HOW INDUCTION UNITS PROVIDE VENTILATION TO HELP PREVENT THE SPREAD OF VIRUSES AND OTHER POLLUTANTS

Engineers Guide to Induction System Ventilation

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ABSTRACT

Induction Air Ventilation is designed to use displacement ventilation.

Displacement ventilation helps reduce pollutants and viruses.

- Cold, clean air drops to the bottom of the room.
- The heat sources in the room such as people, equipment and lighting, provide energy that create heat plumes that raise the clean air to the breathing zone.
- As the air warms further, it carries pollutants up and away from the occupied zone of the spaces.
- The pollutants are then exhausted away from the upper zone.

Raising the pollutants (Co2, virus etc.) up and away from the occupied zone to the exhaust is preferable to mixing and moving them around the room at all heights.

IAV air control valves work in any age induction unit, improving displacement air ventilation efficiency and lowering operating costs.

HOW DO INDUCTION UNITS ACTUALLY PROVIDE VENTILATION?

Most induction systems were designed more than 50 years ago. Most of the installed bases of induction units are over 50 years old as well. Most of the engineers that designed these systems and the sales engineers that provided design assistance are in the twilight of their careers or have already retired.

Many of today's engineers are asking how safe are these systems? Do they provide adequate ventilation especially for the risks to occupants' health we are faced with due to the pandemic?

HOW ACES CAN HELP

We offer assistance to the engineering community in answering these questions. We have assembled information from numerous sources including:

- Original design guides
- New ASHRAE design guides
- Design guides from New Induction equipment manufacturers
- New Ventilation distribution equipment design guides
- Experienced application Engineers presently designing and applying Induction Equipment

BASIC PRIMER

There are some baseline facts that need to be established about the original design criteria. We supply a design synopsis by a professional engineer that has been intimately involved in evaluating the designs of both old and new induction systems. Engineers can use this as a primer to gain a basic understanding of these systems.

INDUCTION HVAC SYSTEMS ORIGINAL DESIGN

When induction HVAC systems were originally designed, Primary Air (generated by remote air handling units) of either 100% outside air or a blend of outside and return air was supplied to the perimeter spaces within a building. This air is filtered, heated or cooled / dehumidified (summer), humidified (winter) and supplied to the terminal induction units. The primary air was typically designed to be supplied at a temperature lower than the dewpoint of the spaces thereby eliminating condensate generation within the occupied areas.

The induction unit receives the primary air and discharges it through nozzles that increase the air's velocity. The high velocity air exiting the nozzle creates a vacuum and draws room air into the unit.

This air is drawn through a heat transfer coil that can either heat or cool the room air. The room and primary air are blended and supplied into the space at a low velocity.

The primary air flow is constant; water flow is regulated to maintain the room temperature set-point based on a thermostat located in return air the space as measured by a bulb at the floor level in the induction unit.

INDUCTION HVAC SYSTEMS SIZING / SELECTION

Sizing an induction terminal unit is relatively simple; the room Summer and Winter HVAC load is calculated which includes transmission loads (walls, glazing, etc.), solar heat gains, lighting, equipment, appliances and occupants.

Additionally, the ventilation load i.e. outside air required for the room's occupant is determined based on building code and/or local ordinance.

Finally, any supplemental air requirements necessary to maintain the space pressurization is determined. The Primary Air Flow in cubic feet per minute (CFM) is then determined:

Primary Air Flow = Transmission Air Flow + Ventilation Air Flow + Pressurization Air Flow

INDUCTION HVAC SYSTEMS SIZING / SELECTION

The induction unit can then be selected.

Each induction unit manufacturer provides performance data which includes Primary Air Flow, Coil Water Flow, Capacity in BTU/hr or BTUH. Capacity tables for gravity or convective heat radiation are also provided.

The induction unit(s) is selected to meet the room heating and cooling loads as well as convective heating for when the air handling units are shut down. The induction unit is designed to maintain the room conditions on a year-round basis.

INDUCTION HVAC SYSTEMS CONCEPT

Induction HVAC system sizing and selection is not that much different than sizing a typical "all air" system using ceiling diffusers or other terminal devices, that is satisfying the loads.

When designing the "all air" system, relatively high velocity supply air is discharged into the room through ceiling diffusers, wall grilles or other device. This produces a "Coanda effect" that essentially creates room air turbulence and blends the room air and supply air together. Air leaves the space through a return or transfer grill. Some perimeter "all air" systems will use linear slot diffusers along windows in order to "wash" the windows with conditioned air.

INDUCTION HVAC SYSTEMS CONCEPT

Diffusers are sized based on the air flow requirement and "throw" that is the distance that the air will maintain its velocity from the diffuser. The selection tables, literature and any other published data for induction units does not include throw, discharge velocity or even primary + room air flows.

The induction system concept is a displacement rather than blending, although at that time displacement ventilation was not defined as such.

Displacement systems supply air at relatively low velocity into a space (primary + induced air flow). The cooled air drops and will fill the space and create stratified layers of cooled air and warm air. The warm air is displaced to the ceiling and out through a return or transfer grill.

INDUCTION HVAC SYSTEMS VARIABLE VOLUME

Varying the air flow through an induction HVAC system is really no different that varying the air flow in an "all-air" system.

- The typical "all-air" variable air volume or VAV system uses a terminal box or other device to reduce the supply air flow to the room.
- As the air flow is reduced, the discharge velocity through the supply diffuser is also reduced and the in many cases the "Coanda effect" is lost. The supply air is "dumped" to the floor. Many newer diffuser designs account for this and minimum air flows are set to avoid this problem. However the system still operates by reducing the total air flow to the space based on the room thermostat. Total air flow includes outside or ventilation air.

VARIABLE VOLUME INDUCTION

- The induction unit variable air flow concept works in the same manner; the primary air flow is reduced based on the room thermostat. A minimum primary air flow is set to maintain minimum outside air requirements. The room air is still displaced, and the same occupied zone is maintained even at reduced primary air flow.
- The induction HVAC system was originally designed on a room air "displacement effect" as opposed to the "Coanda effect" of an "all-air" system. Variable air Volume or VAV design on an induction system is conceptually the same as VAV "all-air" design.

BEYOND THE BASICS

- The following is a deeper dive into the actual design data from dozens of existing buildings.
- We will introduce some new concepts that have emerged in the 50 years since these systems were installed, along with high tech confirmation using computer modeling of flows to provide affirmation of these newer design concepts.
- We will confirm the concept of Displacement Ventilation.
  - This design concept first became popular in Europe in the 1970s. There is no mention of it in the Carrier Design manuals for air distribution from the '60s or ASHRAE Fundamentals Handbook 1985 Edition Chapter 32 Space Air Diffusion. It wasn't until 1999 that ASHRAE had a publication for Guidance to Engineers "System Performance Evaluation and Design Guidelines for Displacement Ventilation" by Glicksman and Chen available from their publications store.

EVALUATING A BUILDING VENTILATION SYSTEM

- The first parameters to establish are the ventilation rates in CFM/ Sq. FT and the outside air rates in CFM per person. In calculating CFM circulated it is necessary to remember that the induction units induce the recirculation of three CFM of room air for each CFM of primary air fed to the nozzles. This equates to the total air circulated being equal to the total air supplied by all the supply fans **plus** three times the Primary airflow.
- **Total Air Circulated = Primary Fan Flow + Interior Fan Flow + 3X(Primary Fan Flow)**
- Most primary air systems were 50% or 100% outside air and additional outside air is supplied by the interior supply fans. If outside air quantity is not on the schedule look at the design return air compared to the chilled water coils inlet and calculate the outside air using a mixed air calculation. Outside air design temperature can be found at the Cooling Tower Schedules if not found at the AHU schedules. In the absence of Outside Design Information use 95 DB 76 WB for these older buildings.

EVALUATING A BUILDING VENTILATION SYSTEM

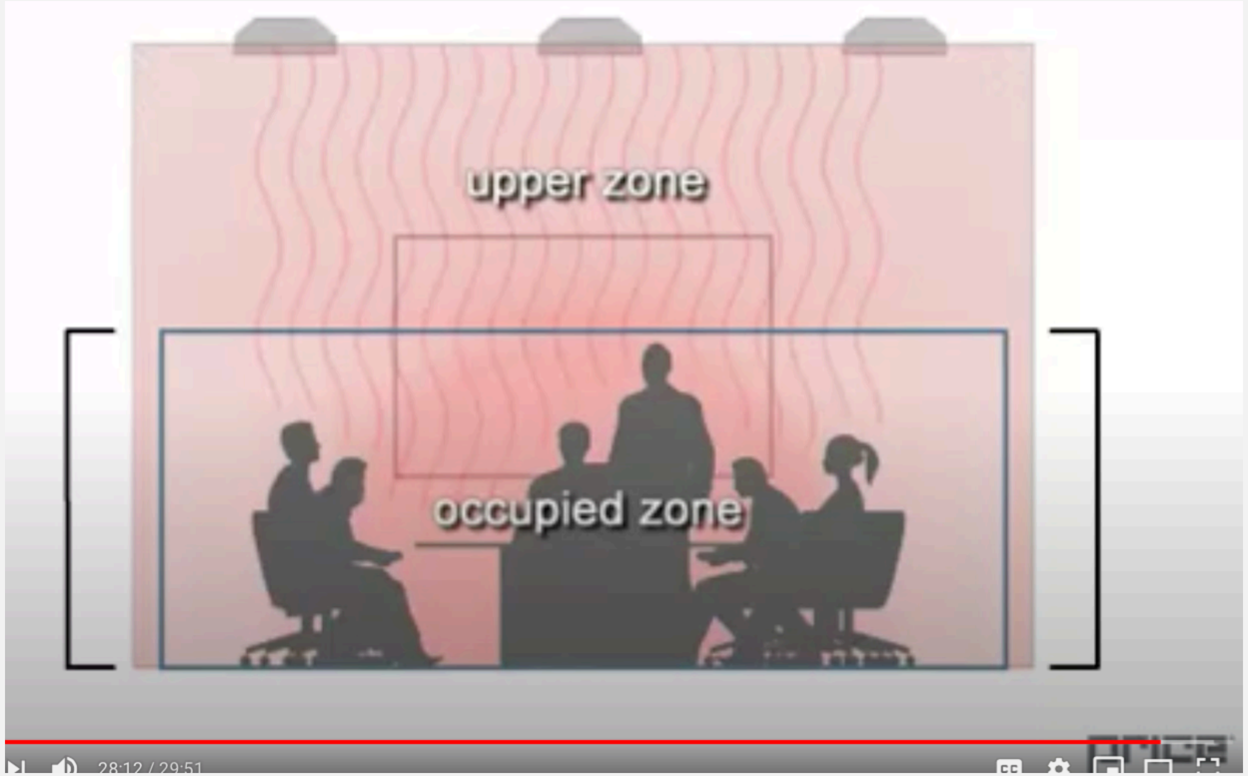
- When outside air is totaled you will find amounts approximately equal to 25% of total fan designs or possibly even more.
- Operating engineers attempted to reduce this amount by closing dampers or installing ductwork to decrease outside air for primary air fans from 100% to 50%. **However, if exhaust fans were not shut off and fan tracking controls installed and operational, the building is negatively pressurized and outside air will be introduced to the building through dampers, leaks, doors etc.**
- You can assume that outside air is equal to the exhaust plus spill air. Total up the exhausts to get this number. Estimate spill air by using mixed air calculations in real time from the BAS.

DISPLACEMENT VENTILATION

Facts about Displacement Ventilation

The concept of displacement ventilation was not a recognized method of ventilation in the US until at least the late 1980s or later. It works on the principals of:

- Providing Cold Supply Air that enters at or drops to the floor
- Buoyancy Forces
- Stratification
- It depends on Computational Fluid Dynamic Modeling (CFD) to visualize
- It was defined and refined out of the need to improve IAQ in spaces



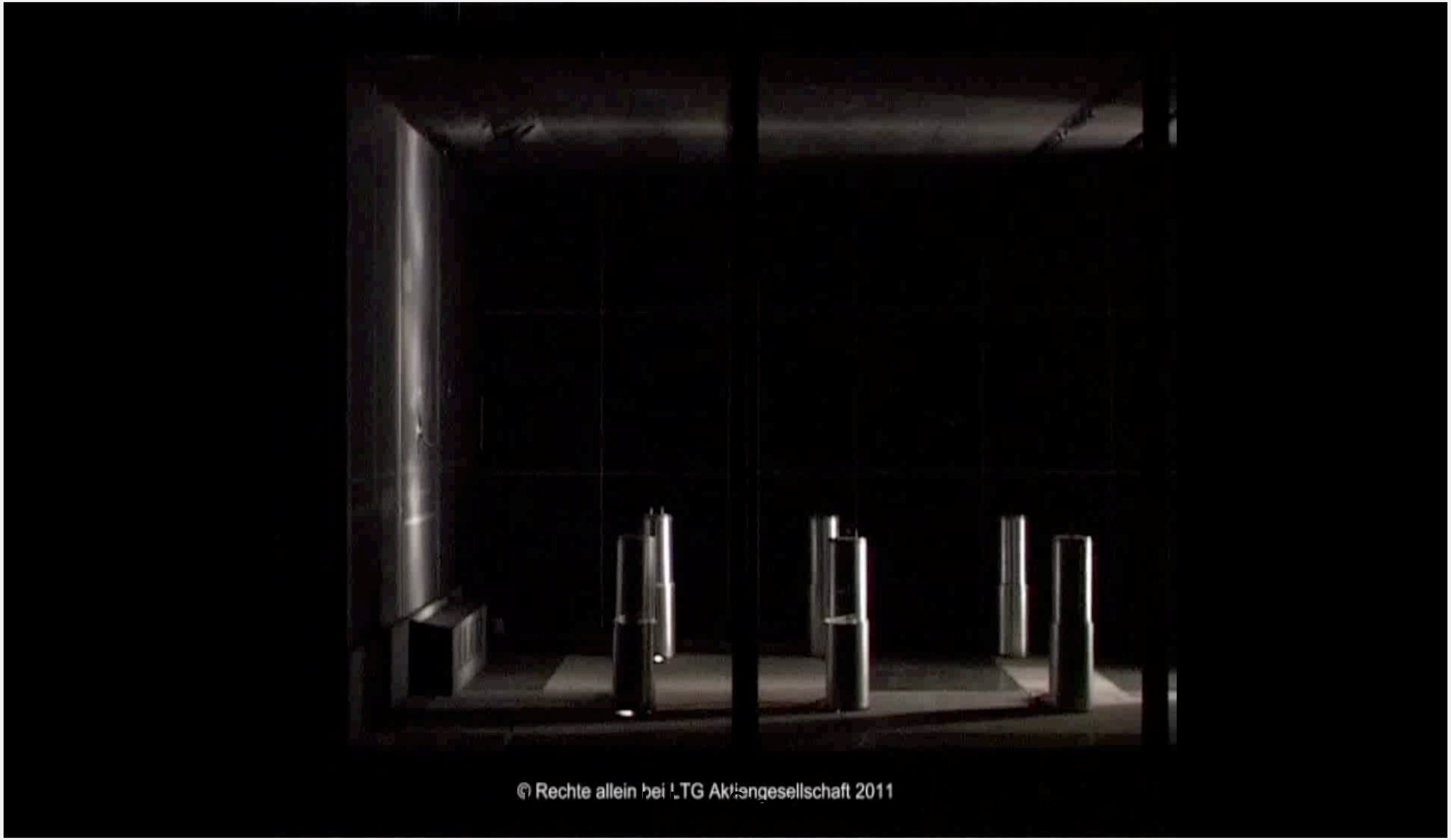
- The spaces are divided at different horizontal planes as occupied zone and upper zone. Cold air is distributed to the lower part of the occupied zone and exhausted from the upper zone.
- The idea is for the cold air to drop to the bottom of the room. The heat sources in the room such as people, equipment and lighting provide energy that causes heat plumes that raise the air and pollutants up and away from the occupied zone of the spaces. The pollutants are then exhausted away from the upper zone.

PRACTICAL APPLICATION

- **As a matter of practical thinking, raising the pollutants (Co2, Virus etc.) up and away from the occupied zone to the exhaust is preferable to mixing it and moving it around the room**.
- The following images show how displacement ventilation works. Short explanations are provided on the slides. Reference materials including ASHRAE manuals are also provided.

New LTG Induction Unit CFD 24 CFM

New LTG Induction Unit CFD 60 CFM



CFD Final Result 24 CFM after 50 seconds

CFD Final Result 60 CFM after 50 seconds

PLUMES AND PENETRATION

On the top right it shows the effect of heat sources on the Displacement layers and plumes that carry away contaminants.

On the bottom it shows the effect of obstructions at lower levels in the occupied zones on the distribution of air along the floor.

forces associated with heat sources or cold sinks. Heat sources such as people, computers, lights, etc. create a rising convection flow known as a thermal plume. The strength of the thermal plume is dependent on the power and geometry of the heat source. The strength of the thermal plume will determine how high the convection flows can rise before the momental is fully dissipated. Cold sinks such as exterior walls or windows can generate convection flows down the wall and across the floor.

Figure 15.6: Air layers

Air Flow Penetration

A displacement system supplying cool air through a diffuser will deliver air along the floor in a thin layer typically less than 8 in. [0.20 m] in height. The supply air spreads across the floor in a similar manner to water flowing out of a tap, filling the entire space. If obstructions such as furniture or partitions are encountered, the air will flow around and beyond the obstruction, as illustrated in **Figure 15.7**. Even rooms with irregular geometries, as illustrated in **Figure 15.8** can be uniformly supplied with air.

When the cool air meets a heat source such as a person or piece of equipment, a portion of the conditioned air is captured by the thermal plume of the heat source, while the remainder of air continues further into the room.

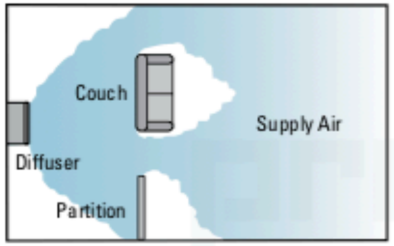


Figure 15.7: Obstruction

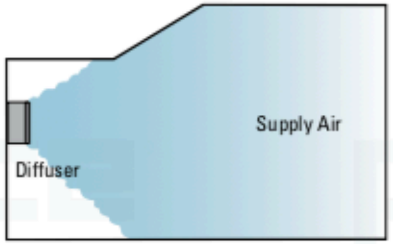


Figure 15.8: Irregular room geometry

When designing the system to deal with the cooling demand of the space, the penetration depth of a displacement diffuser can be 26-30 ft [8-9 m] or more from the face of the diffuser. For rooms exceeding 30 ft [9 m] in length or width, diffusers on several walls are suggested to promote even air distribution.

CONTAMINANTS DISTRIBUTION

The bottom right explains how the distribution of contaminants moves out of the occupied space more quickly and away from the room occupants making the spaces safer as a result of Displacement Ventilation.

Diffuser Air Flow Pattern

In order to avoid draft and minimize induction of room air, it is essential for the displacement diffuser to uniformly deliver the supply air across the entire diffuser face at low velocity. This requires an internal equalization baffle in combination with a low free area face. Yuan, Chen & Glicksman, (1999) recommended 40 fpm [0.2 m/s] in order to maintain acceptable comfort.

A displacement diffuser supplying cool air will result in an air pattern (typically 5 - 10 °F [2 - 5 °C] cooler than the room set-point), resembling **Figure 15.9**. Due to the density of the cool supply air, it falls towards the floor a short distance from the diffuser face and continues along the floor at a depth of approximately 4-8 in. [0.1-0.2m].

When supply air is isothermal (supply air is the same or less than 5 °F [2.5 °C] warmer than the room set-point), the flow will be distributed horizontally into the space, as shown in **Figure 15.10**.

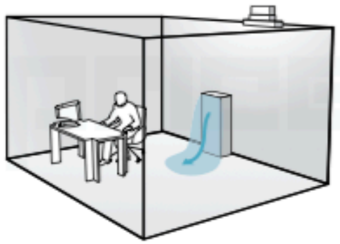


Figure 15.9: Cooling air flow pattern

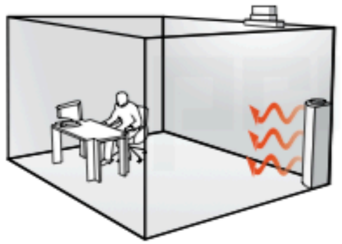


Figure 15.10: Isothermal air flow pattern

Contaminant Distribution

Contaminant distribution is influenced by several factors such as supply air method, contaminant source type, location within the space, heat sources, and space height.

Displacement ventilation improves occupant air quality by reducing the contaminants in the lower portion of the room. The general upward motion of air causes contaminants to concentrate within the upper zone **(Figure 15.11)**.

With mixing ventilation, contaminants are diluted with supply air and are distributed evenly throughout the space. The figure represents contamination distribution in a room supplied with mixing and displacement ventilation for a typical case where the contaminant source is warm (a person, for example).

With displacement ventilation, because the upward convection around a person brings clean air from lower level to the breathing zone, the air in the breathing zone is cleaner than the room air at the same height. Contaminants that are heavier than air need to be extracted at a lower level through a second return if they present a safety concern.

INDUCTION UNITS WERE ALWAYS DESIGNED TO USE DISPLACEMENT VENTILATION

Induction Units were designed to provide mixing in the casing and directly at the outlet of the grills. The design of the grills and velocity of the outlets were never designed to provide a throw or wash the windows. The design and applications manuals for induction units from this period make no mention of throw or velocity and provide no guidance. This is because the engineer, most times, had no control over the design of the enclosure or diffuser. This was left to the discretion of the architect.

MOST COMMON DIFFUSER

This is a picture of the most common discharge diffuser which is a stamped grill designed to throw the air left and right from the center and not out toward the room or up along the window.

The concept of 15Ft back from the perimeter was that the design of the interior system was directed to start this distance from the perimeter and that the perimeter system was assumed to provide for cooling and heating to the point of start of the interior system.

EUROPEAN COMPANIES WITH USA DISTRIBUTION CHAMPION INDUCTION UNIT DESIGN

European companies continue to manufacture and refine the designs of induction systems. They have analyzed the performance of older designs using the new modeling tools available to them. CFD models of old units have shown they work as a mixing system right at the units as originally designed, but a few feet away from the units they actually ventilate the spaces using Displacement Ventilation. The videos shown previously of the CFD models as well as the end results after approximately 50 seconds at two different primary airflow rates (24 and 60 CFM) visually represent what happens.

WHAT SPECIFICATIONS DO WE DESIGN TO?

There is a lot of pressure from the Medical community to direct the HVAC engineering community to change their HVAC designs to make it safer for occupants. Unfortunately, the medical community cannot agree on how the Covid-19 virus spreads.

Still, they would have building owners install expensive filters (that won't work without replacing filter racks and proper safing to prevent leakage) increasing coil sizes, pump sizes, chiller sizes, fan motor sizes and increase energy costs all on unsubstantiated claims that the virus spreads through the HVAC systems. They have closed malls on both coasts demanding these systems be changed before allowing stores to open.

At the same time some states and cities have passed laws imposing huge fines for excess energy consumption!

I am an engineer with 30+ years designing control systems for airflow and pressurization / contamination control for clean rooms, animal labs and BSL 1-4 laboratories, **Before you spend a lot of your customer's money**, listen to this Medical Doctor and Harvard professor's JAMA listed podcast on the spread of Covid-19 Virus. https://edhub.ama-assn.org/jn-learning/audio-player/18524547 (click on this then click on download MP3) or cut and paste this into your browser.

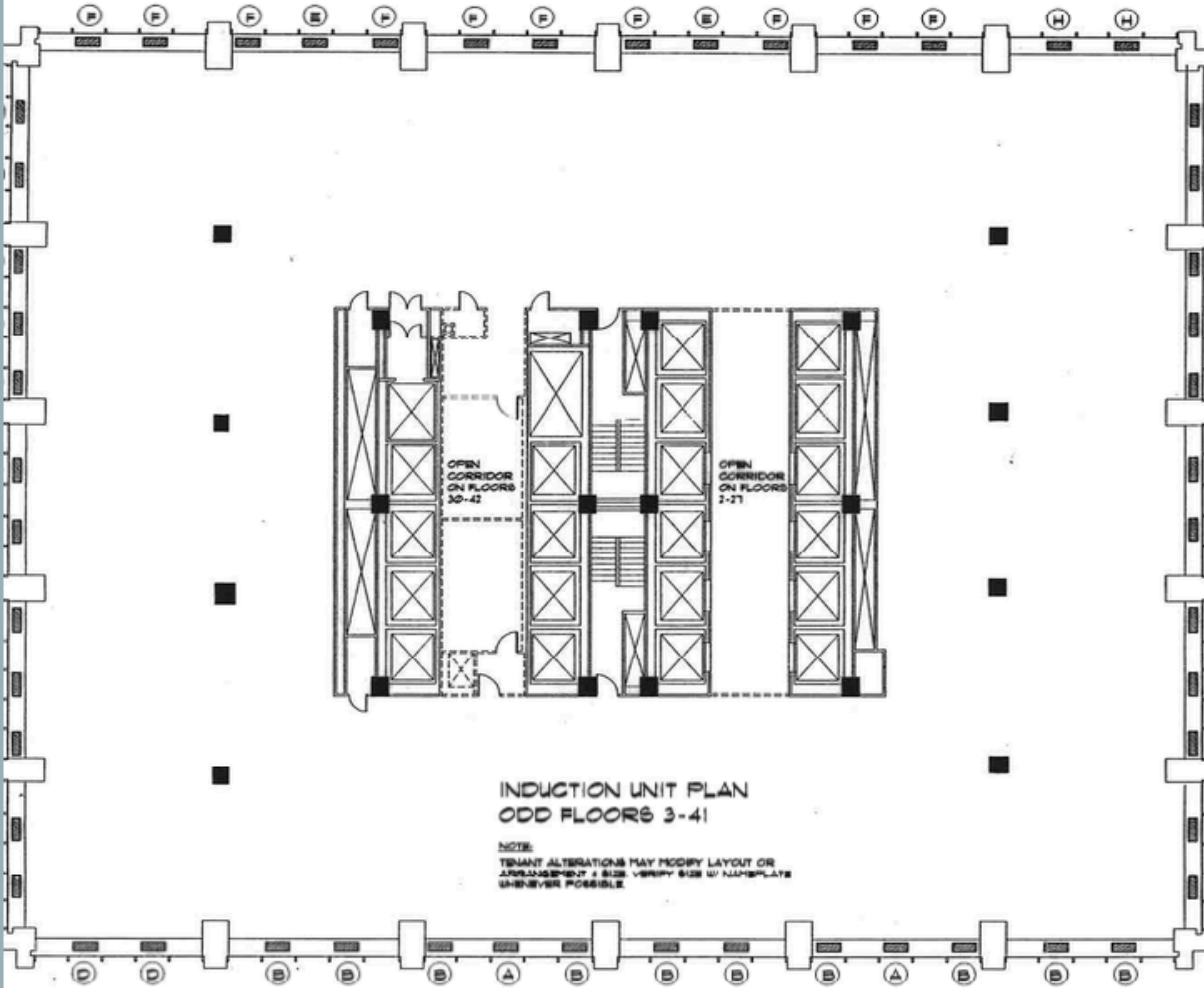
We are **engineers** responsible for our designs and responsible to both occupants and owners for making informed designs**. More air may actually increase danger to the occupants.**

TYPICAL FLOOR LAYOUTS OF INDUCTION UNITS

- The ventilation rates and quantities of outside air being provided to the perimeter of the building by the induction system is a function of the size of the induction units and the amount of outside air being taken in by the primary air AHU.
- The layout of induction units in most induction systems is identical. Every other column is used for primary air risers and every other column is used for secondary water risers. In the most typical minimal system induction units come off the air risers two in series to one side and one unit to the other side. The distance between risers is typically 21 feet center to center and typically (depending on window size) there are three windows per bay between risers. There are then three induction units for every two bays between air risers. (See diagram).

FLOOR INDUCTION UNIT LAYOUT

Typical Floor Induction Unit Layout with 2-3 Induction Units per bay. 1.5 Units per bay is worst case conditions.



PHYSICAL DIMENSIONS OF CONDITIONED AREAS

If we use 42 feet wide and 15 feet back from the windows as the square foot area conditioned by three induction units, it is then 630 square feet. The size of the induction units is a function of the load calculated by the engineer, which is heavily a function of exposure.

For your convenient reference we have created a table based on primary air supply that gives you the information you need for ventilation quantities for both constant and variable volume (in red) primary air systems.

Using worst case conditions of 1.5 units per bay the following calculations apply.

Area	630 sq. ft.
Ceiling Height	8.5 ft.
Induction Rate	3 to 1
OA Unit	50%
# Units	3 two bays
Space Volume	5355 ft. cu.

VENTILATION TABLES FOR CONSTANT VOLUME INDUCTION UNITS

1.5 units per bay for variable size
Primary air supply

Design Primary Air	CFM Air Circulated / Sq Ft	Air Changes / Hr	Outside Air / Sq Ft	OA CFM / 10 ft wide office
20	0.38	2.69	0.048	7.5
25	0.48	3.36	0.060	9.4
30	0.57	4.03	0.071	11.3
35	0.67	4.71	0.083	13.1
40	0.76	5.38	0.095	15.0
45	0.86	6.05	0.107	16.9
50	0.95	6.72	0.119	18.8
55	1.05	7.39	0.131	20.6
60	1.14	8.07	0.143	22.5
65	1.24	8.74	0.155	24.4
70	1.33	9.41	0.167	26.3
75	1.43	10.08	0.179	28.1
80	1.52	10.76	0.190	30.0
85	1.62	11.43	0.202	31.9
90	1.71	12.10	0.214	33.8
95	1.81	12.77	0.226	35.6
100	1.90	13.45	0.238	37.5

VENTILATION TABLES FOR VARIABLE VOLUME INDUCTION UNITS

ACHIEVES 75% FAN HP SAVINGS

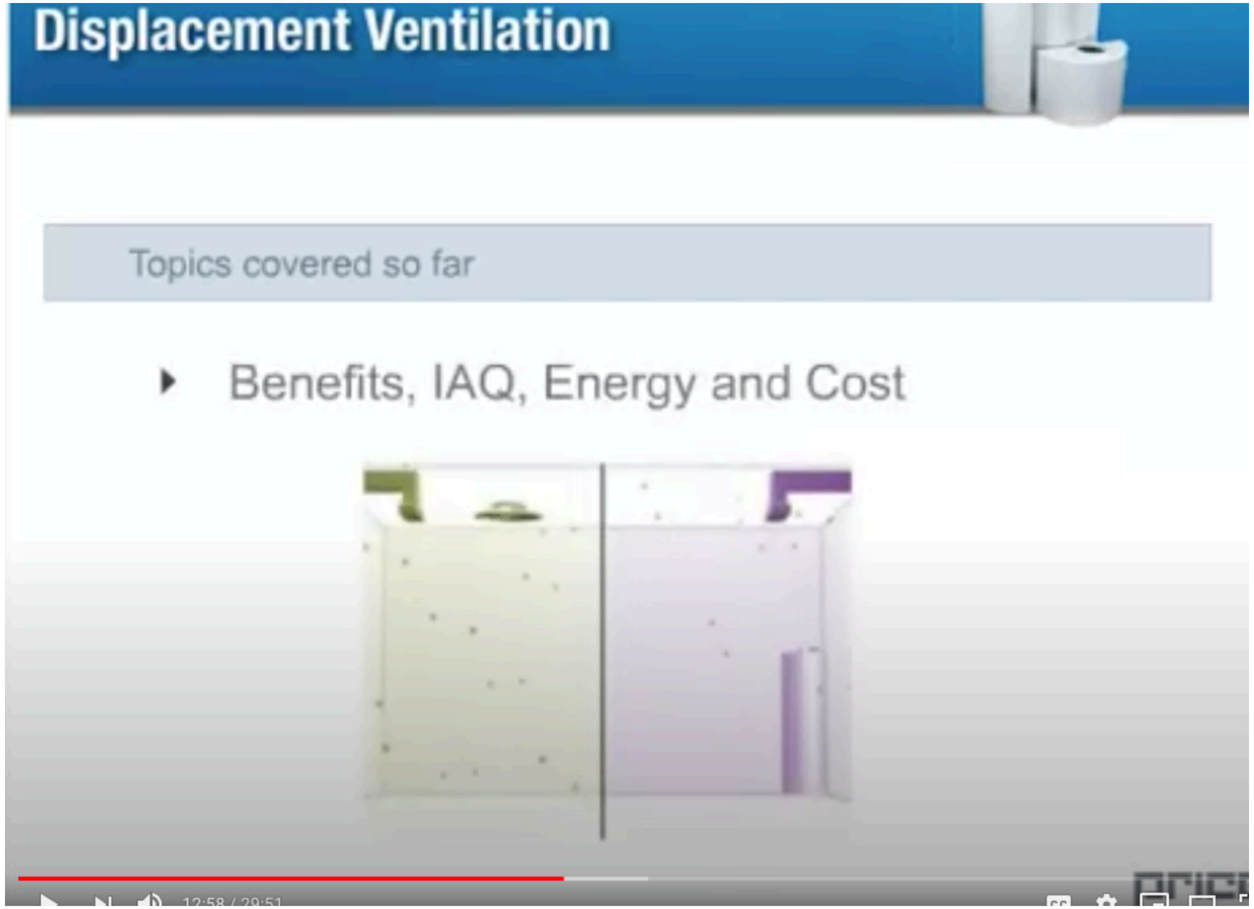
1.5 units per bay for variable size Primary air supply

Design Primary Air	Minimum Primary Air for 75% Savings VAV	CFM Air Circulated / Sq Ft	Air Changes / Hr	Outside Air / Sq Ft	OA CFM / 10 ft wide office
20	11.6	0.22	1.56	0.028	4.4
25	14.5	0.28	1.95	0.035	5.4
30	17.4	0.33	2.34	0.041	6.5
35	20.3	0.39	2.73	0.048	7.6
40	23.2	0.44	3.12	0.055	8.7
45	26.1	0.50	3.51	0.062	9.8
50	29	0.55	3.90	0.069	10.9
55	31.9	0.61	4.29	0.076	12.0
60	34.8	0.66	4.68	0.083	13.1
65	37.7	0.72	5.07	0.090	14.1
70	40.6	0.77	5.46	0.097	15.2
75	43.5	0.83	5.85	0.104	16.3
80	46.4	0.88	6.24	0.110	17.4
85	49.3	0.94	6.63	0.117	18.5
90	52.2	0.99	7.02	0.124	19.6
95	55.1	1.05	7.41	0.131	20.7
100	58	1.10	7.80	0.138	21.8

VENTILATION BY INDUCTION UNITS MEETS OR EXCEEDS ALL REQUIREMENTS FOR AIR CHANGES AND OA IN FULL OR MINIMUM VAV MODES

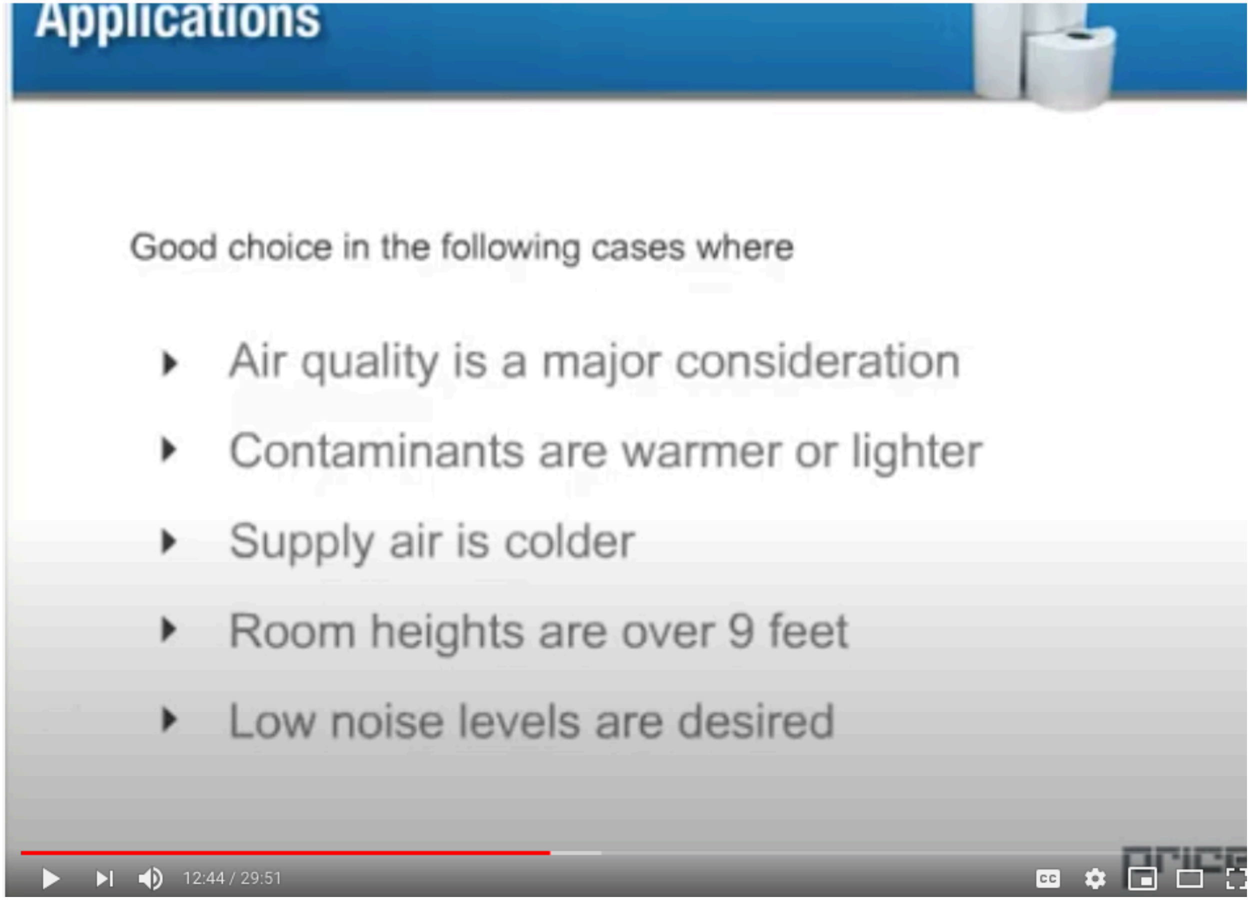
- Both the quantity of air circulated and the quantity of outside air delivered to the offices with an induction system is very high.
- If it is determined that by cutting back on the outside air to the induction system the total amount of outside air to the building is inadequate, it is highly recommended that outside air be supplemented to the interior systems where it will be most needed by use of a fan tracking system.
- The smallest induction units we have found in minimal applications has been 35 CFM. In this size unit, when VAV is applied, 75% savings can be achieved while keeping the air changes above 2 per hour and the outside air above 7.6 CFM per office.

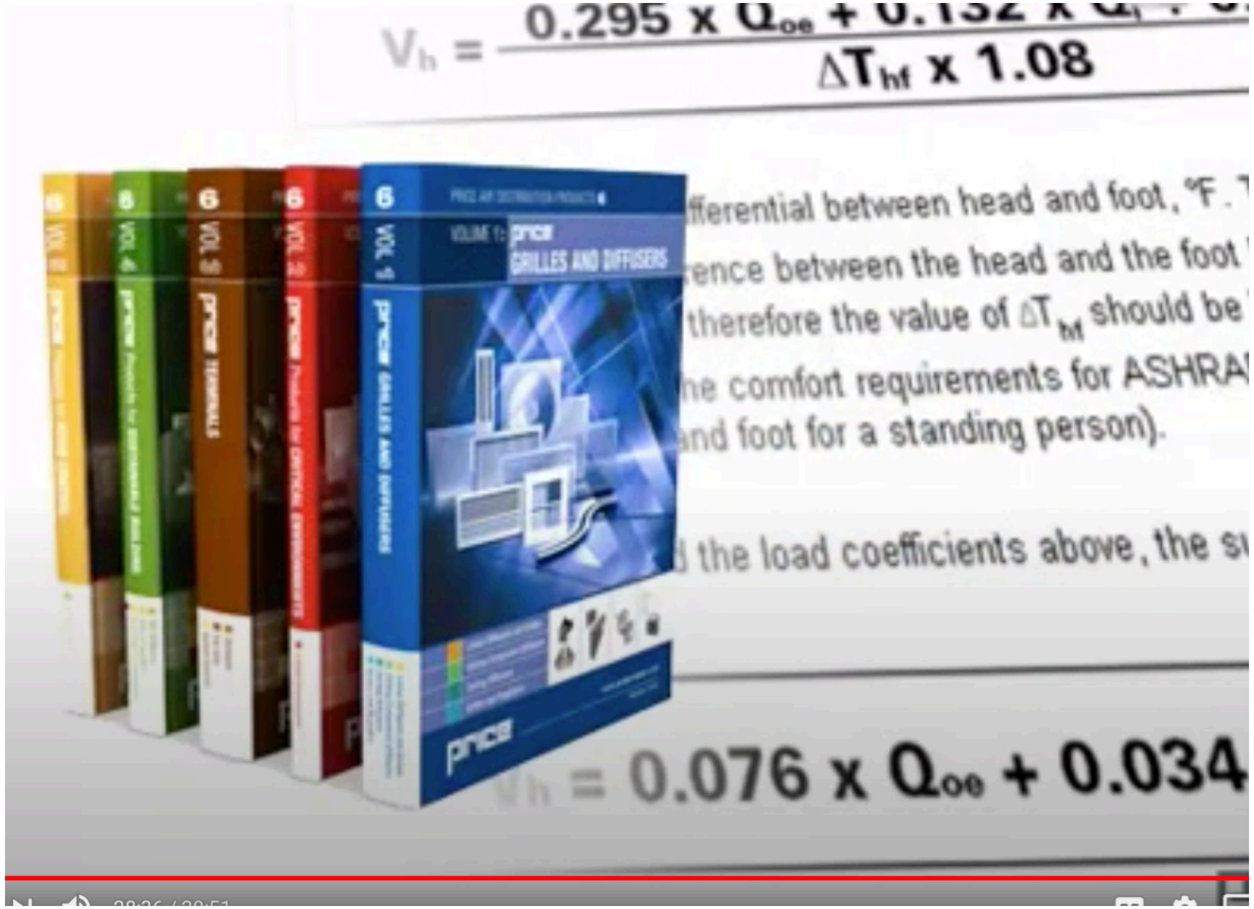
LEED POINTS FOR INDUCTION UNIT DISPLACEMENT VENTILATION



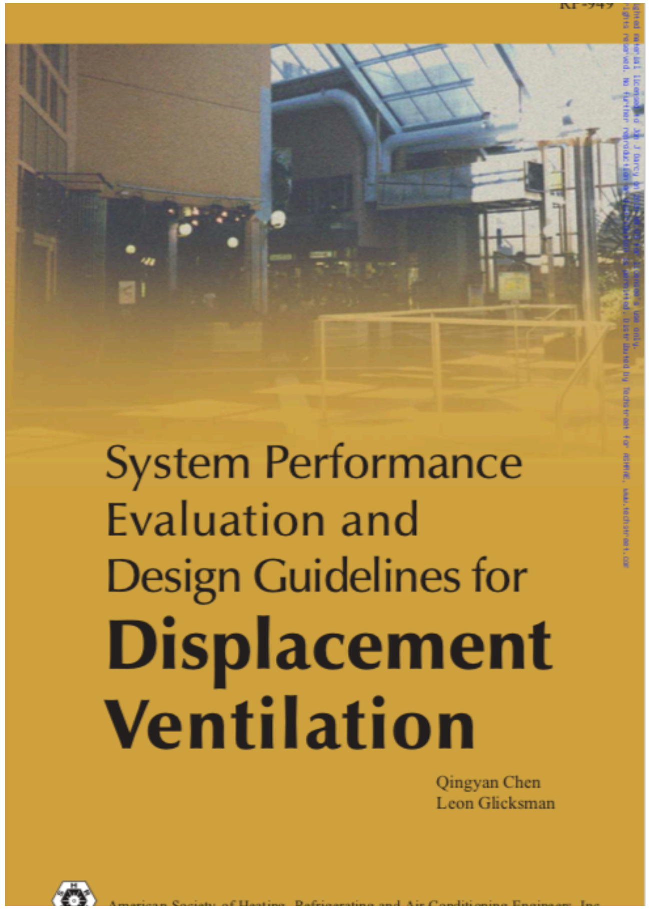
BENEFITS OF DISPLACEMENT VENTILATION

WHEN TO USE DISPLACEMENT VENTILATION





PRICE DESIGN MANUALS CHAPTER 8 DISPLACEMENT VENTILATION (YOUTUBE VIDEO)



ASHRAE GUIDE

Guide to Understanding and Design Guidelines for Displacement Ventilation from 1999.

DTU Library

Airborne transmission between room occupants during short-term events: Measurement and evaluation

Ai, Zhengtao; Hashimoto, Kaho; Melikov, Arsen Krikor

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RECENT PAPER ON COVID TESTING

This paper describes an actual real time test using dummies and real time measurements to assess the spread of contaminants between people in an office environment at different distances from each other and under different ventilation systems. Although none showed encouraging results the demand ventilation tests showed best results in all circumstances.

WE CAN ASSIST YOU

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