Air-Curtain Technology: Theory, Operation, and Applications

David Johnson, director, engineering group, Berner International LLC, and Frank Cuaderno, vice president of sales, Mars Air Systems LLC

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Frank Cuaderno

Vice President of Engineering
AMCA Member Company

- Nearly 28 years of experience in the HVAC industry
- Member of AMCA's Board of Directors and the Chair of the AMCA North American Region Steering committee
- Very involved in AMCA Advocacy committees and initiatives
- Serves on other national and international committees involving national and international codes and regulations

David A. Johnson

Director, Engineering Group
AMCA Member Company

- 34 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.
- Past President & Chairman of the Board of AMCA
- Serves on multiple AMCA, ASHRAE and ISO committees

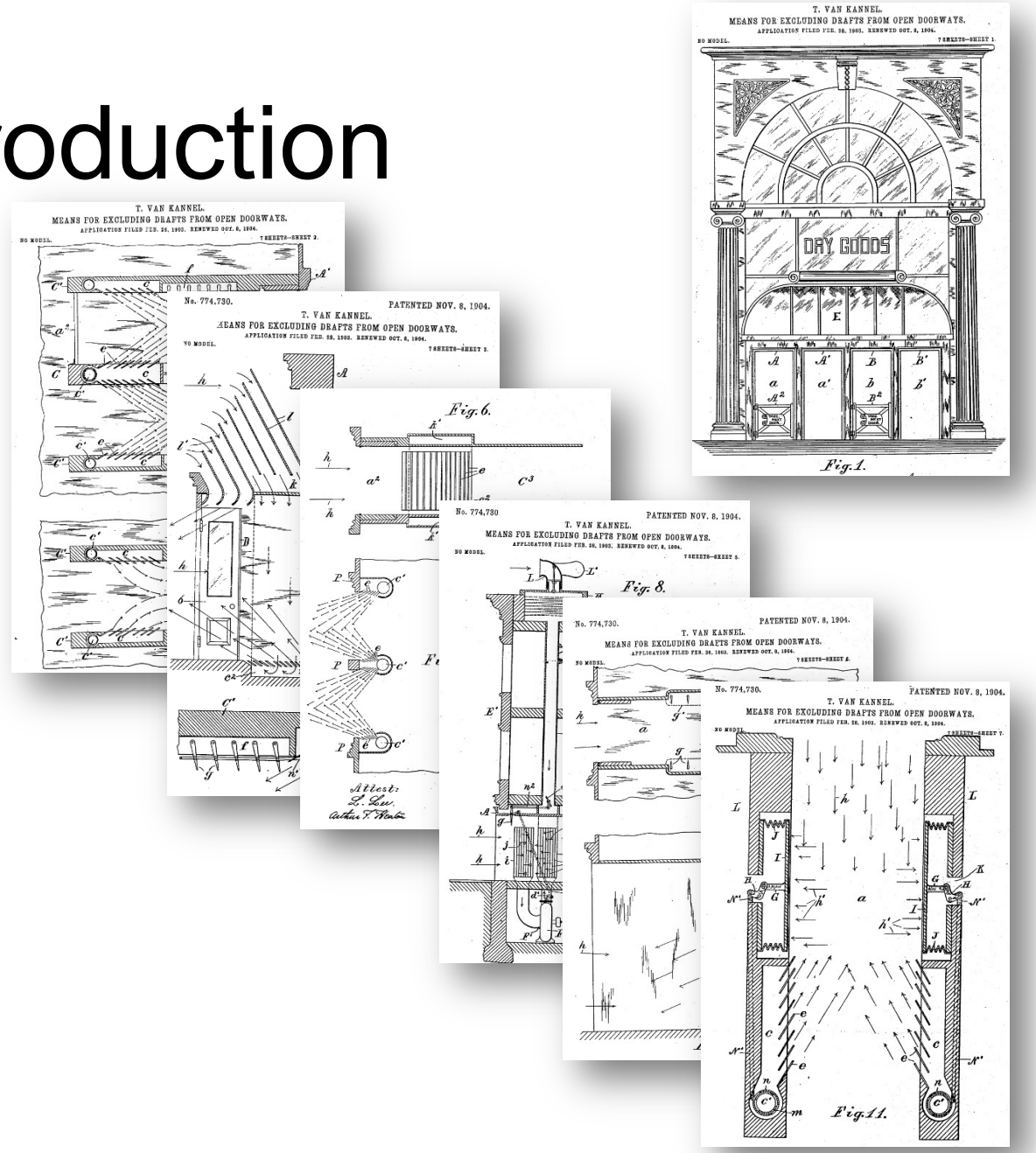
Purpose and Learning Objectives

- The purpose of this presentation is to introduce and educate industry professionals about all facets of Air Curtain technology, including principles, construction, codes, standards and applications.
- At the end of this presentation, you will be able to:
  - Describe the three operating principles of an Air Curtain Unit (ACU).
  - Identify the main entities involved in developing ACU standards and codes and explain how those standards and codes are applied.
  - Name the five most common types of applications where ACUs are used.
  - Explain at least three benefits derived from using an ACU.

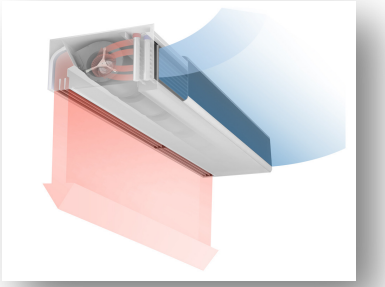
Contents

Air Curtain Units – Introduction

- The first known record of an air curtain is from 1904 when Theophilus Van Kannel received a U.S. patent for one.
- According to records, the first air curtain installation in the States wasn't until 12 years later. In Europe, air curtains became increasingly popular during the late 1940s and 1950s.
- They later became popular in the US in the late 1950s.



What is an Air Curtain Unit



- Industry refers to product as 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.
- **ANSI/AMCA Standard 220 – "*Laboratory Methods of Testing Air Curtain Units for Aerodynamic Performance Rating*"** defines:
  - 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.

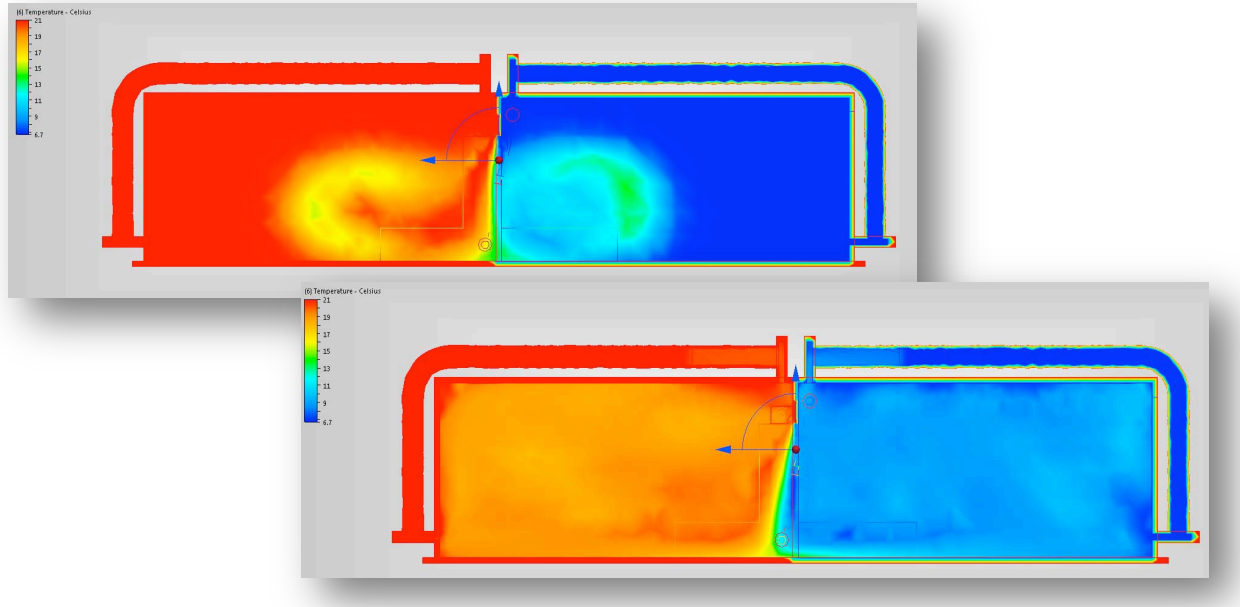
Why Use an Air Curtain Unit

- Creates an aerodynamic seal over an opening that reduces infiltration and exfiltration while providing an unobstructed view.
- Reduce energy costs.
- Contribute to a safe indoor environment.
- Provide chemical free insect control.
- Can contribute to LEED points.
- Can assist in air purification.

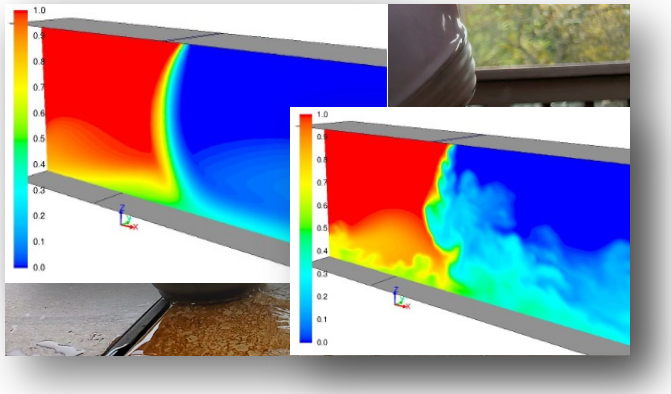
How Do Air Curtain Units Work

- The airstream serves as a barrier over an opening to provide:
  - *Thermal separation* – reduces thermal mixing of two environments
  - *Environmental separation* – repels physical elements (dust, insects, etc.)
  - *Wind resistance* – reduces infiltration between two environments

- Operates on the principles of:
  - Velocity – creates seal & stability
  - Entrainment – separation & return
  - Pressure – used for resistance



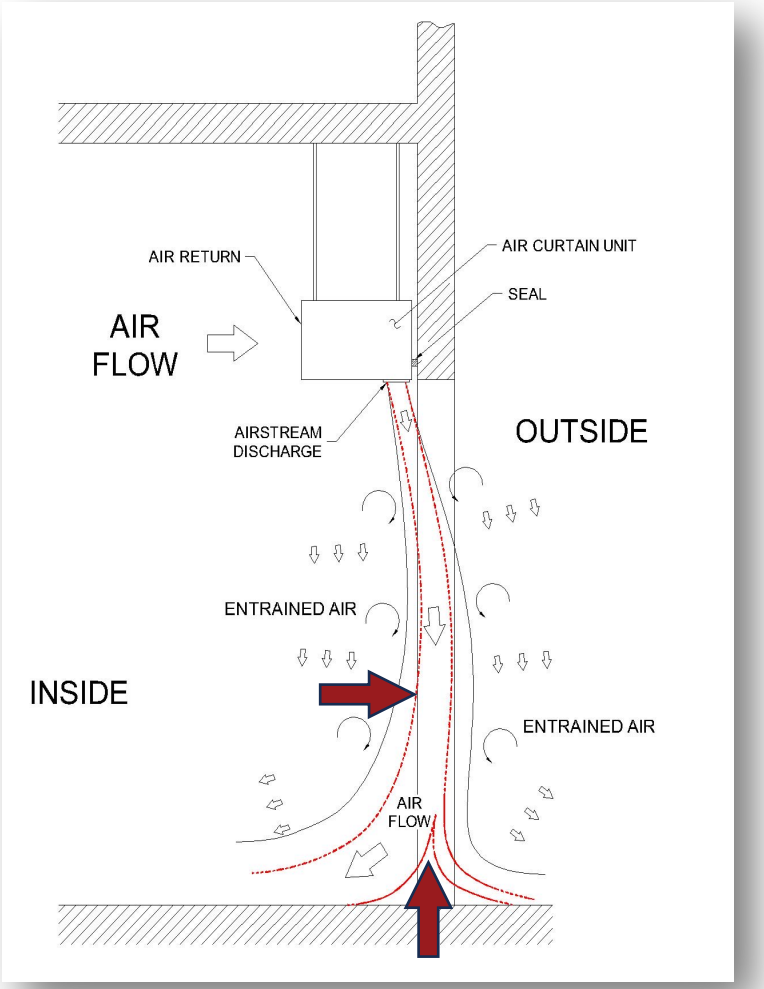
Air Curtain Unit – Theory



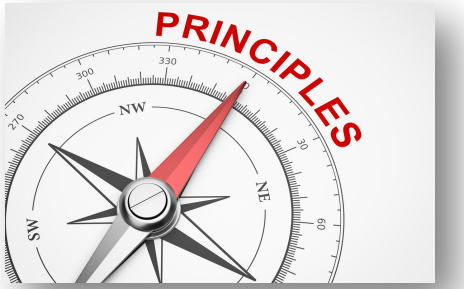
- Velocity - the airstream shall:
  - Reach and strike a barrier (floor, wall, etc.) or another airstream at mounting height.
  - Have a target velocity located at the split region between 400 to 800 fpm (2.0 to 4.0 m/s). Sometimes higher depending on application or site conditions.
- When the airstream splits along a surface it “establishes” and creates stability due to the Coanda effect.
- Low velocities create no split; heated units having door heater effect.
- High velocities at floor: ➡
  - Can resist higher winds until striking the surface creates turbulence.
  - Turbulence = mixing = loss of stability against pressure = can greatly reduce effectiveness.

Air Curtain Unit – Theory

- Entrainment – The airstream entrains volumes of air on both sides of opening and returns it back to the respective areas at the split.
  - Geometry of split - outside of airstream is primarily comprised of *unconditioned* entrained air, ➡ NOT *conditioned* "working" airstream.
  - This is where the 80/20 rule of thumb comes from.
- Pressure – The airstream "skins" the building (or room) pressure and resists infiltration.
  - Foundation for wind resistance, not a vector vs. vector.
  - Stable building pressure required.
  - Why they do not work on tunnels or buildings with large negative pressures.



Air Curtain Unit – Principles

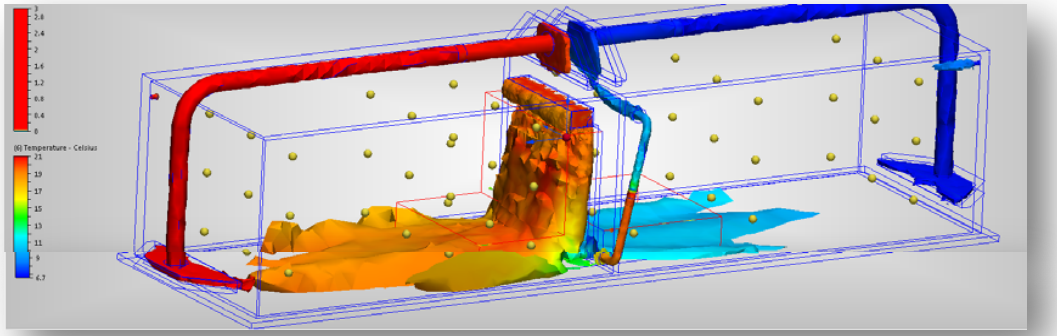


- ACU fundamental function is to generate airstream comprised of:
  - Velocity (function of the volume and nozzle)
  - Depth (function of the nozzle)
  - Uniformity (function of the plenum)
- Airstream design driven by the application; typical relationships are…
  - Environmental = Thick to entrain, enough speed to resist wind
  - Insect Control = 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 Applications = ? (determined by desired outcome)

Separation is achieved using a stable airstream and combination of, airstream vector, entrainment and building pressure.

Air Curtain Unit – Research

- Hundreds of Research and white papers exist on air curtain unit design, application, and effectiveness.
- *Design Data for Air Curtains* and *Heat Transfer Characteristics of the Air Curtain* by Hayes, F.C. and Stoecker, W.F. in 1969 created foundation by which most ACU studies and designs are based.
- Most recent impact to the North American industry was the adoption of the ACU vestibule exception into the most influential energy codes.
- Roadmap comprised of 5 phases.



Air Curtain Unit – Installation

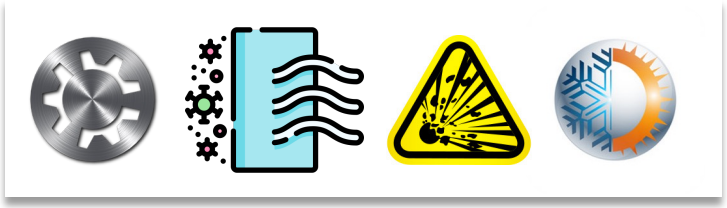
- ACUs utilize a system of fans in a cabinet that discharge into a specialized plenum to generate high uniform velocity that is discharged as an air curtain.
- Sized so nozzle is equal to, or overlaps, the opening.
- Discharge located at the opening or have side shields.
- Be adjustable towards and away from the opening to set split at threshold.
- Seal gaps, use interference solutions such as spacing and shields.
- Follow manufacturer 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

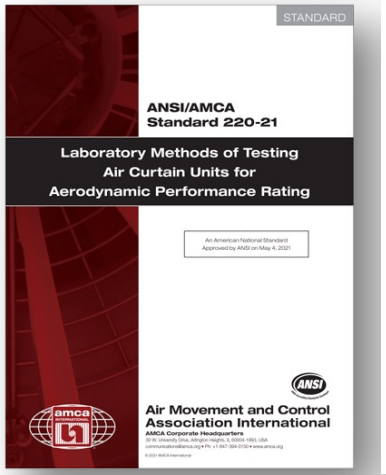
- Options
  - Filters
  - Heating Type
  - Cooling Type
  - Controls

} no impact on effectiveness of airstream



Air Curtain Unit – Standards

- Aerodynamic – Performance
  - ANSI/AMCA 220-21 - *Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings*
  - 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 - 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
  - CE Mark - using CEN, CENELEC, ETSI or harmonized standards
- Additional NFPA, ANSI, IEC, UL and CSA for industrial control, appliances, gas fired equipment, etc.

Air Curtain Unit – Performance Data

- Aerodynamic – AMCA 220-21 & ISO-27327-1-2009
  - 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
  - Data expressed in Octave and One-Third Bands

AMCA data covered by CRP- Certified Ratings Program

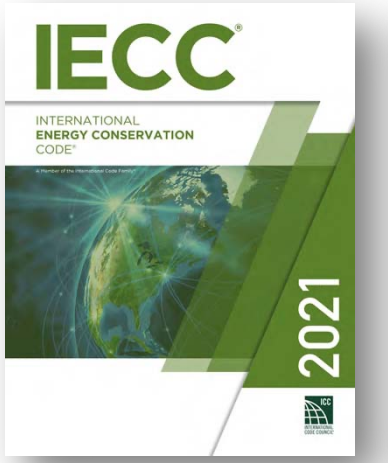
ACU – Performance Criteria

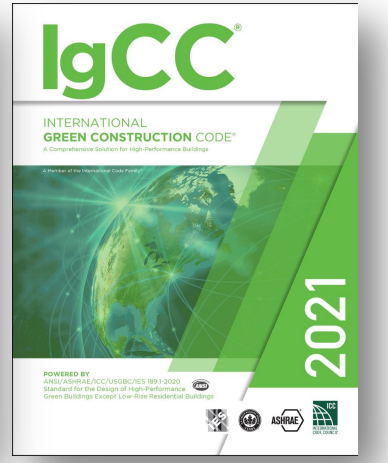
- Heath and Safety – NSF 37 (Pass/Fail)
  - Service Entry – Requires velocity of 8.15 m/s (1600 fpm) at 0.9 m (3 ft) above floor over a grid 75 mm (3 in.) deep.
  - Customer Entry – Requires velocity of 3.05 m/s (600 fpm) at 0.9 m (3 ft) above floor over a grid 200 mm (8 in.) deep.
  - Service Window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

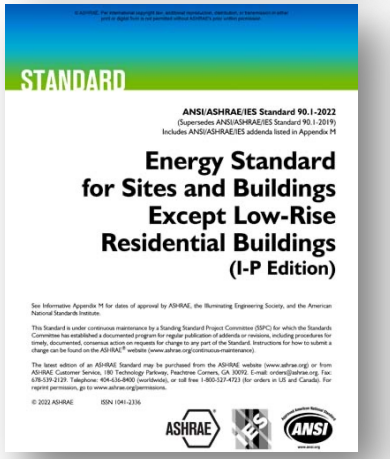
Air Curtain Unit – Energy Codes

- IECC-2021 International Energy Conservation Code
- IgCC-2021 International Green Construction
- ANSI/ASHRAE/IES Standard 90.1-2022 - *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*

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







ACU – Energy Code Research

- Phase I - *Air Curtains: a Proven Alternative to Vestibule Design* - IgCC
- Phase II – *Investigation of the Impact of a Building Entrance Air Curtain on Whole Building Energy Use* - IECC
- Phase III – *Energy Saving Impact of Air Curtain Doors in Commercial Buildings*
- Phase IV – *Accurate Quantifications of Wind Effects on Air Curtain Performances* – ASHRAE 90.1 and 189.1
- Phase V - *Evaluation and Application of Existing Air Curtain Effectiveness Methodology*

$$\eta_{(\frac{AC}{SD})} = 1 - \frac{|Q_{AC}|}{|Q_{SD}|}$$

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.

ACU – Regulation

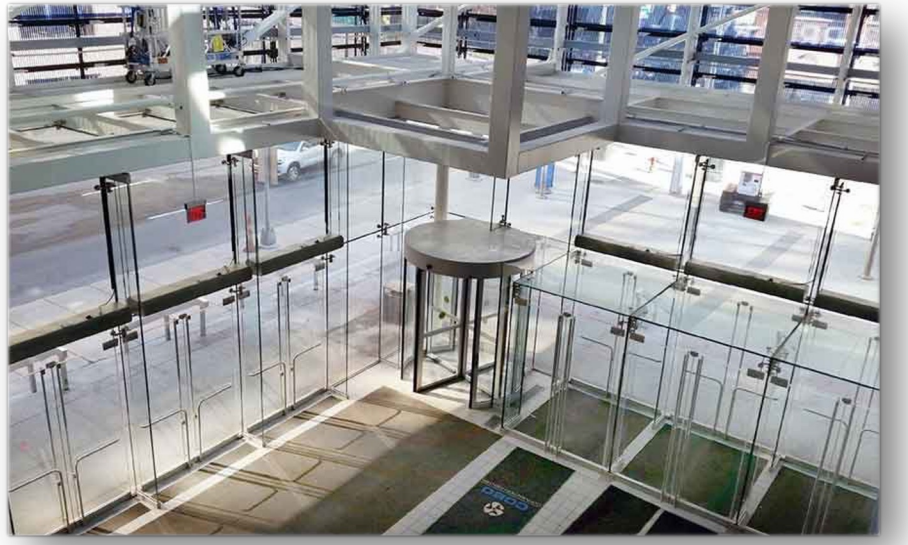
- Federal – Dept. Of Energy Fan Regulation
  - ACU's are currently in the exemptions list of the DOE's draft.
- State – California Energy Commission Title 20 Appliance Efficiency Reg
  - ACU's are currently in the exemptions list of the regulation.
- Future Regulation, Codes and Standards
  - 2025 California Building Energy Efficiency Standards (Title 24, Part 6) CASE considering air curtains as alternative to vestibule based on ASHRAE 90.1.
  - Possible future ratings – would be based on type; Energy or Health.
  - Energy based rating should measure 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. Currently under global development.

Frank Cuaderno

Air Curtain Unit – Applications

- Seven 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*

(first five are the most common)



Air Curtain Unit – Types and Configurations

- Two Types of ACU's:
  - Non-recirculating
  - Recirculating
- Configurations:
  - Horizontal – air flows vertically (most common)
  - Vertical – air flows horizontally
- Major differences
  - Airflow path
  - Cabinet construction
  - Range of effectiveness
  - Purchase and installation costs.

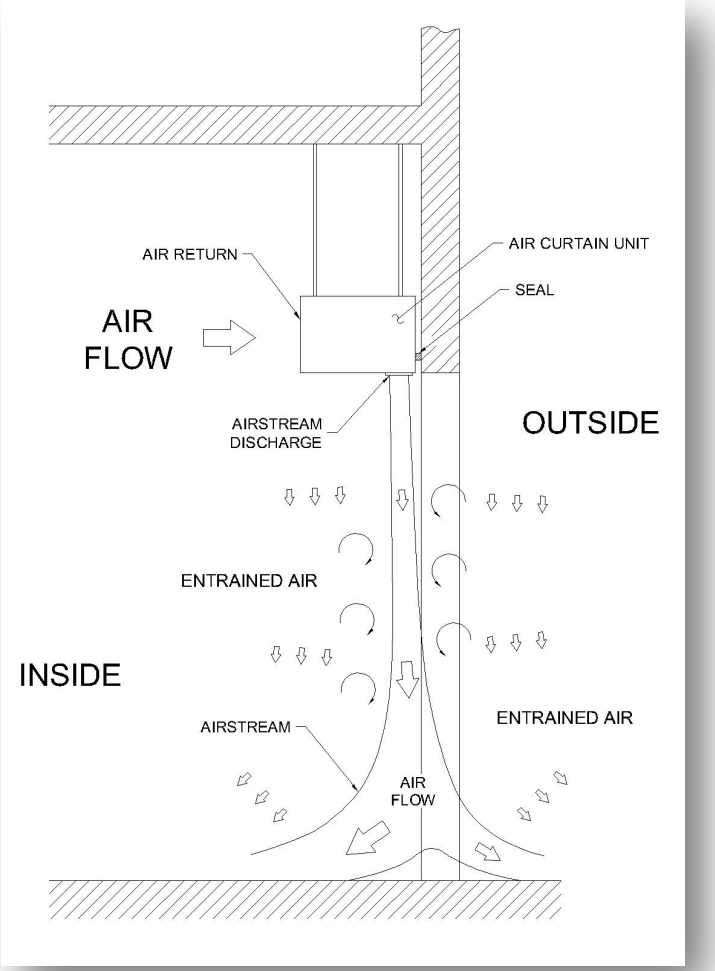
Air Curtain Unit – Operation

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

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

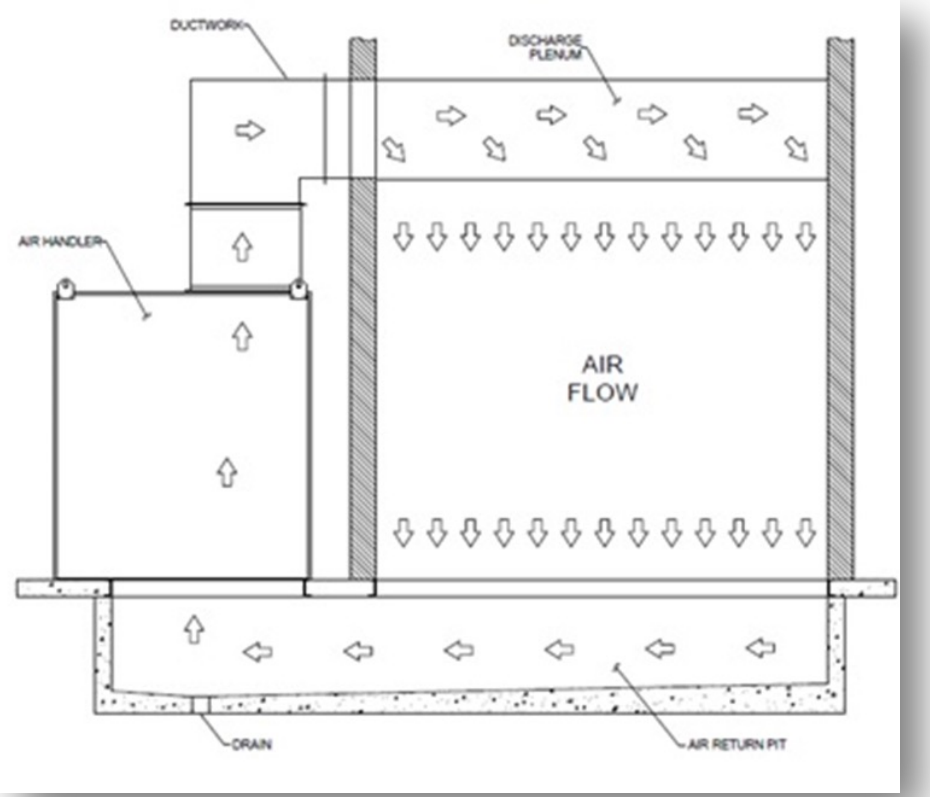
ACU Types – Non-recirculating

- Airflow path 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 simple installation.



ACU Types – Recirculating

- Airflow path draws air from ductwork that collects and returns the discharged air.
- Majority of applications use a plenum and floor return connected to inlet with ductwork (shown)
- Recommended for openings with open 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 thick airstream not effective for insect control. Higher energy consumption.
- Recessed components are perceived as less obtrusive, but larger in size, and complex installation.



Non-Recirculating vs. Recirculating

- Nonrecirculating Advantages
  - Lower purchase, planning, installation, and maintenance costs
  - Retrofittable to existing opening
  - Used for temperature and insect control
- Nonrecirculating Disadvantages
  - Intrusive high velocities
  - Lower overall effectiveness, 60–75%
  - Not recommended for applications open for extended periods of time

- Recirculating Advantages
  - Less intrusive lower velocities
  - Higher effectiveness, 75–85%
  - Used for extended open applications
- Recirculating Disadvantages
  - Higher initial cost
  - Requires planning for installation and maintenance
  - Not intended for fly insect control
  - Considered for niche markets

Applications – 7 Types

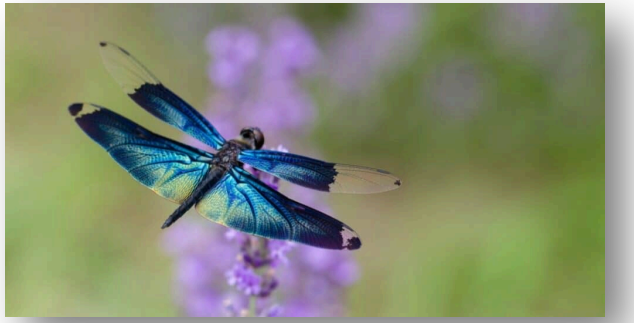
1. Exterior environmental separation

- 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.

Application Types



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.

Application Types

4. Coolers/chill rooms and freezers/cold stores

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

Application Types

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.
- Typical 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.

Application Types

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 are not be capable of overcoming the artificial deflection created by the negative condition.
- In special cases an increase of airflow may 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.

Application Types

7. Special/custom 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.

Air Curtain Unit – Benefits

- Proven energy savings by reducing air transfer across openings.
- Energy savings by reducing load on unitary heating & cooling equipment.
- Protect buildings environment from airborne dust, contaminants, and fumes while supporting increased ventilation and room air de-stratification.
- Maintain employee and customer comfort.
- Increase safety by allowing unhindered traffic flow & unobstructed visibility through an opening for people and vehicles.
- Create usable space around commercial doorways.
- Elimination of ice and fog in cold storage areas.

ACU – Calculators and Sizing

- ROI Calculators
  - ROI (return on investment) calculator – Can estimate the energy savings and payback periods of different types of air curtains. Usually available from manufacturers.
- Sizing Tools
  - Product configurator – Assists in selecting the proper model, including heat type and power required for application. Beneficial to specifiers, engineers, designers, and architects.
  - Submittals and CSI (Construction Specifications Institute) specs– Assists architects and engineers in writing the air curtain specifications.
  - Revit – A software system that works with building information modeling (BIM), provides detailed 3D models w/specs that can be inserted into the project design drawings.

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

Air Curtain Unit – Resources

- AMCA International: www.amca.org
- AMCA inmotion Magazine: www.amca.org/inmotion
  - 2019 Edition: Air Curtains: A Proven Energy-Saving Alternative (Free download available)
- ANSI/AMCA Standards and Publications: www.amca.org/store
  - 220-21: Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings (Available for purchase)
  - 222-16: Application Manual for Air Curtains (Available for Purchase)
  - 300-14: Reverberant Room Method for Sound Testing of Fans (Available for purchase)
- ASHRAE Handbooks: *Applications, Systems and Equipment, Fundamentals*
- Research and white papers: Universities, Government, bookstores such as www.techstreet.com or www.sciencedirect.com

Q & A

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