CAE 464/517 HVAC Systems Design

Spring 2021

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Air distribution systems: Diffuser selection

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HOMEWORK / SOLUTION / EXAM

RECAP

Recap

- Herman Hall systems:

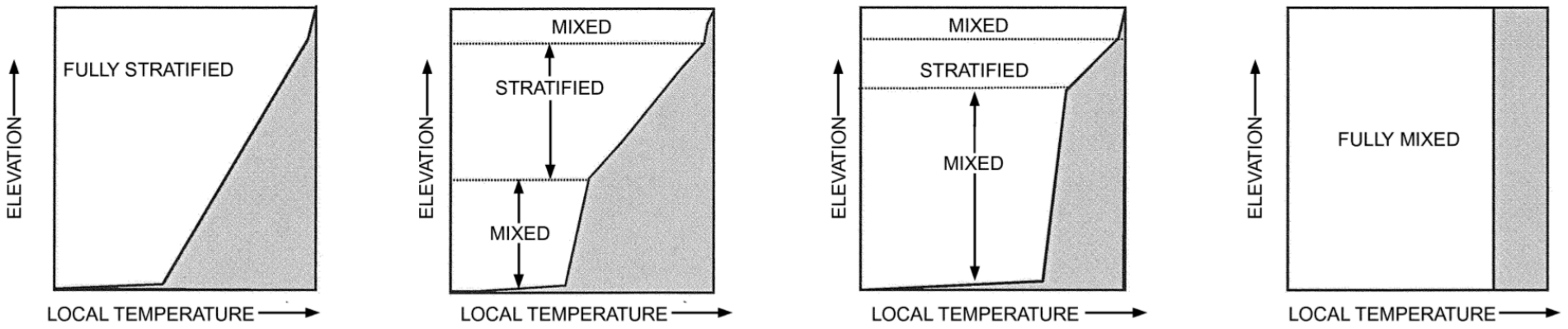
Recap

- Herman Hall systems:

Recap

- Group A
  - Diffusers mounted in or near the ceiling that discharge air horizontally
- Group B
  - Diffusers mounted in or near the floor that discharge air vertically in a non-spreading jet
- Group C
  - Diffusers mounted in or near the floor that discharge air vertically in a spreading jet
- Group D
  - Diffusers mounted in or near the floor that discharge air horizontally
- Group E
  - Diffusers mounted in or near the floor that discharge air vertically down

Recap



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

Recap

Table 1 Typical Applications for Supply Air Outlets

Outlet Types	Fully Mixed			Fully Stratified		Partially Mixed		
	Ceiling Mounted	Wall Mounted	Floor/Sill	Wall Mounted	Floor/Sill	Ceiling Mounted	Wall Mounted	Floor/Sill
Grilles								
Adjustable blade	◎	●	⊗	⊗	⊗	⊗	⊙	⊙
Fixed blade	⊙	◎	⊗	◎	⊙	⊗	⊙	⊗
Linear bar	⊗	●	●	◎	◎	⊗	⊙	●
Nozzle and drum louver	◎	●	⊗	⊗	⊗	⊗	⊗	⊗
Diffusers								
Round	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Square	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Perforated face	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Louvered face	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Plaque face	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Hemispherical	◎	⊗	⊗	⊗	⊗	◎	⊗	⊗
Laminar flow	◎	⊗	⊗	⊗	⊗	◎	⊗	⊗
Linear slot	●	●	⊗	⊗	⊗	⊗	⊗	⊗
T-bar slot	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Light troffer	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Swirl	●	⊗	⊗	⊗	◎	⊗	⊙	●
Displacement	⊗	⊗	⊗	●	●	◎	⊗	⊗
Air dispersion duct	●	◎	⊗	⊗	⊗	◎	◎	⊗

● = often used ◎ = sometimes used ⊙ = seldom used ⊗ = not recommended

Recap

- If you need to know more about the air diffusion and location of diffusers, see the following resources:
  - https://www.ideals.illinois.edu/bitstream/handle/2142/4438/engineeringexperv00000i00435.pdf?sequence=3&isAllowed=y
  - https://www.ideals.illinois.edu/bitstream/handle/2142/4130/engineeringexperv00000i00442.pdf?sequence=3&isAllowed=y

Recap

- In addition to the Fundamentals Chapter 20, ASHRAE Applications Chapter 58 is a good resource

CHAPTER 58

ROOM AIR DISTRIBUTION

Application Guidelines 58.1
Fully Mixed Air Distribution 58.2
Fully Stratified Air Distribution 58.9
Partially Mixed Air Distribution 58.13
Air Dispersion Systems 58.15
Air Terminal Units (ATUs) 58.19
Room Fan-Coil Units 58.26
Heating and Cooling Coil Selection 58.30
Chilled Beams 58.31
Air Curtain Units 58.34

ROOM air distribution systems, like other HVAC systems, are intended to achieve required thermal comfort and ventilation for space occupants and processes. Although air terminals (inlets and outlets), terminal units, local ducts, and the rooms themselves may affect room air distribution, this chapter addresses only air terminals and their effect on occupant comfort. This chapter is intended to help HVAC designers apply air distribution systems to occupied spaces, providing information on characteristics of various air distribution strategies, and tools and guidelines for applications and system design. Naturally ventilated spaces are not addressed; see Chapter 16 of the 2017 *ASHRAE Handbook—Fundamentals* for details. Also see Chapter 20 of the 2017 *ASHRAE Handbook—Fundamentals* for more information on space air diffusion; Chapter 19 of the 2016 *ASHRAE Handbook—HVAC Systems and Equipment* for information on room air distribution equipment; and Chapter 49 of this volume for sound and vibration control guidance.

Room air distribution systems can be classified by (1) their primary objective and (2) the method by which they attempt to accomplish that objective. The objective of any air distribution system can be classified as one of the following:

- Conditioning and/or ventilation of the space for occupant thermal
- **Full thermal stratification systems** (e.g., thermal displacement ventilation) have little or no air mixing in the occupied and/or process space.
- **Partially mixed systems** (e.g., most underfloor air distribution designs) provide limited air mixing in the occupied and/or process space.
- **Task/ambient air distribution** (e.g., personally controlled desk outlets, spot conditioning systems) focuses on conditioning only part of the space for thermal comfort and/or process control.

Because task/ambient design requires a high degree of individual control, it is not covered in this chapter; see Chapter 20 of the 2017 *ASHRAE Handbook—Fundamentals* for details. Guidance is also provided by ASHRAE (2013).

Figure 1 shows the spectrum between the two extremes (full mixing and full stratification) of room air distribution strategies.

1. APPLICATION GUIDELINES

Design Considerations

Architectural and Spatial Constraints. Air distribution products must fulfill both the functional requirement of conditioning

Recap

- In addition to the Fundamentals Chapter 20, ASHRAE Systems and Equipment Chapter 20 is a good resource

CHAPTER 20

ROOM AIR DISTRIBUTION EQUIPMENT

SYSTEMS OVERVIEW 20.1
SYSTEM CLASSIFICATIONS 20.1
Fully Mixed Systems 20.2
Fully Stratified Systems 20.3
Partially Mixed Systems 20.4
EQUIPMENT 20.4
Supply Air Outlets 20.4
Return/Exhaust Air Inlets 20.5
Grilles 20.6
Nozzles and Drum Louvers 20.7
Diffusers 20.7
Terminal Units 20.9
Fan-Coil Units 20.11
Chilled Beams 20.13
Air Curtain Units 20.14

SUPPLY air outlets, terminal units, chilled-beam units, fan-coil units, air curtain units, and textile air dispersion products introduce air into a conditioned space to obtain a desired indoor atmospheric environment. Return and exhaust air are removed from a space through return and exhaust inlets (*inlet* and *outlet* are defined relative to the duct system and not the room, as shown in Figure 1). This chapter describes this equipment, details its proper use, and is intended to help HVAC designers select room air distribution equipment applicable to the air distribution methods outlined in Chapter 58 of the 2019 *ASHRAE Handbook—HVAC Applications.*

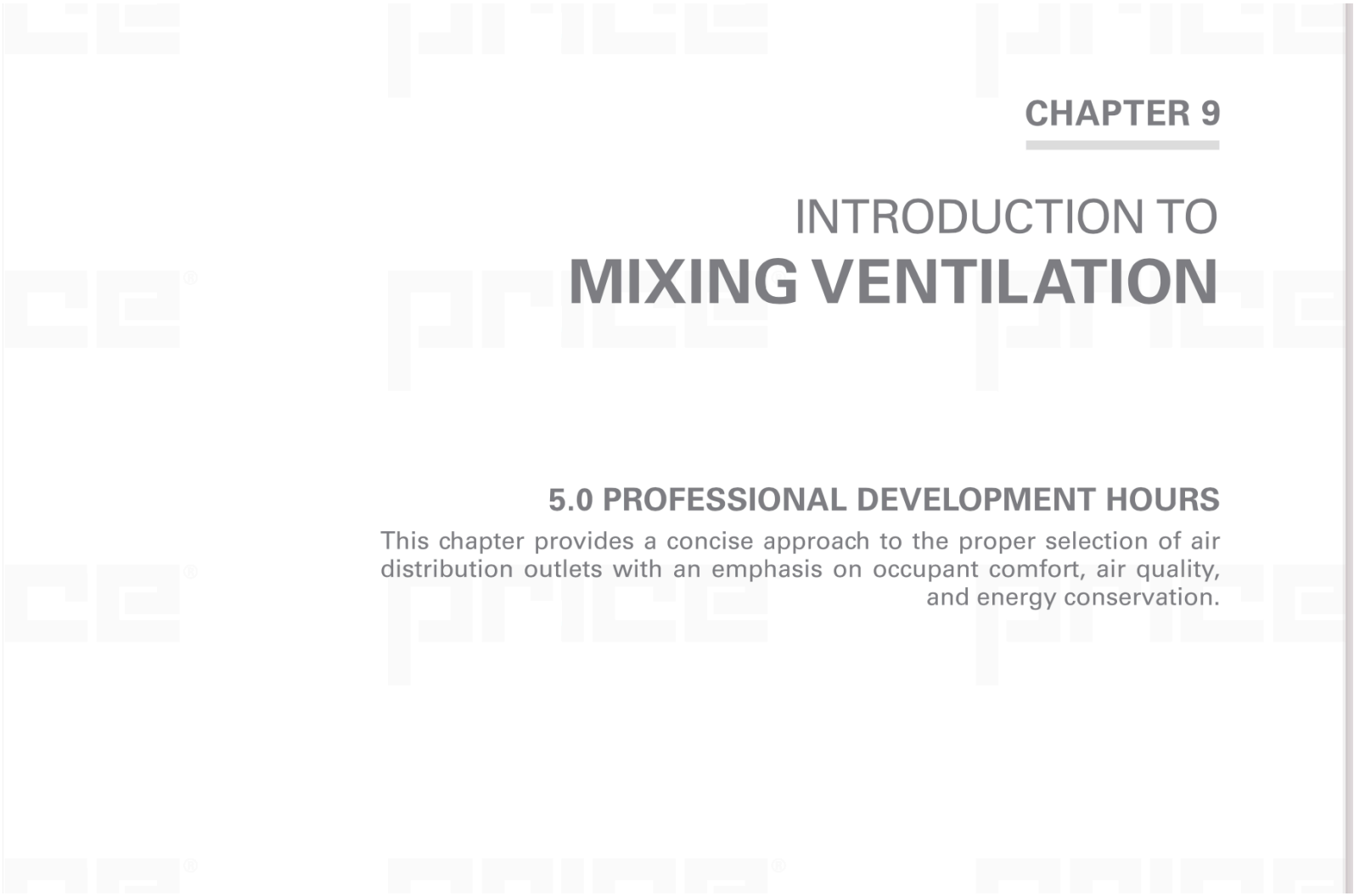
ing and ventilation is provided by the air handling unit. Variable-air-volume (VAV) systems are the prime example of all-air systems, although all-air systems can be constant air volume (variable supply air temperature) as well.

Decoupled Cooling Systems

Decoupled cooling/dehumidification systems rely on preconditioned air from the air-handling unit for space ventilation, but typically have zone-based terminal units that supplement the space sensible and latent cooling. This decoupled cooling/dehumidification may be provided by either chilled water or refrigerant coils

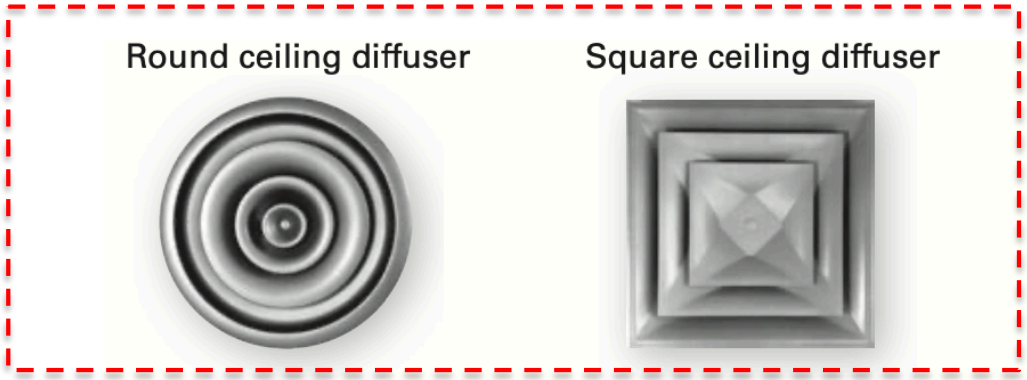
Recap

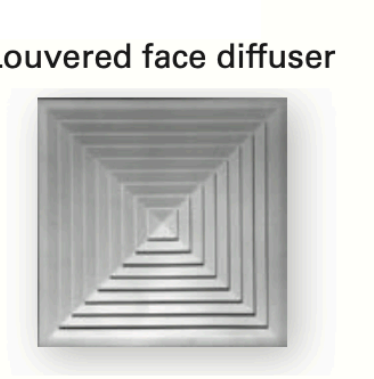
- In addition to the Fundamentals Chapter 20, Chapter 9 of the Engineering Handbook by Price Industries is a good resource

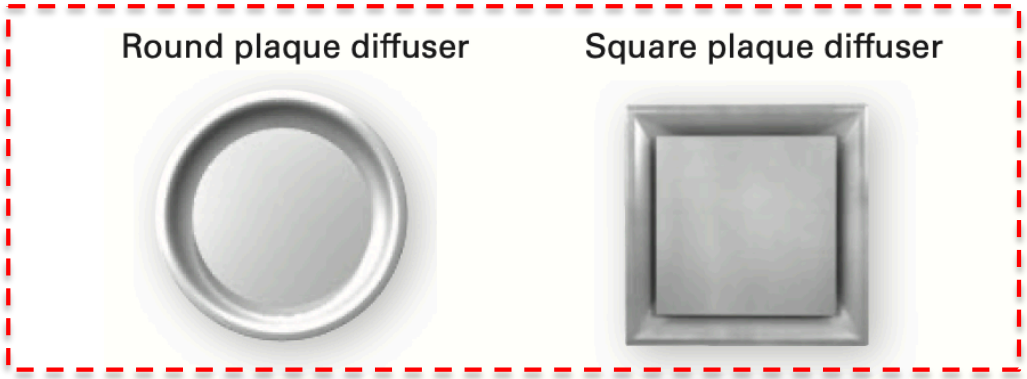


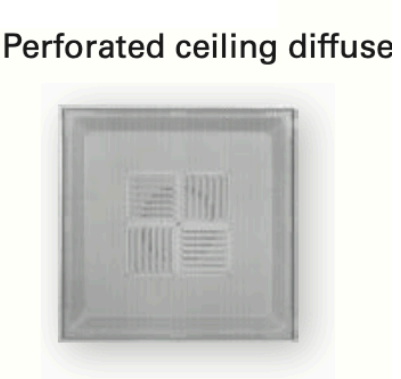
CHARACTERISTICS ROOM LENGTH (DIFFUSER SPACING)

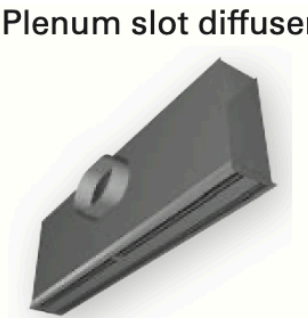
Characteristics Room Length

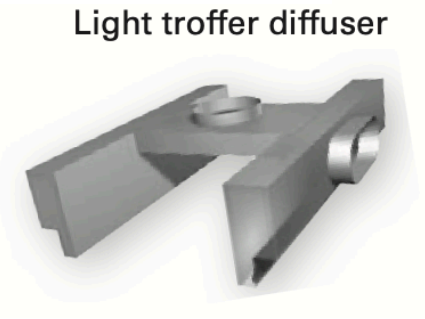








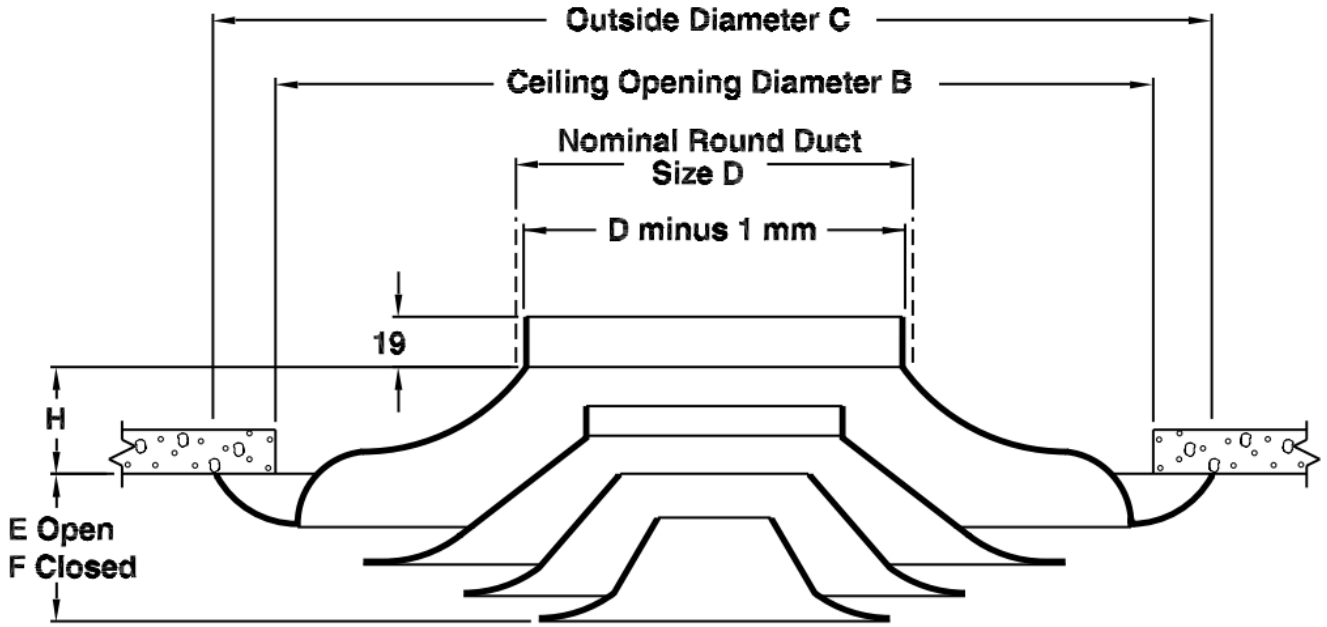




Engineering Guide Air Distribution, Price

Characteristics Room Length

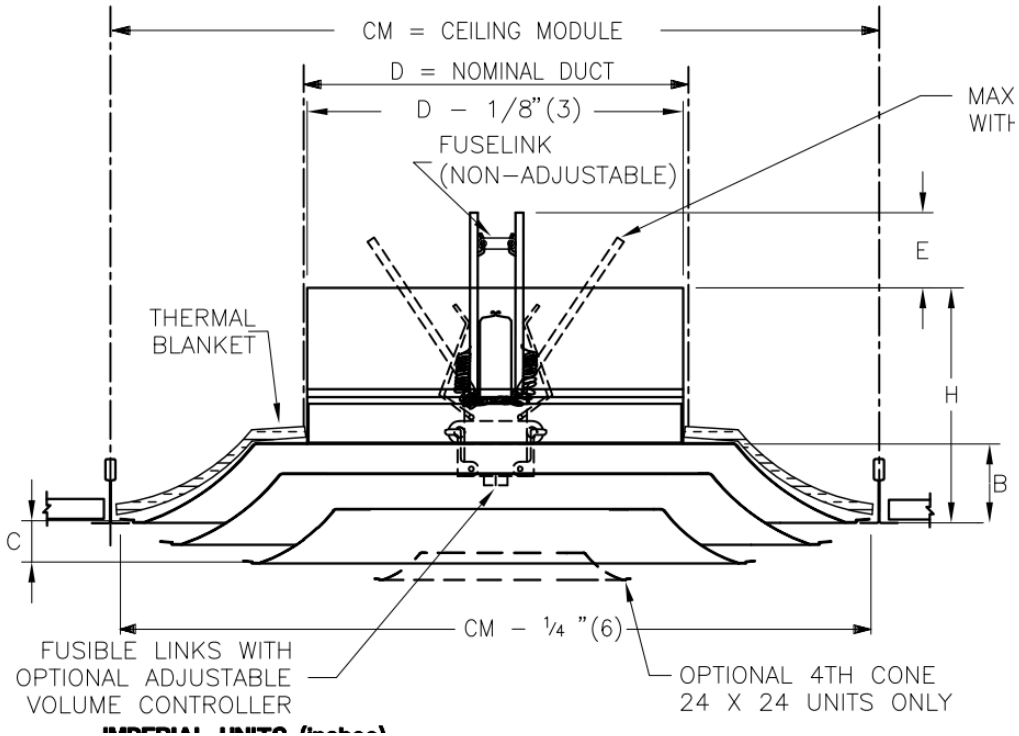
- Round diffusers:
  - ❑ Diameter usually vary from 6” to 36”
  - ❑ Usually work for high flow rates (e.g., gyms, halls, …)
  - ❑ Some have adjustable vanes



https://www.titus-hvac.com/file/1717/m_Tmra.pdf

Characteristics Room Length

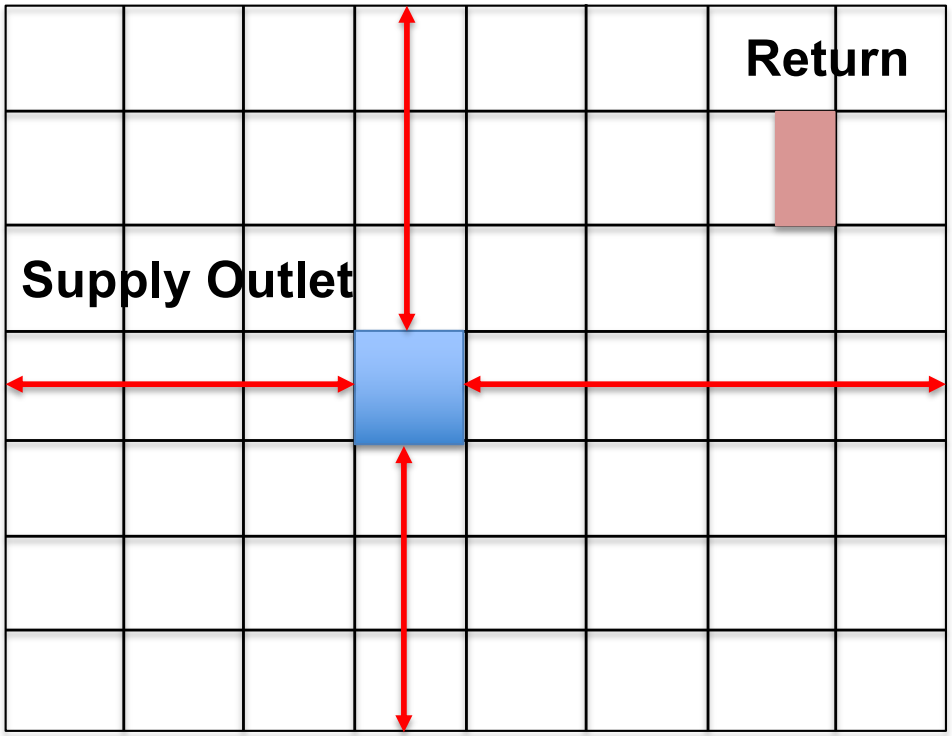
- Square diffusers:
  - ❑ Some common sizes are 12”x12”, 20”x20”, and 24”x24”
  - ❑ Usually work for low flow rates



https://www.priceindustries.com/content/uploads/assets/literature/submittals/section%20c/fire-rated-diffusers-submittal.pdf

Characteristics Room Length

- To identify the characteristics length, we need to identify the location of the air outlets
- Identify the maximum achievable throw
- Add the grid and place supply outlets and returns (e.g., 2” by 2”)



Characteristics Room Length

High Sidewall Grille

Distance to wall perpendicular to jet

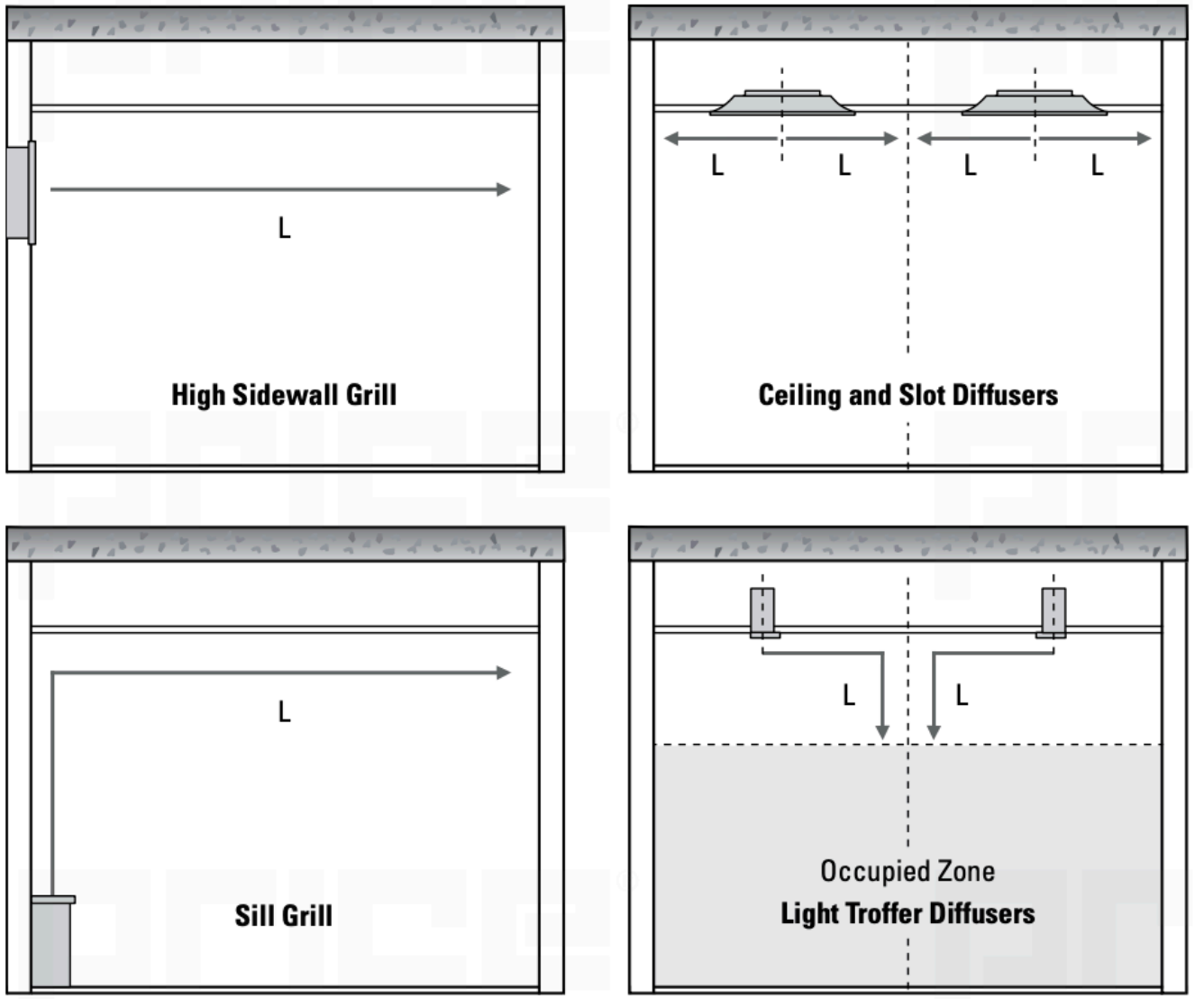
Circular Ceiling Diffuser

Distance to closet wall or intersecting air jet

https://www.zoro.com/zoro-select-sidewallceiling-register-adjustable-4mjk6/i/G3228687/feature-product?gclid=CjwKCAiA767jBRBqEiwAGdAOr9PLHqDn6n9EPQA_dt52anSd56Ufjsi01C2Y1uw7d1UgBStCgclyPBoCYdUQAvD_BwE

http://www.airmate.com/products/rezzin-round/ceiling-diffuser

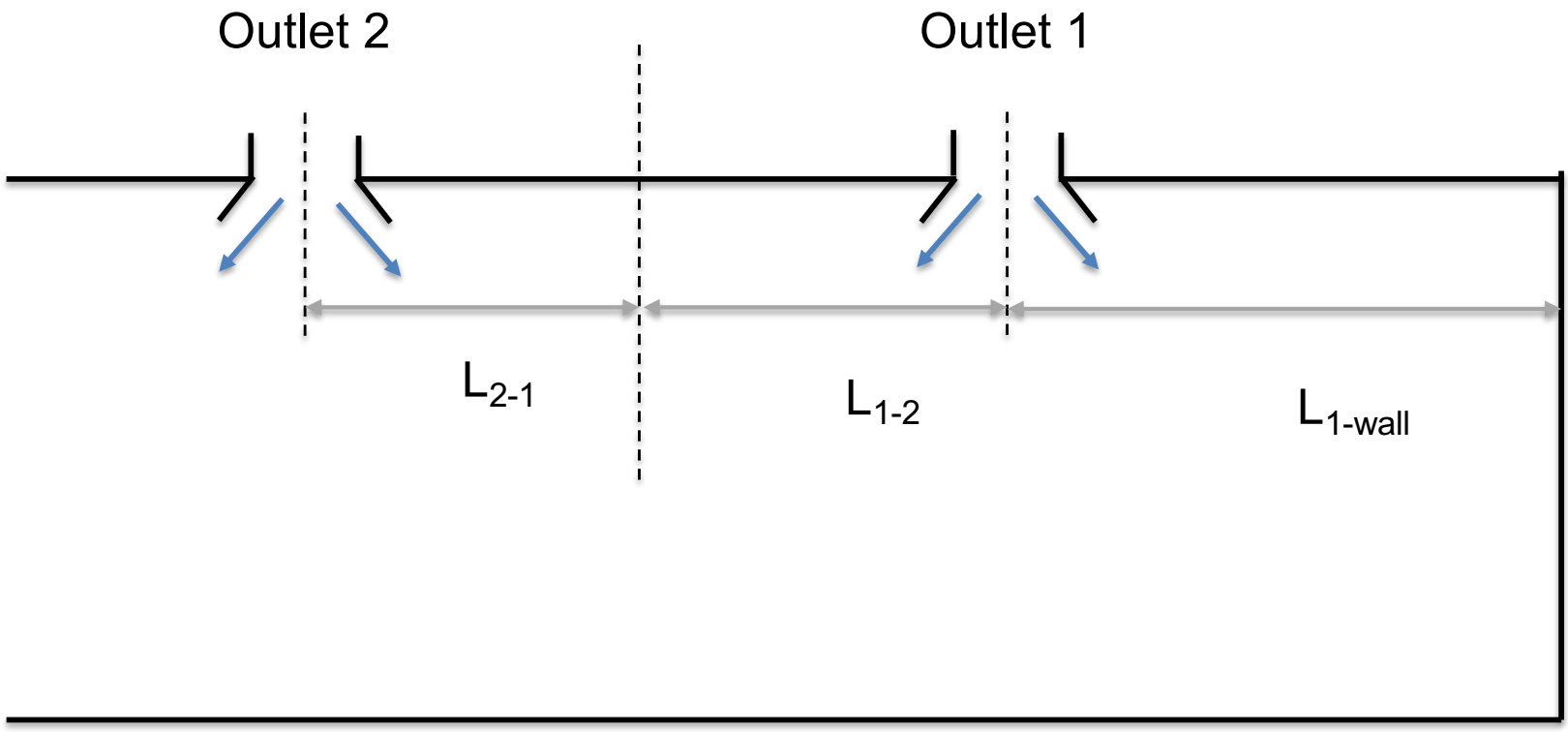
Characteristics Room Length



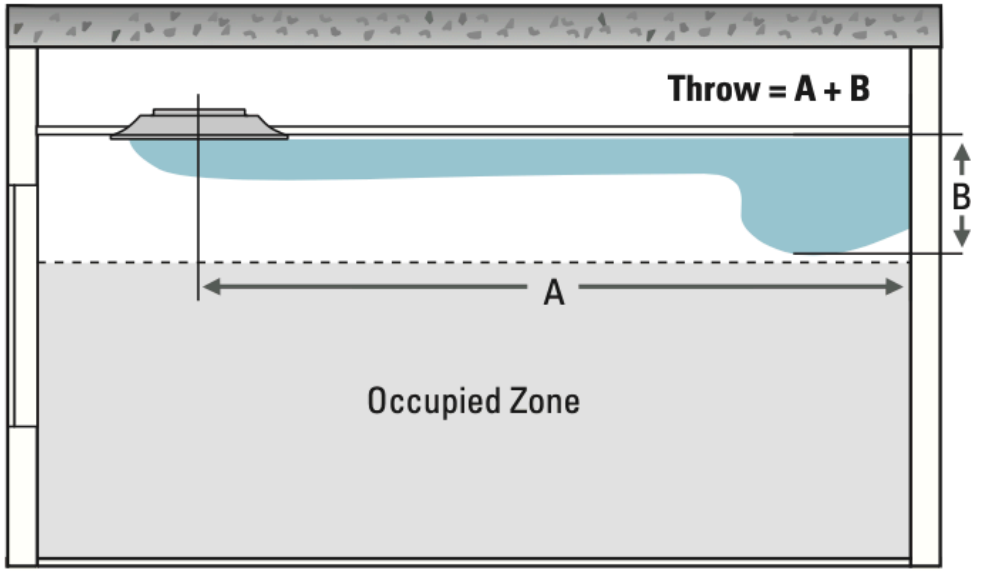
Engineering Guide Air Distribution, Price

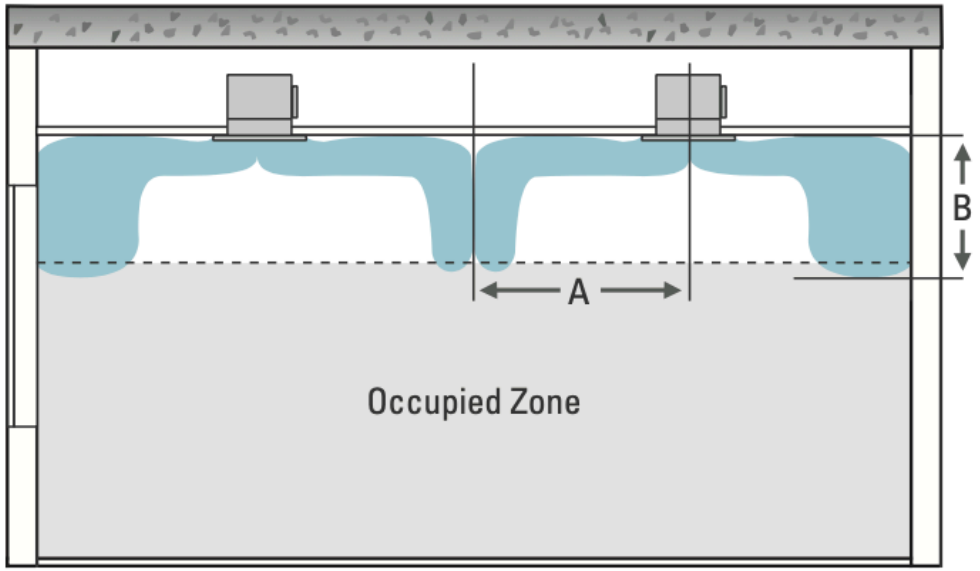
Characteristics Room Length

- How do we select L for the following setup?



Characteristics Room Length





Engineering Guide Air Distribution, Price

Characteristics Room Length

- Various outlet performs differently:

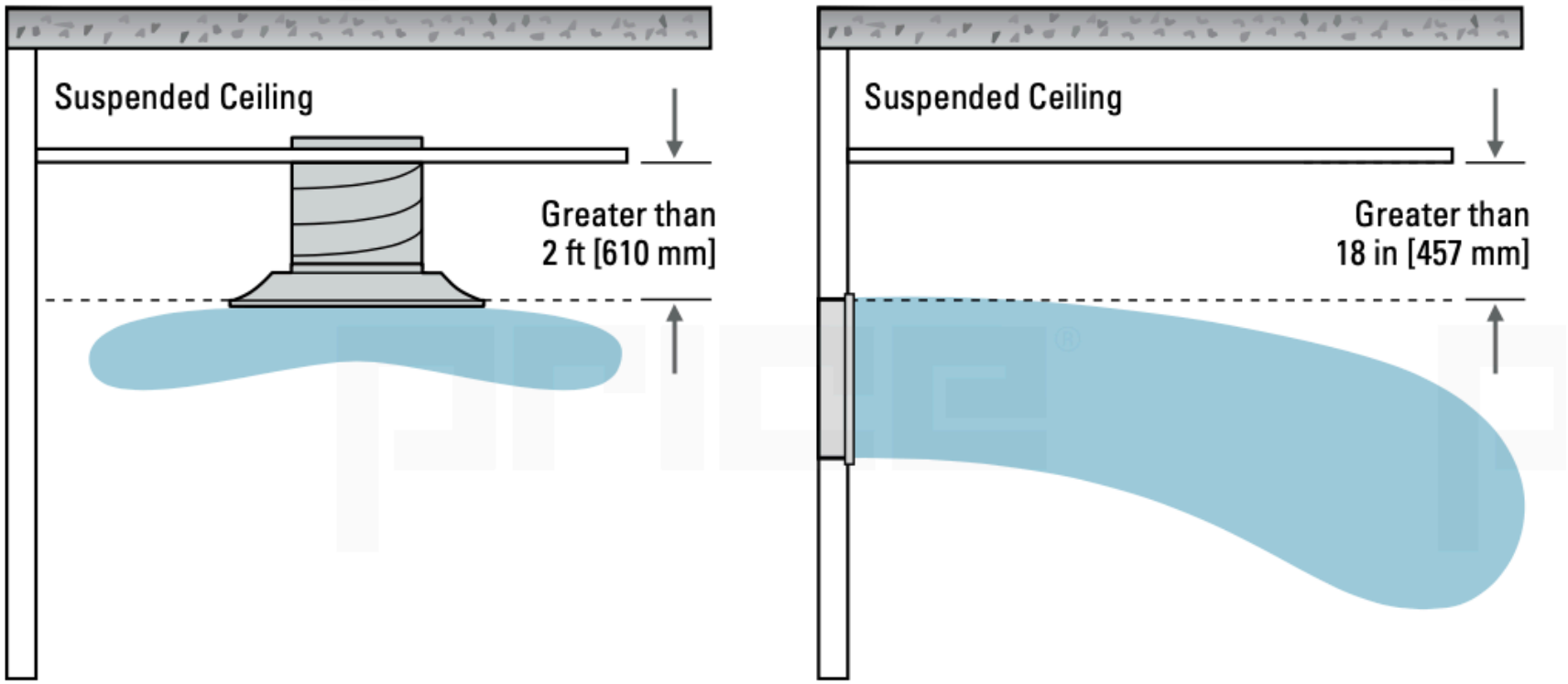
Table 5 Characteristic Room Length for Several Diffusers (Measured from Center of Air Outlet)

Diffuser Type	Characteristic Length *L*
High sidewall grille Adjustable blade Fixed blade Linear bar Nozzle	Distance to wall perpendicular to jet
Horizontal-throw ceiling diffuser Round Square Perforated Louvered Plaque Swirl	Distance to closest wall, midplane between outlets or intersecting air jet
Sill grille	Length of room in direction of jet flow
Ceiling slot diffuser	Distance to wall perpendicular to jet or midplane between outlets
Light troffer diffusers	Distance to midplane between outlets plus distance from ceiling to top of occupied zone

Characteristics Room Length

- We need to be careful of Coanda effect

- For free space mounting, multiply the throw by 0.7



Engineering Guide Air Distribution, Price

Characteristics Room Length

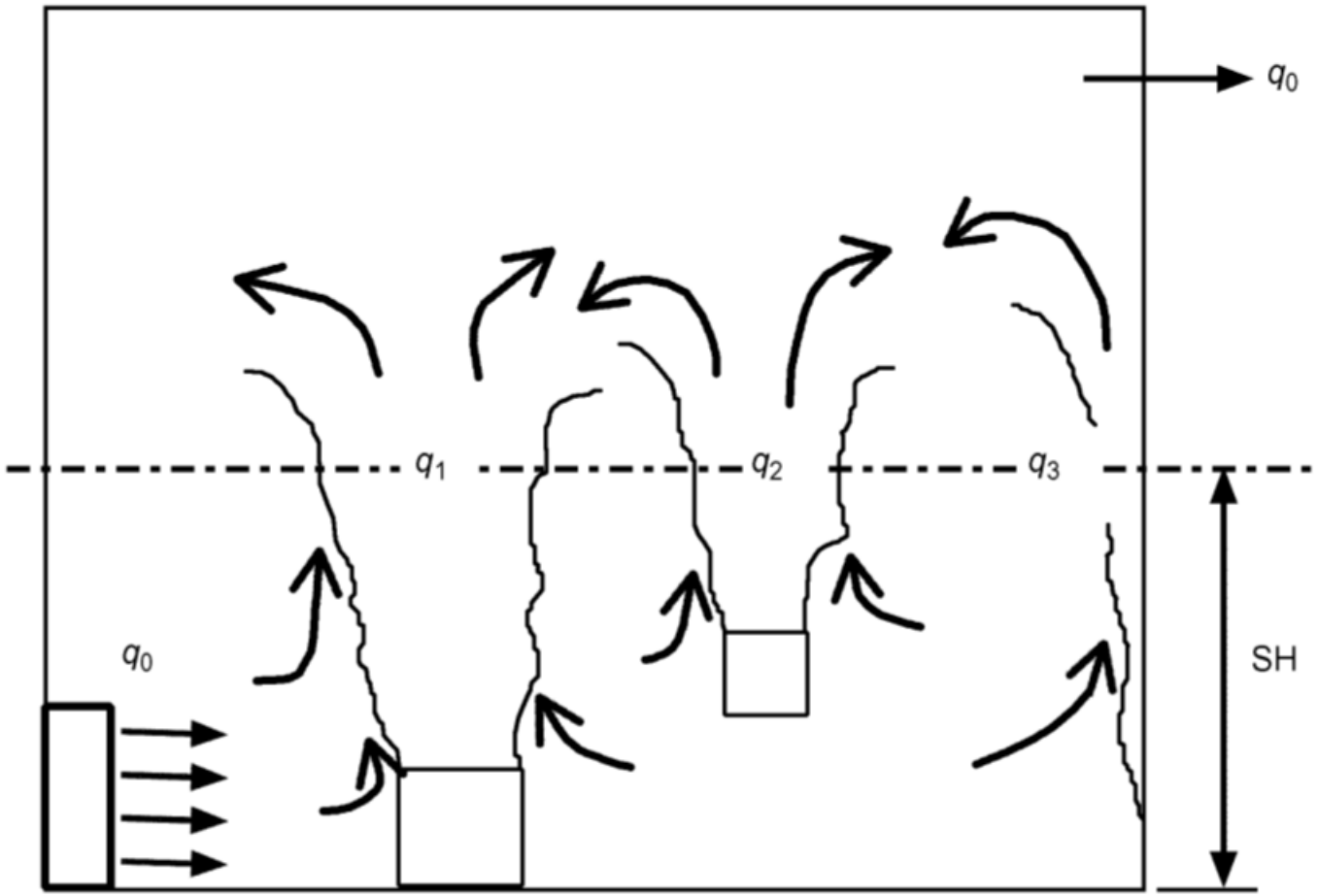
- The following example shows how we know which diffuser type to select:

Table 9.2: 24 in. x 24 in. module [610 mm x 610 mm], 380 cfm [179 L/s], 700 fpm [3.60 m/s] neck velocity, isothermal conditions, 50 fpm [0.25 m/s] terminal velocity

Diffuser Type	Throw Distance, ft [m]
Square Cone	10 [3.0]
Round Cone	9 [2.7]
Perforated 4 way	14 [4.3]
Perforated 1 way	33 [10.1]
Modular Core 4 way	24 [7.3]
Modular Core 1 way	36 [11]

Characteristics Room Length

- Make sure to consider internal objects



DATASHEETS

Datasheets

- We define throw as the terminal velocity
  - 150 fpm (0.75 m/s) = T_{150}
  - 100 fpm (0.50 m/s) = T_{100}
  - 50 fpm (0.25 m/s) = T_{50}

Datasheets

- Manufacture usually report the isothermal condition. To account for the denser supply air, multiply the tabulated values by 0.75. This is to account for a temperature differential of approximately 15 °F.

https://www.priceindustries.com/content/uploads/assets/literature/engineering-guides/air-distribution-engineering-guide.pdf

Datasheets

- Let's look at the manufacture datasheet
  - https://www.priceindustries.com/content/uploads/assets/literature/catalogs/catalog-pages/section%20d/500_600_supply.pdf

Performance Data — Models 510, 520 / 610, 620 / 710, 720 / 910, 920

									NC 20	30			40
	Core Velocity fpm		300	400	500	600	700	800	1000	1200	1400	1600	1800
	Velocity Pressure		.006	.010	.016	.022	.030	.040	.062	.090	.122	.159	.202
Size	Total	0°	.014	.024	.038	.052	.071	.094	.146	.212	.287	.374	.475
	Pressure	22½°	.017	.028	.045	.063	.085	.114	.176	.256	.347	.452	.574
		45°	.025	.042	.067	.093	.126	.168	.261	.379	.514	.669	.850
Ac = 0.15 ft² 7 x 4 6 x 5	cfm		45	60	75	90	105	120	150	180	210	240	270
	NC		—	—	—	—	15	19	26	31	36	40	44
		0°	4-6-12	5-8-14	7-10-16	8-12-17	9-13-19	11-14-20	13-16-22	14-17-24	15-19-26	16-20-28	17-22-30
	Throw	22½°	3-5-10	4-6-11	6-8-13	6-10-14	7-10-15	9-11-16	10-13-18	11-14-19	12-15-21	13-16-22	14-18-24
	ft	45°	2-3-6	3-4-7	3-5-8	4-6-9	5-7-9	5-7-10	6-8-11	7-9-12	8-9-13	8-10-14	9-11-15
Ac = 0.18 ft² 8 x 4 7 x 5 6 x 6	cfm		55	70	90	110	125	145	180	215	250	290	325
	NC		—	—	—	—	16	20	27	32	37	41	45
		0°	4-7-13	6-8-15	7-11-17	9-13-19	10-15-20	11-16-22	14-17-24	15-19-26	17-21-29	18-22-31	19-24-33
	Throw	22½°	3-6-10	5-6-12	6-9-14	7-10-15	8-12-16	9-13-18	11-14-19	12-15-21	14-17-23	14-18-25	15-19-26
	ft	45°	2-3-7	3-4-8	4-5-9	4-7-10	5-7-10	6-8-11	7-9-12	8-10-13	8-10-14	9-11-15	10-12-16

Datasheets

Performance Data — Models 510, 520 / 610, 620 / 710, 720 / 910, 920

									NC 20	30			40	
	Core Velocity fpm		300	400	500	600	700	800	1000	1200	1400	1600	1800	
	Velocity Pressure		.006	.010	.016	.022	.030	.040	.062	.090	.122	.159	.202	
Size	Total	0°	.014	.024	.038	.052	.071	.094	.146	.212	.287	.374	.475	
	Pressure	22½°	.017	.028	.045	.063	.085	.114	.176	.256	.347	.452	.574	
		45°	.025	.042	.067	.093	.126	.168	.261	.379	.514	.669	.850	
Ac = **0.15** ft² 7 x 4, 6 x 5	cfm		45	60	75	90	105	120	150	180	210	240	270	
	NC		—	—	—	—	15	19	26	31	36	40	44	
		0°	4-6-12	5-8-14	7-10-16	8-12-17	9-13-19	11-14-20	13-16-22	14-17-24	15-19-26	16-20-28	17-22-30	
	Throw	22½°	3-5-10	4-6-11	6-8-13	6-10-14	7-10-15	9-11-16	10-13-18	11-14-19	12-15-21	13-16-22	14-18-24	
	ft	45°	2-3-6	3-4-7	3-5-8	4-6-9	5-7-9	5-7-10	6-8-11	7-9-12	8-9-13	8-10-14	9-11-15	
Ac = **0.18** ft² 8 x 4, 7 x 5, 6 x 6	cfm		55	70	90	110	125	145	180	215	250	290	325	
	NC		—	—	—	—	16	20	27	32	37	41	45	
		0°	4-7-13	6-8-15	7-11-17	9-13-19	10-15-20	11-16-22	14-17-24	15-19-26	17-21-29	18-22-31	19-24-33	
	Throw	22½°	3-6-10	5-6-12	6-9-14	7-10-15	8-12-16	9-13-18	11-14-19	12-15-21	14-17-23	14-18-25	15-19-26	
	ft	45°	2-3-7	3-4-8	4-5-9	4-7-10	5-7-10	6-8-11	7-9-12	8-10-13	8-10-14	9-11-15	10-12-16	
Ac = **0.22** ft² 10 x 4, 8 x 5, 7 x 6	cfm		65	90	110	130	155	175	220	265	310	350	395	
	NC		—	—	—	—	17	21	27	33	38	42	45	
		0°	4-7-14	7-10-17	8-12-19	9-15-21	11-16-23	13-17-24	16-19-27	17-21-29	19-23-32	20-25-34	21-26-36	
	Throw	22½°	3-6-11	6-8-14	6-10-15	7-12-17	9-13-18	10-14-19	13-15-22	14-17-23	15-18-26	16-20-27	17-21-29	
	ft	45°	2-4-7	3-5-9	4-6-10	5-7-10	6-8-11	6-9-12	8-10-13	9-11-15	9-12-16	10-12-17	11-13-18	
Ac = **0.26** ft² 12 x 4, 10 x 5, 8 x 6	cfm		80	105	130	155	180	210	260	310	365	415	470	
	NC		—	—	—	—	17	21	28	34	38	42	46	
		0°	5-8-16	7-11-19	9-13-21	10-16-23	12-17-24	14-19-26	17-21-29	19-23-32	20-25-35	22-26-37	23-27-40	
	Throw	22½°	4-6-13	6-9-15	7-10-17	8-13-18	10-14-19	11-15-21	14-17-23	15-18-26	16-20-28	18-21-30	18-22-32	
	ft	45°	3-4-8	4-5-9	4-7-10	5-8-11	6-9-12	7-9-13	8-11-15	9-12-16	10-13-17	11-13-18	12-14-20	
Ac = **0.30** ft² 14 x 4	cfm		90	120	150	180	210	240	300	360	420	480	540	
	NC		—	—	—	—	18	22	29	34	39	43	47	
		0°	5-9-17	8-11-20	9-14-22	11-17-24	13-19-26	15-20-28	18-23-31	20-25-34	22-27-37	24-29-40	25-30-42	
	Throw	22½°	4-7-14	6-9-16	7-11-18	9-14-19	10-15-21	12-16-22	14-18-25	16-20-27	18-22-30	19-23-32	20-24-34	
	ft	45°	3-4-8	4-6-10	5-7-11	6-8-12	7-9-13	8-10-14	9-11-16	10-12-17	11-13-19	12-14-20	12-15-21	

https://www.priceindustries.com/content/uploads/assets/literature/catalogs/complete-sections/section%20a/section-d---grilles-and-registers.pdf

Datasheets

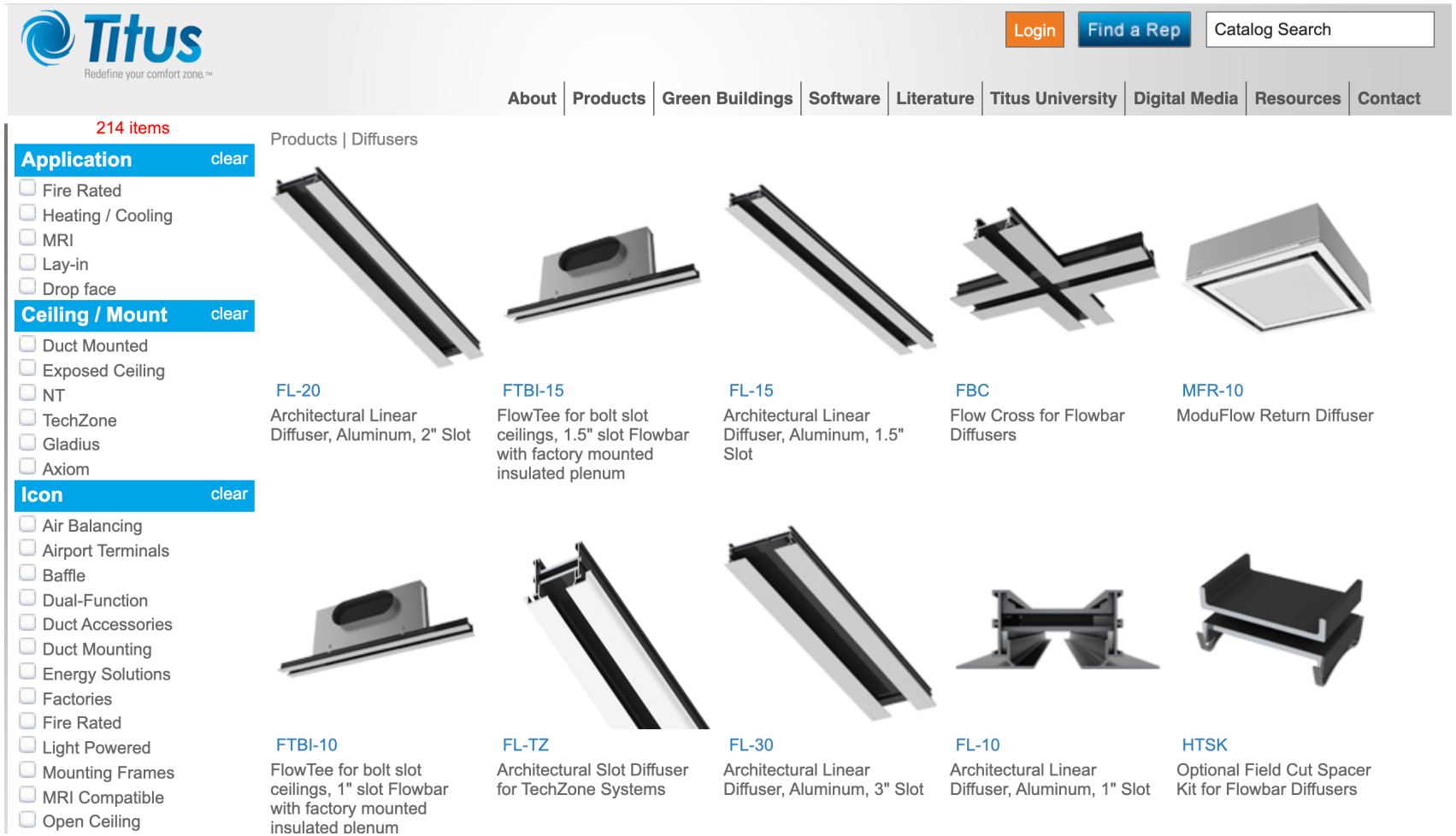
Performance Data

Core Area	Core Velocity fpm		300	400	500	600	700	800	1000	1200
	Velocity Pressure		.006	.010	.016	.022	.031	.040	.062	.090
	Total Pressure	0°	0.017	0.031	0.048	0.069	0.094	0.123	0.192	0.277
		22.5°	0.022	0.039	0.061	0.088	0.119	0.156	0.244	0.351
		45°	0.033	0.060	0.093	0.134	0.182	0.238	0.372	0.536
Ac = **0.22** ft² 10 x 4	cfm		**66**	**88**	**110**	**132**	**154**	**176**	**220**	**264**
	NC	0°	—	—	—	—	**16**	**21**	**27**	**33**
	Throw (ft)	0°	5-7-14	6-9-18	8-12-20	9-14-22	11-17-23	13-18-25	16-20-28	18-22-31
		22°	4-6-11	5-8-14	6-9-16	8-11-17	9-13-19	10-14-20	13-16-22	14-17-25
		45°	2-4-7	3-5-9	4-6-10	5-7-11	6-8-12	6-9-13	8-10-14	9-11-15
Ac = **0.26** ft² 12 x 4 10 x 5	cfm		**78**	**104**	**130**	**156**	**182**	**208**	**260**	**312**
	NC	0°	—	—	—	—	**17**	**21**	**28**	**34**
	Throw (ft)	0°	5-8-15	7-10-19	9-13-21	10-15-24	12-18-25	14-19-27	17-21-30	19-24-33
		22°	4-6-12	5-8-15	7-10-17	8-12-19	10-14-20	11-15-22	14-17-24	15-19-27
		45°	3-4-8	3-5-10	4-6-11	5-8-12	6-9-13	7-10-14	9-11-15	10-12-17
Ac = **0.30** ft² 14 x 4	cfm		**90**	**120**	**150**	**180**	**210**	**240**	**300**	**360**
	NC	0°	—	—	—	—	**18**	**22**	**29**	**34**
	Throw (ft)	0°	6-8-17	7-11-21	9-14-23	11-17-25	13-19-27	15-21-29	18-23-33	21-25-36
		22°	4-7-13	6-9-17	7-11-18	9-13-20	10-15-22	12-17-23	15-18-26	17-20-29
		45°	3-4-8	4-6-10	5-7-12	6-8-13	6-10-14	7-10-15	9-12-16	10-13-18
Ac = **0.34** ft² 16 x 4 12 x 5 10 x 6	cfm		**102**	**136**	**170**	**204**	**238**	**272**	**340**	**408**
	NC	0°	—	—	—	—	**18**	**22**	**29**	**35**
	Throw (ft)	0°	6-9-18	8-12-22	10-15-25	12-18-27	14-21-29	16-22-31	20-25-35	22-27-38
		22°	5-7-14	6-9-18	8-12-20	9-14-22	11-16-23	13-18-25	16-20-28	18-22-30
		45°	3-4-9	4-6-11	5-7-12	6-9-13	7-10-15	8-11-16	10-12-17	11-13-19
Ac = **0.39** ft² 18 x 4 14 x 5 12 x 6	cfm		**117**	**156**	**195**	**234**	**273**	**312**	**390**	**468**
	NC	0°	—	—	—	—	**19**	**23**	**30**	**36**
	Throw (ft)	0°	6-9-19	8-13-24	10-16-26	13-19-29	15-22-31	17-24-33	21-26-37	24-29-41
		22°	5-8-15	7-10-19	8-13-21	10-15-23	12-18-25	13-19-27	17-21-30	19-23-33
		45°	3-5-9	4-6-12	5-8-13	6-9-14	7-11-16	8-12-17	10-13-19	12-14-20

https://www.priceindustries.com/content/uploads/assets/literature/catalogs/complete-sections/section%20a/section-d---grilles-and-registers.pdf

Datasheets

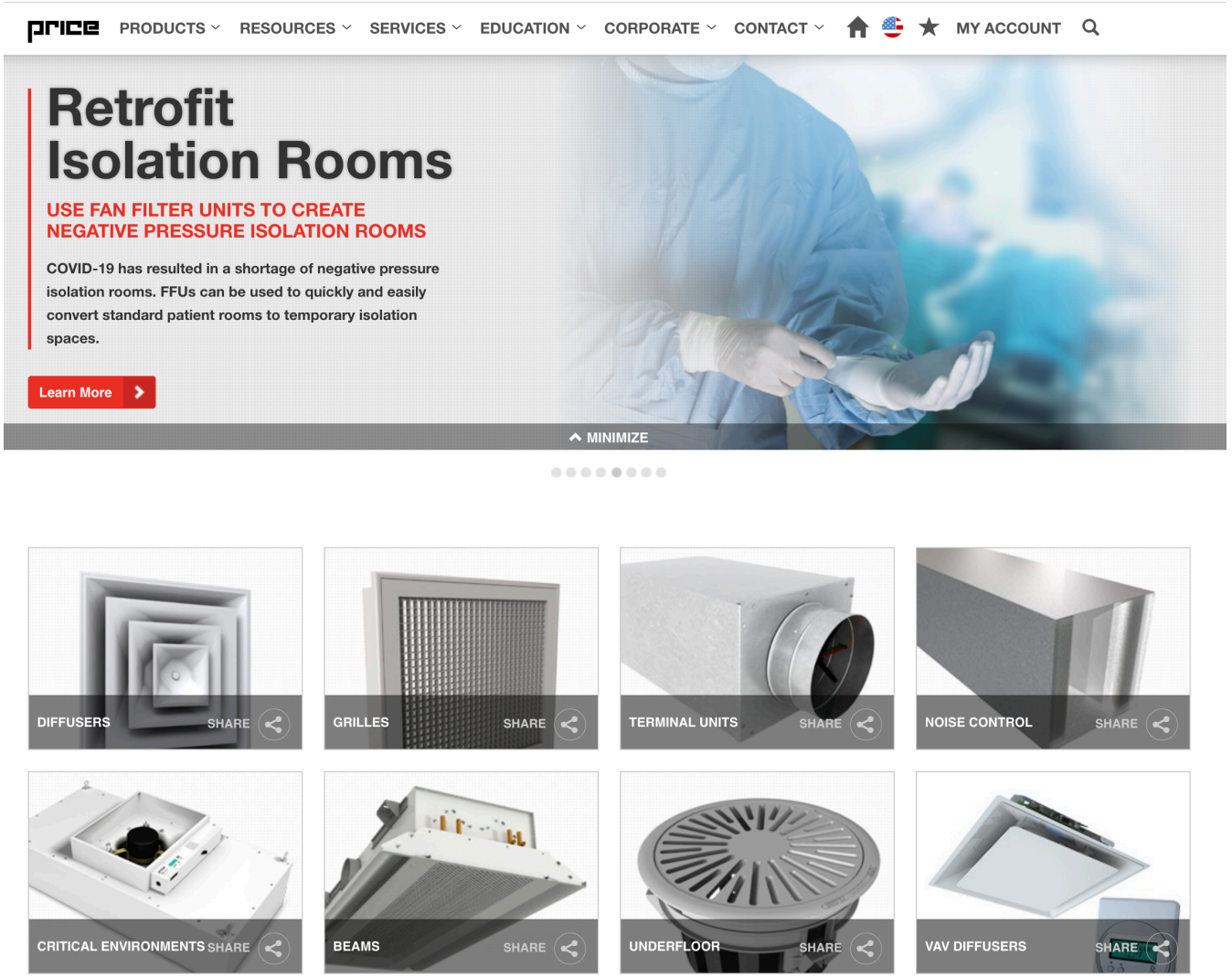
- Please review some diffuser, grille, and register options for the next lectures



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

Datasheets

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



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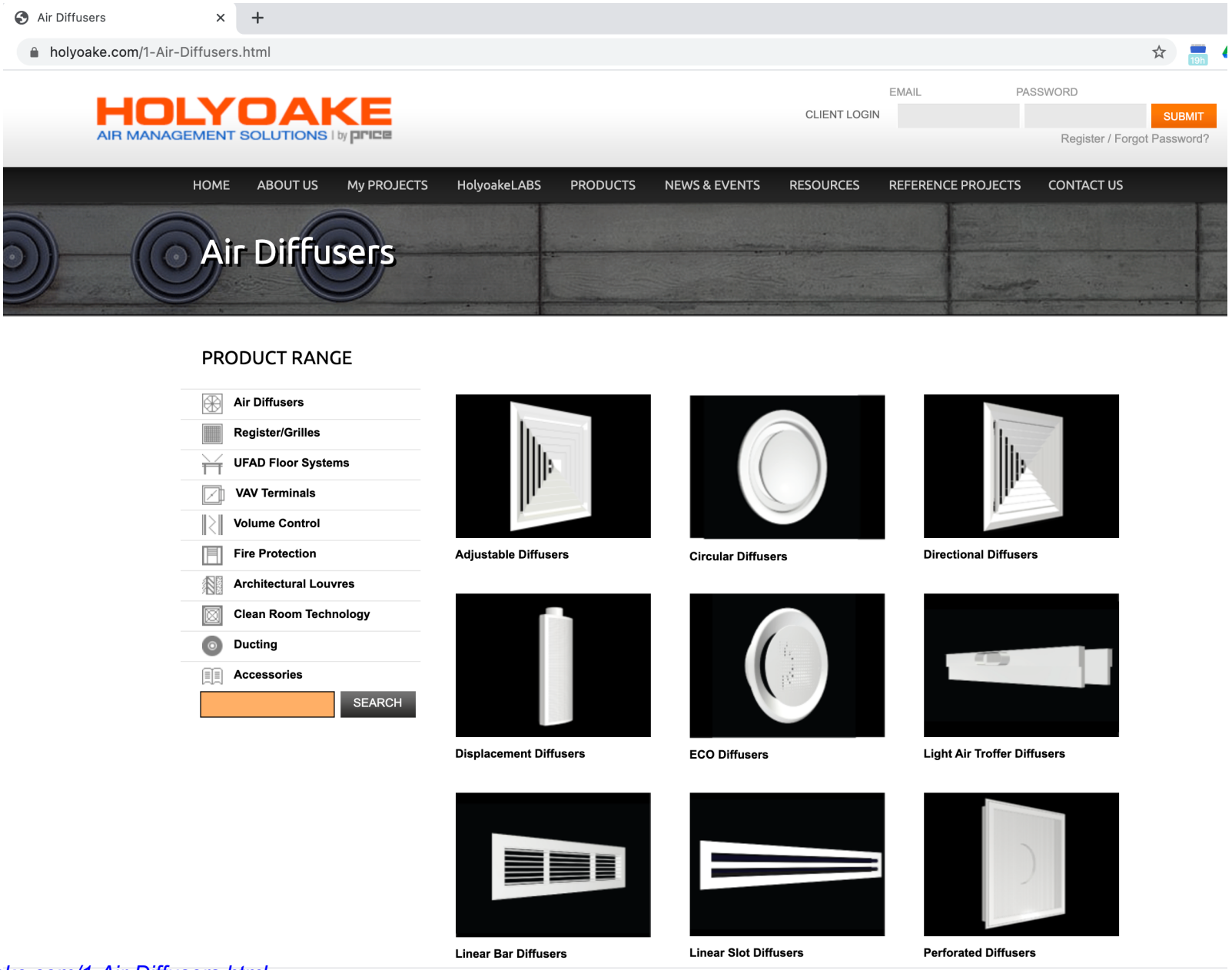
Datasheets

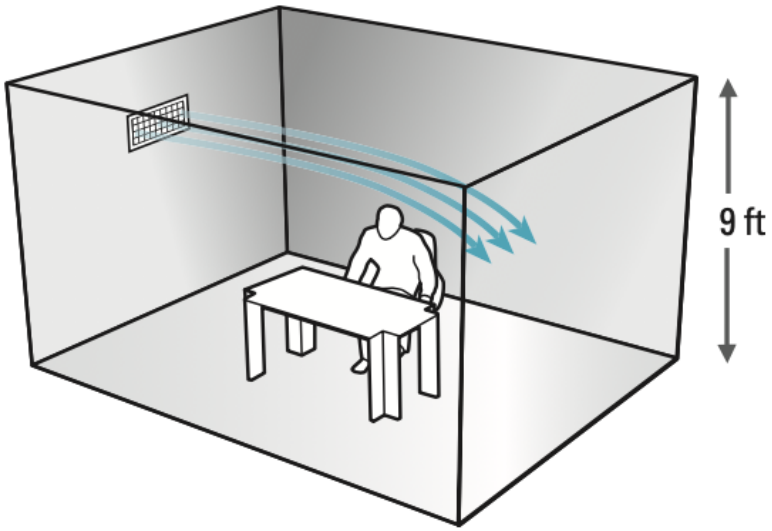


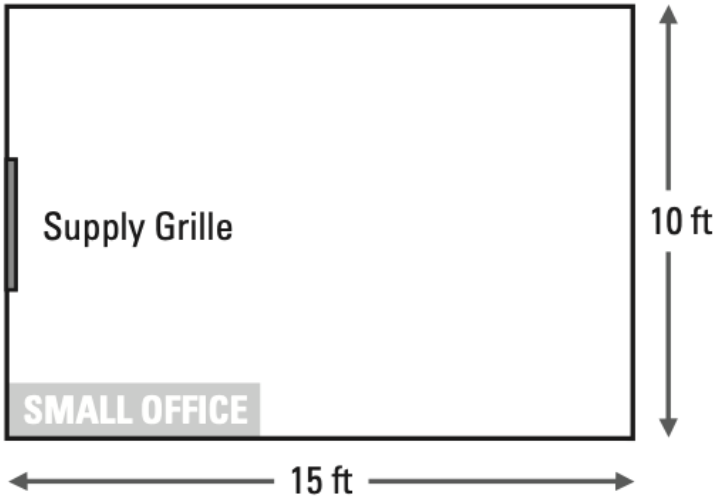
https://www.holyoake.com/1-Air-Diffusers.html

EXAMPLE

Example

- Problem:
  - ❑ Use Price Industries Product
  - ❑ A model 520 (6 in x 5 in) supply air grille.
  - ❑ Grille's air CFM is 150
  - ❑ The floor plan is as the following





https://www.priceindustries.com/content/uploads/assets/literature/engineering-guides/air-distribution-engineering-guide.pdf

Manufacturer Datasheets

- Solution:

Performance Data - Model 520 Series, 6 in. x 5 in. Supply Grille

							NC 20	30
Core Velocity, fpm			**500**	**600**	**700**	**800**	**1000**	**1200**
Velocity Pressure			**.016**	**.022**	**.030**	**.040**	**.062**	**.090**
Size	**Total Pressure**	**0**	.038	.052	.071	0.94	.146	.212
		22½	.045	.063	.085	.114	.176	.256
		45	.067	.093	.0126	.168	.261	.379
Ac = 0.15 ft^2 7 x 4 6 x 5	**cfm**		**75**	**90**	**105**	**120**	**150**	**180**
	NC		-	-	**15**	**19**	**26**	**31**
	Throw, ft	**0**	7-10-16	8-12-17	9-13-19	11-14-20	13-16-22	14-17-24
		22½	6-8-13	6-10-14	7-10-15	9-11-16	10-13-18	11-14-19
		45	3-5-8	4-6-9	5-7-9	5-7-10	6-8-11	7-9-12

https://www.priceindustries.com/content/uploads/assets/literature/engineering-guides/air-distribution-engineering-guide.pdf

Example

- Solution
  - ❑ Isothermal:

0 deflection	22º deflection	45º deflection
22 ft	18 ft	11 ft

  - ❑ Non-Isothermal

0 deflection	22º deflection	45º deflection
$0.75 \times 22 = 17\ ft$	$0.75 \times 18 = 14\ ft$	$0.75 \times 11 = 8\ ft$

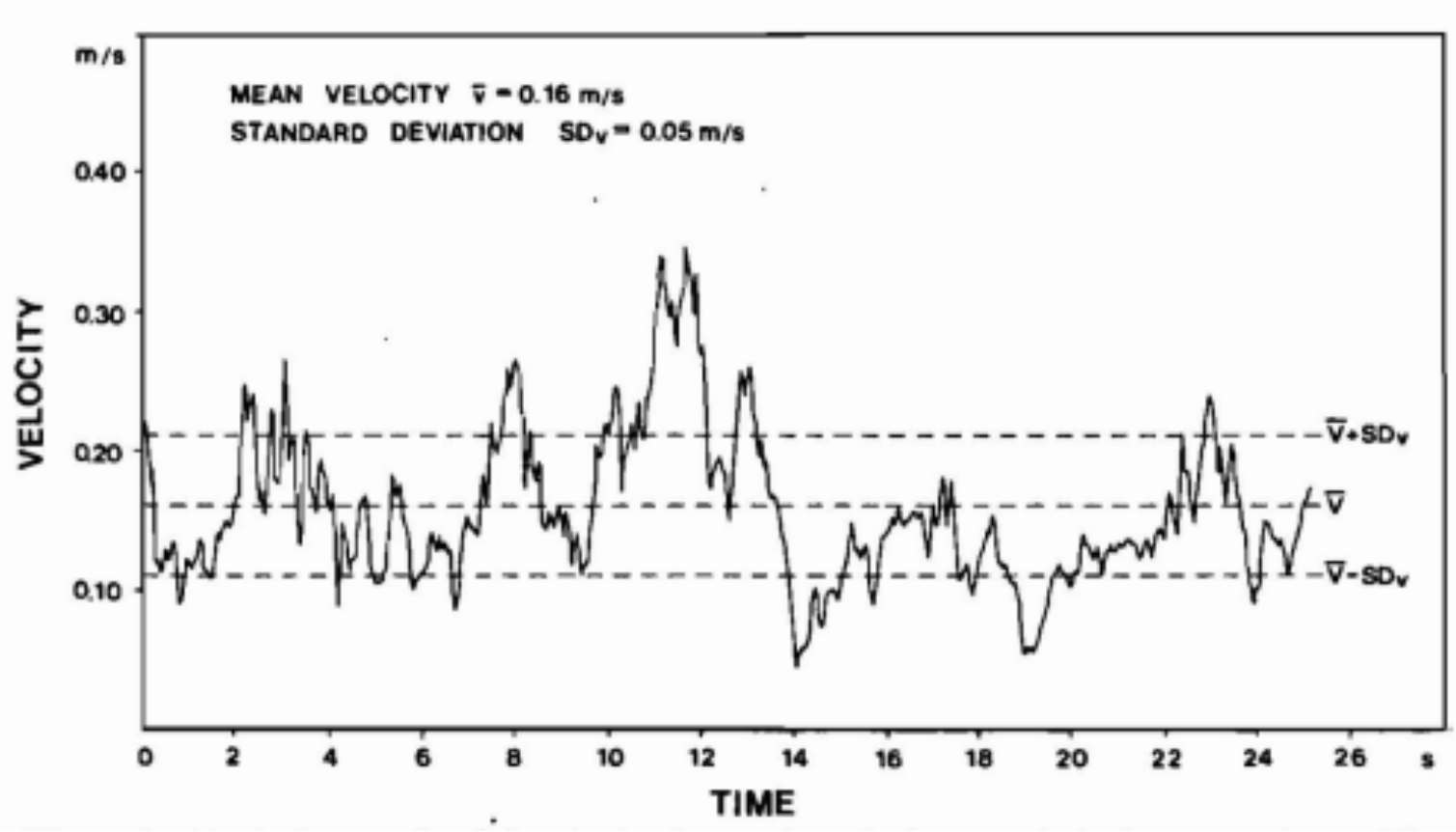
See Example 9.2 and Example 9.3 in the Price Engineering Handbook

https://www.priceindustries.com/content/uploads/assets/literature/engineering-guides/air-distribution-engineering-guide.pdf

AIR DIFFUSION PERFORMANCE INDEX (ADPI)

Air Distribution Performance Index (ADPI)

- Avoid the draft in the space
- Air fluctuate in a typical air conditioned space



Fanger and Christensen, Perception of draught in ventilated spaces

Air Distribution Performance Index (ADPI)

- ADPI is the percentage of points within the occupied zone with a range of effective draft temperature of -3 to 2 F of average room temperature at a coincident velocity of 70 fpm or less than that

- ADPI is a measure of the degree of mixing in zones served by overhead cooling systems

- ADPI of 80 or more is desirable to avoid stratification

Air Distribution Performance Index (ADPI)

- The ADPI is based only on
  - ❑ Air velocity
  - ❑ Effective draft temperature (a combination of local temperature variations from the room average)
  - ❑ Not directly related to the dry-bulb temperature or relative humidity

Air Distribution Performance Index (ADPI)

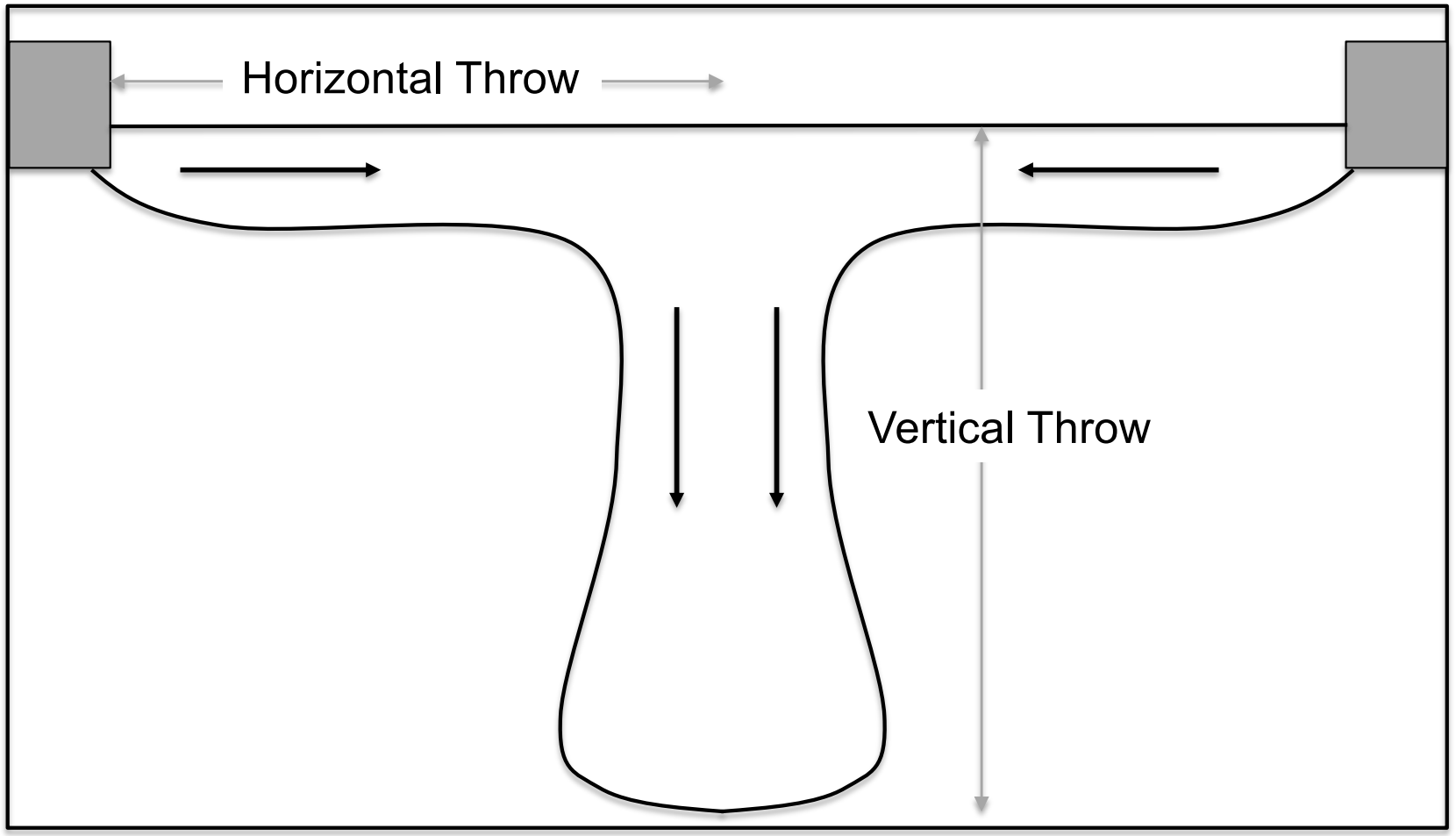
- We define Effective Draft Temperature (EDT):

$$EDT = \left(T_{db,x} - \mathrm{T_{db}}\right) - 0.07 \times (\mathrm{V_x} - 30)$$

- EDT : Effective draft temperature (F)
- T_{db}, x: Local air stream dry-bulb temperature (F)
- T_{db}: Average room dry-bulb temperature (F)
- V_x : Local air stream centerline velocity, fpm

Air Distribution Performance Index (ADPI)

- Use collide air streams to project a high velocity air stream into the occupied zone



Throw Distance = Horizontal Throw + Vertical Throw

Air Distribution Performance Index (ADPI)

Table 6A Air Diffusion Performance Index (ADPI) Selection Guide for Typical Cooling Loads

Terminal Device in Cooling Mode	Installation	Load, Btu/h·ft²	Max. ADPI T_{50}/L	Max. ADPI	T/L Low Limit for ADPI > 80%	T/L High Limit for ADPI > 80%
Adjustable-blade grilles	45° upward blades, High sidewall	8	0.8	98	0.4	1.3
		16	0.9	96	0.5	1.2
	0° horizontal blades, High sidewall	8	1.7	94	1.2	2.2
		16	1.8	88	1.4	2.2
	45° downward blades, High sidewall	8	0.9	76	NA	NA
		16	1	70	NA	NA
Fixed-blade grilles (high sidewall installation)	15° upward blades, High sidewall	8	1.4	96	0.5	2.4
		16	2.1	94	1.2	2.9
	15° downward blades, High sidewall	8	1.9	85	1.5	2.2
		16	2	82	1.8	2.2
Linear-bar grilles (high sidewall installation)	High sidewall	8	1.3	92	0.7	1.8
		16	1.3	88	1.0	1.6
	Sill	8	1.3	94	0.9	1.7
		16	1.3	90	1.0	1.6
Nozzles (high sidewall installation)	High sidewall	8	0.7	96	0.4	2.0
		16	1	89	0.4	1.9
Round ceiling diffuser	Ceiling	8	1.6	99	0.4	3.2
		16	1.9	98	0.5	3.2
Square ceiling diffuser	Ceiling	8	1.8	100	0.8	2.8
		16	1.8	100	0.6	3.1
Perforated diffusers, round pattern	Ceiling	8	1.9	95	0.5	3.3
		16	2.1	95	0.9	3.4
Perforated diffusers, directional pattern (4-way)	Ceiling	8	2.1	100	1.2	3.1
		16	2	95	1.0	2.9
Louvered face diffusers, with lip on deflector blade	Ceiling	8	2.5	100	0.5	4.4
		16	2.6	100	0.6	4.5
Louvered face diffusers, without lip on deflector blade	Ceiling	8	2	100	0.5	3.6
		16	1.8	100	0.4	3.4
Plaque face diffusers	Ceiling	8	1.6	100	0.3	3.0
		16	1.6	100	0.4	3.2
Linear-slot diffusers	Ceiling	8	1.8	100	0.5	3.0
		16	1.8	100	0.5	3.1
T-bar slot diffusers	Ceiling, periphery of a wall	8	1.3	96	0.7	1.9
		16	1.5	90	1.1	1.9
Swirl diffusers	Ceiling	8	1.3	100	0.4	2.4
		16	1.3	98	0.4	2.4
N-slot diffusers	Ceiling	8	1.8	100	1.3	2.4
		16	1.8	95	1.3	2.3

Source: Data developed by Liu et al. (2016) for this chapter from ASHRAE research project RP-1546 (Liu 2016), and air speed limit (70 fpm) extrapolated from data. Additional data point used to create new regressions for ADPI curves to better represent current diffusers/grilles. Table applies to spaces with maximum 12 ft ceiling.

Air Distribution Performance Index (ADPI)

Table 6B Air Diffusion Performance Index (ADPI) Selection Guide for Typical Heating Loads

Terminal Device in Heating Mode	Installation	Load, Btu/h·ft^2	Max. ADPI T_{50}/L	Max. ADPI	T/L Low Limit for ADPI > 80%	T/L High Limit for ADPI > 80%
Adjustable-blade grilles	45° upward blades, High sidewall	10 to 12	1.1	95	0.6	1.9
	0° horizontal blades, High sidewall	10 to 12	1.6	94	1.1	2.4
	45° downward blades, High sidewall	10 to 12	0.7	84	0.6	0.8
Fixed-blade grilles	15° upward blades, High sidewall	10 to 12	1.8	96	1.2	2.8
	15° downward blades, High sidewall	10 to 12	1.4	88	0.6	2.2
Linear-bar grilles	High sidewall	10 to 12	1.2	94	0.6	1.7
	Sill	10 to 12	1.2	100	0.7	1.8
Nozzles (high sidewall installation)	High sidewall	10 to 12	1.5	92	1.0	2.0
Round ceiling diffuser	Ceiling	10 to 12	1.4	93	1.0	2.3
Square ceiling diffuser	Ceiling	10 to 12	1.7	91	2.5	3.4
Perforated diffusers, round pattern	Ceiling	10 to 12	2.1	90	2.0	2.8
Perforated diffusers, directional pattern (4-way)	Ceiling	10 to 12	2.5	87	2.5	3.4
Louvered face diffusers, with lip on deflector blade	Ceiling	10 to 12	2.6	88	2.5	4.4
Louvered face diffusers, without lip on deflector blade	Ceiling	10 to 12	2.1	88	2.1	3.2
Plaque face diffusers	Ceiling	10 to 12	2.1	93	2.1	3.0
Linear-slot diffusers	Ceiling	10 to 12	1.7	90	1.7	3.1
T-bar slot diffusers	Ceiling, periphery of a wall	10 to 12	1.6	91	1.3	2.0
Swirl diffusers	Ceiling	10 to 12	1.4	100	1.4	2.1
N-slot diffusers	Ceiling	10 to 12	1.9	100	1.5	2.4

Source: Data developed by Liu and Novoselac (2015) for this chapter from ASHRAE research project RP-1546 (Liu 2016), and air speed limit (70 fpm) extrapolated from data. Additional data point used to create new regressions for ADPI curves to better represent current diffusers/grilles. Table applies to spaces with maximum 12 ft ceiling.

Air Distribution Performance Index (ADPI)

Table 3 Air Diffusion Performance Index (ADPI) Selection Guide

Terminal Device	Room Load, Btu/h·ft²	X_{50}/L for Maximum ADPI	Maximum ADPI	For ADPI Greater than	Range of X_{50}/L
High sidewall grilles	80	1.8	68	—	—
	60	1.8	72	70	1.5 to 2.2
	40	1.6	78	70	1.2 to 2.3
	20	1.5	85	80	1.0 to 1.9
	<10	1.4	90	80	0.7 to 2.1
Circular ceiling diffusers	80	0.8	76	70	0.7 to 1.3
	60	0.8	83	80	0.7 to 1.2
	40	0.8	88	80	0.5 to 1.5
	20	0.8	93	80	0.4 to 1.7
	<10	0.8	99	80	0.4 to 1.7
Sill grille, straight vanes	80	1.7	61	60	1.5 to 1.7
	60	1.7	72	70	1.4 to 1.7
	40	1.3	86	80	1.2 to 1.8
	20	0.9	95	90	0.8 to 1.3
Sill grille, spread vanes	80	0.7	94	90	0.6 to 1.5
	60	0.7	94	80	0.6 to 1.7
	40	0.7	94	—	—
	20	0.7	94	—	—
Ceiling slot diffusers (for T_{100}/L)	80	0.3	85	80	0.3 to 0.7
	60	0.3	88	80	0.3 to 0.8
	40	0.3	91	80	0.3 to 1.1
	20	0.3	92	80	0.3 to 1.5
Light troffer diffusers	60	2.5	86	80	<3.8
	40	1.0	92	90	<3.0
	20	1.0	95	90	<4.5
Cross-flow pattern diffusers	11 to 50	2.0	96	90	1.4 to 2.7
	11 to 50	2.0	96	80	1.0 to 3.4

T_{50} or X_{50} is used interchangeably

NOISE CONSIDERATIONS

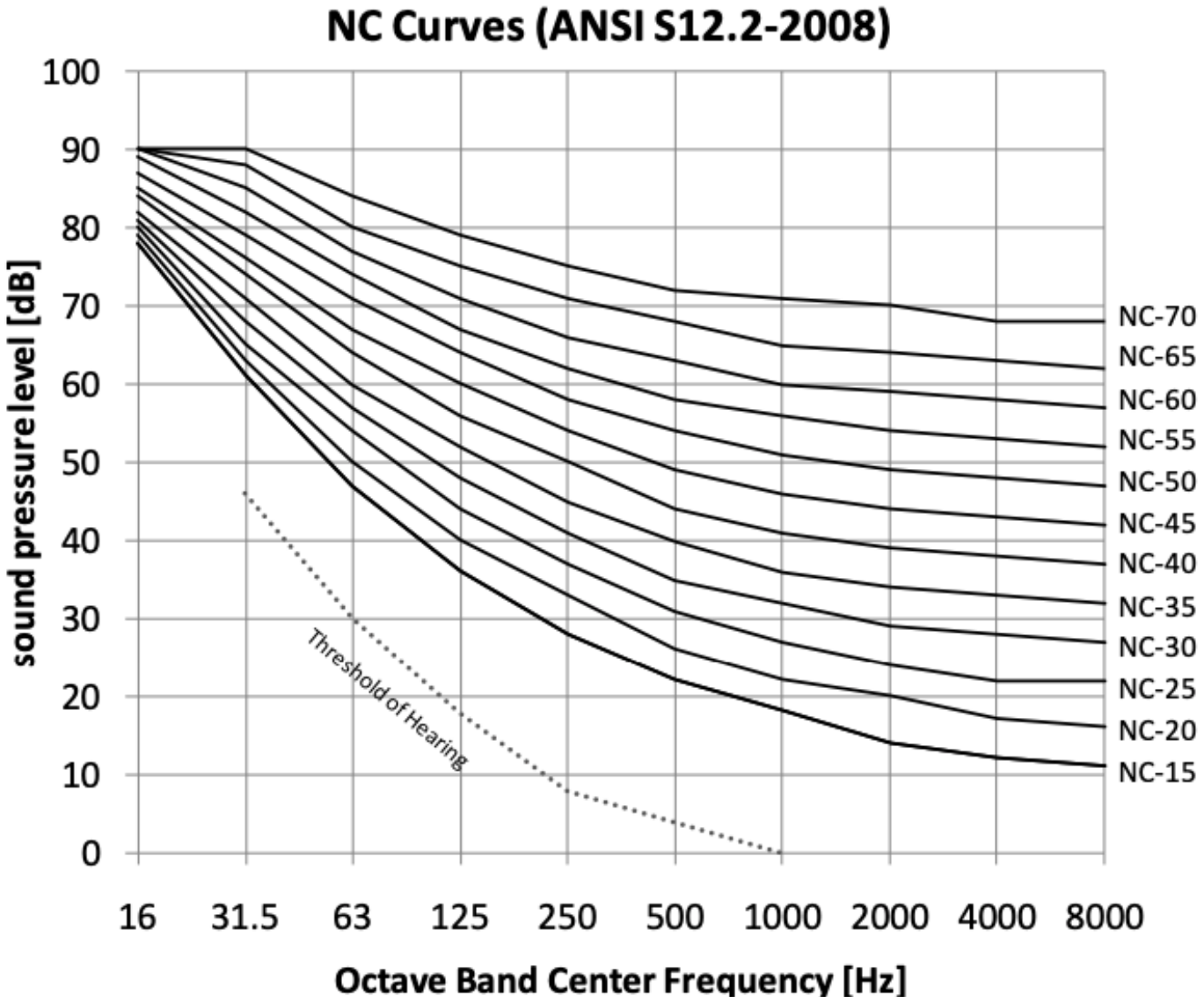
Noise Criteria

- Standard 885 provides “procedure for estimating occupied space sound levels in the application of air terminals and air outlets”

- Noise Criteria (NC) was developed in 1950s to address the noise concern of HVAC systems
  - NC is based on dB
  - NC method was originally limited in design curves
  - Did not include low frequencies
  - No criterion for unbalanced spectrum

- Room Criteria Method (RC) was developed in 1980s

Noise Criteria



http://acessoverd.dominiotemporario.com/doc/Indices_Fundamentais_de_Projeto_e_Qualidade_Workshop-Acoustic.pdf

Noise Criteria

- Generally, within a 10 ft. module the catalog NC rating will apply for diffusers and continuous linear grilles
- We hear only 10 ft. of a continuous diffuser
- A wide open balancing damper in the diffuser neck may add 4–5 NC
- Significantly closed balancing dampers can add more than 10 NC, depending on the duct pressure and supply fan characteristics

Noise Criteria

- Pick NC values match the purpose of room

- Typical NC levels are:
  - ❑ Conference Rooms < NC30
  - ❑ Private offices < NC35
  - ❑ Open offices = NC40
  - ❑ Hallways, utility rooms, rest rooms < NC45

- Sometimes it might be difficult to achieve less than NC30

- Try to select diffusers for NC20-25 (or less)

DIFFUSER SELECTION GUIDELINES (CONSIDERATION OF LOADS)

Diffuser Selection Guidelines

- Find air flow requirement for the space

$$\dot{V} = \frac{\dot{q}_{tot}}{\rho \Delta h} \cong \frac{\dot{q}_{sen}}{\rho \Delta t}$$

  - $\dot{V}$: maximum volumetric flow rate (m^3/s, ft^3/min)
  - $\dot{q}_{tot}$: total design load (W, Btu/hr)
  - $\dot{q}_{sen}$: sensible design load (W, Btu/hr)
  - ρ: air density (kg/m^3, lbm/ft^3) – about 1.08
  - *Δh:* enthalpy difference between supply and return air (J/kg, Btu/lbm)
  - *Δt*: Temperature difference between supply and return air (°C, °F)

- Select diffuser type, number, location

Diffuser Selection Guidelines

- Guideline 1:
  - ❑ Determine the air flow requirements (both outdoor air and the load required) and room size
  - ❑ Obtain reflected ceiling
  - ❑ Select the type of diffuser to be used
  - ❑ Determine room characteristic length
  - ❑ Select the recommended throw-to-length ratio
  - ❑ Select the appropriate diffuser from catalog data
  - ❑ Make sure that other specifications are met (e.g., noise or total pressure)

Diffuser Selection Guidelines

- Guideline 2:
  - ❑ Use equalizing grids on direct diffuser connections
  - ❑ Locate balancing dampers at branch take-off
  - ❑ Keep flexible duct bends as gentle as possible
  - ❑ Flex is a great attenuator of upstream noise sources
  - ❑ Keep duct velocities as low as possible but over sizing can result in higher thermal loss

Diffuser Selection Guidelines

- Guideline 3:
  - Occupants may need to hear diffusers at full load to be assured system is operating
  - Noisy diffusers work better at mixing air than quiet ones
  - Oversized diffusers may have excessive drop at low flows

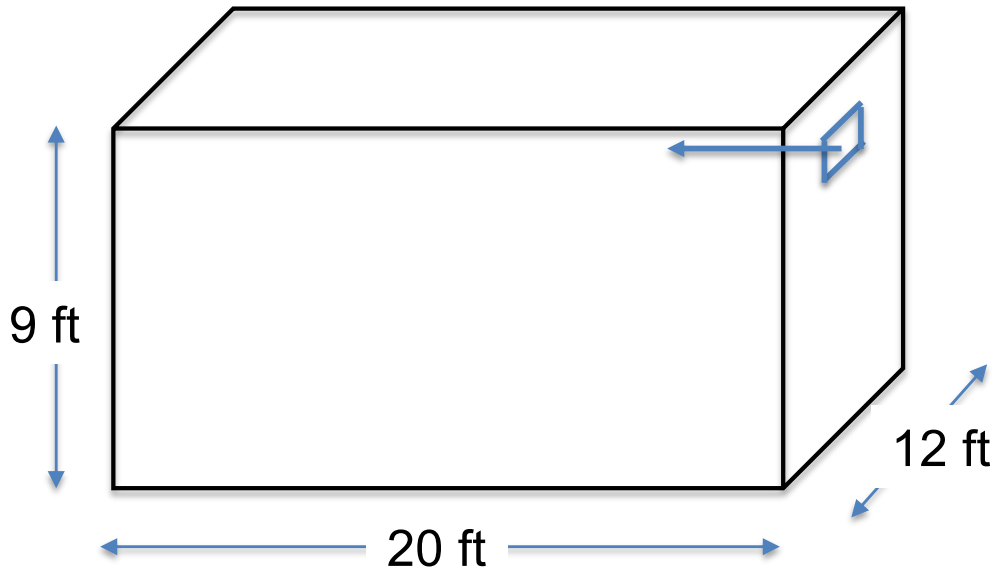
CLASS ACTIVITY

Class Activity

- For a 20 by 12 ft room, with 9 ft ceiling, with uniform loading of 10 Btu/h·ft^2 or 2400 Btu/h and air volumetric flow of 1 cfm/ft^2 or 240 cfm for one outlet, find the size for a 0° deflection horizontal blade, high sidewall grille located at center of 12 ft end wall, 9 in. from ceiling (From ASHAE A19 – Chapter 58).

Class Activity

- Solution:



$$Characteristics\ Length = 20\ ft$$

Class Activity

- Solution:
  - ❑ Cooling model (Table 6A)
  - ❑ Consider maximum condition

Table 6A Air Diffusion Performance Index (ADPI) Selection Guide for Typical Cooling Loads

Terminal Device in Cooling Mode	Installation	Load, Btu/h·ft²	Max. ADPI T_{50}/L	Max. ADPI	T/L Low Limit for ADPI > 80%	T/L High Limit for ADPI > 80%
Adjustable-blade grilles	45° upward blades, High sidewall	8	0.8	98	0.4	1.3
		16	0.9	96	0.5	1.2
	0° horizontal blades, High sidewall	8	1.7	94	1.2	2.2
		16	1.8	88	1.4	2.2
	45° downward blades, High sidewall	8	0.9	76	NA	NA
		16	1	70	NA	NA
Fixed-blade grilles (high sidewall installation)	15° upward blades, High sidewall	8	1.4	96	0.5	2.4
		16	2.1	94	1.2	2.9
	15° downward blades, High sidewall	8	1.9	85	1.5	2.2
		16	2	82	1.8	2.2
Linear-bar grilles (high sidewall installation)	High sidewall	8	1.3	92	0.7	1.8
		16	1.3	88	1.0	1.6
	Sill	8	1.3	94	0.9	1.7
		16	1.3	90	1.0	1.6

$$\frac{T_{50}}{L} = 1.8 \quad \rightarrow T_{50} = 1.8 \times 20 = 36\ ft$$

Class Activity

- Solution:
  - ❑ Heating model (Table 6B)
  - ❑ Consider maximum condition

Table 6B Air Diffusion Performance Index (ADPI) Selection Guide for Typical Heating Loads

Terminal Device in Heating Mode	Installation	Load, Btu/h·ft^2	Max. ADPI T_{50}/L	Max. ADPI	T/L Low Limit for ADPI > 80%	T/L High Limit for ADPI > 80%
Adjustable-blade grilles	45° upward blades, High sidewall	10 to 12	1.1	95	0.6	1.9
	0° horizontal blades, High sidewall	10 to 12	1.6	94	1.1	2.4
	45° downward blades, High sidewall	10 to 12	0.7	84	0.6	0.8
Fixed-blade grilles	15° upward blades, High sidewall	10 to 12	1.8	96	1.2	2.8
	15° downward blades, High sidewall	10 to 12	1.4	88	0.6	2.2
Linear-bar grilles	High sidewall	10 to 12	1.2	94	0.6	1.7

$$\frac{T_{50}}{L} = 1.6 \quad \rightarrow T_{50} = 1.6 \times 20 = 32\ ft$$

Then, use the manufacture's catalog

Class Activity

- Solution:
  - To satisfy both models of operation, consider one or pick a common throw distance that resides within the overall ADPI range of both modes

Class Activity

- Solution:
  - ❑ Let's look at some manufacture datasheets:

Performance Data — Models 510, 520 / 610, 620 / 710, 720 / 910, 920

									NC 20	30			40
	Core Velocity fpm		300	400	500	600	700	800	1000	1200	1400	1600	1800
	Velocity Pressure		.006	.010	.016	.022	.030	.040	.062	.090	.122	.159	.202
Size	Total	0°	.014	.024	.038	.052	.071	.094	.146	.212	.287	.374	.475
	Pressure	22½°	.017	.028	.045	.063	.085	.114	.176	.256	.347	.452	.574
		45°	.025	.042	.067	.093	.126	.168	.261	.379	.514	.669	.850
Ac = 0.15 ft² 7 x 4, 6 x 5	cfm		45	60	75	90	105	120	150	180	210	240	270
	NC		—	—	—	—	15	19	26	31	36	40	44
		0°	4-6-12	5-8-14	7-10-16	8-12-17	9-13-19	11-14-20	13-16-22	14-17-24	15-19-26	16-20-28	17-22-30
	Throw	22½°	3-5-10	4-6-11	6-8-13	6-10-14	7-10-15	9-11-16	10-13-18	11-14-19	12-15-21	13-16-22	14-18-24
	ft	45°	2-3-6	3-4-7	3-5-8	4-6-9	5-7-9	5-7-10	6-8-11	7-9-12	8-9-13	8-10-14	9-11-15
Ac = 0.18 ft² 8 x 4, 7 x 5, 6 x 6	cfm		55	70	90	110	125	145	180	215	250	290	325
	NC		—	—	—	—	16	20	27	32	37	41	45
		0°	4-7-13	6-8-15	7-11-17	9-13-19	10-15-20	11-16-22	14-17-24	15-19-26	17-21-29	18-22-31	19-24-33
	Throw	22½°	3-6-10	5-6-12	6-9-14	7-10-15	8-12-16	9-13-18	11-14-19	12-15-21	14-17-23	14-18-25	15-19-26
	ft	45°	2-3-7	3-4-8	4-5-9	4-7-10	5-7-10	6-8-11	7-9-12	8-10-13	8-10-14	9-11-15	10-12-16
Ac = 0.22 ft² 10 x 4, 8 x 5, 7 x 6	cfm		65	90	110	130	155	175	220	265	310	350	395
	NC		—	—	—	—	17	21	27	33	38	42	45
		0°	4-7-14	7-10-17	8-12-19	9-15-21	11-16-23	13-17-24	16-19-27	17-21-29	19-23-32	20-25-34	21-26-36
	Throw	22½°	3-6-11	6-8-14	6-10-15	7-12-17	9-13-18	10-14-19	13-15-22	14-17-23	15-18-26	16-20-27	17-21-29
	ft	45°	2-4-7	3-5-9	4-6-10	5-7-10	6-8-11	6-9-12	8-10-13	9-11-15	9-12-16	10-12-17	11-13-18
Ac = 0.26 ft² 12 x 4, 10 x 5, 8 x 6	cfm		80	105	130	155	180	210	260	310	365	415	470
	NC		—	—	—	—	17	21	28	34	38	42	46
		0°	5-8-16	7-11-19	9-13-21	10-16-23	12-17-24	14-19-26	17-21-29	19-23-32	20-25-35	22-26-37	23-27-40
	Throw	22½°	4-6-13	6-9-15	7-10-17	8-13-18	10-14-19	11-15-21	14-17-23	15-18-26	16-20-28	18-21-30	18-22-32
	ft	45°	3-4-8	4-5-9	4-7-10	5-8-11	6-9-12	7-9-13	8-11-15	9-12-16	10-13-17	11-13-18	12-14-20
Ac = 0.30 ft² 14 x 4	cfm		90	120	150	180	210	240	300	360	420	480	540
	NC		—	—	—	—	18	22	29	34	39	43	47
		0°	5-9-17	8-11-20	9-14-22	11-17-24	13-19-26	15-20-28	18-23-31	20-25-34	22-27-37	24-29-40	25-30-42
	Throw	22½°	4-7-14	6-9-16	7-11-18	9-14-19	10-15-21	12-16-22	14-18-25	16-20-27	18-22-30	19-23-32	20-24-34
	ft	45°	3-4-8	4-6-10	5-7-11	6-8-12	7-9-13	8-10-14	9-11-16	10-12-17	11-13-19	12-14-20	12-15-21
Ac = 0.34 ft² 16 x 4, 12 x 5, 10 x 6	cfm		100	135	170	205	240	270	340	410	475	545	610
	NC		—	—	—	—	19	23	29	35	40	44	47
		0°	5-9-18	8-12-21	10-15-24	12-19-26	14-20-28	16-22-30	20-24-33	22-26-37	23-28-40	25-30-42	26-32-45
	Throw	22½°	4-7-14	6-10-17	8-12-19	10-15-21	11-16-22	13-18-24	16-19-26	18-21-30	18-22-32	20-24-34	21-26-36
	ft	45°	3-4-9	4-6-11	5-8-12	6-9-13	7-10-14	8-11-15	10-12-17	11-13-18	12-14-20	12-15-21	13-16-22

GRILLES AND REGISTERS

https://www.priceindustries.com/content/uploads/assets/literature/catalogs/catalog-pages/section%20d/500_600_supply.pdf