AMCA *insite* Webinar Series

Air Curtains: Energy Codes & Standards

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Webinar Moderator

- Joined AMCA in 2017
- Leads development and publication of technical articles, white papers and educational materials.
- Editor-in-chief of the multiple award-winning *AMCA inmotion* magazine.

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Air Curtains: Energy Codes & Standards

Purpose and Learning Objectives

The purpose of this webinar is to inform AMCA members and industry professionals about the benefits of air curtains as an alternative to vestibules, and the impact of related energy codes and standards.

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

1. Describe the three operating principles of an Air Curtain Unit (ACU).
2. Identify the main entities involved in issuing the ACU standards and codes and explain how those standards and codes are applied.
3. Compare the advantages and disadvantages of the two types of ACU's.
4. Explain the benefits derived from using an ACU.

Frank Cauderno

Member, AMCA Air Curtain Engineering Committee

Air Curtains: Applications & Benefits; Research & Tools

- VP of Engineering Mars Air Systems, LLC in Gardena, CA (LA Area)
- Nearly 25 years of experience in the HVAC industry
- Member of AMCA's Board of Directors and the Vice-Chair of the AMCA North American Steering committee
- Serves on other national and international committees involving national and international codes and regulations

David Johnson

Member, AMCA Air Curtain Engineering Committee

Air Curtains: Theory & Operation; Energy Codes

- Director of Engineering at Berner International LLC.
- 30 years working in the HVAC industry primarily focused on air curtain systems.
- Holds patents for Air Curtain digital controller, electric heating element and nozzle designs.
- Engages in regulatory affairs concerning national, international and government codes and standards.
- Serves on AMCA, ASHRAE and ISO committees and currently Chairman of the Board of AMCA International.

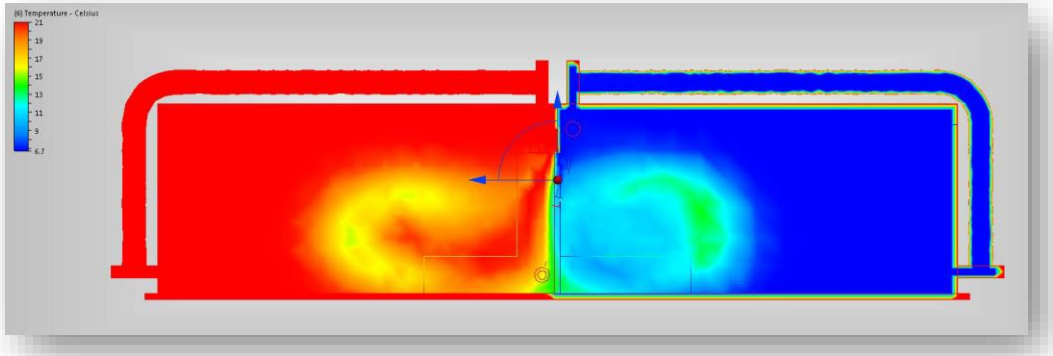
Air Curtain Unit – Definition

- Industry refers to the product as an Air Curtain, Air Door, Fly Fan…
- AMCA defines the product as an Air Curtain Unit (ACU) and the airstream it produces as an air curtain.
- AMCA 220 definitions:
  - **ACU** – An air moving device that produces an air curtain (or boundary of air) where the width is at least five times the depth and the discharge is not intended to be connected to unitary ductwork.
  - **Air Curtain** – A directionally controlled stream of air with a minimum width to depth aspect ratio of 5:1. When applied across the entire height and width of an opening it reduces the infiltration or transfer of air from one side of the opening to the other and/or inhibits the passage of insects, dust or debris.
- They create a seal to save energy and provide a clean, comfortable environment while allowing smooth, uninterrupted traffic flow and unobstructed vision through the opening.

Air Curtain Unit – Theory

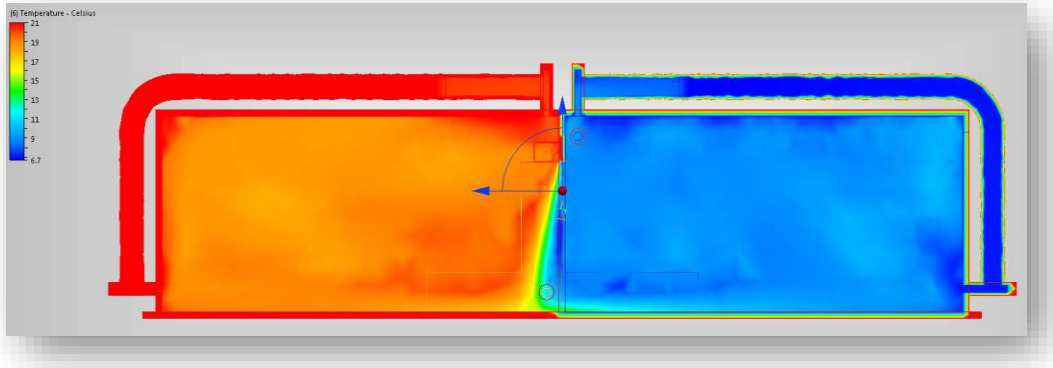
- Airstream serves as a barrier when doors or windows are opened.
  - **Environmental separation** – repels physical elements (dust, insects, etc.)
  - **Thermal separation** – reduces thermal mixing of two environments
  - **Wind resistance** – reduces infiltration between two environments

- Operates on principles of:
  - **Velocity vector** – seal & stability
  - **Entrainment** – separation & return
  - **Pressure** – working foundation



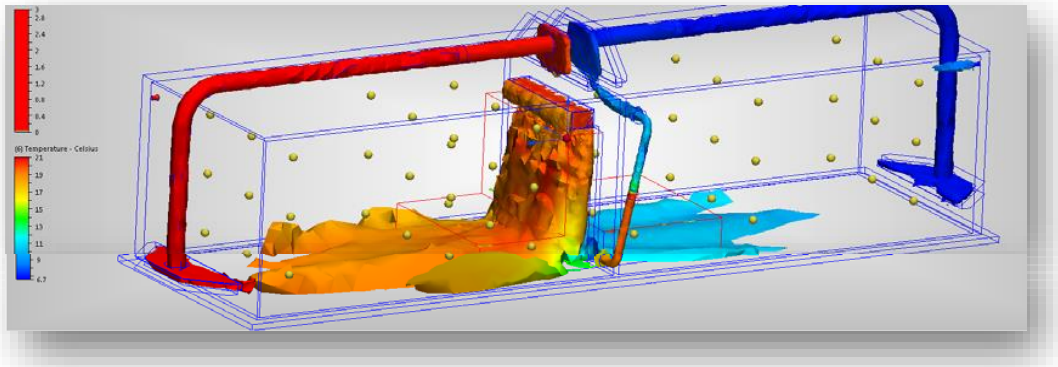
Air Curtain Unit – Theory

- **Velocity** – Airstream must cross the opening and split
  - By striking a barrier (floor, wall, etc.) or another airstream.
  - Typically measures between 2 to 4 m/s (400 to 800 fpm) depending on type of application.
- When airstream splits along a surface it creates stability
- Separation is achieved using the combination of:
  - Stable airstream
  - Entrainment
  - Building pressure



Air Curtain Unit – Theory

- **Entrainment** – The airstream entrains volumes of air on both sides and returns back to respective areas at split.
- **Resistance** – The airstream "skins" the building (or room) pressure and resists infiltration especially from wind.
- Low velocities create no split resulting in mixing or door heater affect.
- Higher velocities at floor
  - Can resist higher winds until…
  - Too high = turbulence = mixing
  - Greatly reduces effectiveness



Air Curtain Unit – Principles

- Fundamental function - generate airstream
  - Velocity (function of the nozzle)
  - Depth (function of volume and nozzle)
  - Uniformity (function of the plenum)

- Airstream design depends on the application, but not limited to…
  - Environmental = Thick enough to entrain, enough speed to resist wind
  - Insect Control = Thick enough and very high velocity to effect flight path
  - Cold storage = Thin high velocity to reduce entrainment
  - Recirculating = Very thick and low velocity to maximize entrainment
  - Special = ?

Air Curtain Unit – Principles

- Utilizes a fan, or system of fans, mounted inside a cabinet.
- Fan(s) discharge into a specialized plenum to generate high uniform velocity, discharged as an air curtain.
- Always sized so nozzle is equal to, or overlaps, the opening.
- Mounted above or alongside and as close as possible to opening.
- Horizontal mount above the opening discharges air vertically. Vertical mount alongside of opening discharges air horizontally.
- Seal gaps, use interference solutions such as spacing and shields.
- Follow manufacturers recommendations on sizing.

Air Curtain Unit – Construction

- **Application environment**
  - Hazardous Locations
  - Non-Hazardous Locations
- **Component considerations**
  - Cabinet materials
  - Fan type
  - Motor type
  - Air discharge style
  - Controls
  - Communication
- **Options**
  - Filters
  - Heating Type
  - Cooling Type

  } no impact on effectiveness of airstream
  - Integrated Control Communication

Air Curtain Unit – Operation

- Construction and operation driven by objective, market, building type and application.

- Including but not limited to…
  - Institutional
  - Manufacturing
  - Restaurant
  - Retail
  - Cold Storage
  - Insect Control
  - Energy savings, health and safety, code compliance, processing, etc.

Air Curtain Unit – Standards

- **Aerodynamic – Performance**
  - ANSI/AMCA 220-05 - *Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating*
  - ISO-27327-1:2009 *Fans - Air curtain units - Part 1: Laboratory methods of testing for aerodynamic performance rating*
- **Sound – Performance**
  - ANSI/AMCA 300-14 - *Reverberant Room Method for Sound Testing of Fans*
  - ISO-27327-2:2014 - *Fans - Air curtain units - Part 2: Laboratory methods of testing for sound power*

Air Curtain Unit – Standards

- **Health and Safety – Pass/Fail**
  - ANSI/NSF 37-2017 - Air curtains for entranceways in food and food service establishments
  - UL 507 - Electric Fans
  - UL 2021 - Fixed and Location-Dedicated Electric Room Heaters
  - UL 1995 - Heating and Cooling Equipment
  - C22.2 No. 46 - Electric Air Heaters
  - C22.2 No. 113 - Fans and Ventilators

  - Additional standards NFPA, ANSI, IEC, ISO, UL and CSA for safety, controls, appliances, gas fired equipment, etc.

Air Curtain Unit – Performance Data

- **Aerodynamic – AMCA 220-05 & ISO-27327-1**
  - Air volume – Measured on test chamber (AMCA 210)
  - Average Outlet Velocity – Calculation of CFM/discharge area (ref. only)
  - Velocity projection – RMS value of peak velocity across discharge
  - Uniformity – Standard of deviation of peak velocity across discharge
  - Power rating – Measured kW of power consumed during air volume test
- **Sound Power – AMCA 300-14 & ISO-27327-2**
  - Installation Type A: free inlet, free outlet
  - Expressed in Octave and One-Third Bands
- Data covered by AMCA CRP

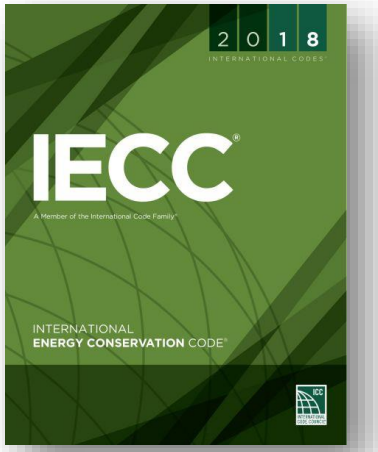
Air Curtain Unit – Performance Criteria

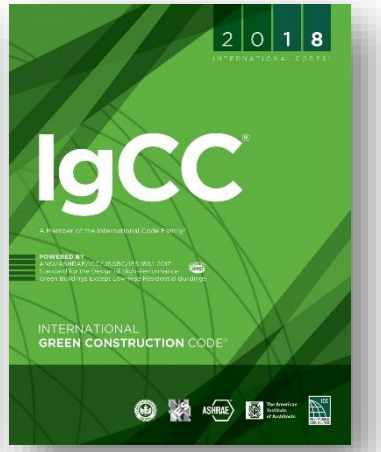
- **Heath and Safety** – NSF 37 (Pass/Fail)
  - **Service Entry** – Requires velocity of 8.15 m/s (1600 fpm) at 0.9 m (3 ft.) above floor over a grid 75 mm (3 in.) deep.
  - **Customer Entry** – Requires velocity of 3.05 m/s (600 fpm) at 0.9 m (3 ft.) above floor over a grid 200 mm (8 in.) deep.
  - **Service Window** – Requires velocity of 3.05 m/s (600 fpm), 1/3 the distance of vertical opening above service window counter top.

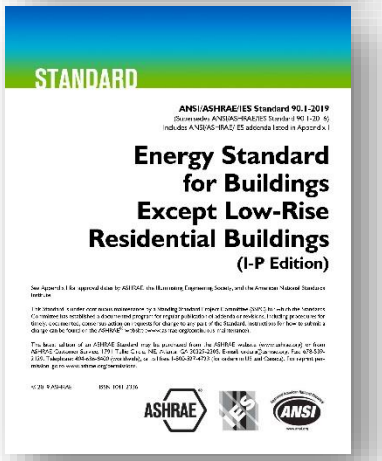
Air Curtain Unit – Energy Codes

- **ANSI/ASHRAE/IES Standard 90.1-2019** - *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- **ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2017**- *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*
- **IECC-2018 International Energy Conservation Code**
- **IgCC-2018 International Green Construction**

- All require 2 m/s (400 fpm) velocity at floor w/ heavy emphasis on commissioning.







Air Curtain Unit – Health Codes

- California - Health and Safety Code - HSC
  - Division 104. Environmental Health
    - Part 7. California retail food code
      - CHAPTER 8. Physical Facilities
        - ARTICLE 6. Vermin and Animals
        - 114259.2. Passthrough windows of up to 432 square inches are approved if equipped with an air curtain device.
      - Exemptions
        - 114427. During all hours of operation, air curtains shall be in operation over all unclosed door openings to the outside to exclude flying pests.

Air Curtain Unit – Regulation

- **Federal** – Dept. Of Energy Fan Regulation
  - ACU's are currently in the exemptions list of the DOE's draft.
- **State** – California Energy Commission Title 24 Energy Code
  - ACU's are currently in the exemptions list of the draft.
  - 2022 California Building Energy Efficiency Standards (Title 24, Part 6) considering air curtains as alternative to vestibule based on ASHRAE 90.1.
- **Future Regulation, Codes and Standards**
  - Types of ratings – Energy or Health based?
  - Energy based rating needed that measures effectiveness at resisting infiltration, not converting electrical power to air volume.
  - An **Effectiveness** rating would allow regulating and code bodies to establish a performance based minimal allowable ranking.

Frank Cauderno

Member, AMCA Air Curtain Engineering Committee

Air Curtains: Applications & Benefits; Research & Tools

Applications & Benefits

- **Discuss 2 Types of Air Curtains**
  - *Nonrecirculating*
  - *Recirculating*

- **Discuss 7 Types of Applications**
  - *Exterior environmental separation*
  - *Interior environmental separation*
  - *Flying insect control*
  - *Coolers/chill rooms and freezers/cold stores*
  - *Ovens*
  - *Negative building pressure*
  - *Special/custom*

Applications & Benefits

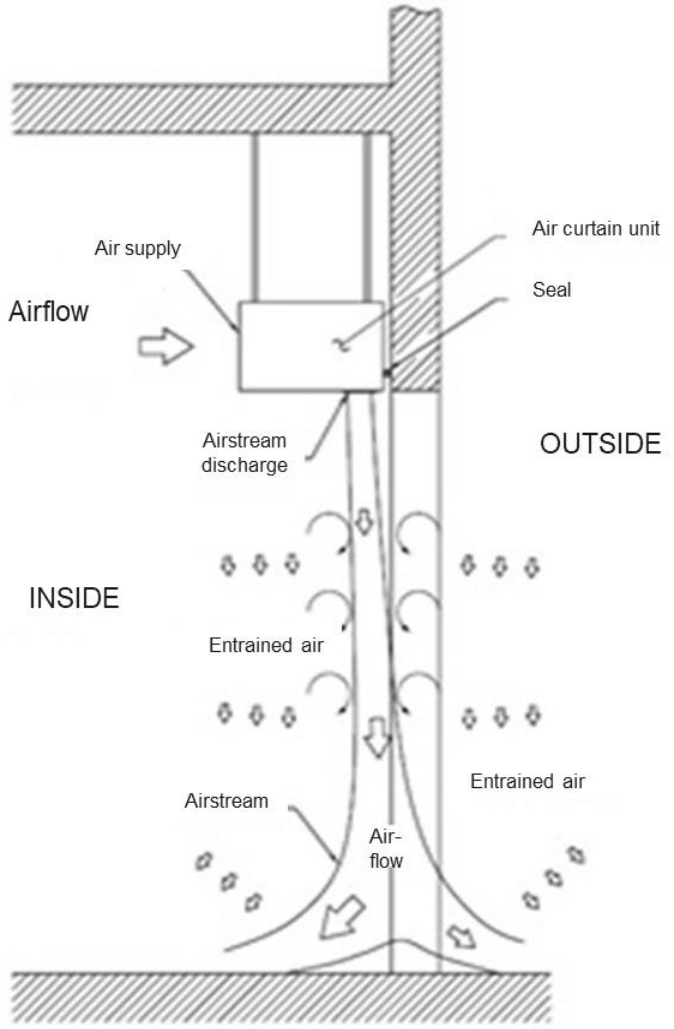
ACU Type

- ACU's are classified by two different types:
  - *Non-recirculating* – Horizontal mount (most common) or vertical
  - *Recirculating* – Horizontal mount (most common) or vertical
- Horizontal mount flows vertically, vertical mount flows horizontally
- Major differences:
  - Airflow path
  - Cabinet construction
  - Range of effectiveness
  - Purchase and installation costs.

Applications & Benefits

ACU Type – Non-recirculating

- Draws air directly from the surrounding environment and not directly from the discharge.
- If equipped with inlet ductwork that draws air from outside, surrounding environment still considered non-recirculating.
- Can be surface or recess mounted.
- Used for flying insect control applications exclusively due to ability to generate high velocities and turbulent jetties.
- Most commonly used system due to low initial purchase and installation costs.
- Typically used for special applications due to flexibility in construction, smaller size, and installation.

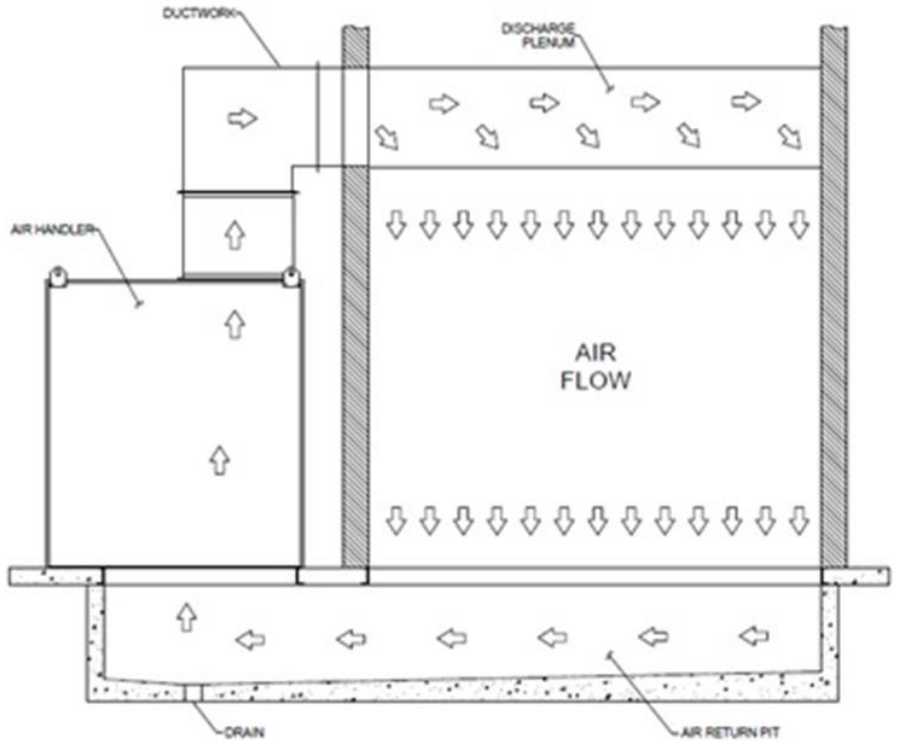


Nonrecirculating, horizontally mounted, high-velocity air curtain unit

Applications & Benefits

ACU Type – Recirculating

- Draws air from ductwork that collects and returns the discharged air back to the inlet.
- Majority of applications use a plenum and floor return connected to inlet with ductwork (shown).
- Recommended for openings without doors for extended periods of time with a high rate of traffic.
- Higher energy effectiveness rating, but only suitable for thermal separation applications.
- Uses low-velocity deep airstream; not effective for insect control. Typically higher energy consumption.
- Recessed components are perceived as less obtrusive.



Recirculating,
horizontally mounted air curtain unit

Applications & Benefits

Non-recirculating vs. Recirculating

Nonrecirculating Advantages

- Lower planning, installation, and maintenance costs
- Retrofittable to existing opening
- Used for temperature and insect control

Nonrecirculating Disadvantages

- Intrusive high velocities
- Lower overall energy effectiveness, 60%–80%
- Not recommended for extended open applications

Recirculating Advantages

- Less intrusive lower velocities
- Higher effectiveness, 80%–90%
- Used for extended open applications

Recirculating Disadvantages

- Higher initial cost
- Requires planning for installation and maintenance
- Not intended for flying insect control
- Considered for more of a niche market

Applications & Benefits

7 Types of Applications

1. Exterior environmental separation

- Exterior door protection from the unwanted infiltration of outdoor air and the escape of indoor air due to the wind and/or temperature differences.
- Related applications: loading docks, transportation terminals, and airplane hangars.

2. Interior environmental separation

- Protection between interior rooms connected by a common opening. Prevents infiltration of unconditioned air or loss of conditioned air from one room to another caused by temperature differential.
- Can be controlled by an air curtain with an air performance requirements (velocities) much smaller than that typically used for exterior applications.

Applications & Benefits

7 Types of Applications

3. Flying insect control

- External openings or doorways protected from the unwanted entry of flying insects.
- Common requirement in facilities that produce, process, or serve food products, such as kitchens, cafeterias, pass-through windows, and restaurants.
- Requires an air curtain unit with a higher airstream velocity to repel flying insects. (Per NSF 37, 600 FPM and 1600 FPM 3’ from the floor for front and rear doors, respectively.)
- Higher airstream velocity units reduce the energy effectiveness. In this application type, food safety requirements supersede energy savings requirements.

Applications & Benefits

7 Types of Applications

4. Coolers/chill rooms and freezers/cold stores

- Protects against loss of refrigerated air through openings/doorways in coolers and freezers.
- Three types of applications:
  - Cooler to freezer
  - Ambient to cooler
  - Ambient to freezer
- Typically (but not limited to) indoor applications so ACU only needs to overcome infiltration due to temperature differential and not wind pressure.
- Typically horizontally mounted on the warm side so airstream split can be balanced against air trying to leave cold room.
- Can be difficult to balance and may require a vertical mount, cold side mount, dampers, and/or multispeed motors to effectively protect the opening.

Applications & Benefits

7 Types of Applications

5. Ovens

- Protection against the loss of heated air through openings/doorways in ovens.
- Normally mounted horizontally over oven opening, angled slightly inward toward the oven to prevent the hot air from escaping through the top of the opening.
- Typically indoor applications so ACU only needs to overcome airflow due to temperature differential and not wind pressure.
- Ovens typically designed to maintain a neutral pressure with surrounding environment.
- ACU should be adjusted to only entrain and turn back the heated air to avoid creating an unbalanced condition by forcing air into the oven.
- ACU mounting location should provide adequate protection from exposure to hot air that would escape oven in an event where ACU is shut down.

Applications & Benefits

7 Types of Applications

6. Negative building pressure

- Typical ACU operation requires building to be neutral or positively pressurized.
- Special consideration required for openings where negative pressure (building exhausts more air than supply air) exists.
- Standard air curtain airflow rates will not be capable of overcoming the artificial deflection created by the negative condition.
- In special cases an increase of airflow may be used to overcome a slightly negative condition.
- Addition of heat will assist in tempering the air curtain discharge and adding supplemental heat to the area, providing comfort to those near and around the opening.

Applications & Benefits

7 Types of Applications

7. Special/custom

Air curtain units can be used for other applications; some examples are:

- Protection against the infiltration of dust
- Water removal in drying processes
- Smoke and odor containment
- The defrosting of doorways

In these cases, effectiveness will be defined by how the air curtain resolves the application issues, and not energy effectiveness.

Applications & Benefits

Benefits

- Air Curtains are proven to retain energy loss across the door.
- Reduce the load on heating & cooling equipment
- Protect a building's inside environment from:
  - Windborne dust
  - Contaminants
  - Fumes
- Enhance a building's functionality for work, dining, shopping and play.
- Increase safety by providing a clear, unobtrusive view of an opening for both people and motorized vehicles.

Research & Tools

Research – The Initial Study

"Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use" (Wang 2013)

- Conducted by Liangzhu Wang, PhD, Assistant Professor at the Dept. of Building, Civil and Environmental Engineering of Concordia University, Montreal, Canada.
- Appeared in the *AMCA inmotion* Fall 2013 edition
- Concluded that **ACU reduced air infiltration significantly** across a building entrance door under various pressure conditions using ANSYS Fluent CFD software.
- Calculated air pressure and infiltration and compare annual building energy usage and loss between a single door, an air curtain and a vestibule using TRNSYS and CONTAM energy modeling software applied to DOE reference model three-story office building.
  - Results verified ACU's allowed less infiltration than vestibule and much less than single door.
  - Found that ACU's were equally effective or better at energy savings in all ASHRAE 90.1 climate zones where vestibules were required.

Research & Tools

Research & Subsequent Studies

- The success of this original study lead to three more subsequent studies commissioned by AMCA International and completed by Dr. Wang at Concordia University.
- The initial study was primarily numerically based, conducted for only one building, and did not account for true-to-life applications and configurations.
- These subsequent studies were to take into account validation, additional building models and the impact of wind on effectiveness.

Research & Tools

Research – The Second Study

"Energy Saving Impact of Air Curtain Doors in Commercial Buildings" (Wang, 2016)

Expanding numerical study and energy simulations, two additional building configurations were modeled– strip mall and outpatient healthcare facility.

CDF Simulations

- Experimental validation of modeling was conducted
- 2-D Particle Image Velocimetry (PIV) system
- Nd:YAG Laser and helium filled soap bubble seeds
- Visualize the airflow of isothermal ACU *(Figure 1)*
- Small scale test chamber dimensioned to Yuill vestibule study to validate the theoretical modeling results (Yuill, 1996)

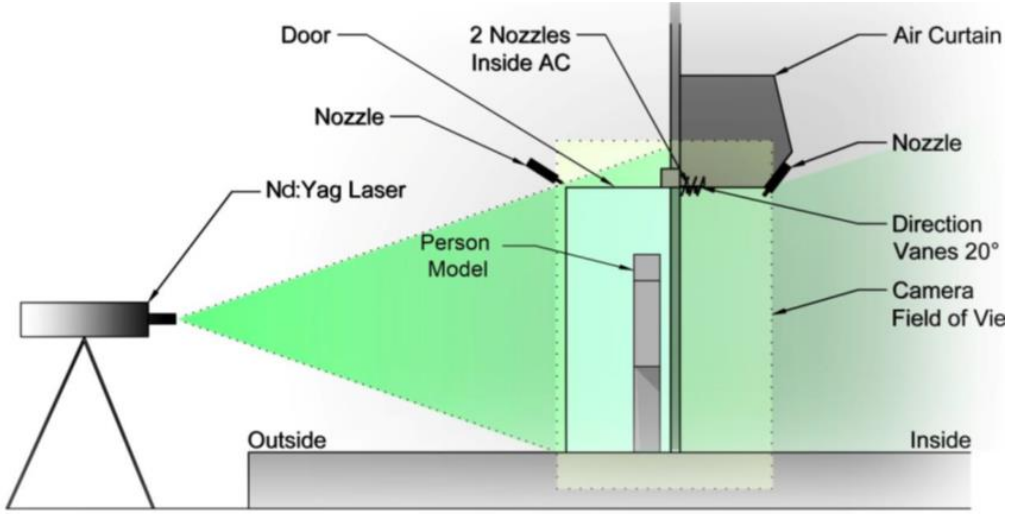
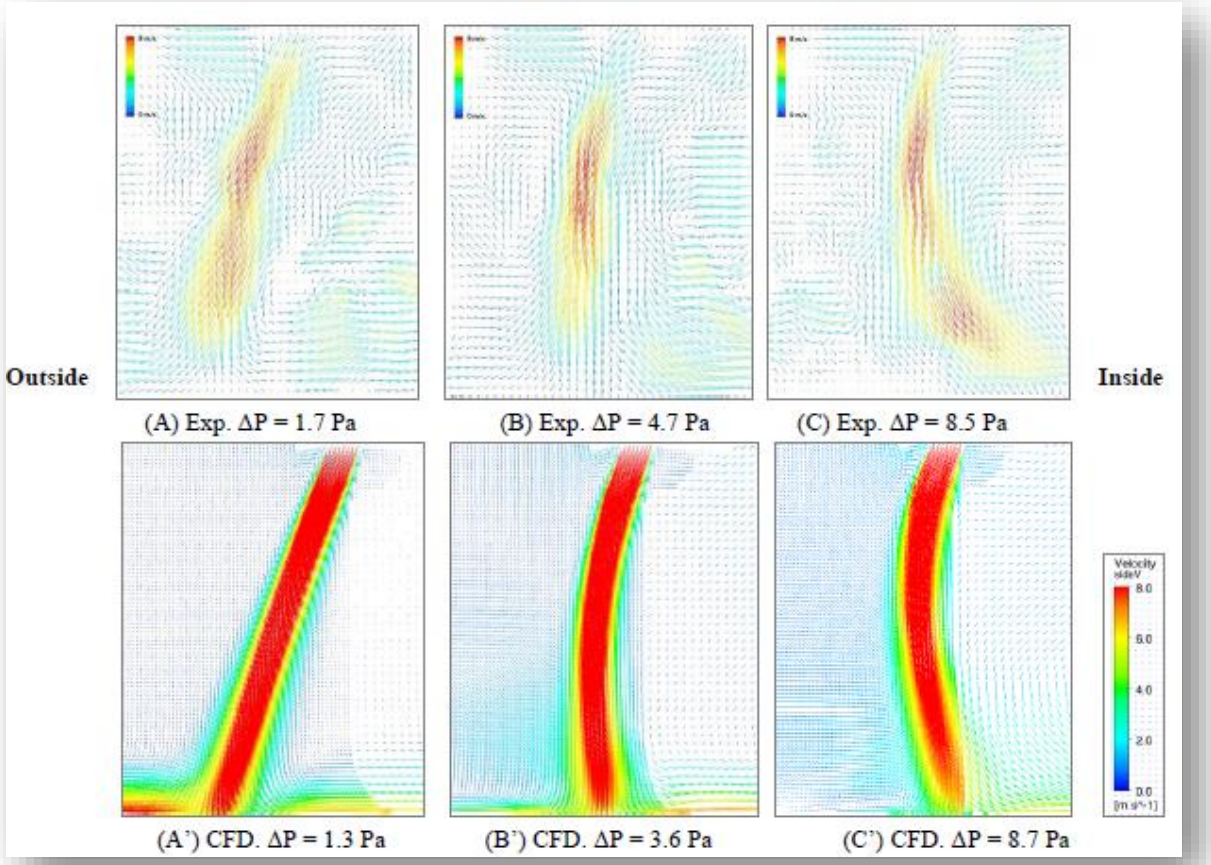


Figure 1. YAG Laser field of view with seeding locations and person model in doorway.

CFD Simulations

- Results captured by PIV RMS data for airflows confirmed the three airflow regions found in the previous study *(Figure 2)*:
  - Inflow breakthrough
  - Outflow breakthrough
  - Optimum conditions
- Experimental infiltration rates measured through chamber with ACU conformed well to data obtained from numerical CFD simulations within the pressure difference range of -2 Pa to 20 Pa.
- Data also confirmed the ability of the model developed in the first study, to estimate ACU performance in the optimum and inflow breakthrough conditions.



CFD Simulations

Methodology Validation:

Based on infiltration/pressure measurements and visualized airflow data gathered at the doorway, it was concluded that the modeling method used in previous numerical studies (Wang & Zhong, 2013) was valid, and could accurately capture performance of ACU's in regard to air infiltration through double swing doors.

A comparison of the simulated and the experimental data is illustrated in Figure 3.

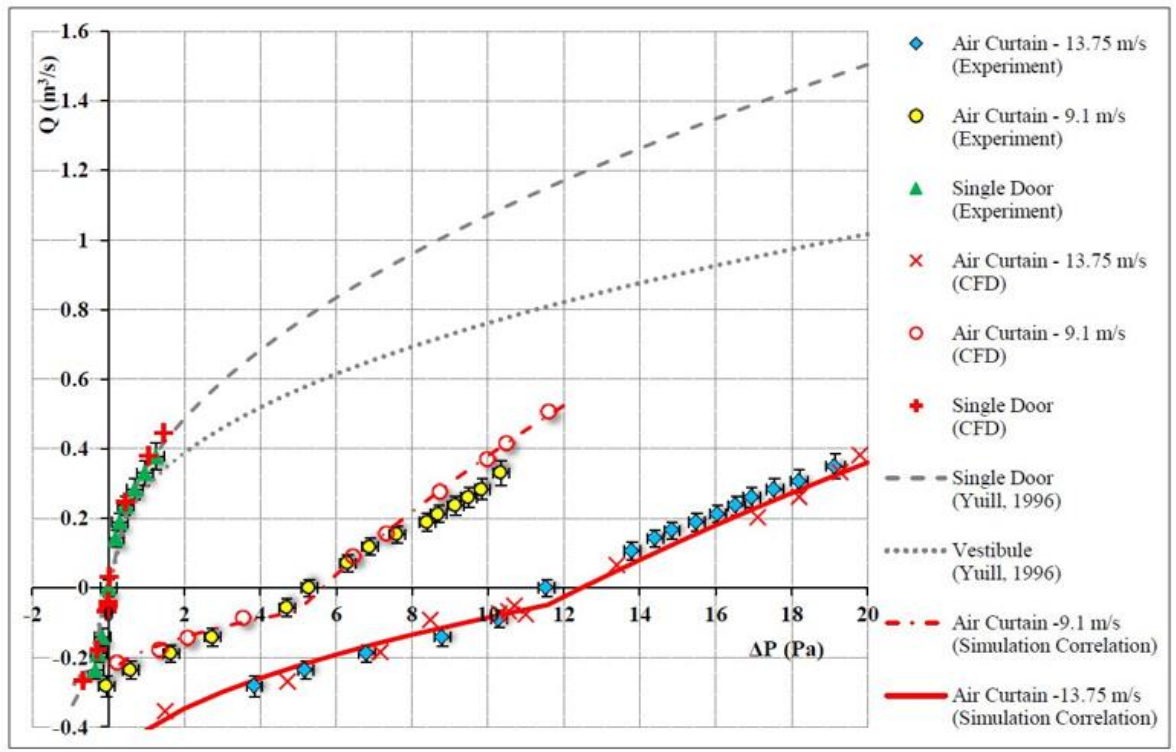


Figure 3. Comparison of experimental and CFD simulation data for air curtain and single door

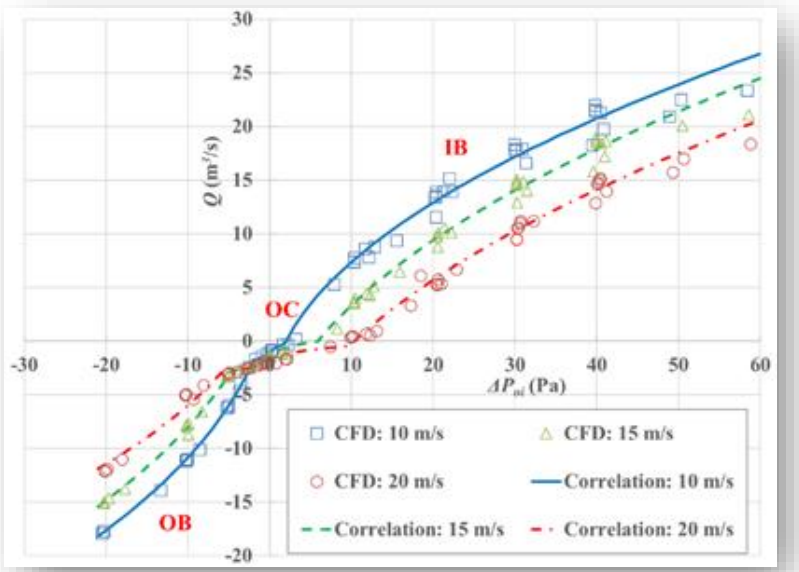
CFD Simulations

Investigation for Impact Factors:

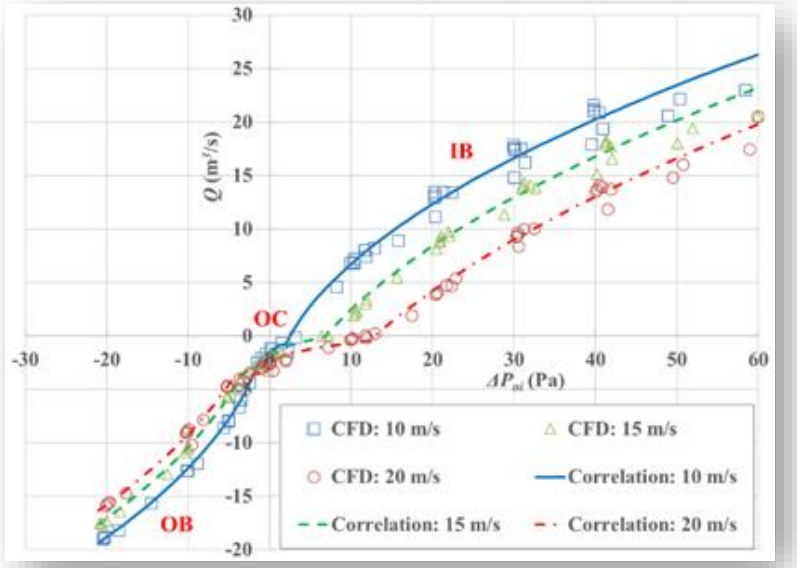
Next an extensive numerical study of over 600 CFD cases performed using ANSYS Fluent to see impact of varying conditions.

Simulations with discharge velocities of **10, 15 and 20 m/s**, outward discharge angles of **10°, 15° and 20°** and doors at different opening angles with and without people.

At highest operating point, with discharge velocity of 20 m/s, 20° outward discharge angle and a person in the doorway, **the correlated simulation results demonstrated ACU's outperformed vestibules** within the pressure range of range of $-7 < \Delta P < 54$ Pa.



10° air curtain angle



20° air curtain angle

Research & Tools

Research – The Third Study

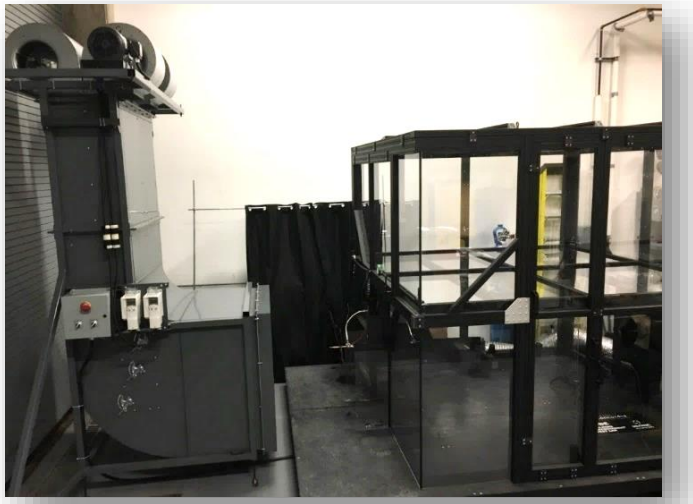
"Wind Effects on Air Curtain Aerodynamics Performance" (Wang & Stathopoulos, March 2018)

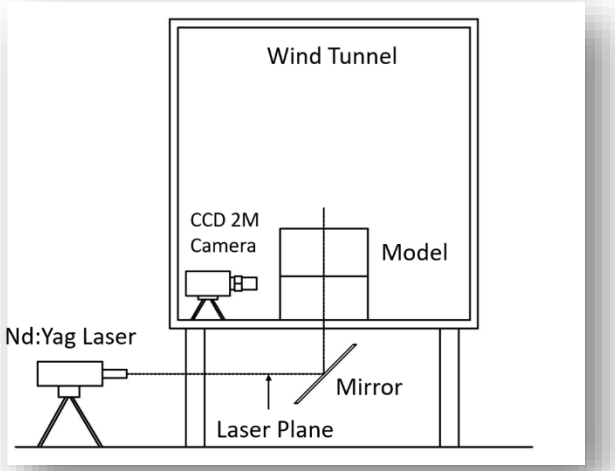
- Impact of wind is commonly considered to be significant; no studies exist on the effect of wind loading.
- Previous study did preliminary investigation of wind by producing a representative pressure differential across the opening of the large-scale chamber.
- This study's aim was a more comprehensive evaluation using:
  - Scale testing with wind generator on large-scale chamber
  - Sub-scale Atmospheric Boundary Layer Wind Tunnel at the Building Aerodynamics Laboratory of Concordia University.

Research & Tools

Research – The Third Study

- Wind generator built to create a 10 m/s wind field directly in front of a large-scale chamber.
- Limited lab space required too close proximity, resulting in a limitation of uniformly distributed velocity to 4 m/s.
- Sub-scaled wind tunnel approach adopted to complement the wind generator tests and test for varying wind direction.
- Two series of measurements taken to evaluate wind impact:
  - *Overall-performance* – Variable discharge velocity and infiltration (building pressure) with constant wind speed.
  - *Comparative performance* – Constant discharge velocity and infiltration (building pressure) with variable wind speed.

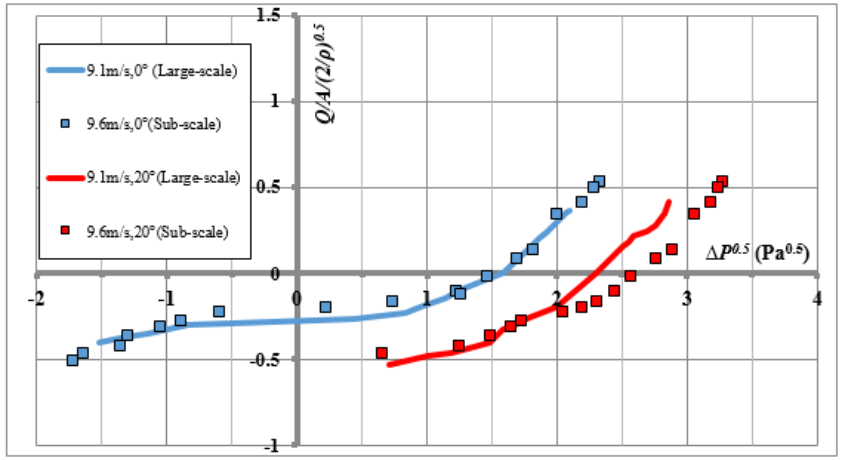




Research & Tools

Results – The Third Study

- Correlated sub-scale model and large-scale chamber results, allowed for single door and vestibule scaling.
- Overall-performance
  - Minimal impact to effectiveness until higher wind speeds, e.g. 3 or 4 m/s.
  - Impact was minimal when the discharge velocity speeds and angles are set to ensure good seal.
- Comparative performance
  - High winds drastic impact on low pressure differentials.
  - When jet reached floor no impact until 4 m/s.
  - Worst wind attack angle 0° (parallel to door), no further effect until 90° (perpendicular to door).
  - Person under or in front of doorway improved performance since flow is blocked from both directions.



Comparison of large scale and subscale chambers

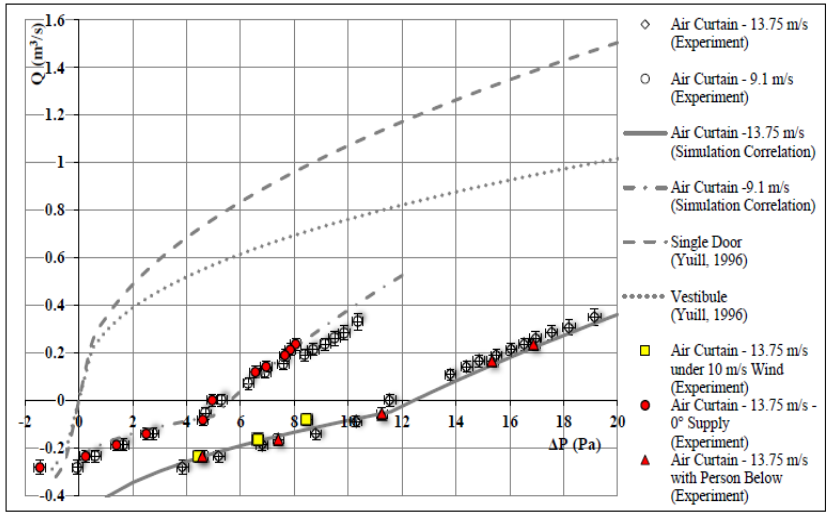
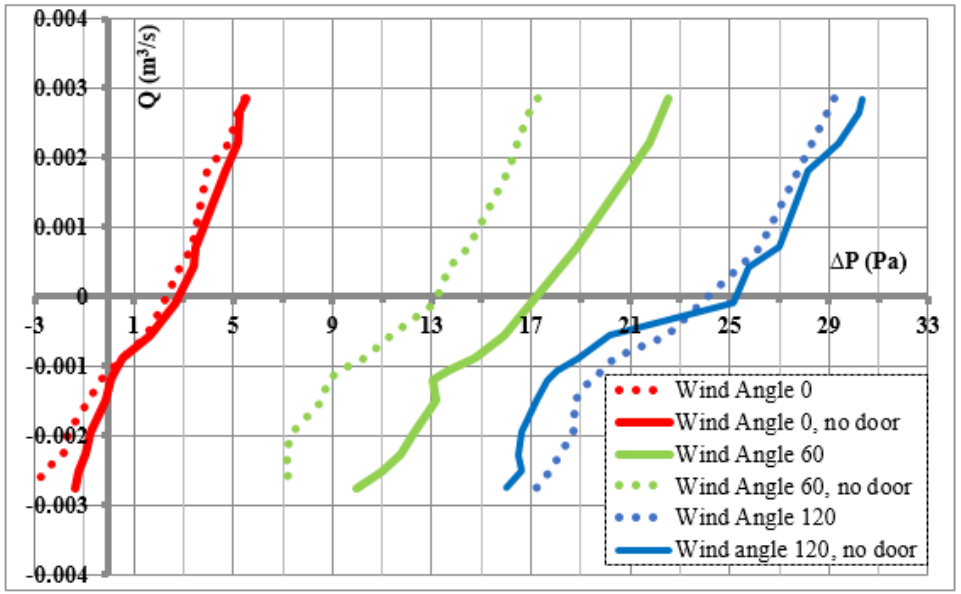


Figure 4. Comparison of measured air curtain performances under the conditions of a.) no wind and 10 m/s wind, b.) 0° and 20° supply jet angles and c.) without person and with a person below the air curtain

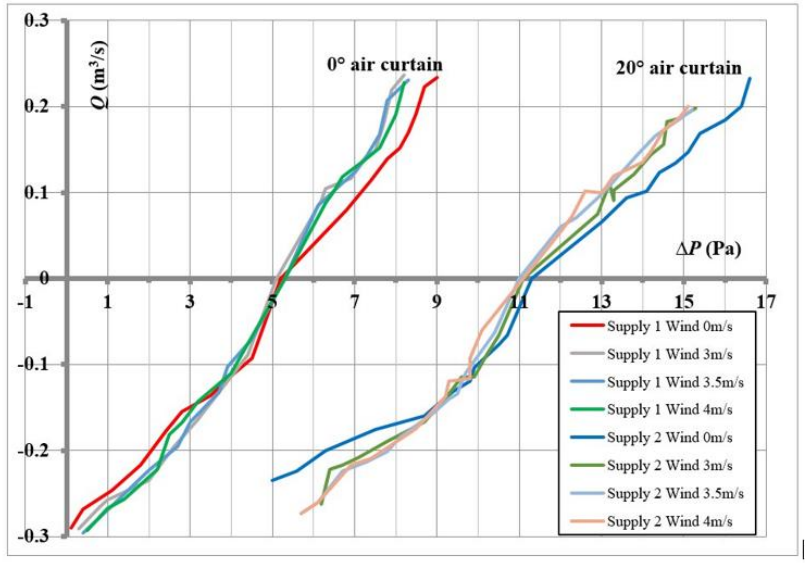
Comparison of CFD and experiments with wind effects

Research & Tools

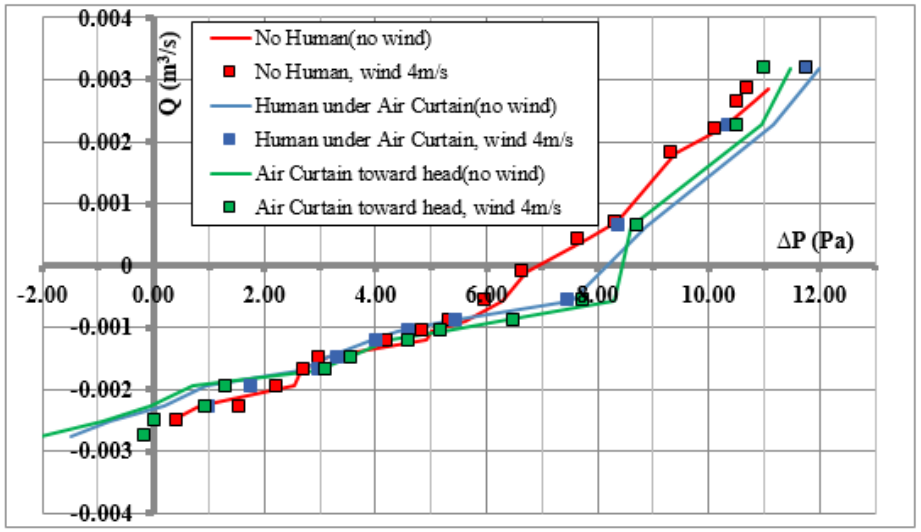
Results – The Third Study



Wind angel effect on performance comparison with and w/o door



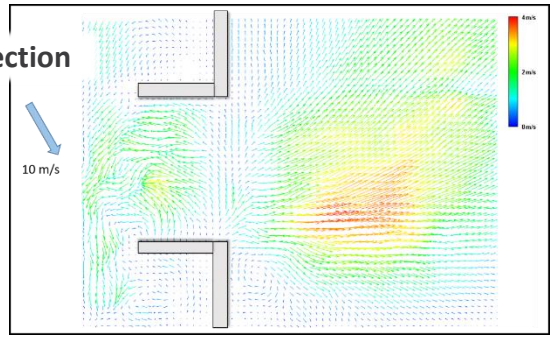
Comparative performance under different wind speeds and ACU supply angles (same ACU speed)



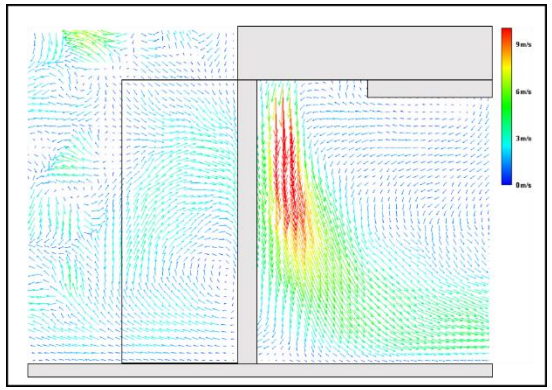
Comparative performance with and without a person in doorway

Research & Tools

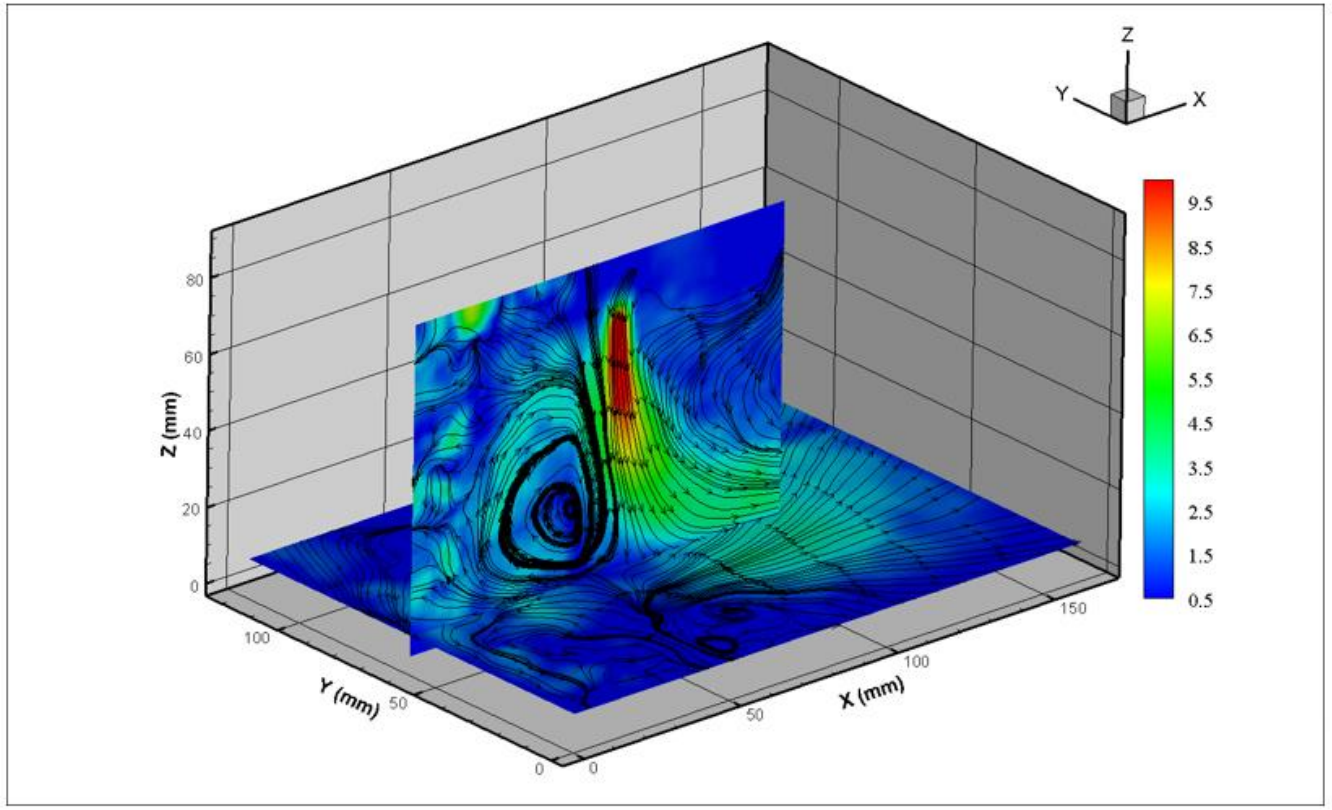
Results – The Third Study



Top View



Side View



Comparative Performance – 2D and 3D flow streamlines of PIV results for10 m/s, 60° wind and 9.6 m/s, 0° air curtain unit with the double swing door

Research & Tools

Research – The Forth Study

"Relating Aerodynamics Performance to Air Curtain Effectiveness" (Wang & Shu, November 2018)

- Provides the foundation to develop a calculation method that relates the aerodynamics performance test methods in ANSI/AMCA Standard 220-05 or ISO 27327-1:2009 directly to evaluating the air curtain's capability of reducing infiltration/exfiltration rates.
- Provides case studies of actual products for a range of mounting heights up to 10m to demonstrate process and validation using experimental results from the previous studies.
- Currently under development by the AMCA Air Curtain Engineering Committee, it aims to be a methodology that is inexpensive, scalable and based on existing air curtain aerodynamic performance testing methods.
- Once completed it is expected to be proposed for inclusion into ANSI/AMCA Standard 220 and ISO 27327-3.

ROI Calculators & Sizing Tools

ROI Calculators

- **ROI (return on investment) calculator** – Can estimate the energy savings and payback periods of different types of air curtains. Typically available from manufacturers.
- Many engineering tools available for building owners to use when designing an air curtain system.

Sizing Tools

- **Product configurator** – Will assist in selecting the proper models, including the type of heat and power required for each application, which is beneficial to the specifiers, engineers, designers, and architects.
- **Submittals and CSI (Construction Specifications Institute) specs**– Assist architects and engineers in writing the air curtain specifications.
- **Revit** – A software system that works with building information modeling (BIM), provides detailed 3D models that can be inserted into the project design drawings.

>> Using one or a combination of these tools will ensure a properly designed project.

Resources

- **AMCA International:** *www.amca.org*
- **2019 *AMCA inmotion*:** *http://bit.ly/AMCAinmotion2019*

  > "Air Curtains: A Proven Energy-Saving Alternative"
- **ANSI/AMCA Standard 220-05:** *Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings (*available for purchase): *www.amca.org/store*
- **ANSI/AMCA Standard 300-14:** *Reverberant Room Method for Sound Testing of Fans (*available for purchase): *www.amca.org/store*

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- TOPIC: *Industrial Fans*

Registration details to be announced soon!