CAE 464/517 HVAC Systems Design

Spring 2021

February 25, 2021

Air distribution systems: Classification of air diffusion

Built
Environment
Research
@ IIT

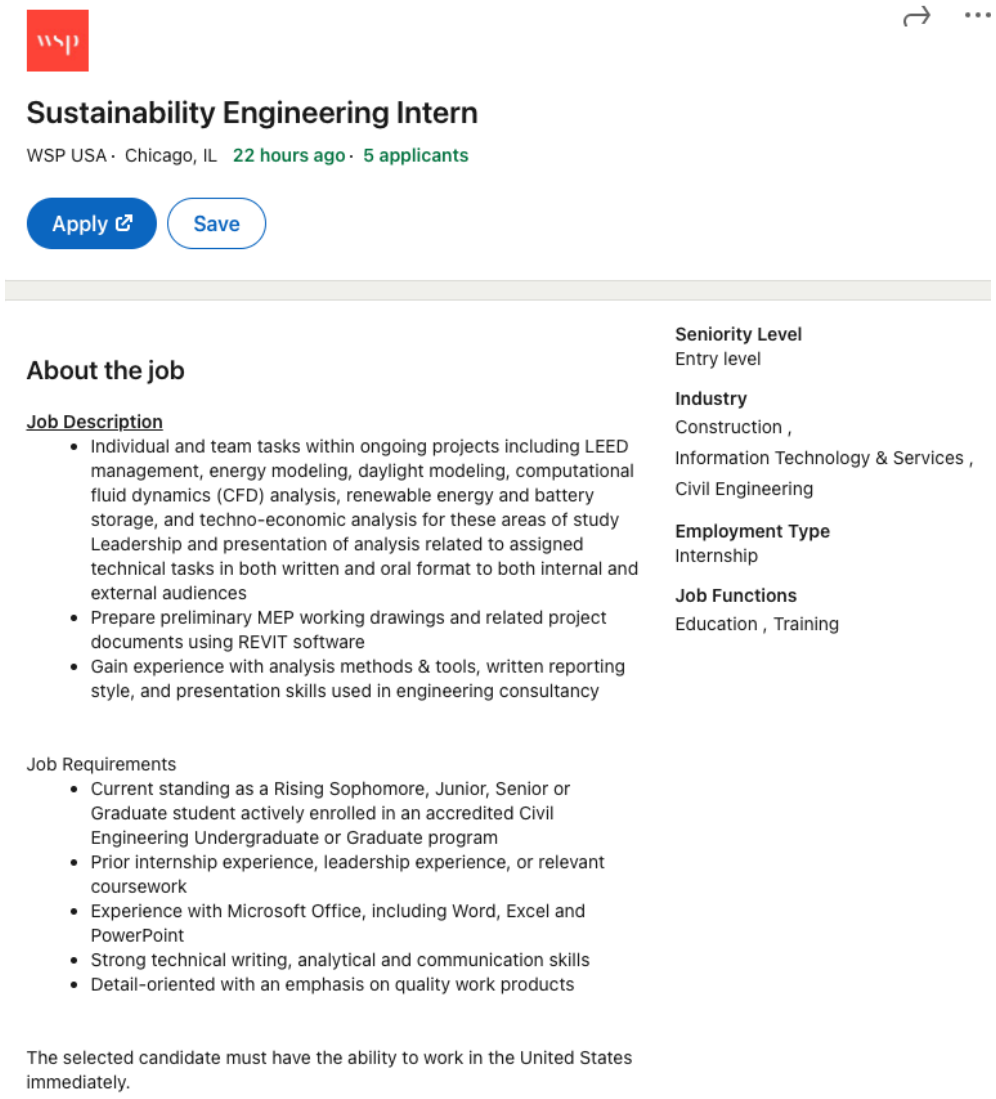
Advancing energy, environmental, and sustainability research within the built environment

www.built-envi.com

Dr. Mohammad Heidarinejad, Ph.D., P.E.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
muh182@iit.edu

ANNOUNCEMENTS

Announcements



Sustainability Engineering Intern

WSP USA · Chicago, IL 22 hours ago · 5 applicants

Apply Save

About the job

Job Description

- Individual and team tasks within ongoing projects including LEED management, energy modeling, daylight modeling, computational fluid dynamics (CFD) analysis, renewable energy and battery storage, and techno-economic analysis for these areas of study Leadership and presentation of analysis related to assigned technical tasks in both written and oral format to both internal and external audiences
- Prepare preliminary MEP working drawings and related project documents using REVIT software
- Gain experience with analysis methods & tools, written reporting style, and presentation skills used in engineering consultancy

Job Requirements

- Current standing as a Rising Sophomore, Junior, Senior or Graduate student actively enrolled in an accredited Civil Engineering Undergraduate or Graduate program
- Prior internship experience, leadership experience, or relevant coursework
- Experience with Microsoft Office, including Word, Excel and PowerPoint
- Strong technical writing, analytical and communication skills
- Detail-oriented with an emphasis on quality work products

The selected candidate must have the ability to work in the United States immediately.

Seniority Level
Entry level

Industry
Construction ,
Information Technology & Services ,
Civil Engineering

Employment Type
Internship

Job Functions
Education , Training

https://search0.smartsearchonline.com/pb/jobs/jobdetails.asp?job_number=47754

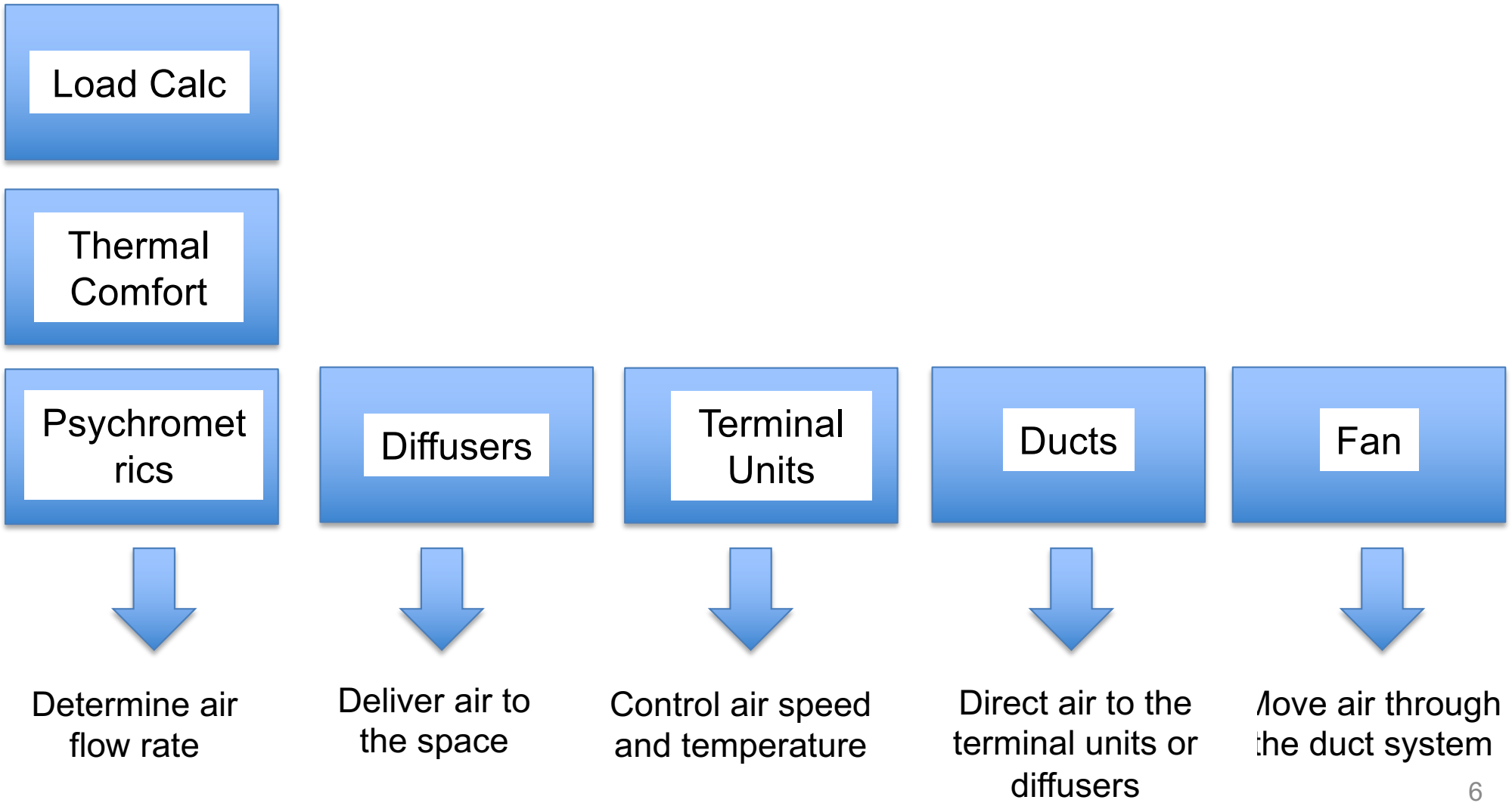
https://www.linkedin.com/jobs/view/2423191286/?refId=5%2FyPHkBbSZWcU7cNoDMFYg%3D%3D

HOMEWORK / SOLUTION / GROUP

RECAP

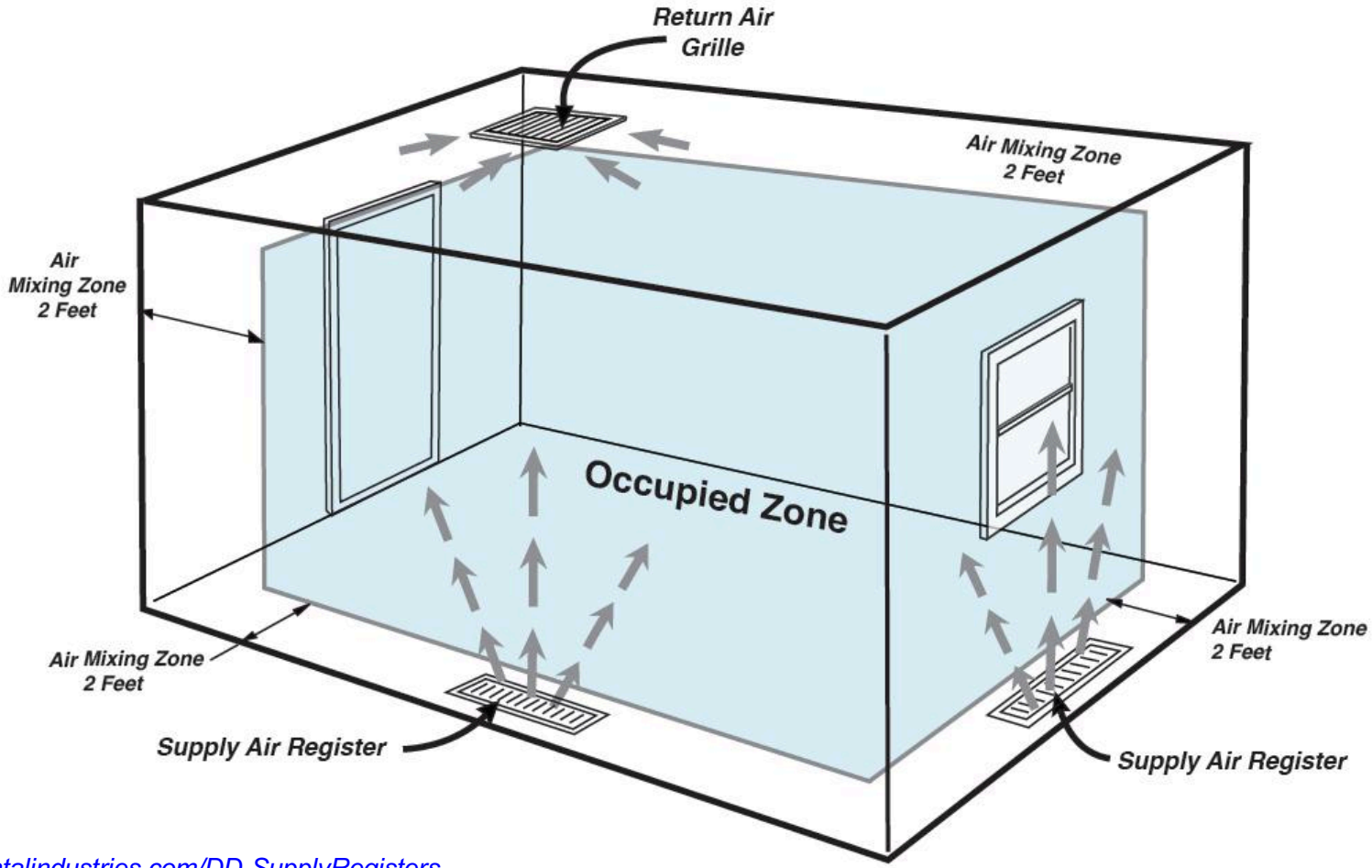
Recap

- There are a couple of components required for the design of an air distribution



Recap

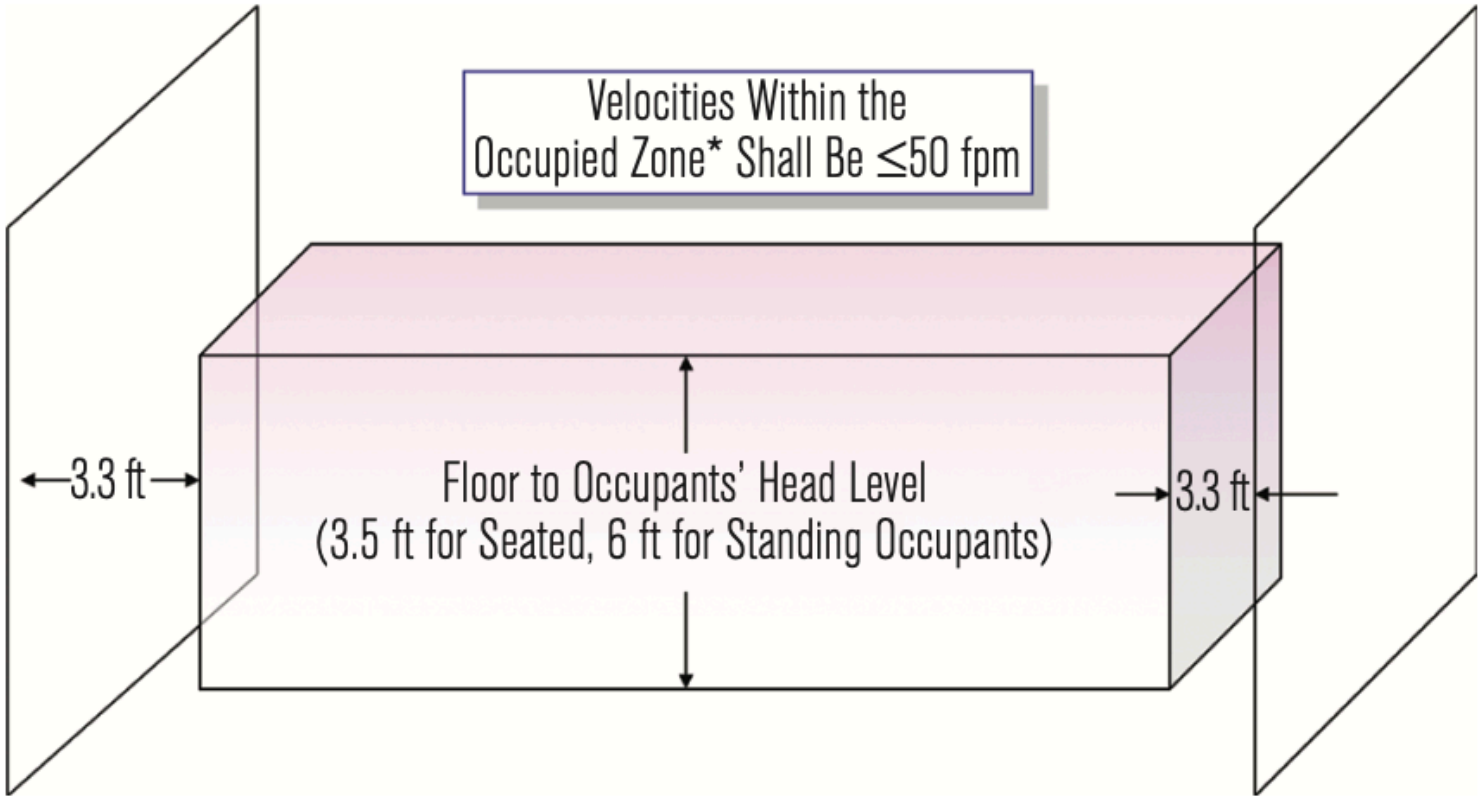
- We are interested in the occupied zone (or breathing zone):
  - ❑ 2 feet from any wall
  - ❑ 6 feet from the floor



https://www.continentalindustries.com/DD-SupplyRegisters

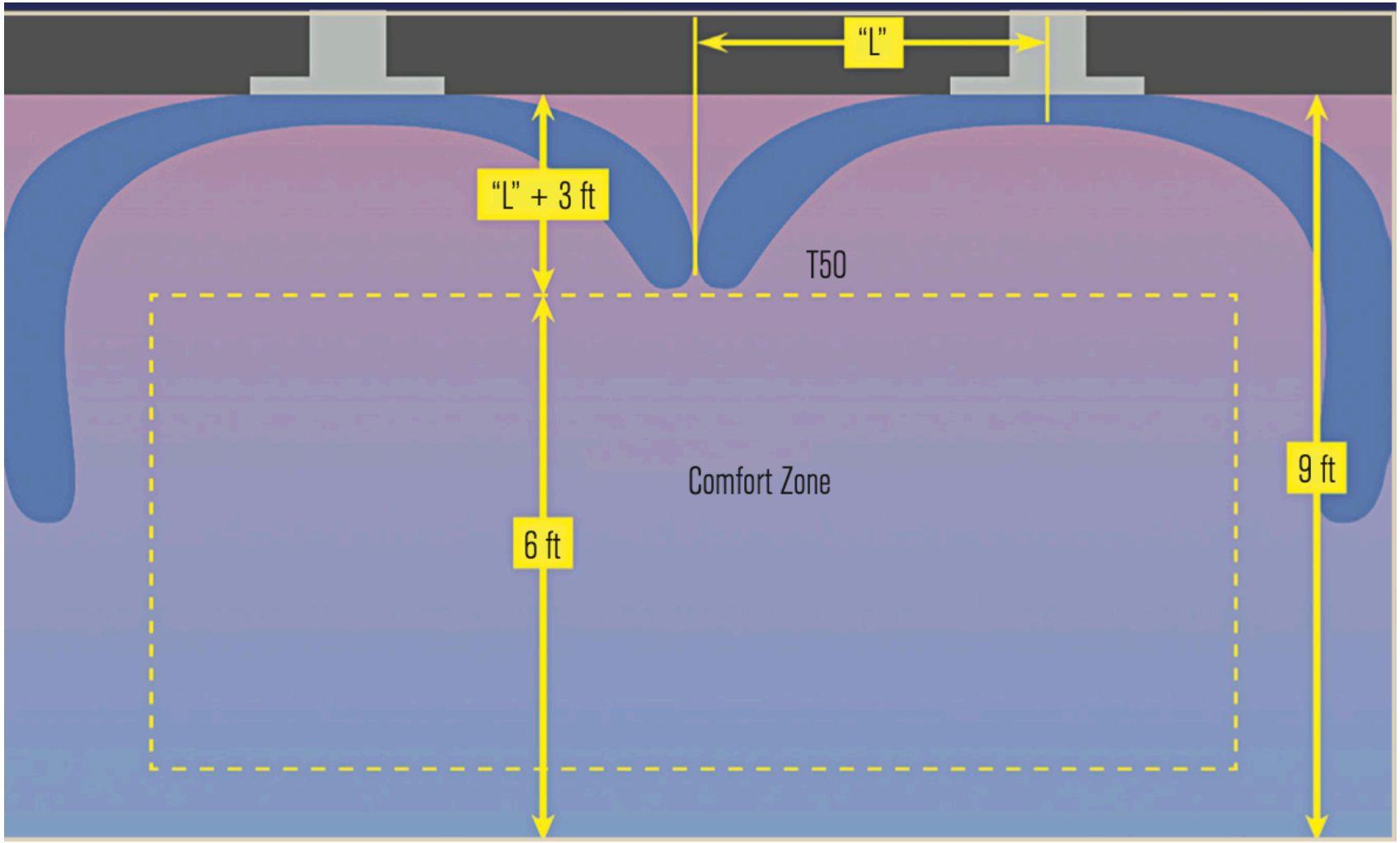
Recap

- The definition of the occupied zone can vary:



Recap

- The definition of the occupied zone can vary:



AIR DIFFUSION

Air Diffusion

Round ceiling diffuser

Square ceiling diffuser

Louvered face diffuser

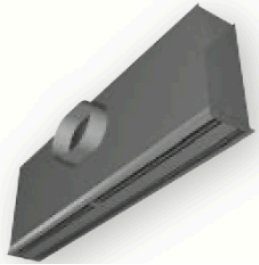
Round plaque diffuser

Square plaque diffuser

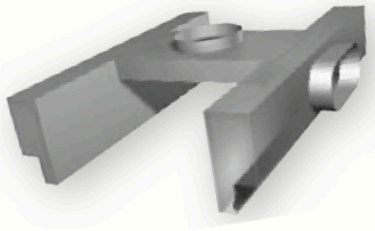
Perforated ceiling diffuse

Round Twist Diffuser

Plenum slot diffuser

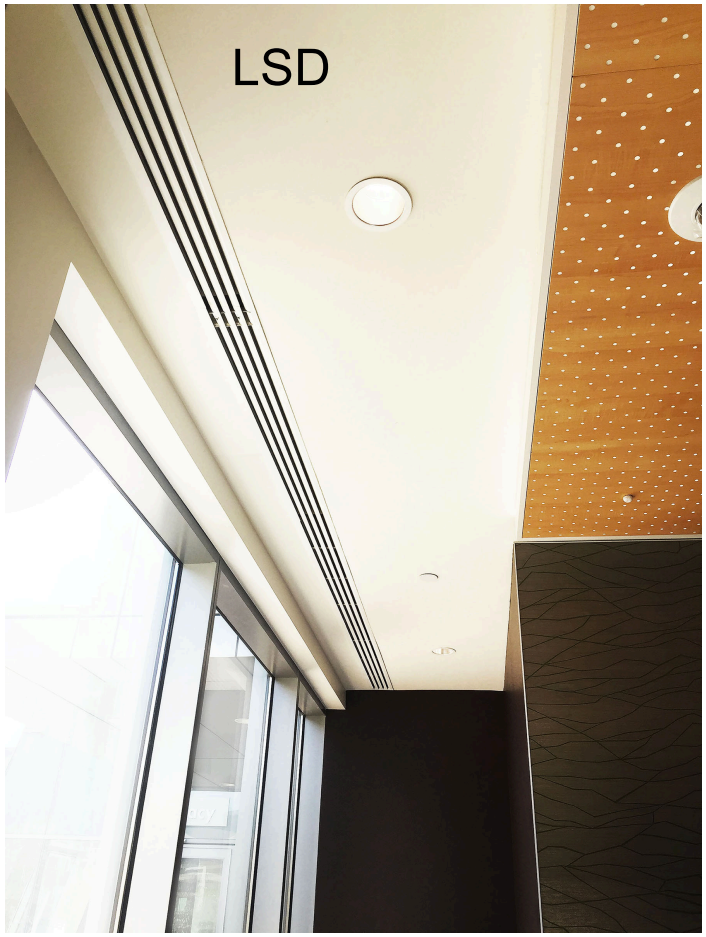


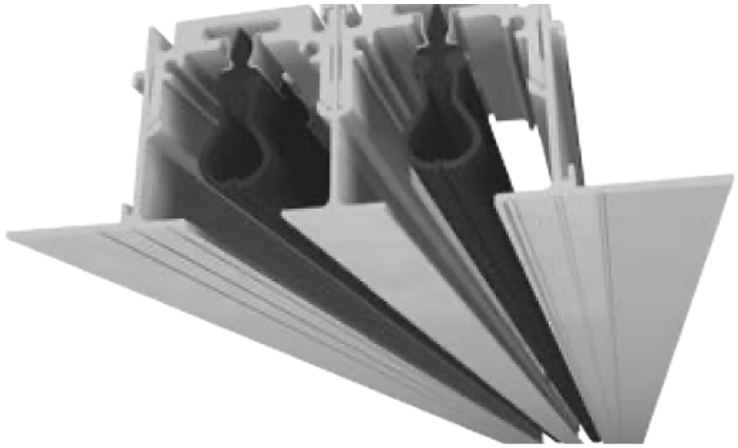
Light troffer diffuser



Engineering Guide Air Distribution, Price

Air Diffusion

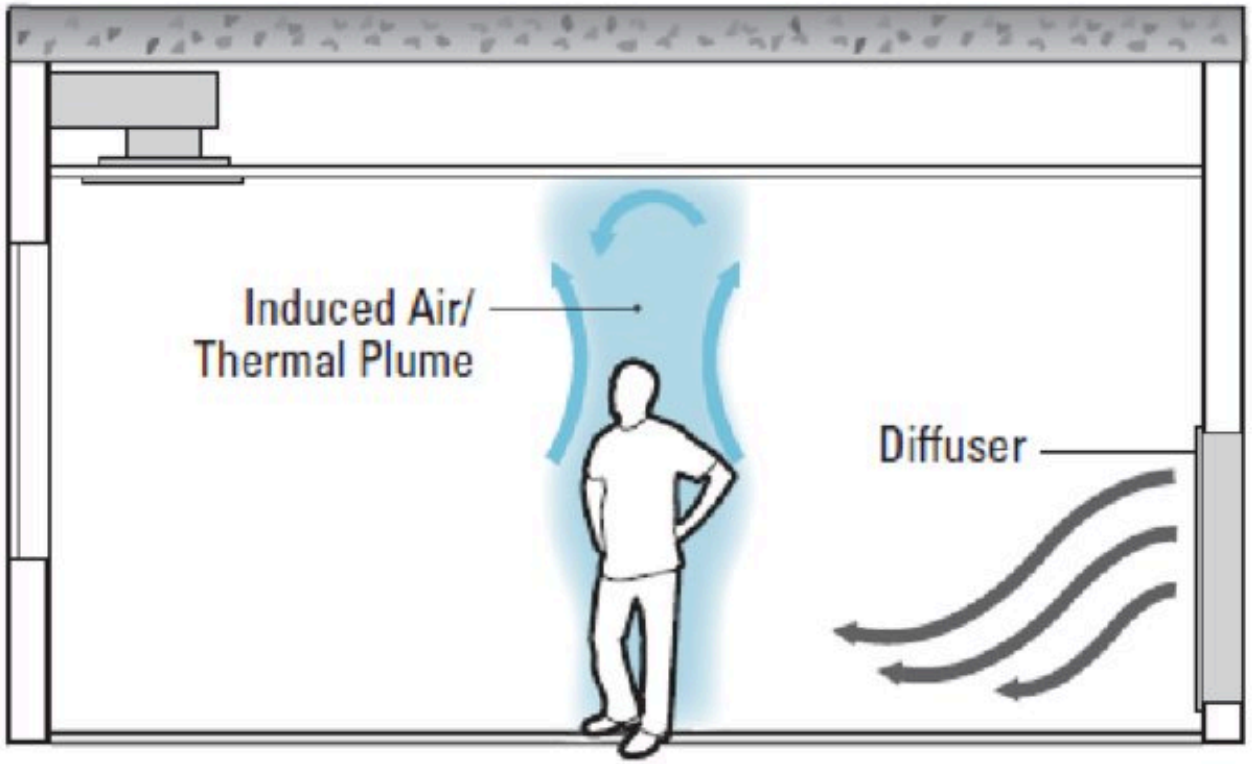




https://www.homedepot.com/p/Everbilt-8-in-x-8-in-4-Way-Square-Ceiling-Diffuser-EA504M-08X08/300539275 & http://www.acutherm.com/product/tlc-linear/. & Engineering Guide Air Distribution, Price
https://www.homeessentialsdepot.com/truaire-3-way-aluminum-square-ceiling-diffuser-8-in-x-8-in-3562230-3562230/?gclid=EAIaIQobChMIlJTpv7O24AIVBLnACh1SMwM9EAkYAiABEgKBqPD_BwE
http://grilletech.com.au/product/linear-slot-diffuser/

Air Diffusion

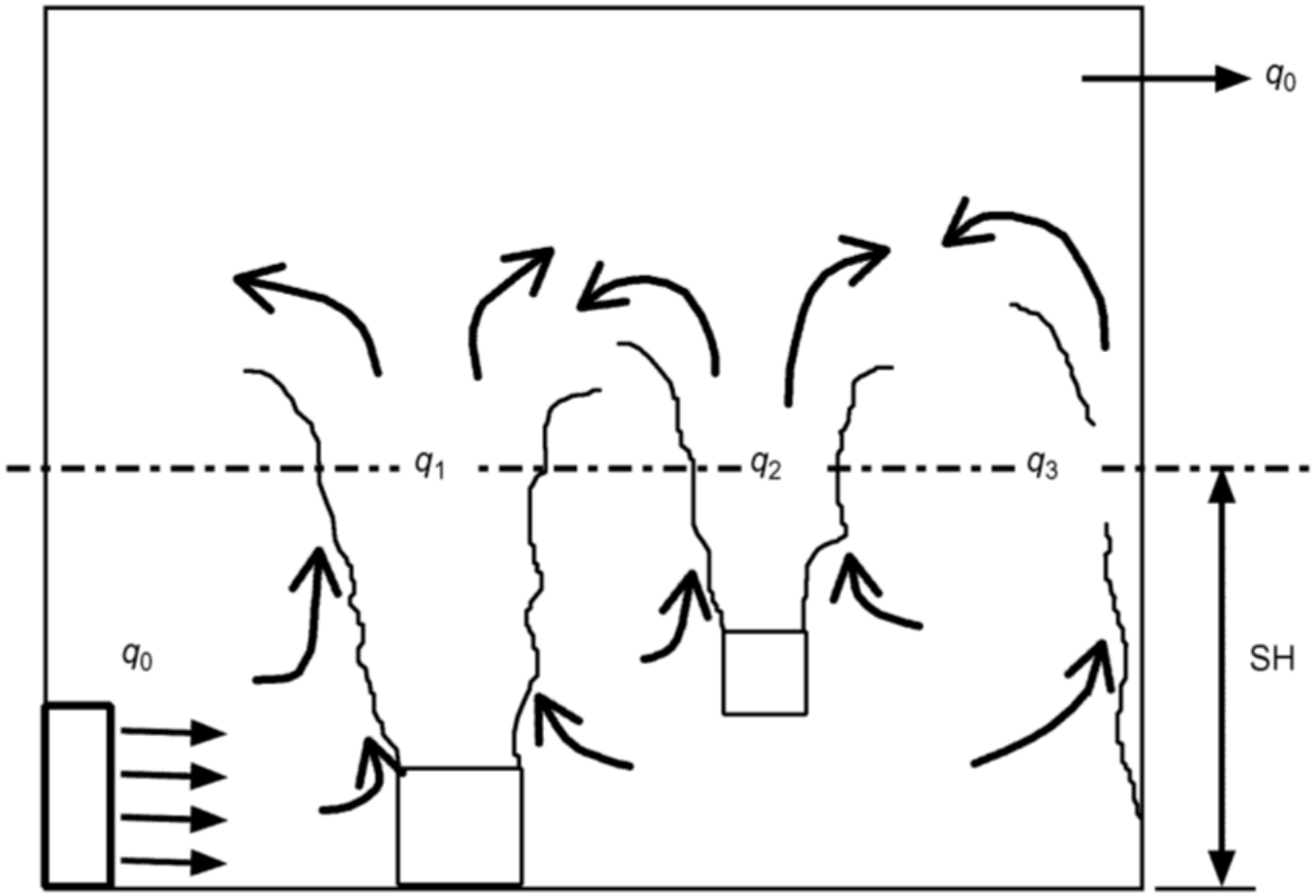
- Thermal Displacement Ventilation (TDV):
  - ❑ Introduce cool air into a space at low face velocities
  - ❑ Let convection and stratification move warm contaminated air up to returns



https://www.researchgate.net/publication/323471882_Alternatives_to_conventional_air_conditioning_systems_-_A_review/figures?lo=1

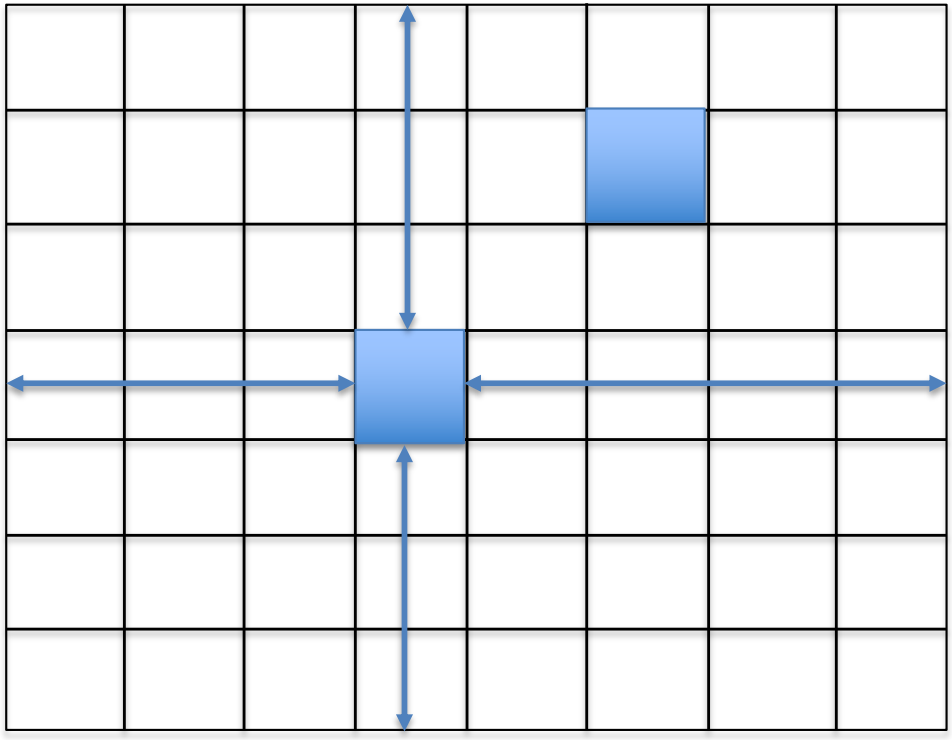
Air Diffusion

- We need to make sure to consider internal objects



Air Diffusion

- To identify the characteristics length, we need to identify the location of the air outlets
- Identify the maximum achievable throw:



Air Diffusion

High Sidewall Grille

Distance to wall perpendicular to jet

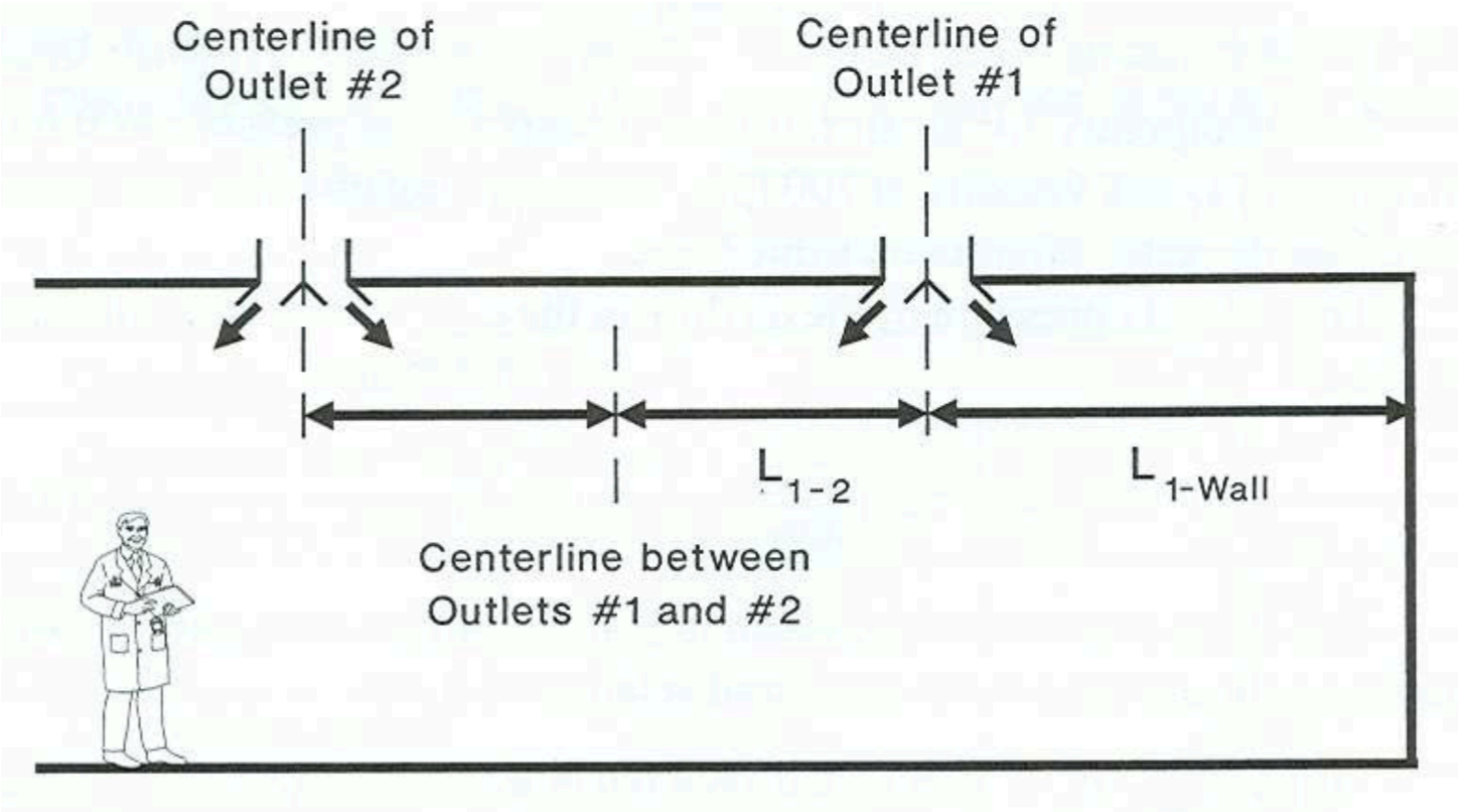
Circular Ceiling Diffuser

Distance to closet wall or intersecting air jet

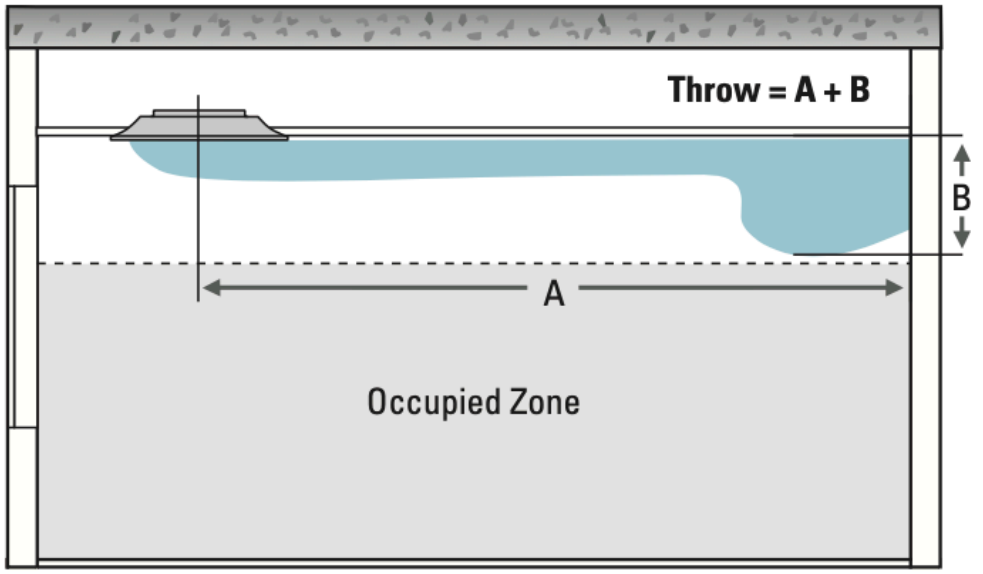
https://www.zoro.com/zoro-select-sidewallceiling-register-adjustable-. &. http://www.airmate.com/products/rezzin-round/ceiling-diffuser
4mjk6/i/G3228687/featureproduct?gclid=CjwKCAiA767jBRBqEiwAGdAOr9PLHqDn6n9EPQA_dt52anSd56Ufjsi01C2Y1uw7d1UgBStCgclyPBoCYdUQAvD_BwE

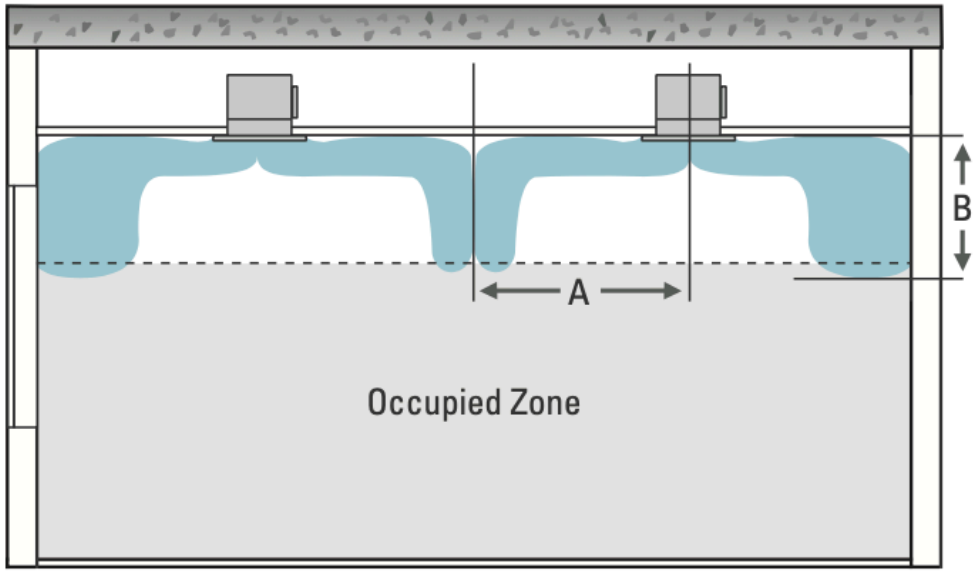
Air Diffusion

- The available length (L) for outlet #1 is the lesser of $L_{1\text{-wall}}$ and $L_{1\text{-}2}$ for this case



Air Diffusion

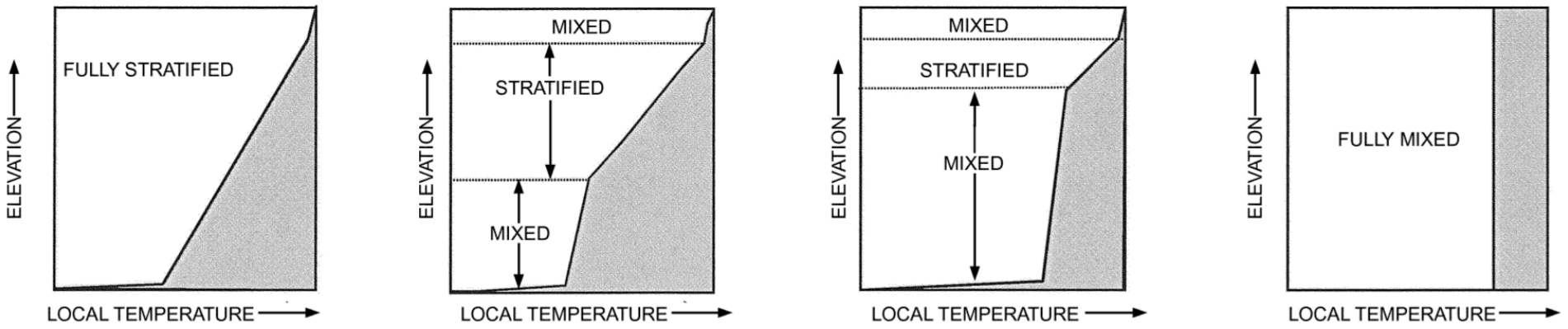




Engineering Guide Air Distribution, Price

VERTICAL TEMPERATURE STRATIFICATION PROFILES

Vertical Temperature Stratification Profiles



PARTIALLY MIXED ROOM AIR DIFFUSION METHODS

FULLY STRATIFIED ROOM AIR DISTRIBUTION SYSTEMS

FULLY MIXED ROOM AIR DISTRIBUTION SYSTEMS

EXAMPLES:

- Thermal displacement using low-velocity cool air
- Natural ventilation

EXAMPLES:

- Underfloor air distribution (using room air induction) in cooling operation
- Underseat air distribution (using room air induction) in cooling operation
- Task/ambient cooling (using furniture-based outlets)
- Task/ambient (spot) cooling or heating (industrial applications)

EXAMPLES:

- Overhead mixed air supply in cooling operation
- Fan-coil units and unit ventilators
- High-velocity floor-based supply in heating operation

Vertical Temperature Stratification Profiles

- Fully mixed systems: Room air fully mixed
  - ❑ Little or no thermal/pollutant stratification vertically
  - ❑ Achieved by achieved by supplying large amounts of conditioned air into the room either from overhead or underfloor
  - ❑ Conditioning of the space achieved by diluting space air with the supply air
  - ❑ Overhead air distribution is an example of this distribution

Vertical Temperature Stratification Profiles

- Fully stratified systems: Space is fully stratified vertically
  - ❑ There is a distinct thermal gradient
  - ❑ Happens through the displacement ventilation systems

Vertical Temperature Stratification Profiles

- Partially mixed systems:
  - ❑ This arises when the occupied space is fully mixed and maintained at a condition distinctly different from the unoccupied zone
  - ❑ The unoccupied volume is usually stratified into three zones whose relative lengths may vary
  - ❑ Most underfloor air distribution systems (UFAD) are examples of this type

CLASSIFICATION OF AIR DIFFUSION METHODS

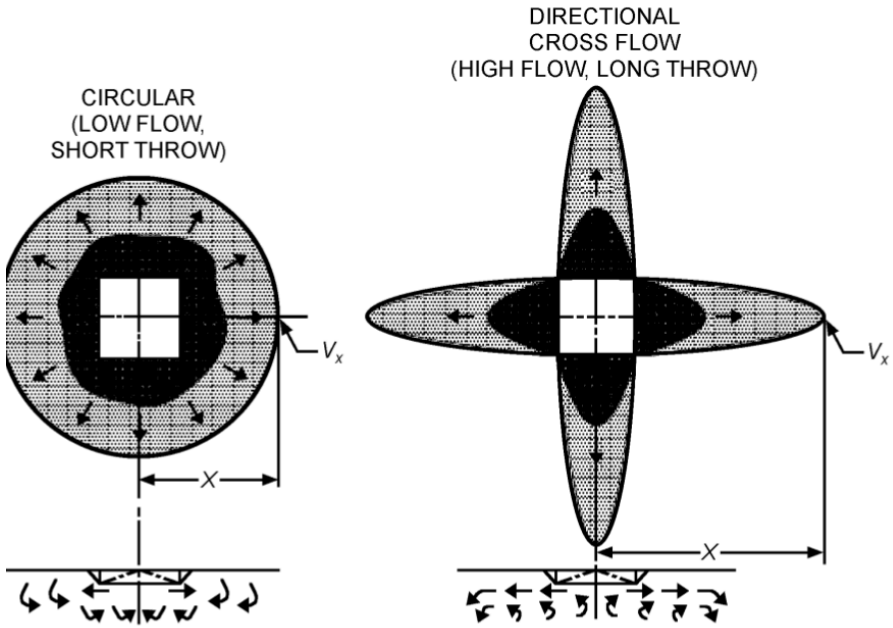
Outlet Classification

- Group A
  - Outlets mounted in or near the ceiling that discharge air horizontally
  - Outlets discharge horizontally the air that is not influenced by an adjacent surface
- Group B
  - Outlets mounted in or near the floor that discharge air vertically in a non-spreading jet
- Group C
  - Outlets mounted in or near the floor that discharge air vertically in a spreading jet
- Group D
  - Outlets mounted in or near the floor that discharge air horizontally
- Group E
  - Outlets that project supply air vertically downward

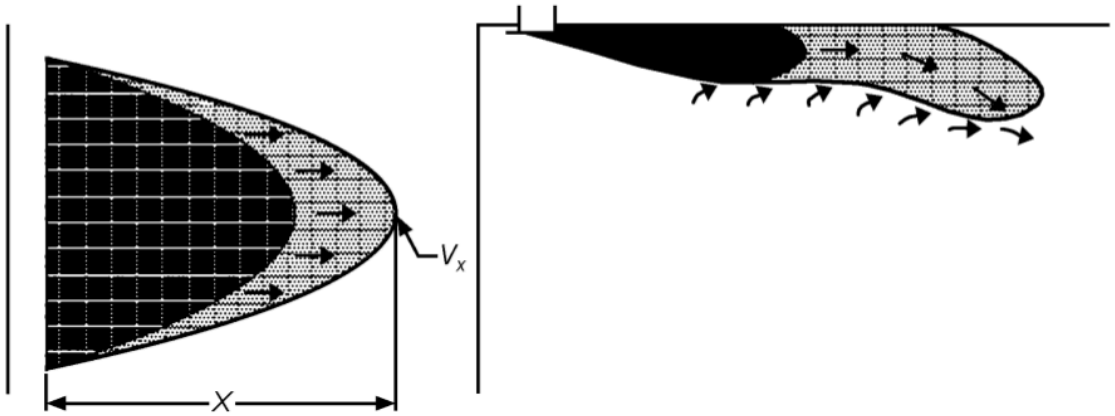
Group A1 (Ceiling: Horizontal Discharge)

- High sidewall grilles
- Sidewall diffusers
- Ceiling diffusers
- Linear ceiling diffusers

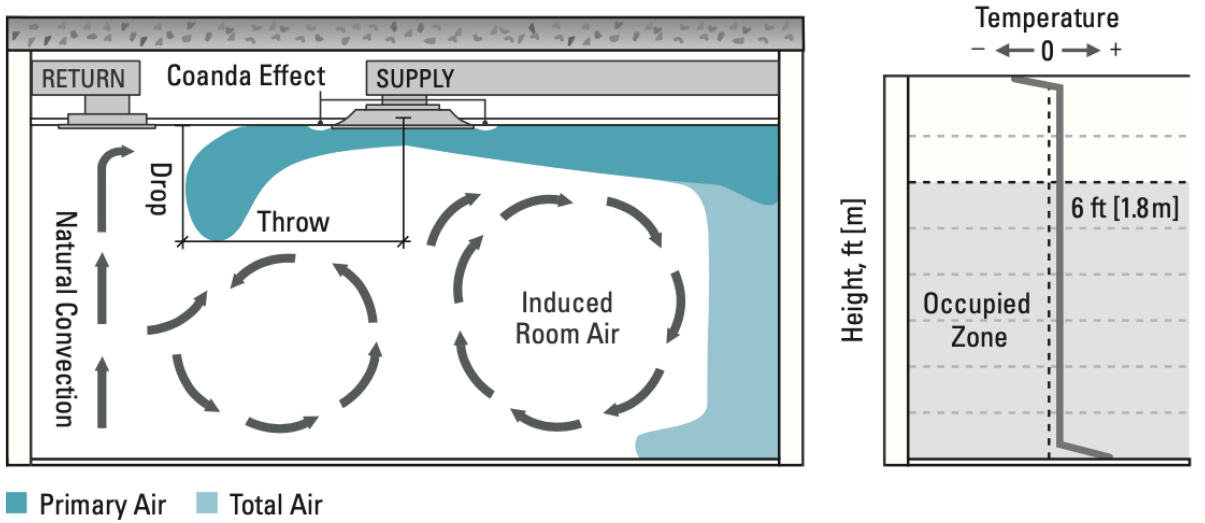
Group A1 (Ceiling: Horizontal Discharge)

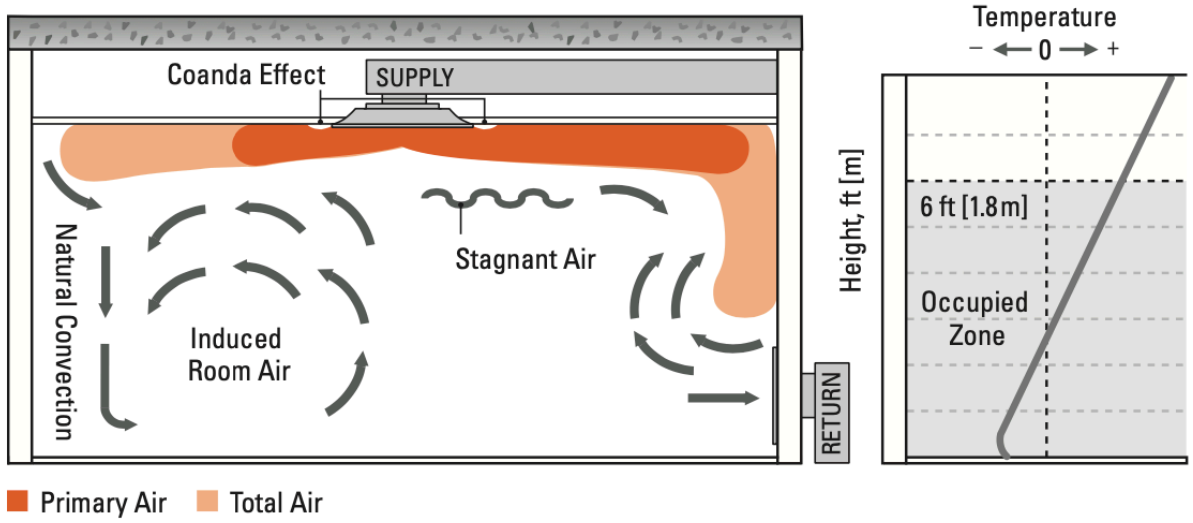


Non-Isothermal



Group A1 (Ceiling: Horizontal Discharge)



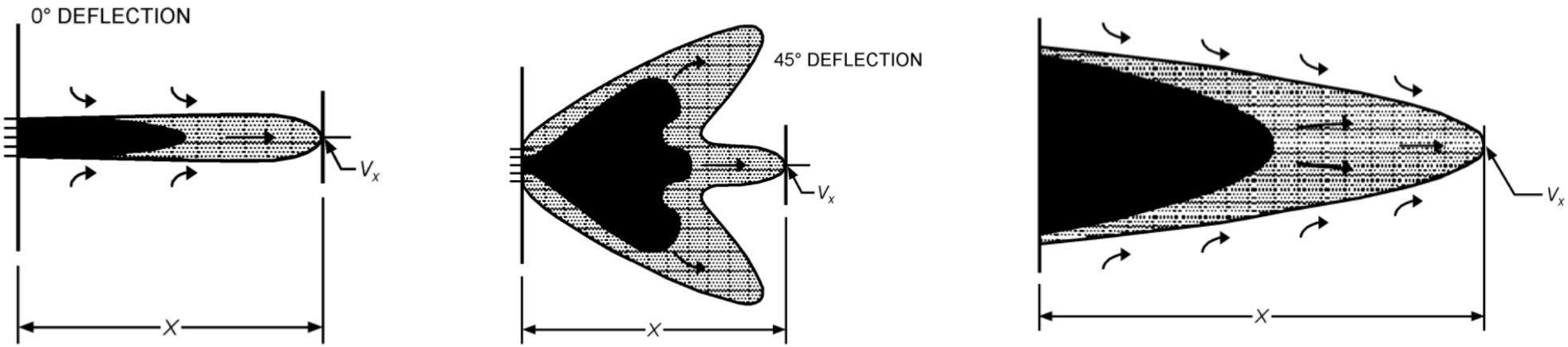


What do you think any of these configurations are good for heating or cooling?

Engineering Guide Air Distribution, Price

Group A2 (Horizontal Discharge Not Surface)

- Similar to A2 with higher stratification for the cooling close to the ceiling



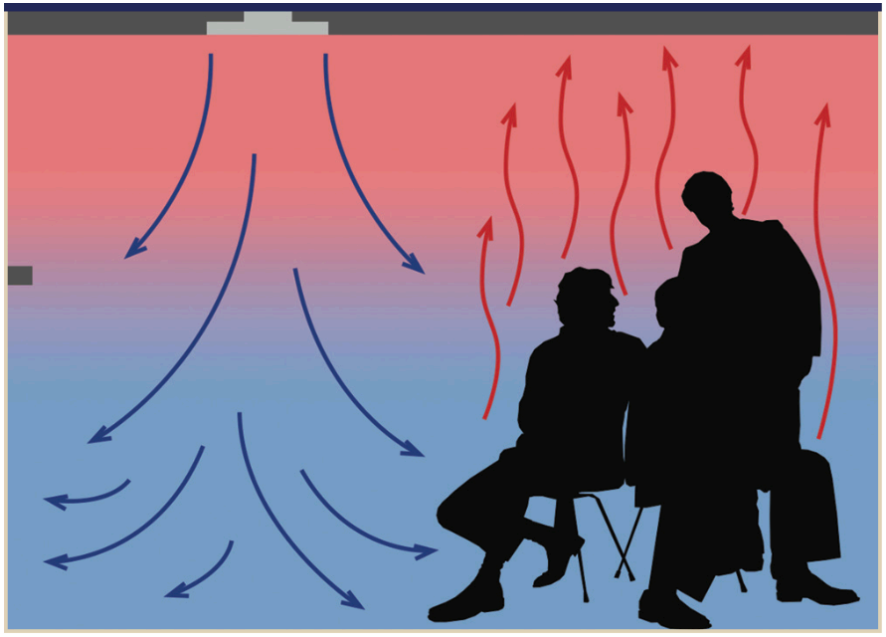
Group A (Ceiling: Horizontal Discharge)

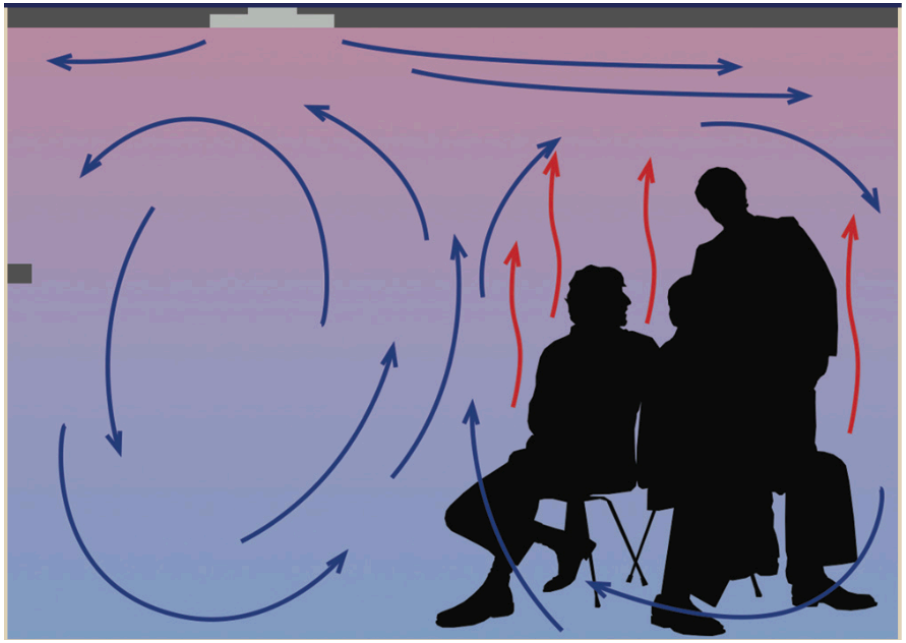
- Often used in mild climates and on the second and succeeding floors of multistory buildings
- Not recommended for cold climates or with unheated floors
- Because the primary air project radially in all directions, the rate of entrainment is large, causing the high-momentum jet to diffuse quickly
- Ceiling diffuser allow handling larger quantities of air at higher velocities than other types

Group A (Ceiling: Horizontal Discharge)

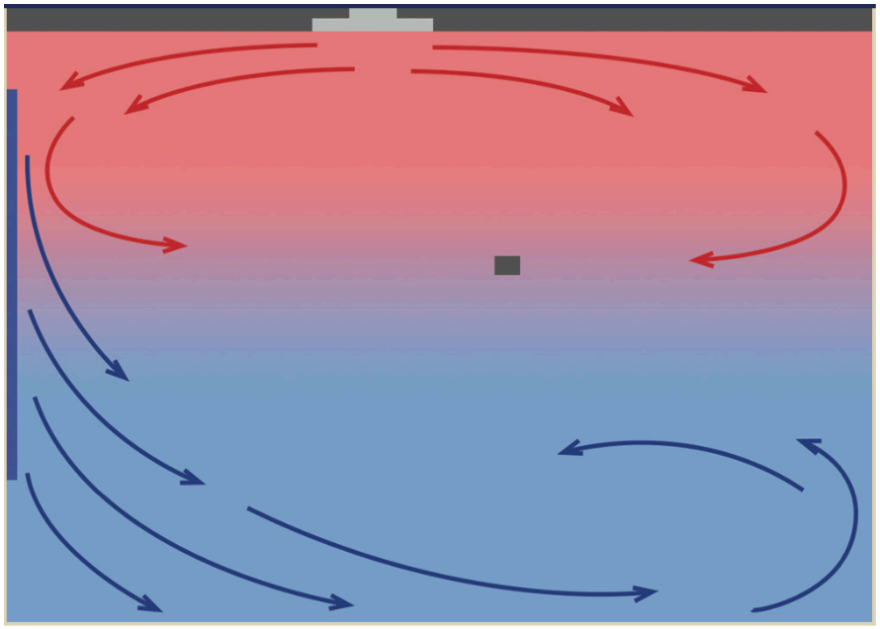
- Quite effective for cooling
- Not recommended for heating unless the floor is above a heated space
- Linear diffusers fall into this group
  - ❑ Good for cooling
  - ❑ Require a supplemental heating system

Group A (Ceiling: Horizontal Discharge)



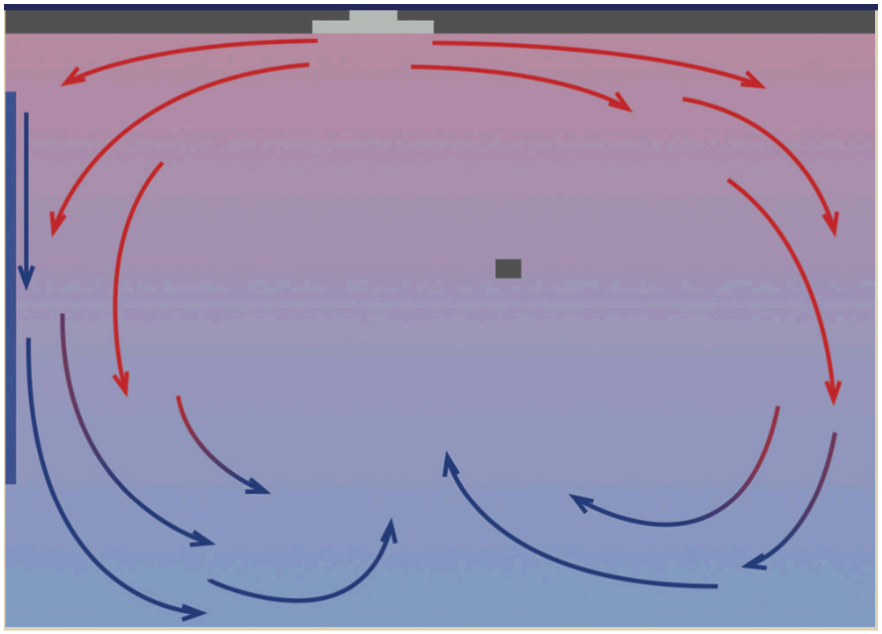


Group A (Ceiling: Horizontal Discharge)



$\Delta T > 15$ °F (8.3°C)

$V \sim 150\ fpm\ (0.75\ \frac{m}{s})$



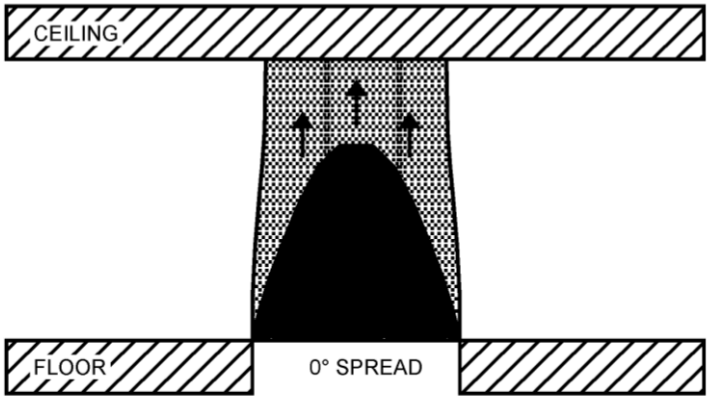
$\Delta T < 15$ °F (8.3°C)

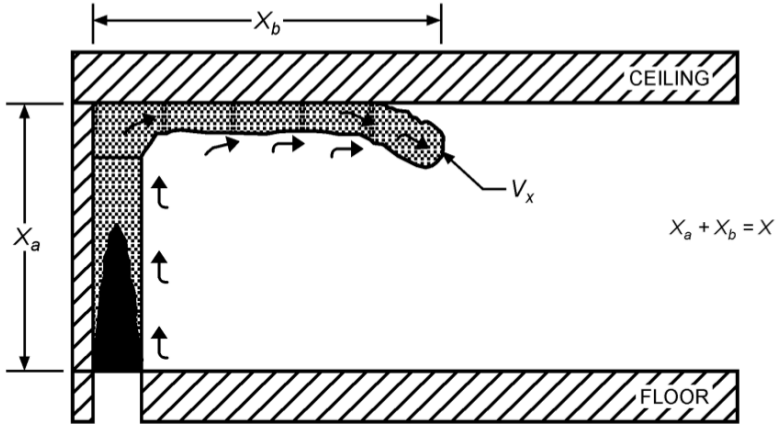
Group B (Vertical Discharge – Non spreading)

- Floor registers
- Baseboard units
- Low sidewall units
- Linear type grilles

Group B (Vertical Discharge – Non spreading)

- Satisfactory performance for cooling
- Less desirable for heating because a larger stratified zone will usually occur





Outlet in or near floor, non spreading linear jets

4ºF (2ºC) Acceptable to 85% of occupants

Group C (Vertical Discharge –spreading)

- Floor diffusers
- Sidewall diffusers
- Linear type diffusers

Group C (Vertical Discharge –spreading)

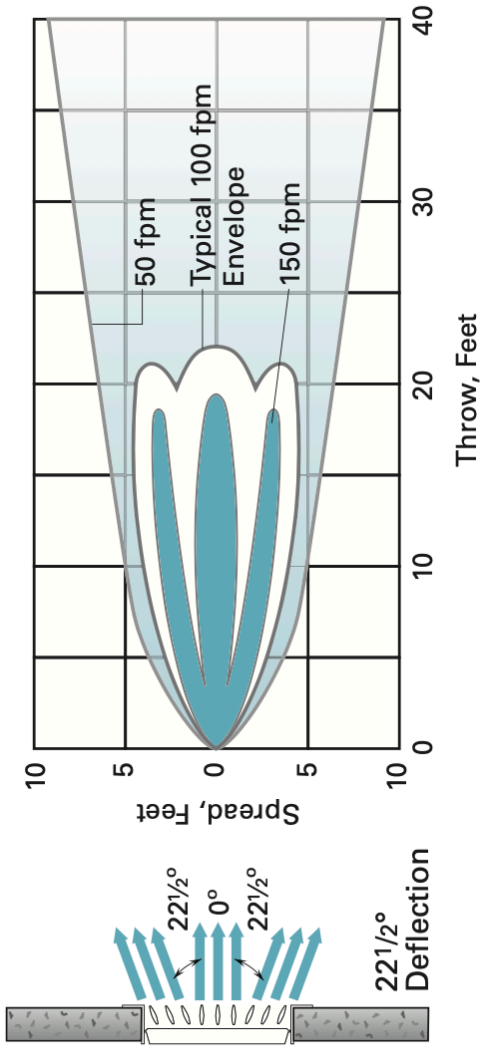
- Usually assume superior for heating applications, especially:
  - ❑ The floor is located over an unheated space or a slab
  - ❑ Considerable glass area exists in the wall

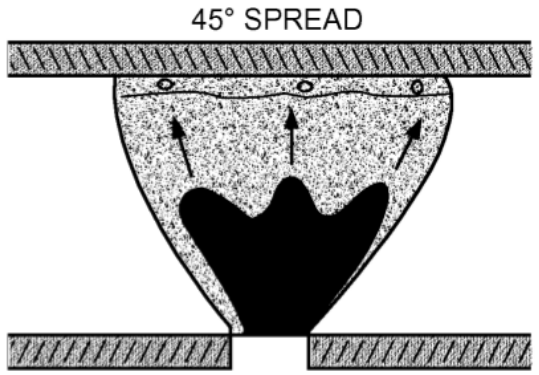
- Diffusers with a wide spread are usually best for heating because buoyancy tends to increase the throw

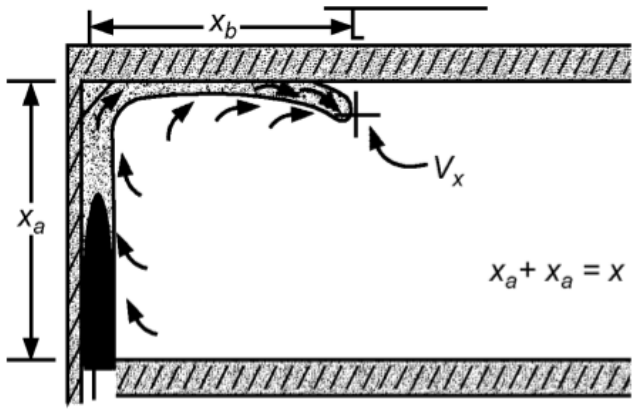
- Similarly, these diffusers are not good for cooling application because the throw may not be adequate for mixing

- Sometimes diffusers are available to change depending on the season

Group C (Vertical Discharge –spreading)







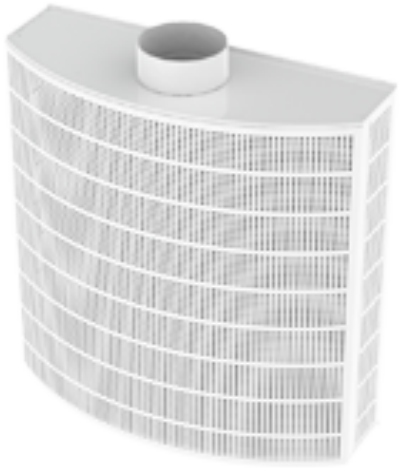
Engineering Guide Air Distribution, Price

Group C (Vertical Discharge –spreading)

https://www.titus-hvac.com/image/5EA02474-A2E8-476D-982D-8F1333BB8D7F

Group D (Horizontal Discharge)

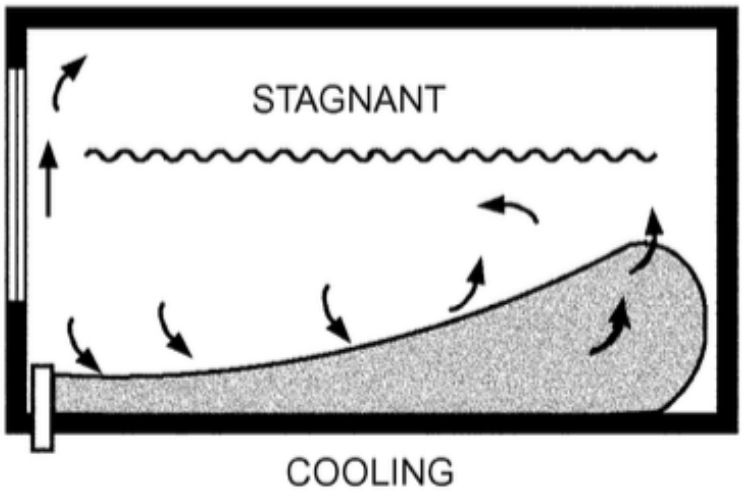
- They are good for displacement ventilation to remove large amount of contaminants from a space



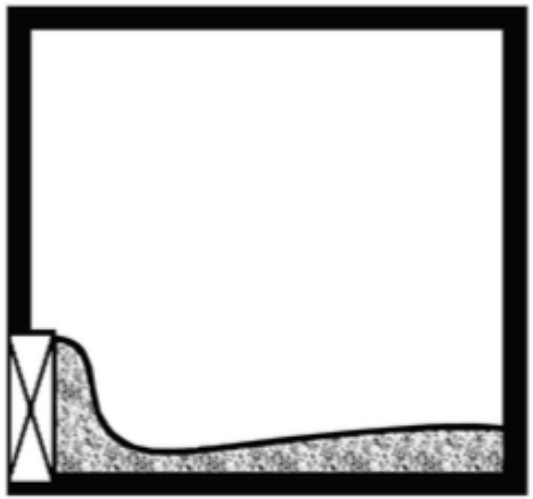
https://www.titus-hvac.com/image/385DF132-B511-42A2-9944-F5358C2B1234

Group D (Horizontal Discharge)

- Baseboard registers
- Low-sidewall registers



Outlet Group D (High Velocity) - (Nonisothermal)

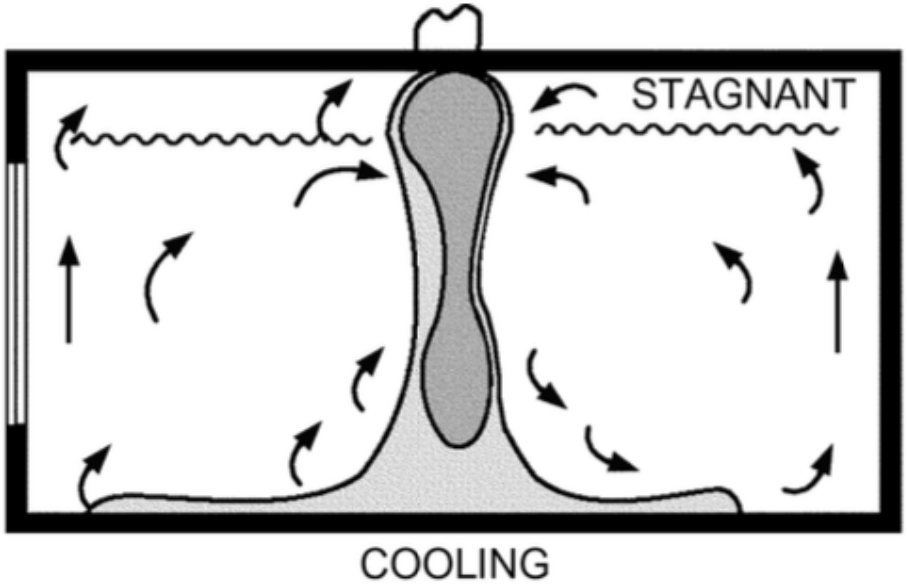


Outlet Group D (Low Velocity) - Nonisothermal

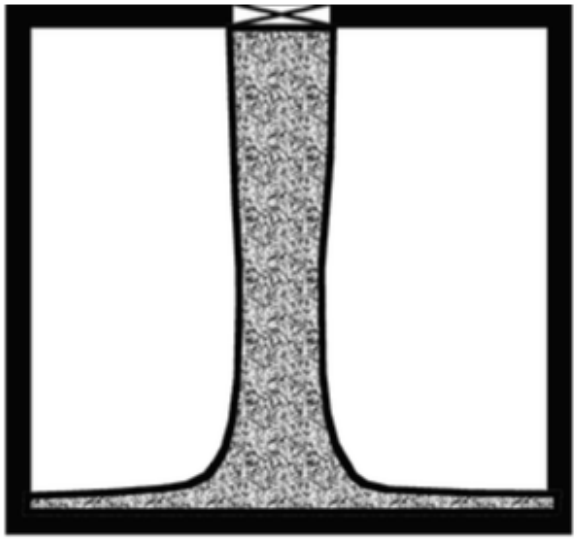
Group E (Vertical Discharge)

- These outlets are used in partially stratified systems
  - ❑ Ceiling diffusers
  - ❑ Linear grilles
  - ❑ Sidewall diffusers
- These outlets use low discharge velocities
- In mixed systems, they use higher discharge velocities
- Are used for a special applications such as cooling large glasses

Group E (Vertical Discharge)



Outlet Group E (High Velocity) - (Nonisothermal)



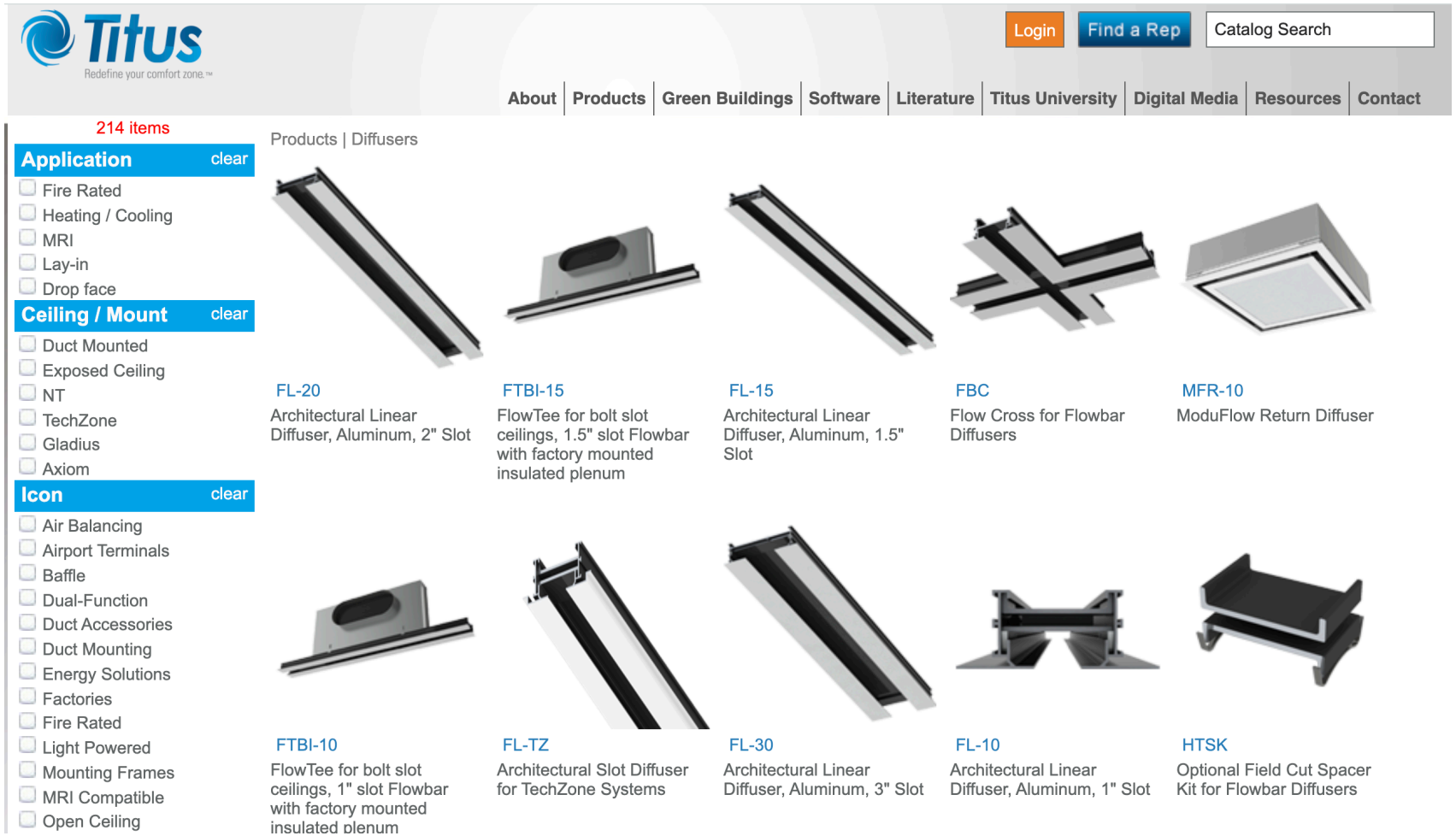
Outlet Group E (Low Velocity) - Nonisothermal

Return Air & Exhaust Grilles

- Less important than diffusers since velocity decreases significantly as the area increases
- Their location has little effect on room air motion
- From energy standpoint, it is economical to return the coolest air to the heating coil and warmest air to the cooling coil (Stagnation region)
- However, careful consideration is required for high ceiling, atrium, and large vertical glass surfaces
- Always, make sure to avoid short circuiting of supply air

Supply and Return Options

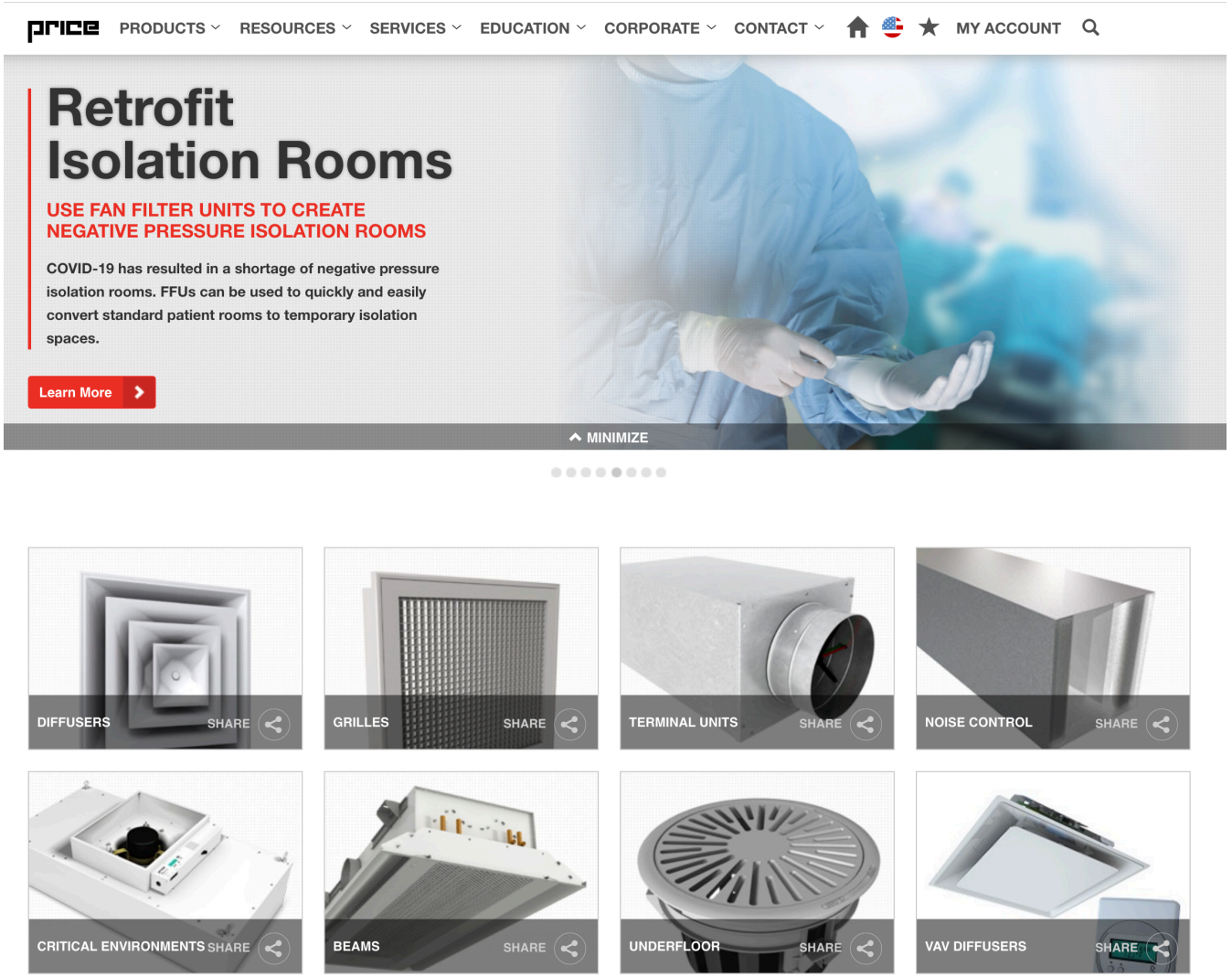
- Please review some diffuser, grille, and register options for the next lectures



https://www.titus-hvac.com/Products/Diffusers

Supply and Return Options

- Please review some diffuser, grille, and register options for the next lectures



https://www.priceindustries.com/#close

REVISITING ASHRAE 62.1

Revisiting ASHRAE 62.1

- ASHRAE 62.1 also provides:
  - ❑ Criterion for reduction in the outdoor delivery rate when recirculated air is treated
  - ❑ Criterion for variable ventilation rates when the air volume in the space can be used to dilute contaminants
- Many municipals have their own prescribed rates that can differ from ASHRAE
- ASHRAE 62.1 notation uses airflow rate as V

Revisiting ASHRAE 62.1

- Air change rate:

$$ACH = \frac{Q}{V}$$

- Time Constant:

$$\tau = \frac{V}{Q} = \frac{M}{\dot{m}}$$

- ACH: Air change rate (air changes/hour)
- Q: Volumetric flow rate ft^3/hr
- V: Room volume ft^3
- τ: Time constant
- M: Mass of air in the space
- $\dot{m}$: mass flow rate of outdoor air

CLASS ACTIVITY

Class Activity

- Calculate the volumetric flow rate (in CFM and $\frac{ft^3}{hr}$) and time constant for the following condition:
  - ❑ Office area: 800 ft^2
  - ❑ Office height: 10 ft

Class Activity

- Solution:
  - ❑ Office areas usually have an ACH between 2 to 6

$$\tau = \frac{1}{2\ [1/hr]} = 0.5\ hour$$

$$2 = \frac{Q}{(800 \times 10)}$$

$$Q = 16{,}000\,\frac{ft^3}{hr} = 16{,}000 \times \frac{ft^3}{hr} \times \frac{1\ hr}{60\ minutes} = 266\ CFM$$

Air Change Terms

- Ventilation effectiveness provides measure of an air distribution system's ability to remove an internally generated pollutant

- Age-of-air (θ): Time in which some quantity of outside air has been in a particular building or space (hr)

Outdoor Air Requirement

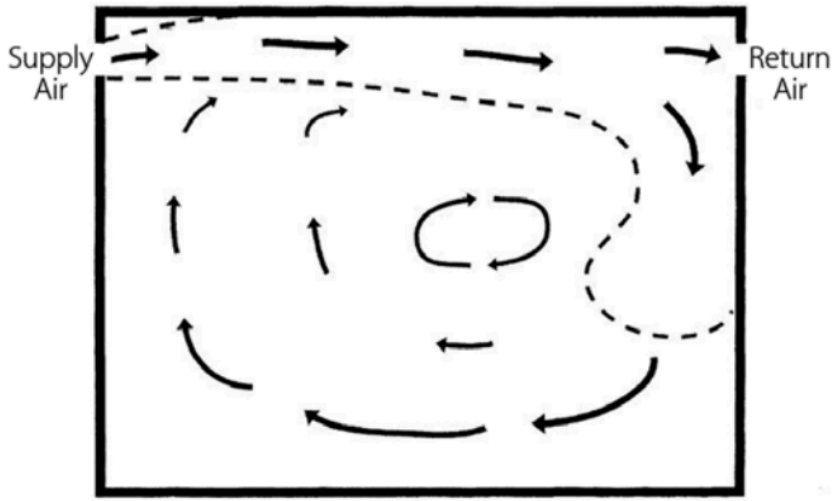
- The per person rate is to dilute the contaminants the occupants create
- The per space rate is related to dilute the contaminants created by furnishings and non-occupant activities
- Calculate the zone outdoor air flow rate from the breathing zone air flow rate

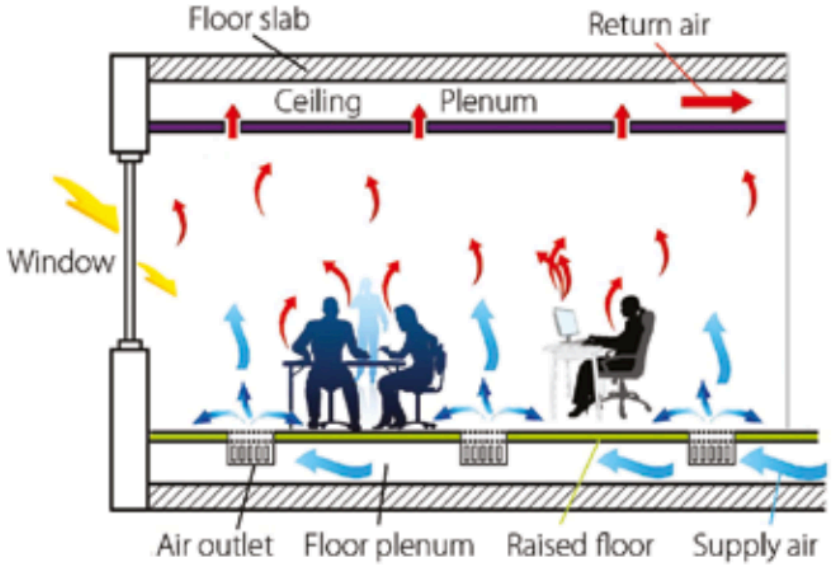
$$V_{oz} = \frac{V_{bz}}{E_z}$$

Ventilation Effectiveness

- The zone effectiveness depends upon
  - ❑ The location of the supply air diffusers
  - ❑ The location of he return air vents
  - ❑ Heating or cooling mode

- All three of these factors go into determining how much mixing takes place



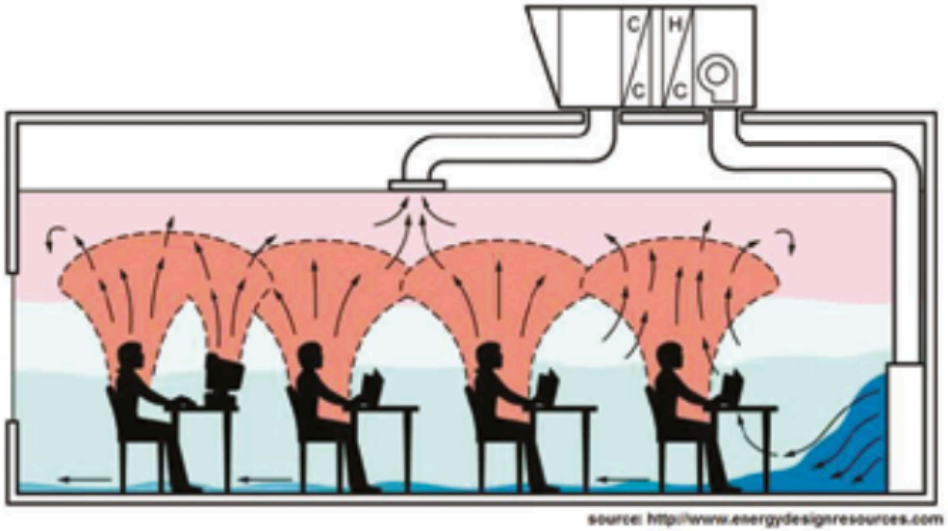


Kemal Gungor et al.

Ventilation Effectiveness

- It is better to use the ASHRAE 62.1 table, but common ventilation effectiveness are calculated as:

Heating/Cooling	Supply	Return	E_z
Cooling	Overhead	Overhead	1.0
Heating	Underfloor	Opposite	1.0
Heating	Overhead	Overhead	0.8
Heating	Displacement	Overhead	0.7



source: http://www.energydesignresources.com

MECHANICAL DRAWINGS

Mechanical Drawings

- Please, see Chapter 38 of ASHRAE Fundamentals: Abbreviations and Symbols. This chapter entails:

  - ❑ Abbreviations
  - ❑ Letter symbols
  - ❑ Graphical symbols

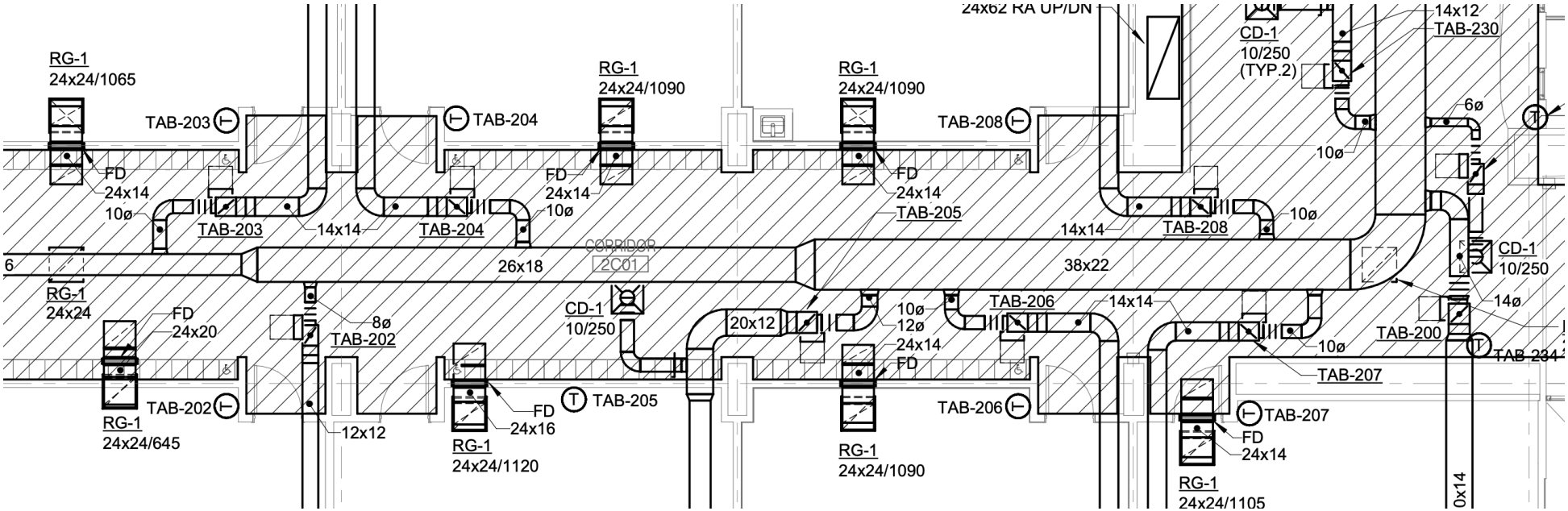
CHAPTER 38

ABBREVIATIONS AND SYMBOLS

Abbreviations for Text, Drawings, and Computer Programs 37.1
Letter Symbols 37.1
Dimensionless Numbers 37.4
Mathematical Symbols 37.4
Subscripts 37.5
Graphical Symbols for Drawings 37.5
Piping System Identification 37.10

Mechanical Drawings

- A good approach starts drawing on the existing architectural drawings:



Mechanical Drawings

- Look for the Mechanical Symbols, Notes, and Abbreviations page (usually M.000, M.00.00, …)

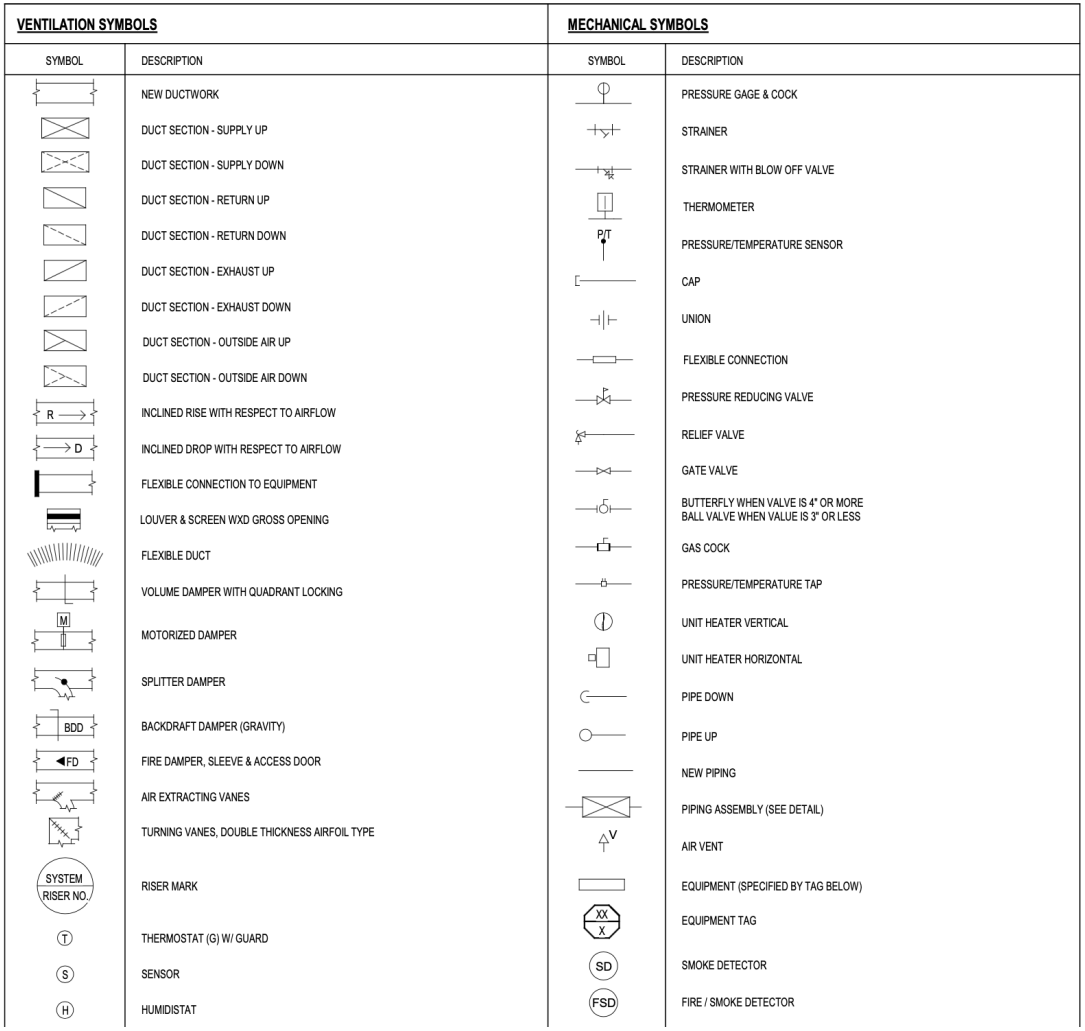
LOCATION:
3101 South Wabash Ave.
Chicago, IL 60616

PROJECT:
IIT BAILEY HALL

DRAWING TITLE
MECHANICAL SYMBOLS, NOTES & ABBREVIATIONS

DRAWING NUMBER:
M.000

© DIRK DENISON ARCHITECTS 2019



VENTILATION SYMBOLS		MECHANICAL SYMBOLS	
SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	NEW DUCTWORK		PRESSURE GAGE & COCK
	DUCT SECTION - SUPPLY UP		STRAINER
	DUCT SECTION - SUPPLY DOWN		STRAINER WITH BLOW OFF VALVE
	DUCT SECTION - RETURN UP		THERMOMETER
	DUCT SECTION - RETURN DOWN	P/T	PRESSURE/TEMPERATURE SENSOR
	DUCT SECTION - EXHAUST UP		CAP
	DUCT SECTION - EXHAUST DOWN		UNION
	DUCT SECTION - OUTSIDE AIR UP		FLEXIBLE CONNECTION
	DUCT SECTION - OUTSIDE AIR DOWN		PRESSURE REDUCING VALVE
R	INCLINED RISE WITH RESPECT TO AIRFLOW		RELIEF VALVE
D	INCLINED DROP WITH RESPECT TO AIRFLOW		GATE VALVE
	FLEXIBLE CONNECTION TO EQUIPMENT		BUTTERFLY WHEN VALVE IS 4" OR MORE BALL VALVE WHEN VALUE IS 3" OR LESS
	LOUVER & SCREEN WXD GROSS OPENING		GAS COCK
	FLEXIBLE DUCT		PRESSURE/TEMPERATURE TAP
	VOLUME DAMPER WITH QUADRANT LOCKING		UNIT HEATER VERTICAL
M	MOTORIZED DAMPER		UNIT HEATER HORIZONTAL
	SPLITTER DAMPER		PIPE DOWN
BDD	BACKDRAFT DAMPER (GRAVITY)		PIPE UP
FD	FIRE DAMPER, SLEEVE & ACCESS DOOR		NEW PIPING
	AIR EXTRACTING VANES		PIPING ASSEMBLY (SEE DETAIL)
	TURNING VANES, DOUBLE THICKNESS AIRFOIL TYPE	V	AIR VENT
SYSTEM RISER NO.	RISER MARK		EQUIPMENT (SPECIFIED BY TAG BELOW)
		XX / X	EQUIPMENT TAG
T	THERMOSTAT (G) W/ GUARD	SD	SMOKE DETECTOR
S	SENSOR	FSD	FIRE / SMOKE DETECTOR
H	HUMIDISTAT		

Mechanical Drawings

- Look for the Mechanical Symbols, Notes, and Abbreviations page (usually M.000)

SYSTEMS ABBREVIATIONS

DUCTWORK

ABBREVIATION	SYSTEM NAME
FLUE	BOLIER FLUE
CAI	COMBUSTION AIR INTAKE
DE	DRYER EXHAUST
GE	EXHAUST AIR
OA	OUTSIDE AIR
RA	RETURN AIR
SA	SUPPLY AIR
TE	TOILET EXHAUST

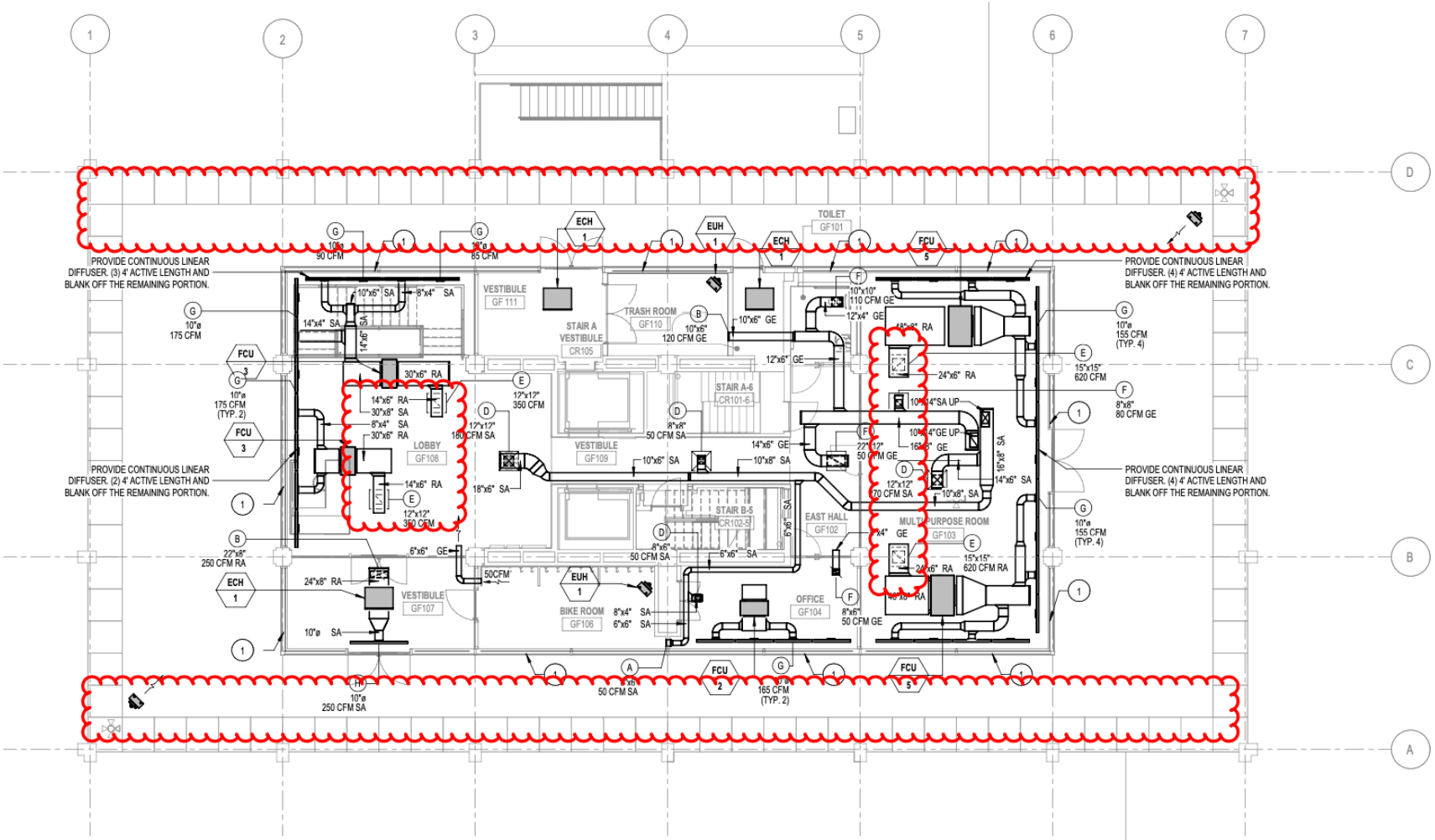
MECHANICAL PIPING

ABBREVIATION	SYSTEM NAME
CD	CONDENSATE DRAIN
NGMP	NATURAL GAS MEDIUM PRESSURE
RFGG	REFRIGERATION GAS
RFGL	REFRIGERATION LIQUID

MECHANICAL ABBREVIATIONS

ABBREVIATION	DESCRIPTION
AC	AIR CONDITIONER
ACH	AIR CHANGES PER HOUR
ADS	AIR DIRT SEPARATOR
AFF	ABOVE FINISH FLOOR
AFG	ABOVE FINISHED GRADE
AFMS	AIR FLOW MONTIORING STATION
AFU	ANNUAL FUEL EFFICIENCY RATIO
AHU	AIR HANDLER
AMP	AMPERAGE
APD	AIR PRESSURE DROP
AS	AIR SEPARATOR
ATU	AIR TERMINAL UNIT
AUX.	AUXILLARY
B	BOILER
BAS	BUILDING AUTOMATION SYSTEM
BLDG	BUILDING
BTU	BRITSH THERMAL UNITS
BTU/H	BRITISH THERMAL UNITS PER HOUR
CAI	COMBUSTION AIR INTAKE
CAP.	CAPACITY
CAV	CONSTANT AIR VOLUME
CAV	CABINET UNIT HEATER
CC	COOING COIL
CFH	CUBIC FEET PER HOUR
CFM	CUBIC FEET PER MINUTE
CFM	GAUGE
CHWP	CHILLED WATER PUMP
CLG	CEILING
CO2	CARBON DIOXIDE
CONN	CONNECTION
COP	COEFFICIENT OF PERFORMANCE
CP	STEAM CONDENSATE PUMP
CRAC	COMPUTER ROOM AIR CONDITIONER
CT	COOLING TOWER
CUH	CABINET UNIT HEATERS
CWP	CONDESER WATER PUMP
DB	DRY-BULB TEMPERATURE
DE	DRYER EXHAUST
DEF	DRYER EXHAUST FAN
DIA, Ø	DIAMETER
DN	DOWN
DOA	DEDICATED OUTSIDE AIR
EAD	EXHAUST AIR DAMPER
EAT	ENTERING AIR TEMPERATURE
EER	ENERGY EFFICIENCY RATIO
EF	EXHAUST FAN
EFF	EFFICIENCY
ESP	EXTERNAL STATIC PRESSURE
ET	EXPANSION TANK
EUH	ELECTRIC UNIT HEATERS
EWT	ENTERING WATER TEMPERATURE
EX	EXISTING
EXH	EXHAUST

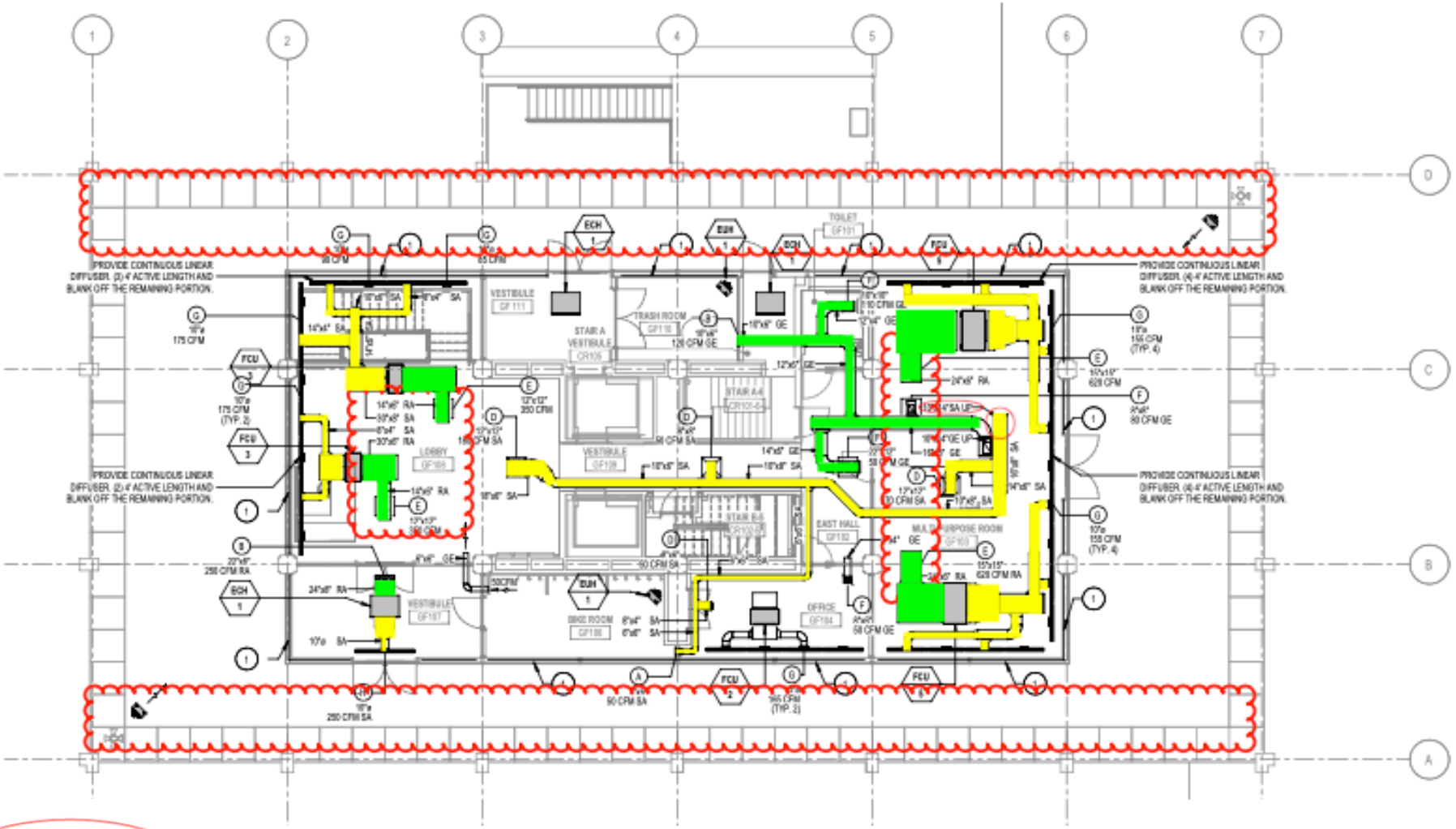
Mechanical Drawings: Air distribution



2 LEVEL 1 - MECHANICAL DUCTWORK PLAN
1/8" = 1'-0"

0' 4' 8' 16' 32'

Mechanical Drawings: Air distribution



Mechanical Drawings: Air distribution

VENTILATION SCHEDULE

	ROOM NO.	ROOM NAME	CLASSIFICATION	S.F. AREA	CODE REQUIREMENTS				ACTUAL PROVIDED				FAN SYSTEM		REMARKS
					MECHANICAL VENTILATION (CFM)		NATURAL LIGHT & VENT (SF)		MECHANICAL VENTILATION (CFM)		NATURAL LIGHT & VENT (SF)				
					SUPPLY CFM	EXHAUST CFM	GLASS AREA	VENT AREA	SUPPLY CFM	EXHAUST CFM	GLASS AREA	VENT AREA	SUPPLY	EXHAUST	
LOWER LEVEL	BA101	TOILET ROOM	TOILET ROOMS	63	0	130	-	-	0	130	-	-	-	ERV-1	
	CR101	STAIR A	STAIR	77	-	-	-	-	0	0	-	-	-	-	
	CR103	ELEVATOR PIT	STORAGE INACTIVE	49	0	0	-	-	0	0	-	-	-	-	
	CR104	ELEVATOR	ELEVATOR	66	-	-	-	-	0	0	-	-	-	-	
	HA101	EAST HALL	CORRIDORS	125	NR	NR	-	-	50	50	-	-	ERV-1	ERV-1	
	HA102	VESTIBULE	CORRIDORS	171	NR	NR	-	-	50	50	-	-	ERV-1	ERV-1	
	HA103	LOUNGE	LOUNGE	1406	1410	2110	-	-	1420	2110	NONE	NONE	ERV-1	ERV-1	
	LL101	TRANSFORMER ROOM	STORAGE INACTIVE	173	0	0	-	-	0	0	-	-	-	-	
	LL102	CONDENSER ROOM	STORAGE INACTIVE	460	0	0	-	-	0	0	-	-	-	-	
	LL103	ATS ROOM	STORAGE INACTIVE	39	0	0	-	-	0	0	-	-	-	-	
	LL104	SWITCH ROOM	STORAGE INACTIVE	112	0	0	-	-	0	0	-	-	-	-	
	LL105	BUILDING STORAGE	STORAGE INACTIVE	1915	0	0	-	-	50	50	-	-	ERV-1	ERV-1	
	LL106	JANITOR'S CLOSET	JANITOR'S CLOSET	45	0	90	-	-	0	90	-	-	-	ERV-1	
	LL107	IT CLOSET	STORAGE INACTIVE	29	0	0	-	-	0	0	-	-	-	-	
	LL109	MULTI-PURPOSE ROOM	OFFICE	278	170	85	-	-	240	85	NONE	NONE	ERV-1	ERV-1	
	LL110	LAUNDRY	LAUNDRIES (PUBLIC)	274	415	415	-	-	415	420	-	-	ERV-1	ERV-1	
	LL111	LIGHT WELL	EXTERIOR	70	-	-	-	-	0	0	-	-	-	-	
	LL112	FITNESS CENTER	GYMNASIUM	378	760	570	-	-	795	570	12.83	NONE	ERV-1	ERV-1	
	LL113	PUMP ROOM	STORAGE INACTIVE	809	0	0	-	-	0	0	-	-	-	-	
	LL115	STORAGE	STORAGE INACTIVE	172	0	0	-	-	0	0	-	-	-	-	
	ST101	STAIR C	STAIR	171	-	-	-	-	0	0	-	-	-	-	
	ST102	ACCESSORY STAIR	STAIR	164	-	-	-	-	0	0	-	-	-	-	
LEVEL 1	CR101	STAIR A	STAIR	77	-	-	-	-	0	0	-	-	-	-	
	CR102	STAIR B	STAIR	85	-	-	-	-	0	0	-	-	-	-	

VENTILATION SCHEDULE

ROOM NAME	ORDINANCE CLASSIFICATION	MIN. VENTILATION RATE CFM/SQ. FT.		FLOOR AREA SQ. FT.	ORDINANCE REQUIREMENTS		ACTUAL PROVIDED		SYSTEM SERVED BY		REMARKS
		SUPPLY	EXHAUST		SUPPLY CFM	EXHAUST CFM	SUPPLY CFM	EXHAUST CFM	AIR HANDLING UNIT	EXHAUST FAN	
FIRST FLOOR											
COLLEGE & CAREER CENTER 1015	CLASSROOM	1.5	0.75	994	1,491	746	1,500	1,500	AHU-1	AHU-1	
CORRIDOR N112	CORRIDOR	0.0	0.0	301	0	0	50	50	AHU-1	AHU-1	