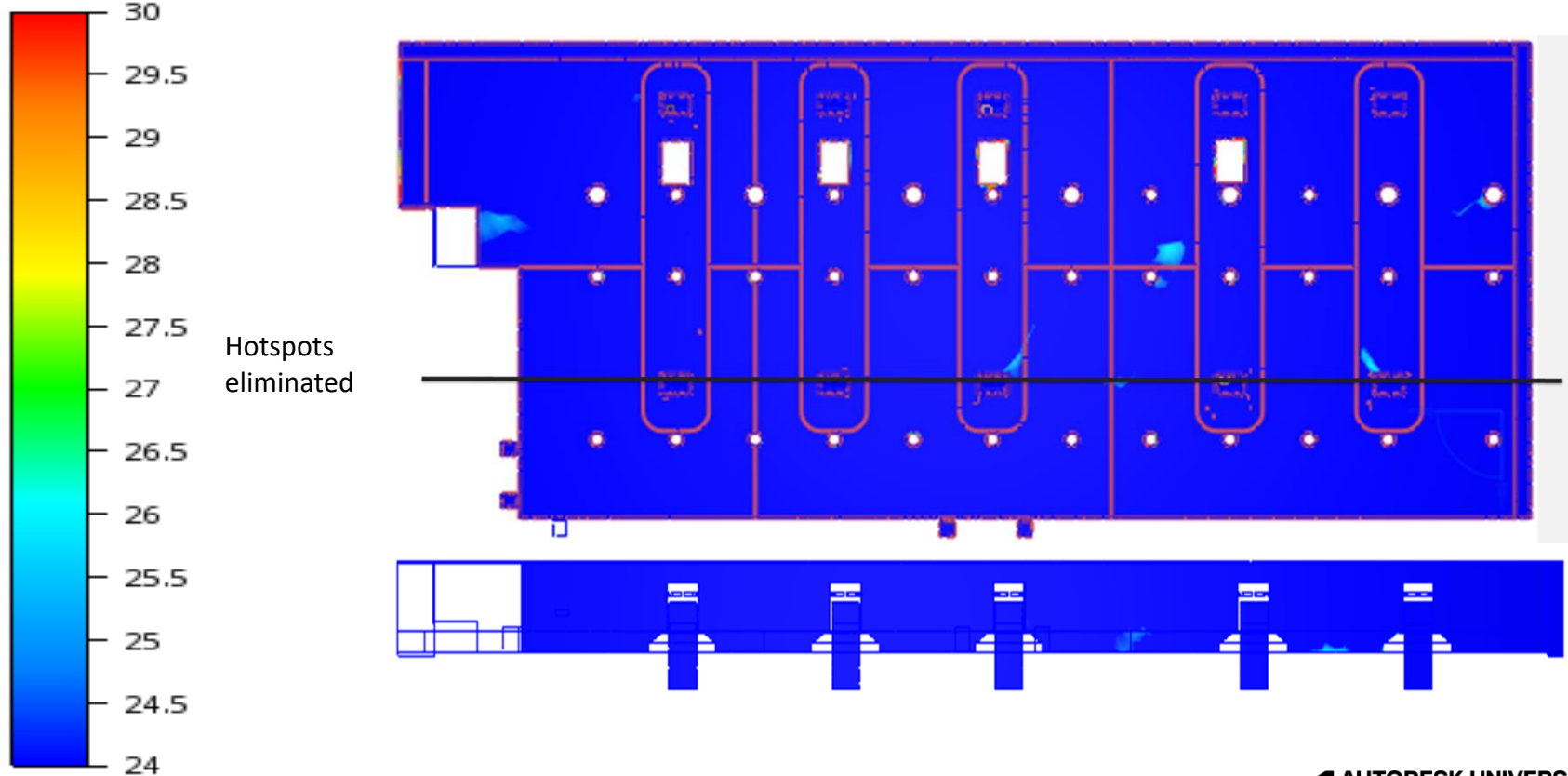
Velocity results – Optimized design (Baggage reclaim)

(1) Velocity Magnitude - m/s



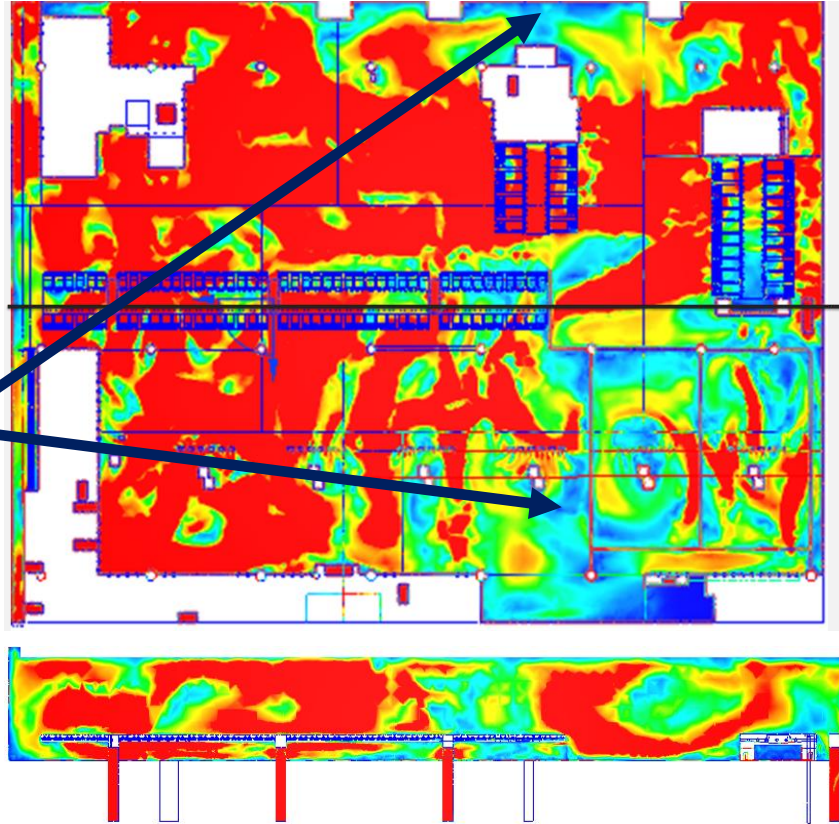
Temperature results – Optimized design (Baggage reclaim)

(6) Temperature - Celsius

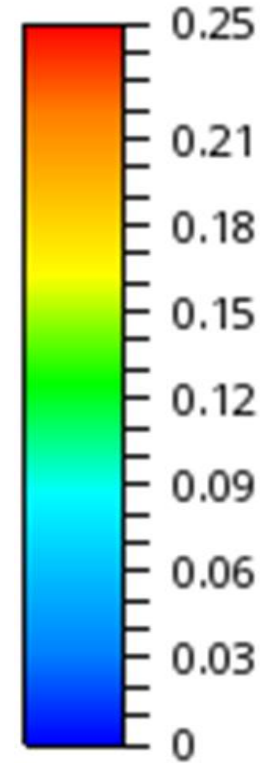


Velocity results- Baseline design (Check-in hall)

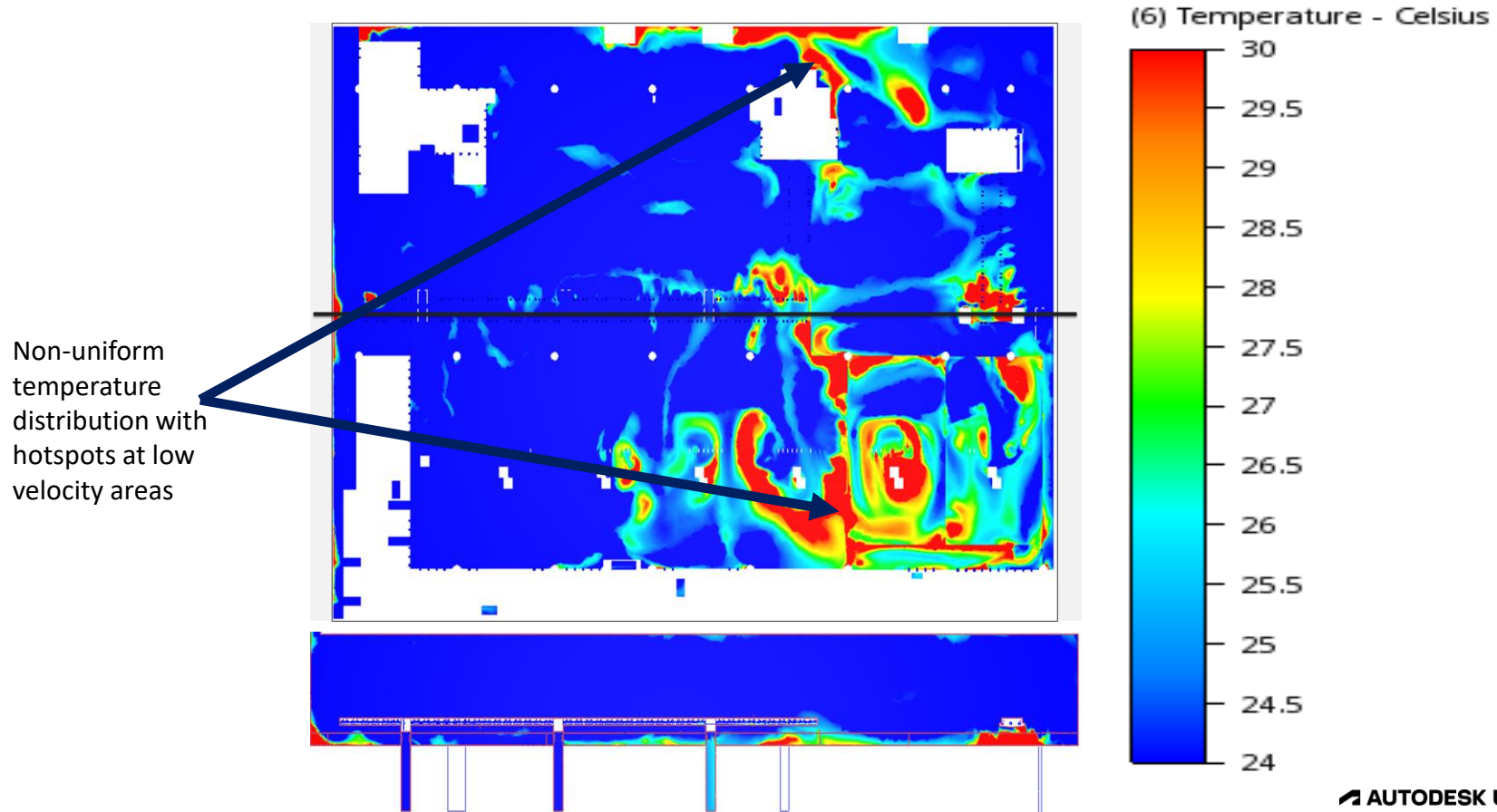
Non-uniform
velocity distribution
with low velocity
areas $< 0.25\text{m/s}$



(1) Velocity Magnitude - m/s

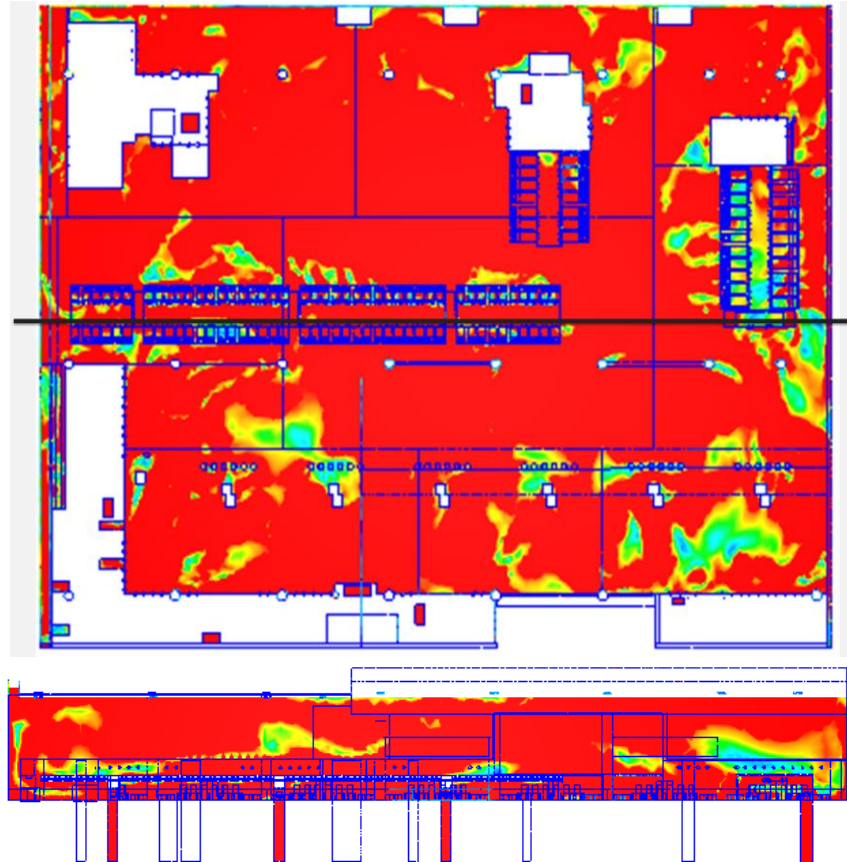


Temperature results – Baseline design (Check-in hall)

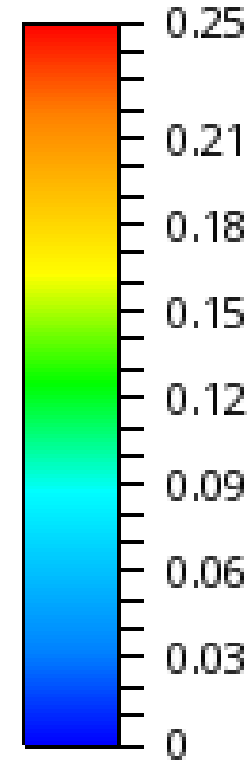


Velocity results – Optimized design (Check-in hall)

Uniform velocity distribution with most of occupied area with velocity ≥ 0.25 m/s

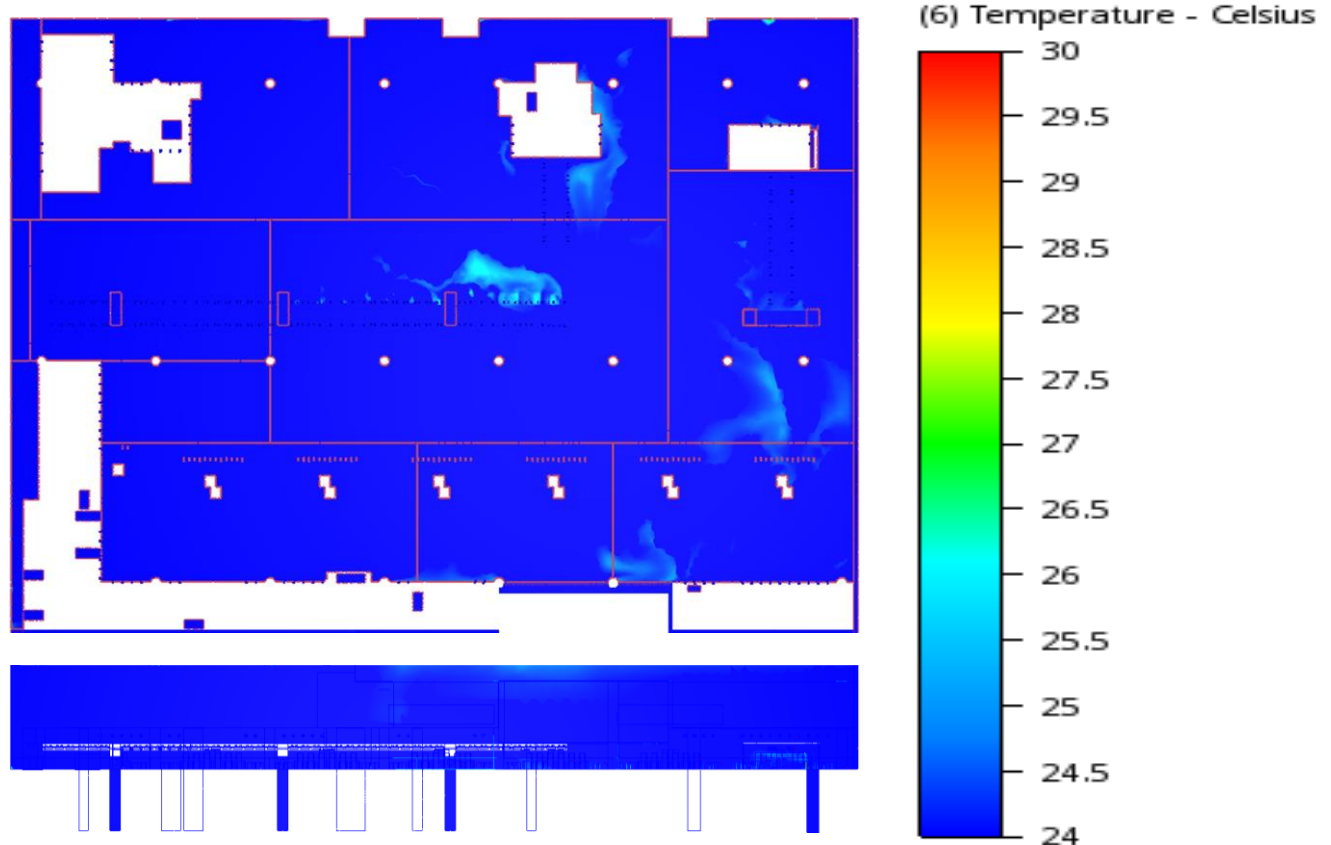


(1) Velocity Magnitude - m/s



Temperature results – Optimized design (Check-in hall)

Uniform temperature distribution with occupied area at $24 \pm 1^\circ \text{C}$

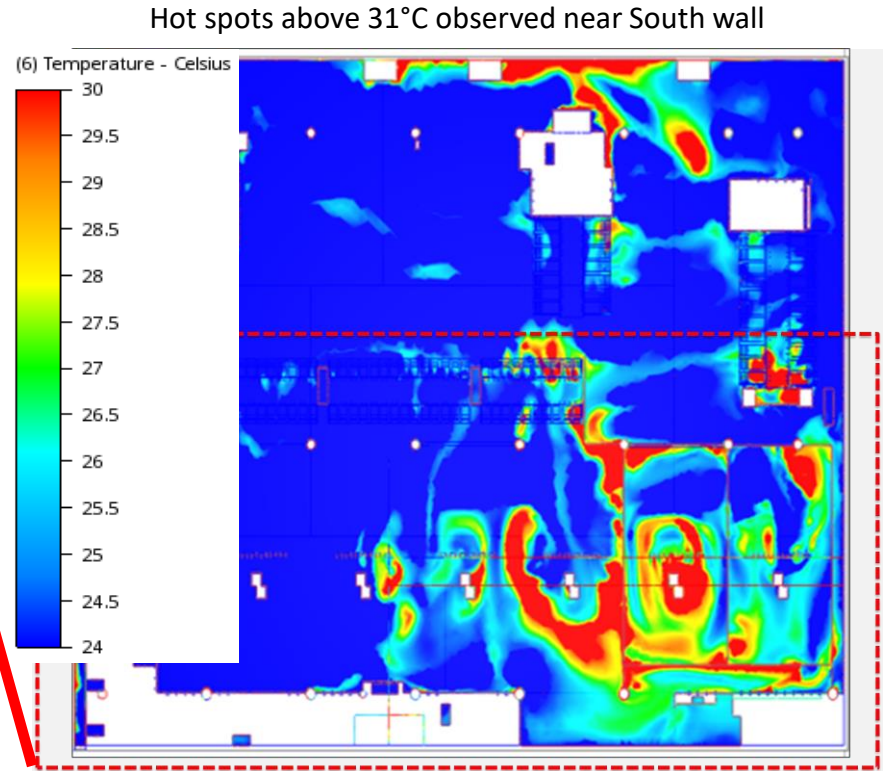
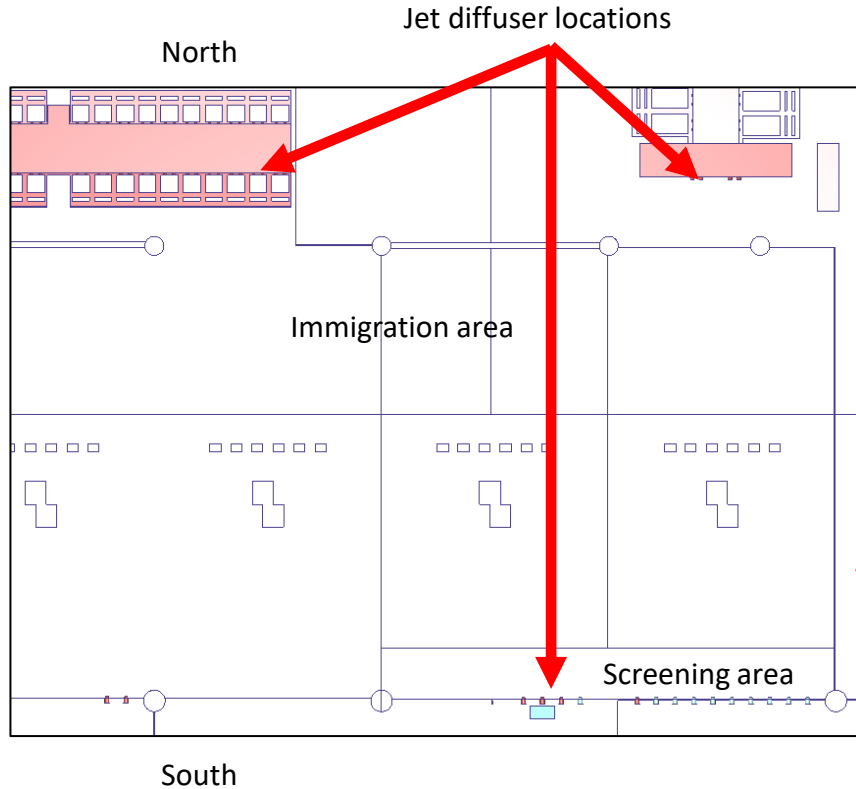




Design Optimization

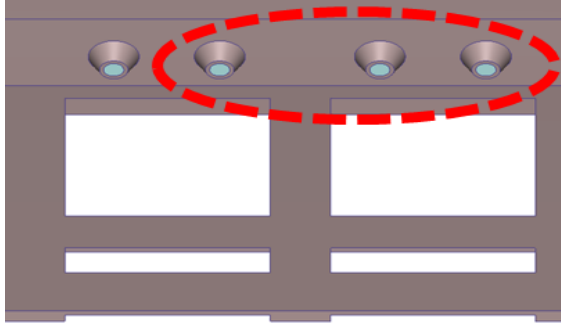
Check-in Hall - Temperature and air flow velocity

Baseline Design: Temperature results

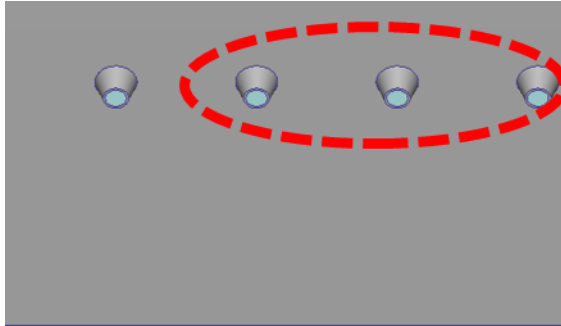
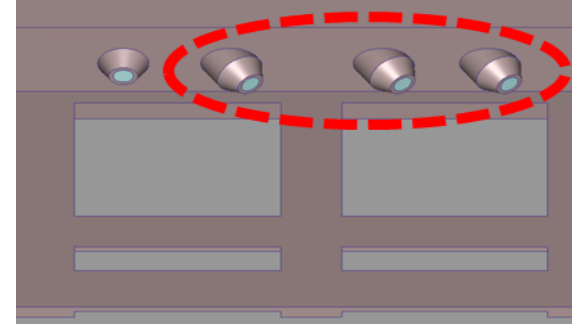


Design Option 1: Change in diffuser angle and CFM

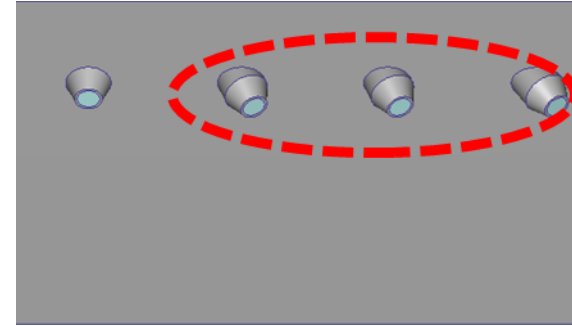
Diffuser flow discharge angle changed to 15 degrees to address high temperature regions



Immigration area



Screening area

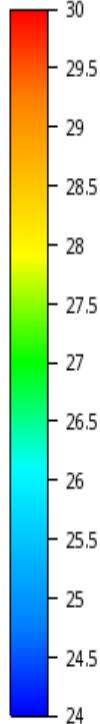


Baseline Design

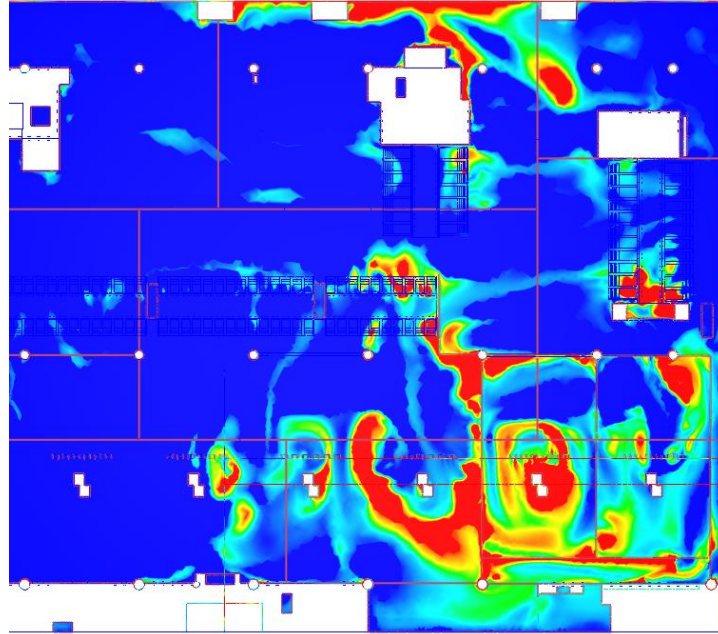
Design Option 1

Design Option 1: Comparison with Baseline Design

(6) Temperature - Celsius

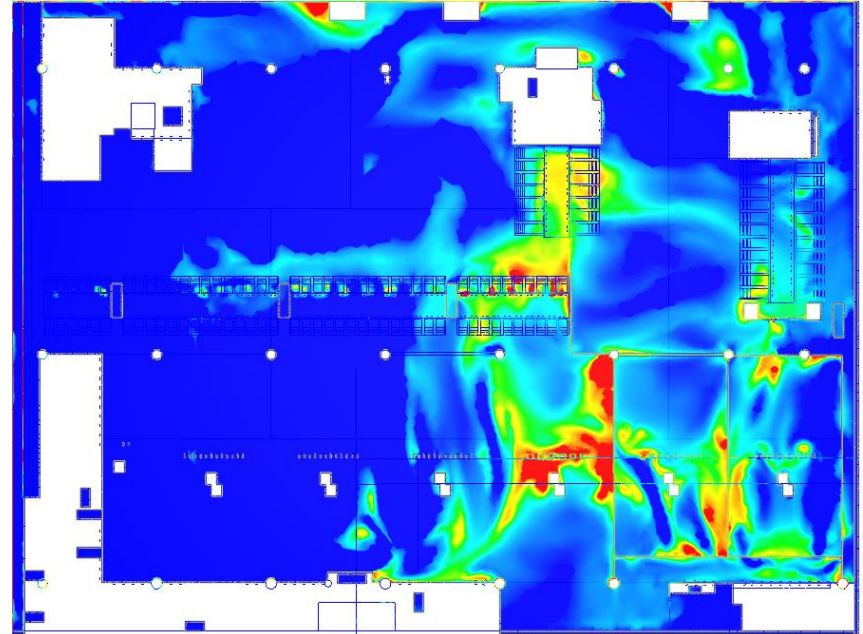


Hot spots (30-35°C)



Baseline Design

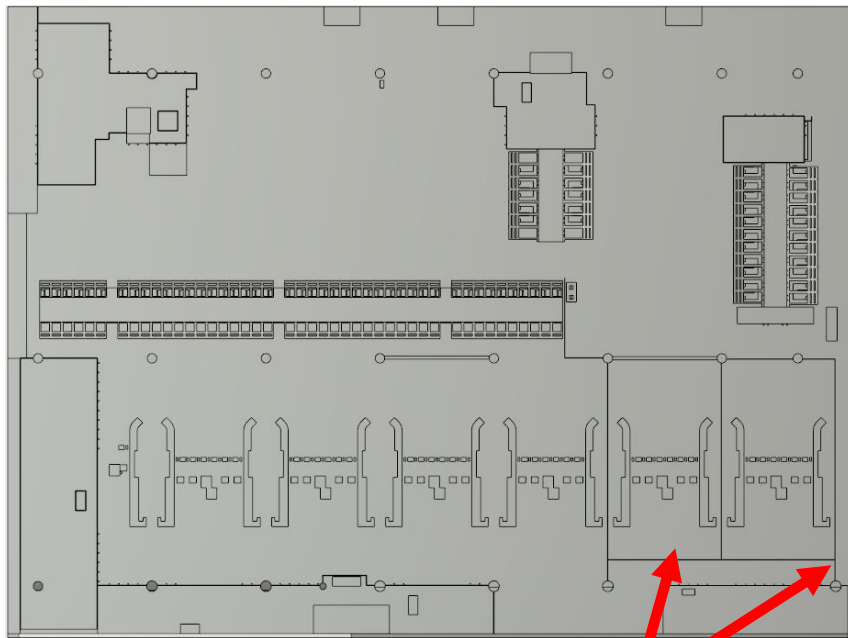
Hot spots (30-35°C) extent reduced



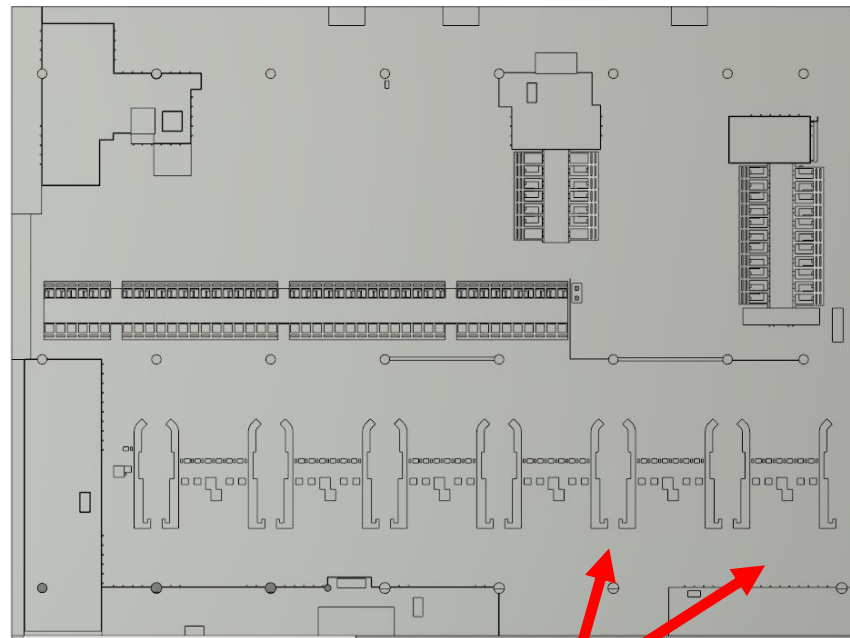
Design Option 1

Design Option 2: Change in interior arch layout

No Glass panels near South Wall for better air flow distribution



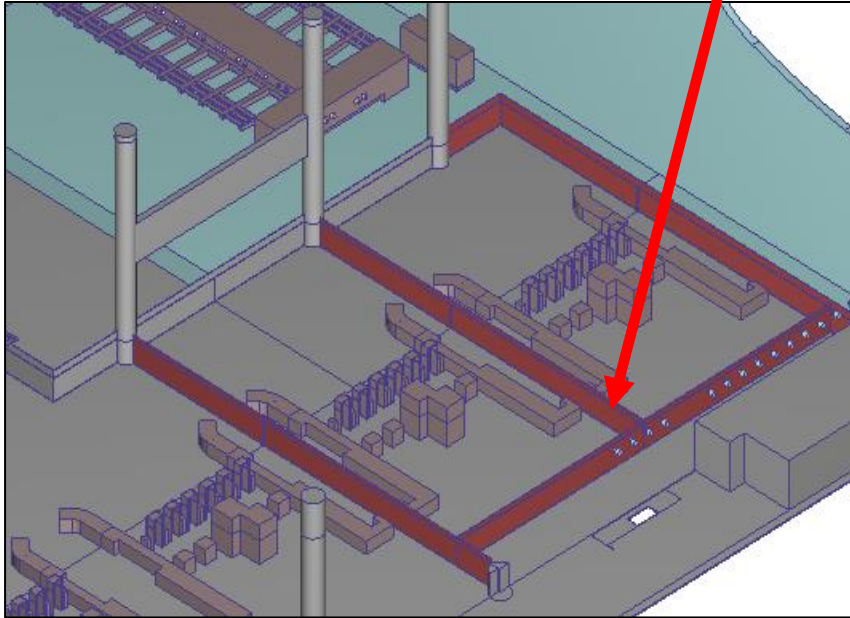
South wall glass panels



South wall glass panels removed

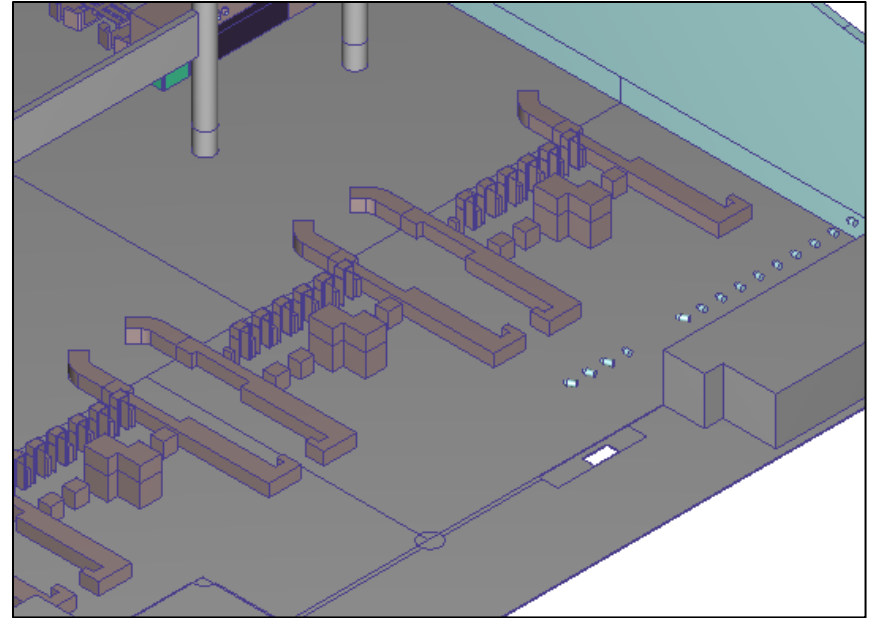
Design Option 2: Arch layout change w.r.t Option1

Glass panel partitions



Design Option -1

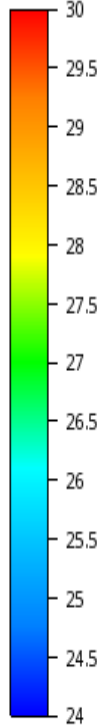
Glass panel partitions removed



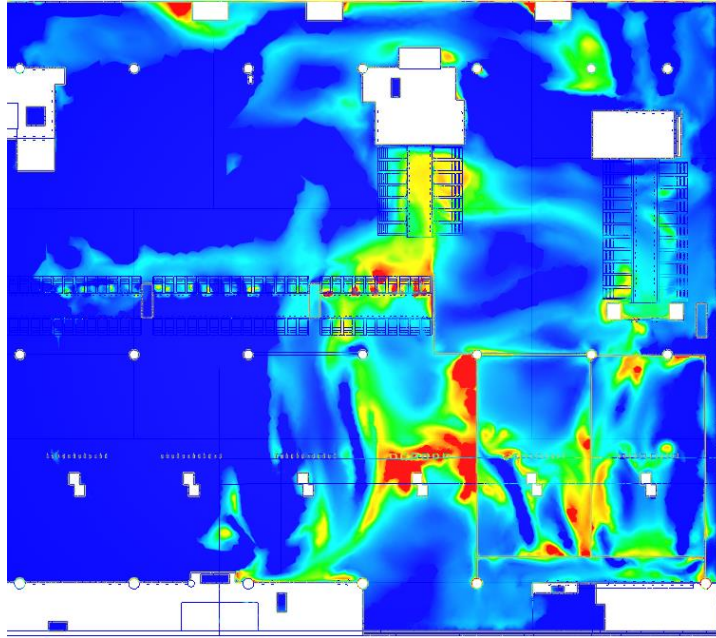
Design Option - 2

Design Option 2: Comparison with Design Option 1

(6) Temperature - Celsius

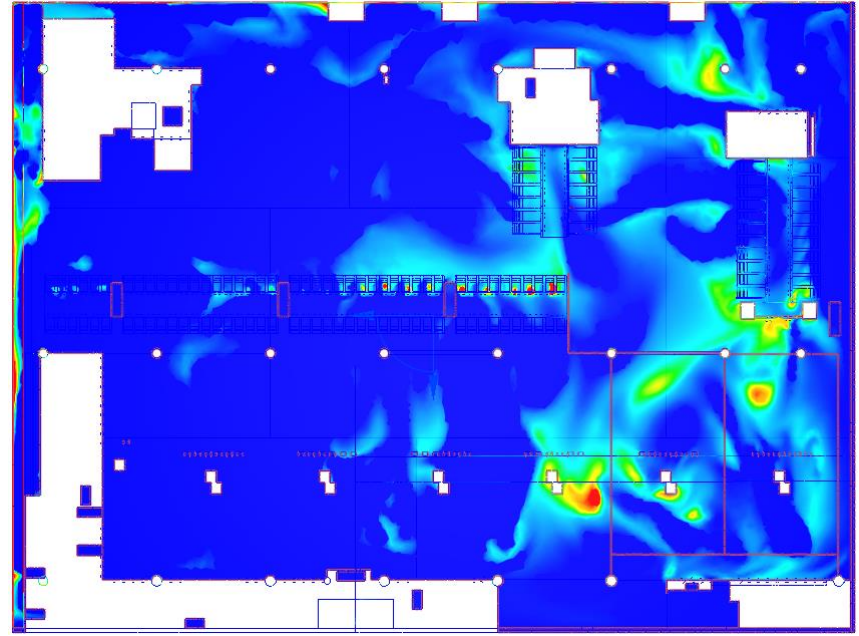


Hot spots (30-35°C)



Design Option -1

Hot spots (28-30°C) - extent reduced significantly

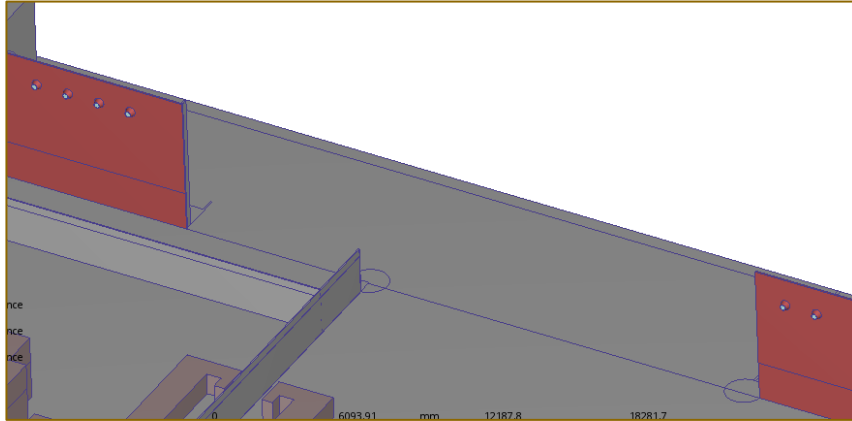
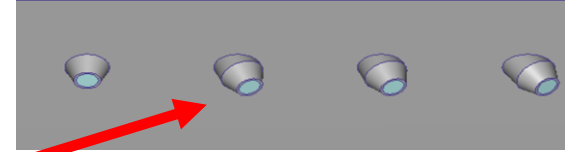


Design Option - 2

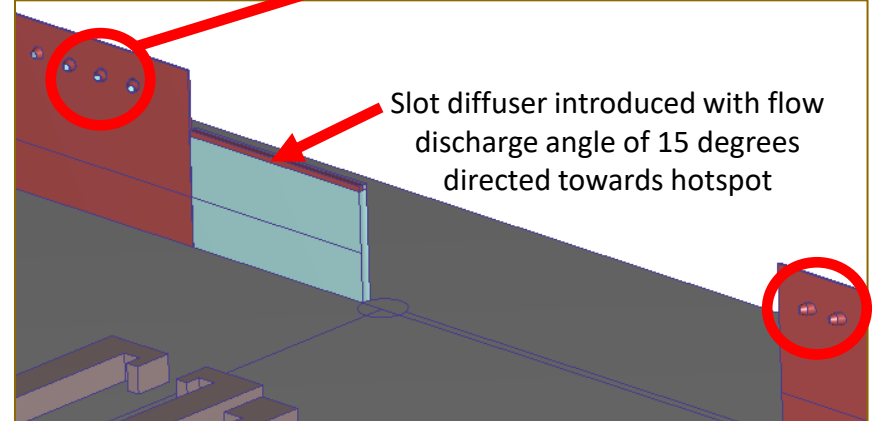
Design Option 3: Change in diffuser angles and CFM

Changed near South wall

Diffuser flow discharge angle changed from 15 to 20 degrees directed towards hotspots



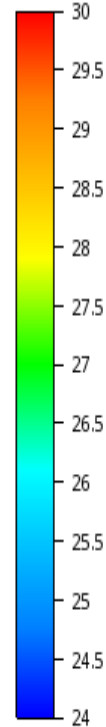
Design Option -2



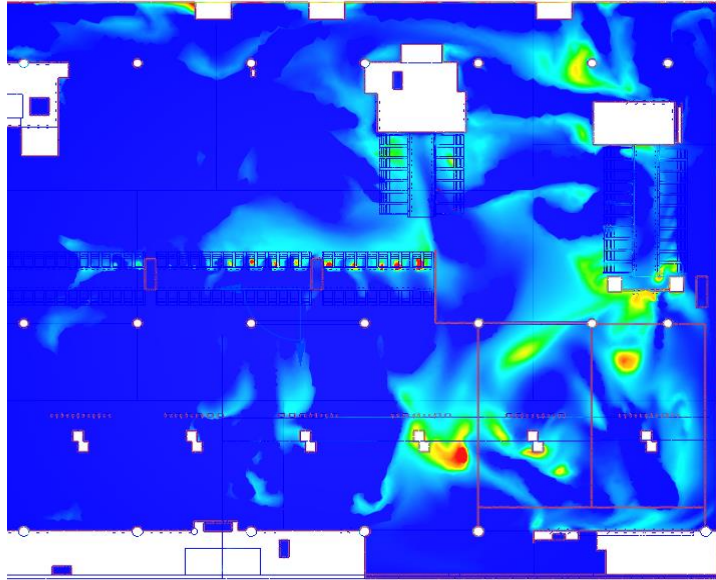
Design Option - 3

Design Option 3: Comparison with Design Option 2

(6) Temperature - Celsius

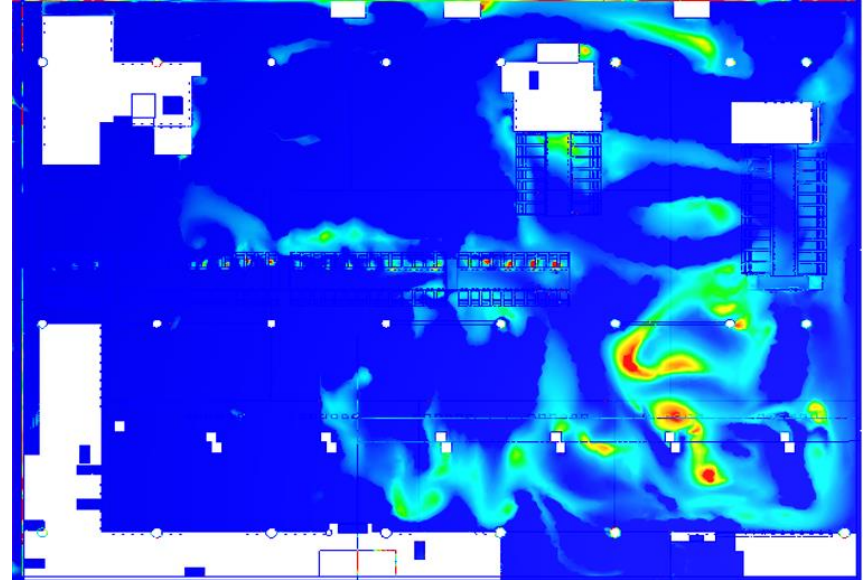


Hot spots (28-30°C)



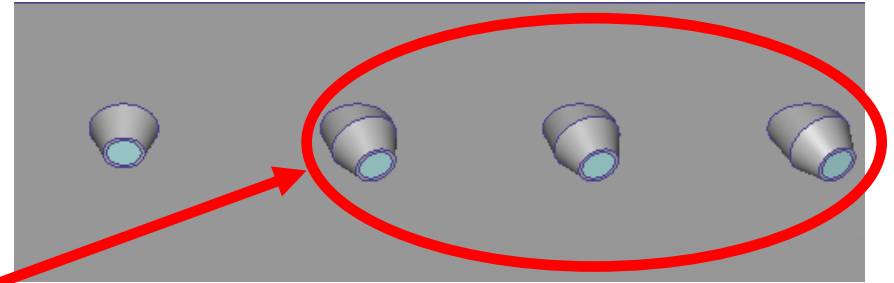
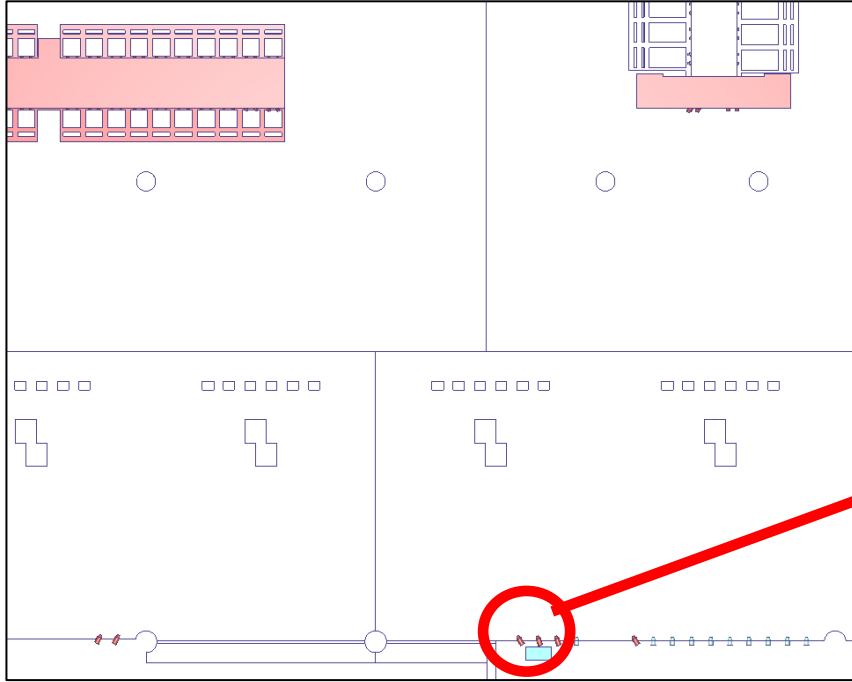
Design Option -2

Hot spots (28-30°C)



Design Option - 3

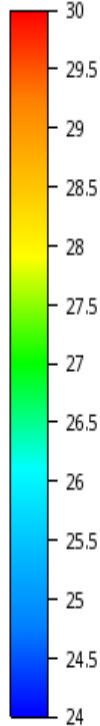
Design Option 4: Revised CFM- South wall Jet Diffuser



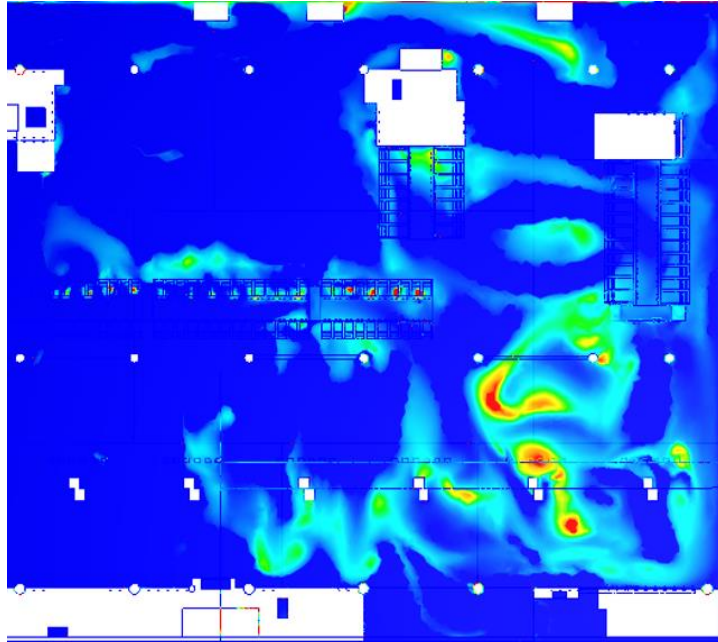
Revised airflow rate from 552 CFM
1200 CFM

Design Option 4: Comparison with Design Option 3

(6) Temperature - Celsius

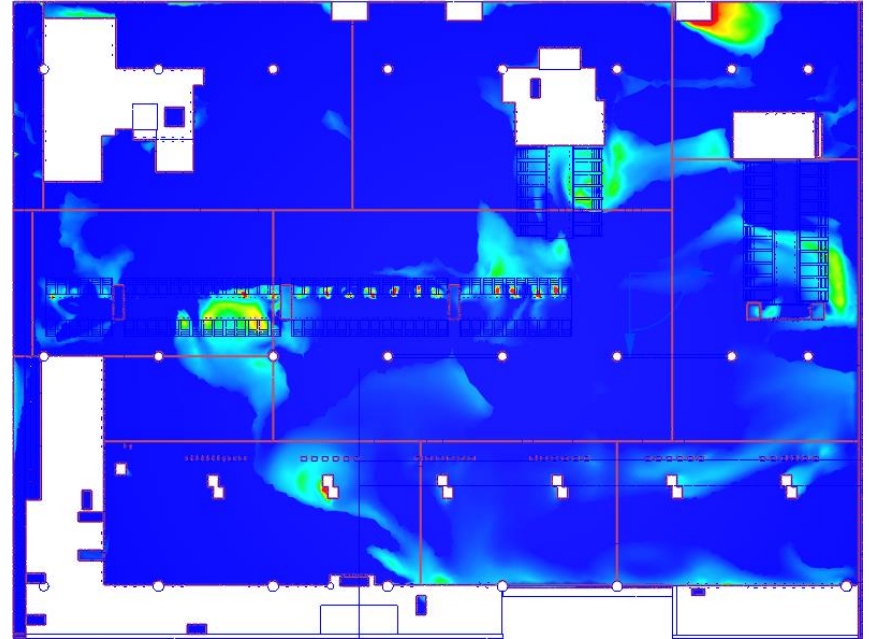


Hot spots (28-30°C)



Design Option - 3

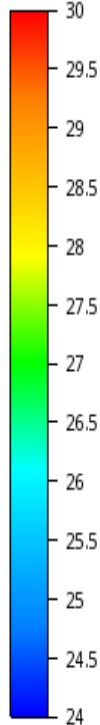
Hot spots (28-30°C) reduced and most of occupied area is within 24 °C



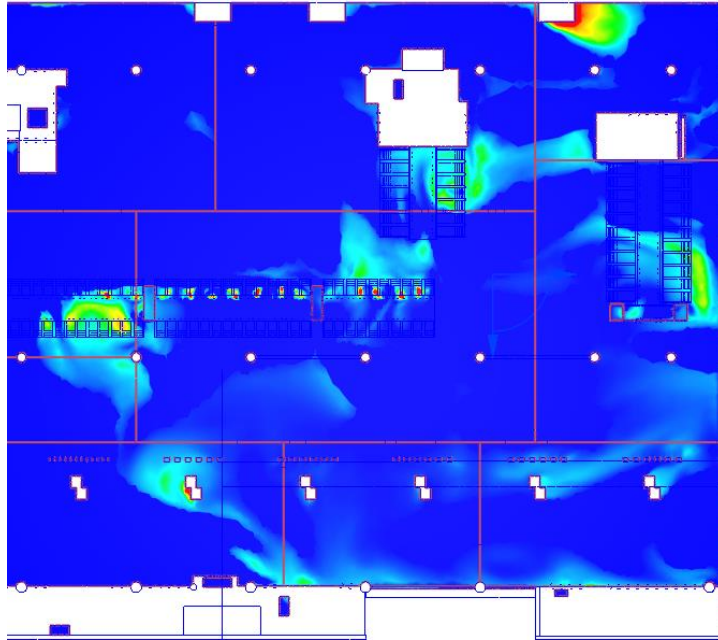
Design Option - 4

Design Option 4: Effect of mixed convection

(6) Temperature - Celsius

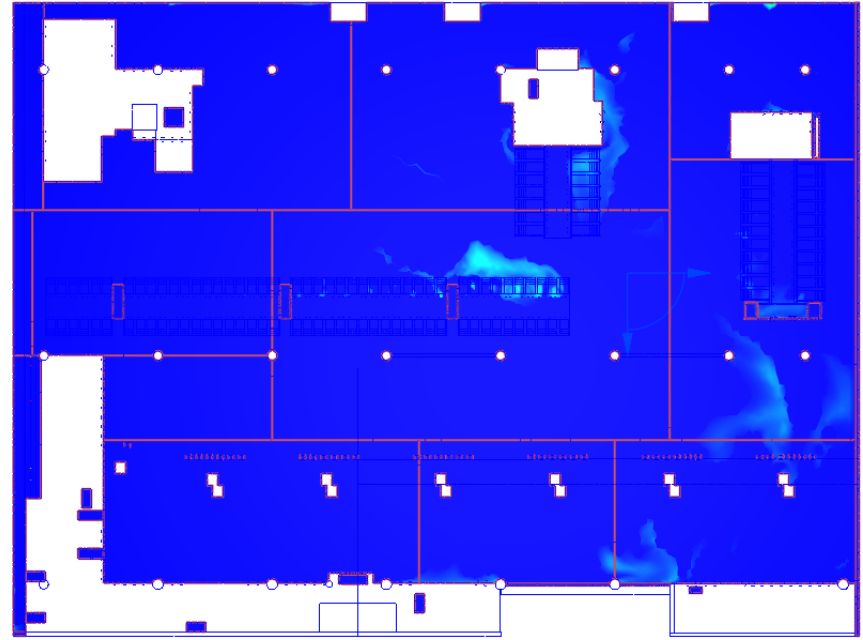


Hot spots (28-30°C)



Design Option - 4 (Fixed air properties)

Hot spots (28-30°C) eliminated and occupied area within 24°C



Design Option - 4 (Variable air properties)

Conclusions

Better HVAC designs using Autodesk CFD

The design of Check-in Hall of the airport has been optimized based on the flow and thermal results from Air conditioning analysis using Autodesk CFD. With the change in the diffuser angles and CFMs as well as using mixed convection, hot spots with temperatures greater than 31⁰C have been reduced to the design temperature limit of 24⁰C. The following results from Autodesk CFD Simulation provided insights into design adequacy:

- Air flow velocity values and pattern – a measure of air quality and cooling
- Temperature values and distribution – a measure of thermal comfort

Thus, air-conditioning analysis using Autodesk CFD led to the conclusion that the optimized HVAC design is adequate for thermal comfort in passenger terminal building of airport.

Thank you....

