HVAC Systems Duct Design

Mark Terzigni
Project Manager
Technical Services
SMACNA

Fundamentals

- Velocity
  - fpm

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

- Velocity Pressure
  - in. w.g.

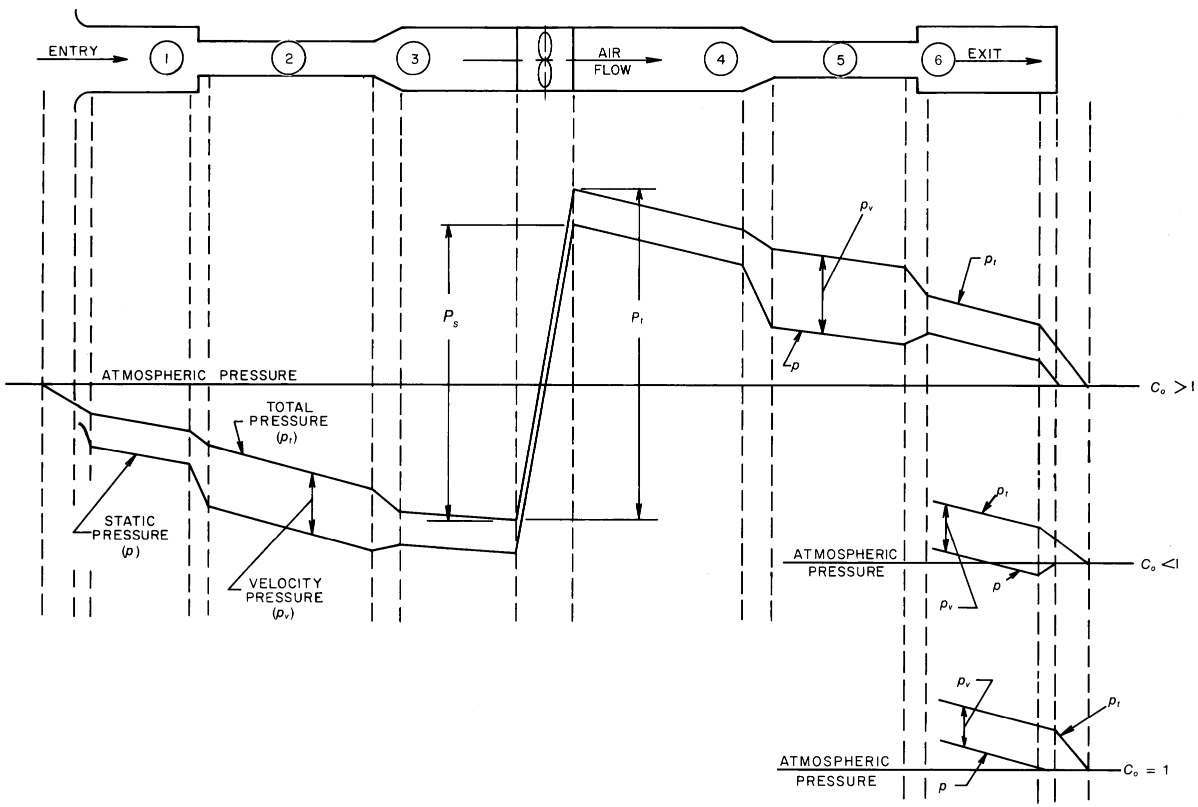
$$p_v = \left(\frac{V}{4005} \right)^2$$

Fundamentals

- Static Pressure
  - Total Pressure – Velocity Pressure
- Total Pressure (loss)
  - Darcy Weisbach Equation

$$\Delta p = \left(\frac{12 f L}{D_h} + \Sigma C \right) \rho \left(\frac{V}{1097} \right)^2$$

Pressure Changes



Design Procedures

- Arrange outlets/inlets
- Adjust calculated air quantities for
  - Heat gain/loss
  - Leakage
    - Duct
    - Equipment (VAV box)
    - Accessories (dampers, sensors, access doors,etc.)
  - Space pressurization

Design Procedures

- Select outlet sizes based on manufacturer's data
- Sketch the system (connect the dots)
- Divide the system into sections
  - Section is any change in flow, size, shape
- Size the system using required/preferred method

Design Procedures

- Calculate the system total pressure loss
- Layout the system in detail
  - Space limitations
  - Obstructions/coordination concerns
- Resize duct sizes to balance
- Analyze noise levels
  - Use sound attenuation where necessary

Design Methods Overview

- Equal Friction
  - Size ductwork based on a constant pressure loss per unit length (.08-.1 in. w.g. per 100 ft.)
  - Larger sizes require less energy but have a higher initial cost
  - Smaller sizes require more energy but will have a reduced initial cost.
  - Practical for simple systems
  - Duct Calculators

Design Methods Overview

- Static Regain
  - Obtain the same static pressure at diverging flows
    - Change duct sizes down stream
  - Iterative process best handled by computers
  - Start the process by selecting a maximum velocity in the "root section"
  - Higher velocities require more energy but have a lower initial cost
  - Lower velocities require less energy but have a higher initial cost

Design Methods Overview

- T-method
  - Calculation intensive (use software)
  - Considers current building costs, energy costs and future costs.
  - The calculation process involves:
    - condensing the system
    - fan selection (the simulation uses actual fan curves)
    - expanding the system

Design Methods Overview

- Extended Plenum
  - 1-6 in. w.g. systems
  - Duct velocity up to 3000 fpm
  - Branch velocity should not exceed trunk velocity
  - Balancing dampers should be used at each branch
  - Can result in low velocities
    - Excessive heat gain/loss

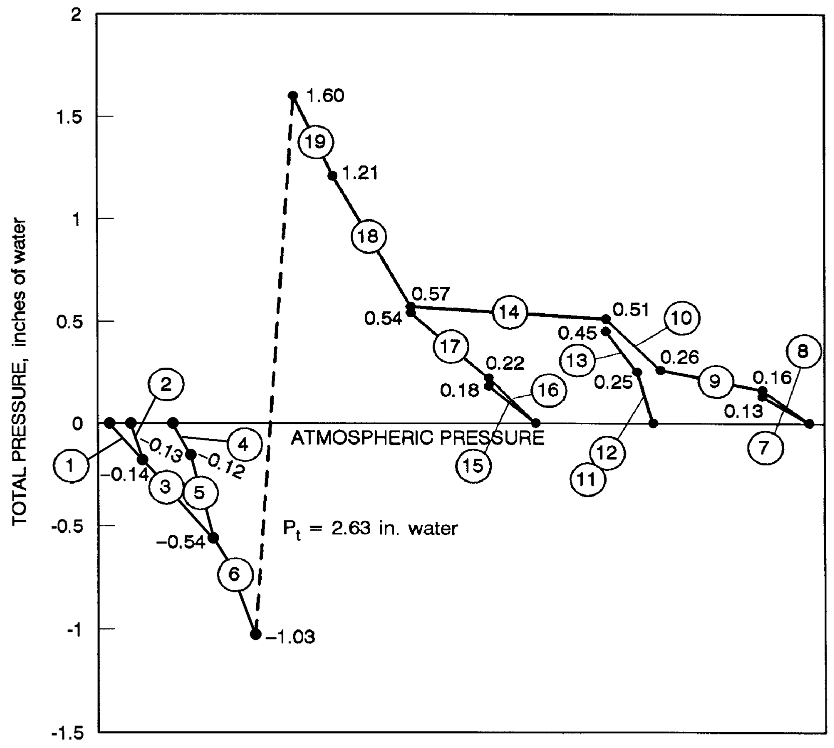
Design Methods Overview

- Extended Plenum
  - Low operating cost
  - Easier to balance
  - Less fittings
  - Easy to modify for (tenant changes)

Design Methods Overview

- Constant Velocity
  - Used primarily for material conveyance
  - Maintain sufficient velocities to suspend material
  - Converging flows should offset

Design Methods Overview



Design Considerations

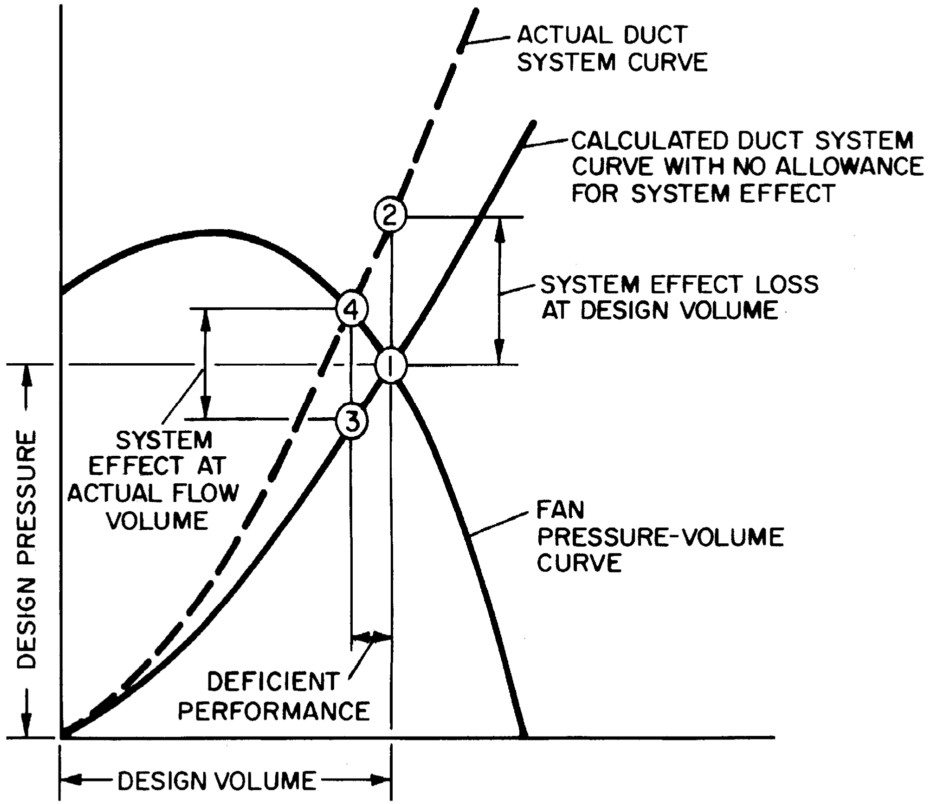
- Stack Effect
  - Height of the building
  - Elevator shafts, stairwells, other shafts
- Wind effect
  - Prevailing wind direction
  - Shape of building and nearby objects
  - Location of intakes and exhausts

Design Considerations

- Inlet and outlet conditions
  - Fan curves are “ideal”
  - Inlet conditions to avoid
    - Pre-rotation
    - Turbulent flow
  - Can not be correct by simply adding to the required pressure
  - Results in a new curve

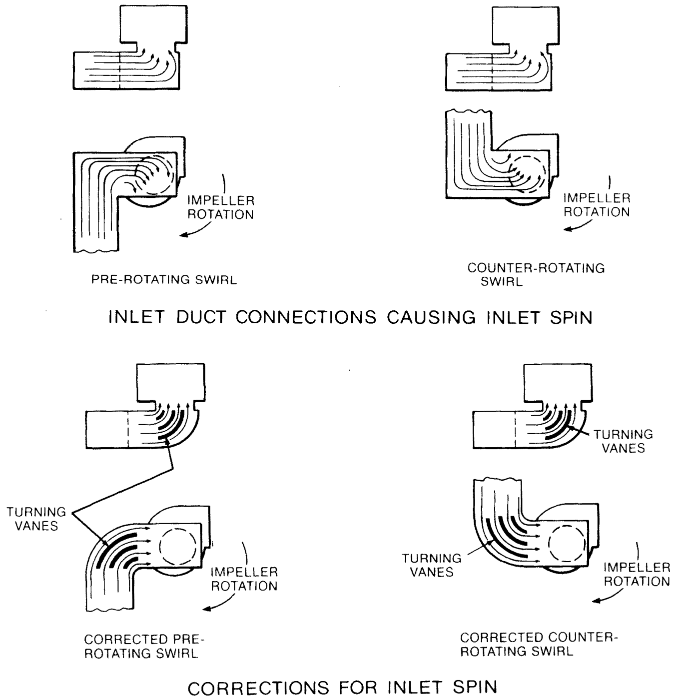
Design Considerations

- Inlet and outlet conditions



Design Considerations

- Fan system effect



Design Considerations

- Fan system effect
- Difficult to asses
- Approximations exist (ASHRAE Duct Fitting Database)
- Experience

Design Considerations

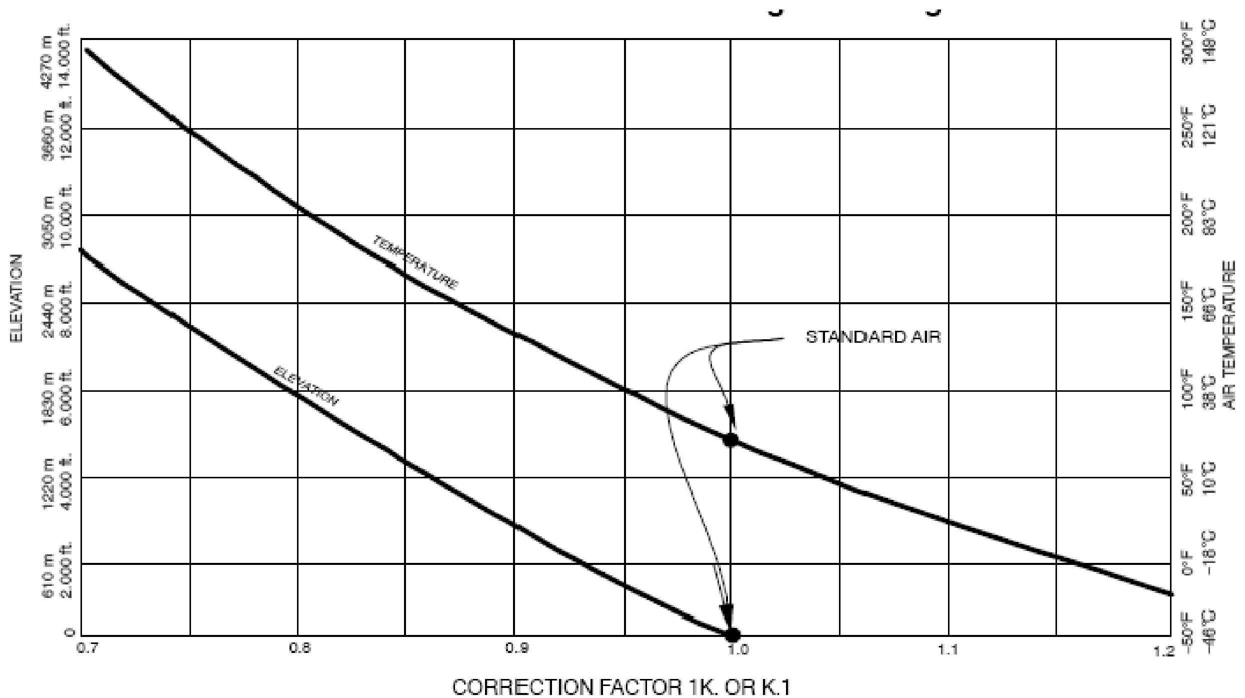
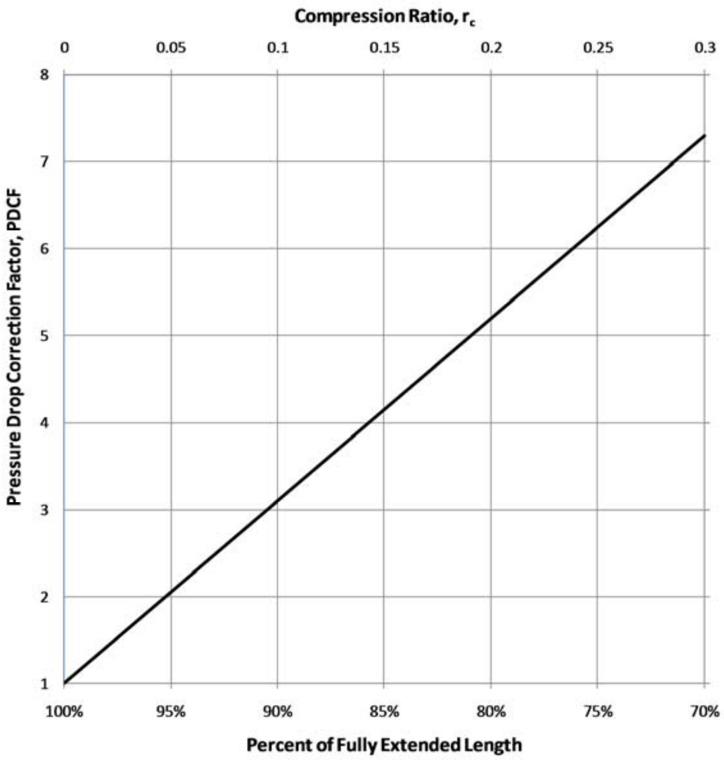


FIGURE A–4 AIR DENSITY FRICTION CHART CORRECTION FACTORS

Design Considerations

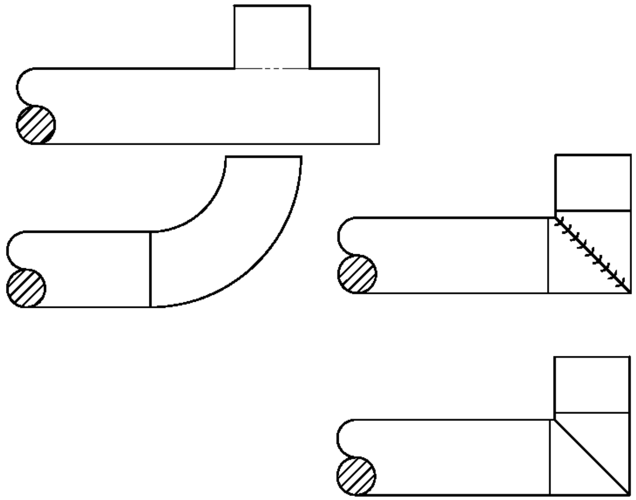
- Flex Duct



Design Considerations

- The contractor wants to use a different type of elbow, is that OK?
  - It depends on the location in the system
  - What type of fitting is the proposed replacement?
  - What are the actual losses in the system?
    - Velocity pressure
    - Loss coefficient

Fittings



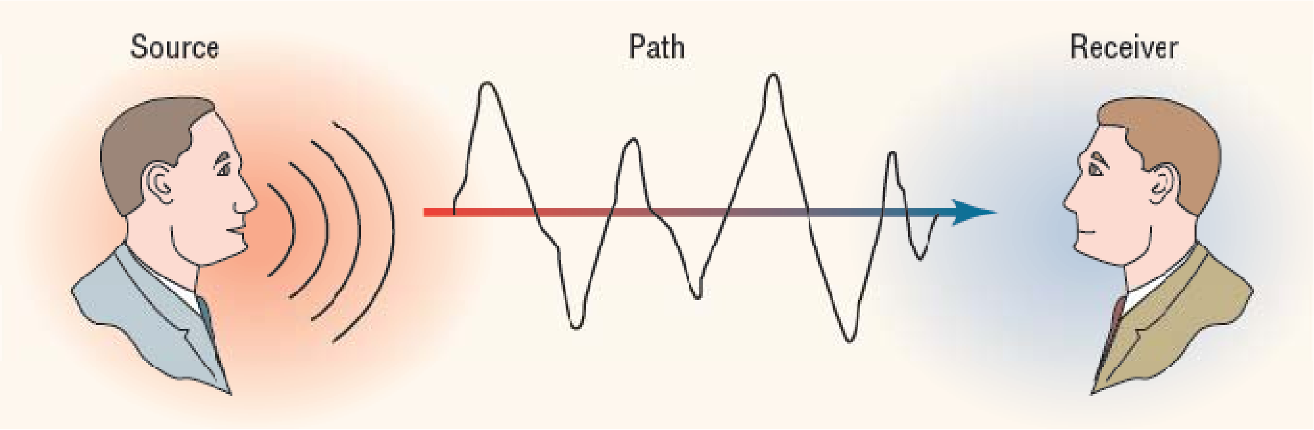
Comments

- Avoid using extractors
  - Poor airflow
  - Noise
- Use an elbow for the final branch in a duct run.
  - Cushion effect
- Boot taps
  - Best performance for cost

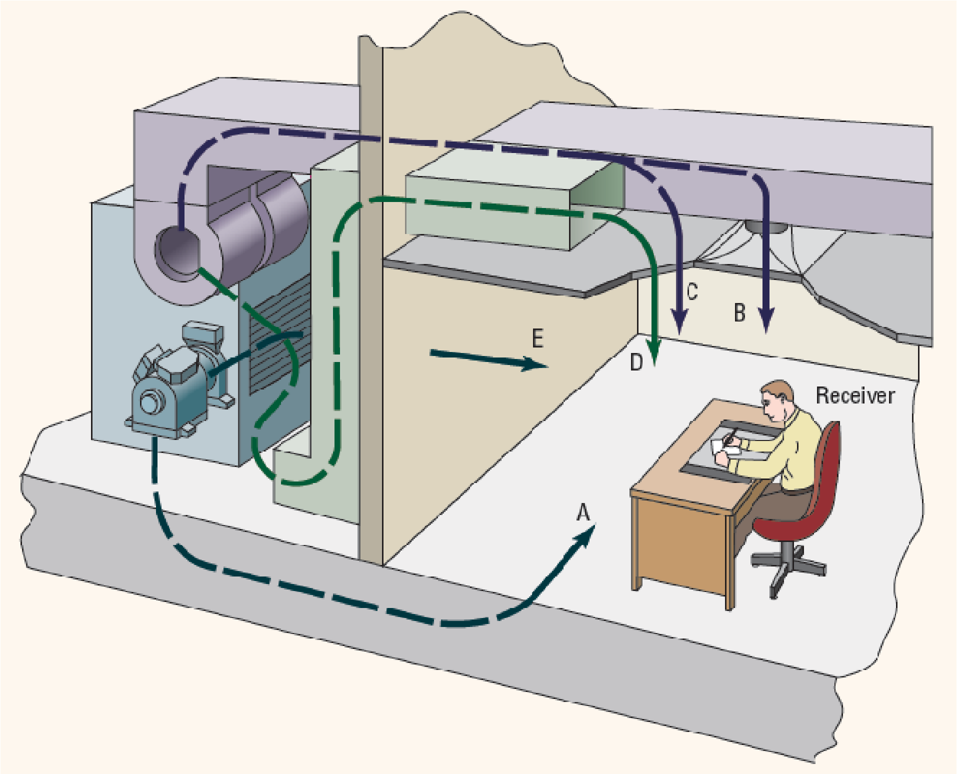
Acoustics

- If it is good for airflow it is usually good for acoustics.
- Three components:
  - Source
  - Path
  - Receiver

Acoustics



Acoustics



Acoustics

- Easy Math

Difference	Add to higher level
0 to 1 dB	3 dB
2 to 4 dB	2 dB
5 to 9 dB	1 dB
10-plus dB	0 dB

Acoustics

- Weighting
  - Human ear is less sensitive to low and high frequencies
  - More sensitive to mid-frequencies

Acoustics

- A-Weighting
  - Usually used for outdoor sound calculations
- NC
  - Sound is fitted to a curve
  - Based on 8 frequencies
  - Does not evaluate the overall shape of the curve
  - Most used method
  - NC-35
  - 63 Hz – 8K Hz

Acoustics

- ROOM CRITERIA Mark II (RC)
- Evaluates the shape
- Currently ASHRAE'S preferred method

Acoustics

- Start with quiet equipment
- Locate air-handling equipment in less sensitive areas
- Allow for proper fan outlet conditions
  - Rectangular length 1.5 x largest dimension
  - Round length 1.5 x diameter

Acoustics

- Use radiused elbows where possible
- Larger ductwork reduces velocity and reduces generated noise
- Avoid abrupt changes in layout
- Place dampers away from outlets
- Flexible connections to equipment

Acoustics

- Power splits
  - Ratio of areas
    - $L1 = 10 \times \log (A1 \div (A1 + A2))$
    - $L2 = 10 \times \log (A2 \div (A1 + A2))$
  - Units dB, applies across all frequencies, straight subtraction

Acoustics

- Low Frequency Noise
  - Breakout – Break in
  - Rectangular
    - Where breakout noise is beneficial
    - Do not use where break in noise is a concern
  - Round
    - Does not allow as much breakout
    - Does not allow as much break in
  - Thicker liner attenuates lower frequencies

Acoustics

- Medium-High frequency
  - Easier to attenuate than low
  - Lined or double walled duct
  - Lengthen runs if necessary
  - Silencers

Acoustics

- Silencers
  - Can be very effective at attenuating sound
    - Insertion loss
  - Pressure drops
  - Generated noise
  - Elbow
  - Locate in the wall or as close as possible
  - Do not locate right off of a fan

Acoustics

- Reactive silencers
  - Low to no pressure drops
- Dissipative
  - No fill use baffles and “chambers”

Duct Design

Questions?