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Good, Better, & Best Duct Design

An Overview for ASHRAE Bi State Chapter
March 14, 2012

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Introduction

- Why Duct Design?
- How to Design?
- Design Process (8 steps)
- Fundamentals
- Design Methods

Introduction

- Ductwork Types
- Sound Control
- Leakage Control
- Exposed Ductwork
- Specifications

FUNDAMENTALS

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Fundamentals

Flow Rate (Q)

Q = V x A

WHERE:

Q – volume flow rate of airflow (cfm)

V – velocity (ft/min)

A – area (sq ft)

Fundamentals

Total Pressure = Static Pressure + Velocity Pressure

TP = SP + VP

WHERE:

TP – in wg

SP – in wg

VP – in wg

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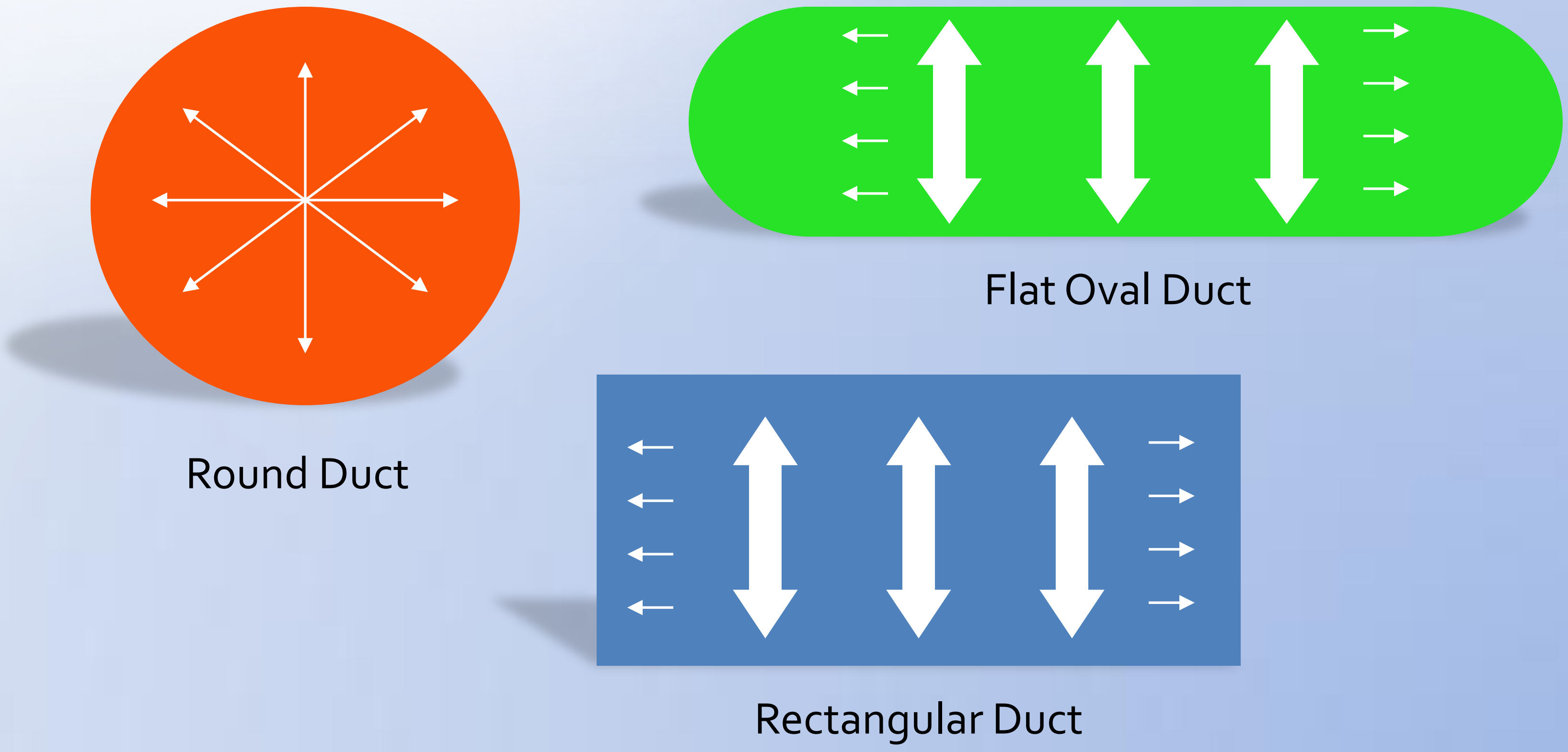
Fundamentals

Duct static pressure on various duct shapes



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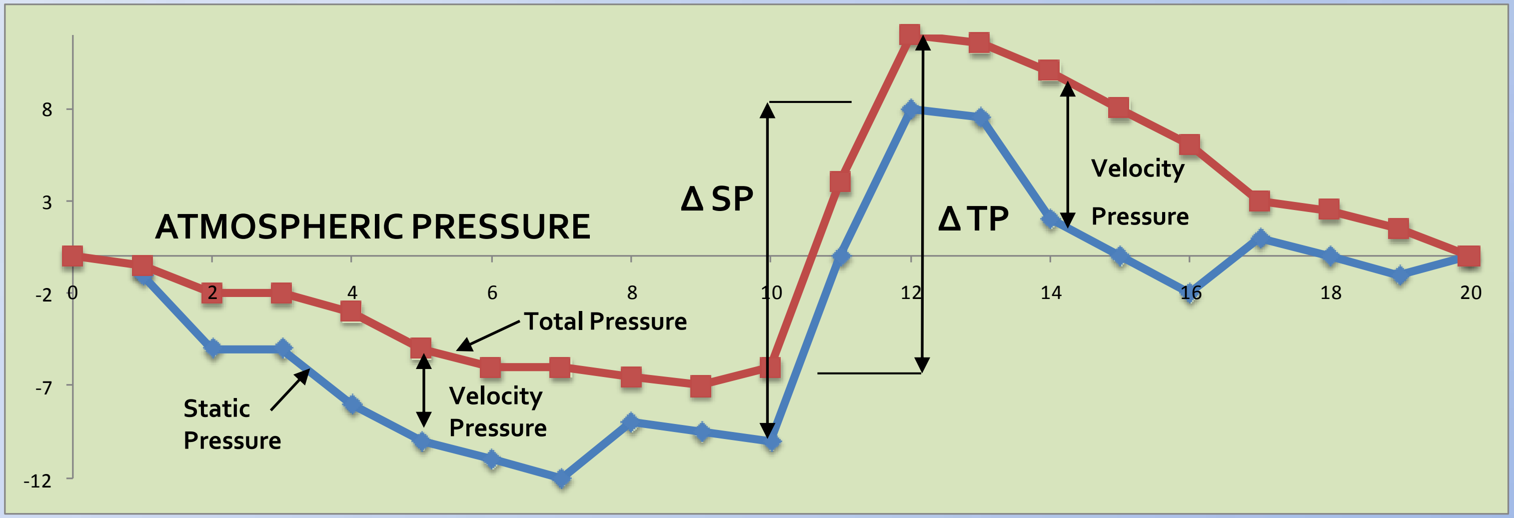
Fundamentals

Fan and duct pressure changes in duct



Fundamentals

Fan Laws

$$\frac{Q_2}{Q_1} = \frac{RPM_2}{RPM_1}$$

$$\frac{BHP_2}{BHP_1} = \left(\frac{Q_2}{Q_1}\right)^3$$

$$\frac{FTP_2}{FTP_1} = \left(\frac{Q_2}{Q_1}\right)^2$$

Q = volume flow rate of airflow (cfm)

RPM = fan speed (revolutions/minute)

BHP = brake horse power (hp)

FTP = fan total pressure (in wg)

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Design Considerations

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Design Considerations

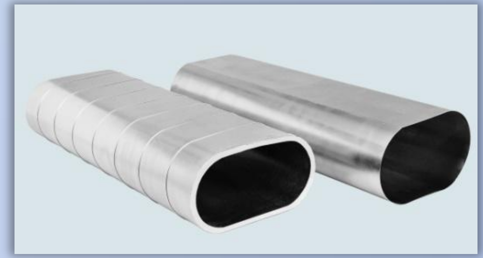
Duct Types

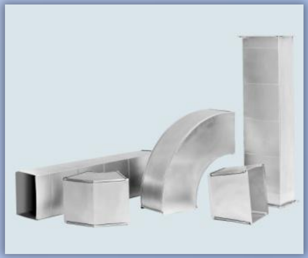
Round — spiral and longitudinal seam duct

Flat Oval — spiral and longitudinal seam duct

Rectangular

Other — semi/quarter round, triangular



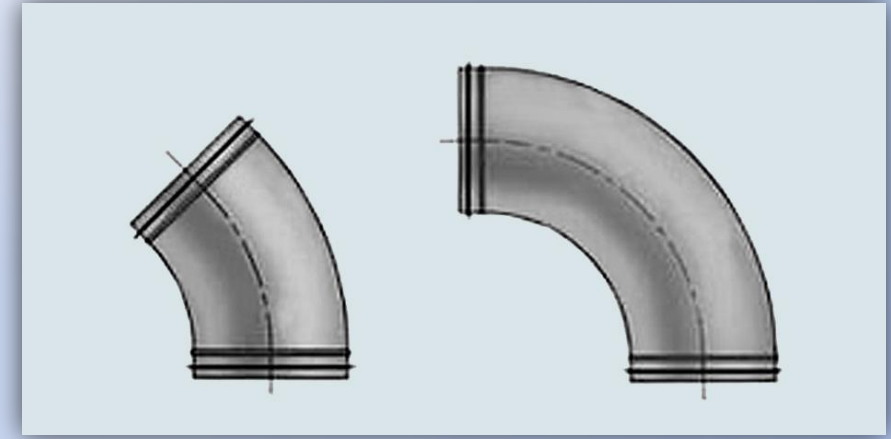


Design Considerations

Fitting Types

Elbows

- Pressed – 45° and 90°, 3- to 12-inch diameter

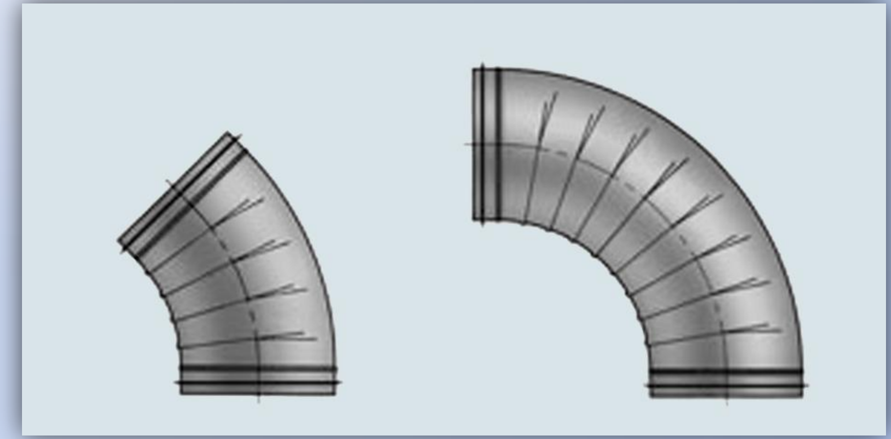


Design Considerations

Fitting Types

Elbows

- Pleated – 45° and 90°, 3- to 16-inch diameter

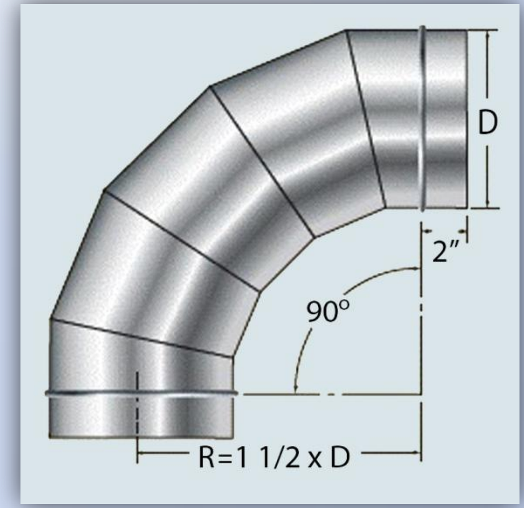


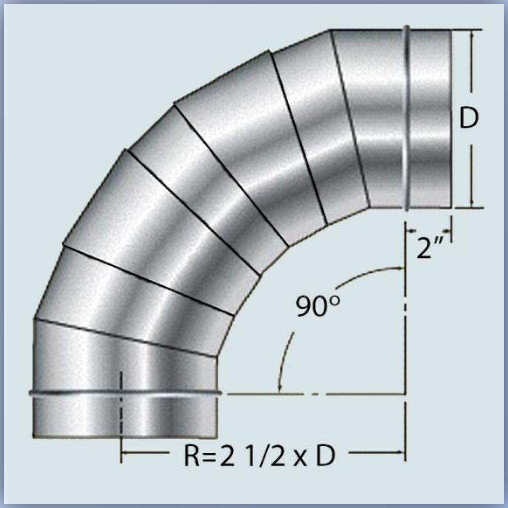
Design Considerations

Fitting Types

Elbows

- Gored – std
- Gored – long radius





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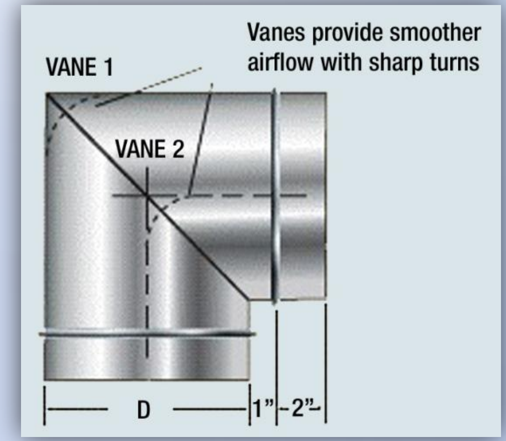
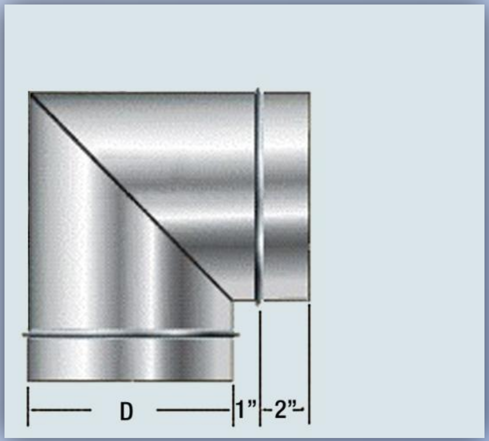
Design Considerations

Fitting Types

Elbows

- Mitered – vanes
- Mitered – no vanes





Design Considerations

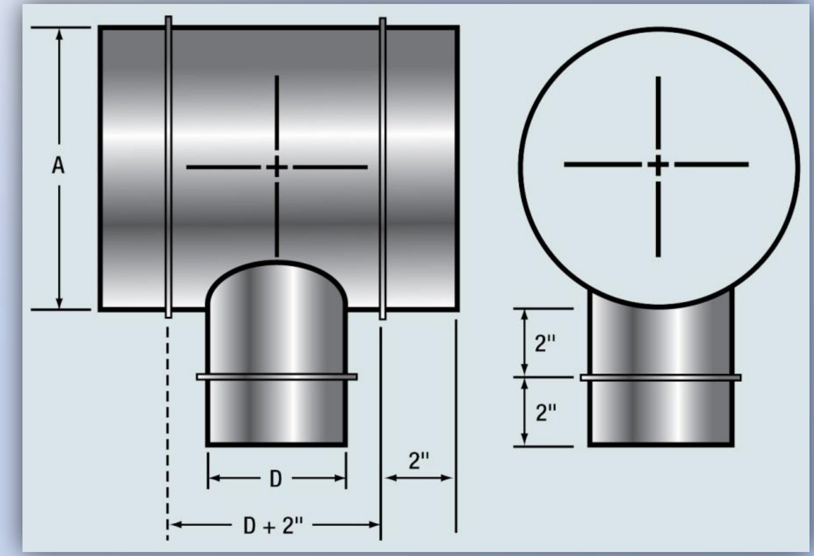
click to play video

Design Considerations

Fitting Types

Divided Flow

- Straight Tee

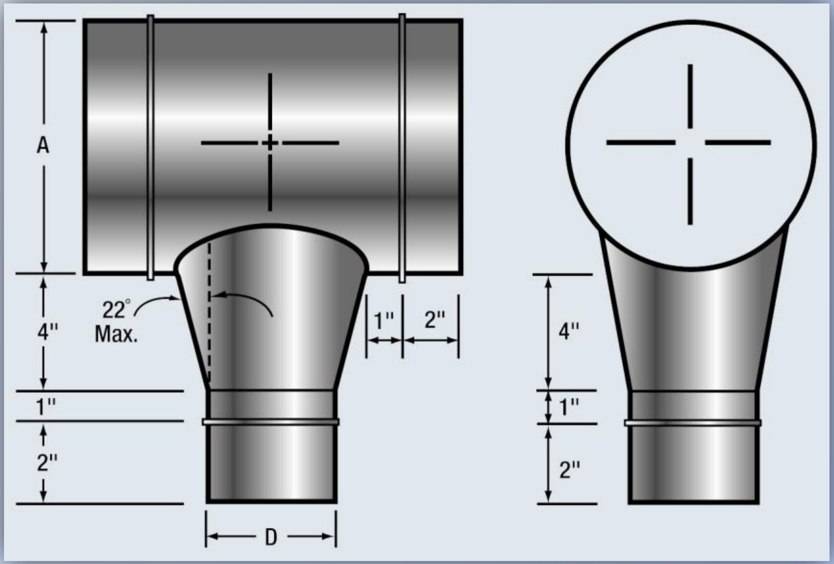


Design Considerations

Fitting Types

Divided Flow

- Conical Tee

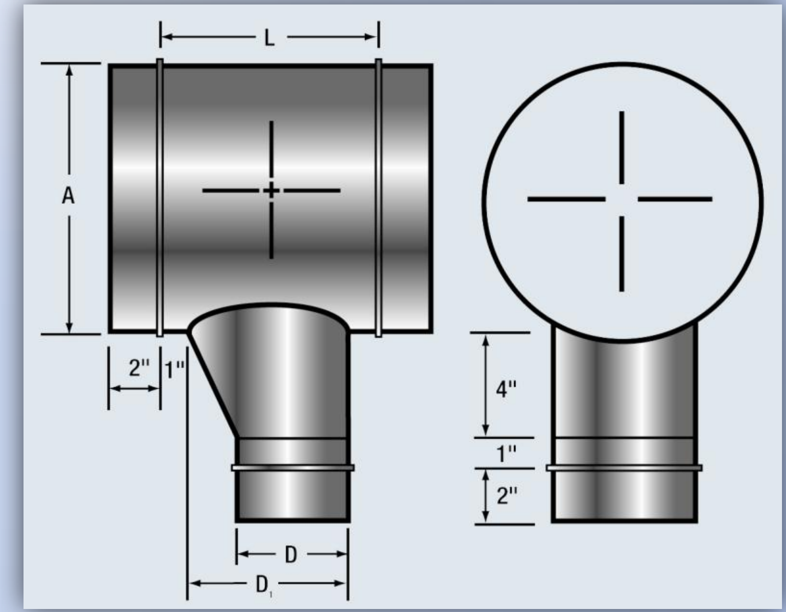


Design Considerations

Fitting Types

Divided Flow

- LoLoss™ Tee

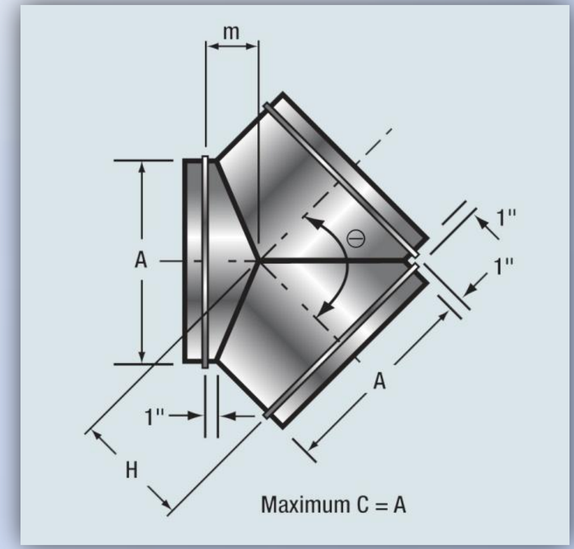


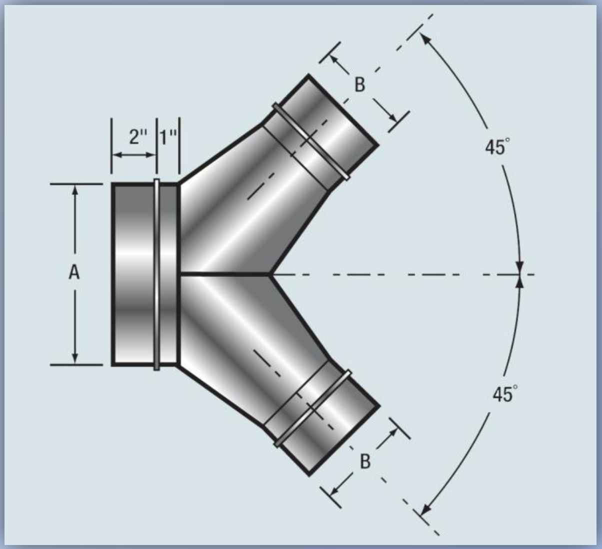
Design Considerations

Fitting Types

Divided Flow

- Y-Branch
- Reducing Y-Branch



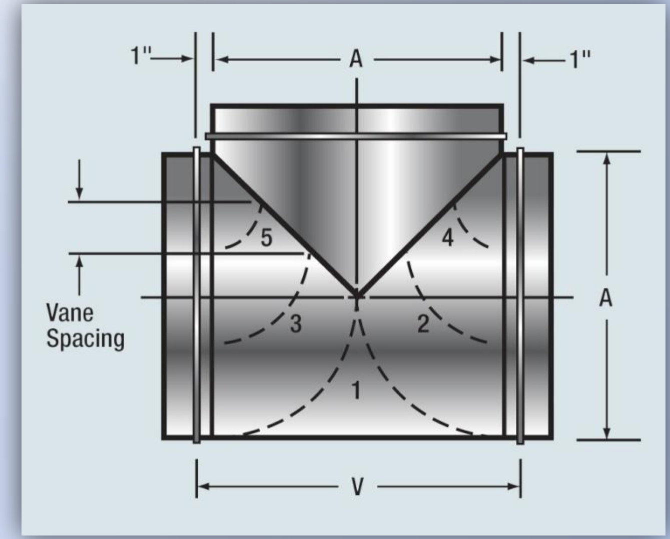


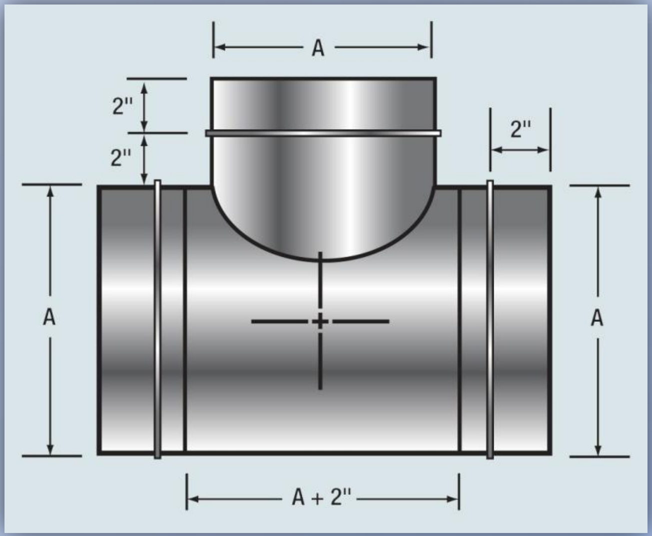
Design Considerations

Fitting Types

Divided Flow

- Bullhead Tee – vanes
- Bullhead Tee – no vanes





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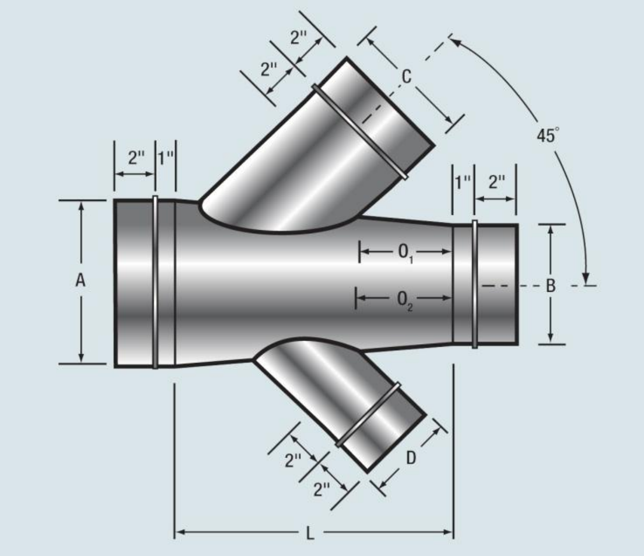
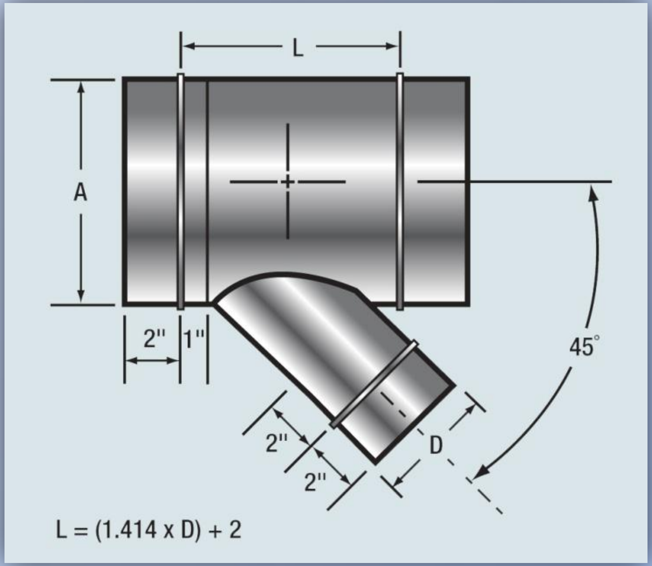
Design Considerations

Fitting Types

Divided Flow

- Laterals





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Design Considerations

Fitting Types

Converging Flow

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Design Considerations

Supply Design Methods

1. Equal friction
2. Static regain
3. Velocity reduction
4. “T” method

Design Considerations

Exhaust/Return Design Methods

1. Exhaust
   a. Constant velocity
   b. Equal friction

2. Return
   a. Equal friction
   b. Velocity reduction

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Energy Consumption

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Energy Consumption

- Factors
  1. cfm, sp, efficiency, fuel cost, and hours
  2. Operation cost vs aspect ratio
- System Annual Operating Cost

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Performance Considerations

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Performance Considerations

Annual Operational Costs

$$\frac{\text{Cost}}{\text{Year}} = \left(\frac{Q_{fan} \times FTP}{8{,}520 \times eff} \right) \times \frac{\text{Hours}}{\text{Year}} \times \frac{\$}{kwh}$$

WHERE:

Cost/Year = system first year operating cost ($)

Q_{fan} = system volume flow rate (cfm)

FTP = system total operating pressure (in wg)

Hours/Year = number of hours the system operates in one year

$/kwh = cost of energy

eff = fan/motor drive combined efficiency

8,520 = conversion factor to kwh (kilowatt hours)

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Sound Control

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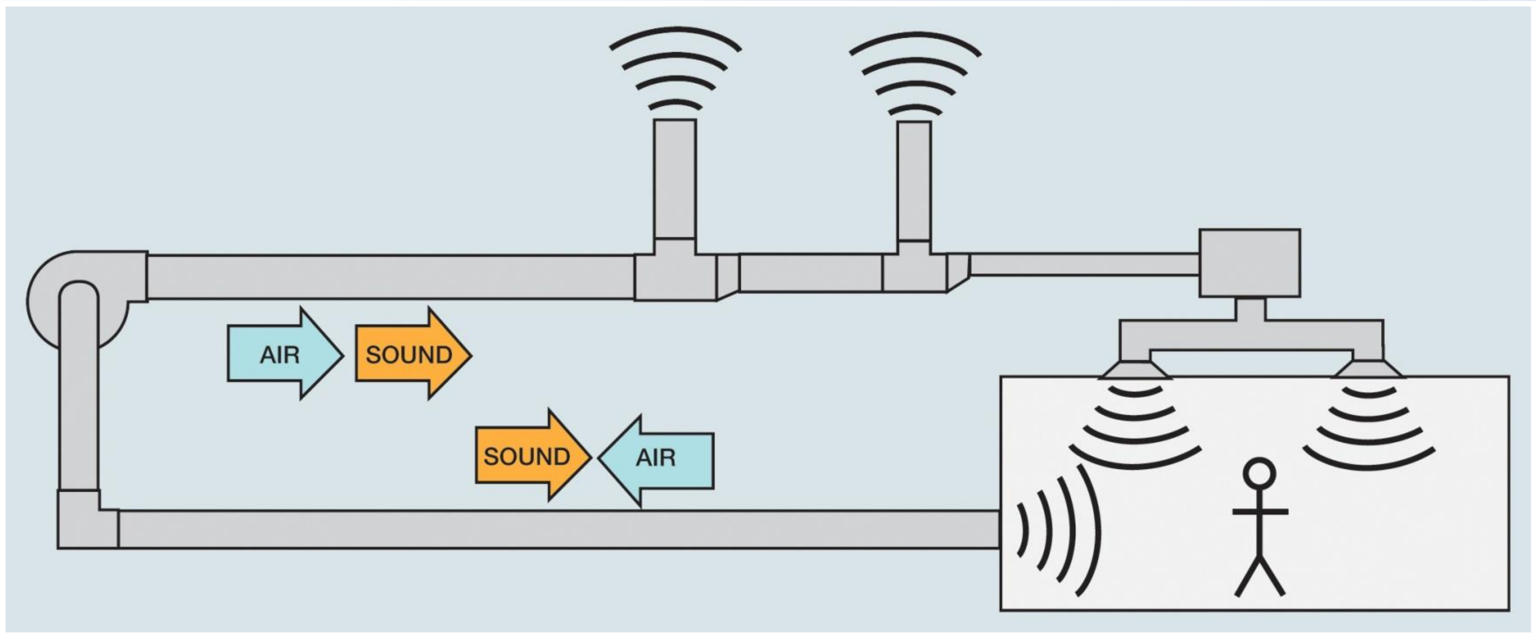
Sound Control

Design Process

1. Determine acceptable noise criteria (NC) rating for the space
2. Determine the sound source spectrum
3. Calculate the resultant sound level criteria
4. Compare resultant sound levels
5. Select the appropriate noise control products to attain the needed NC level

Sound Control

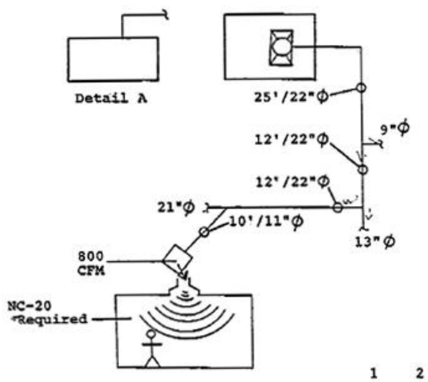
Duct System Acoustics

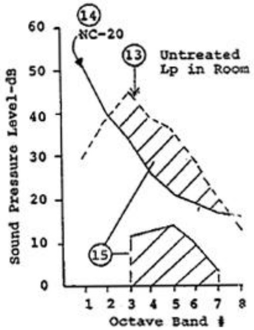


Sound Control

Calculate Resultant Sound Levels

DUCT SYSTEM ACOUSTICS SAMPLE PROBLEM



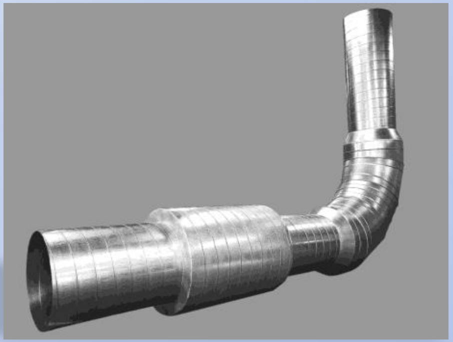


	1 63	2 125	3 250	4 500	5 1000	6 2000	7 4000	8 800C
(1) Estimated Fan Power Level	60	62	63	58	57	52	44	36
(2) Bare Duct Att. - 25'/22"ϕ	-4	-3	-1	-1	-1	-1	-1	-1
(3) 2 Elbows - 22"ϕ Radiused	0	0	0	-2	-4	-6	-6	-6
(4) Power Split - 22"/22"/9"	-1	-1	-1	-1	-1	-1	-1	-1
(5) Bare Duct Att. - 12'/22"ϕ	-2	-1	-1	-1	-1	-1	-1	-1
(6) Power Split 22"/22"/13"	-1	-1	-1	-1	-1	-1	-1	-1
(7) Bare Duct Att. - 12'/22"ϕ	-1	-1	-1	-1	-1	-1	-1	-1
(8) Power Split - 22"/21"/11"	-7	-7	-7	-7	-7	-7	-7	-7
(9) Bare Duct Att. - 10'/11"ϕ	-2	-2	-1	-1	-1	-1	-1	-1
(10) End Reflection	-8	-4	-1	0	0	0	0	0
(11) Lw into Room	34	42	49	43	40	33	25	17
(12) Room Factor Correction	-4	-4	-4	-4	-4	-4	-4	-4
(13) Untreated Lp in Room	30	38	45	39	36	29	21	13
(14) NC-20 Maximum Lp	51	40	33	26	22	19	17	16
(15) Additonal Attenuation Required △ (13)-(14)	-	-	12	13	14	10	4	-

Sound Control

Sound Control Devices

Pressurized enclosure



Round duct silencer

k-27 duct and fittings

Rectangular duct silencers

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Why Leakage Control?

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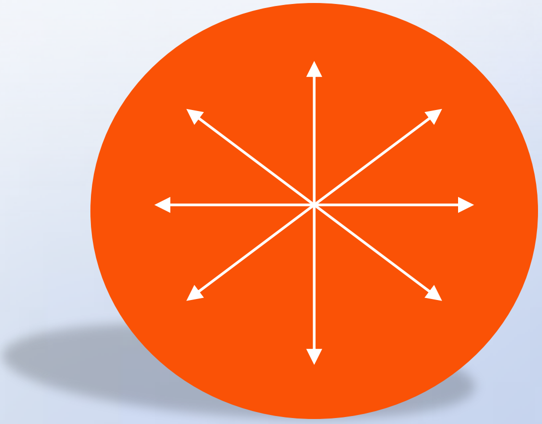
Leakage Control

Performance considerations

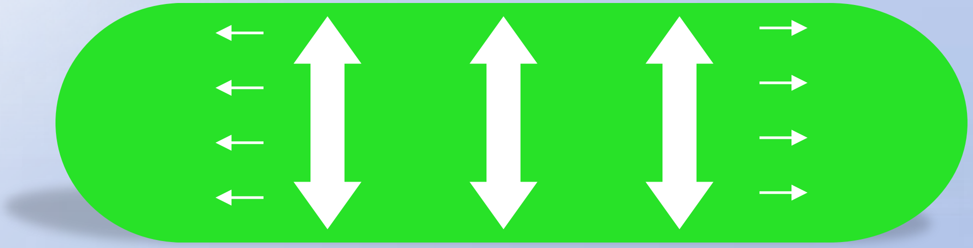
1. Airflow quantities
2. Airflow quality
3. Airflow pressure
4. Energy consumption
5. Annual operational cost
6. Balanced airflow

Fundamentals

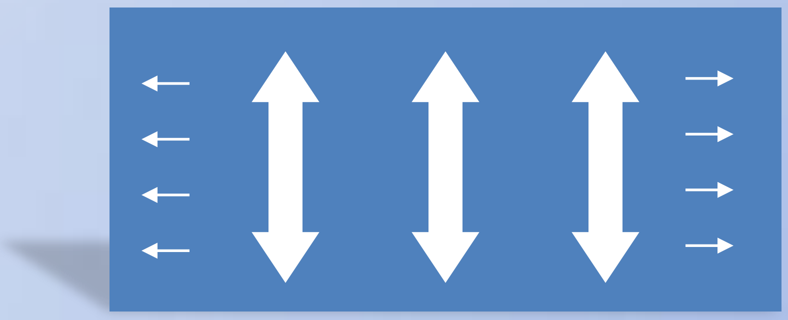
Duct static pressure on various duct shapes



Round Duct



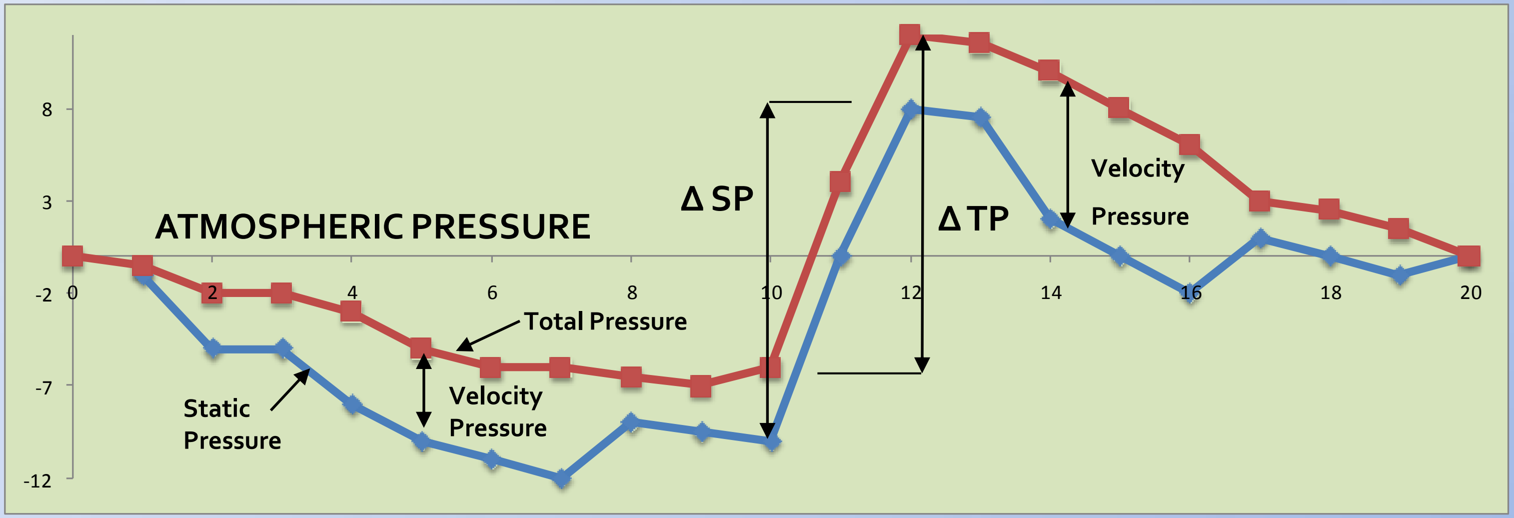
Flat Oval Duct



Rectangular Duct

Fundamentals

Fan and duct pressure changes in duct



What does SMACNA say?

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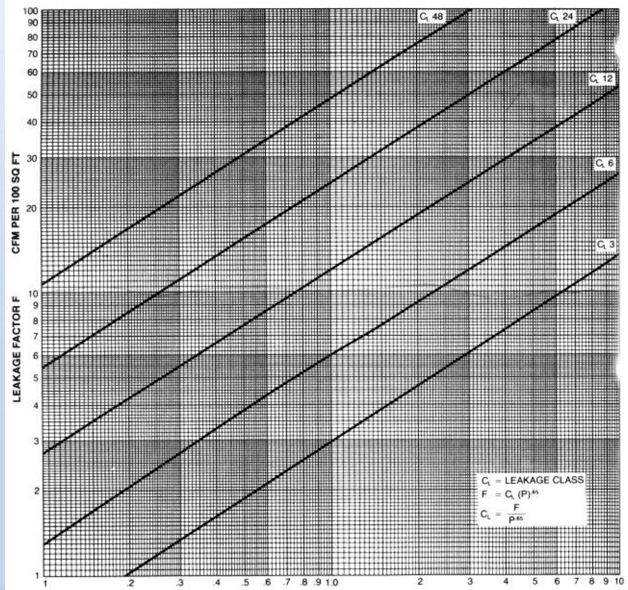
SMACNA

Leakage cfm/100 sq ft vs Test Pressure



PRESSURE IN INCHES OF WATER

SEE TABLE 4-1 FOR ASSOCIATED DUCT CONSTRUCTION CLASS

SEE APPENDIX E FOR TABULAR FORM OF FIGURE 4-1

DUCT LEAKAGE CLASSIFICATION **FIG. 4-1**

SMACNA HVAC Air Duct Leakage Test Manual—1st Ed.

4-2

SMACNA

Leakage Classes

TABLE 4-1
APPLICABLE LEAKAGE CLASSES

DUCT CLASS	1/2", 1", 2" W.G.	3" W.G.	4", 6", 10" W.G.
SEAL CLASS	C	B	A
SEALING APPLICABLE	TRANSVERSE JOINTS ONLY	TRANSVERSE JOINTS AND SEAMS	JOINTS, SEAMS AND ALL WALL PENETRATIONS
LEAKAGE CLASS			
RECTANGULAR METAL	24	12	6
ROUND METAL	12	6	3

NOTES:

1. Leakage classes in Table 4-1 apply when the designer does not designate other limits and has specified Seal Class C for 1/2" and 1" w.g. See text on sealing in the HVAC-DCS manual.
2. Unsealed rectangular metal duct may follow Leakage Class 48.
3. Fibrous glass duct may follow Leakage Class 6 (at 2" w.g. or less).
4. Unsealed flexible duct leakage average is estimated to be Class 30. Sealed nonmetal flexible duct is an average of Class 12.
5. See SMACNA HVAC Duct Systems Design manual Table 5-1 for longitudinal seam leakage rates.
6. Although Seal Class A or B might be assigned for lower pressures, the leakage class may not conform to those associated with the higher pressure. Other construction details influence results.
7. Leakage Class (C_L) is defined as being the leakage rate (CFM/100 S.F.) divided by $P^{.65}$ where P is the static pressure (IN. W.G.). When P is numerically equal to 1" the leakage rate is C_L. See Figure 4-1.
8. The duct pressure classification is not the fan static pressure nor the external static pressure (on an HVAC unit) unless the system designer has made such an assignment in his contract documents. Unless construction class is otherwise specified it means a static pressure classification in the SMACNA HVAC-DCS. Those classifications pertain to maximum operating pressure in the duct as follows:

   0.5" w.g. maximum
   0.6" to 2" w.g. maximum
   1.1" to 2" w.g. maximum
   2.1" to 3" w.g. maximum
   3.1" to 4" w.g. maximum
   4.1" to 6" w.g. maximum
   6.1" to 10" w.g. maximum

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4-3

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Duct Geometry and Leakage

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Duct Geometry and Leakage

Typical Duct Geometries

1. Round
2. Flat oval
3. Rectangular

SMACNA Leakage Class at Seal Class A

1. Round: 3 cfm/100 sq ft
2. Flat oval: 3 cfm/100 sq ft
3. Rectangular: 6 cfm/100 sq ft

WHAT IS WRONG WITH THIS PICTURE???

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Duct Geometry and Leakage

Cost of Leakage

$$\frac{Cost}{Year} = \left(\frac{Q_{fan} \times FTP}{8{,}520 \times eff}\right) \times \frac{Hours}{Year} \times \frac{\$}{kwh}$$

WHERE:

Cost/Year = system first year operating cost ($)

Q_{fan} = system volume flow rate (cfm)

FTP = system total operating pressure (in wg)

Hours/Year = number of hours the system operates in one year

$/kwh = cost of energy

eff = fan/motor drive combined efficiency

8,520 = conversion factor to kwh (kilowatt hours)

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Duct Geometry and Leakage

Impact of Leakage

Energy Cost Example									
Cost/year = [CFM x TP]/[8,520 x Eff] x Hours/Year x $/kwh									
Leakage %	CFM (cu ft/min)	RPM (rev/min)	SP (in wg)	VP (in wg)	TP (in wg)	BHP (hp)	Oper/yr ($/year)	Extra Oper/yr ($/year)	Increased Oper/yr (%)
0	20,000	530	1.5	0.39	1.89	6.68	5,600	0	0
5	21,000	557	1.65	0.43	2.08	7.73	6,481	881	15.7
10	22,000	583	1.82	0.47	2.29	8.89	7,452	1,852	33.3
15	23,000	610	1.98	0.52	2.50	10.16	8,515	2,915	52.1
20	24,000	636	2.16	0.56	2.72	11.54	9,675	4,075	73
30	26,000	689	2.54	0.66	3.20	14.68	12,301	6,701	120
Assumed:	electric rate $0.15		0.15						
	52 wk x 6 d/wk x 24 hr		7,488 hr						
	fan/motor eff (%)		89						
	initial velocity		2,501						

Duct Geometry and Leakage

Suggested Leakage Levels

Leakage Levels

Test Pressure (in wg)	SMACNA Class 3 (cfm/100 sq ft)	Leakage (%)
0-1	3.0	2
1-2	4.6	2
2-3	6.0	1
3-4	7.4	1
4-6	9.6	0.5
6-10	13.5	0.5

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Duct Geometry and Leakage

Leakage Specification (minimum requirements)

1. Test pressure (in wg)
2. Allowable leakage (cfm/100 sq ft)
3. Test procedure
4. Report of findings
5. Certified test equipment

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Exposed Ductwork

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Exposed Ductwork

A. Duct types

1. Round
2. Flat oval
3. Rectangular
4. Other: semi/quarter round, triangular

B. Elbow types

1. Pressed
2. Pleated
3. Gored

C. Divided flow fittings

1. Straight tee
2. Conical tee
3. LoLoss™ tee

Exposed Ductwork

Institutional

Exposed Ductwork

Commercial

Exposed Ductwork

Industrial

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Exposed Ductwork

Controlled Air Distribution

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Exposed Ductwork

High Bay and Boot Taps

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Material Considerations

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Material Considerations

Metallic

1. Galvanized steel, G60/G90/phosp.
2. Stainless steel, 304/316/finish #2d/#4
3. Aluminum, type 3003-H14
4. PVC-coated
5. SilverGuard™ antimicrobial

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Material Considerations

Non-metallic

1. FRP (fiberglass reinforced plastic)
2. Fibrous duct board
3. Flexible
4. Dry wall
5. Fabric, open or closed weave

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Sealants and Adhesives

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Sealants and Adhesives

Types

1. Water based
2. Solvent based

Common Properties

1. No surface preparation
2. +/- 40 in wg
3. High solids content
4. Curing time 24-48 hours

Sealants and Adhesives

LEED Applications

1. Solvent/water based
2. Low VOCs <250 g/l

Outside/Underground Applications

1. Solvent based
2. Resistant to weather and ultraviolet rays

Tapes

1. 2-part tape/sealant
2. +/- 40 in wg
3. Flexible
4. Butyl gasket for flange face

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Diffusers, what type?

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Diffusers, what type?

Exposed Features

Diffusers, what type?

Exposed Features

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Specification Considerations

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Specification Considerations

1. SMACNA duct construction standards 2005
2. Joint types
3. Hanging and support
4. Handling/shipping/cleaning
5. Finish welding/pacification/grinding
6. Double-wall and lining
7. Painting
8. Material types
9. Leakage testing

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Conclusions

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Conclusions

1. Fundamentals
2. Design methods
3. Energy consumption
4. Sound control
5. Leakage control
6. Exposed ductwork
7. Materials
8. Specifications