# CAE 464/517 HVAC Systems Design

Spring 2023

# March 21, 2023

Air distribution systems: Duct design

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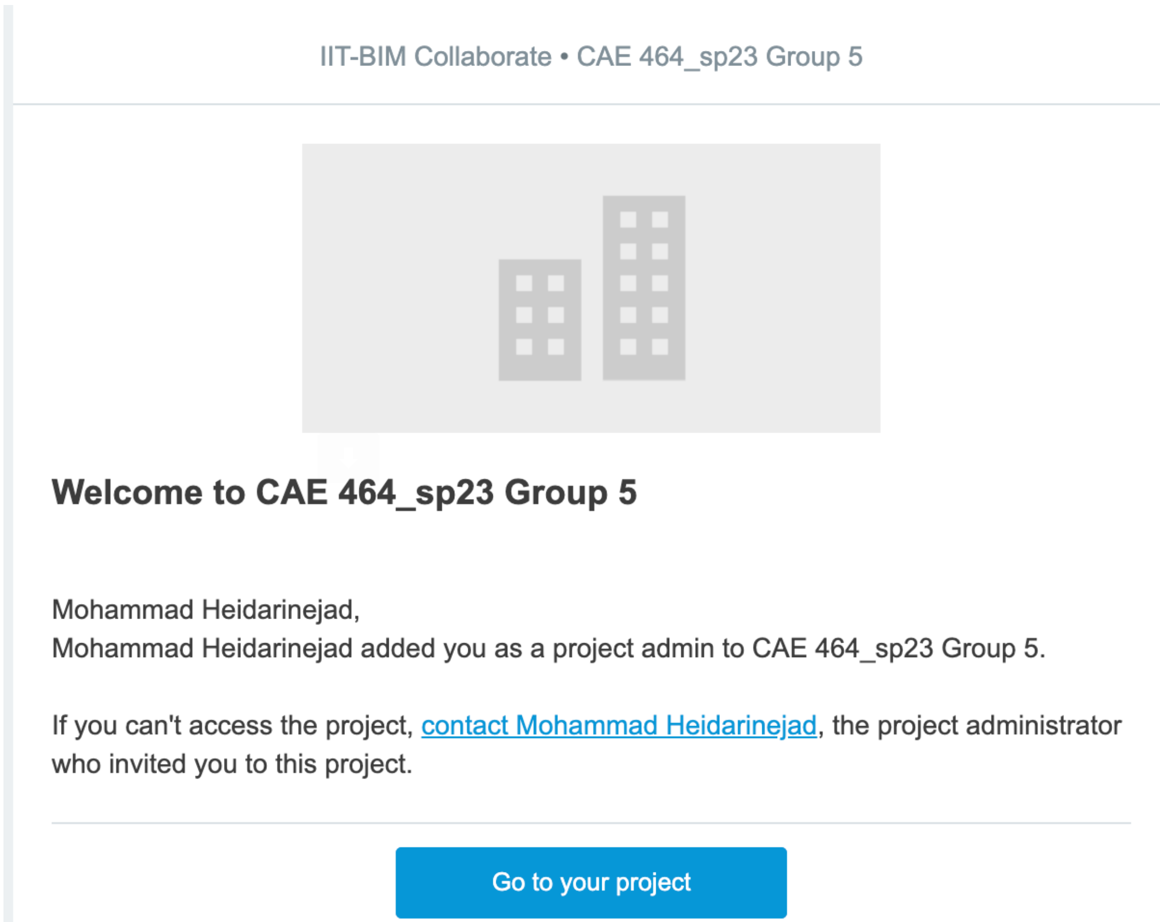
# ANNOUNCEMENTS

# Announcements

- Assignment 4 is posted (due next week)

- Do not forget to work on Project Part 2



IIT-BIM Collaborate • CAE 464_sp23 Group 5

**Welcome to CAE 464_sp23 Group 5**

Mohammad Heidarinejad,
Mohammad Heidarinejad added you as a project admin to CAE 464_sp23 Group 5.

If you can't access the project, contact Mohammad Heidarinejad, the project administrator who invited you to this project.

Go to your project

# Announcements

- Final project presentation:
  - ❑ May 4, 8 am to 10 am
  - ❑ Location: Hermann Hall
  - ❑ All students are are required to present

# Announcements

- Do not forget to review the Q&A file:

SUMMARY +

OUTLINE



## CAE 464/517 Spring 2023 Q&As

### Project Part 1

**Question:** After class when we spoke with you, you mentioned that the maximum amount of space types we should use is 4. We came up with:
Corridor/Transition
Operating/Patient Room
Office
Lounge/Recreation
as per ASHRAE common space types for hospitals.

https://docs.google.com/document/d/1m6ezSI6Bi9wGQcjnaYj_iAXY2kzRICPYWkKfayNp5WE/edit#heading=h.7xv0zdhfny5a

# Ductwork in Practice

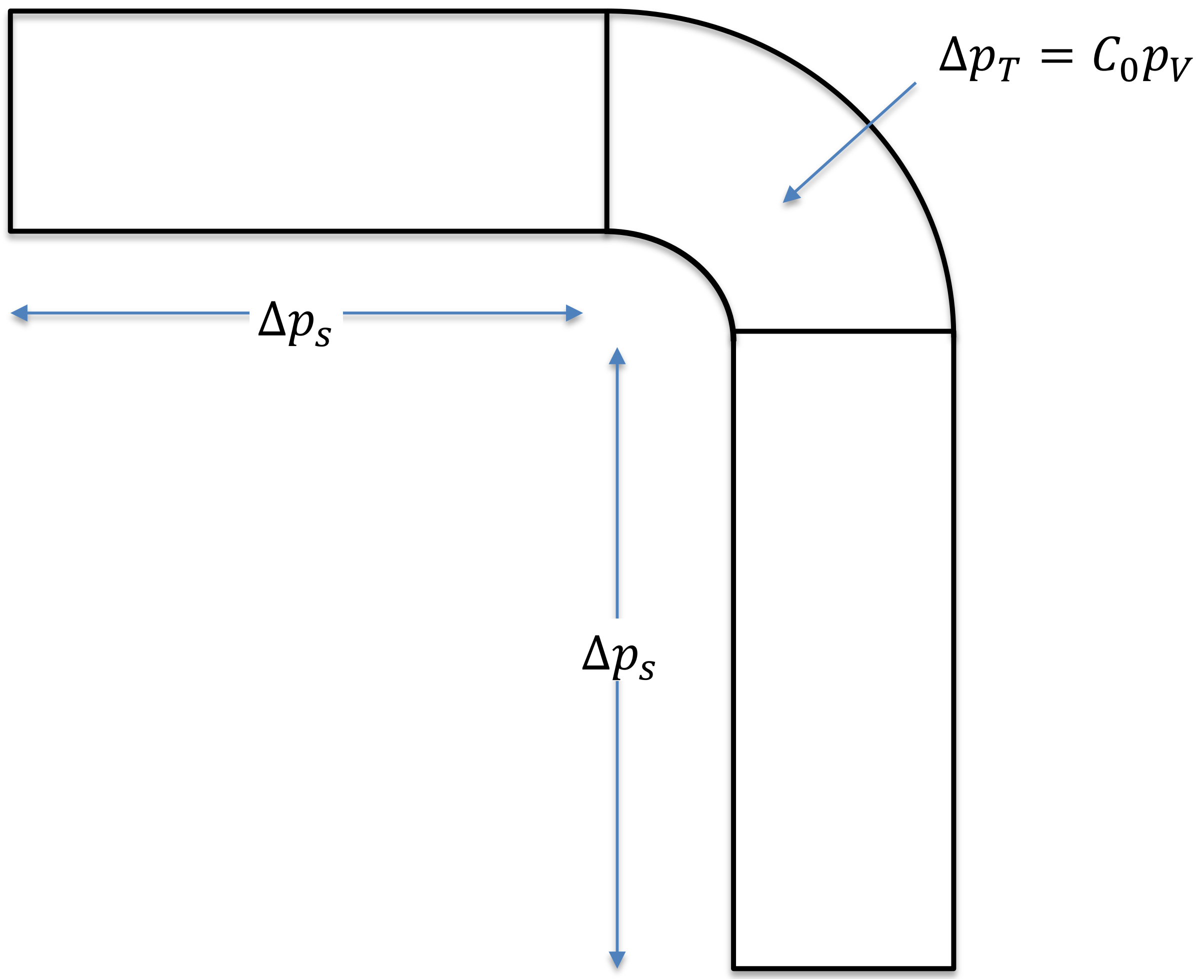
- Adding interesting and daily application of HVAC systems:

  https://docs.google.com/presentation/d/15bvvZ0VVm9SgonCzZ5N07MBvl0YdVRYaph6Z3evveJA/edit#slide=id.g1f2938fcdac_0_0

# RECAP

# Recap

- Pressure drop calculations (elbows and transitions)

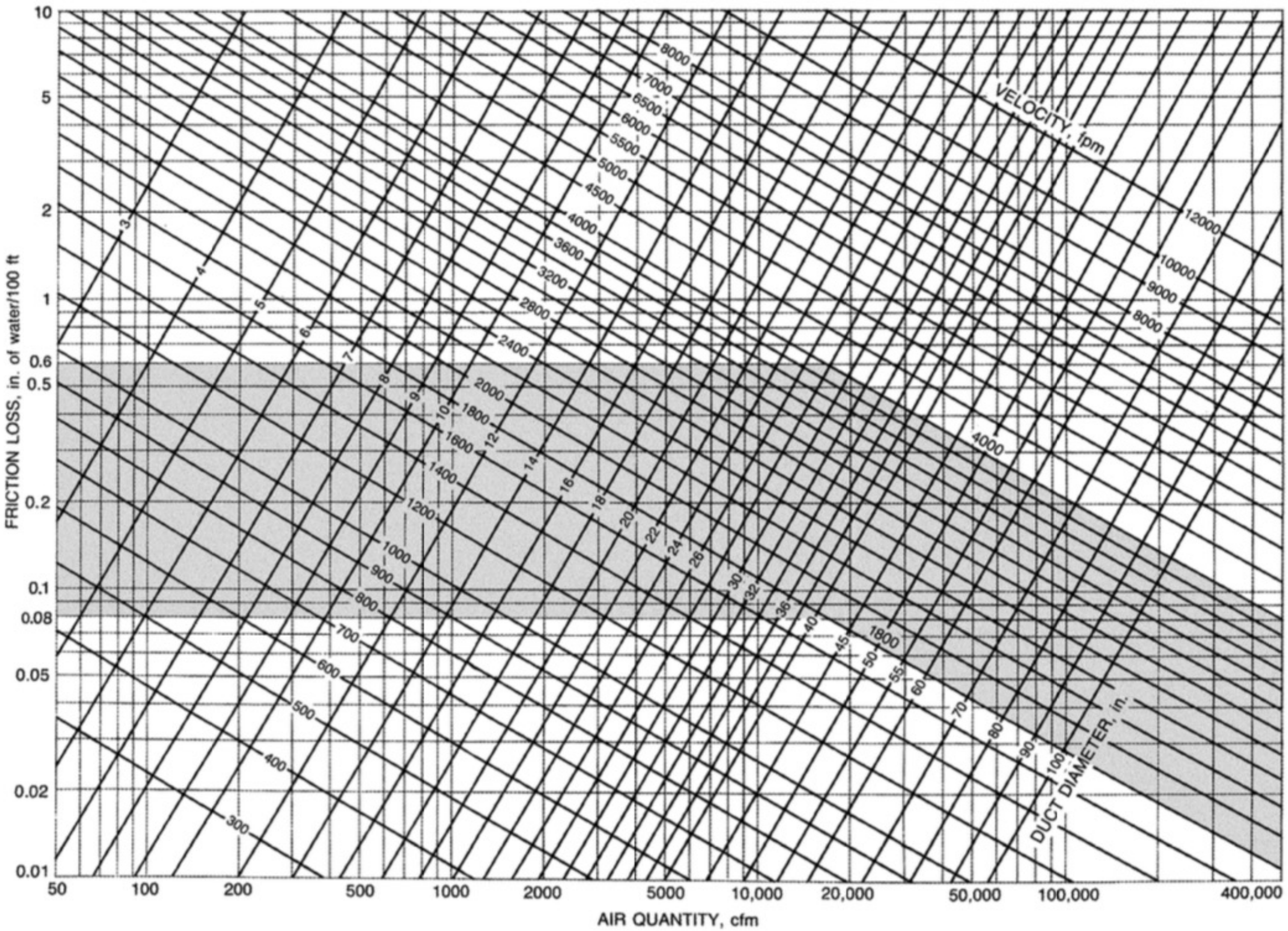


# Recap

$$p_{v,o} = \left(\frac{V_o}{4{,}005}\right)^2$$

| Duct velocity $V_o$ (fpm) | Duct pressure $p_v$ (in w.c.) |
|---|---|
| 4,000 | 1.00 |
| 3,000 | 0.56 |
| 2,000 | 0.25 |
| 1,000 | 0.06 |

# Recap


FRICTION LOSS, in. of water/100 ft
AIR QUANTITY, cfm
VELOCITY, fpm
DUCT DIAMETER, in.
10
5
2
1
0.6
0.5
0.2
0.1
0.08
0.05
0.02
0.01
50
100
200
500
1000
2000
5000
10,000
20,000
50,000
100,000
400,000

# Recap

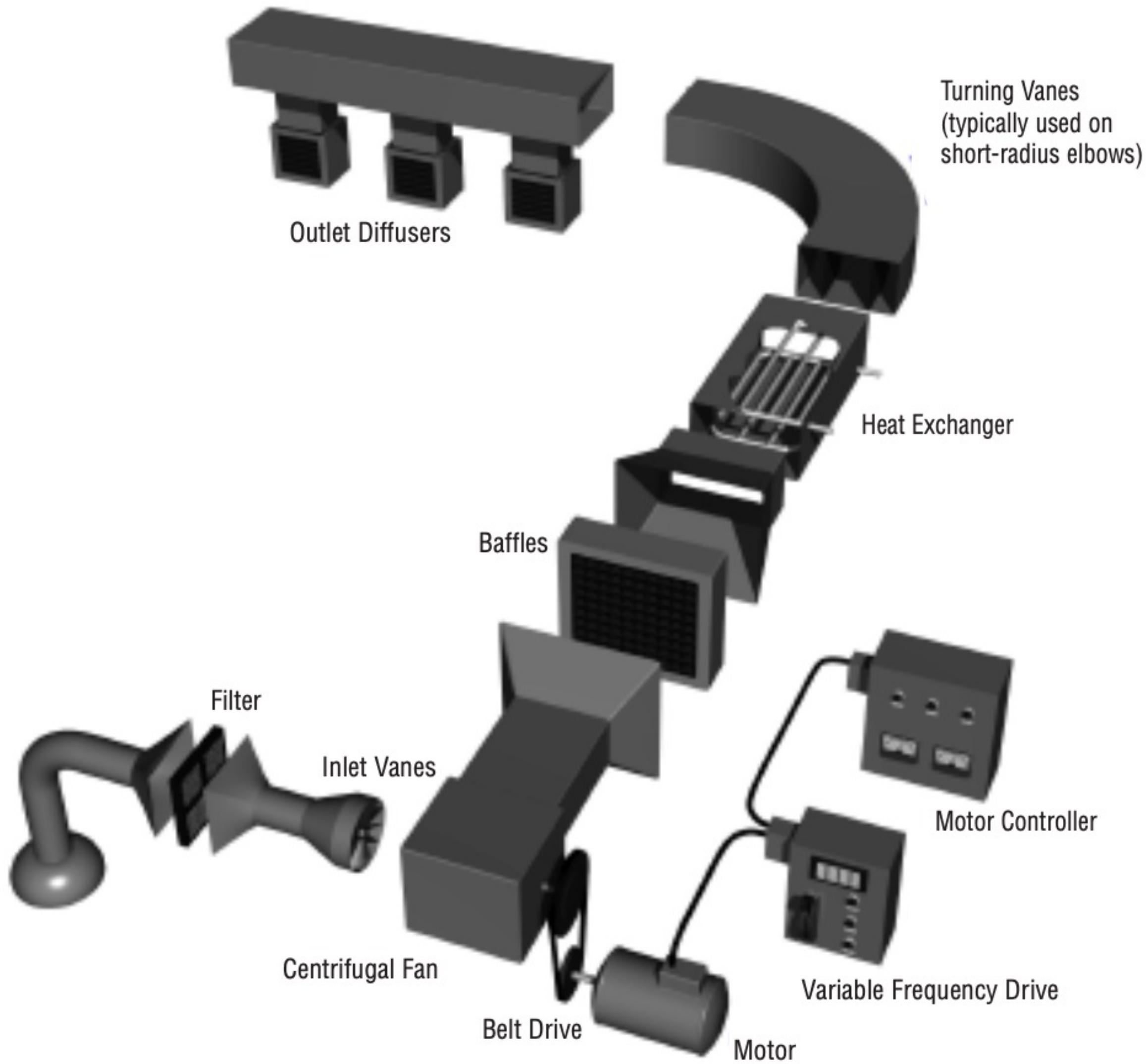
- See Table 12 for the recommended maximum airflow velocities:

**Table 12 Recommended Maximum Airflow Velocities to Achieve Specified Acoustic Design Criteria***

| Duct Location | NC or RC Rating in Adjoining Occupancy | Maximum Airflow Velocity, fpm | |
|---|---|---|---|
| | | Rectangular Duct | Round Duct |
| 1 | 2 | 3 | 4 |
| In shaft or above solid drywall ceiling | 45 | 3500 | 5000 |
| | 35 | 2500 | 3500 |
| | 25 or less | 1500 | 2500 |
| Above suspended acoustical ceiling | 45 | 2500 | 4500 |
| | 35 | 1750 | 3000 |
| | 25 or less | 1000 | 2000 |
| Duct within occupied space | 45 | 2000 | 3900 |
| | 35 | 1450 | 2600 |
| | 25 or less | 950 | 1700 |

# Ductwork in Practice

- The air distribution includes various components:






https://www.nrel.gov/docs/fy03osti/29166.pdf

# Recap

- You can use other resources (e.g., Chapter 8 of the Price Industries Handbook)
- Older version of ASHRAE Handbook

https://utahashrae.org/images/meeting/011119/Slides/smacna_duct_design_fundamentals.pdf

http://ftp.demec.ufpr.br/disciplinas/TM184/VENTILACAO_LOCAL_EXAUSTORA/DUCT_DESIGN.pdf

# Recap

- Some common fitting terminology are:

| Fitting Function | Geometry | Category | Sequential Number |
|---|---|---|---|
| S: **S**upply | D: Round (**D**iameter) | 1. Entries | 1, 2, 3, … |
| | | 2. Exits | |
| E: **E**xhaust / Return | R: **R**ectangular | 3. Elbows | |
| | | 4. Transitions | |
| C: **C**ommon (supply/ return) | F: **F**lat oval | 5. Junctions | |
| | | 6. Obstructions | |
| | | 7. Fan and system interactions | |
| | | 8. Duct-mounted equipment | |
| | | 9. Dampers | |
| | | 10. Hoods | |

# DUCT DESIGN METHODS

# Duct Design Methods

- Codes & standards
- Airflow rates
- Single line ductwork
- Size ductwork
- Calculate pressure drop
- Establish system total pressure

# Duct Design Methods

- There are different duct design methods:
  - ❑ ***Equal friction:*** Size based on chosen friction loss rate (per 100 ft) for each duct section to balance the pressure gradient (commonly used)
  - ❑ ***Equal velocity:*** Size based on maintaining a constant velocity for duct sections (applicable for simple or industrial systems to carry particles out)
  - ❑ ***Balanced capacity:*** Equal pressure drops from fan to outlets of each branch (e.g., VAV systems)
  - ❑ ***Static regain:*** Duct size at the fan is selected using the friction chart to get the starting velocity. Other main ducts are sized to achieve static regain from section to section, meaning keep static pressure same throughout a system

# Duct Design Methods

- The velocity classifications are important:

| Method | Velocity | Velocity Range | Pressure Drop |
|---|---|---|---|
| Equal friction | Low Velocity | Less than 2500 fpm (13 m/s) | Less than 0.15 in./100 ft (1 Pa/m) [0.1 in./100 ft is a common value] |
| Equal velocity | | | |
| Balanced capacity | | | |
| Static regain | High Velocity | Up to 4500 fpm (23 m/s) | Less than 0.7 in./100 ft (4.7 Pa/m) |

# Duct Design Methods

- When do we use high velocity design?
  - ❑ When the heating or cooling loads are large (e.g., commercial buildings)
  - ❑ Special considerations are required (e.g., balancing and leakage control)

# Duct Design Methods

- When do we use low velocity design?
  - When the low flow rate is adequate, and it is is possible to to run large ductwork
  - Can achieve low fan energy use

# EQUAL FRICTION METHOD

# Equal Friction Method

- The design friction rate per unit length (in. w.c per 100 ft) is maintained

- The aim is to design a well-balanced system

- If the layout is symmetrical and all runs from fan to diffuser approximately the same length this method works well

# Equal Friction Method

- However, in most duct systems, there are variety of duct runs from long to short.

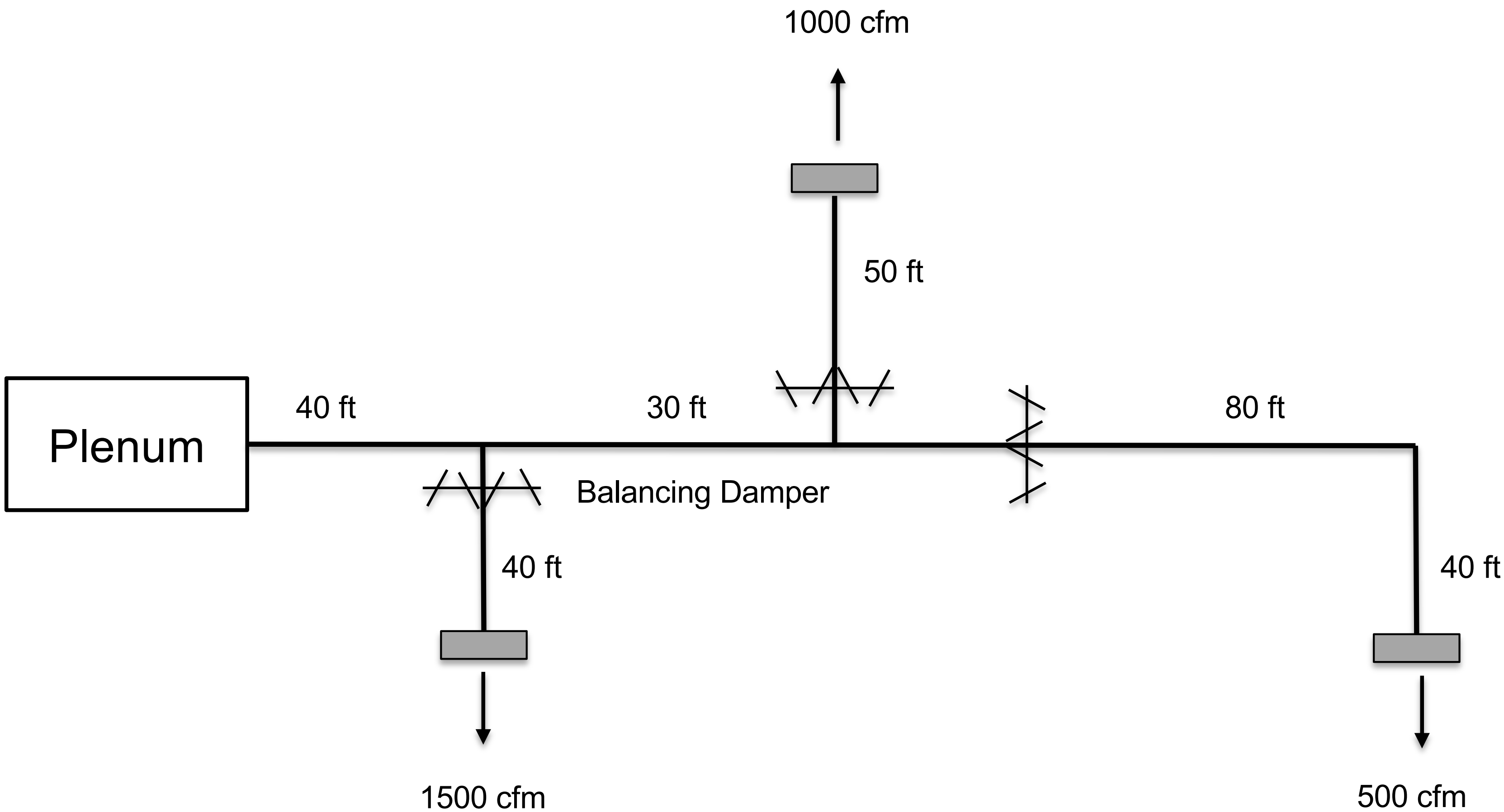
- Thus, short runs need to use balancing dampers in order to balance the flow rate to each space, which can cause considerable noise

# Equal Friction Method

- The design friction rate depends upon the velocity allowable in the system
- Start from usually know flow rates adjacent to the fan to establish the lost pressure per unit of length
- After sizing the designer need to compute the total pressure loss of the longest run with the consideration of all fittings

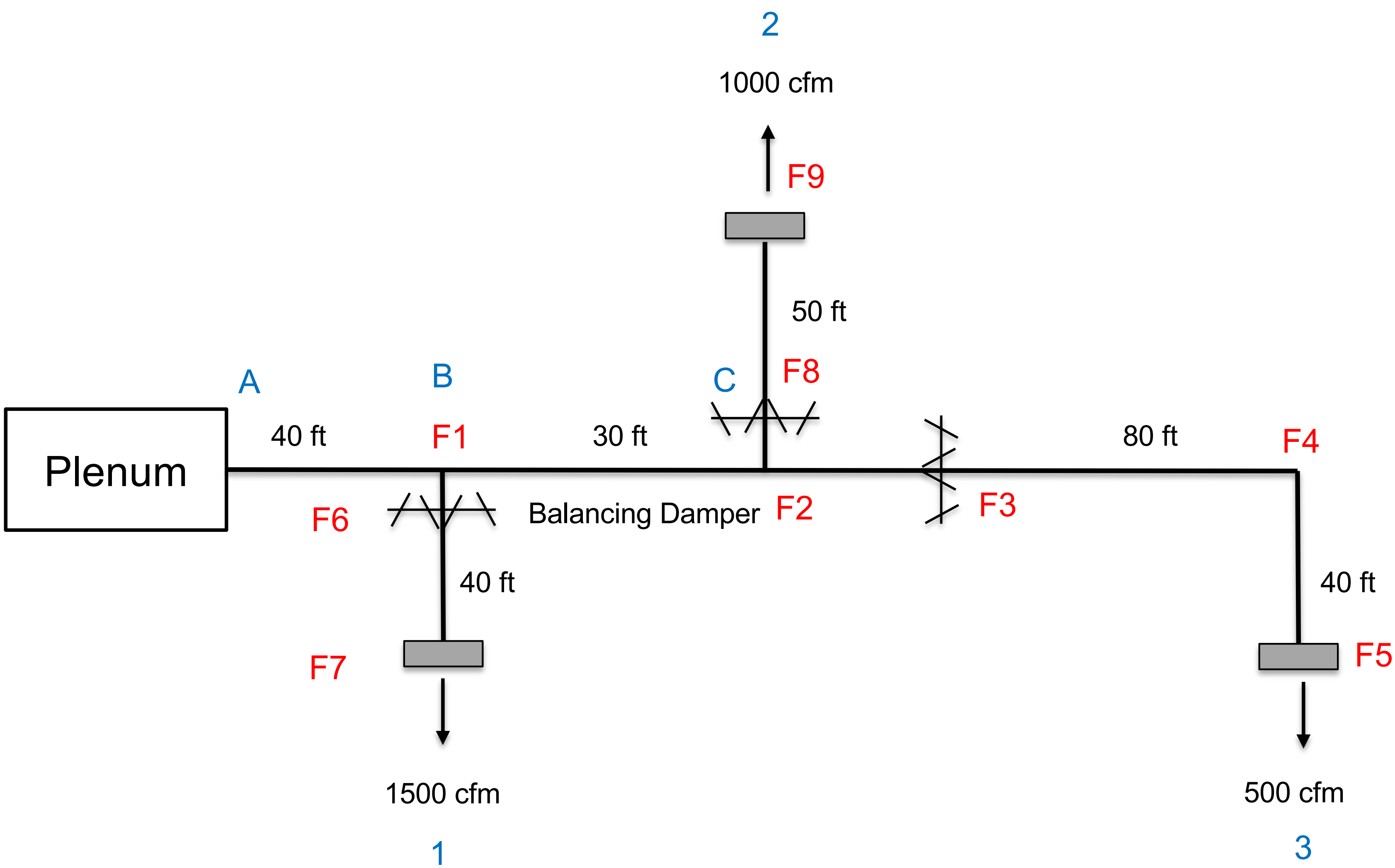
# Equal Friction Method

- **Example:**
  - Loss for each outlet is 0.05 in. w.c.
  - Maximum velocity mains = 1,300 fpm, branches = 900 fpm
  - Uniform pressure loss/100 ft and for elbows r/W = 1.0



# Equal Friction Method

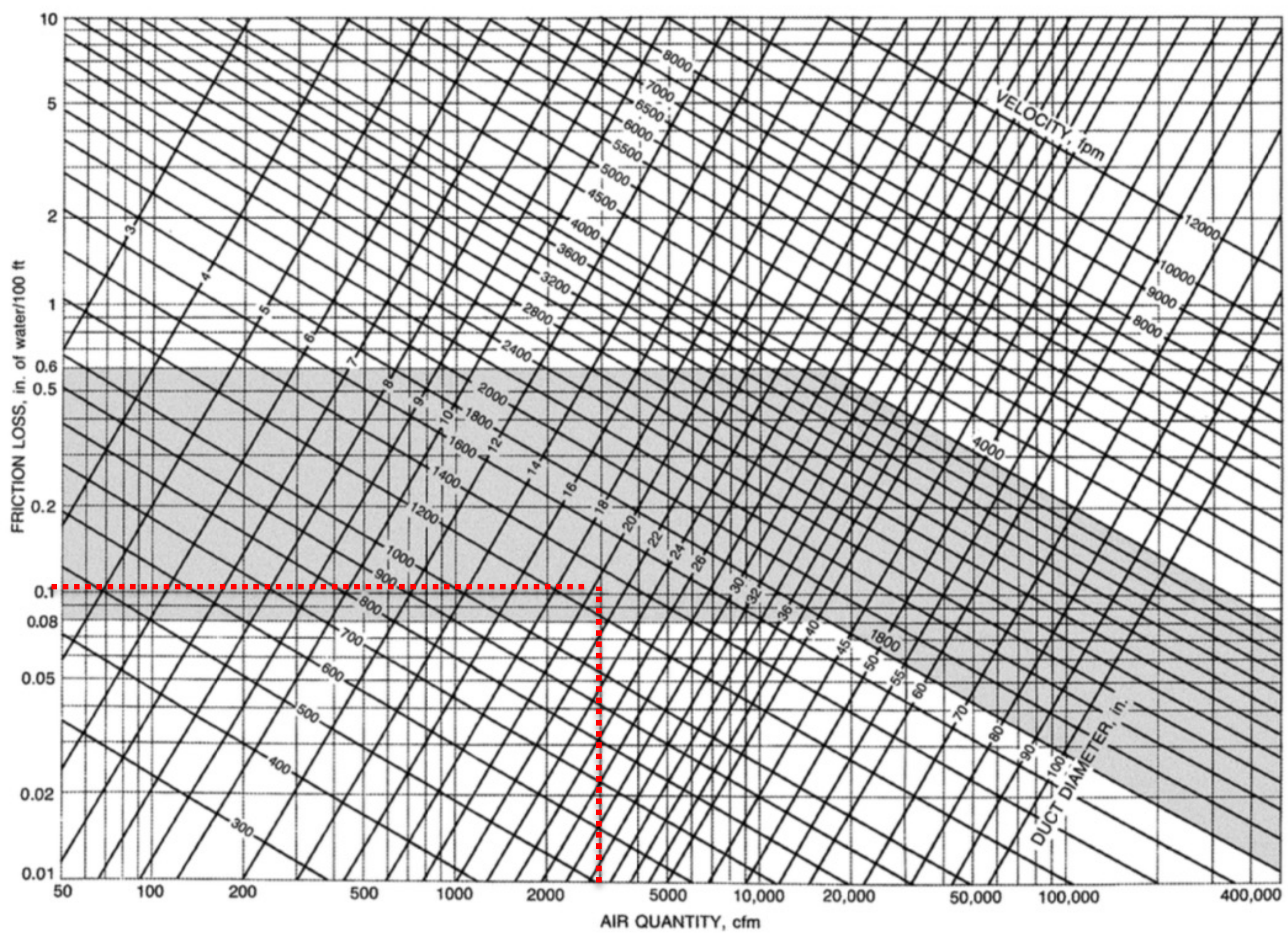
- **Solution:**
  - ❑ Add labels for different branches and fittings



# Equal Friction Method

- **Solution:**
  - Estimate the equal friction method

$$Q_{main} = 500\ cfm + 1500\ cfm + 1000\ cfm = 3000\ cfm \qquad V_{max} = 1300\ fpm$$



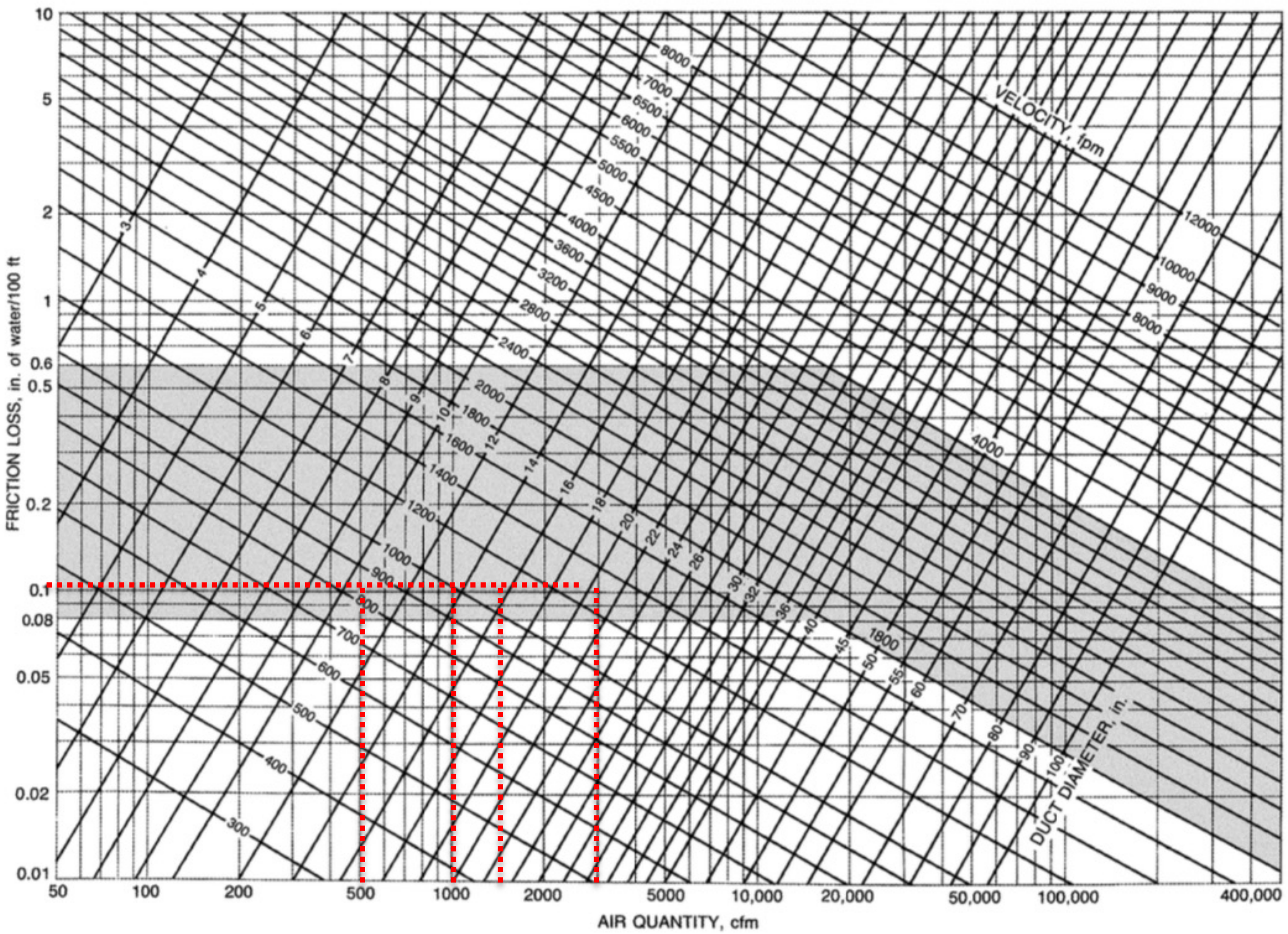
# Equal Friction Method

- **Solution:**
  - ❑ Construct a tabular air flow

| Section | Air Flow Rate (cfm) | Duct Size (in) | Duct (in Rectangular) | Velocity (fpm) |
|---|---|---|---|---|
| AB | 3,000 | | | |
| BC | 1,500 | | | |
| B1 | 1,500 | | | |
| C2 | 1,000 | | | |
| C3 | 500 | | | |

# Equal Friction Method

- **Solution:**
  - ❑ Find round diameters and velocities



# Equal Friction Method

- **Solution:**
  - ❑ Add the duct sizes and velocity rates

| Section | Air Flow Rate (cfm) | Duct Size (in) | Duct (in Rectangular) | Area ($ft^2$) | Velocity (fpm) |
|---|---|---|---|---|---|
| AB | 3,000 | 21 | | | 1,059 |
| BC | 1,500 | 16 | | | 1,000 |
| B1 | 1,500 | 16 | | | 1,000 |
| C2 | 1,000 | 14.5 | | | 750 |
| C3 | 500 | 11 | | | 600 |

# Equal Friction Method

- **Solution:**
  - ❑ Find square duct sizes

| 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 | | | | | | | | | | | | | | C-3 |
| 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 | | | | | | | | | | | | | C-2 |
| 15 | | | 38 | 30 | 25 | 22 | 19 | 16 | 14 | | | | | | | | | | | | |
| 16 | | | 45 | 36 | 30 | 25 | 22 | 18 | 15 | | | | | | | | | | | | B-C |
| 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 | | | | | | | | | | A-B |

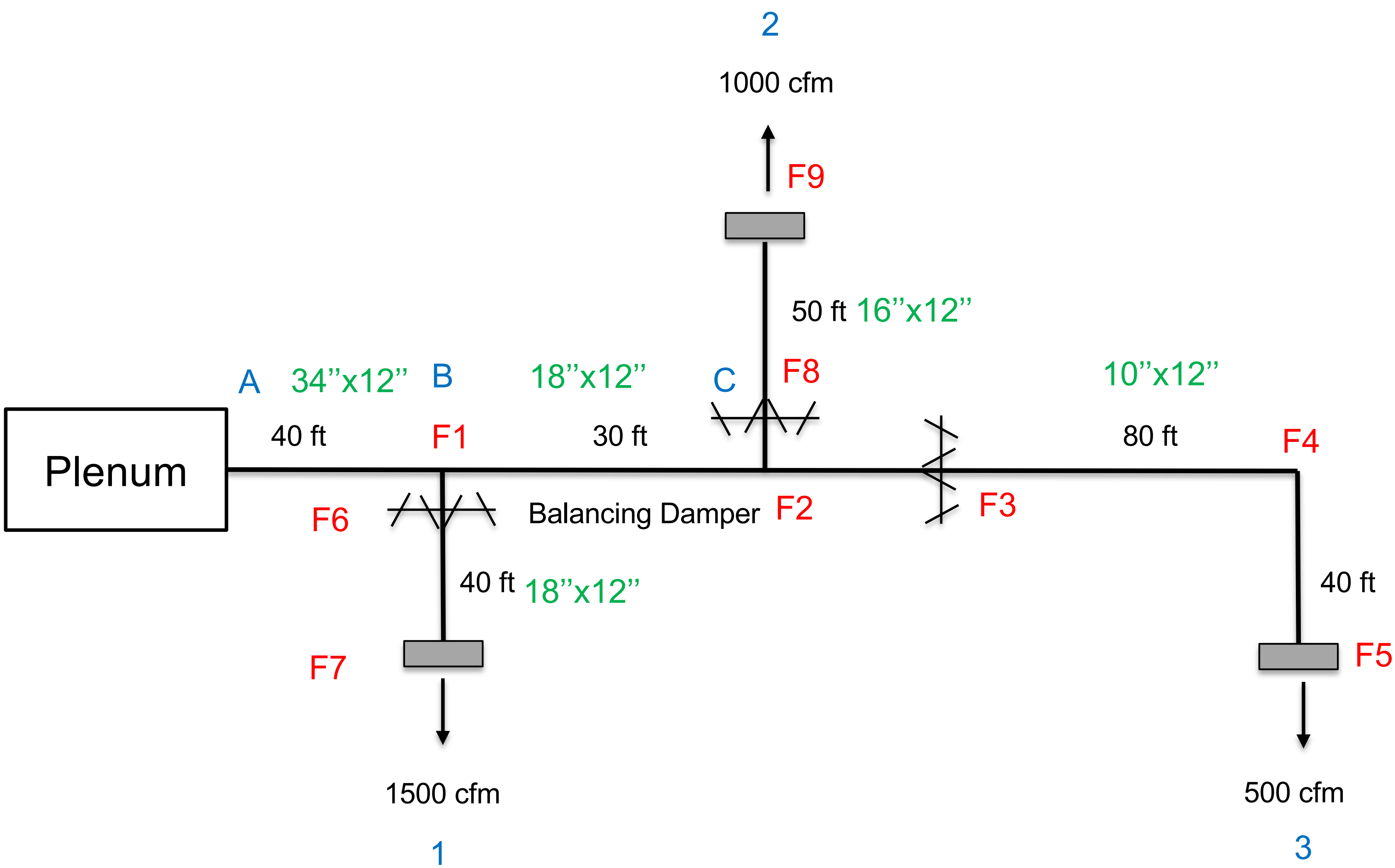
# Equal Friction Method

- **Solution:**
  - ❑ Add the rectangular values to the table

| Section | Air Flow Rate (cfm) | Duct Size (in) | Duct (in Rectangular) | Area (ft$^2$) | Velocity (fpm) |
|---|---|---|---|---|---|
| AB | 3,000 | 21 | 34 / 12 | 2.83 | 1,059 |
| BC | 1,500 | 16 | 18 /12 | 1.50 | 1,000 |
| B1 | 1,500 | 16 | 18 / 12 | 1.50 | 1,000 |
| C2 | 1,000 | 14.5 | 16 / 12 | 1.33 | 750 |
| C3 | 500 | 11 | 10 / 12 | 0.83 | 600 |

# Equal Friction Method

- **Solution:**
  - ❑ Add the calculated ductwork sizes to the diagram



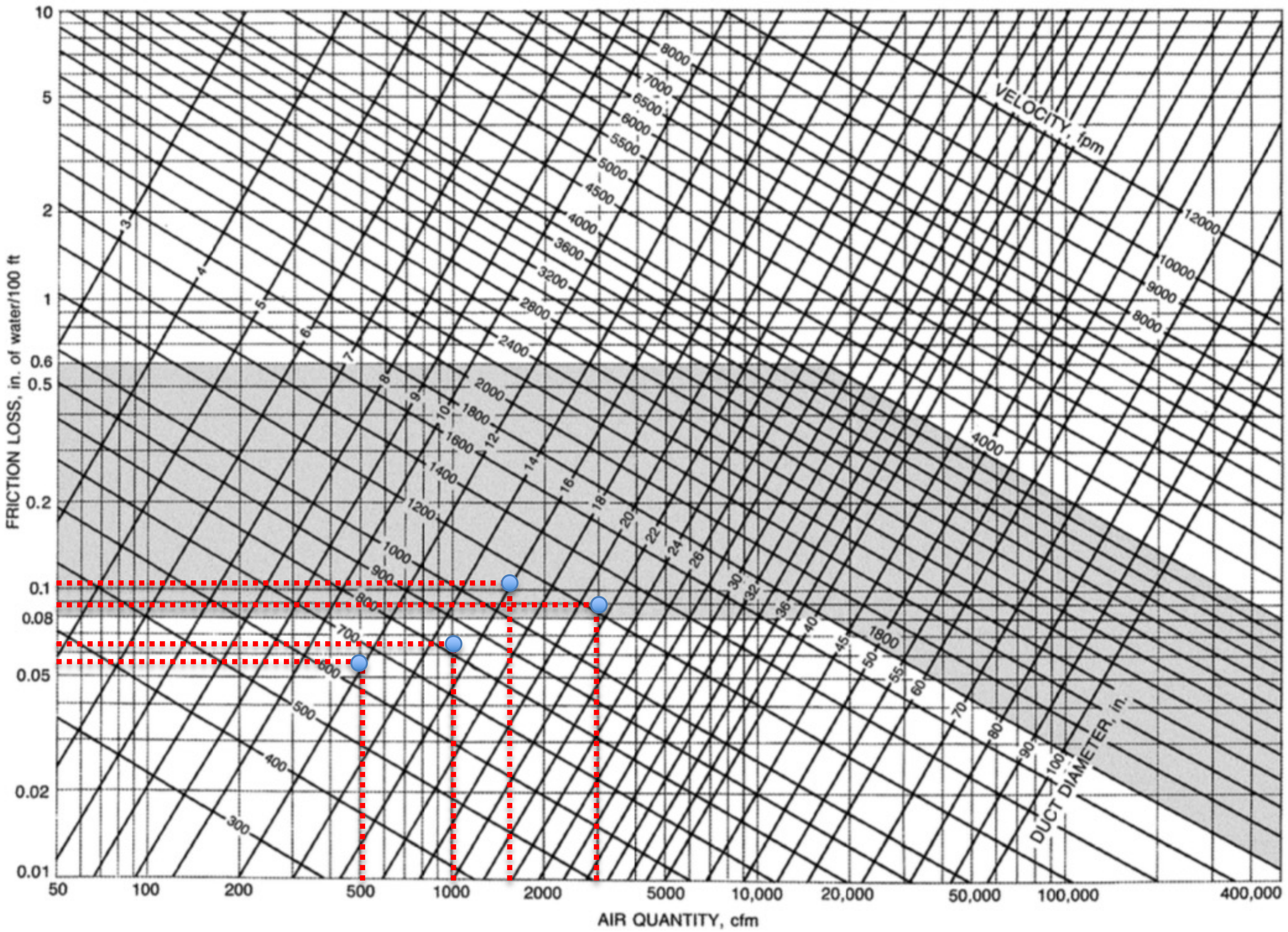
# Equal Friction Method

- **Solution:**
  - ❑ Find the friction loss (in/100 ft) since we made slight changes to the duct cross sections

| Section | Air Flow Rate (cfm) | Duct (in Rectangular) | $D_e$ (in) | Friction Loss (in/100 ft) | Length (ft) | Section Loss (in. w.c.) |
|---|---|---|---|---|---|---|
| AB | 3,000 | 34 / 12 | 21.4 | | 40 | 0.035 |
| BC | 1,500 | 18 /12 | 16 | | 30 | 0.03 |
| B1 | 1,500 | 18 / 12 | 16 | | 40 | 0.04 |
| C2 | 1,000 | 16 / 12 | 15.1 | | 50 | 0.033 |
| C3 | 500 | 10 / 12 | 12 | | 120 | 0.067 |

# Equal Friction Method

- **Solution:**
  - ❑ Friction losses (in/100 ft)



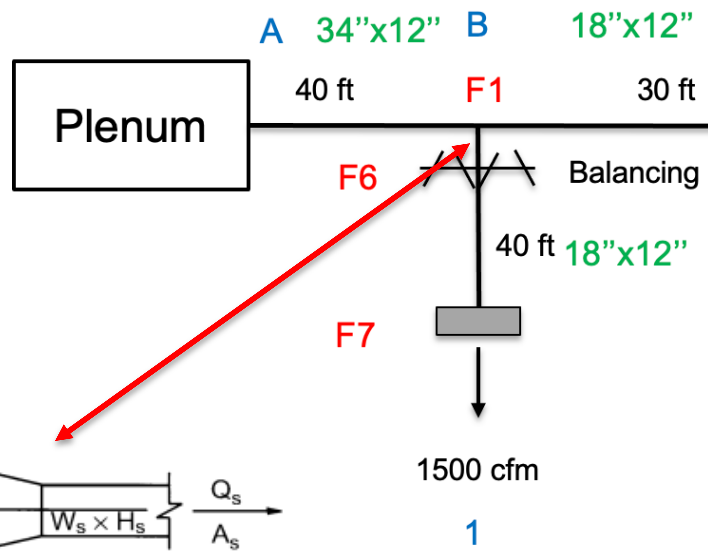
# Equal Friction Method

- **Solution:**
  - ❑ Find the friction losses (in/100 ft)

| Section | Air Flow Rate (cfm) | Duct (in Rectangular) | $D_e$ (in) | Friction Loss (in/100 ft) | Length (ft) | Section Loss (in. w.c.) |
|---|---|---|---|---|---|---|
| AB | 3,000 | 34 / 12 | 21.4 | 0.088 | 40 | $0.088\times\left(\frac{40}{100}\right)=0.035$ |
| BC | 1,500 | 18 /12 | 16 | 0.1 | 30 | $0.1\times\left(\frac{30}{100}\right)=0.03$ |
| B1 | 1,500 | 18 / 12 | 16 | 0.1 | 40 | $0.1\times\left(\frac{40}{100}\right)=0.04$ |
| C2 | 1,000 | 16 / 12 | 15.1 | 0.065 | 50 | $0.065\times\left(\frac{50}{100}\right)=0.0325$ |
| C3 | 500 | 10 / 12 | 12 | 0.056 | 120 | $0.056\times\left(\frac{120}{100}\right)=0.067$ |

# Equal Friction Method

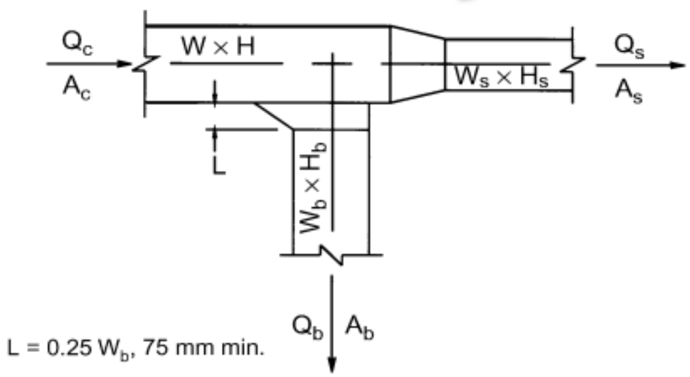
- **Solution:**
  - Select fittings




**SR5-13 Tee, 45 Degree Entry Branch, Diverging**

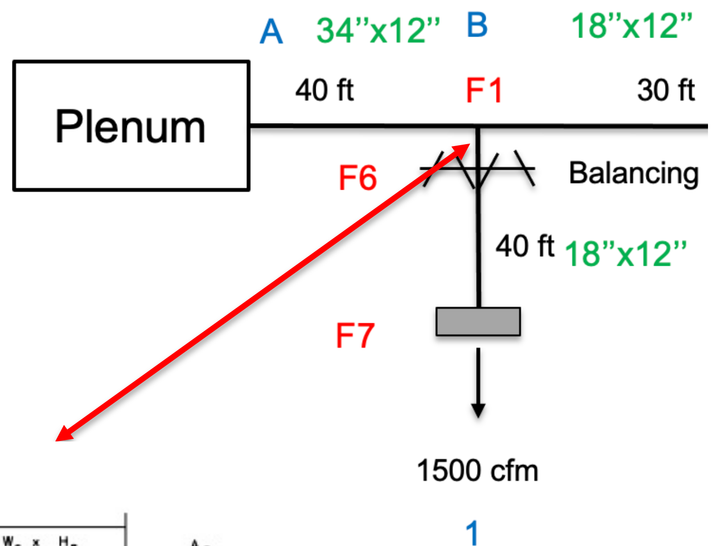
| | $C_b$ Values | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Q_b/Q_c$ | | | | | | | | |
| $A_b/A_c$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 0.73 | 0.34 | 0.32 | 0.34 | 0.35 | 0.37 | 0.38 | 0.39 | 0.40 |
| 0.2 | 3.10 | 0.73 | 0.41 | 0.34 | 0.32 | 0.32 | 0.33 | 0.34 | 0.35 |
| 0.3 | 7.59 | 1.65 | 0.73 | 0.47 | 0.37 | 0.34 | 0.32 | 0.32 | 0.32 |
| 0.4 | 14.20 | 3.10 | 1.28 | 0.73 | 0.51 | 0.41 | 0.36 | 0.34 | 0.32 |
| 0.5 | 22.92 | 5.08 | 2.07 | 1.12 | 0.73 | 0.54 | 0.44 | 0.38 | 0.35 |
| 0.6 | 33.76 | 7.59 | 3.10 | 1.65 | 1.03 | 0.73 | 0.56 | 0.47 | 0.41 |
| 0.7 | 46.71 | 10.63 | 4.36 | 2.31 | 1.42 | 0.98 | 0.73 | 0.58 | 0.49 |
| 0.8 | 61.79 | 14.20 | 5.86 | 3.10 | 1.90 | 1.28 | 0.94 | 0.73 | 0.60 |
| 0.9 | 78.98 | 18.29 | 7.59 | 4.02 | 2.46 | 1.65 | 1.19 | 0.91 | 0.73 |

| | $C_s$ Values | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Q_s/Q_c$ | | | | | | | | |
| $A_s/A_c$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 0.04 | | | | | | | | |
| 0.2 | 0.98 | 0.04 | | | | | | | |
| 0.3 | 3.48 | 0.31 | 0.04 | | | | | | |
| 0.4 | 7.55 | 0.98 | 0.18 | 0.04 | | | | | |
| 0.5 | 13.18 | 2.03 | 0.49 | 0.13 | 0.04 | | | | |
| 0.6 | 20.38 | 3.48 | 0.98 | 0.31 | 0.10 | 0.04 | | | |
| 0.7 | 29.15 | 5.32 | 1.64 | 0.60 | 0.23 | 0.09 | 0.04 | | |
| 0.8 | 39.48 | 7.55 | 2.47 | 0.98 | 0.42 | 0.18 | 0.08 | 0.04 | |
| 0.9 | 51.37 | 10.17 | 3.48 | 1.46 | 0.67 | 0.31 | 0.15 | 0.07 | 0.04 |



# Equal Friction Method

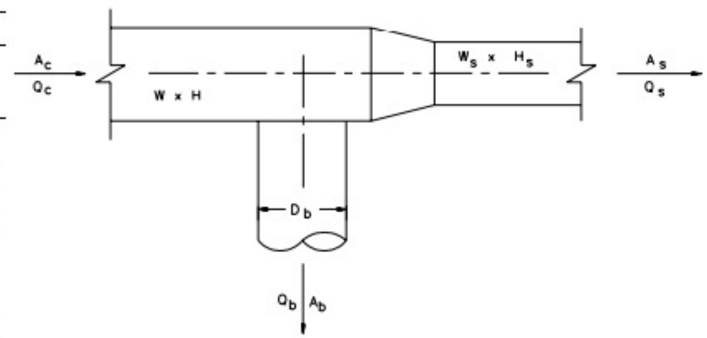
- **Solution:**
  - ❑ Select fittings




**SR5-11 Tee, Rectangular Main to Round Tap, Diverging**

| | $C_b$ Values | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Q_b/Q_c$ | | | | | | | | |
| $A_b/A_c$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 1.58 | 0.94 | 0.83 | 0.79 | 0.77 | 0.76 | 0.76 | 0.76 | 0.75 |
| 0.2 | 4.20 | 1.58 | 1.10 | 0.94 | 0.87 | 0.83 | 0.80 | 0.79 | 0.78 |
| 0.3 | 8.63 | 2.67 | 1.58 | 1.20 | 1.03 | 0.94 | 0.88 | 0.85 | 0.83 |
| 0.4 | 14.85 | 4.20 | 2.25 | 1.58 | 1.27 | 1.10 | 1.00 | 0.94 | 0.90 |
| 0.5 | 22.87 | 6.19 | 3.13 | 2.07 | 1.58 | 1.32 | 1.16 | 1.06 | 0.99 |
| 0.6 | 32.68 | 8.63 | 4.20 | 2.67 | 1.96 | 1.58 | 1.35 | 1.20 | 1.10 |
| 0.7 | 44.30 | 11.51 | 5.48 | 3.38 | 2.41 | 1.89 | 1.58 | 1.38 | 1.24 |
| 0.8 | 57.71 | 14.85 | 6.95 | 4.20 | 2.94 | 2.25 | 1.84 | 1.58 | 1.40 |
| 0.9 | 72.92 | 18.63 | 8.63 | 5.14 | 3.53 | 2.67 | 2.14 | 1.81 | 1.58 |

| | $C_s$ Values | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Q_s/Q_c$ | | | | | | | | |
| $A_s/A_c$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.1 | 0.04 | | | | | | | | |
| 0.2 | 0.98 | 0.04 | | | | | | | |
| 0.3 | 3.48 | 0.31 | 0.04 | | | | | | |
| 0.4 | 7.55 | 0.98 | 0.18 | 0.04 | | | | | |
| 0.5 | 13.18 | 2.03 | 0.49 | 0.13 | 0.04 | | | | |
| 0.6 | 20.38 | 3.48 | 0.98 | 0.31 | 0.10 | 0.04 | | | |
| 0.7 | 29.15 | 5.32 | 1.64 | 0.60 | 0.23 | 0.09 | 0.04 | | |
| 0.8 | 39.48 | 7.55 | 2.47 | 0.98 | 0.42 | 0.18 | 0.08 | 0.04 | |
| 0.9 | 51.37 | 10.17 | 3.48 | 1.46 | 0.67 | 0.31 | 0.15 | 0.07 | 0.04 |



# Equal Friction Method

- **Solution:** Compute fittings

| Section | Fitting No | Fitting Type | ASHRAE Fitting No. | Parameters | Loss Coefficient | Velocity (fpm) | $P_v$ (in. w.c.) | $P_t$ (in. w.c.) |
|---|---|---|---|---|---|---|---|---|
| AB | $F1_b$ | Tee Branch | SR5-13 | $\frac{A_b}{A_c}=\frac{1.5}{2.83}=0.53$ $\frac{Q_b}{Q_c}=\frac{1500}{3000}=0.5$ | 0.82 | 1,000 | 0.062 | 0.051 |
| | $F1_s$ | Tee Straight | SR5-13 | $\frac{A_b}{A_c}=\frac{1.5}{2.83}=0.53$ $\frac{Q_b}{Q_c}=\frac{1500}{3000}=0.5$ | 0.06 | 1,000 | 0.062 | 0.004 |
| BC | F2 | Tee Branch | SR5-13 | $\frac{A_b}{A_c}=\frac{1.33}{1.50}=0.9$ $\frac{Q_b}{Q_c}=\frac{1000}{1500}=0.67$ | 1.33 | 752 | 0.035 | 0.047 |
| | F2 | Tee Straight | SR5-13 | $\frac{A_b}{A_c}=\frac{0.83}{1.5}=0.55$ $\frac{Q_b}{Q_c}=\frac{500}{1500}=0.3$ | 0.58 | 602 | 0.023 | 0.013 |
| B1 | F3 | Damper | CR9-1 | $q=0^0$ | 0.19 | 600 | 0.022 | 0.004 |
| | F4 | Elbow | CR3-1 | $\frac{r}{W}=1$ $\frac{H}{W}=1.2$ | 0.20 | 600 | 0.022 | 0.004 |
| | F5 | Outlet | ---- | ---- | --- | | --- | 0.050 |
| C2 | F7 | Damper | CR9-1 | $q=0^0$ | 0.19 | 1,000 | 0.062 | 0.012 |
| | F8 | Outlet | ---- | ---- | --- | | --- | 0.050 |
| C3 | F6 | Damper | CR9-1 | $q=0^0$ | 0.19 | 750 | 0.035 | 0.007 |
| | F9 | Outlet | ---- | ---- | --- | | --- | 0.050 |

# Equal Friction Method

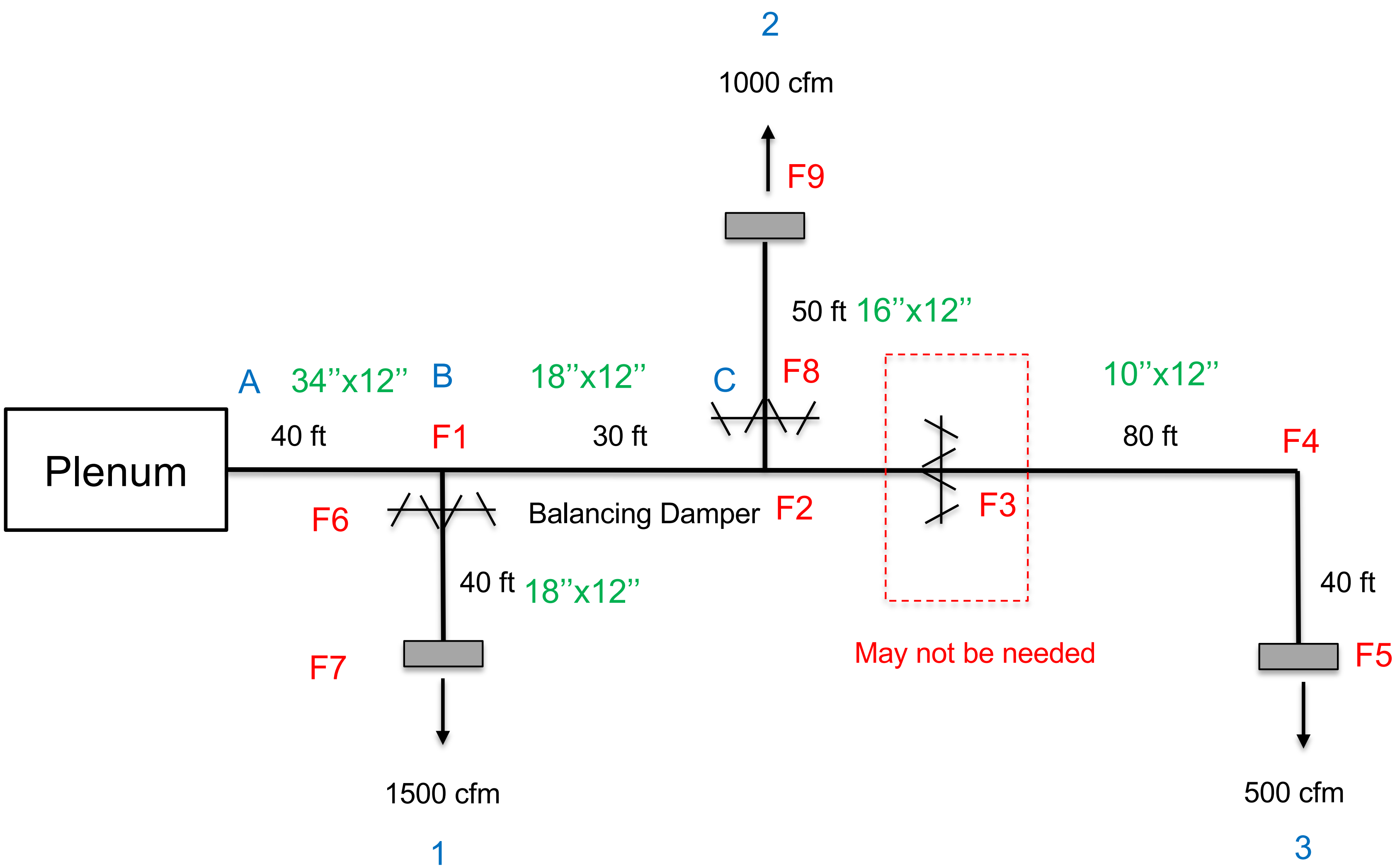
- **Solution:** Pressure loss summary for different paths

$\Delta P$ (in. w.c.)

| Path | Note | Duct | Tee | Duct | Tee | Damper | Duct | Outlet | Total | Differential |
|---|---|---|---|---|---|---|---|---|---|---|
| ABC3 | Path/Fitting Duct | AB | F1S | BC | F2S | F3 | C3 | Value | | Path $\Delta P$ |
| | | 0.035 | 0.004 | 0.03 | 0.013 | 0.004 | 0.067 | 0.05 | 0.204 | 0.000 |
| ABC2 | Path/Fitting Duct | AB | F1 | BC | F2 | F6 | C2 | Value | | Path $\Delta P$ |
| | | 0.035 | 0.004 | 0.03 | 0.013 | 0.007 | 0.033 | 0.05 | 0.171 | 0.032 |
| AB1 | Path/Fitting Duct | AB | F1 | --- | --- | F7 | B1 | Value | | Path $\Delta P$ |
| | | 0.035 | 0.051 | --- | --- | 0.012 | 0.04 | 0.05 | 0.188 | 0.015 |

# Equal Friction Method

- **Solution (summary):**



# Equal Friction Method

- Another example is presented in this reference:

■ **8.2 Duct Design Fundamentals**

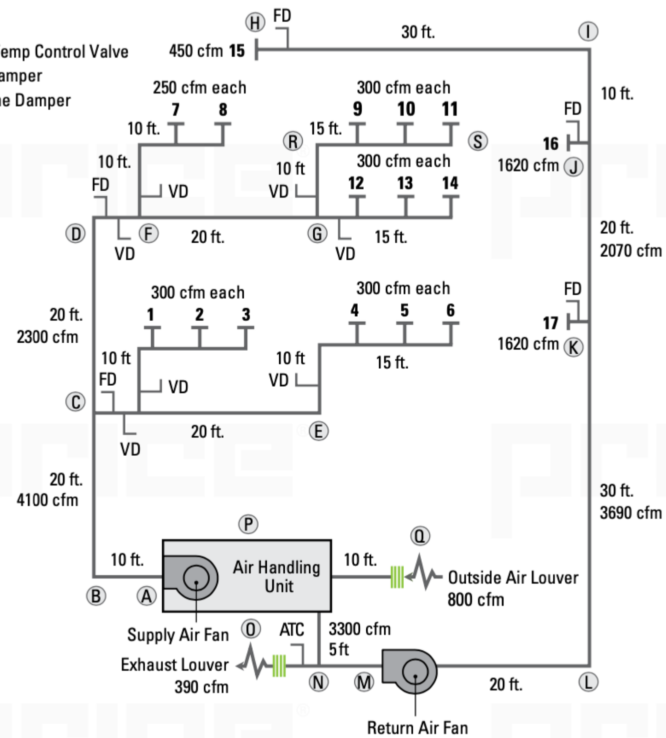
price

**IP** **Example 8.3 - Duct Sizing**

As shown below, a schematic duct layout has been prepared for a building HVAC system that shows dampers, air volumes, duct length, and other information needed to properly size the duct. Note that all supply and return locations are numbered. A friction loss of 0.1 in. w.c./100 ft will be used for the sizing calculations. The total required discharge static pressure needed to supply the duct layout will be estimated.

The ductwork will be rectangular, but is sized as round and then converted to the rectangular format.

**Legend**
ATC - Air Temp Control Valve
FD - Fire Damper
VD - Volume Damper



# Equal Friction Method

- See Chapter 21 – Page 21.24 of the Fundamentals for another example:

**Example 8.** For the VAV system shown in Figure 26, design the duct system by both the equal friction (EF) and static regain (SR) methods, and compare the section duct sizes, total pressure required for each path, and the unbalance between paths.

The system is located in Denver (5430 ft elevation) and the duct is spiral round, galvanized steel (absolute roughness ε = 0.0004 ft). The duct system is located above a suspended acoustical ceiling, and the allowable background sound in the occupied spaces is NC-35. Terminals T1, T2, T3, and T4 (VAV boxes with a one-row hot-water coil) are 800 cfm. VAV box loss coefficients are 1.68.

# BALANCED CAPACITY METHOD

# Balanced Capacity Method

- The balanced design method uses the duct network principle

- For all network problems, it satisfies the continuity and the work-energy principles throughout the network

# Balanced Capacity Method

- Based on the continuity equation, the summation of air flow rate into any junction is zero

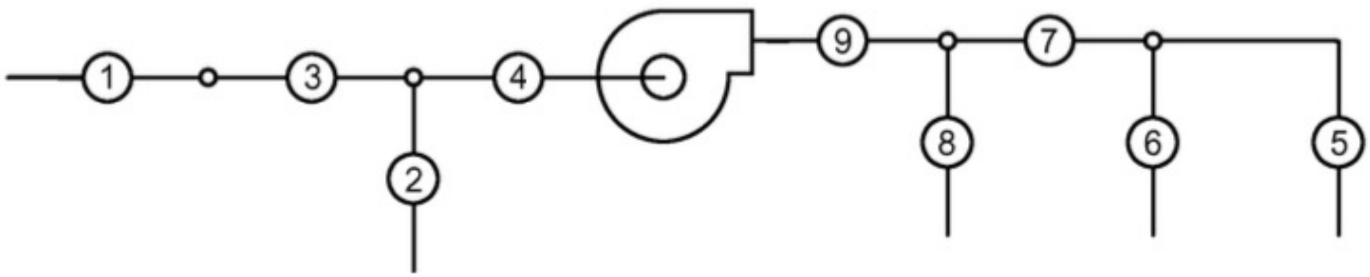
$$\Sigma \pm Q = 0$$

- Based on the network-energy equation, the total pressure loss around any single loop of the network is zero

$$\Sigma \pm P = 0$$

# Balanced Capacity Method

- Satisfy all the possible pressure drops




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

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

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

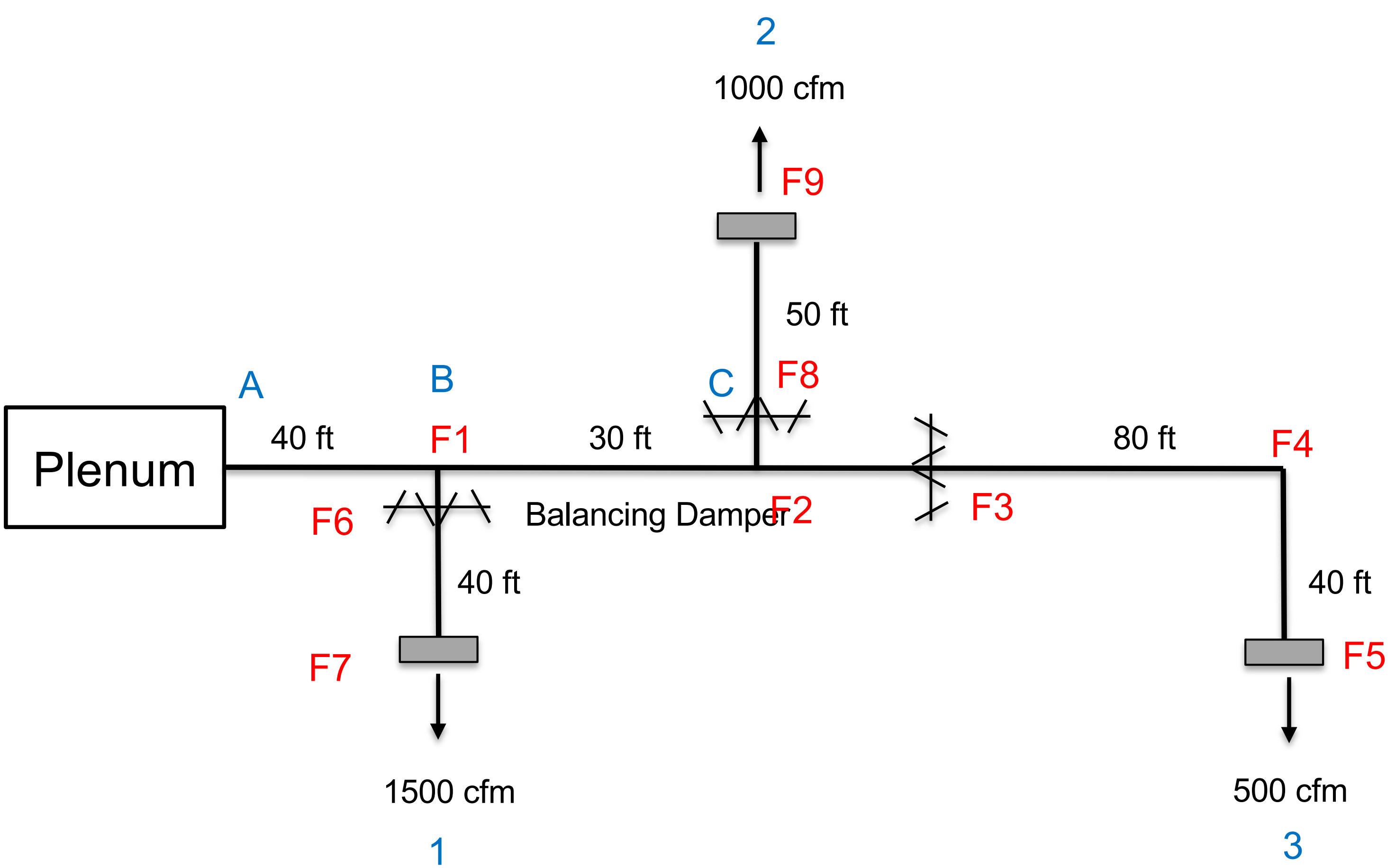
$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5$$

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

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

# Balanced Capacity Method

- Satisfy all the possible pressure drops



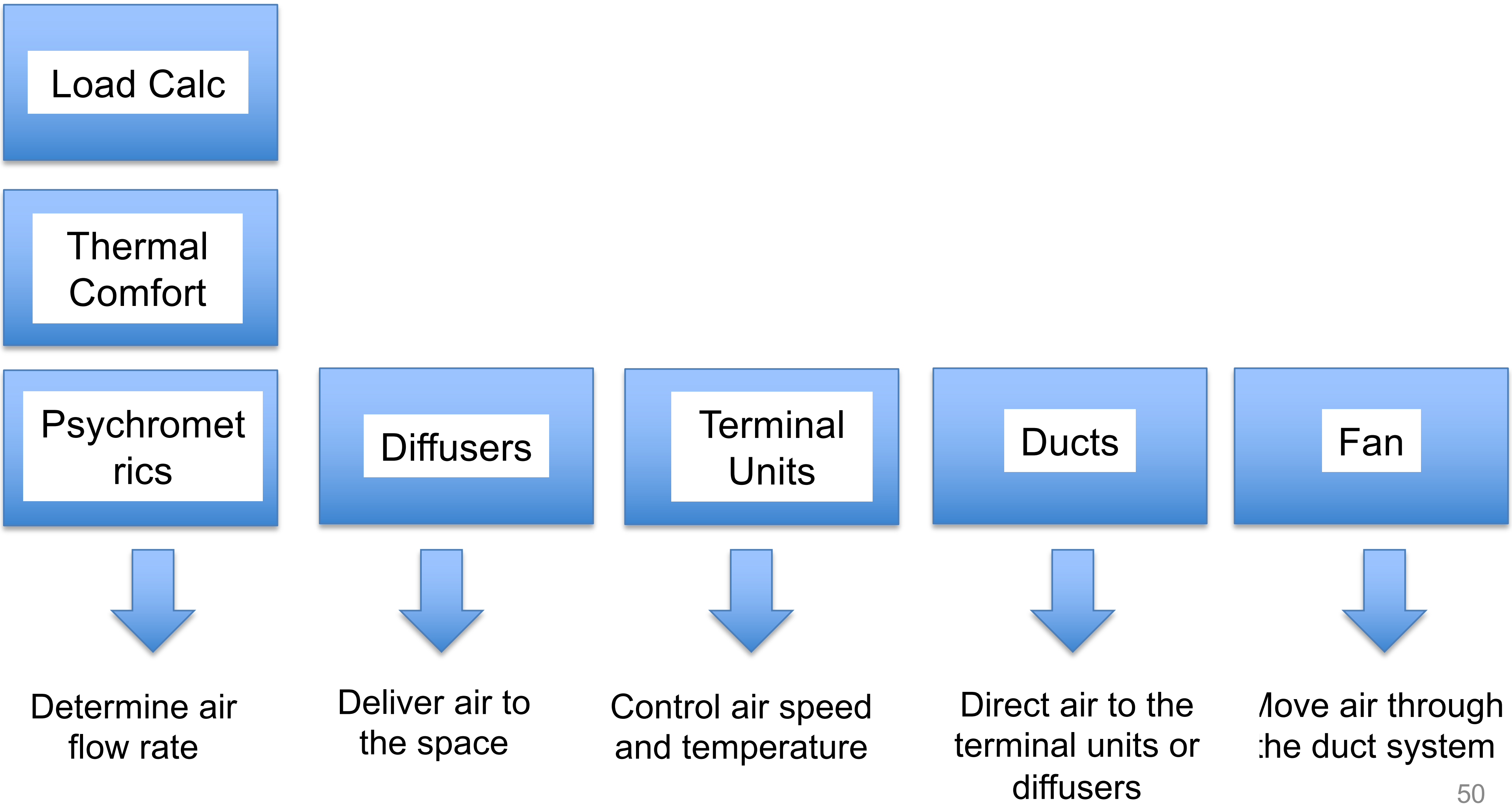

$$Q_1 = 1500\ cfm$$
$$Q_2 = 1000\ cfm$$
$$Q_3 = 500\ cfm$$
$$\Sigma Q = 3000\ cfm$$

$$\Delta P_{A1} = \Delta P_{A2}$$
$$\Delta P_{A1} = \Delta P_{A3}$$

# SYSTEM CHARACTERISTICS CURVE

# System Characteristics Curve

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



# System Characteristics Curve

- Overall system resistance can be written as:

$$\Delta P_{total} = \sum \Delta P_{Ductwork} + \sum \Delta P_{fittings} =$$

$$= \sum f \frac{L}{D}\left(\frac{\rho V^2}{2g_c}\right) + \sum K \left(\frac{\rho V^2}{2g_c}\right)$$

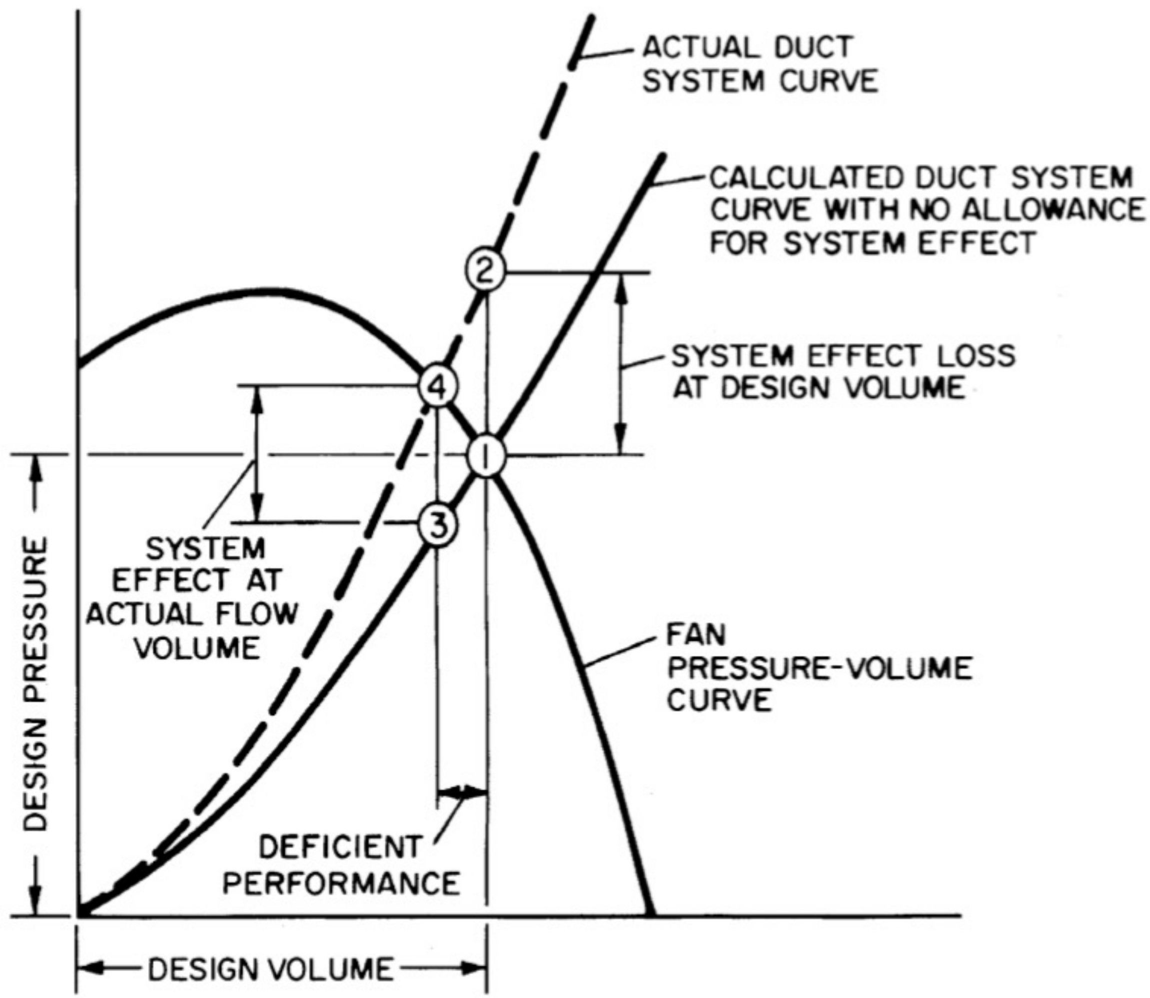
# System Characteristics Curve

- Overall system resistance can be written as:

$$\Delta P_{total} = (Constant) \times \dot{Q}^2$$

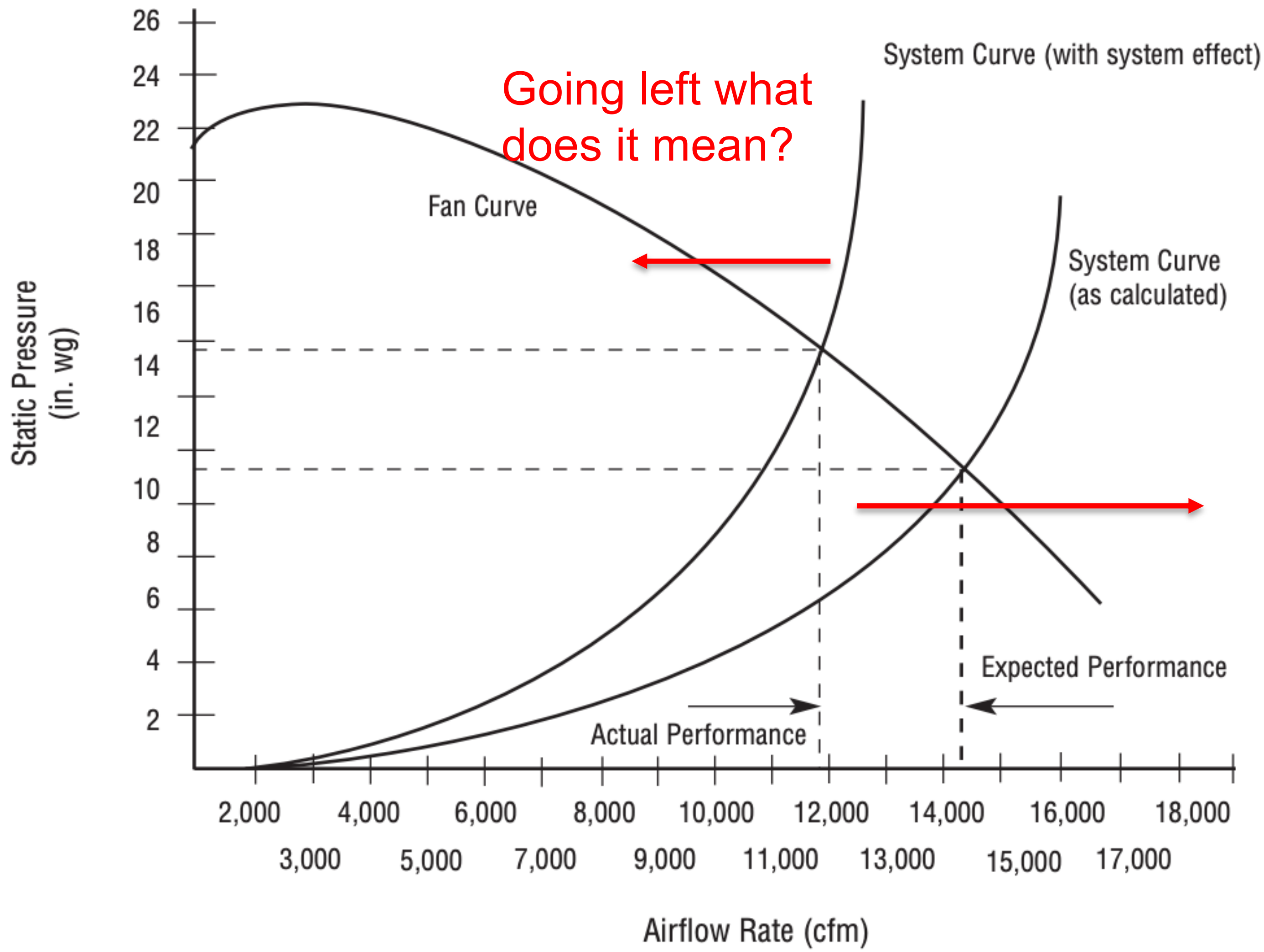
# System Characteristics Curve

- Flow through any resistance (i.e., duct and fittings) is proportional to the square root of the pressure causing the flow



# System Characteristics Curve

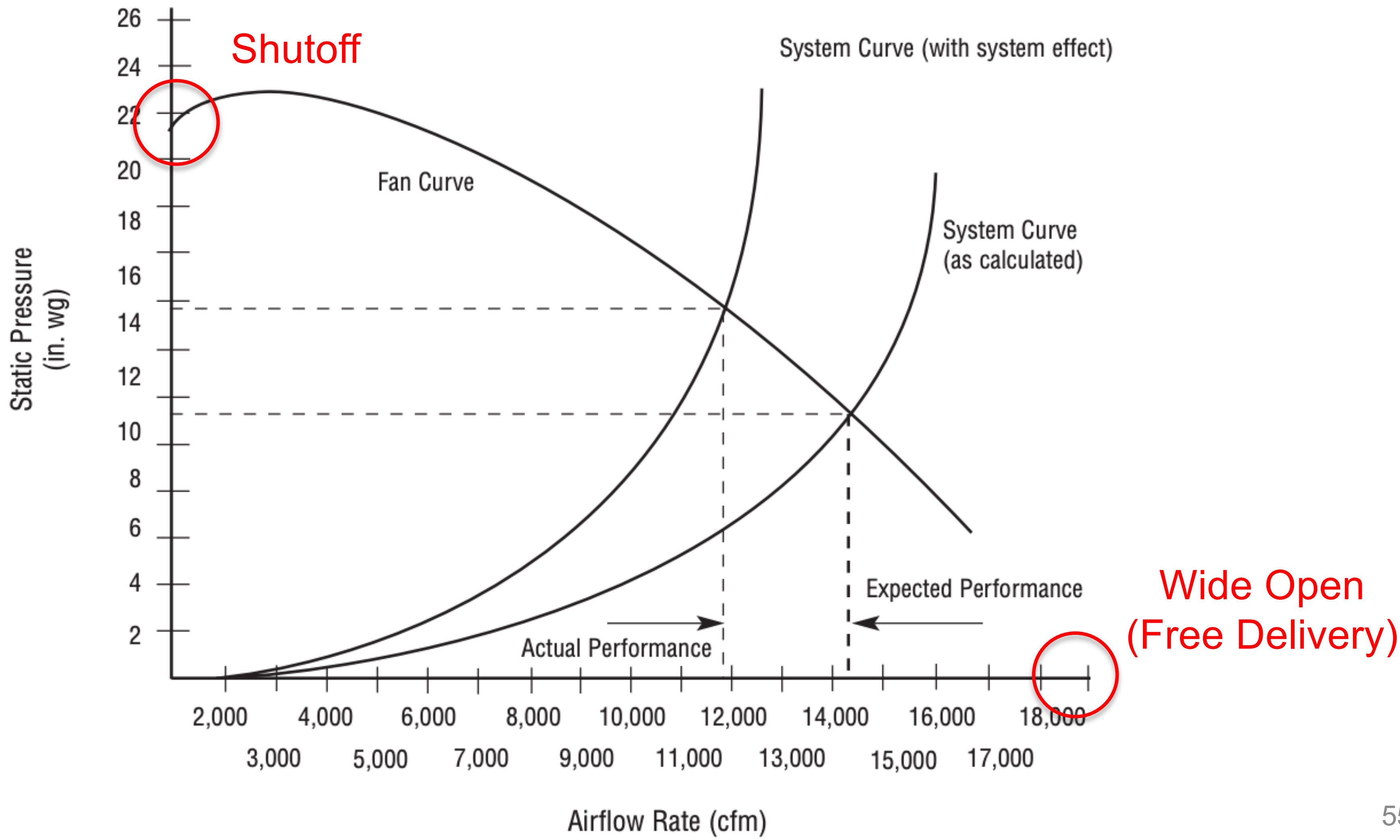
- This relationship defines the flow versus pressure characteristics of a system




https://www.nrel.gov/docs/fy03osti/29166.pdf

# System Characteristics Curve

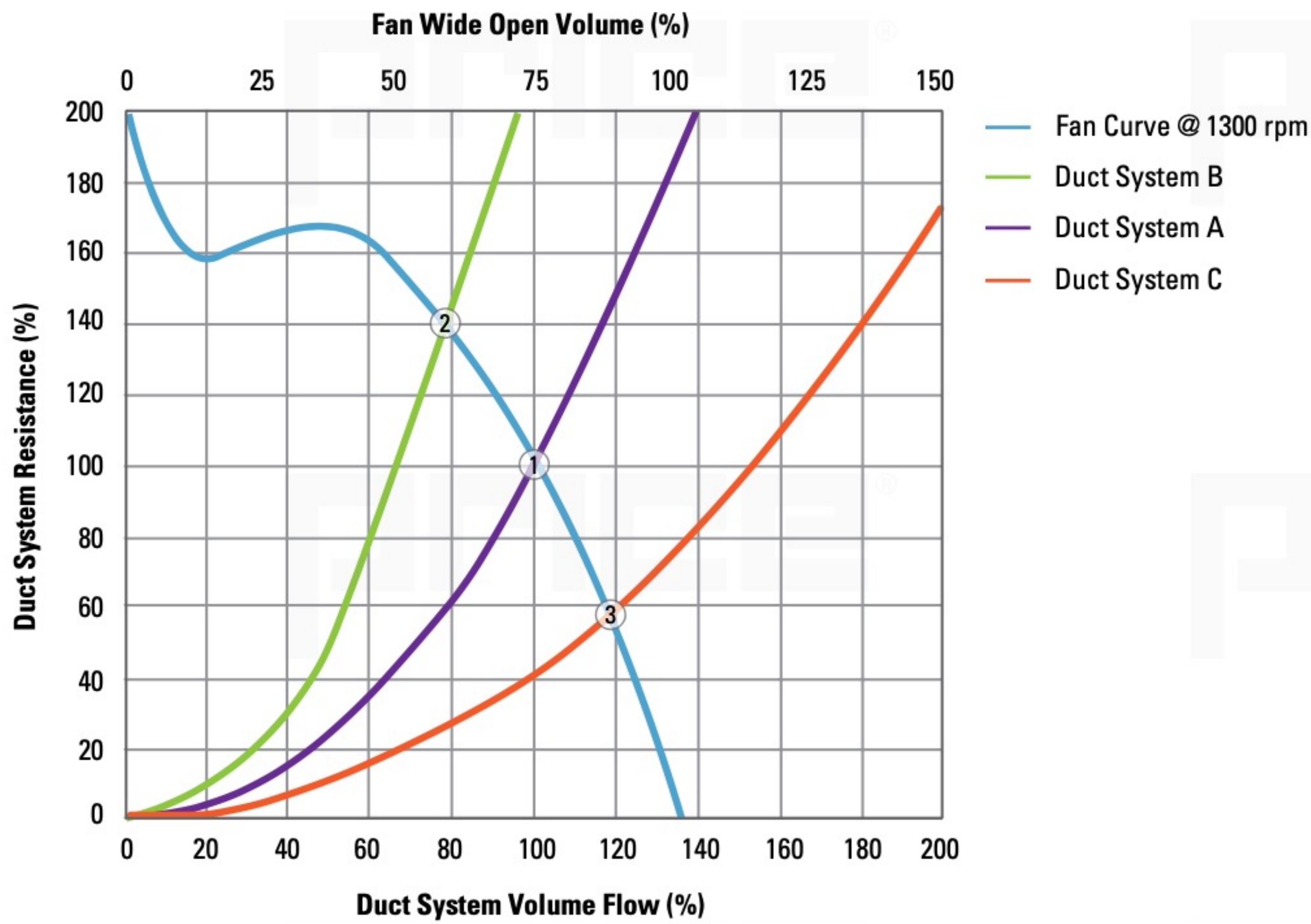
- This relationship defines the flow versus pressure characteristics of a system




https://www.nrel.gov/docs/fy03osti/29166.pdf

# System Characteristics Curve

- The best operating point varies based on the resistance in the system (i.e., system curves)



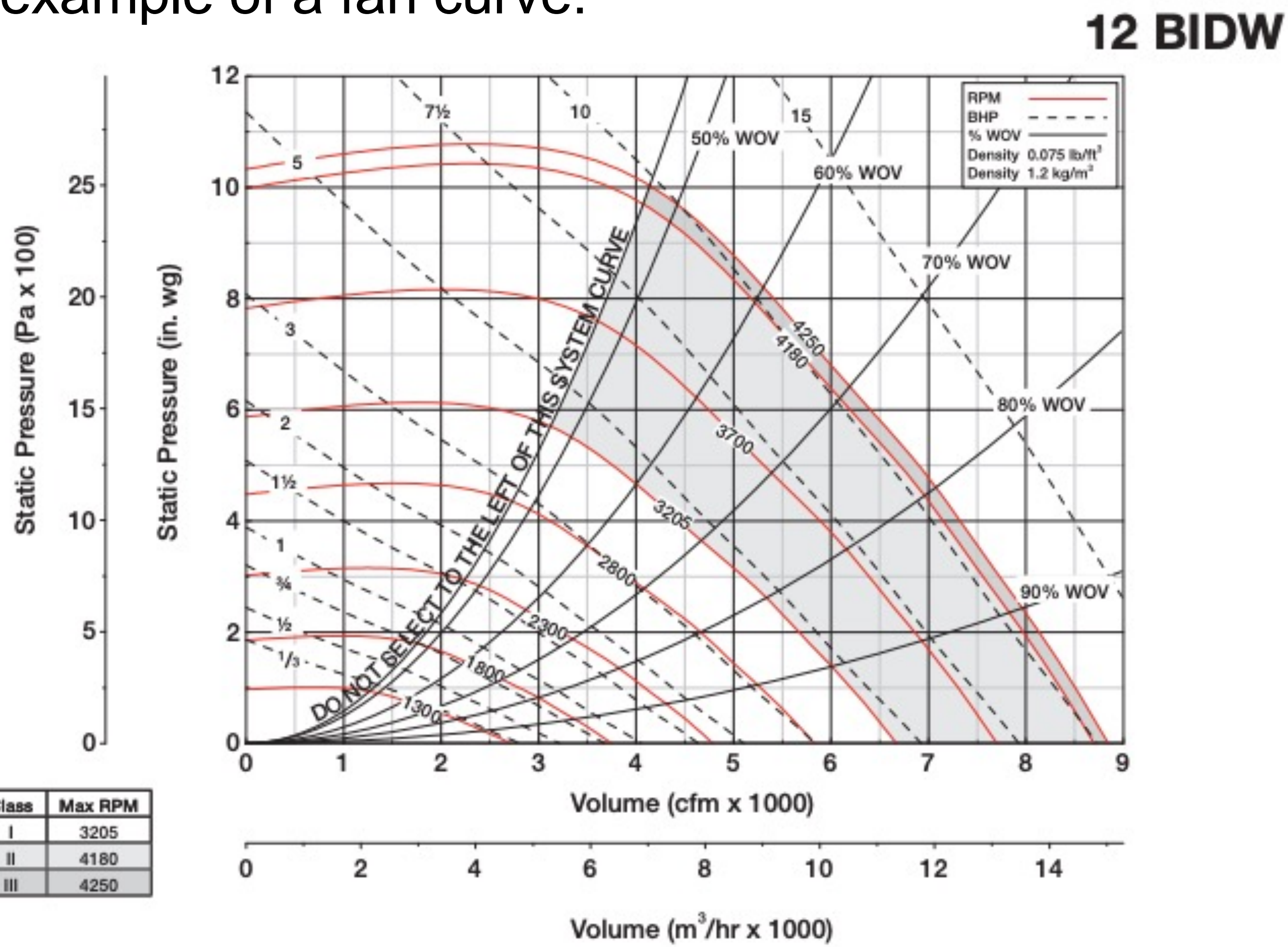



*Price Industries Engineering Handbook*

# FAN PERFORMANCE CURVE

# Fan Performance Curve

- An example of a fan curve:




| Class | Max RPM |
|---|---|
| I | 3205 |
| II | 4180 |
| III | 4250 |

% WOV = (CFM X 100) / (RPM X 2.08)

https://content.greenheck.com/public/DAMProd/Original/10002/CentrifugalDWPerfSuppl_catalog.pdf

# Fan Performance Curve

- An example of a fan curve:

## 24 BIDW

| 24 BIDW |
|---|
| Wheel Diameter = 24½ in. |
| Outlet Area = 6.21 $ft.^2$ |
| Tip Speed = 6.41 x RPM |
| Maximum BHP = $(RPM/599)^3$ |

| |
|---|
| Minimum Starting HP = 1 |
| Maximum RPM Class I = 1568 |
| Maximum RPM Class II = 2045 |
| Maximum RPM Class III = 2577 |

| CFM | OV | STATIC PRESSURE (in. wg) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.25 | | 0.50 | | 0.75 | | 1.00 | | 1.25 | | 1.50 | | 1.75 | | 2.00 | | 2.25 | | 2.50 | |
| | | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP |
| 5000 | 805 | 416 | 0.34 | 504 | 0.58 | 585 | 0.85 | 656 | 1.14 | | | | | | | | | | | | |
| 6000 | 966 | 462 | 0.46 | 542 | 0.74 | 613 | 1.04 | 681 | 1.36 | 744 | 1.71 | 801 | 2.06 | | | | | | | | |
| 7000 | 1127 | 512 | 0.62 | 586 | 0.94 | 650 | 1.26 | 711 | 1.62 | 769 | 1.99 | 826 | 2.39 | 878 | 2.79 | 927 | 3.20 | 972 | 3.63 | | |
| 8000 | 1288 | 564 | 0.82 | 632 | 1.17 | 692 | 1.54 | 748 | 1.92 | 801 | 2.32 | 851 | 2.74 | 903 | 3.18 | 951 | 3.64 | 997 | 4.10 | 1040 | 4.57 |
| 9000 | 1449 | 619 | 1.07 | 679 | 1.46 | 737 | 1.87 | 789 | 2.28 | 838 | 2.70 | 886 | 3.16 | 931 | 3.62 | 977 | 4.11 | 1022 | 4.61 | 1065 | 5.11 |
| 10000 | 1610 | 675 | 1.36 | 730 | 1.79 | 783 | 2.23 | 833 | 2.70 | 879 | 3.15 | 923 | 3.62 | 968 | 4.12 | 1009 | 4.63 | 1049 | 5.16 | 1090 | 5.70 |
| 11000 | 1771 | 731 | 1.72 | 782 | 2.19 | 831 | 2.66 | 879 | 3.16 | 924 | 3.68 | 965 | 4.17 | 1005 | 4.68 | 1046 | 5.23 | 1085 | 5.78 | 1122 | 6.35 |
| 12000 | 1932 | 789 | 2.14 | 836 | 2.64 | 882 | 3.16 | 925 | 3.69 | 969 | 4.24 | 1009 | 4.80 | 1048 | 5.34 | 1084 | 5.88 | 1122 | 6.47 | 1159 | 7.08 |
| 13000 | 2093 | 848 | 2.63 | 891 | 3.17 | 933 | 3.73 | 975 | 4.29 | 1015 | 4.87 | 1055 | 5.47 | 1092 | 6.08 | 1128 | 6.66 | 1162 | 7.25 | 1196 | 7.86 |
| 14000 | 2254 | 907 | 3.20 | 947 | 3.76 | 986 | 4.37 | 1025 | 4.97 | 1063 | 5.58 | 1101 | 6.21 | 1137 | 6.86 | 1172 | 7.51 | 1205 | 8.14 | 1237 | 8.78 |
| 15000 | 2415 | 967 | 3.85 | 1003 | 4.44 | 1040 | 5.08 | 1077 | 5.73 | 1113 | 6.37 | 1148 | 7.03 | 1183 | 7.71 | 1217 | 8.41 | 1250 | 9.11 | 1281 | 9.79 |
| 16000 | 2576 | 1027 | 4.58 | 1060 | 5.21 | 1095 | 5.88 | 1129 | 6.57 | 1164 | 7.26 | 1198 | 7.95 | 1230 | 8.66 | 1264 | 9.39 | 1295 | 10.1 | 1326 | 10.9 |
| 17000 | 2737 | 1087 | 5.41 | 1118 | 6.07 | 1151 | 6.78 | 1184 | 7.50 | 1216 | 8.24 | 1248 | 8.97 | 1280 | 9.71 | 1310 | 10.5 | 1342 | 11.2 | 1372 | 12.0 |
| 18000 | 2898 | 1147 | 6.34 | 1177 | 7.04 | 1207 | 7.77 | 1239 | 8.53 | 1269 | 9.31 | 1300 | 10.1 | 1330 | 10.9 | 1359 | 11.6 | 1388 | 12.4 | 1418 | 13.3 |
| 19000 | 3059 | 1208 | 7.38 | 1236 | 8.11 | 1264 | 8.86 | 1294 | 9.67 | 1323 | 10.5 | 1352 | 11.3 | 1381 | 12.1 | 1410 | 12.9 | 1437 | 13.8 | 1465 | 14.6 |
| 20000 | 3220 | 1269 | 8.52 | 1295 | 9.29 | 1321 | 10.1 | 1350 | 10.9 | 1378 | 11.8 | 1405 | 12.6 | 1433 | 13.5 | 1460 | 14.3 | 1487 | 15.2 | 1513 | 16.1 |

https://content.greenheck.com/public/DAMProd/Original/10002/CentrifugalDWPerfSuppl_catalog.pdf