# CAE 464/517 HVAC Systems Design

Spring 2023

## February 28, 2023

Air distribution systems: Diffuser selection examples and intro to pressure loss in ducts

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# ANNOUNCEMENTS

# Announcements

Cyclone Energy Group

ASHRAE Illinois Institute of Technology
Student Branch

## Commissioning Skills

## to Improve Building Performance

**SPEAKER**

**Commissioning Team Technical Leader**

**Jed Starner**

**WHEN**

**March 2nd, 2023**
**12:40 pm – 1:40 pm**

**WHERE**

**John T. Rettaliata Engineering Center, RE 242**

**TALK ABOUT**

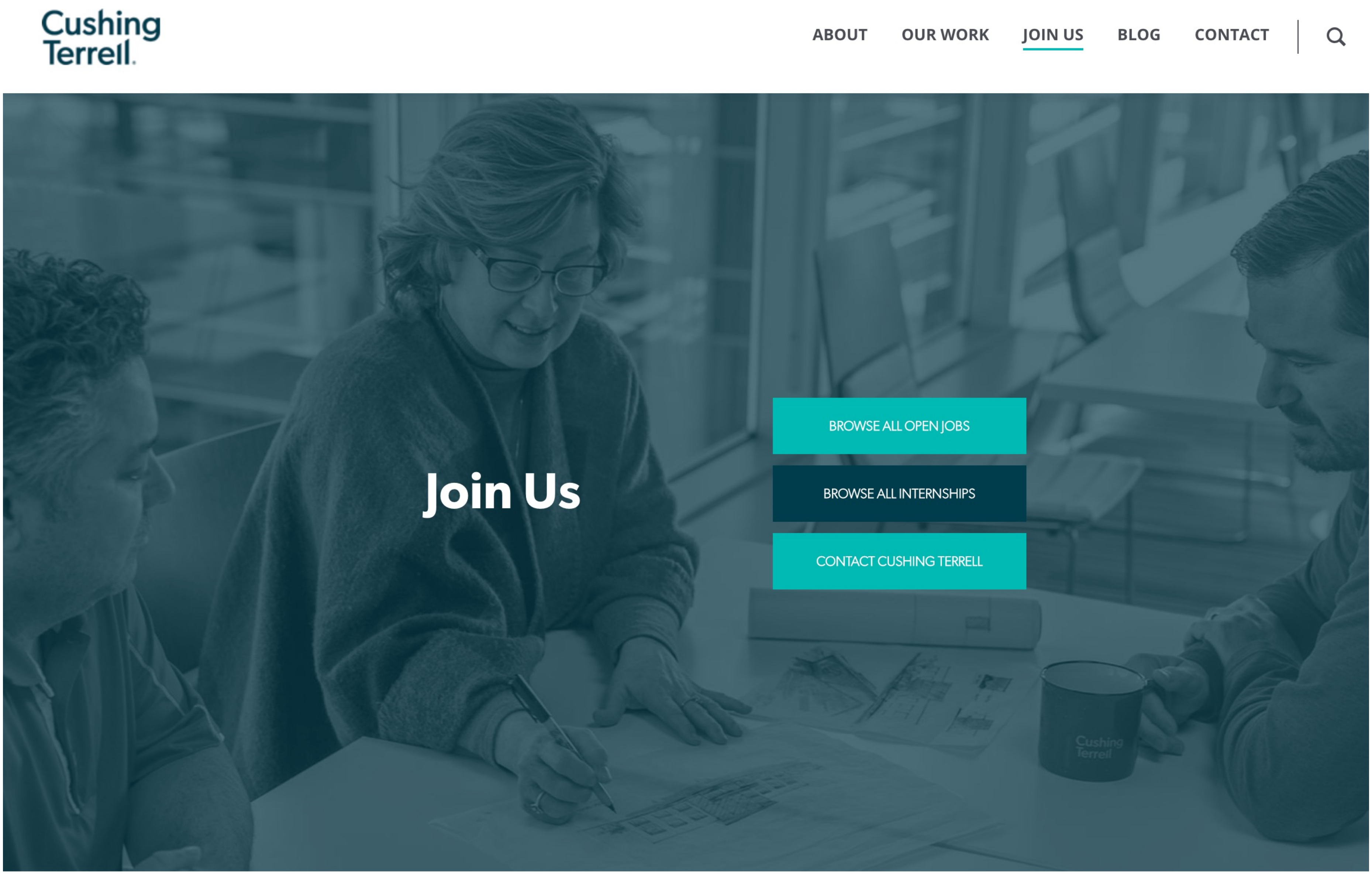
- ✓ Careers in Commissioning Services
- ✓ Work Experiences

For more information, feel free to contact ASHRAE official email
ashrae_iit@iit.edu

Interested in Joining

**Lunch will be provided!**

# Announcements



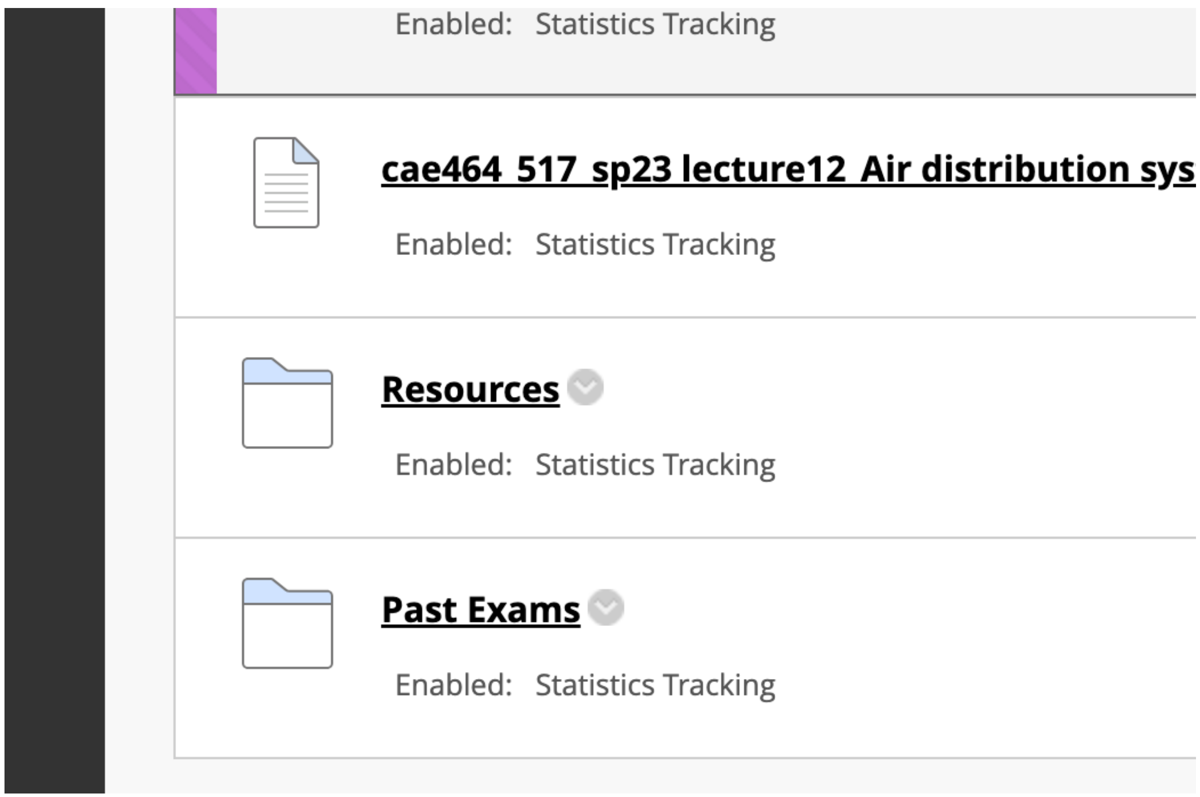
# HOMEWORK / PROJECT / EXAM

# Homework / Project / Exam

- Assignment 3 solution is posted (both the sample solution for OpenStudio and the Excel file for the load calcs)

# Homework / Project / Exam

- The first midterm exam is on March 7:
  - ❑ Exam starts at 8:35 (be on-time)
  - ❑ Covers the materials before March 2, 2023
  - ❑ Open book and open notes
  - ❑ Past exams are posted



# Homework / Project / Exam

- Project is posted
  - ❑ Follow the timeline closely (no extension will be granted) – Next submission is by the end of next week
  - ❑ Highly recommend to start working on that ASAP
  - ❑ No group composition changes for Part 1 is allowed

# RECAP

# Recap

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

| Size | | | | | | | | | 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 Pressure | 0° | .014 | .024 | .038 | .052 | .071 | .094 | .146 | .212 | .287 | .374 | .475 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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

# Recap

# Recap

- 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<br>Adjustable blade<br>Fixed blade<br>Linear bar<br>Nozzle | Distance to wall perpendicular to jet |
| Horizontal-throw ceiling diffuser<br>Round<br>Square<br>Perforated<br>Louvered<br>Plaque<br>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 |

# Recap

**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.

# DIFFUSER SELECTION GUIDELINES (CONSIDERATION OF LOADS)

# Diffuser Selection Guidelines

- How much air do we need for the space?

# 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)
- ❑ $\rho$: 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

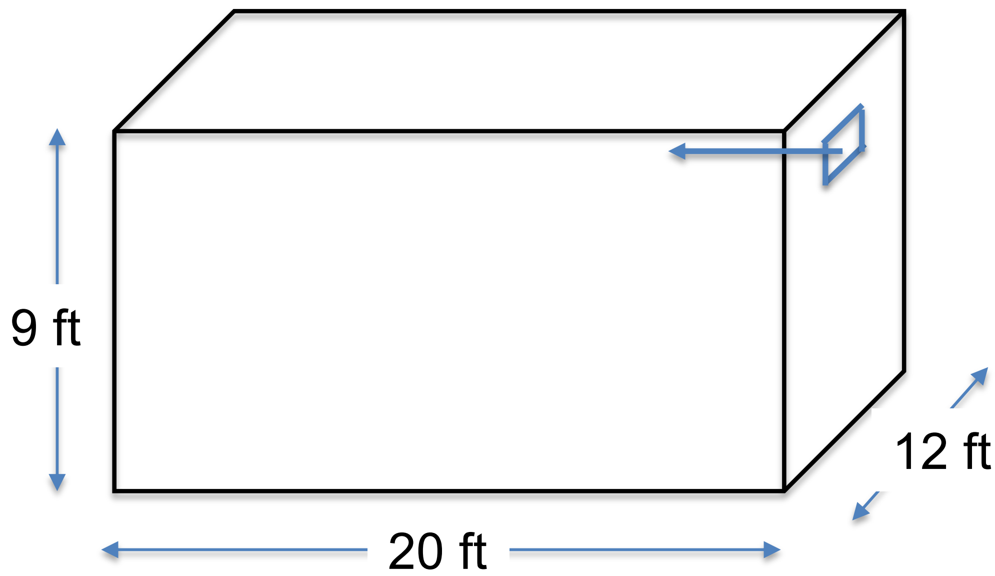
# CLASS ACTIVITY

# 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·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 | 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·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 | 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

GRILLES AND REGISTERS

| Size | | | 300 | 400 | 500 | 600 | 700 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 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 Pressure | 0° | .014 | .024 | .038 | .052 | .071 | .094 | .146 | .212 | .287 | .374 | .475 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |
| | Throw ft | 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 |
| | | 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 |
| | | 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 |

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

# SUPPLY AND RETURN FACE VELOCITY

# Supply and Return Face Velocity

- Common prescribed face velocities for supplies are:
  - Between 500 to 750 fpm for residential buildings
  - Between 500 to 1,000 fpm for commercial buildings (e.g., offices)
  - Between 1000 to 1500 from for stores or the spaces with a high ceiling

# Supply and Return Face Velocity

- Consider a low face return velocity
  - ❑ At maximum value of 400-600 fpm
  - ❑ At maximum value of 450 fpm with return filter
  - ❑ Desirable design value of 300 fpm max for filter grilles and 500 fpm max for nonfilter grilles
  - ❑ A single point return cannot be oversized like a supply
  - ❑ Consider multiple return locations where balancing is more critical to pull in relevant amounts from each room
  - ❑ Noise is not expected from a return



http://www.hartandcooley.com/files/assets/files/1498682161_HCB_851531_EngineeringData_13Ed_June2017_web.pdf

# Supply and Return Face Velocity

- Consider a low face velocity:
  - ❑ Place returns in stagnant air locations that need to be reconditioned:
  - ❑ High for cooling mode (hot air rises)
  - ❑ Low for heating mode (cold air falls)
  - ❑ Do not place returns near a supply register's throw range
  - ❑ Desirable to place returns at an opposite corner of the room
  - ❑ Most of the room air movement is done by supplies



http://www.hartandcooley.com/files/assets/files/1498682161_HCB_851531_EngineeringData_13Ed_June2017_web.pdf

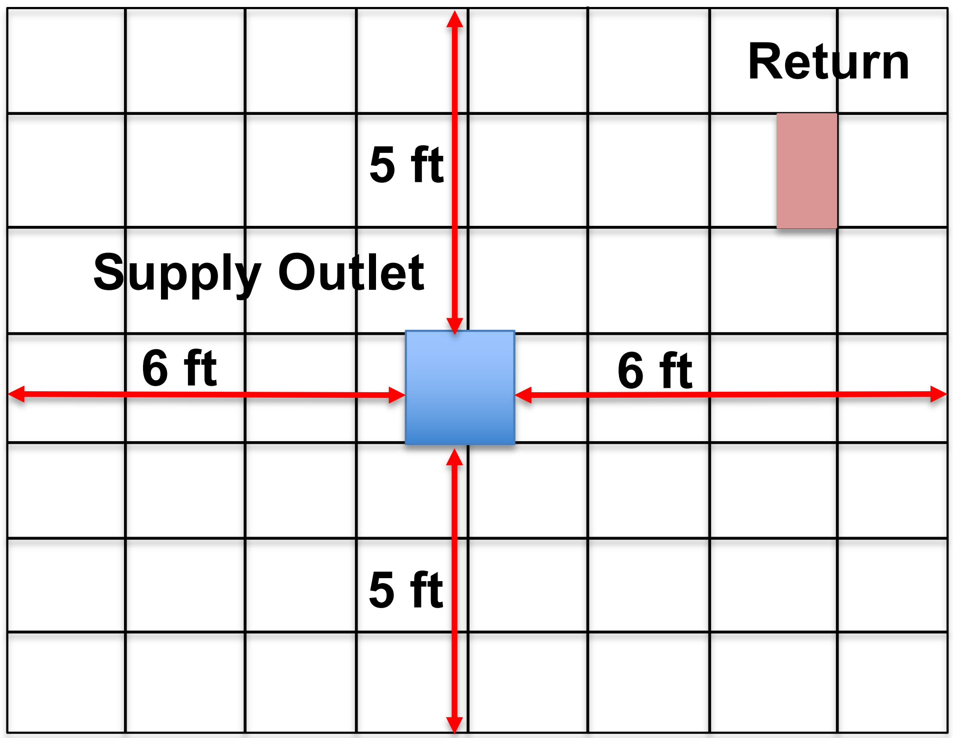
# EXAMPLE (DIFFUSER DESIGN)

# Example (ADPI)

- Known:
  - ❑ An office area
  - ❑ Load = 1,200 Btu/hr
  - ❑ Supply air and return air temperature difference = 20 F
  - ❑ Airflow rate = 280 CFM
  - ❑ Noise criteria $\leq$ 35
  - ❑ Plan to install ceiling diffuser(s)
  - ❑ Room size 12 ft by 10 ft
  - ❑ Cooling calculations are needed only
  - ❑ Select diffuser(s) such as Flush-faced perforated, dropped-faced multi-coned, square, flush-faced plaque paneled, flush-faced mitered-louvered

# Example (ADPI)

- Place the grid displacement
- Find the throw




- We can assume 5 ft, assuming the 1 ft close to the wall is not in the occupied space

# Example (ADPI)

- Check ADPI for the perforated and louvered ceiling diffuser

$$\frac{Load}{Area} = \frac{1{,}200\,\frac{Btu}{hr}}{(12\,ft \times 10\,ft)} = 10\,\frac{Btu}{hr-ft^2}$$

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

| Terminal Device in Cooling 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% |
|---|---|---|---|---|---|---|
| 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 |

# Example (ADPI)

- Check ADPI for the perforated ceiling diffuser (Cooling)

- ❑ $\frac{T_{50}}{L} = 2\ (Max\ for\ 95\%)$
- ❑ $\frac{T_{50}}{L} = 1\ to\ 2.9\ (Greater\ than\ 80\%)$
- ❑ $\frac{T_{50}}{L} = 1{\times}5ft = 5ft$
- ❑ $\frac{T_{50}}{L} = 2{\times}5 = 10ft\ \ (Max\ ADPI)$
- ❑ $\frac{T_{50}}{L} = 2.9{\times}5 = 14.5ft$

# Example (ADPI)

- Check ADPI for the perforated ceiling diffuser (Cooling)

## PDF/PDN/PDC/PDMC/PDSP
Perforated Face Supply Diffuser

## PERFORMANCE DATA

### PDF/PDFE - 16 in. x 16 in.

| Inlet Size | Neck Velocity (fpm) | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1200 | 1400 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Velocity Pressure (in. w.g.) | .006 | .010 | .016 | .022 | .031 | .040 | .050 | .062 | .090 | .122 |
| 6 Ø | Total Pressure (in. w.g.) | .012 | .021 | .033 | .047 | .064 | .084 | .106 | .131 | .189 | .257 |
| | Flow Rate (cfm) | 59 | 78 | 98 | 118 | 137 | 157 | 176 | 196 | 235 | 274 |
| | Sound (NC) | - | - | - | 19 | 24 | 28 | 32 | 35 | 41 | 46 |
| | Throw (ft.) 4 Way | 0-1-4 | 1-2-6 | 1-3-7 | 2-4-8 | 3-5-9 | 4-6-10 | 4-7-10 | 5-7-11 | 6-8-12 | 7-9-13 |
| | Throw (ft.) 3 Way | 1-1-5 | 1-2-7 | 2-4-9 | 2-5-10 | 3-6-11 | 4-7-11 | 5-8-12 | 6-9-13 | 7-10-14 | 8-11-15 |
| | Throw (ft.) 2 Way | 1-2-7 | 1-3-10 | 2-5-12 | 3-7-13 | 4-8-14 | 6-10-15 | 7-11-16 | 8-12-17 | 10-13-19 | 11-14-20 |
| | Throw (ft.) 1 Way | 1-2-9 | 2-4-12 | 3-6-15 | 4-9-17 | 5-10-18 | 7-12-19 | 9-13-20 | 10-15-21 | 12-17-23 | 14-18-25 |
| 6 x 6 | Total Pressure (in. w.g.) | .013 | .024 | .037 | .054 | .073 | .096 | .121 | .150 | .215 | .293 |
| | Flow Rate (cfm) | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 300 | 350 |
| | Sound (NC) | - | - | 17 | 22 | 27 | 31 | 35 | 38 | 44 | 48 |
| | Throw (ft.) 4 Way | 1-1-5 | 1-2-7 | 2-4-9 | 2-5-9 | 3-6-10 | 4-7-11 | 5-8-11 | 6-9-12 | 7-9-13 | 8-10-14 |
| | Throw (ft.) 3 Way | 1-2-6 | 1-3-8 | 2-5-10 | 3-6-11 | 4-7-12 | 5-8-13 | 6-9-14 | 7-10-14 | 8-11-16 | 10-12-17 |
| | Throw (ft.) 2 Way | 1-2-8 | 2-4-11 | 3-6-14 | 4-8-15 | 5-10-16 | 7-11-17 | 8-13-18 | 9-14-19 | 11-15-21 | 13-16-23 |
| | Throw (ft.) 1 Way | 1-3-11 | 2-5-14 | 3-8-17 | 5-11-19 | 7-12-20 | 9-14-22 | 11-16-23 | 12-17-24 | 14-19-26 | 16-20-29 |
| 8 Ø | Total Pressure (in. w.g.) | .017 | .029 | .046 | .066 | .090 | .118 | .149 | .184 | .265 | .360 |
| | Flow Rate (cfm) | 105 | 140 | 175 | 209 | 244 | 279 | 314 | 349 | 419 | 489 |
| | Sound (NC) | - | - | 21 | 26 | 31 | 35 | 39 | 42 | 48 | 52 |
| | Throw (ft.) 4 Way | 1-2-7 | 2-3-9 | 2-5-10 | 3-7-11 | 5-8-12 | 6-9-13 | 7-10-14 | 7-10-14 | 9-11-16 | 10-12-17 |
| | Throw (ft.) 3 Way | 1-2-8 | 2-4-11 | 3-7-12 | 4-8-13 | 6-9-14 | 7-11-15 | 8-11-16 | 9-12-17 | 11-13-19 | 12-14-20 |
| | Throw (ft.) 2 Way | 1-3-11 | 2-6-14 | 4-9-16 | 6-11-18 | 8-12-19 | 9-14-20 | 11-15-22 | 12-16-23 | 14-18-25 | 16-19-27 |
| | Throw (ft.) 1 Way | 2-4-13 | 3-7-18 | 5-11-20 | 7-13-22 | 10-15-24 | 12-18-26 | 13-19-27 | 15-20-29 | 18-22-31 | 19-24-34 |
| | Total Pressure (in. w.g.) | .019 | .034 | .053 | .076 | .104 | .136 | .172 | .212 | .305 | .415 |



https://www.priceindustries.com/content/uploads/assets/literature/catalogs/performance-data/section%20c/pdf-perforated-face-supply-diffuser-performance-data.pdf

# Example (ADPI)

- Remember manufacture report isothermal numbers

| Inlet Size | Diffuser Type | Isothermal | Non-Isothermal | Decision |
|---|---|---|---|---|
| NC | | | 35 | |
| CFM | | | 279 | |
| 8" | 4-Way | 13 | $= 13 \times 0.75 = 9.75$ | Good Option |
| | 3-Way | 15 | $= 15 \times 0.75 = 11.25$ | May work |
| | 2-Way | 20 | $= 20 \times 0.75 = 15.00$ | |



https://www.priceindustries.com/content/uploads/assets/literature/catalogs/performance-data/section%20c/pdf-perforated-face-supply-diffuser-performance-data.pdf

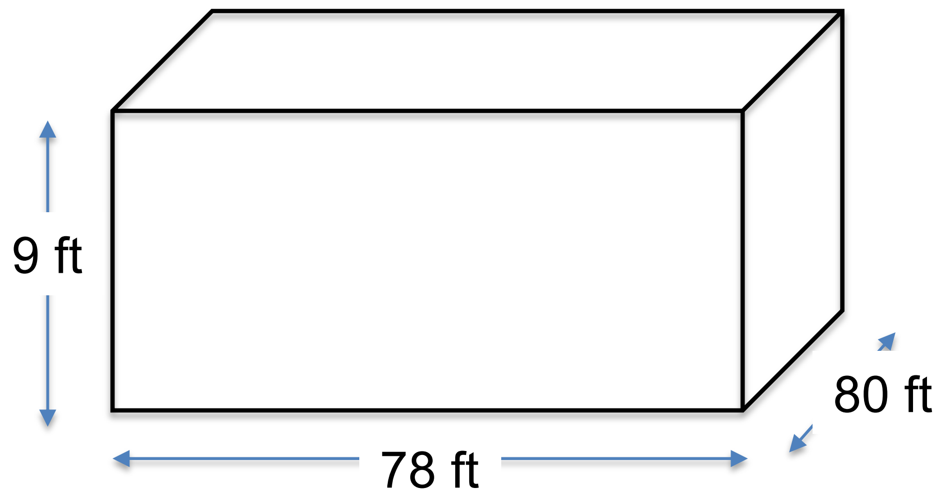
# Example (ADPI)

- Can you find one from the datasheets for a return face velocity between 300 to 400 fpm?
- You can consider face blades (e.g., 35 degrees )

# EXAMPLE (DIFFUSER DESIGN)

# Example (ADPI)

- Select round ceiling diffusers for a room with the size of 80 ft and 78 ft and the height of 9 ft. The room has a cooling load of 112,000 Btu/hr and a design air supply rate of 2,600 cfm. Locate the diffusers on the floor plan.



# Example (ADPI)

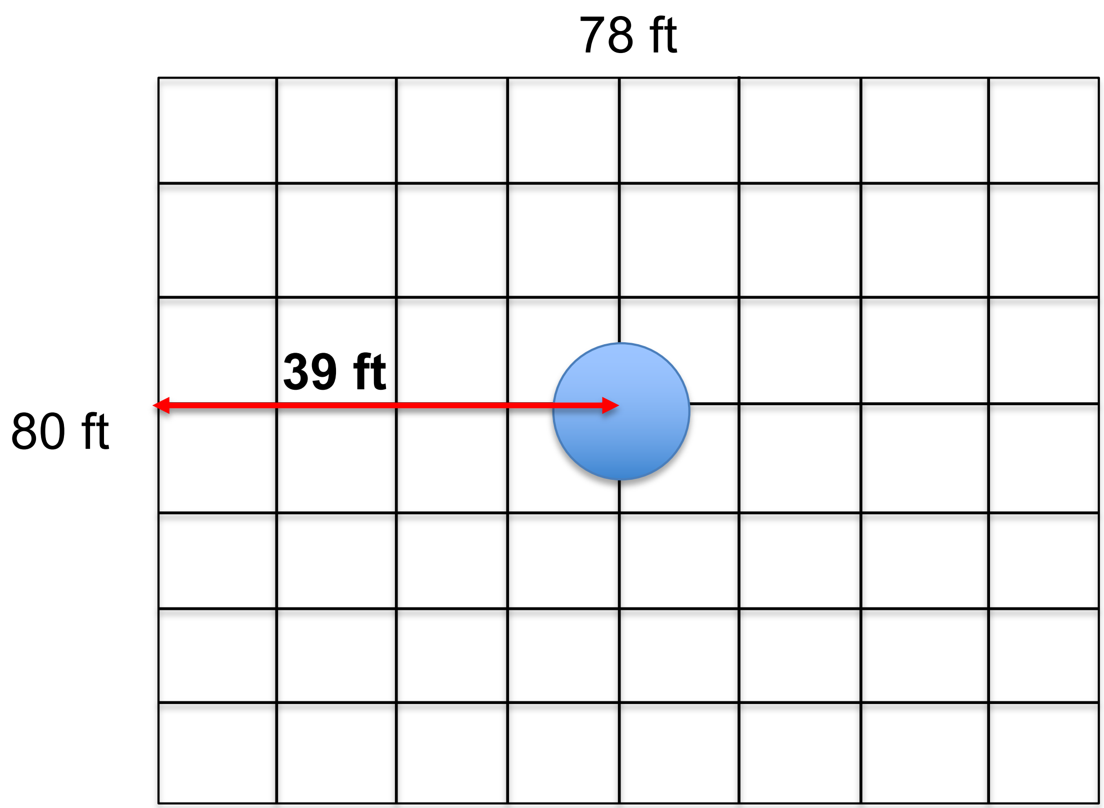
- Use ADPI to find the ideal throw to characteristic length ratio with the room load

- Be mindful of the noise criterion (NC) value while selecting your diffuser size.
  - ❑ Office: Less than 30
  - ❑ Levels above an NC of 50 are considered noisy

- Think about the air diffusion layout
  - ❑ Various ways exist
  - ❑ Can use 4 to 9 round ceiling diffusers for this problem

# Example (ADPI)

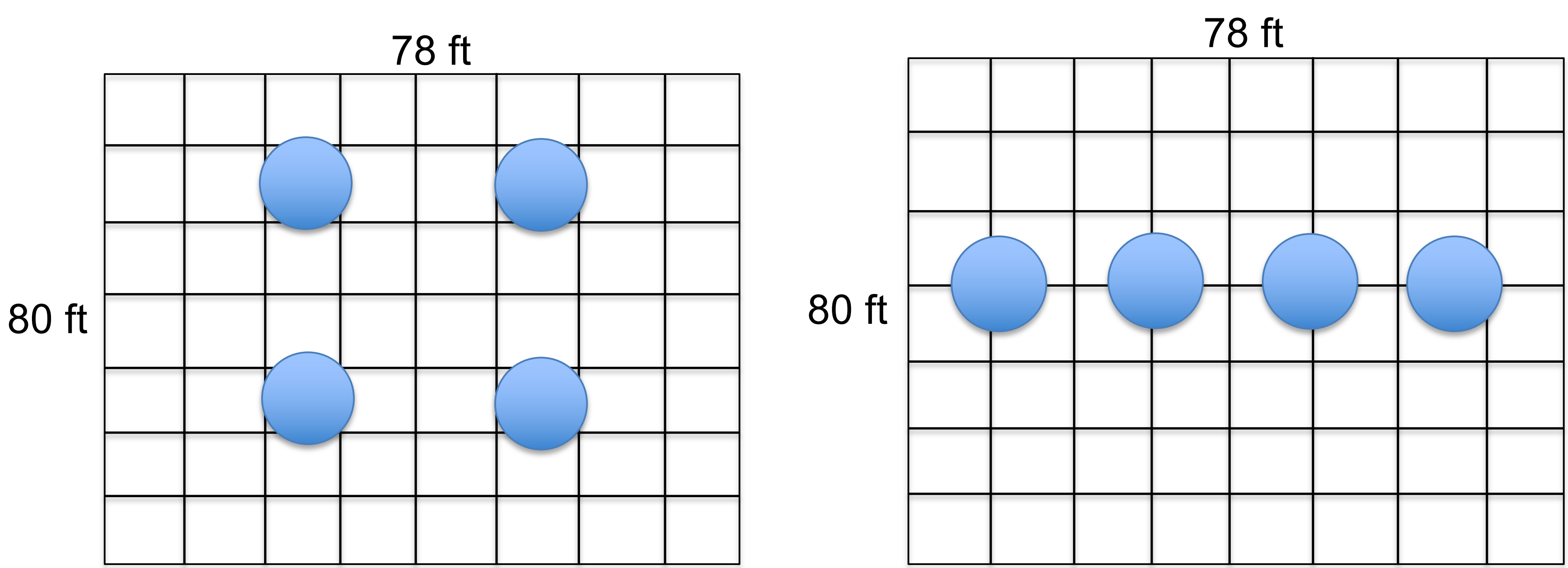
- Consider one single diffuser for the entire room (e.g., round ceiling)
- Would this work?



# Example (ADPI)

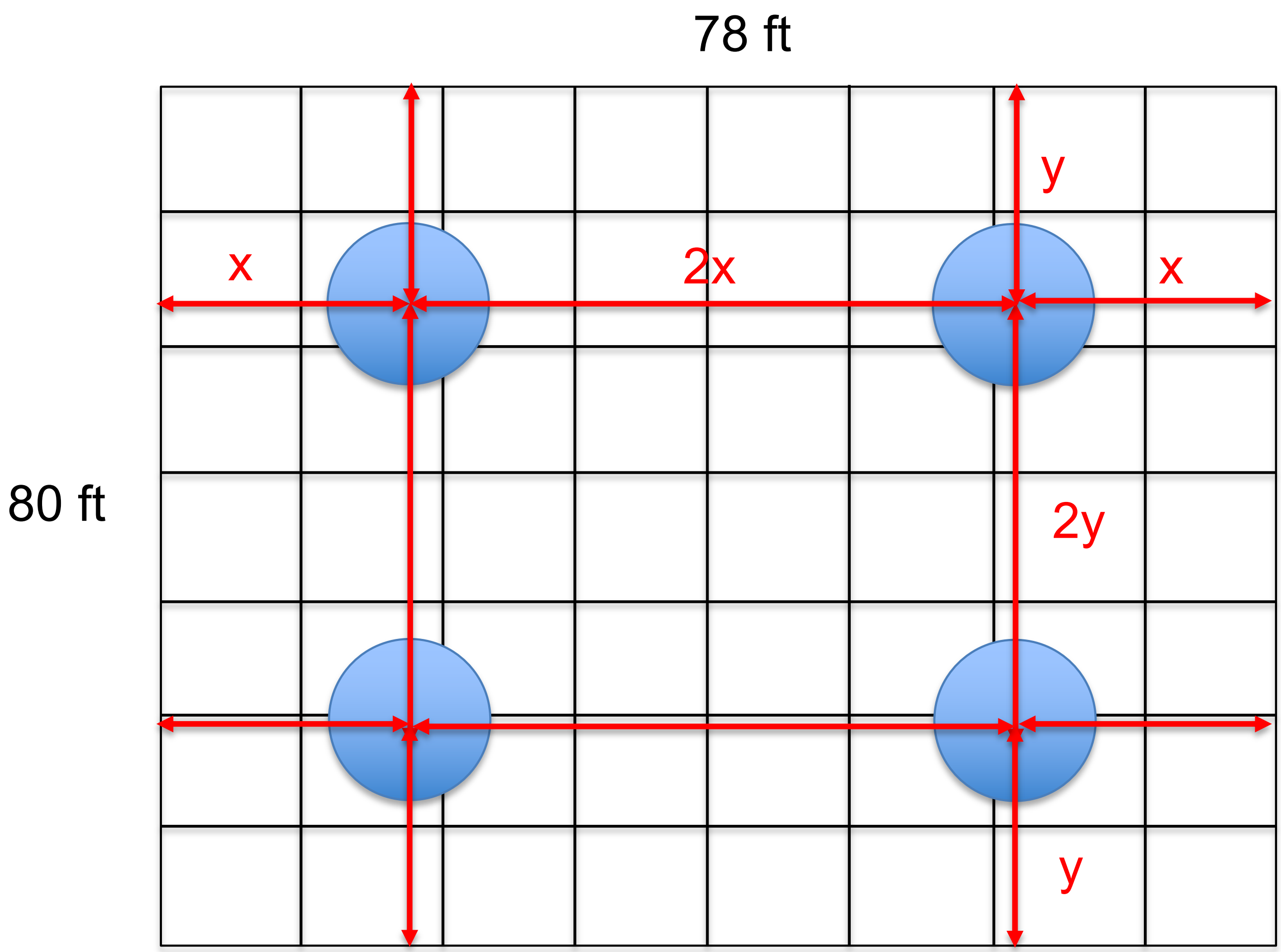
- Looking at the diffuser table data indicates that such a diffuser would be large and could be noisy

- Placing 4 in a grid pattern should give better choices. Would this work?



# Example (ADPI)

- How about this one?




$y + 2y + y = 4y = 80 \ \rightarrow y = 20\ ft$

$x + 2x + x = 4x = 78 \ \rightarrow x = 19.5\ ft$

# Example (ADPI)

- Characteristics length:

$$L = \frac{78}{4} = 19.5\ ft$$

- Or:

$$L = \frac{80}{4} = 20.0\ ft$$

- We can assume we are focusing on the occupied zone and the length close to the wall is ignored. Therefore, we can consider 19.5

# Example (ADPI)

- Find the characteristic length (L)
- Find the throw ($X_{50}$)

| Diffuser Type | Characteristic Length *L* |
|---|---|
| High sidewall grille | Distance to wall perpendicular to jet |
| Circular ceiling pattern diffuser | Distance to closest wall or intersecting air jet |
| Sill grille | Length of room in direction of jet flow |
| Ceiling slot diffuser | Distance to wall or midplane between outlets |
| Light troffer diffusers | Distance to midplane between outlets plus distance from ceiling to top of occupied zone |
| Cross-flow pattern ceiling diffusers | Distance to wall or midplane between outlets |

# Example (ADPI)

- Volume flow rate per diffuser:

$$\dot{Q} = \frac{2600\ cfm}{4\ diffusers} = 650\ cfm\ per\ diffuser$$

# Example (ADPI)

- Room load:

$$\frac{112000\ Btu/hr}{80ft\ *78\ ft} = 17.95\,\frac{Btu}{hr.ft^2}$$

# Example (ADPI)

- Look at the ADPI table. If the number for the ADPI is too high, in addition to table 6-A and 6-B, look at this general table

| Terminal Device | Room Load, Btu/h·ft$^2$ | $X_{50}/L$ 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 |

# Example (ADPI)

- Calculate $\frac{X_{50}}{L}$:

$$\frac{X_{50}}{L} = 0.8$$

$$X_{50} = L * 0.8 = 19.5 * 0.8 = 15.6\ ft$$

# Example (ADPI)

- Look at the manufacture datasheets (Option 1):

| | Plaque Position | Flow Rate (cfm) | 218 | 273 | 327 | 382 | 436 | 491 | 545 | 654 | 763 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 in. | Center | Total Pressure (in. w.g.) | 0.019 | 0.030 | 0.043 | 0.058 | 0.076 | 0.096 | 0.118 | 0.171 | 0.232 |
| | | Sound (NC) | - | - | - | - | 16 | 19 | 22 | 28 | 32 |
| | | Horizontal Throw (ft) | 3-4-8 | 3-5-10 | 4-6-11 | 4-7-13 | 5-8-15 | 6-9-17 | 6-10-19 | 8-11-23 | 9-13-27 |
| | Down | Total Pressure (in. w.g.) | 0.016 | 0.025 | 0.036 | 0.049 | 0.064 | 0.081 | 0.100 | 0.144 | 0.196 |
| | | Sound (NC) | - | - | - | - | 16 | 19 | 22 | 27 | 31 |
| | | Horizontal Throw (ft) | 2-4-7 | 3-5-9 | 4-6-11 | 4-7-13 | 5-7-15 | 6-8-17 | 6-9-19 | 7-11-22 | 9-13-26 |
| | Up | Total Pressure (in. w.g.) | 0.024 | 0.037 | 0.053 | 0.072 | 0.095 | 0.120 | 0.148 | 0.213 | 0.290 |
| | | Sound (NC) | - | - | - | - | 15 | 19 | 22 | 28 | 33 |
| | Vertical Projection to 50fpm | 10°F Heating | 11 | 12 | 14 | 15 | 16 | 17 | 17 | 19 | 21 |
| | | 20°F Heating | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 19 |
| | | 30°F Heating | 9 | 10 | 11 | 12 | 13 | 13 | 14 | 16 | 17 |
| | | 40°F Heating | 8 | 9 | 10 | 10 | 11 | 12 | 13 | 14 | 15 |

NC 20 NC 30

- This is higher than what we needed:

$$22 \times 0.75 = 16.5\ ft$$



https://www.priceindustries.com/content/uploads/assets/literature/catalogs/performance-data/section%20c/rpd-round-plaque-diffuser-performance-data.pdf

# Example (ADPI)

- Look at the manufacture datasheets (Option 2):

| Size | | Neck Velocity (fpm) | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1200 | 1400 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Velocity Pressure (in. w.g.) | .010 | .016 | .023 | .031 | .040 | .051 | .063 | .090 | .122 |
| 12 in. | Plaque Position | Flow Rate, Flow Rate (cfm) | 314 | 393 | 471 | 550 | 628 | 707 | 785 | 942 | 1099 |
| | Center | Total Pressure (in. w.g.) | 0.019 | 0.030 | 0.043 | 0.058 | 0.076 | 0.096 | 0.118 | 0.171 | 0.232 |
| | | Sound (NC) | - | - | - | 18 | 22 | 26 | 29 | 34 | 39 |
| | | Horizontal Throw (ft) | 3-5-9 | 4-6-11 | 5-7-14 | 5-8-16 | 6-9-18 | 7-10-21 | 8-11-23 | 9-14-28 | 11-16-32 |
| | Down | Total Pressure (in. w.g.) | 0.016 | 0.025 | 0.036 | 0.049 | 0.064 | 0.081 | 0.100 | 0.144 | 0.196 |
| | | Sound (NC) | - | - | - | 19 | 23 | 26 | 29 | 34 | 38 |
| | | Horizontal Throw (ft) | 3-4-9 | 4-6-11 | 4-7-14 | 5-8-16 | 6-9-18 | 7-10-21 | 7-11-23 | 9-13-28 | 10-16-32 |
| | Up | Total Pressure (in. w.g.) | 0.032 | 0.050 | 0.071 | 0.097 | 0.127 | 0.161 | 0.198 | 0.285 | 0.389 |
| | | Sound (NC) | - | - | - | 19 | 23 | 27 | 30 | 35 | 40 |
| | Vertical Projection to 50fpm | 10°F Heating | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 22 | 24 |
| | | 20°F Heating | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 22 |
| | | 30°F Heating | 10 | 11 | 13 | 14 | 15 | 15 | 16 | 18 | 19 |
| | | 40°F Heating | 9 | 10 | 11 | 12 | 13 | 14 | 14 | 16 | 17 |

NC 20 NC 30 NC 40

- This is higher volume flow rate than what we needed, but the throw is acceptable. This is overall a better option:

$$21 \times 0.75 = 15.75\ ft$$

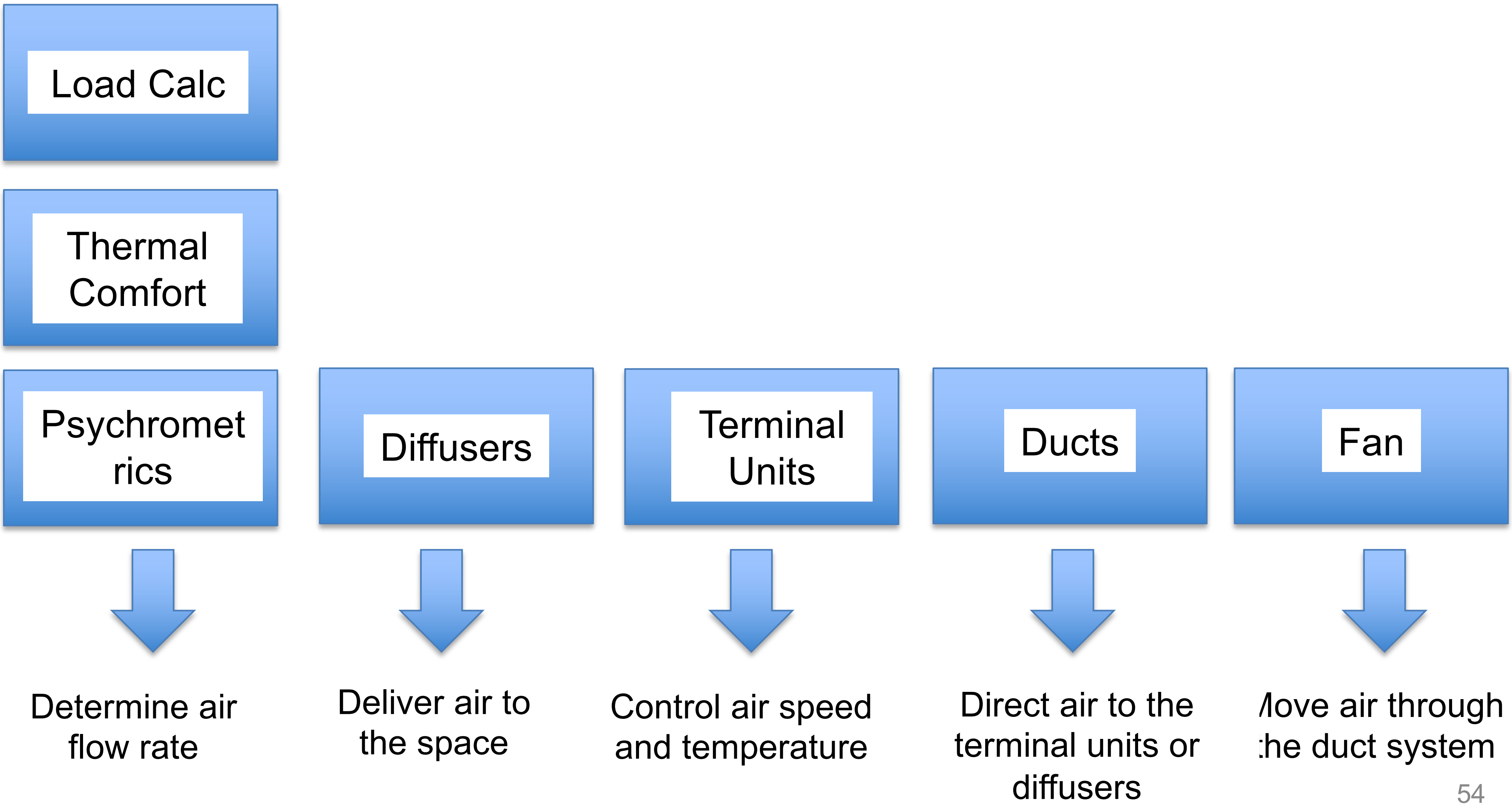


https://www.priceindustries.com/content/uploads/assets/literature/catalogs/performance-data/section%20c/rpd-round-plaque-diffuser-performance-data.pdf

# INTRO TO PRESSURE LOSS IN DUCTS AND FITTINGS

# Intro to Pressure Loss in Ducts and Fittings

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



# Intro to Pressure Loss in Ducts and Fittings

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + H_M - H_L = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

Static head

Lost head (L)

$$P_1 + \frac{\rho V_1^2}{2} + \rho z_1 + \rho H_M - \rho L_h = P_2 + \frac{\rho V_2^2}{2} + \rho z_2$$

Static pressure

Lost pressure

# Intro to Pressure Loss in Ducts and Fittings

- No change in the elevation


$$P_1 + \frac{\rho V_1^2}{2} = P_2 + \frac{\rho V_2^2}{2} + \rho L_h$$

- Total pressure in the duct section

$$P_{total,1} = P_{total,2} + \Delta P_f$$

# Intro to Pressure Loss in Ducts and Fittings

- We define system requirements

$$P_{total} = \sum_{i \epsilon F_{up}} \Delta \mathrm{p}_{\mathrm{t_i}} + \sum_{i \epsilon F_{down}} \Delta \mathrm{p}_{\mathrm{t_i}}$$

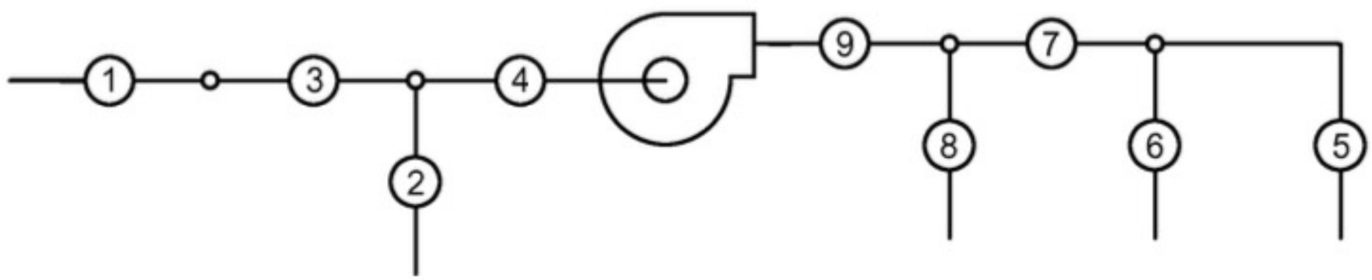
$$i = 1,2, \ldots n_{up}, n_{down}$$

- ❑ $F_{up}$ and $F_{down}$ : Sets of duct sections returns and downstream of fan
- ❑ $\epsilon$: Symbol that ties duct sections into system paths from exhaust/return air terminals to supply terminals

# CLASS ACTIVITY

# Class Activity

- Example: What is the pressure requirement for balancing airflow in this configuration?



# Class Activity

- Solution: The following equations must be satisfied to attain pressure balancing for design airflow

$$P_{total} = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5$$

$$P_{total} = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_6$$

$$P_{total} = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_8$$

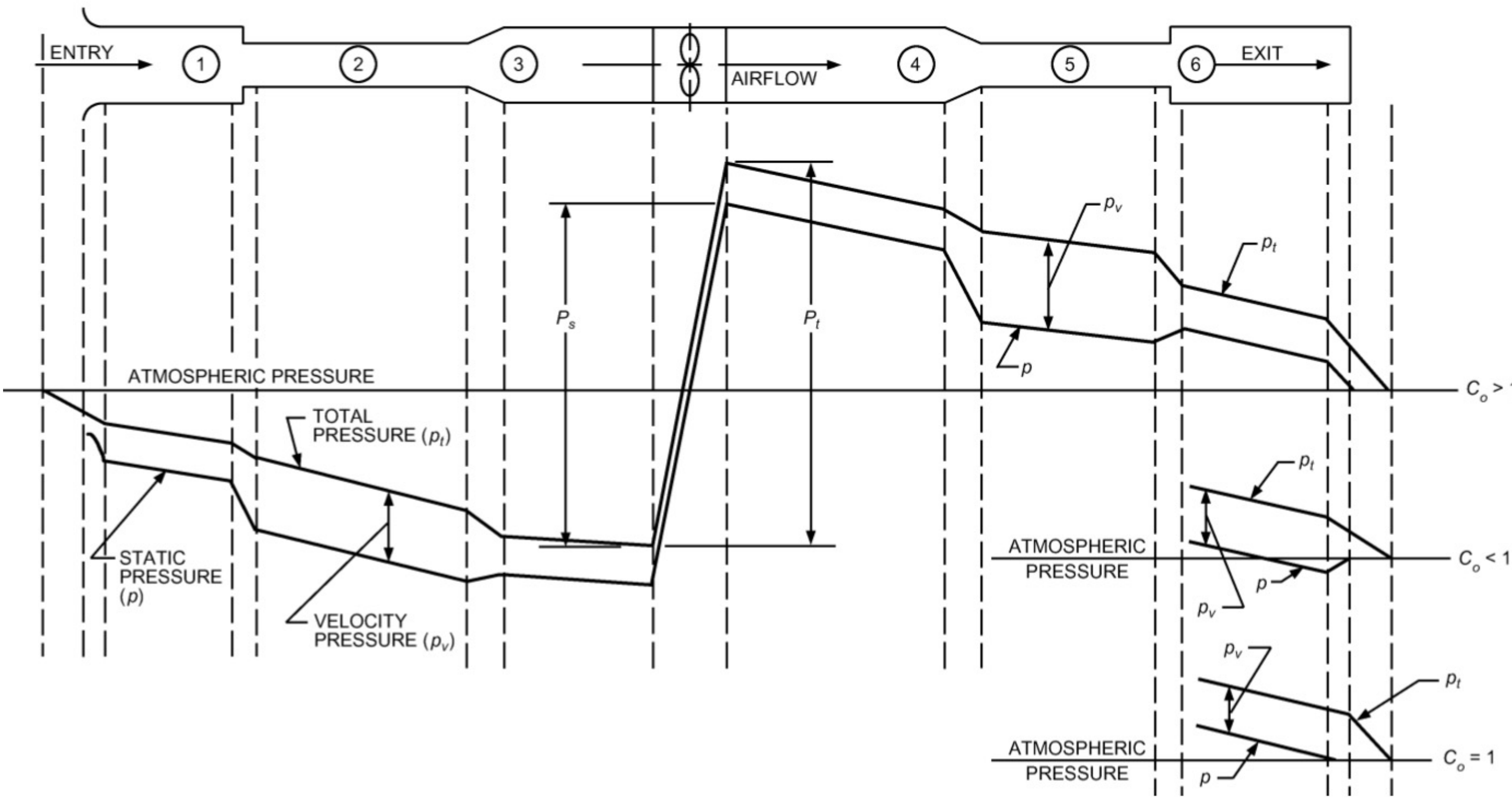
$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5$$

$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_6$$

$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_8$$

# TOTAL FAN PRESSURE

# Total Fan Pressure



# Total Fan Pressure

- The airflow system principals are:
  - ❑ The measure of the amount of energy required to move air from one location to another is the change (decrease) in the total pressure within the system
  - ❑ The total pressure $(P_{total})$ at any location within a system is a measure of the total mechanical energy at that location. It is the sum of the static pressure and the velocity pressure
  - ❑ In any duct system, the total pressure always decreases in the direction of airflow
  - ❑ In any system having two or more branches, the losses in total pressure between the fan and the end of each branch are the same
  - ❑ Static pressure and velocity pressure are mutually convertible and can either increase or decrease in the direction of flow

# PRESSURE LOSSES IN DUCTS AND FITTINGS

# Pressure Losses in Ducts and Fittings

- Consider loss coefficient (K) for fittings as:

$$Loss\ of\ section = K\left(\frac{V^2}{2g}\right)$$

- Adding them together, the total losses in the pipe is:

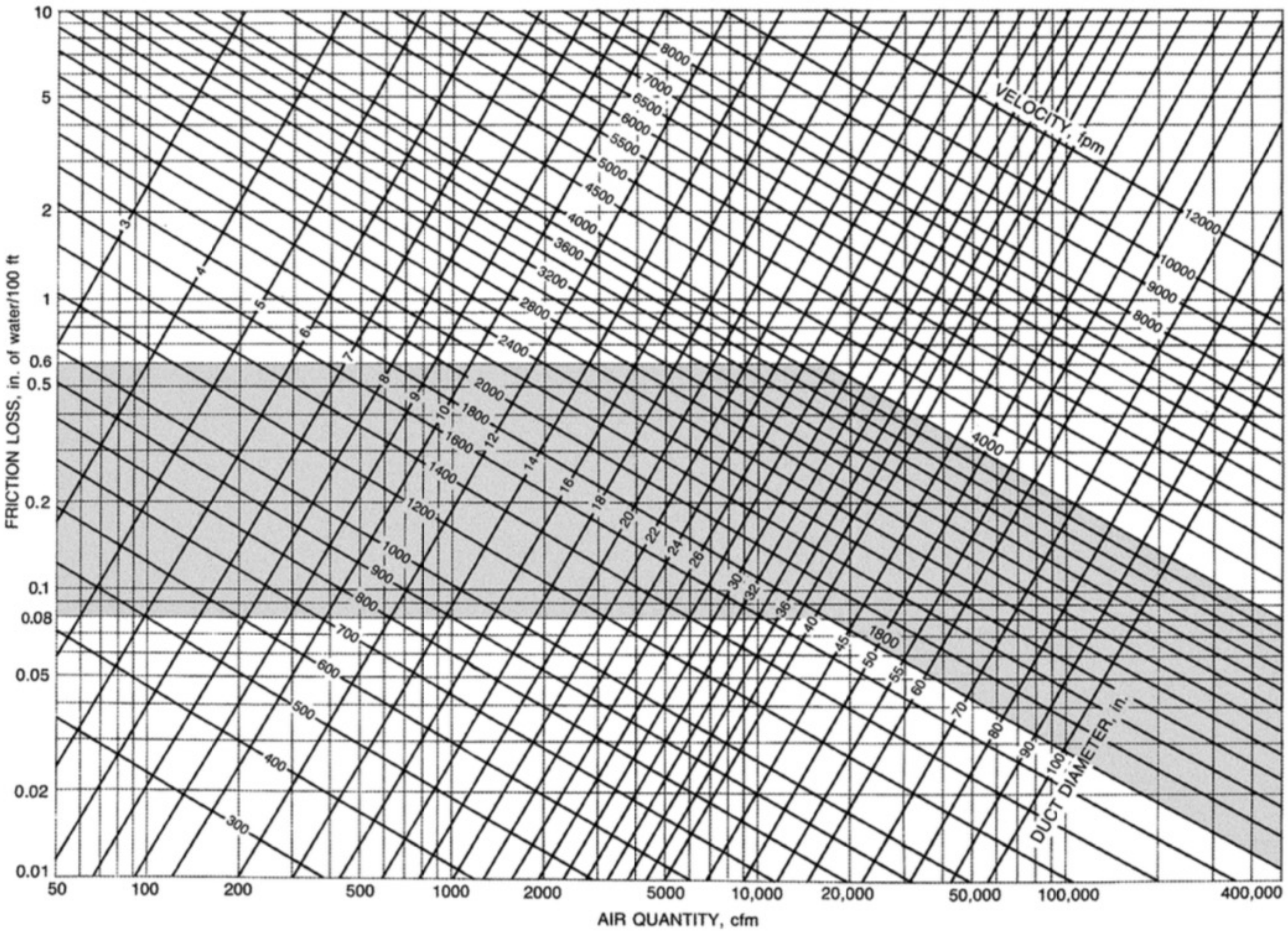
$$H_{Lf} = \left[K + f\left(\frac{L}{D}\right)\right]\left(\frac{V^2}{2g}\right)$$

# Pressure Losses in Ducts and Fittings

**Table 1 Duct Roughness Factors**

| 1 | 2 | 3 |
|---|---|---|
| | **Absolute Roughness ε, ft** | |
| **Duct Type/Material** | **Range** | **Roughness Category** |
| Drawn tubing (Madison and Elliot 1946) | 0.0000015 | Smooth 0.0000015 |
| PVC plastic pipe (Swim 1982) | 0.00003 to 0.00015 | Medium smooth 0.00015 |
| Commercial steel or wrought iron (Moody 1944) | 0.00015 | |
| Aluminum, round, longitudinal seams, crimped slip joints, 3 ft spacing (Hutchinson 1953) | 0.00012 to 0.0002 | |
| *Friction chart*: | | |
| Galvanized steel, round, longitudinal seams, variable joints (Vanstone, drawband, welded. Primarily beaded coupling), 4 ft joint spacing (Griggs et al. 1987) | 0.00016 to 0.00032 | Average 0.0003 |
| Galvanized steel, spiral seams, 10 ft joint spacing (Jones 1979) | 0.0002 to 0.0004 | |
| Galvanized steel, spiral seam with 1, 2, and 3 ribs, beaded couplings, 12 ft joint spacing (Griggs et al. 1987) | 0.00029 to 0.00038 | |
| Galvanized steel, rectangular, various type joints (Vanstone, drawband, welded. Beaded coupling), 4 ft spacing[a] (Griggs and Khodabakhsh-Sharifabad 1992) | 0.00027 to 0.0005 | |
| *Wright Friction Chart:* | | |
| Galvanized steel, round, longitudinal seams, 2.5 ft joint spacing, ε = 0.0005 ft | Retained for historical purposes [See Wright (1945) for development of friction chart] | |
| Flexible duct, nonmetallic and wire, fully extended (Abushakra et al. 2004; Culp 2011) | 0.0003 to0.003 | Medium rough 0.003 |
| Galvanized steel, spiral, corrugated,[b] Beaded slip couplings, 10 ft spacing (Kulkarni et al. 2009) | 0.0018 to 0.0030 | |
| Fibrous glass duct, rigid (tentative)[c] | — | |
| Fibrous glass duct liner, air side with facing material (Swim 1978) | 0.005 | |
| Fibrous glass duct liner, air side spray coated (Swim 1978) | 0.015 | Rough 0.01 |
| Flexible duct, metallic corrugated, fully extended | 0.004 to 0.007 | |
| Concrete (Moody 1944) | 0.001 to 0.01 | |

# Pressure Losses in Ducts and Fittings



# Pressure Losses in Ducts and Fittings

- Based on:
  - ❑ Standard air
  - ❑ Round galvanized sheet metal with 4 ft joints
  - ❑ Absolute roughness of 0.0003 ft

- No correction for:
  - ❑ Medium roughness
  - ❑ Temperature range 40 ºF to 100 ºF
  - ❑ Elevations to 1,500 ft
  - ❑ Duct pressure range -20 to 20 in w.c

- Variation of +/- 5%

# Pressure Losses in Ducts and Fittings

- We define circular equivalent of rectangular ducts as:

$$D_e = 1.30\,\frac{(ab)^{0.625}}{(a+b)^{0.25}}$$

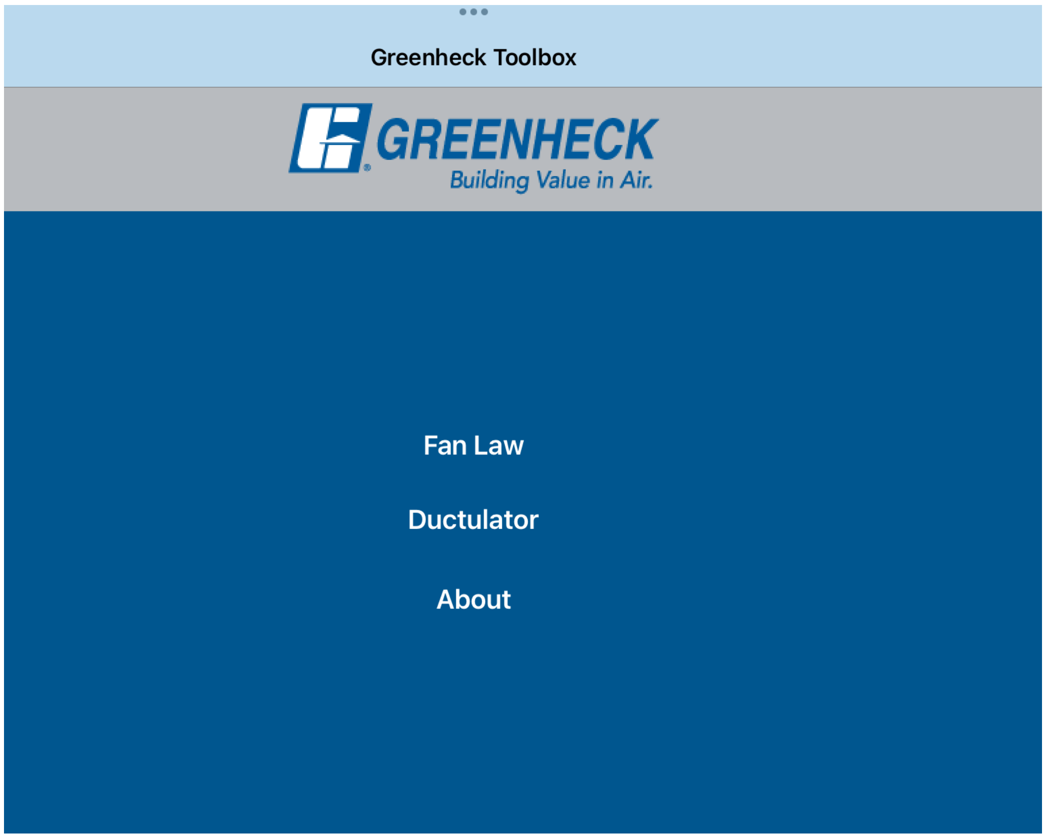
- Where:
  - ❑ $D_e$: Circular equivalent of a rectangular duct (in)
  - ❑ $a$: Height of duct (in)
  - ❑ $b$: Width of duct (in)

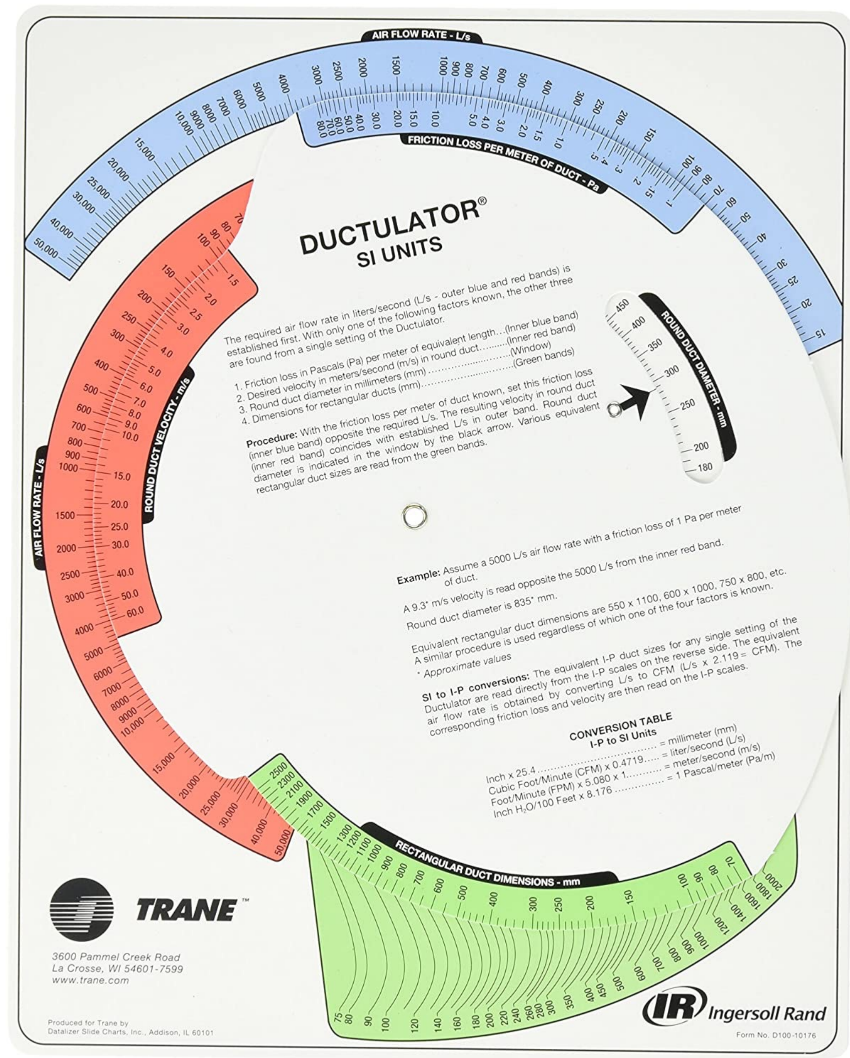
# Pressure Losses in Ducts and Fittings

| Circular Duct Diameter, in. | Length of One Side of Rectangular Duct (*a*), in. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **12** | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** | **34** | **36** |
| | Length Adjacent Side of Rectangular Duct (*b*), in. | | | | | | | | | | | | | | | | | | | |
| 5 | 5 | | | | | | | | | | | | | | | | | | | |
| 5.5 | 6 | 5 | | | | | | | | | | | | | | | | | | |
| 6 | 8 | 6 | | | | | | | | | | | | | | | | | | |
| 6.5 | 9 | 7 | 6 | | | | | | | | | | | | | | | | | |
| 7 | 11 | 8 | 7 | | | | | | | | | | | | | | | | | |
| 7.5 | 13 | 10 | 8 | 7 | | | | | | | | | | | | | | | | |
| 8 | 15 | 11 | 9 | 8 | | | | | | | | | | | | | | | | |
| 8.5 | 17 | 13 | 10 | 9 | | | | | | | | | | | | | | | | |
| 9 | 20 | 15 | 12 | 10 | 8 | | | | | | | | | | | | | | | |
| 9.5 | 22 | 17 | 13 | 11 | 9 | | | | | | | | | | | | | | | |
| 10 | 25 | 19 | 15 | 12 | 10 | 9 | | | | | | | | | | | | | | |
| 10.5 | 29 | 21 | 16 | 14 | 12 | 10 | | | | | | | | | | | | | | |
| 11 | 32 | 23 | 18 | 15 | 13 | 11 | 10 | | | | | | | | | | | | | |
| 11.5 | | 26 | 20 | 17 | 14 | 12 | 11 | | | | | | | | | | | | | |
| 12 | | 29 | 22 | 18 | 15 | 13 | 12 | | | | | | | | | | | | | |
| 12.5 | | 32 | 24 | 20 | 17 | 15 | 13 | | | | | | | | | | | | | |
| 13 | | 35 | 27 | 22 | 18 | 16 | 14 | 12 | | | | | | | | | | | | |
| 13.5 | | 38 | 29 | 24 | 20 | 17 | 15 | 13 | | | | | | | | | | | | |
| 14 | | | 32 | 26 | 22 | 19 | 17 | 14 | | | | | | | | | | | | |
| 14.5 | | | 35 | 28 | 24 | 20 | 18 | 15 | | | | | | | | | | | | |
| 15 | | | 38 | 30 | 25 | 22 | 19 | 16 | 14 | | | | | | | | | | | |
| 16 | | | 45 | 36 | 30 | 25 | 22 | 18 | 15 | | | | | | | | | | | |
| 17 | | | | 41 | 34 | 29 | 25 | 20 | 17 | 16 | | | | | | | | | | |
| 18 | | | | 47 | 39 | 33 | 29 | 23 | 19 | 17 | | | | | | | | | | |
| 19 | | | | 54 | 44 | 38 | 33 | 26 | 22 | 19 | 18 | | | | | | | | | |
| 20 | | | | | 50 | 43 | 37 | 29 | 24 | 21 | 19 | | | | | | | | | |
| 21 | | | | | 57 | 48 | 41 | 33 | 27 | 23 | 20 | | | | | | | | | |

# Pressure Losses in Ducts and Fittings

- Ductulator options exist



# CLASS ACTIVITY

# Class Activity

- Example: For a duct of 12 in by 12 in delivers 1,000 cfm. Find equivalent duct size and the friction loss per 100 ft of duct length

# Activity

- Solution:

| Circular Duct Diameter, in. | Length of One Side of Rectangular Duct (*a*), in. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 |
| | Length Adjacent Side of Rectangular Duct (*b*), in. | | | | | | | | | | | | | | | | | | | |
| 5 | 5 | | | | | | | | | | | | | | | | | | | |
| 5.5 | 6 | 5 | | | | | | | | | | | | | | | | | | |
| 6 | 8 | 6 | | | | | | | | | | | | | | | | | | |
| 6.5 | 9 | 7 | 6 | | | | | | | | | | | | | | | | | |
| 7 | 11 | 8 | 7 | | | | | | | | | | | | | | | | | |
| 7.5 | 13 | 10 | 8 | 7 | | | | | | | | | | | | | | | | |
| 8 | 15 | 11 | 9 | 8 | | | | | | | | | | | | | | | | |
| 8.5 | 17 | 13 | 10 | 9 | | | | | | | | | | | | | | | | |
| 9 | 20 | 15 | 12 | 10 | 8 | | | | | | | | | | | | | | | |
| 9.5 | 22 | 17 | 13 | 11 | 9 | | | | | | | | | | | | | | | |
| 10 | 25 | 19 | 15 | 12 | 10 | 9 | | | | | | | | | | | | | | |
| 10.5 | 29 | 21 | 16 | 14 | 12 | 10 | | | | | | | | | | | | | | |
| 11 | 32 | 23 | 18 | 15 | 13 | 11 | 10 | | | | | | | | | | | | | |
| 11.5 | | 26 | 20 | 17 | 14 | 12 | 11 | | | | | | | | | | | | | |
| 12 | | 29 | 22 | 18 | 15 | 13 | 12 | | | | | | | | | | | | | |
| 12.5 | | 32 | 24 | 20 | 17 | 15 | 13 | | | | | | | | | | | | | |
| 13 | | 35 | 27 | 22 | 18 | 16 | 14 | 12 | | | | | | | | | | | | |
| 13.5 | | 38 | 29 | 24 | 20 | 17 | 15 | 13 | | | | | | | | | | | | |
| 14 | | | 32 | 26 | 22 | 19 | 17 | 14 | | | | | | | | | | | | |
| 14.5 | | | 35 | 28 | 24 | 20 | 18 | 15 | | | | | | | | | | | | |
| 15 | | | 38 | 30 | 25 | 22 | 19 | 16 | 14 | | | | | | | | | | | |
| 16 | | | 45 | 36 | 30 | 25 | 22 | 18 | 15 | | | | | | | | | | | |
| 17 | | | | 41 | 34 | 29 | 25 | 20 | 17 | 16 | | | | | | | | | | |
| 18 | | | | 47 | 39 | 33 | 29 | 23 | 19 | 17 | | | | | | | | | | |
| 19 | | | | 54 | 44 | 38 | 33 | 26 | 22 | 19 | 18 | | | | | | | | | |
| 20 | | | | | 50 | 43 | 37 | 29 | 24 | 21 | 19 | | | | | | | | | |
| 21 | | | | | 57 | 48 | 41 | 33 | 27 | 23 | 20 | | | | | | | | | |

# Class Activity

$$D_e = 1.30 \frac{(ab)^{0.625}}{(a+b)^{0.25}}$$

$$D_e = 1.30 \frac{(12 \times 12)^{0.625}}{(12+12)^{0.25}}$$

$$D_e = 13.1\ in$$

# Class Activity