Car Park Ventilation Solutions: Part 2

AMCA Speakers Network Presentation | AMCA International | www.amca.org

Lisa Cherney

Education Manager, AMCA International

Webinar Moderator

- 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.

Introductions & Guidelines

- Participation Guidelines:
  - Audience will be muted during the webinar.
  - Questions can be submitted anytime via the GoToWebinar platform and will be addressed at the end of the presentation.
  - Reminder: This webinar is being recorded!
  - To earn PDH credit for today, please stay clicked onto the webinar **for the entire hour**.
  - A post-webinar evaluation will be emailed to everyone one hour after today's broadcast, and it must be completed to qualify for today's PDH credit.

Q & A

To submit questions:

- From the attendee panel on the side of the screen, select the "Questions" drop down option.

- Type your question in the box and click "Send".

- Questions will be answered at the end of the program.

AMCA International has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

Attendance for the entire presentation AND a completed evaluation are required for PDH credit to be issued.

DISCLAIMER

The information contained in this webinar is provided by AMCA International as an educational service and is not intended to serve as professional engineering and/or manufacturing advice. The views and/or opinions expressed in this educational activity are those of the speaker(s) and do not necessarily represent the views of AMCA International. In making this educational activity available to its members and others, AMCA International is not endorsing, sponsoring or recommending a particular company, product or application. Under no circumstances, including negligence, shall AMCA International be liable for any damages arising out of a party's reliance upon or use of the content contained in this webinar.

COPYRIGHT MATERIALS

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.

Erik Scheffrahn

Technical Manager: Car Parks & Fire Safety,
AMCA Member Company

- Involved in the development of jet fan parking garage ventilations systems since 1995.
- Involved in the turnkey approval, engineering and project management of these systems globally.
- Was a member of the British Standard Committee responsible for the publication of BS 7346 part 7 Code of Practice on the functional recommendations and calculation methods for smoke and heat control systems for covered car parks (which also includes a section on the day-to-day ventilation requirements).

Aaron Sherman

Product Manager & Consultant, AMCA Member Company

- For over 7 years has worked in all facets of applications and product lines that support residential, commercial, industrial and portable solutions.
- Starting in technical support and inside sales, he has helped broaden his knowledge in multiple industries. Over the last 4 years his focus has been on the HVAC and Controls market.
- Supporting engineers, integrators, contractors, and distributors via trainings both on the technical and sales side to ensure the correct solution is provided.
- If you have any questions regarding gas detection he is a great resource to reach out to.

Purpose and Learning Objectives

The purpose of this presentation is to answer questions asked at the end of the previous presentation "Introduction to Parking Garage Ventilation Solutions". When reviewed, the questions asked related to six separate, but related themes:

- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control Systems & Sensors
- Jet Fan Technical Capabilities

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

1. Evaluate effective parking garage ventilation design.
2. Specify the appropriate parking garage ventilation system needed per project.

Agenda

- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control System & Sensors
- Jet Fan Technical Capabilities

Applicable Design Codes and Standards

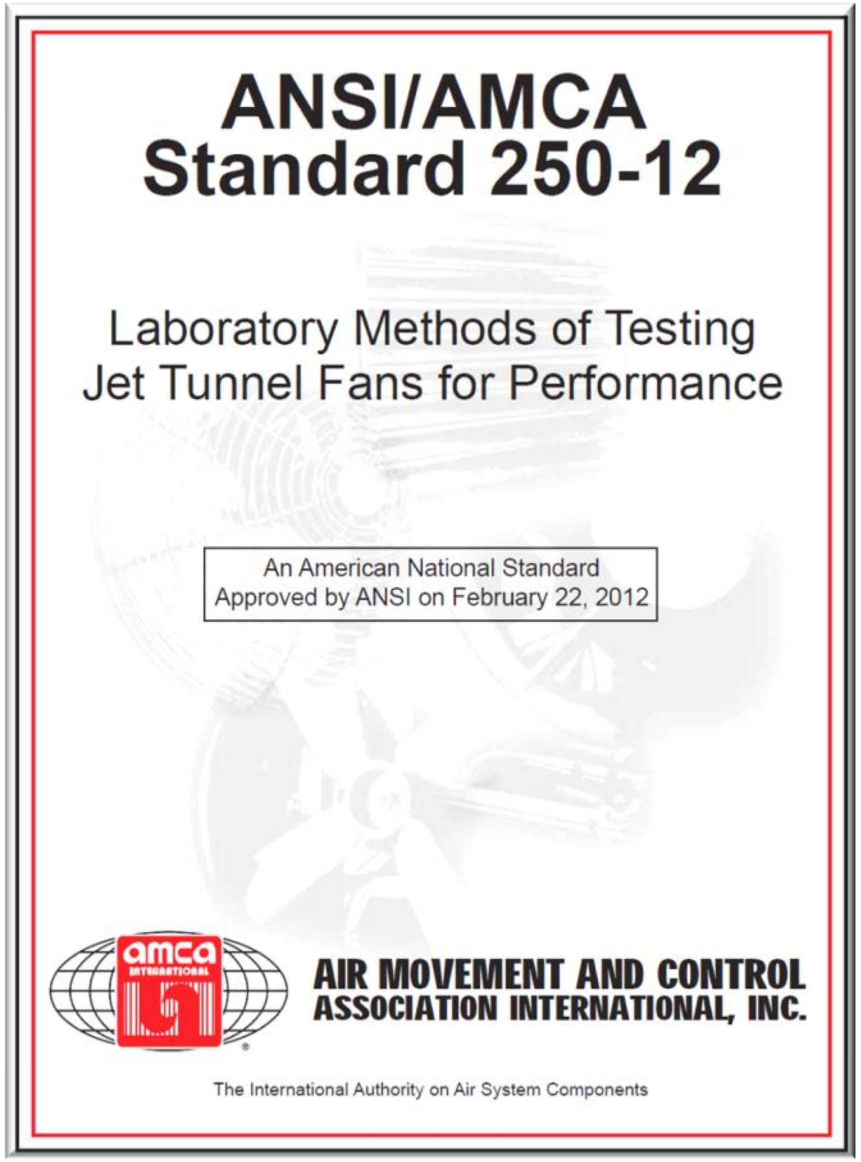
- Parking garage ventilation systems in the USA are typically required to comply with the requirements of the international mechanical code (IMC) 2015 or 2015 ASHRAE Handbook Section 15.19.
- There is a current proposal (FS90-21) being discussed for the 2021 revision of the IMC that shaft enclosures should be permitted to be penetrated by ducts and air transfer openings protected with listed fire and smoke dampers installed in accordance with their listing.
- Proposal G68-21 advocates the maximum size of a private garage (that do not require mechanical ventilation) be increased from 1,000 to 3,000 square feet.
- Proposal M51-21, M52-21, M53-21 and M54-21 clarify return air opening requirements.

Monitoring Code and Standard Development

- AMCA is an active participant in NFPA, ICC, IAPMO, UL and ISO, each of which develop codes or standards that impact the air movement and control industry.
- AMCA also works with the Hickman Group who maintain relationships with regulatory agencies and associations including the International Code Council (ICC), United States Department of Energy (DOE), National Association of Home Builders (NAHB), regional Code Official Chapters and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
- Hickman Group staff serve on technical committees including the ICC's Sustainability, Energy, High Performance Building Code Action Committee (SEHPCAC), ASHRAE 90.1, and The Energy Rating Index Workgroup for the Florida Building Commission.
- Through their own activity and the relationship with the Hickman Group, AMCA is able to keep members briefed on proposed and forthcoming changes to codes and standards.

AMCA 250

- The technical committee responsible for AMCA 250 is considering a change to the scope of AMCA 250, removing the word “tunnel” from the standard and in so doing extending AMCA 250 to cover jet fans in all applications.
- The technical committee also considered adding a jet fan specific sound measurement method to AMCA 250 but appears not to favor doing so.
- Another pending discussion is measurement of vibration, specifically if it should be added to AMCA 250. It is noteworthy that client specifications routinely require jet fan vibration to be measured.


ANSI/AMCA
Standard 250-12

Laboratory Methods of Testing
Jet Tunnel Fans for Performance

An American National Standard
Approved by ANSI on February 22, 2012

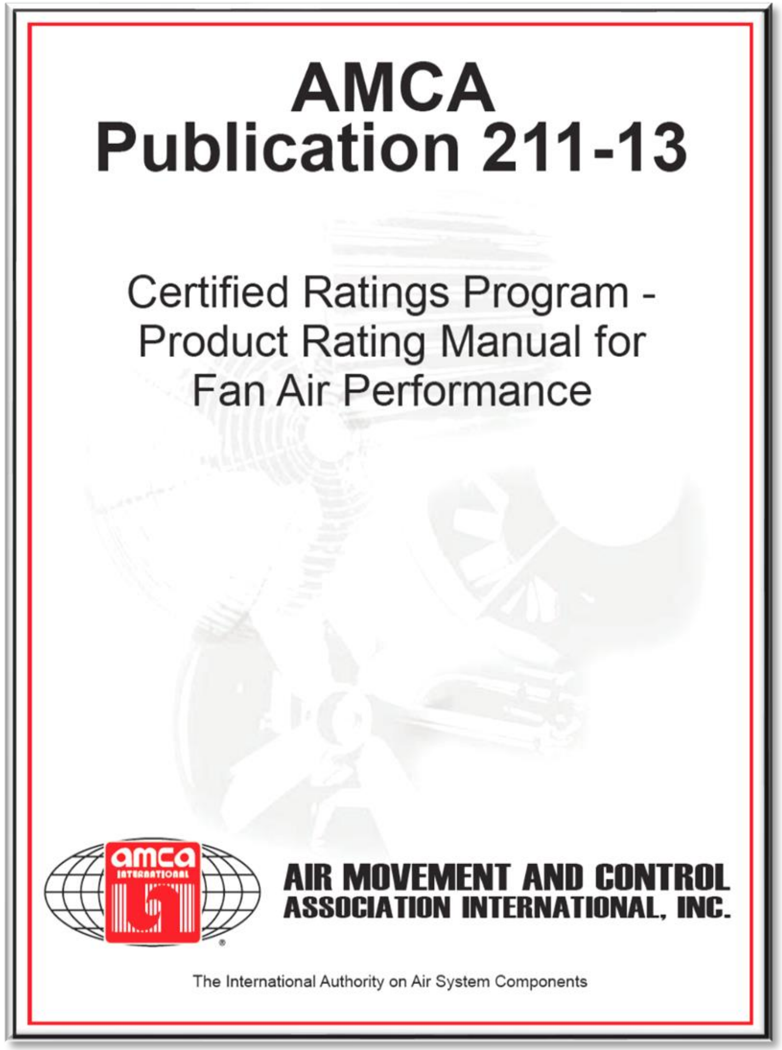
AIR MOVEMENT AND CONTROL
ASSOCIATION INTERNATIONAL, INC.

The International Authority on Air System Components

AMCA Certification

- Following the October 2018 revision of AMCA Publication 211, *Certified Ratings Program Product Rating Manual for Fan Air Performance*, jet fans can no longer be certified using ANSI/AMCA Standard 210/ASHRAE Standard 51 and ISO 5801. They must be certified using ANSI/AMCA Standard 250.

- AMCA 250: 2012 states that jet fan sound measurement are made in accordance with the requirements of AMCA 300-96 *Reverberant Room Method for Sound Testing of Fans.*


AMCA
Publication 211-13

Certified Ratings Program - Product Rating Manual for Fan Air Performance

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.

The International Authority on Air System Components

Agenda

- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control System & Sensors
- Jet Fan Technical Capabilities

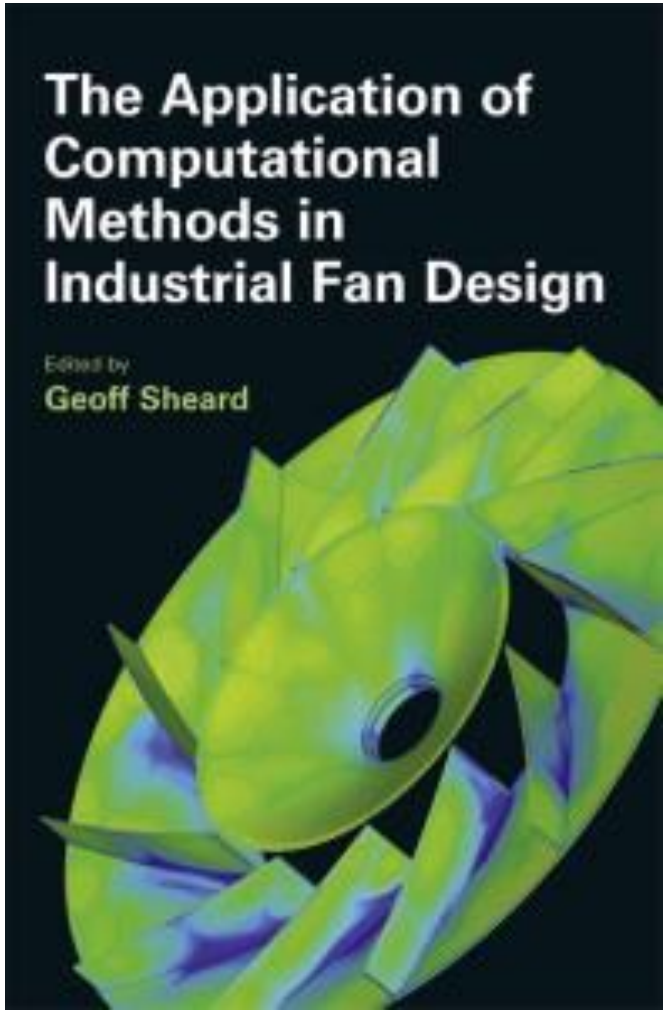
What is CFD?

"Computational Fluid Dynamics (CFD) is the process of mathematically modeling a physical phenomenon involving fluid-flow and solving it numerically."

- In the mid 1970's a NASA scientist predicted that "wind tunnel testing will no longer be needed by the end of the decade".
- Today, almost 50 years latter, there is no sign of anyone closing their laboratories any time soon.
- What do we conclude from this? NASA scientists are dumb? They did put a man on the moon, 12 actually. They can't be completely stupid.

What is CFD?

- Perhaps counter-intuitively, applying CFD into air movement and control applications is harder then applying it to the design of a new aircraft or rockets.
- Air movement fans are not that aerodynamic, and there is nothing more difficult then predicting “bad” aerodynamics.
- Despite the above reservation, since 2010 computing power has dropped in price ($0.1 per CPU hour on the AWS cluster) to the point where you can run a CFD with a fine enough mesh to give accurate results.
- If you want more detail, you can find it in my book that contains a most excellent 416 pages of detail. However, it may be easier on you to just accept; CFD can work these days if you know what you are doing.



When to Apply CFD?

- Laboratory testing and CFD analysis are like religion, you either believe or you do not. Believers and non-believers tend not to talk, preferring to characterize each other as less competent than desirable.
- The fact of the matter is that laboratory testing and CFD in combination work better then either in isolation.
- There tends to be an 80:20 rule in life generally, you can get 80% of the result with 20% of the effort.
- Hence, if you spend just 20% of your lab budget on CFD, you will probably get 80% of the benefit.

How is CFD Applied in Practice

- If adding CFD into the mix results in a “better process” what does “better” actually mean?
- In practice “better” means pragmatism: use your lab to do what a lab does best and CFD to do what it does best.
  - Example: it’s easy to measure jet fan thrust in a lab and difficult to do it with CFD, so measure it in a lab.
  - Example: you could establish the effectiveness of a car park ventilation system by setting the car park on fire. That would work, but its easier to do it in CFD, so use CFD.
- Hence, better means being able to have a go at doing those things you can’t realistically do experimentally using CFD.
- The alternative is to do what you have always done, leave your competitors to figure out how use CFD to steal you lunch. As long as you’re over 60 and only need another two or three years before retiring that strategy will work just fine.

Agenda

- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control System & Sensors
- Jet Fan Technical Capabilities

Ducted vs Un-Ducted Systems

- Traditionally, parking garage ventilation systems have been ducted systems.
- Today, the market is shifting towards un-ducted jet fan based ventilation systems.
- Using a standard size jet fan throughout a parking garage works in practice as a consequence of monitoring and control capability.
- By monitoring CO and NOx levels around the parking garage, jet fans can be turned on or off as needed.
- If wind direction and strength impact the concentration of pollutants in one region of the parking garage, jet fans can be reversed if necessary and again, switched on or off to keep pollutants below prescribed levels.
- Hence un-ducted systems tend to be more demanding of monitoring and control systems.

System Design Considerations

- Primary design considerations are the requirements for normal and fire-mode ventilation. These can be a simple air exchange per hour, or by-calculation.
- In any project there will be a specification, and usually a fire officer who ultimately must sign-off that a ventilation system has met the requirements of that specification.
- In an ideal world, the ventilation system designer would coordinate with the architect, optimizing vehicle entrances and exits for normal and fire-mode operation. In practice, the ventilation system designer typically gets involved after a design has been developed.
- Jet fan based un-ducted systems tend to be better suited to working around a previously developed building design. This helps to minimize initial cost.
- As jet fan-based systems require a more developed monitoring and control capability, demand-controlled ventilation also tends to be more of an option. This helps reduce operating costs.

Supply and Exhaust Air Strategies

- A parking garage ventilation system can leverage the parking garage design. Fresh air can be drawn in though access ramps, and stairwells can be used to extract air during normal operation and then using reversible fans be pressurized during fire-mode.
- There is however a need to extract smoke in the event of a fire. A single-level parking garage may be able to use jet fans to direct smoke out of the access ramp.
- With larger or multi-level car parks it may not be possible to configure the ventilation system to address all required fire scenarios without both reversible supply and reversible exhaust fans.
- Depending on parking garage detail design, motorized dampers may make isolation of one level with a fire possible. In theory at least one stairwell could then be pressurized to allow those trapped to escape, with another being used to exhaust smoke and hot gas.

Installation Considerations

- Jet fans may be installed between structural elements of a parking garage; this may be over driveways or designated parking areas.
- The primary installation consideration driving jet fan selection is maintaining minimum allowable height between the floor and jet fan.
- The “throw” of a jet fan depends on the jet fan size. Manufacturers typically publish the throw and spread of a jet fan jet, see example below.

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

Agenda

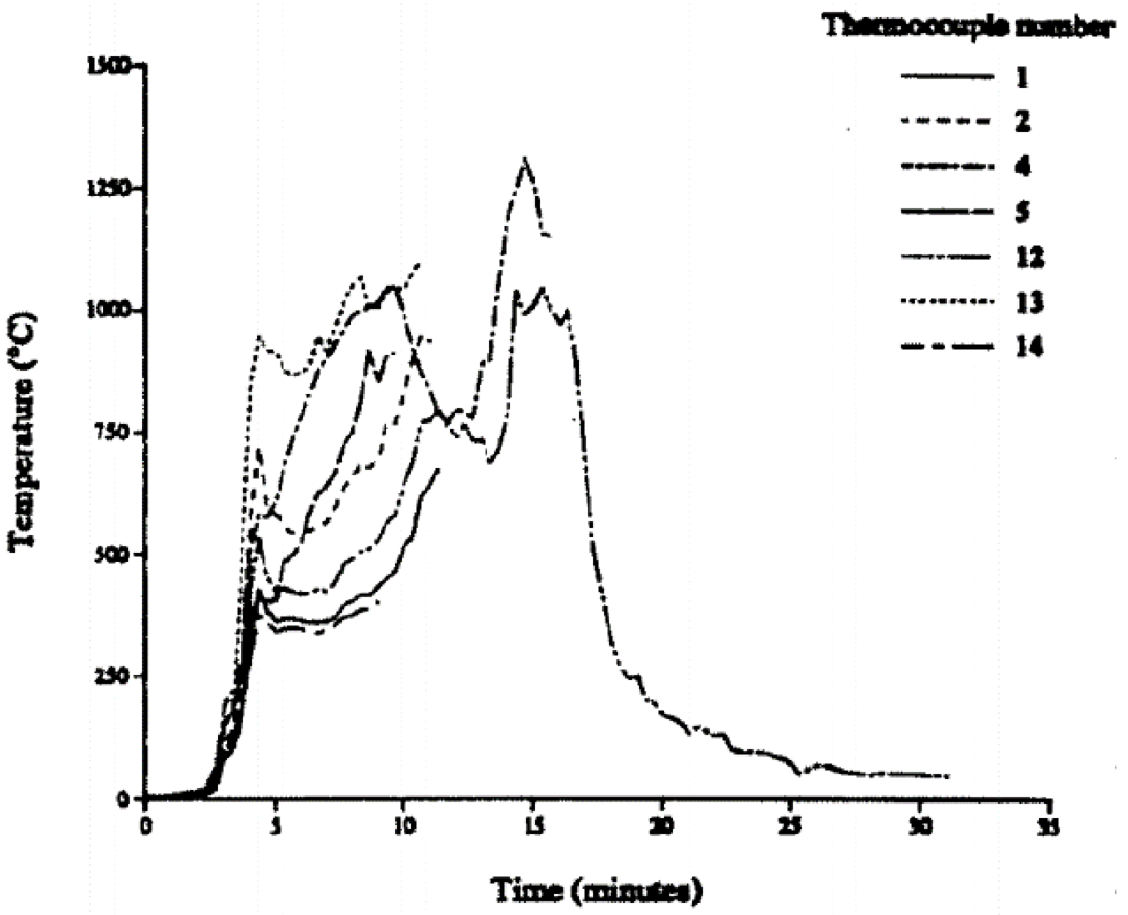
- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control System & Sensors
- Jet Fan Technical Capabilities

Planning for the Worst

Partially collapsed parking garage at Norway's Stavanger Airport after a fire in January 2020.

Ducted vs Un-Ducted Systems

- The graph to the right is taken from Ship, M., and Spearpoint, M., “Measurement of the Severity of Fires Involving Private Motor Vehicles”, *Fire and Materials*, Vol 19., 1995
- The graph shows temperature above a car during a fire test.
- Temperature peaks at over 1,250C (2,282F).
- No ventilation duct or jet fan can withstand such extreme temperature.



Ducted vs Un-Ducted Systems

- If subjected to the direct heat of a burning car, a ventilation system duct will fail, potentially compromising the ability of the entire ventilation system.
- If subjected to the direct heat of a burning car, a ventilation system jet fan will fail, however the remaining jet fans can continue to operate.
- Hence, the distributed form of a jet fan-based parking garage ventilation system makes it intrinsically more damage-tolerant then a duct based ventilation system.

System Design Considerations

- At its most fundamental, the ventilation system should drive smoke and hot air away from escape routes in the event of a fire.
- Hence, although perhaps counter intuitive, it is necessary to supply air in the event of a fire, even if doing so actually increases fire intensity.
- Pressurizing all stairwells in the event of a fire ensures that all stairways are escape routes.
- Additionally, pressurizing stairwells prevents them from becoming chimneys that otherwise could allow smoke to move from floor to floor in a multi-level car park.
- In a multi-level car park, a fire typically starts at one point on one level. A priority for the ventilation system is to minimize the movement of smoke and hot air from level to level.

System Design Considerations

System Design Considerations

Supply and Exhaust Air Strategies

- Supplying all make-up air though ramps is a potential strategy during normal ventilation.
- However, in fire-mode it is more usual to supply air through stairwells to pressurize them and in so doing ensure they stay clear of smoke and hot air.
- The two points above are not necessarily in conflict if the supply and extract fans are reversible.
- If supply and extract fans are reversible, then both will likely need to be fire-rated as either could be subjected to smoke and hot air depending on the fire scenario.

Installation Considerations

- If a jet fan is positioned immediately above a car that is on fire, the jet fan will fail.
- Failure of any one jet fan will not compromise the ventilation system as the ventilation design takes into account the fact that it may need to operate with any one jet fan not operational.
- The probability of jet fans being burnt out by a car on fire is reduced by positioning them over driveways where cars are not parked.
- However, defensive positioning of jet fans does not eliminate the need for the ventilation system to operate in fire mode with any one jet fan not operational.

Agenda

- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control System & Sensors
- Jet Fan Technical Capabilities

Critical Requirements

- Typically, a parking garage ventilation system will be validated via a CFD analysis of each defined fire scenario.
- The set of defined fire scenarios are intended to identify worst-case circumstances.
  - Hence, a ventilation system that is effective in all fire scenarios will be effective in-service in any situation.
- Each fire scenario may require the ventilation system to be configured differently.
- Hence, the control system must be capable of configuring the ventilation system to match the configuration used during validation of each fire scenario.
- Configuring the ventilation system to match the configuration used when validating each of the fire scenario becomes progressively more demanding of the control system as the parking garage becomes larger and more complex.
  - The most complex ventilation system I have personally been involved required the ventilation system to be both configured and validated for 143 fire scenarios.

Sensors and Sensor Location

- In any ventilation system, sensors tend to be the most unreliable components. A solution is redundancy; adding more sensors so the system can operate in the event any single one fails.
- CO an NOx sensors are typically required for normal operation. These sensors would typically be part of an automatic demand-based control system, with jet fans being started progressively as pollutants build up.
- Smoke detectors and temperature sensors are typically required for fire-mode.
- Video cameras may also be included to assist operators when identifying the location and intensity of a fire and any people in the near vicinity.

Operating Modes

- In normal operating mode CO and NOx sensors are typically monitored, with supply, exhaust and jet fans being turned on or off in response to pollutant levels.
- In fire mode, the ventilation system is typically configured based on the location of the fire.
- Given that normal mode is demand-based, and fire-mode is dependent on where the fire is, its not possible to make general comments about the preferred starting sequence of supply, exhaust and jet fans.

Emerging Control Technologies

- Control systems are continuously evolving, and artificial intelligence (AI) technology is advancing the next generation control systems.
- AI-based controllers offer unique characteristics:
  - They learn from experience.
  - Specifically, they can learn to recognize sub-optimal behavior; useful for minimizing normal operation operating costs.
  - They can utilize non-traditional inputs, for example visual information from video feeds; useful for identifying a fire early and triggering fire-mode.
- Although not high-profile right now, before the end of this decade AI will make itself felt in a diverse range of applications.
  - Amazon is aggressively developing AI based robots to eliminate people from their distribution centers.
  - Tesla has prototype self-driving, 18-wheel trucks.
  - If you bought a TV in the last two years, it's an AI engine that is upscaling the input to 4 or 8K.
- It's a matter of when, not if, AI is applied into control systems generally and parking garage ventilation system control systems specifically.

Agenda

- Codes, Standards & Certification
- Computational Fluid Dynamics (CFD)
- System Design: Normal Operation
- System Design: Fire Mode
- Control System & Sensors
- Jet Fan Technical Capabilities

The Role of Deflectors

- Deflectors are occasionally fitted to deflect the jet downward and away from a structural building element.
- Deflectors are typically capable of operating in both normal and fire mode.
- Deflectors are usually used with uni-directional jet fans, although can be used with reversible jet fans if required.
- Silencers, screens and deflectors diminish jet fan thrust. Hence if tested, a jet fan should be fitted with all those elements that will be fitted in-service.

Reversible vs Uni-Directional

- In all but the most simple of parking garages, the range of fire scenarios that must be accommodated make reversible jet fans preferable.
- Reversible jet fans result in a more configurable ventilation system and therefore a more flexible ventilation system.
- The design of a reversible jet fan blade is challenging. Typical fans are pressure-developing and uni-directional. A reversible jet fan is neither.
- Further, reversible jet fans cannot have a conventional guide vane. In combination with the above, this results in reversible jet fans being less efficient than unit-directional jet fans.
- In theory, a parking garage ventilation system could be configured from uni-directional jet fans, some pointing one way and some the other. In practice this approach usually requires more jet fans in total resulting in higher initial cost.

Jet Fan Specification

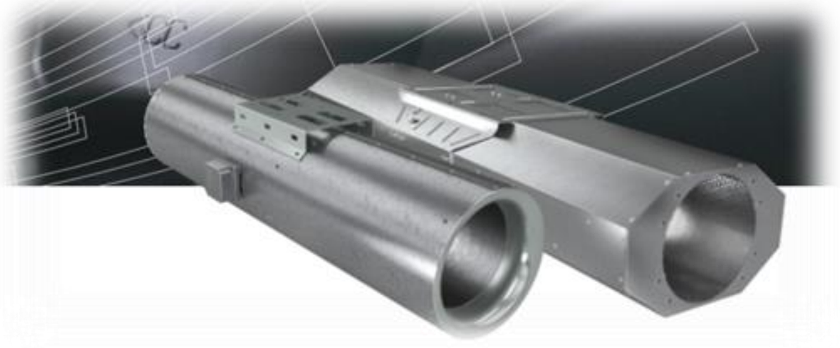
- Jet fans are specified in terms of thrust, not CFM ,as its thrust they produce. A jet fan imparts a momentum change to the air passing though it. This momentum change manifests itself as an equal and opposite reaction at the jet fan mounting points.
- This reaction can be measured as a thrust on a thrust test rig, see photo to the right.
- The photo shows a jet fan mounted on a thrust frame prior to laboratory testing.

Motor Options

- The need to operate in the event of a fire typically results in a need for jet fan motors to have a one-time operating capability at elevated temperature for a defined time.
- A typical temperature / time requirement is 482F (250C) for two hours.
- An Electronically Commutated (EC) motor is:
  - Designed to run on an alternating current (AC) power supply, but it in fact bears a closer resemblance to a direct current (DC) motor.
  - It is essentially a permanent magnet, brushless DC motor that incorporates on-board electronics. The added electronics allow an EC motor to combine the best features from both AC and DC motors, and improve on them.
  - Most notable EC Motors have higher efficiency.
- The high efficiency of EC motors makes them generally attractive in a wide range of applications. However, the permanent magnets loose magnetism at temperatures lower than those typically of the jet fan application. Hence, EC motors are not used in jet fans.

Jet Fan Configuration

- When height must be minimized, an octagonal or oval jet fan is used.
- Thrust typically does not reduce significantly with the switch from round to oval or rectangular jet fans.
- Reducing the thickness of the silencer under the jet fan has the potential to reduce silencer effectiveness. However, as illustrated in the image below, increasing silencer thickness on each side is a way to minimize any increase in jet fan noise.
- Axial jet fans are always the lowest cost of ownership jet fan option, if ceiling height allows their use.



Resources

- **AMCA International**: www.amca.org

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

  > 250-12: Laboratory Methods of Testing Jet Tunnel Fans for Performance *(Available for purchase)*

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

  > 211-13: Certified Ratings Program - Product Rating Manual for Fan Air Performance *(Free PDF download)*

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, June 16
- 12:00 - 1:00pm CT
- ***Severe Duty Louvers***
- Presenter: Doug Petty, Product Manager - Louvers, AMCA Member Company

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