Introduction to Parking Garage Ventilation Solutions

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- Joined AMCA in February 2019
- Responsible for development of AMCA's education programs; staff liaison for the Education & Training Subcommittee
- Projects include webinars, online education modules, presentations at trade shows, AMCA Speakers Network and other duties as assigned.

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Dr. Geoff Sheard

Consultant, AMCA Member Company

- Over 40 years experience in the aerodynamic and mechanical design of rotating equipment
- International expert in fan technology and development of high efficiency fans for commercial and industrial application
- Holds a BEng in mechanical engineering, a DPhil in aerodynamics plus a DSc awarded for the application of aerospace design techniques in commercial and industrial fan design.
- Past President of AMCA and Chairman of the FAN 2012, 2015, 2018 and 2022 conference organizing committee

Introduction to Parking Garage Ventilation Solutions

Purpose and Learning Objectives

The purpose of this presentation is to provide an introduction into Parking Garage ventilation, and specifically the benefits and design approach to Parking Garage ventilation when using jet fans.

At the end of this presentation you will be able to:

1. Identify the two methods used when deciding on the minimum ventilation rate for a Parking Garage.
2. Understand why using a ducted ventilation system is problematic in a Parking Garage when it can be used routinely in other parts of the same building.
3. Recognize a jet fan and understand its role in Parking Garage ventilation systems.
4. Define two operating modes a Parking Garage ventilation system is designed for.
5. Understand the primary cause of death for those trapped in a Parking Garage fire.

AMCA Publications & Standards

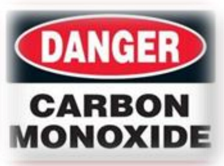
- ANSI/AMCA Standard 210-16/ASHRAE 51-16: ***Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*** establishes uniform test methods for a laboratory test of a fan or other air moving device to determine its aerodynamic performance.
- AMCA Publication 201-02 (R2011): ***Fans and Systems*** is aimed primarily at the designer of the air moving system and discusses information necessary for proper fan selection.
- AMCA Standard 99-16: ***Standards Handbook*** is intended to help create and establish common terminology throughout the fan industry, thereby making it easier for the designer of the air moving system.

Agenda

- Design Objectives & Design Approaches
- System Performance Requirements
- Jet Fan Fundamentals & Design Strategy
- Jet Fan Range for Parking Garage
- Smoke Extraction in the Event of a Fire
- Controls & System Interaction
- Design Validation Using CFD Analysis

Main reasons for requiring ventilation in enclosed parking garages…

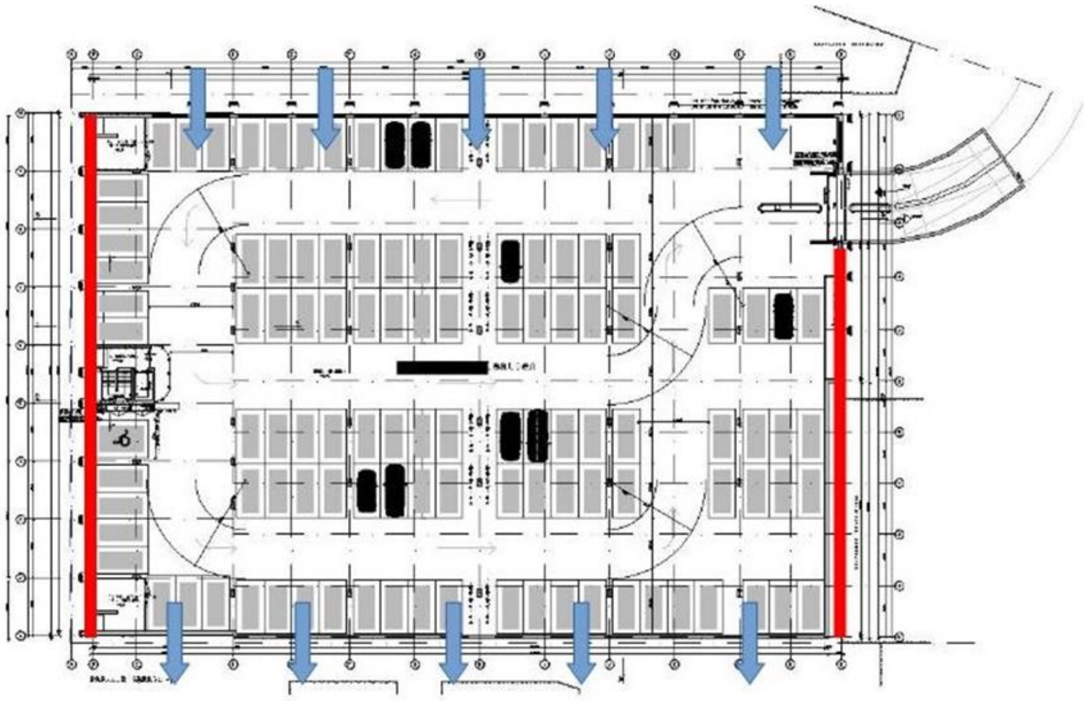
A. Reduce toxic levels of ***Carbon Monoxide*** and ***Nitrogen Oxides*** within parking garage.



B. Provide a means of ***extracting smoke during or after a fire has been extinghuised.***

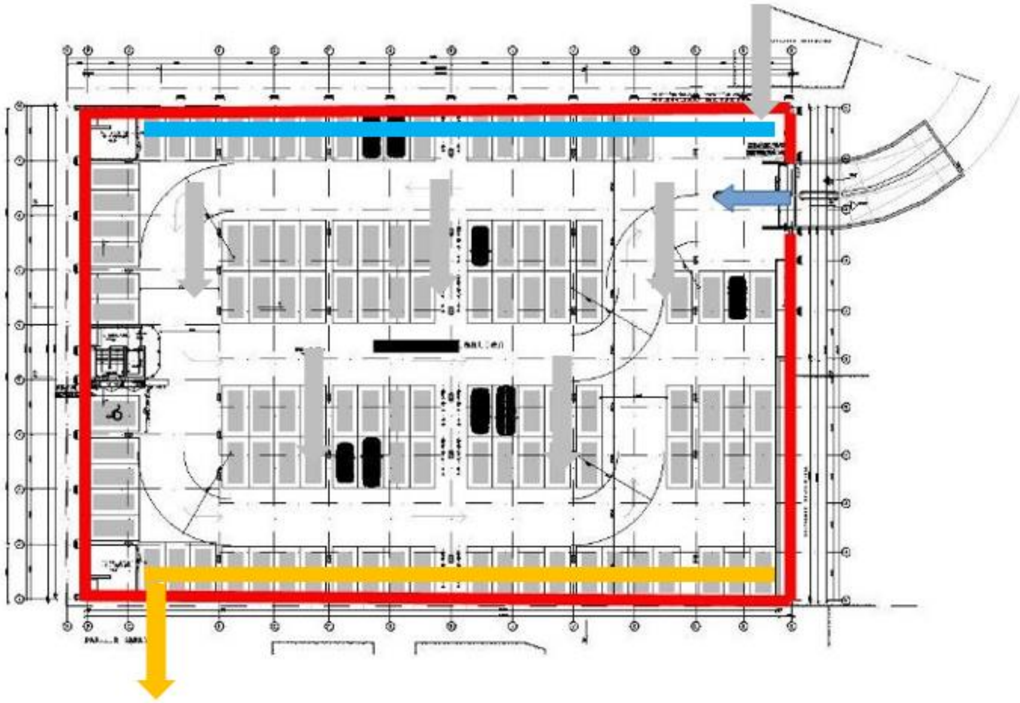
Feasible Design Approaches…..*open sided*

Two opposing walls, sufficiently open to atmosphere providing sufficient through draft.



Feasible design approaches…..*fully enclosed*

Mechanical extract and natural or mechanical supply of replacement air.



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System Performance Requirements

Design Approach

1. Applying a ***fixed air quantity multiplier*** relative to the floor area or volume.

2. ***Based upon calculation*** estimating amount of traffic, usage of the Parking Garage and average Carbon Monoxide emission/car.

Design Approach: Int. Mechanical Code (IMC) 2015

SECTION 404
ENCLOSED PARKING GARAGES

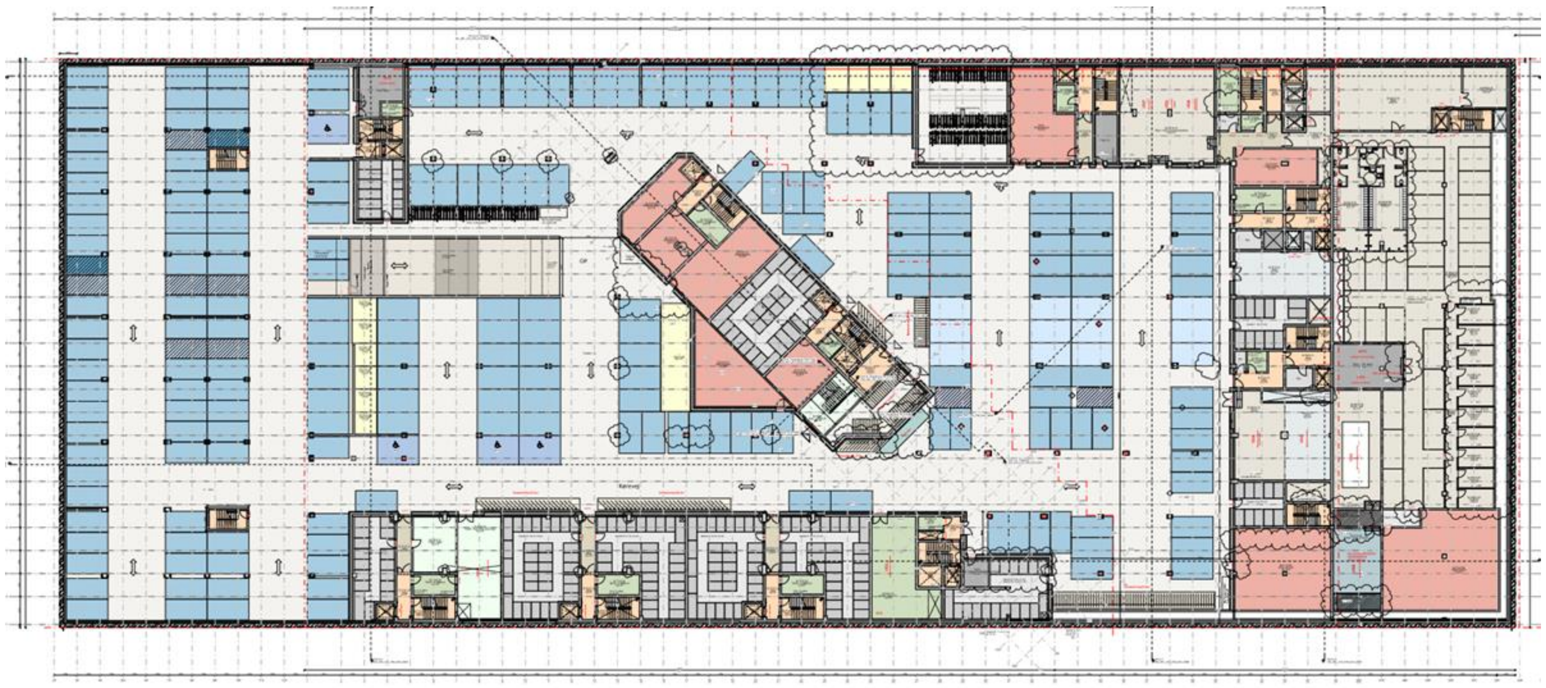
404.1 Enclosed parking garages. Where mechanical ventilation systems for enclosed parking garages operate intermittently, such operation shall be automatic by means of carbon monoxide detectors applied in conjunction with nitrogen dioxide detectors. Such detectors shall be installed in accordance with their manufacturers' recommendations.

404.2 Minimum ventilation. Automatic operation of the system shall not reduce the ventilation airflow rate below 0.05 cfm per square foot ($0.00025\ m^3/s \cdot m^2$) of the floor area and the system shall be capable of producing a ventilation airflow rate of 0.75 cfm per square foot ($0.0038\ m^3/s \cdot m^2$) of floor area.

404.3 Occupied spaces accessory to public garages. Connecting offices, waiting rooms, ticket booths and similar uses that are accessory to a public garage shall be maintained at a positive pressure and shall be provided with ventilation in accordance with Section 403.3.

Design Approach: Int. Mechanical Code (IMC) 2015

Parking Garage area: 81,000 ft^2



IMC 2015 requirements

Design extract: 60,750 CFM

Minumum extract: 4,050 CFM

Dutch Building Code

Design extract: 50,000 CFM

Minumum extract: 9,000 CFM

Design Approach: 2015 ASHRAE Handbook Section 15.19

Ventilation Requirements and Design

ASHRAE research project RP-945 (Krarti and Ayari 1998) found that the design ventilation rate required for an enclosed parking facility depends chiefly on four factors:

- Acceptable level of contaminants in the parking facility
- Number of cars in operation during peak conditions
- Length of travel and the operating time for cars in the garage
- Emission rate of a typical car under various conditions

Design Approach:
2015 ASHRAE Handbook Section 15.19

- **Calculated approach...**
  - Number of cars in operation during peak conditions:
  - Length of travel and operating time of cars in the garage:
  - Emission rate of typical car under various conditions (average):

3-5% (Standard)

15-20% (e.g. Stadiums, malls..)

60 – 180 seconds (generally)

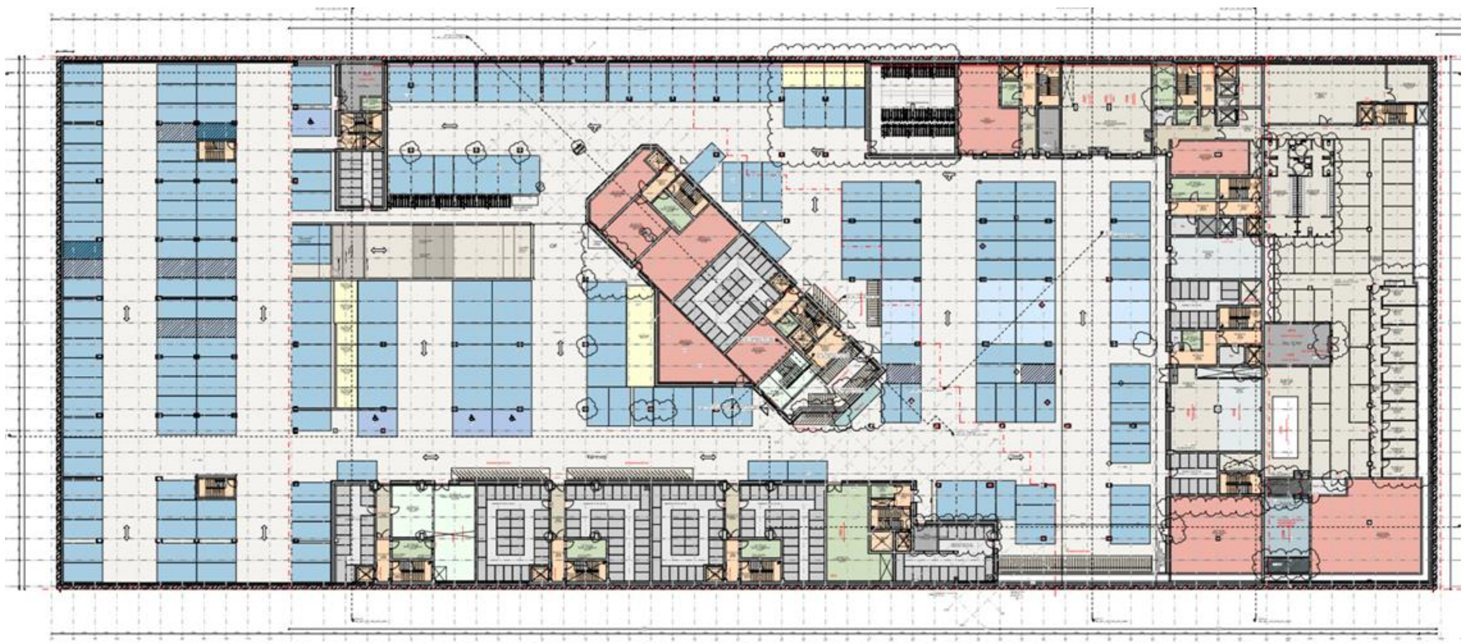
Winter: 1.480 lb/h

Summer: 0.367 lb/h

Design Approach:
2015 ASHRAE Handbook Section 15.19

Calculated approach…

- Parking area floor area: 81,000 ft^2
- Parking garage capacity: 225 cars
- Parking garage height: 9 ft



Design Approach:
2015 ASHRAE Handbook Section 15.19

- **Calculated approach...**
  - Number of cars running at peak conditions:
  - Average CO emission winter conditions:
  - Average travel time within structure:
  - Maximum acceptable level of CO:

Say 20%	20% 0f 225	45 cars
1.544 lb./h(1)	45 * 1.544 lb./h	69.48 lb/h
120 seconds		
35 ppm		

Design Approach:
2015 ASHRAE Handbook Section 15.19

Calculated approach...

Step 1	Establish peak CO concentration per ft^2	69.48 / 81,000	0.00086 lb/h per ft^2
Step 2	Normalize peak CO level with reference level	(100 * 0.00086)/0.00546[(1)]	15.75
Step 3	Determine minimum ventilation rate	0.0000948[(1)] * 15.75 * 120	0.179 cfm/ft^2
Step 4	Determine air change rate	(0.179 * 60) / 9	**1.2 air changes per hour**

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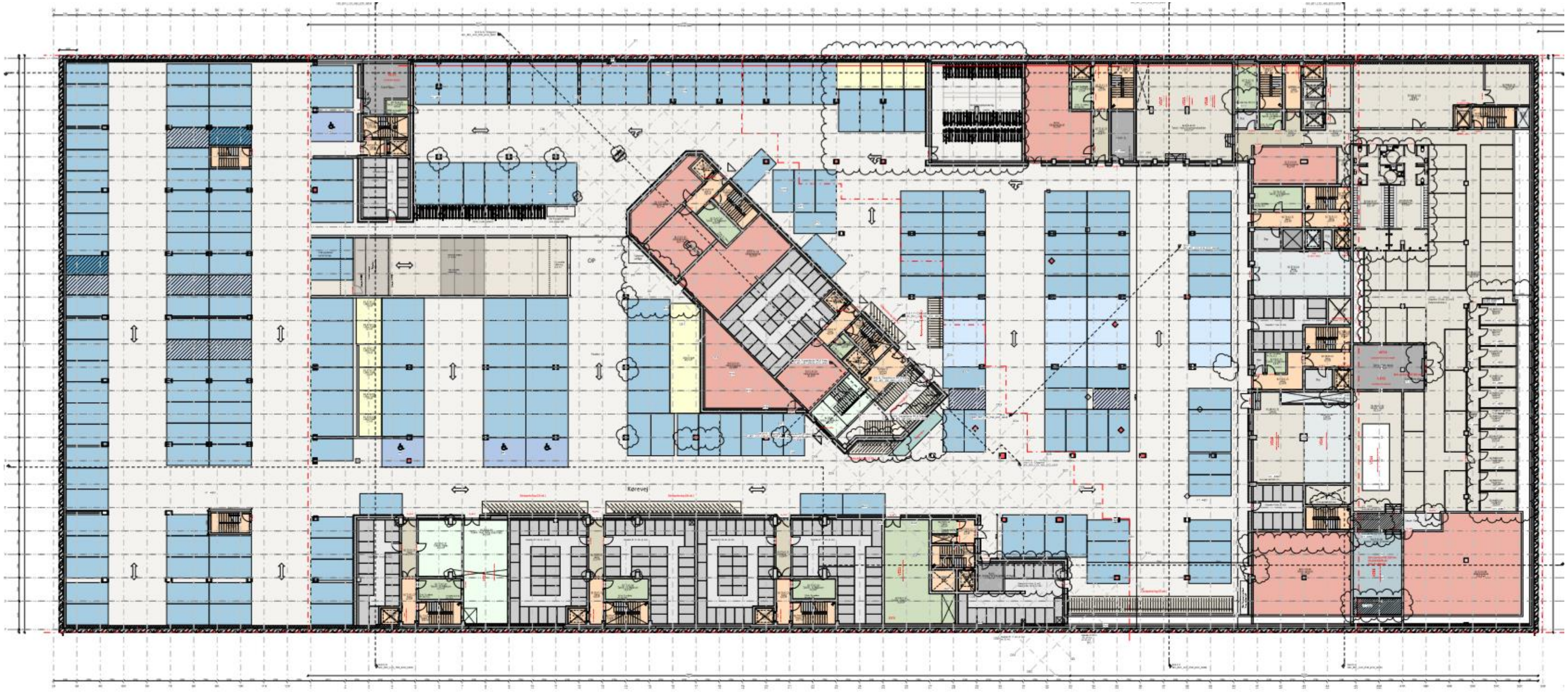
Jet Fan Fundamentals & Design Strategy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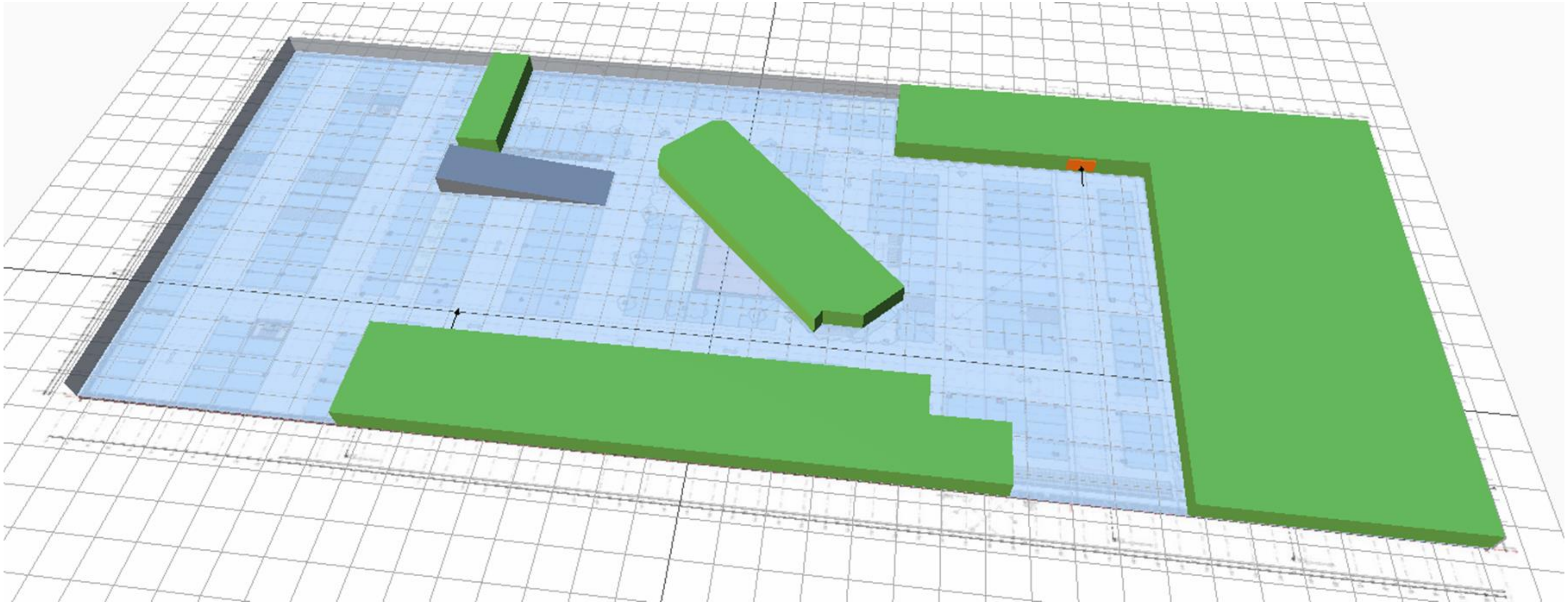
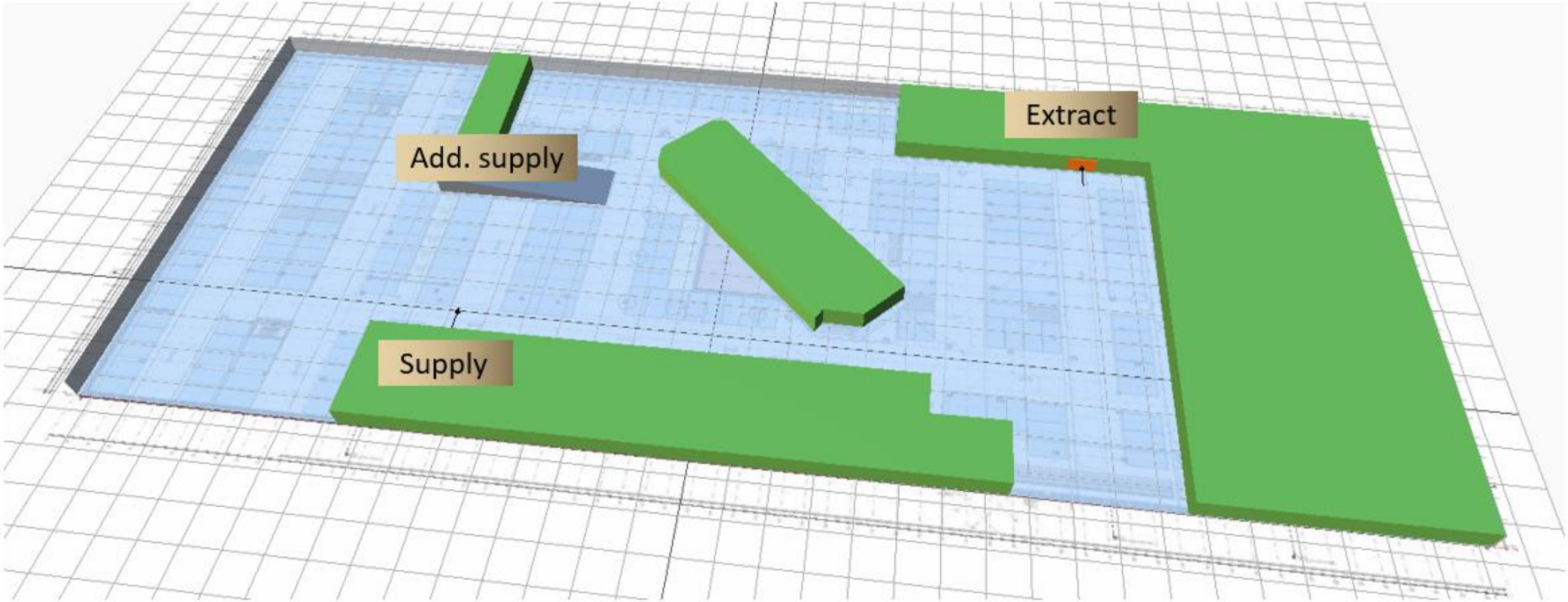
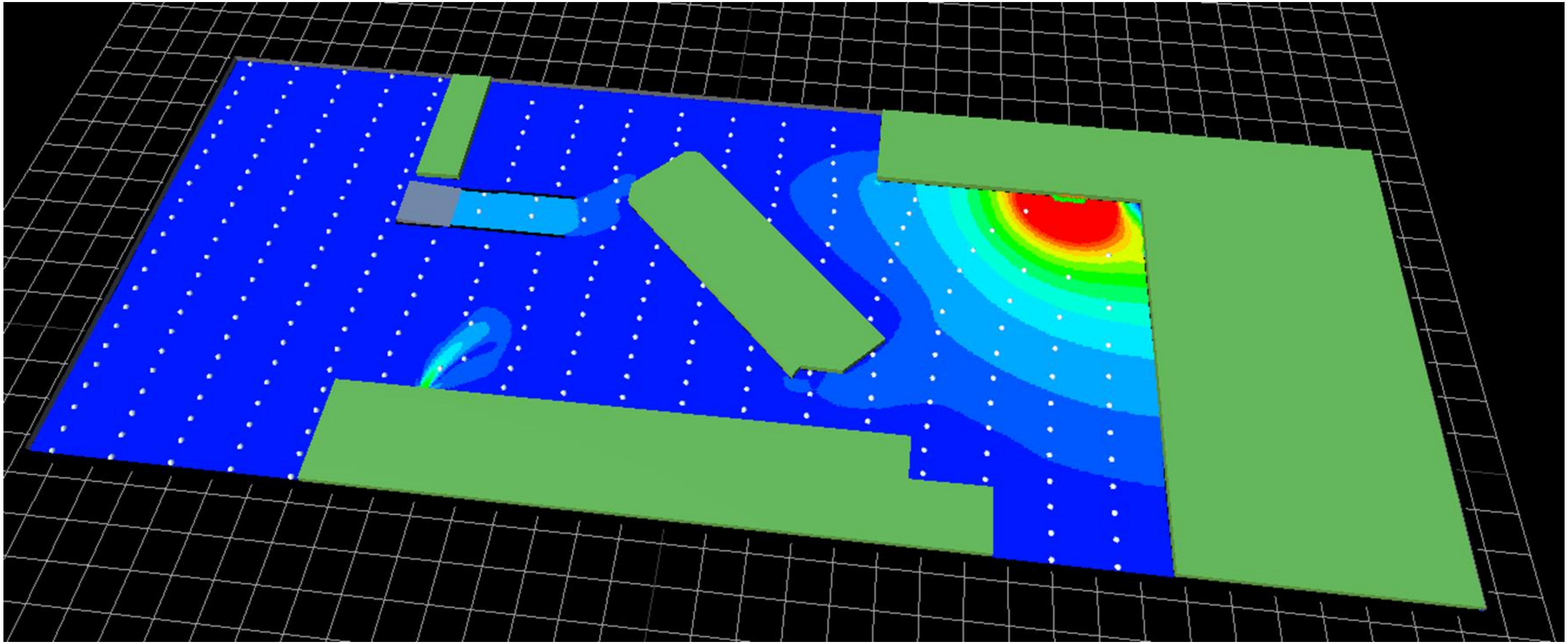
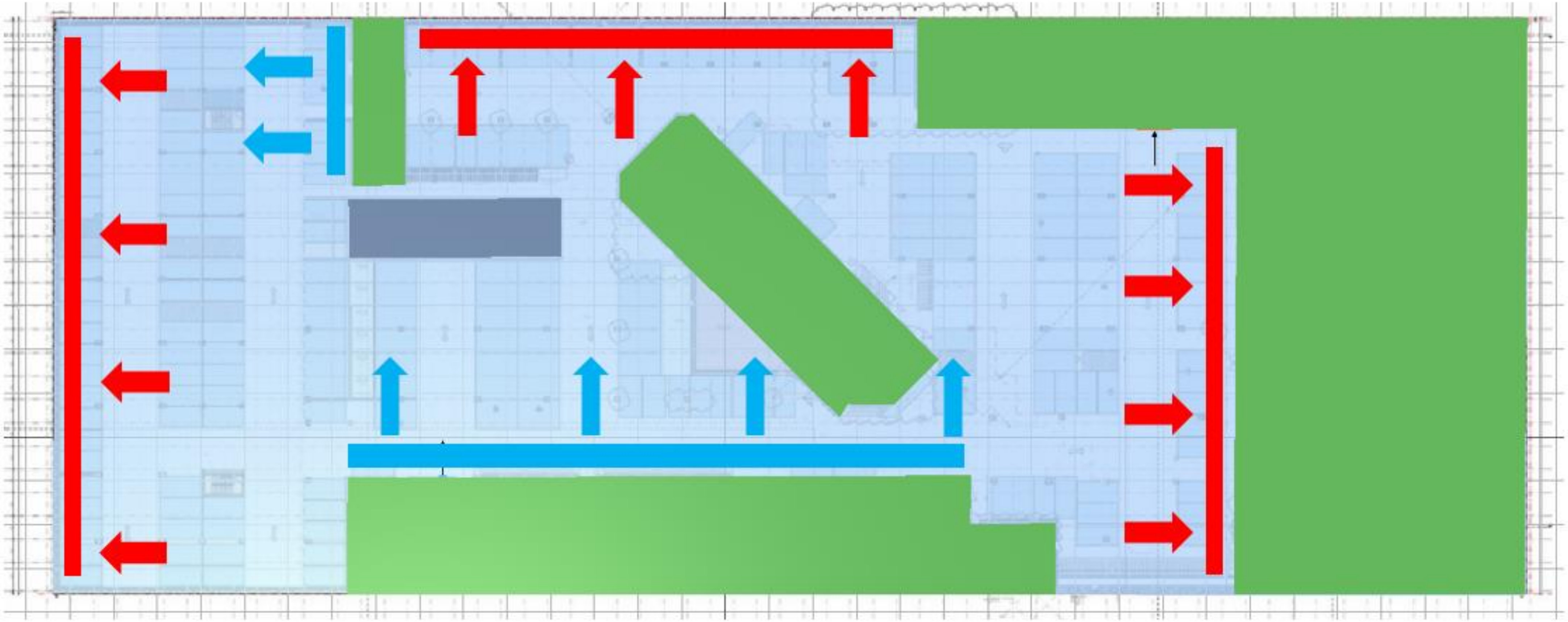



Add. supply
Extract
Supply



Ducted Approach



Ducted Approach

- Space limitations
- Non-efficient duct design
- Impossible to do performance driven designs such as the control of smoke
- Due to high system resistances, higher friction thus higher power requirement
- Higher maintenance costs

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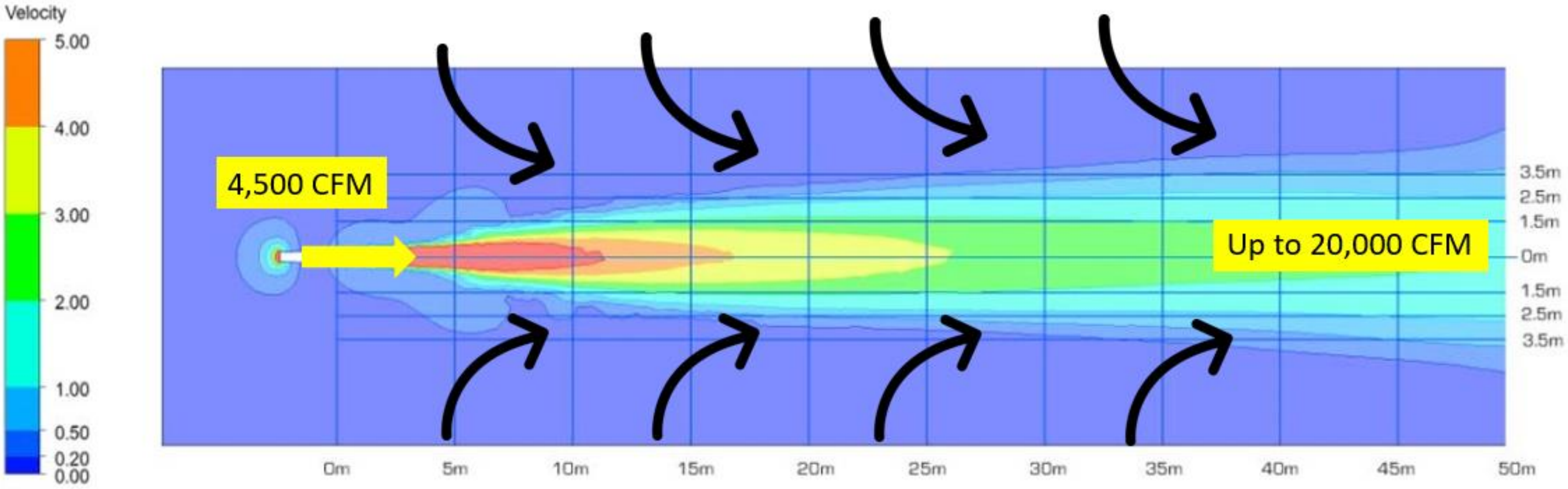
Jet Fan Range for Parking Garages

Jet Thrust Approach

Jet Thrust Systems

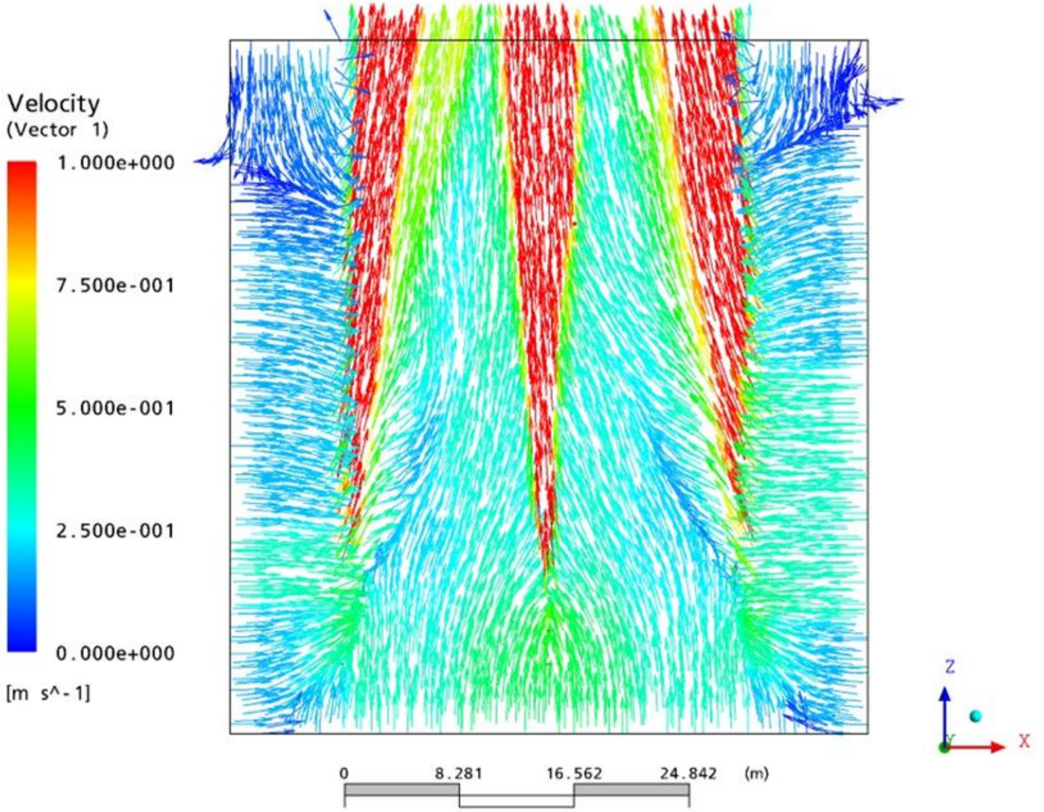
- Reduced space requirement
- Aero-dynamically more efficient due to positive forward thrust
- Possible to provide more performance driven designs for instance controlling smoke
- Flexible and easier installation
- Lower overall power requirement
- Together with intelligent controls lower operational costs
- Easy maintenance

Jet Thrust Fan Fundamentals

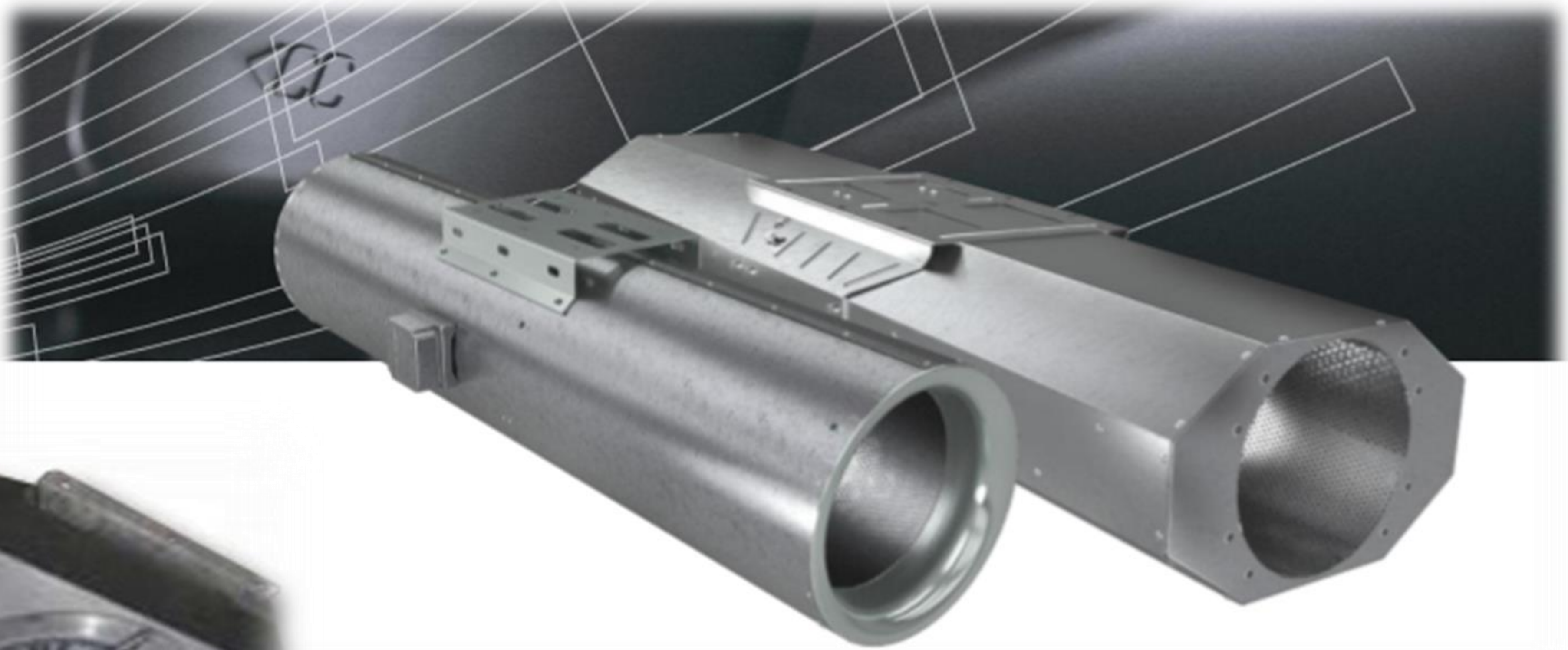


Jet Thrust Fan Fundamentals

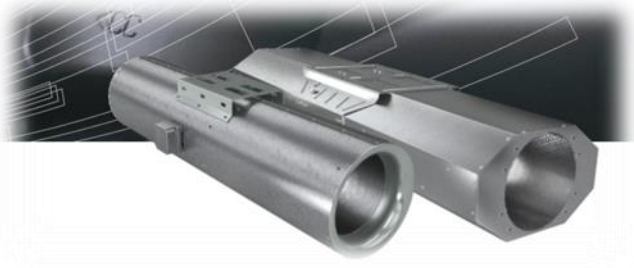
Indicative Jet Fan performance (CFD top view, 3 Jet fans in parallel)



Jet Thrust/Induction Fans



Jet Thrust/Induction Fans



Diameter (mm)	Thrust (N)	Volume (m3/s)	Sound Power (L_{WA})	Sound Power (L_{PA}) @ 3m	Pole Speed	Nominal Power (kW)	Full Load Current (A)	Starting Current (A)
	High / Low Speed	High / Low Speed	High / Low Speed	High / Low Speed	High / Low Speed	High / Low Speed	High / Low Speed	High / Low Speed
Uni-Directional								
JTv Slim Line (60Hz)								
315	40 / 10	1.61 / 0.82	77 / 62	56 / 41	2 / 4	1.20 / 0.16	2.70 / 0.70	13.4 / 2.30
355	57 / 15	2.16 / 1.11	84 / 68	63 / 47	2 / 4	1.30 / 0.18	2.90 / 0.60	13.4 / 2.30
400	71 / 18	2.73 / 1.38	81 / 68	60 / 47	2 / 4	1.70 / 0.22	3.70 / 1.00	21.4 / 4.40
400 Max	88 / 23	3.03 / 1.54	81 / 68	60 / 47	2 / 4	2.39 / 0.32	5.20 / 1.40	30.1 / 6.20
JTv Low Profile (60Hz)								
315	34 / 9	1.49 / 0.76	77 / 61	56 / 40	2 / 4	1.20 / 0.16	2.70 / 0.70	13.4 / 2.30
355	48 / 13	1.98 / 1.02	77 / 61	56 / 40	2 / 4	1.30 / 0.18	2.90 / 0.60	13.4 / 2.30
400	66 / 17	2.64 / 1.34	81 / 65	60 / 44	2 / 4	1.70 / 0.22	3.70 / 1.00	21.4 / 4.40
400 Max	85 / 22	2.98 / 1.51	82 / 67	61 / 46	2 / 4	2.39 / 0.32	5.20 / 1.40	30.1 / 6.20

355 – 13 lb of Thrust

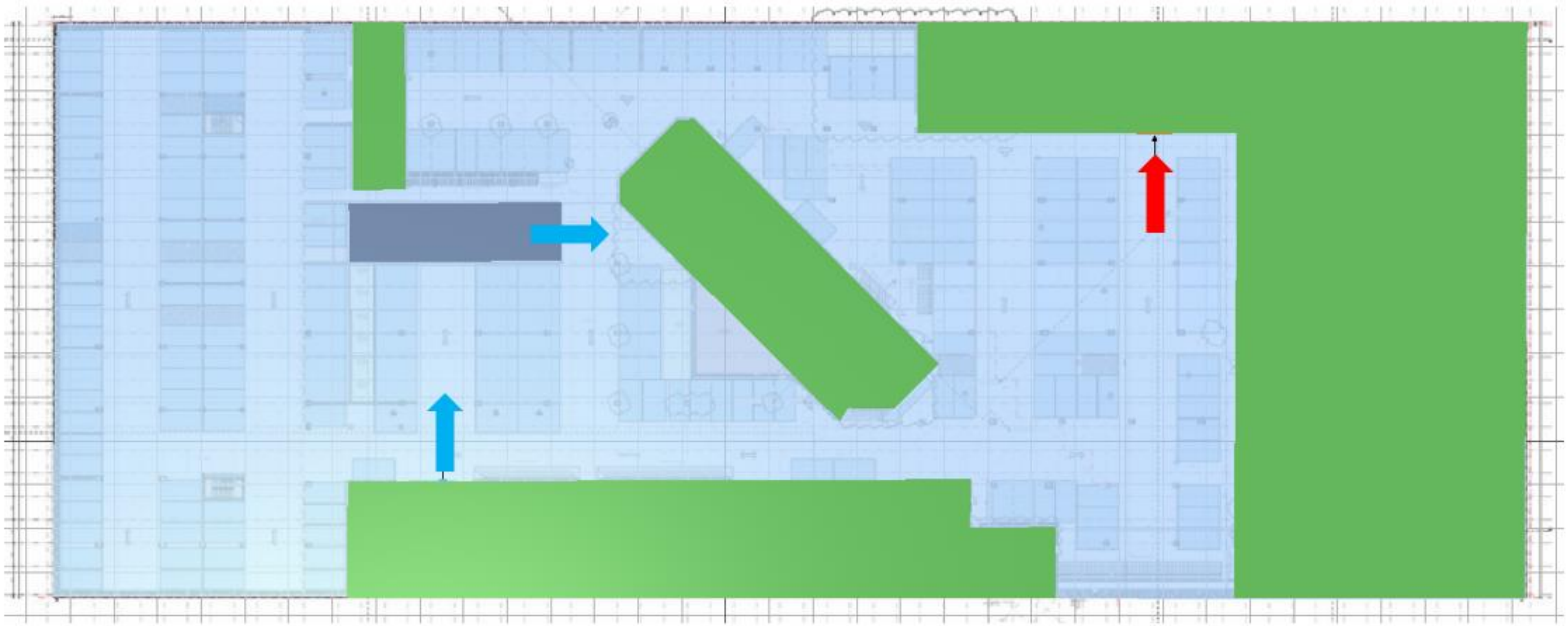
400 – 16 lb of Thrust

Jet Thrust/Induction Fans

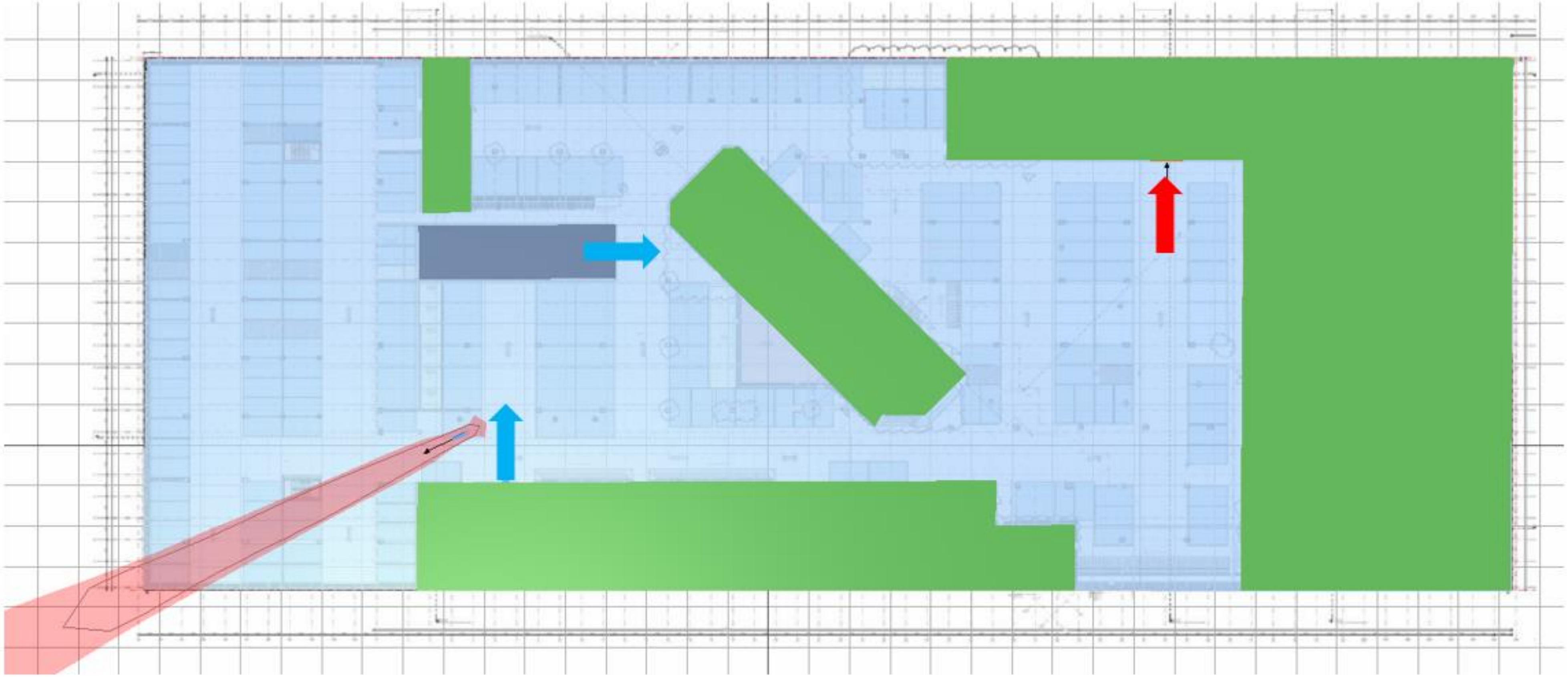
Dia	Product Type	Thrust N	Volume m^3/s	Sound Power Lw_A	Sound Pressure Lp_A @ 3m	Rpm	Nominal Power kW	Full Load Current (A)	Starting Current (A)
50N	Induction	50/12	1.5/0.77	98/77	83/62	1670/830	1.5/0.37	3.4/1.43	20/5

11 lb of Thrust

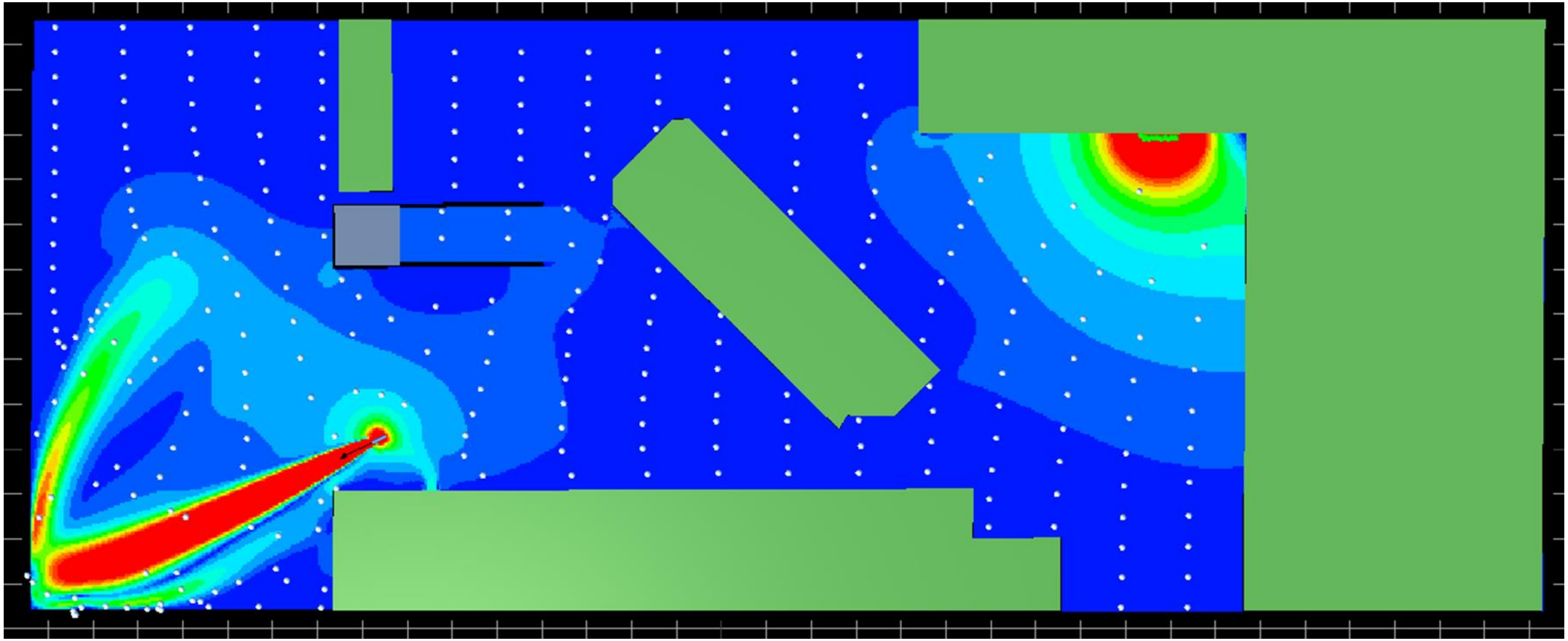
Jet Thrust Approach



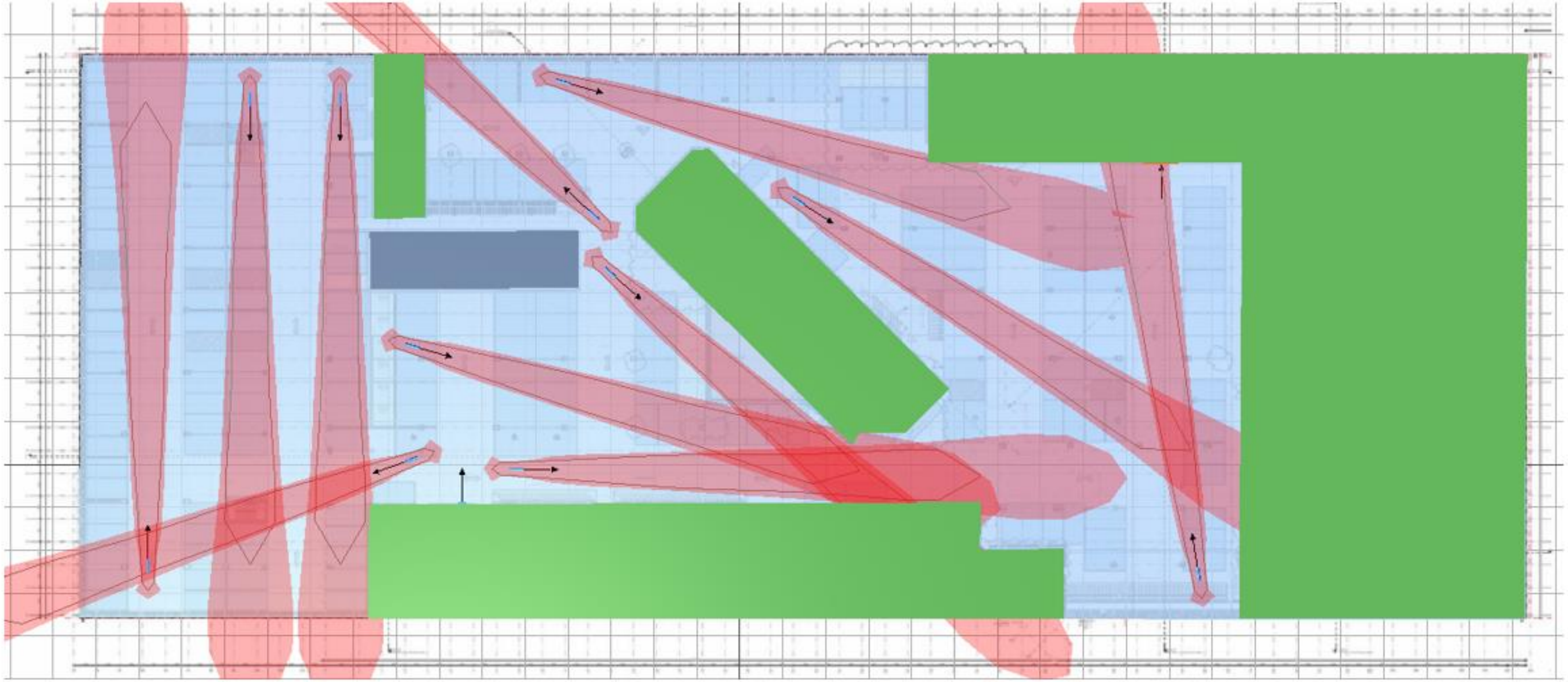
Jet Thrust Approach



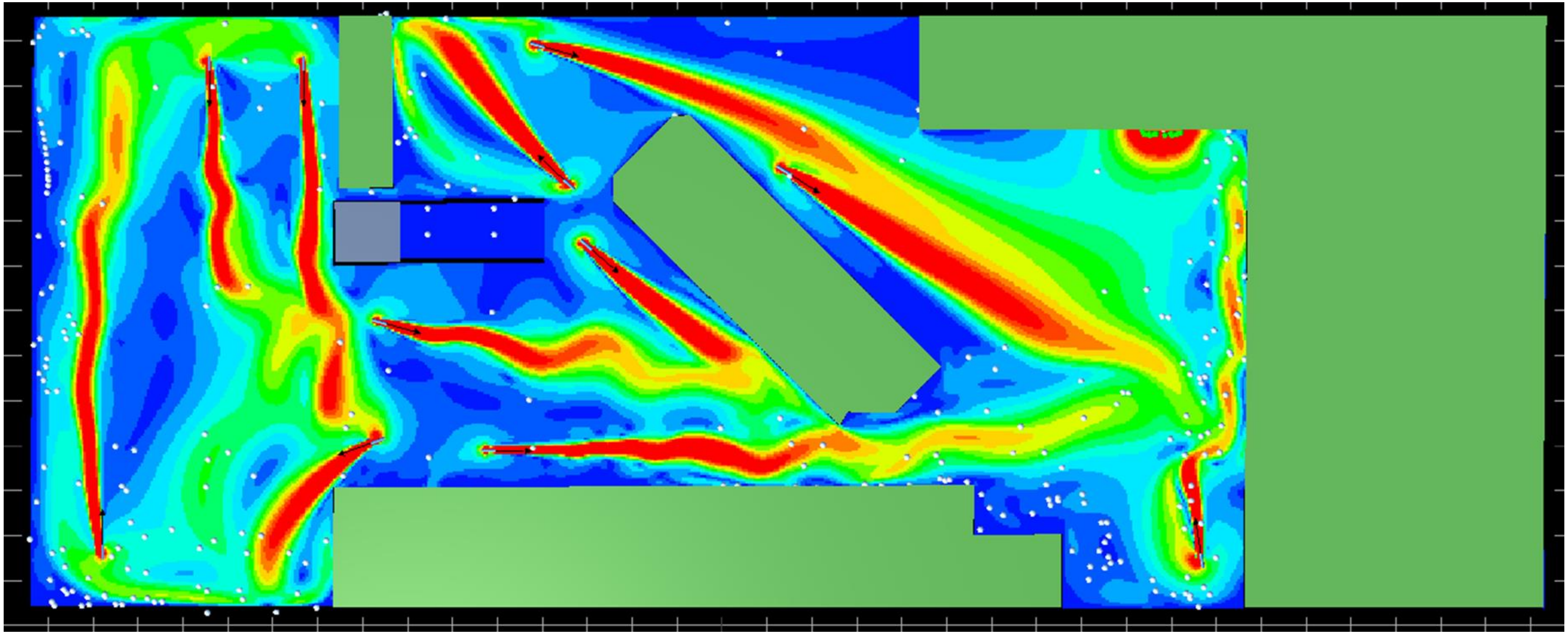
Jet Thrust Approach



Jet Thrust Approach



Jet Thrust Approach

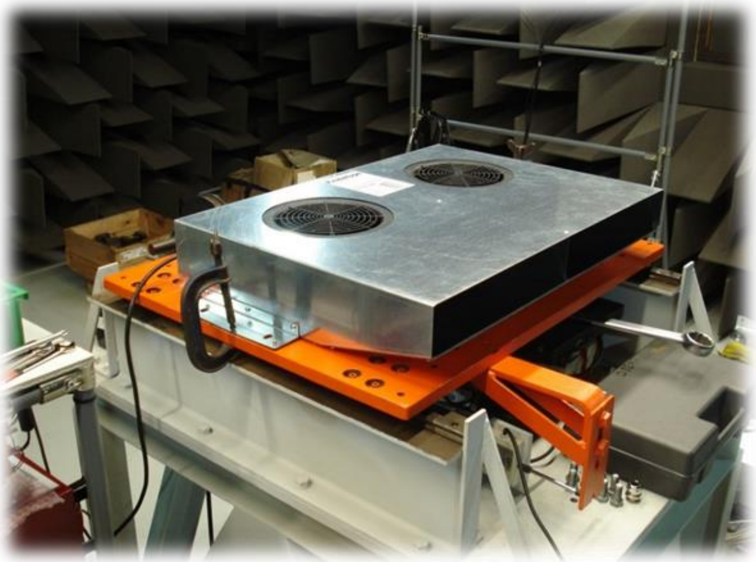


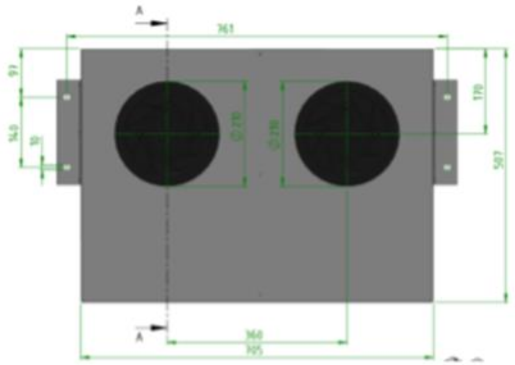
Jet Thrust Approach

Estimate on required number of units for provisional design purposes.

Unit output Thrust	Throw length	Spreading (centre to centre spacing)
11 lb / 50 Newton	148 ft	25 ft
13 lb / 57 Newton	195 ft	30 ft
16 lb / 71 Newton	230 ft	35 ft

Very Low Profile Induction Fan Unit





Nominal data		
Voltage	200 - 240	V
Frequency	50/60	Hz
Phase	Single	
Input power	0.23	kW
Current	2.48	A
Thrust (theoratical)	12	N
Max. Air flow rate	2,600	m^3/h
Fan impeller speed	2,510	rpm
Weight	15.3	kg
Temperature data		
Max. air temperature	55	°C
Sound data		
Sound pressure level at 3 meters 90° (free field)	67	db(A)
Protection / Classification		
Insulation class	B	
Enclosure class, motor	IP 44	

Very Low Profile Induction Fan Unit

Estimate on required number of units for provisional design purposes.

Unit output Thrust	Throw length	Spreading (centre to centre spacing)
3 lb / 13 Newton	80 – 85 ft	18-20 ft
11 lb / 50 Newton	148 ft	25 ft
13 lb / 57 Newton	195 ft	30 ft
16 lb / 71 Newton	230 ft	35 ft

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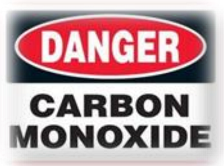
Smoke Extraction in the Event of a Fire

Main reasons for requiring ventilation in enclosed parking garages…

A. Reduce toxic levels of ***Carbon Monoxide*** and ***Nitrogen Oxides*** within parking garage.



B. Provide a means of ***extracting smoke during or after a fire has been extinghuised.***

What About Dealing with Smoke?

First…

Life safety of the public has to come from passive fire safety measures (fire escapes).

What About Dealing with Smoke?

Second…

Ventilation system design should not be such that it will compromise evacuation of the public.

What About Dealing with Smoke?

Two possible design approaches…

1. *Clearing smoke during and after the fire.*

2. *Maintaining sufficient visibility for fire firefighters allowing more efficient firefighting, reducing fire load limiting structural damage.*

What About Dealing with Smoke?

Code of Practice BS 7346 Part 7

- *Functional recommendations for smoke & heat control systems for covered Parking Garages.*

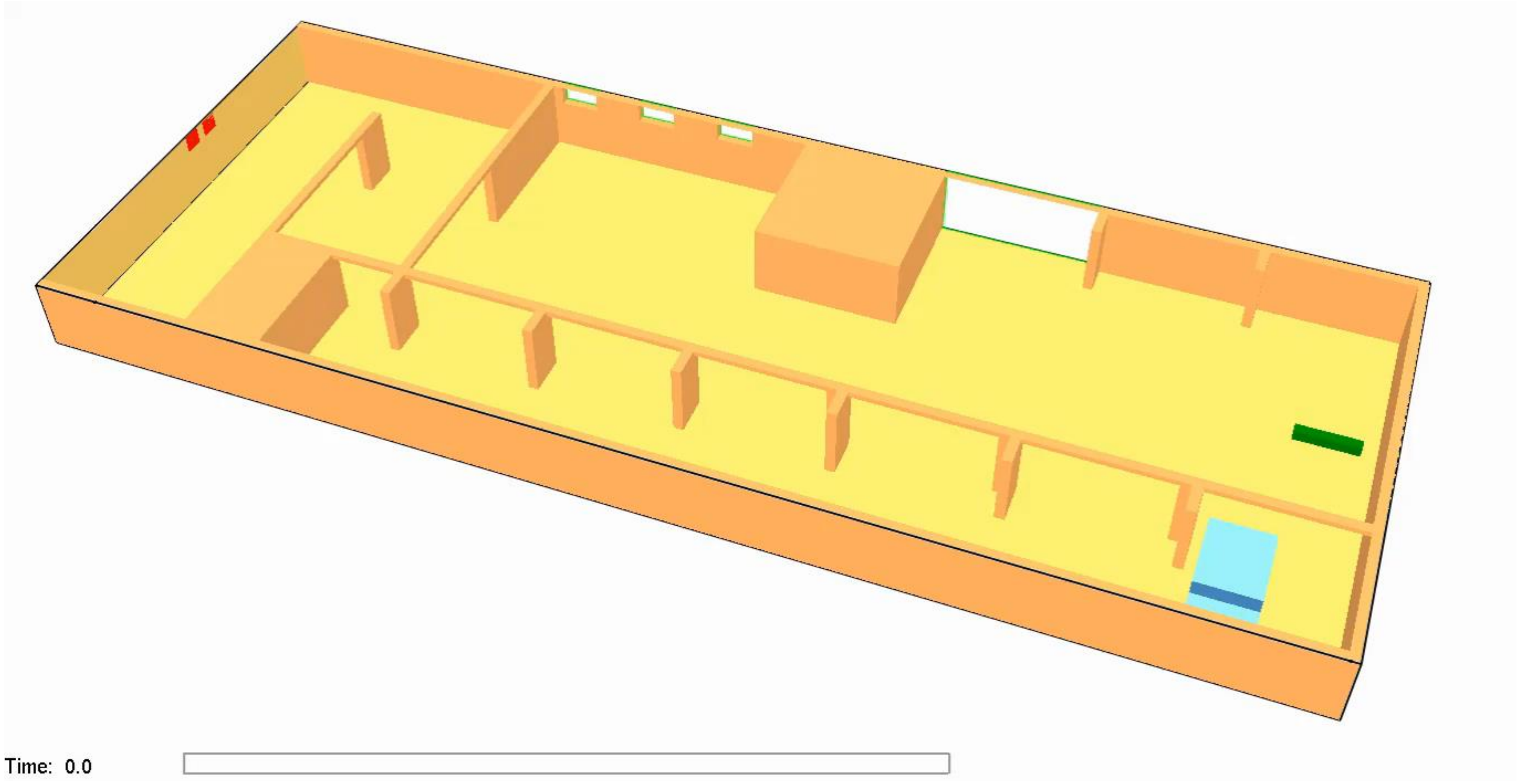
Commonly Used Standards

Code of Practice BS 7346 Part 7

- **Section 9:** Smoke clearance at 10 ACH
- **Section 10:** Assist Fire-fighter access

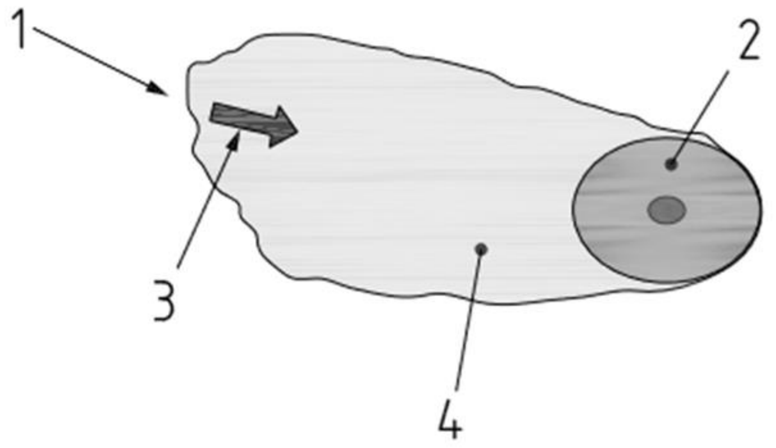
System Performance in Smoke Mode

Smoke Clearance System (10 ACH)



System Performance in Smoke Mode

Code of Practice BS 7346 Part 7 – Section 10



Key

1 Fire-fighter access point

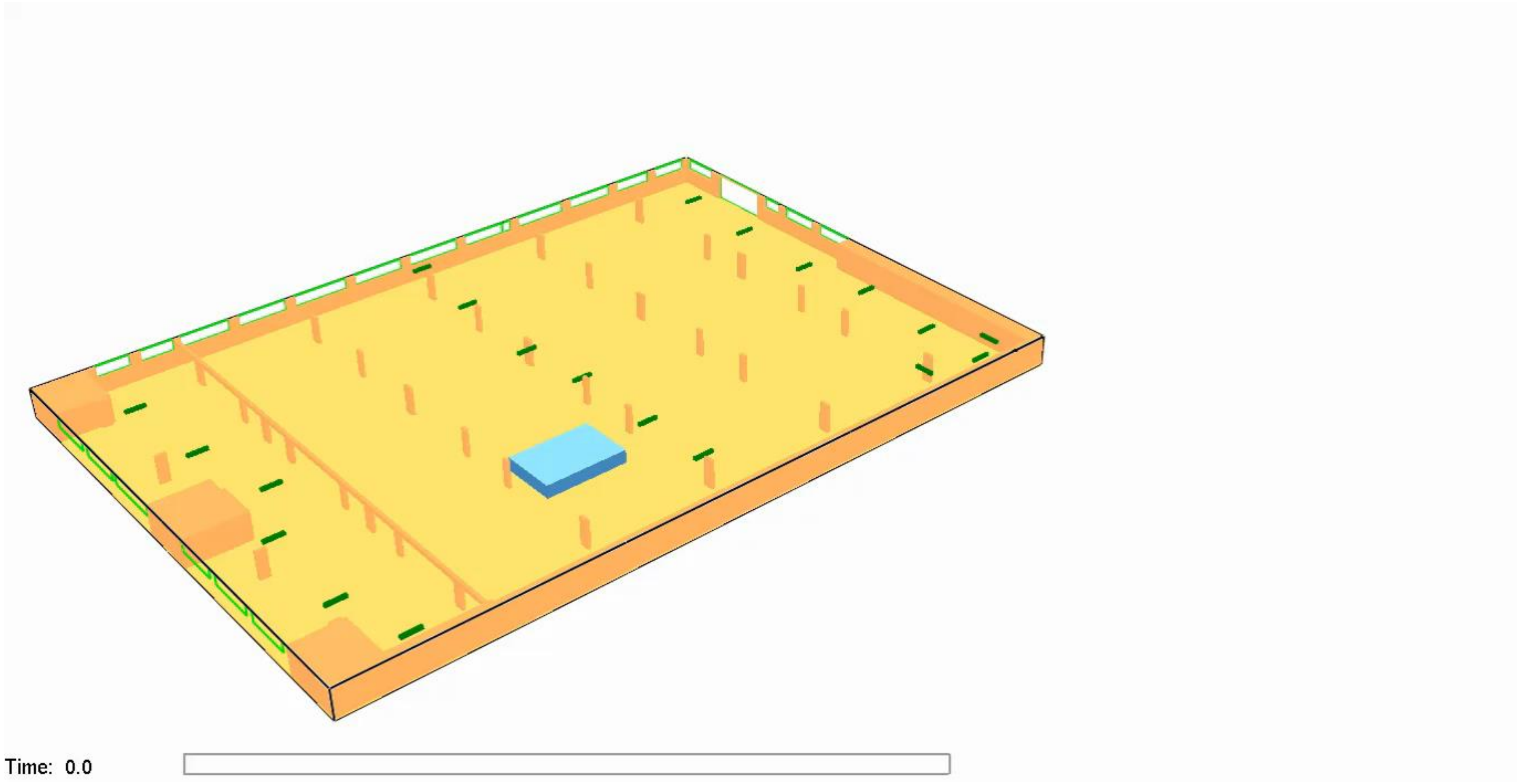
2 Visibility within 10 m of the fire can be zero

3 Fire service approach

4 Visibility in this area is at least 10 m

System Performance in Smoke Mode

Assisting Fire-fighter Access/Smoke Control (Engineered Solution)



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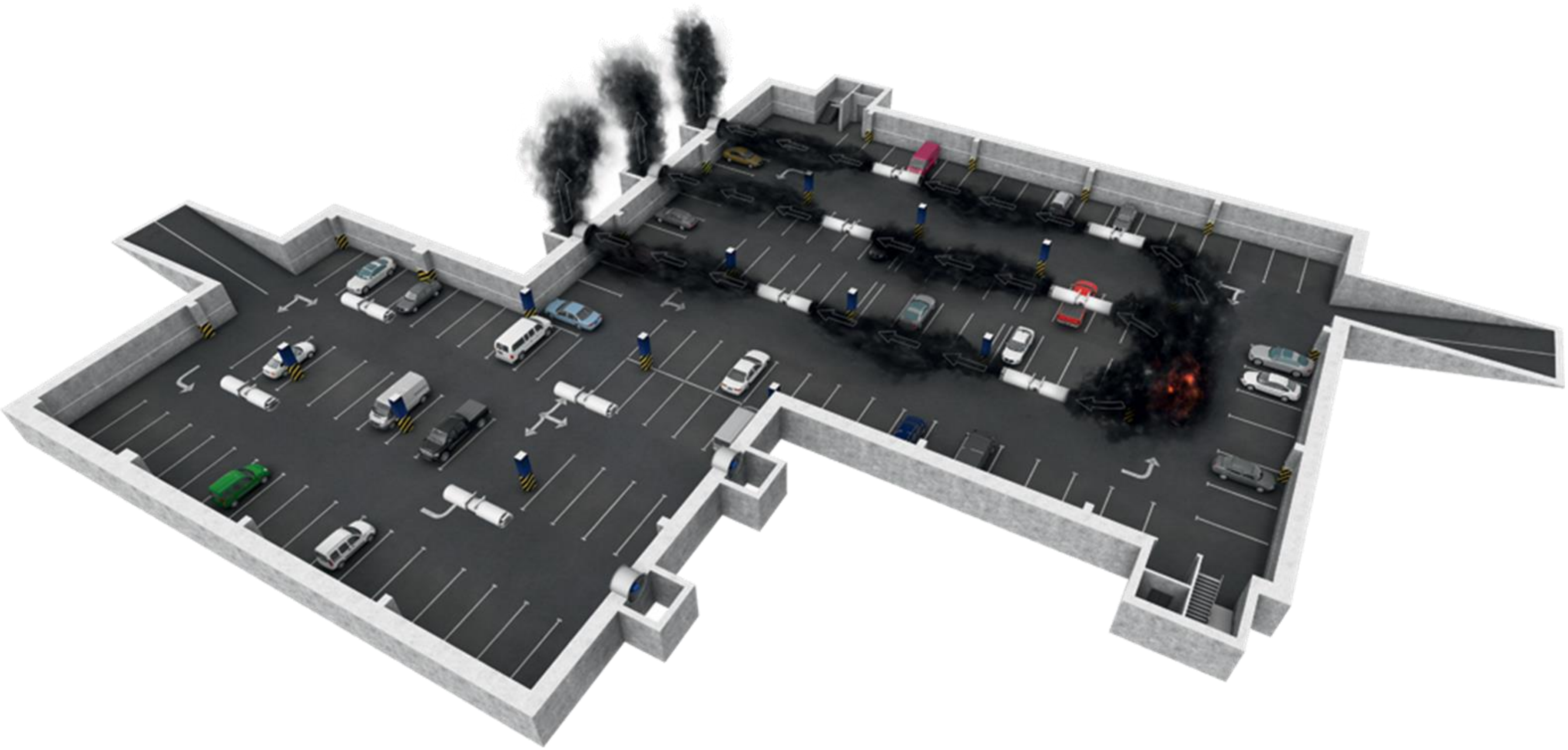
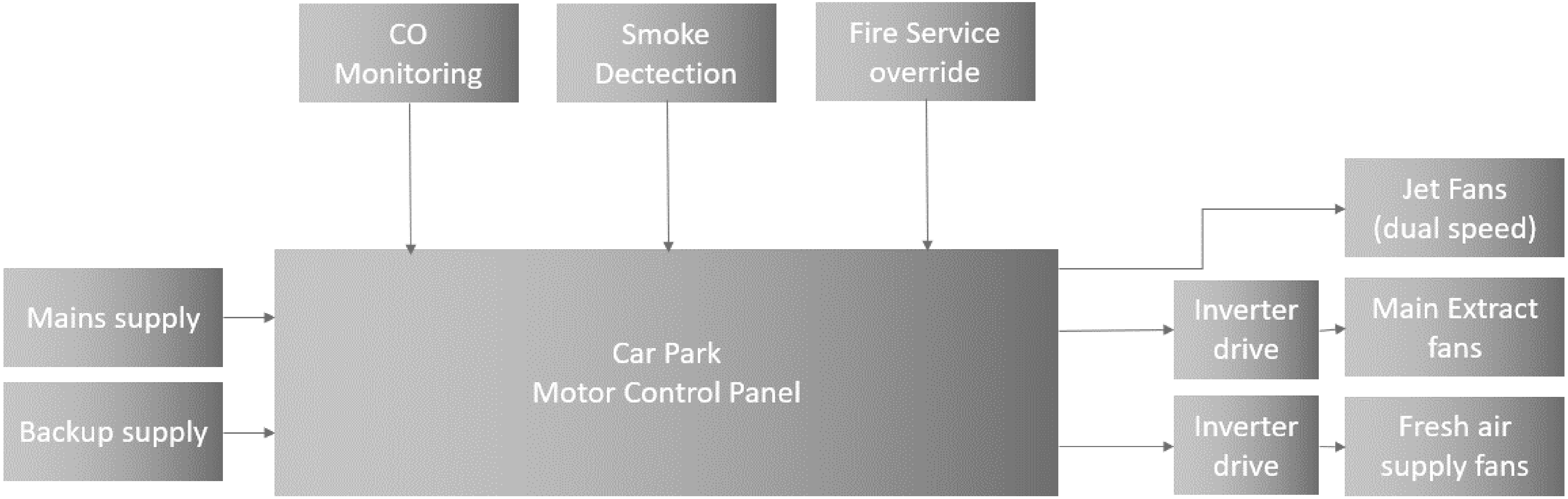
Controls & System Interaction

The Overall System



The Overall System



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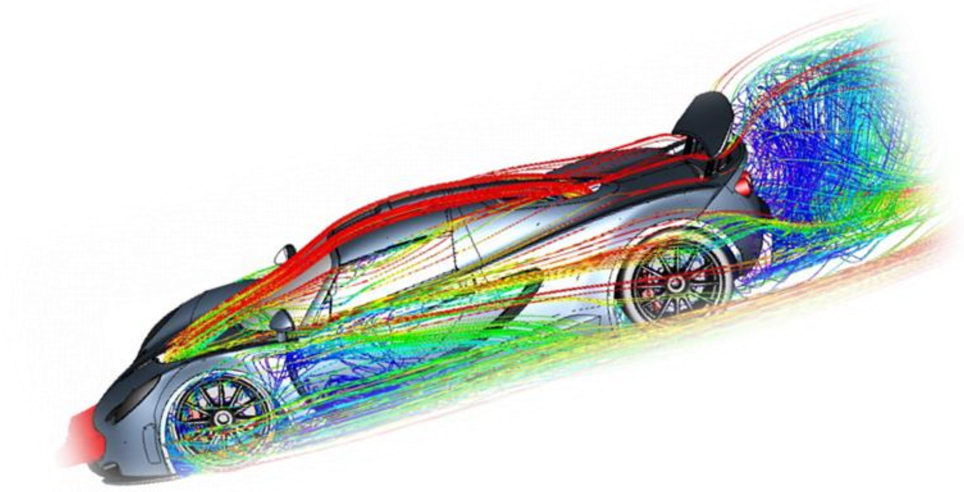
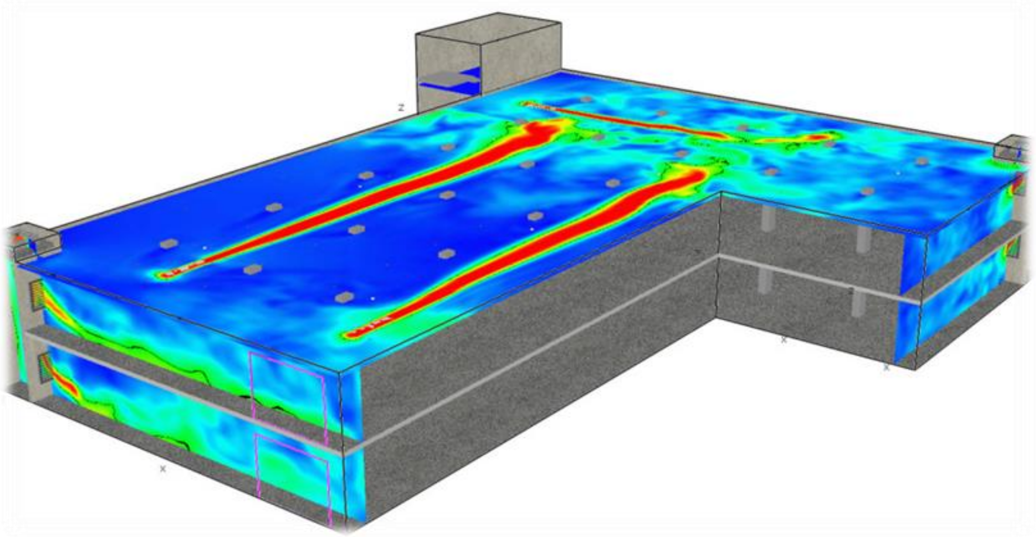
Design Validation Applying CFD Analysis

Design Validation Using Computational Fluid Dynamics

Allows detailed assessment of air flow patterns and behaviour by solving ***ITERATIVE*** (repeating) ***NUMMERIC EQUATIONS.***





Design Validation Using Computational Fluid Dynamics

The Principle:

- Convert structural layout design in a CFD domain
- Divide domain into a quantity of cells
- Within each cell resolve a number of Navier-Stokes equations
- Convert numeric data into graphic represenation of:
  - Air velocity profiles
  - Air quality (CO contamination levels)
  - Smoke spread
  - Smoke density & visibility
  - Temperature distribution

Design Validation Using Computational Fluid Dynamics

Air Velocities:

- Sample graphic representation of air velocity profiles
- Highlighting areas of high and low velocity
- Assess velocities at different heights

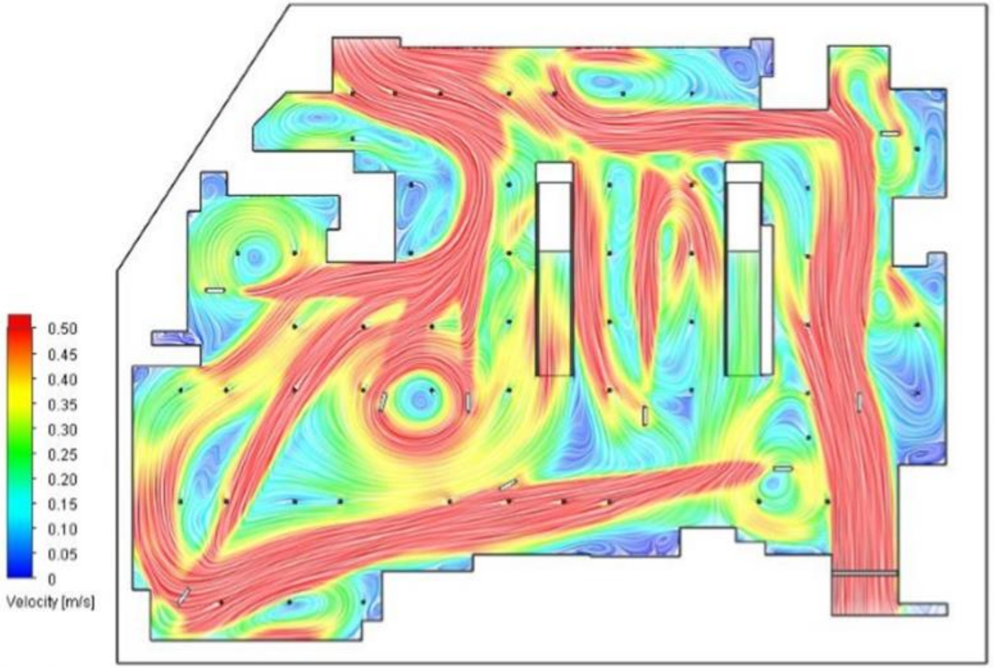


Figure 1: Velocity Streamlines at 1.8m Level 0

Design Validation Using Computational Fluid Dynamics

Air Velocity Vectors:

- Sample graphic representation of air velocity vectors
- Highlighting areas of high and low velocity vectors
- Allowing assessments of velocities vectors at different heights
- Allowing assessments of air direction and possible re-circulation

Figure 2: Velocity Vectors at 1.8m Level 0

Design Validation Using Computational Fluid Dynamics

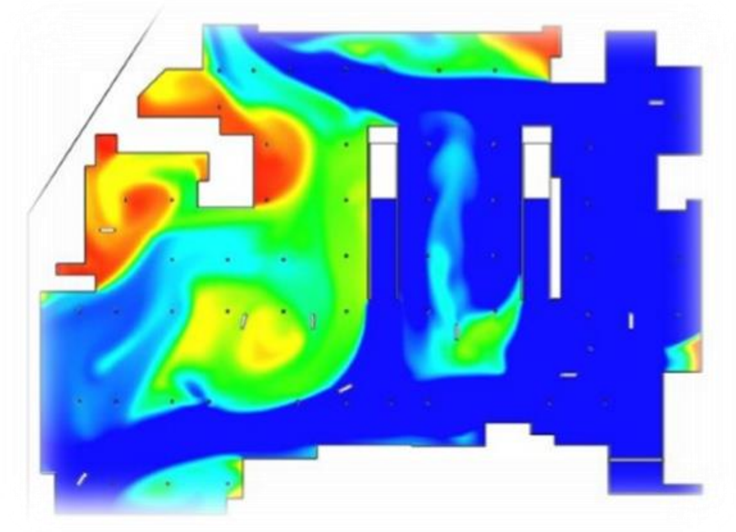
Air Contamination Analysis:

Sample graphic representation of contamination levels

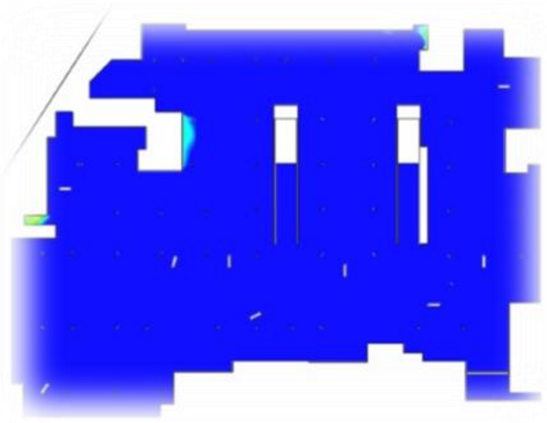
A = CO contamination (Red = high levels of CO, Blue = low levels of CO)

B = CO contamination with ventilation system in operation

A

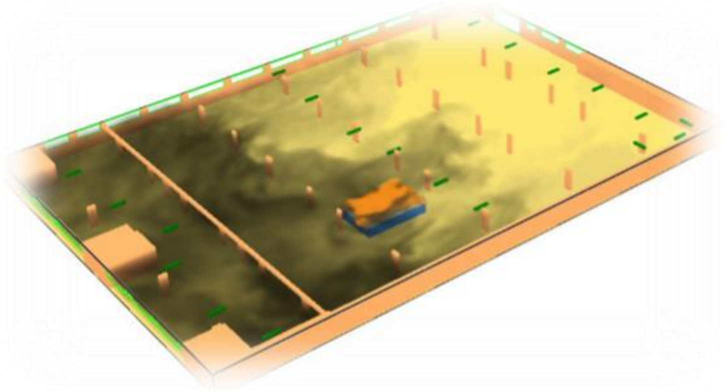


B

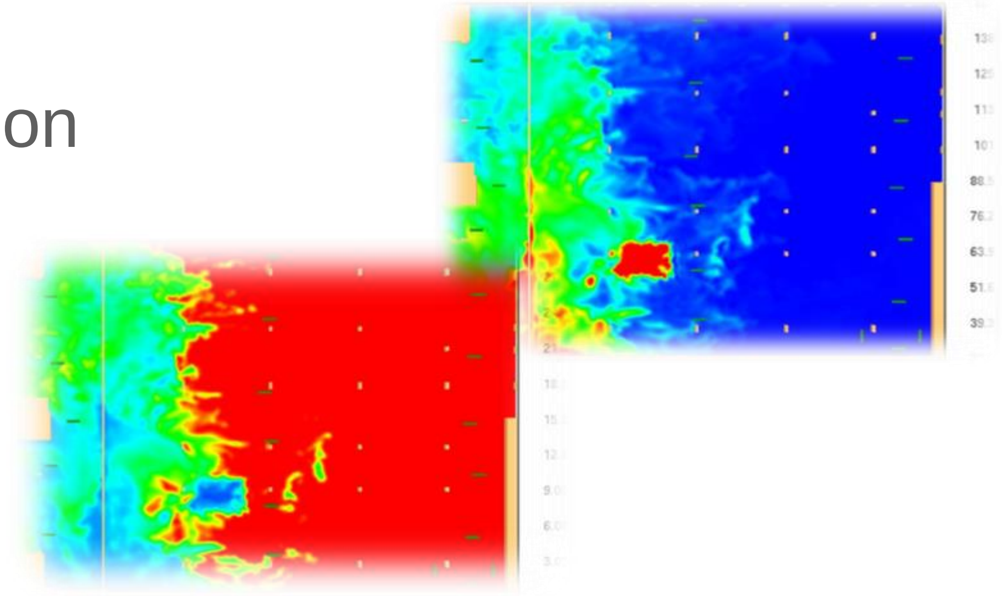


Design Validation Using Computational Fluid Dynamics

Fire & Smoke Analysis:



- Sample graphic representation of fire/smoke
- Assessment of Smoke Density
- Assessment of Optical Visibility
- Assessment of Temperature Distribution



Resources

- **AMCA International**: www.amca.org
- **ANSI/AMCA Standards:** www.amca.org/store

  > 99-16: *Standards Handbook* *(Available for purchase)*

  > 210-16/ASHRAE 51-16: Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating *(Available for purchase)*

- **AMCA Publication:** www.amca.org/store

  > 201-02 (R2011): Fans and Systems *(Available for purchase)*

Thank you for your time!

*To receive PDH credit for today's program, you **must** complete the online evaluation, which will be sent via email 1 hour after this webinar.*

PDH credits and participation certificates will be issued electronically within 30 days, once all attendance records are checked and online evaluations are received.

Attendees will receive an email at the address provided on your registration, listing the credit hours awarded and a link to a printable certificate of completion.

Questions?

NEXT PROGRAM

Join us for our next AMCA *insite*™ Webinar:

- Wednesday, April 21
- 6:00-7:00pm CT
- ***AMCA & RSES Journal Webinar: Field Modifications of Fire, Smoke, and Combination Fire/Smoke Dampers***
- Presenter: James Carlin, Product Manager- Dampers, AMCA Member Company

>> For additional webinar details go to: *www.amca.org/webinar*