

SYSTEM EFFECT

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Introduction

System Effect theory AMCA 201

Installation Guideline

Fault & Fixed

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Introduction

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(CUSTOMER CALL)

...I have some trouble with your fan is not sufficient flow and pressure following the design...

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(CUSTOMER CALL)

I ordered 3000 cfm 1 in-wg. Fan

Measurement is 2000 cfm 0.75 in-wg

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(FAN MAUFACTURING SAID)

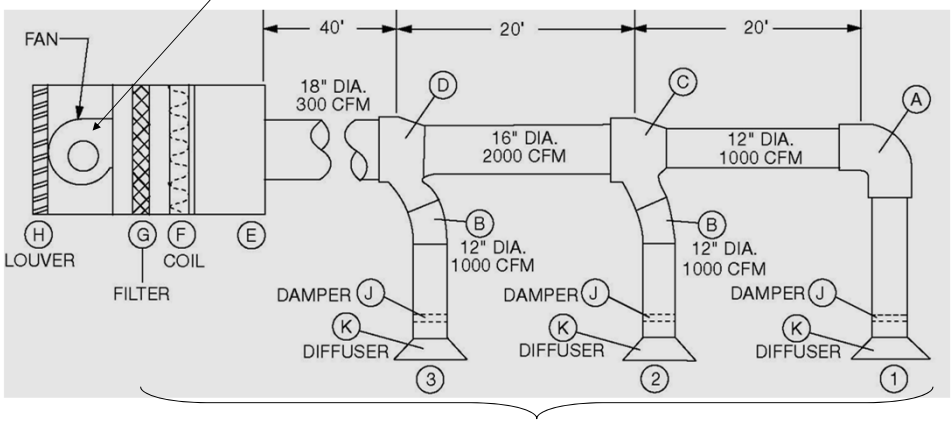
Our fan of course have no fault..... product were certified by AMCA

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?

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Ductwork Example



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Causes of Non-Performing Systems

- System resistance miscalculated.
- Fan not properly selected.
- Defective fan (or fan rating).
- ***There is a system effect loss.***

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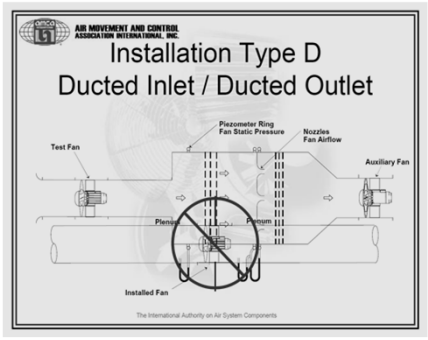
Fan Manufacturer's Responsibility

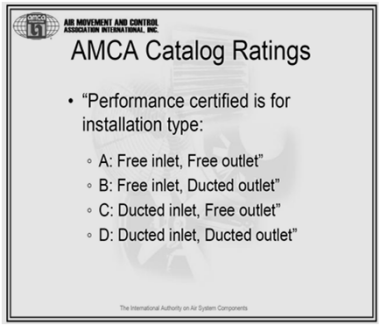
- Provide accurate fan performance ratings.
- Provide a fan built within tolerance so that it is capable of meeting its rating.

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What is System Effect ?

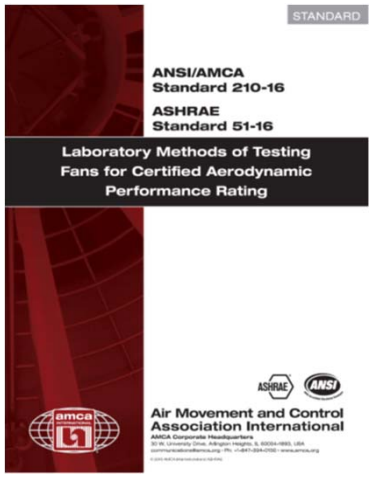
- The difference in performance between a fan tested in the laboratory and one tested in a real installation.





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AMCA Publication 210-16



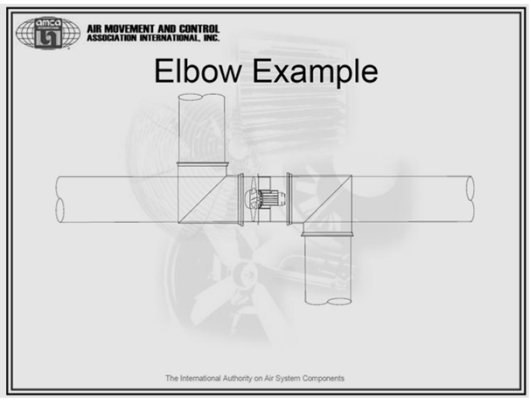
- Defines standard methods of testing fans for rating



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Definition of System Effect

- Fans in actual systems are often less than ideal.



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Definition of System Effect

- Fan ratings are established using AMCA 210 test codes that are close to ideal conditions.
- Fans in actual systems are often less than ideal.
- The difference in performance for the same fan tested in both conditions is the “System Effect”.

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What is System Effect ?

System Effects Defined:

- ***Anything you place in close proximity before or after the fan that effects the cataloged performance.***

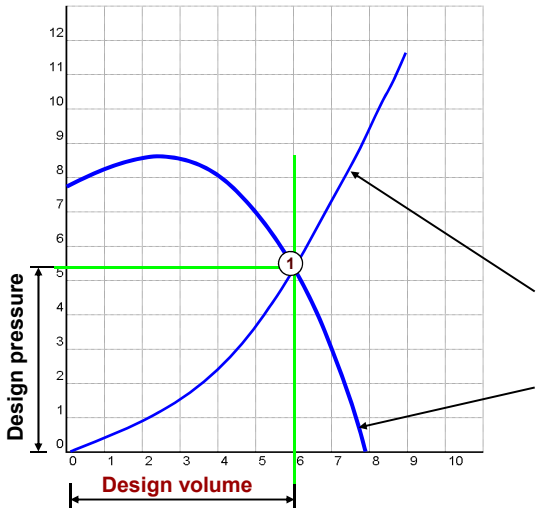
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What System Effect is Important?

- **Can decrease performance**
- **Can cause excess vibration**
- **Can cause excess noise**
- **Can require more energy (HP) to achieve rated performance**
- **Takes time to determine and understand**

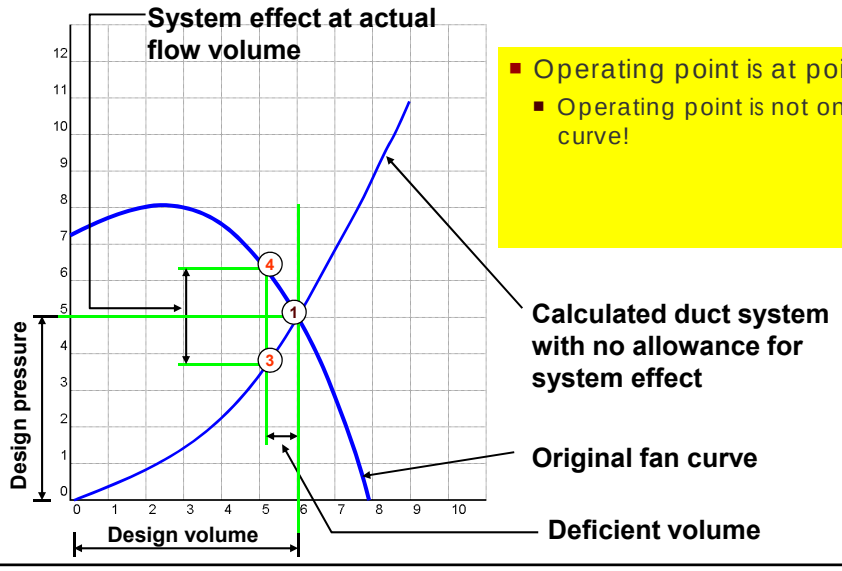
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Normal System Performance



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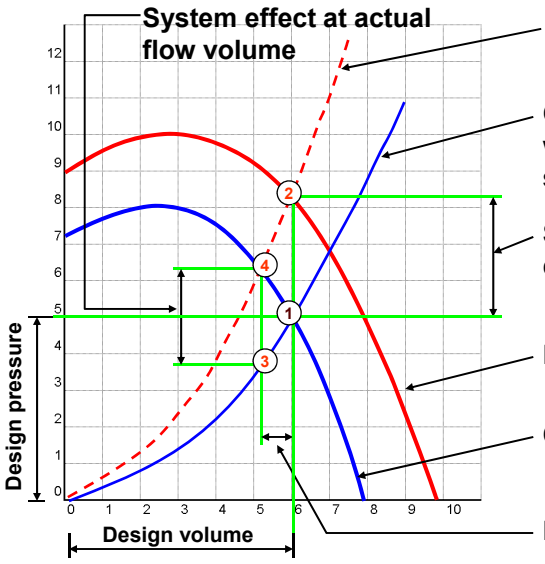
Deficient Performance With System Effect



- Operating point is at point 3
  - Operating point is not on fan curve!

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Correcting For System Effect



Actual duct system with system effect

Calculated duct system with no allowance for system effect

System effect loss at design volume

New fan curve

Original fan curve

Deficient volume

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AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.

Fan Laws for Speed Change

$$Q_c = \left(\frac{N_c}{N}\right) Q$$ Q, Fan Airflow Rate

$$P_c = \left(\frac{N_c}{N}\right)^2 P$$ P, Fan Pressure

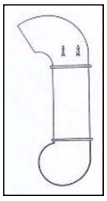
$$H_c = \left(\frac{N_c}{N}\right)^3 H$$ H, Fan Power

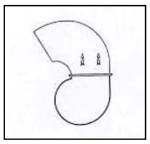
The International Authority on Air System Components

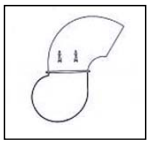
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Conclusion from AMCA VDO

OUTLET







Vp = 1" | Vp = 0.85" | Vp = 0.7"

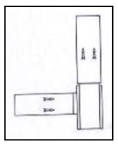
Velocity Pressure	Velocity (fpm)	Q (%)	N rpm (%)	N' rpm (%)	Power (kW) Increased (%)
1.00"	4005	100	100	100	-
0.85"	3692	92.2	100	108 (100/92.2)	26 $(1.08)^3$
0.70"	3350	83.6	100	120 (100/83.6)	73 $(1.20)^3$

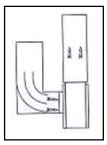
Note :
1) N' = New fan speed to achieve design capacity
2) Velocity Pressure = $(V/4005)^2$ Inch -wg.
V = fpm
3) Fan law
$P1 / P2 = (N1/N2)^3$
P = Power (kW)
N = Fan speed (rpm)

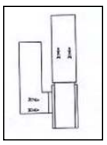
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Conclusion from AMCA VDO

INLET







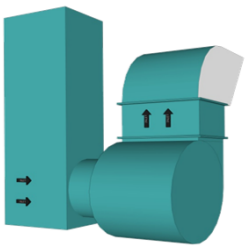
Vp = 1" | Vp = 0.75" | Vp = 0.6"

Velocity Pressure	Velocity (fpm)	Q (%)	N rpm (%)	N' rpm (%)	Power (kW) Increased (%)
1.00"	4005	100	100	100	-
0.75"	3468	86.6	100	115 (100/86.6)	52 $(1.15)^3$
0.60"	3102	77.5	100	129 (100/77.5)	115 $(1.29)^3$

Note :
1) N' = New fan speed to achieve design capacity
2) Velocity Pressure = $(V/4005)^2$ inch-wg.
V = fpm
3) Fan law
$P1 / P2 = (N1/N2)^3$
P = Power (kW)
N = Fan speed (rpm)

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Worse Case Inlet & Outlet



Vp = 0.36"

Velocity Pressure	Velocity (fpm)	Q (%)	N rpm (%)	N' rpm (%)	Power (kW) Increased (%)
1.00"	4005	100	100	100	-
0.36	2400	60	100	167 (100/60)	366 $(1.67)^3$

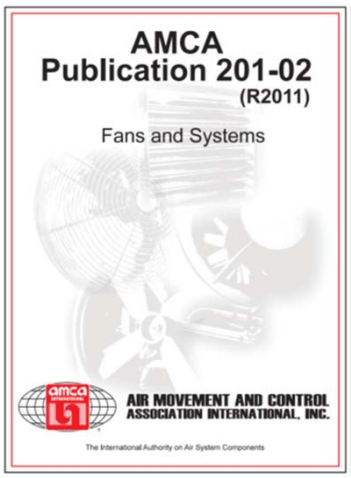
Note :
1) N' = New fan speed to achieve design capacity
2) Velocity Pressure = $(V/4005)^2$ inch-wg.
V = fpm
3) Fan law
$P1 / P2 = (N1/N2)^3$
P = Power (kW)
N = Fan speed (rpm)

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SYSTEM EFFECT THEORY

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AMCA Publication 201-02



- The bible of system effects
- Generated from ASHRAE funded research

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Purpose of Discussion

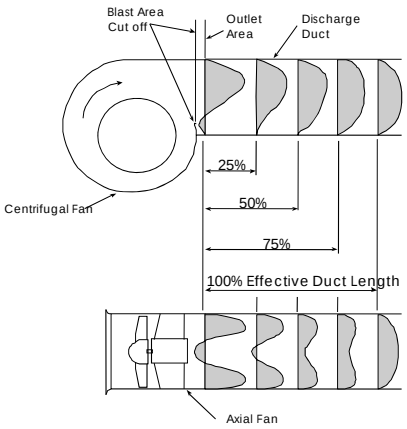
- Aimed primarily at the fan system designer

There are two goals:

- Avoid poor fan system configurations
- When optimum conditions cannot be met, use the “system effect” factors to estimate any losses during system design.

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Effective Duct Length



Avoid Installed

- Elbow
- Silencer
- Damper

Avoid Measure Air Volume

Function

- Uniform
- Static pressure regain
- Noise

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De (Effective Duct Length)

Effective Duct Length

Effective Duct Length = 2.5 Duct Diameters for 2,500 FPM or less

Add 1 duct diameter for each additional 1,000 FPM

For rectangular ducts, the equivalent duct diameter is

(4 x width x length / 3.14) ^ 0.5

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Thumb Rules

- Minimum of 2.5 Duct Diameters on Outlet,
- Minimum 3 to 5 Duct Diameters on Inlet, and
- Avoid Inlet Swirl

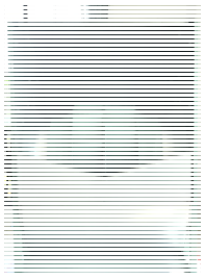
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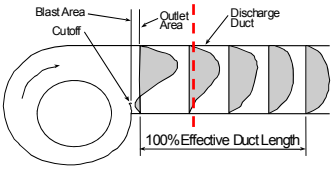
How are the Losses Quantified ?

- AMCA 201 publishes data for a variety of configurations
- Most identify a “Loss Curve” which is based on the configuration and identified by a letter
- Most also need the air velocity as a parameter.

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System Effect Curves for Outlet Ducts - Centrifugal Fans

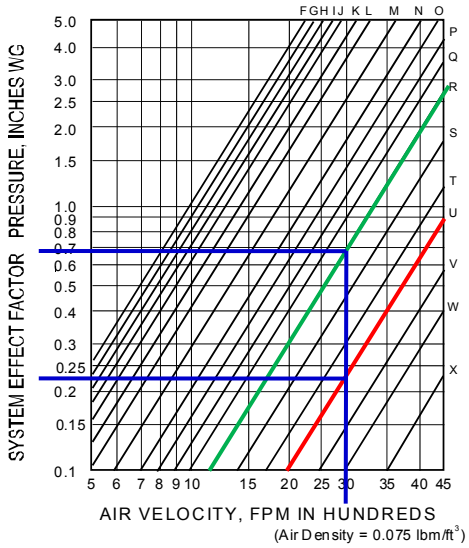




Blast Area / Outlet Area	System Effect Curve				
	No Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
0.4	P	R-S	U	W	–
0.5	P	R-S	U	W	–
0.6	R-S	S-T	U-V	W-X	–
0.7	S	U	W-X	–	–
0.8	T-U	VW	X	–	–
0.9	W-W	W-X	–	–	–
1.0	–	–	–	–	–

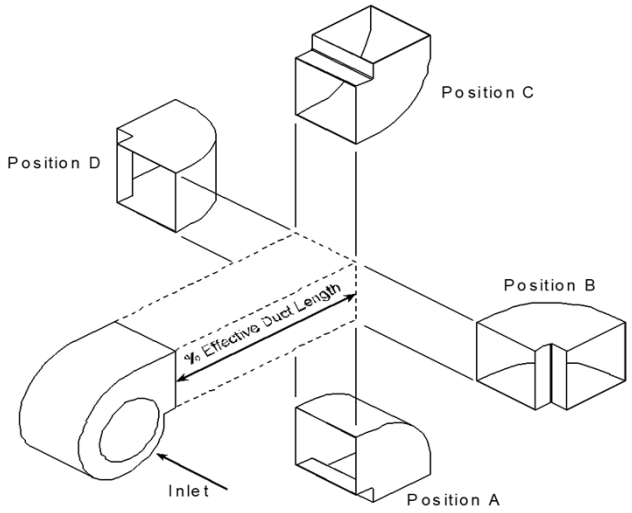
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System Effect Curve



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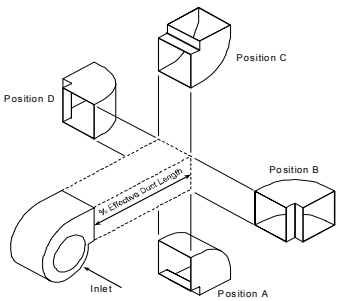
Outlet Elbows - Centrifugal Fans



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System Effect Curves for SWSI Fans

Blast Area Outlet Area	Outlet Elbow Position	No Outlet Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
0.4	A	N	O	P-Q	S	
	B	M-N	N	O-P	R-S	
	C	L-M	M	N	Q	
	D	L-M	M	N	Q	
0.5	A	O-P	P-Q	R	T	
	B	N-O	O-P	Q	S-T	N
	C	M-N	N	O-P	R-S	O
	D	M-N	N	O-P	R-S	
0.6	A	Q	Q-R	S	U	S
	B	P	Q	R	T	Y
	C	N-O	O	Q	S	S
	D	N-O	O	Q	S	T
0.7	A	R-S	S	T	V	E
	B	Q-R	R-S	S-T	U-V	M
	C	P	Q	R-S	T	
	D	P	Q	R-S	T	E
0.8	A	S	S-T	T-U	W	F
	B	R-S	S	T	V	F
	C	Q-R	R	S	U-V	E
	D	Q-R	R	S	U-V	C
0.9	A	T	T-U	U-V	W	T
	B	S	S-T	T-U	W	
	C	R	S	S-T	V	F
	D	R	S	S-T	V	A
1	A	T	T-U	U-V	W	C
	B	S-T	T	U	W	T
	C	R-S	S	T	V	O
	D	R-S	S	T	V	R

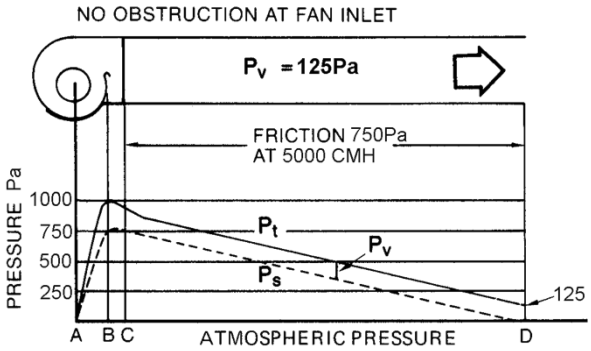


For DWDI fans determines SEF using the curve for SWSI fans. Then apply the appropriate multiplier from the tabulation below

MULTIPLIERS FOR DWDI FANS
ELBOW POSITION A, C = ΔP X 1.00
ELBOW POSITION B = ΔP X 1.25
ELBOW POSITION D = ΔP X 0.85

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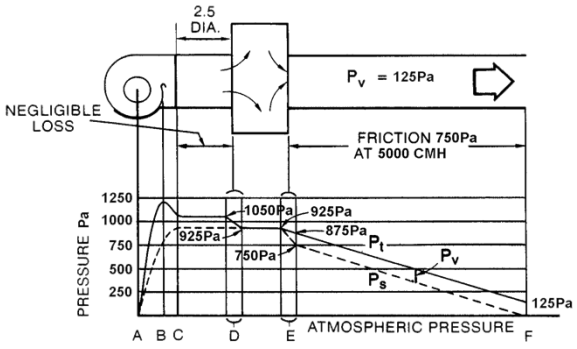
PRESSURE GRADIENTS – Fan as Tested



C-D	duct friction	750 Pa (duct design)
A	free inlet	0 Pa (no SEF)
B-C	outlet with straight duct attached for 2 or more dia.	0 Pa (no SEF)
REQUIRED Fan Ps		750 Pa

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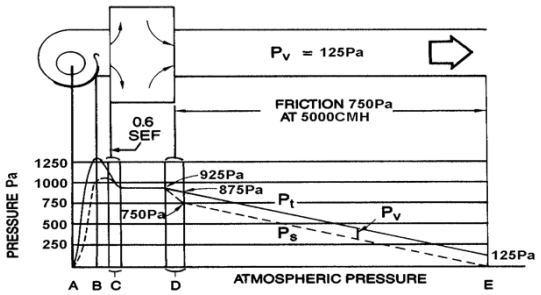
PRESSURE GRADIENTS – Plenum Effect



E-F	duct friction at 5000CMH (Q)	750 Pa (duct design)
E	contraction loss-plenum to duct	50 Pa (part of duct system)
E	Ps energy required to create velocity at E	125 Pa (part of duct system)
D	Pv loss (also Pt loss) at D as result of air velocity decrease Ps does not change from duct to plenum at D	0 Pa
C-D	outlet duct on fan as tested	0 Pa
REQUIRED Fan Ps		925 Pa

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PRESSURE GRADIENTS – Abrupt Expansion at Fan Outlet



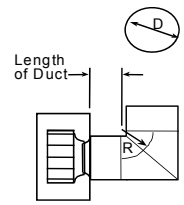
D-E	duct friction at 5000CMH (Q)	750 Pa (duct design)
D	contraction loss-plenum to duct	50 Pa (part of duct system)
D	Ps energy required to create velocity at D	125 Pa (part of duct system)
B-C	SEF	150 Pa
B-C	Pv loss (also Pt loss) at C as result of air velocity decrease Ps does not change from duct to plenum at C	0 Pa
	REQUIRED Fan Ps	1075 Pa

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System Effect on round inlet ducts

System Effect Curves

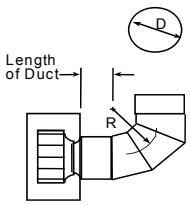
R/D	No Duct	2D Duct	5D Duct
--	N	P	R-S



2 piece mitered round section

System Effect Curves

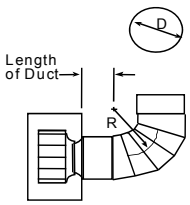
R/D	No Duct	2D Duct	5D Duct
0.5	O	Q	S
0.75	Q	R-S	T-U
1.0	R	S-T	U-V
2.0	R-S	T	U-V
3.0	S	T-U	V



3 piece mitered round section

System Effect Curves

R/D	No Duct	2D Duct	5D Duct
0.5	P-Q	R-S	T
0.75	Q-R	S	U
1.0	R	S-T	U-V
2.0	R-S	T	U-V
3.0	S-T	U	V-W

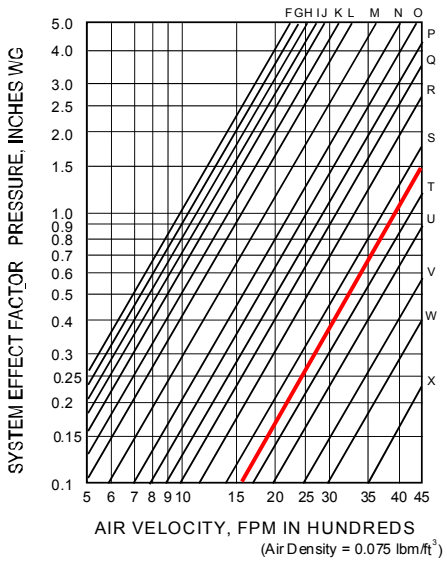


4 or more piece mitered round section

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System Effect Curve

Any velocity greater than 1500 fpm would develop a system effect

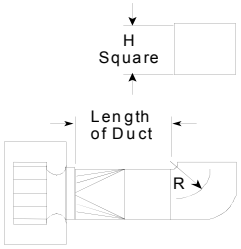


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System Effect - Square elbow and turning vanes

System Effect Curves

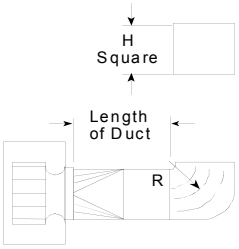
R/D	No Duct	2D Duct	5D Duct
0.5	O	Q	S
0.75	P	R	S-T
1.0	R	S-T	U-V
2.0	S	T-U	V



Square elbow - no turning vanes

System Effect Curves

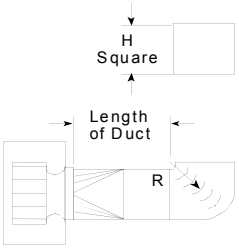
R/D	No Duct	2D Duct	5D Duct
0.5	S	T-U	V
1.0	T	U-V	W
2.0	V	V-W	W-X



Square elbow - long turning vanes

System Effect Curves

R/D	No Duct	2D Duct	5D Duct
0.5	S	T-U	V
1.0	T	U-V	W
2.0	V	V-W	W-X

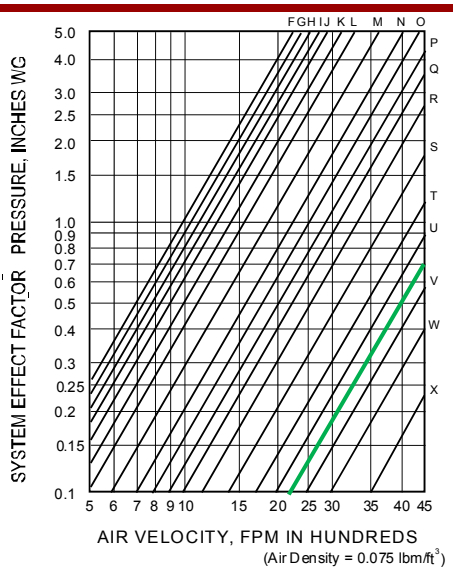


Square elbow - short turning vanes

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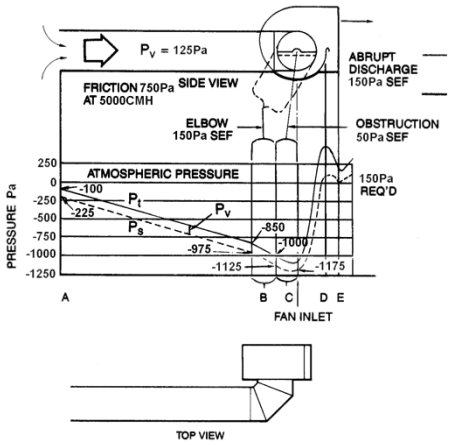
System Effect Curve

Any velocity greater than 2250 fpm would develop a system effect



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PRESSURE GRADIENTS – Exhaust System

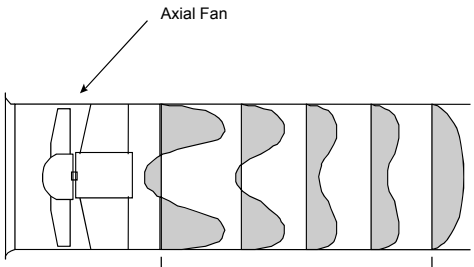


A	Entrance loss-sharp edge duct	100 Pa (duct design)
A-B	Duct friction at 5000CMH	750 Pa (duct design)
B	SEF 1	150 Pa
C	SEF 2	50 Pa
E	Fan Pv	125 Pa
E	SEF 3	150 Pa
REQUIRED Fan Pt		1325 Pa

Fan Ps = fan Pt – fan Pv
Fan Ps = 1325 Pa – 125 Pa
Fan Ps = 1200 Pa

42

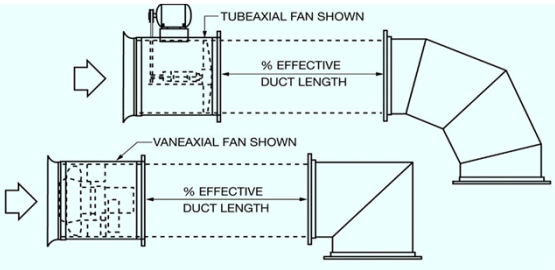
System Effect Curves for Outlet Ducts - Axial Fans



	No Duct	12% Effective Duct	25% Effective Duct	75% Effective Duct	100% Effective Duct
Tube axial Fan	--	--	--	--	--
Vane axial Fan	U	V	W	--	--

43

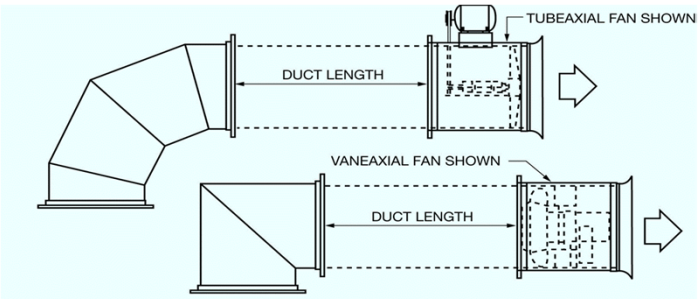
S. E. Curves for Outlet Elbows - Axial



	90# ELBOW	NO DUCT	12% EFFECTIVE DUCT	25% EFFECTIVE DUCT	50% EFFECTIVE DUCT	100% EFFECTIVE DUCT
Tubeaxial Fan	2 & 4 Pc	—	—	—	—	—
Vaneaxial Fan	2 Pc	U	U-V	V	W	—
Vaneaxial Fan	4 Pc	W	—	—	—	—

44

S. E. Curves for Inlet Elbows - Axial



	H/T	90° ELBOW	NO DUCT	0.5 D [1] [2]	1.0 D [1] [2]	3.0D
Tubeaxial Fan	0.25	2 Pc	U	V	W	—
Tubeaxial Fan	0.25	4 Pc	X	—	—	—
Tubeaxial Fan	0.35	2 Pc	V	W	X	—
Vaneaxial Fan	0.61	2 Pc	Q-R	Q-R	S-T	T-U
Vaneaxial Fan	0.61	4 Pc	W	W-X	—	—

45

Review

- Minimum 2.5 duct diameters on Outlet
- Minimum 3 - 5 duct diameters on Inlet
- Avoid inlet swirl

If any of these general rules are broken, make sure to take system effect into account.

46

Installation Guideline

47

Frequently fault

Inlet Conditions

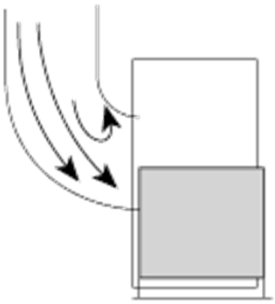
- elbows too close to fan inlet
- abrupt duct transition
- inlet spin due to duct design
- dampers not fully open
- damper locations
- poorly designed guards
- inlet too close to walls or bulkhead
- inlet boxes

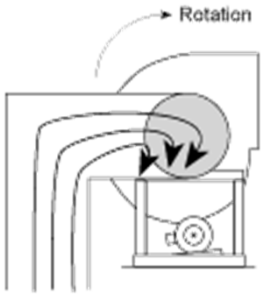
48

Fan Inlet Layout

Centrifugal

Not Recommended



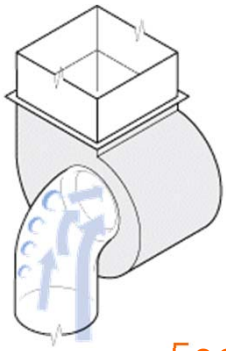


49

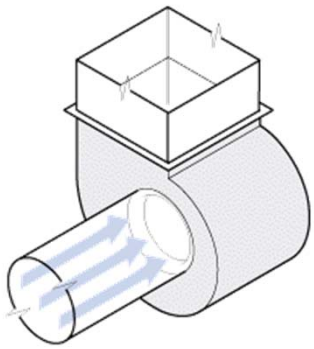
Fan Inlet Layout

Centrifugal

Not Recommended



Recommended



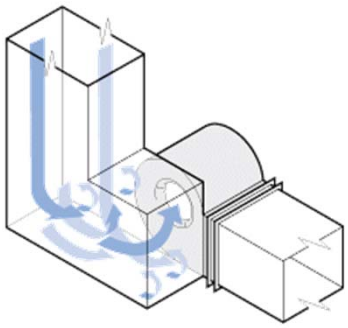
Eccentric inlet flow

50

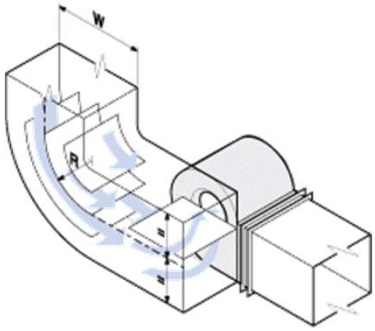
Fan Inlet Layout

Centrifugal

Not Recommended



Recommended



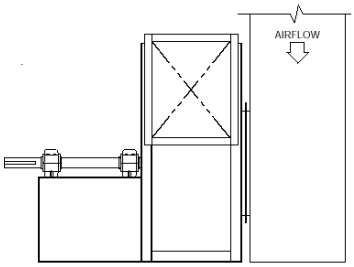
Spinning of air at inlet connection

51

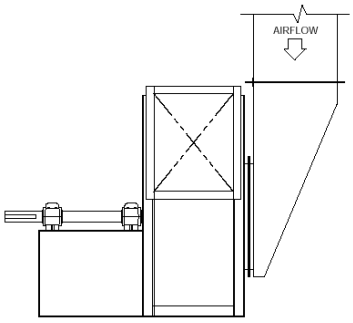
Fan Inlet Layout

Centrifugal

Not Recommended



Recommended

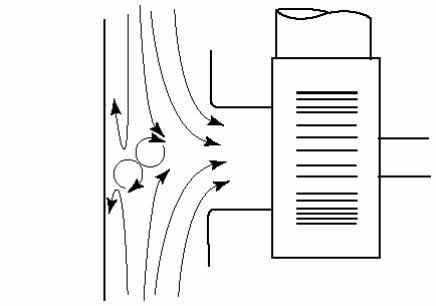


52

Fan Inlet Layout

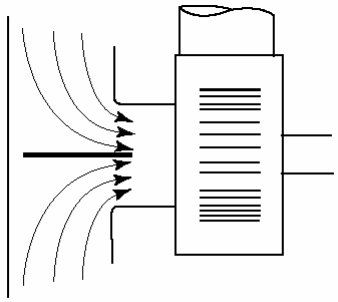
Centrifugal

Not Recommended



Placing the fan inlet too close to the tee can impair fan performance.

Recommended



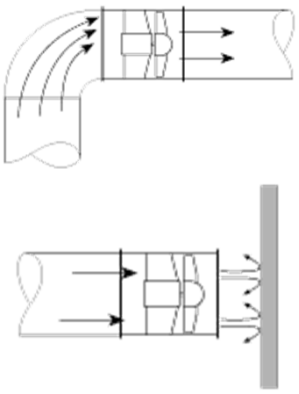
If space constraints force a close gap, the use of a splitter plate is recommended.

53

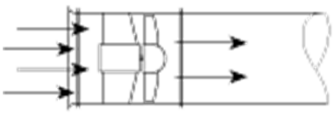
Fan Inlet-Outlet Layout

Axial

Not Recommended



Recommended

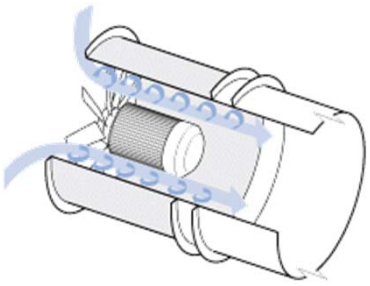


54

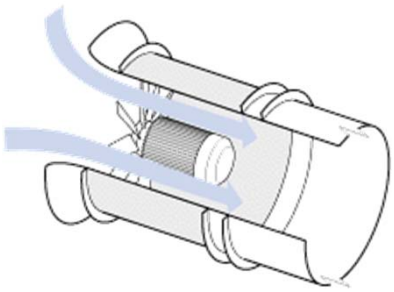
Fan Inlet Layout

Axial

Not Recommended



Recommended



Inlet cones

55

Frequently fault

Outlet Conditions

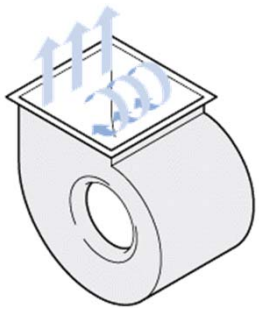
- elbows too close to fan outlet
- abrupt transitions
- free discharge
- damper location
- weatherhoods
- discharge guards
- discharge too close to wall or bulkhead

56

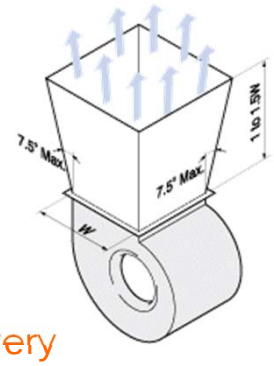
Fan Outlet Layout

Centrifugal

Not Recommended



Recommended



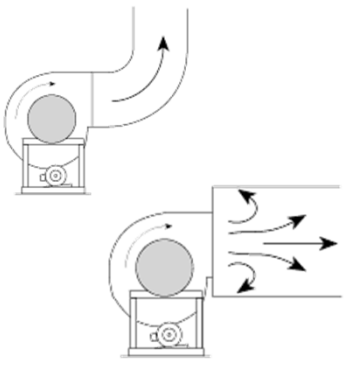
Pressure Recovery

57

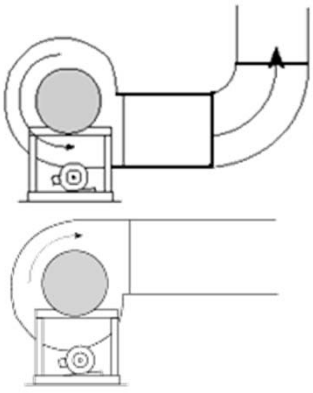
Fan Outlet Layout

Centrifugal

Not Recommended



Recommended



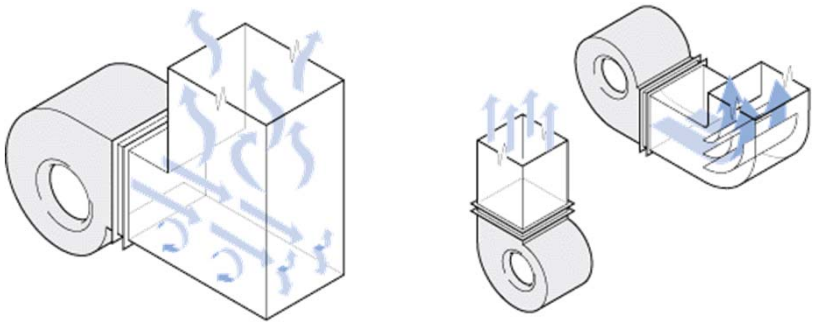
58

Fan Outlet Layout

Centrifugal

Not Recommended

Recommended



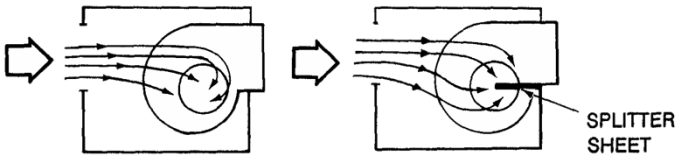
Bends on fan Outlet

59

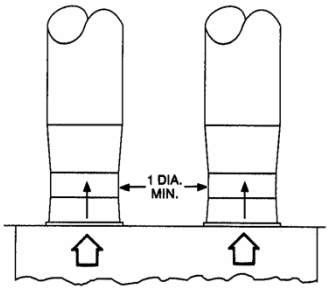
ENCLOSURES

- Plenum and Cabinet Effects

- Fan in Plenum with Non-Symmetrical Inlet



- Parallel installation of axial flow fan

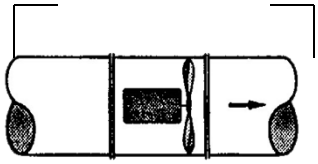


60

Fan Air Direction

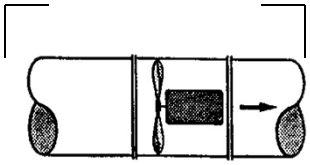
Axial

Not Recommended



Motor upstream of impeller increases turbulence and noise.

Recommended

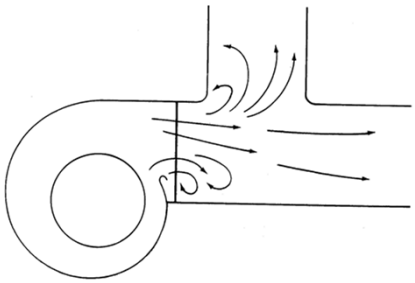


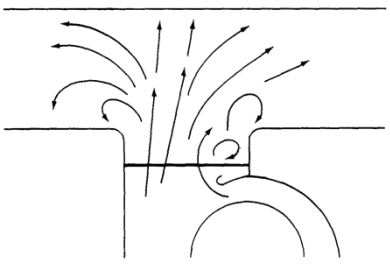
Motor downstream from impeller minimizes turbulence and noise.

61

Duct Branches

- Avoid location of split or duct branch close to fan discharge.
- Provide a straight section of duct to allow for air diffusion.

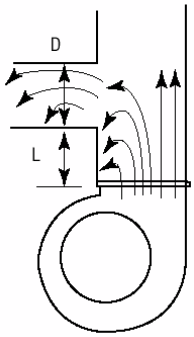




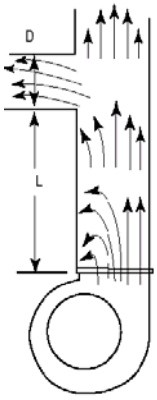
62

Duct Branches

Not Recommended



Recommended



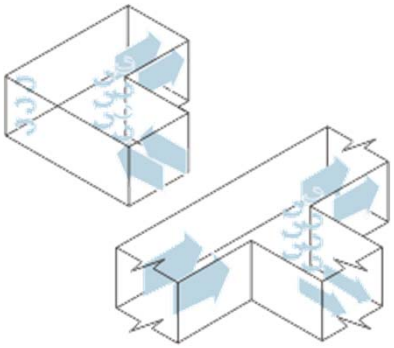
L>3D

63

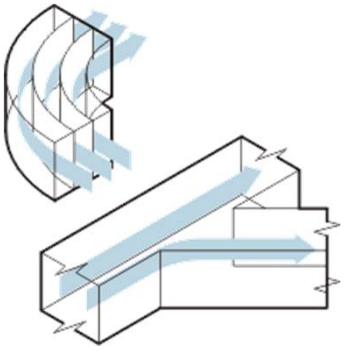
Duct Branches

Duct

Not Recommended



Recommended

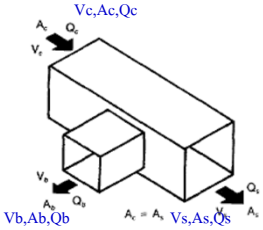


Changing direction of airflow

64

Q. Tee, Rectangular Main and Branch

Vc,Ac,Qc



Branch, Coefficient C (See Note 8)

V_b/V_c	Q_b/Q_c 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.2	1.03								
0.4	1.04	1.01							
0.6	1.11	1.03	1.05						
0.8	1.16	1.21	1.17	1.12					
1.0	1.38	1.40	1.30	1.36	1.27				
1.2	1.52	1.61	1.68	1.91	1.47	1.66			
1.4	1.79	2.01	1.90	2.31	2.28	2.20	1.95		
1.6	2.07	2.28	2.13	2.71	2.99	2.81	2.09	2.20	
1.8	2.32	2.54	2.64	3.09	3.72	3.48	2.21	2.29	2.57

For Main Loss Coefficient (C) see Fitting 14-14A (Page 14.33)

Vb/Vc = 1

Qb/Qc = 0.5

Coefficient C = 1.27

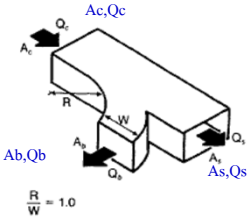
If V = 2000 fpm , VP = $(2000/4005)^2$ = 0.25 inch-wg

Fitting Loss = CxVP = 1.27x0.25 = 0.32 inch-wg

65

W. Wye, Rectangular (15)

Ac,Qc



Branch, Coefficient C (See Note 8)

A_b/A_s	A_b/A_c	Q_b/Q_c 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.25	0.25	0.55	0.50	0.60	0.85	1.2	1.8	3.1	4.4	6.0
0.33	0.25	0.35	0.35	0.50	0.80	1.3	2.0	2.8	3.8	5.0
0.5	0.5	0.62	0.48	0.40	0.40	0.48	0.60	0.78	1.1	1.5
0.67	0.5	0.52	0.40	0.32	0.30	0.34	0.44	0.62	0.92	1.4
1.0	0.5	0.44	0.38	0.38	0.41	0.52	0.68	0.92	1.2	1.6
1.0	1.0	0.67	0.55	0.46	0.37	0.32	0.29	0.29	0.30	0.37
1.33	1.0	0.70	0.60	0.51	0.42	0.34	0.28	0.26	0.26	0.29
2.0	1.0	0.60	0.52	0.43	0.33	0.24	0.17	0.15	0.17	0.21

Ab/As = 1

Ab/Ac = 0.5

Qb/Qc = 0.5

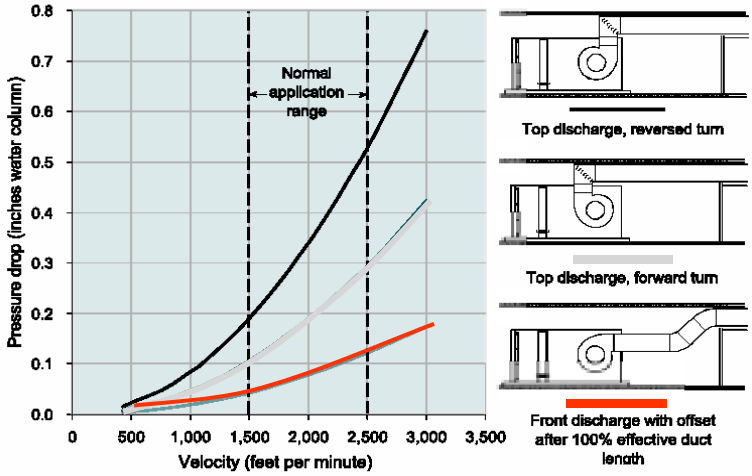
Coefficient C = 0.52

If V = 2000 fpm , VP = $(2000/4005)^2$ = 0.25 inch-wg

Fitting Loss = CxVP = 0.52x0.25 = 0.13 inch-wg

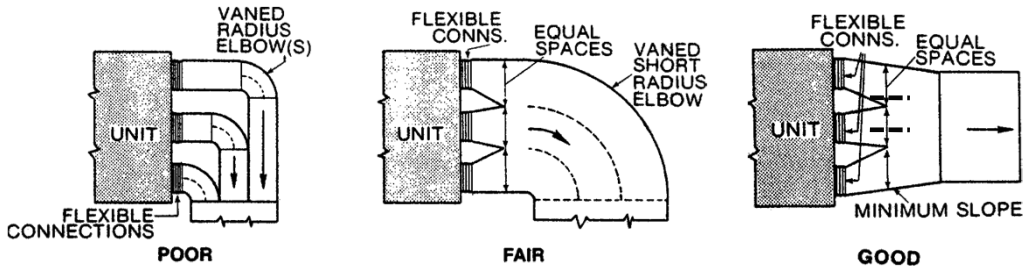
66

Typical HVAC Unit Connection



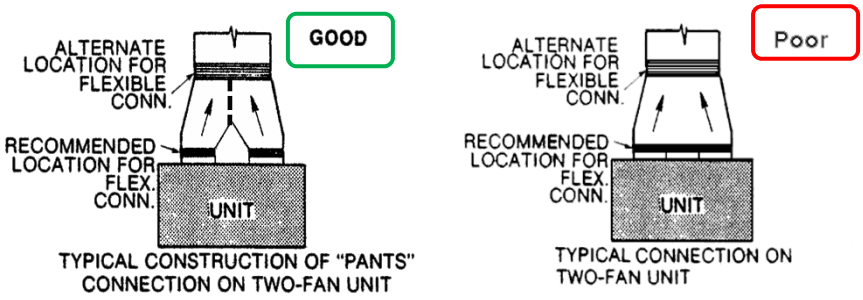
67

Typical HVAC Unit Connection



68

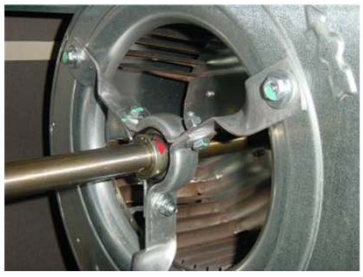
Typical HVAC Unit Connection



69







70





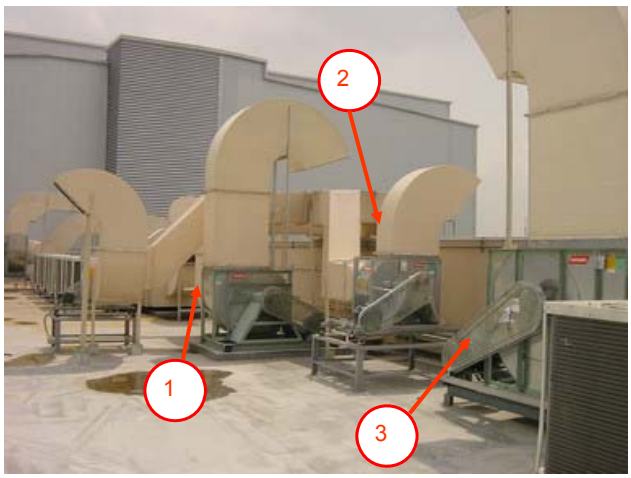
71

Fault & Fixed

72

Poor Outlet

73

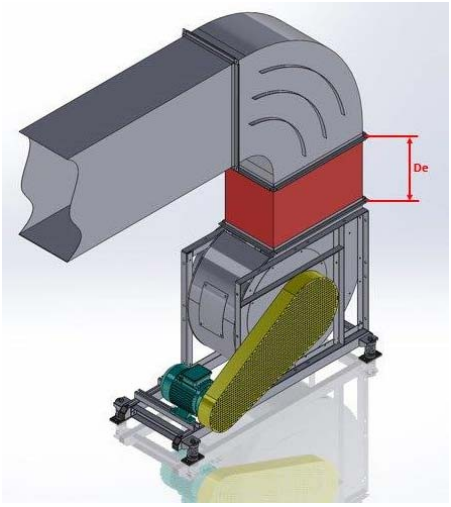


74

Fault



Fixed

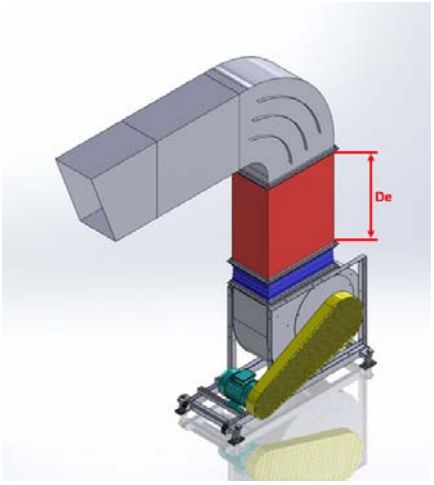


75

Fault



Fixed

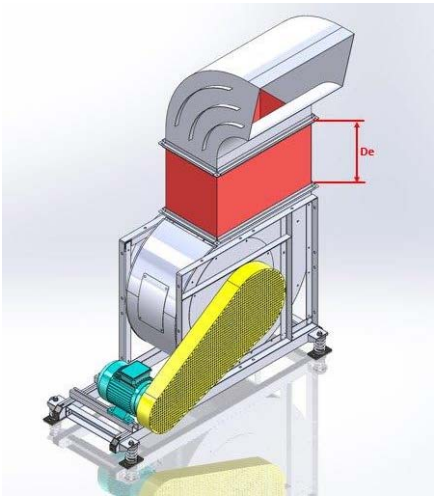


76

Fault



Fixed

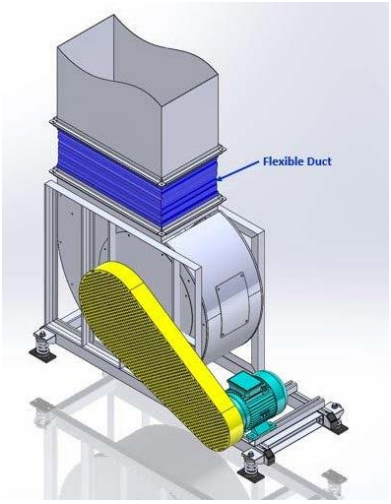


77

Fault



Fixed

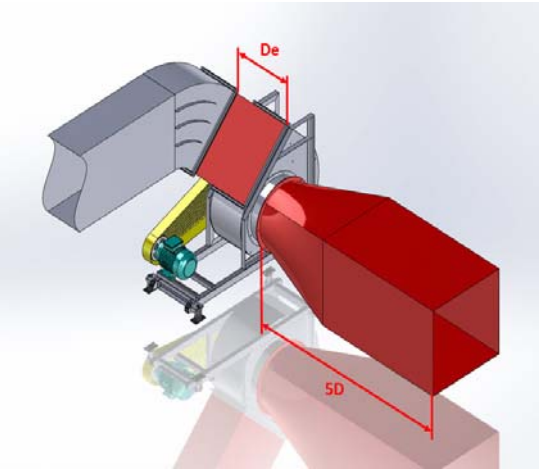


78

Fault



Fixed

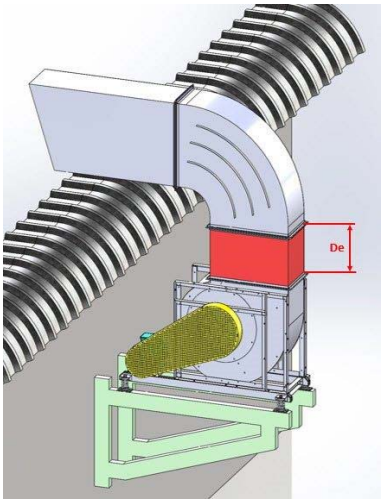


79

Fault



Fixed

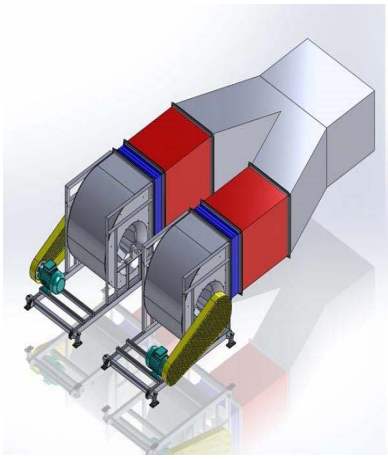


80

Fault



Fixed

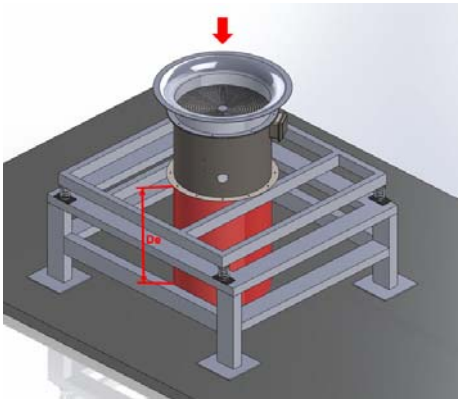


81

Fault



Fixed

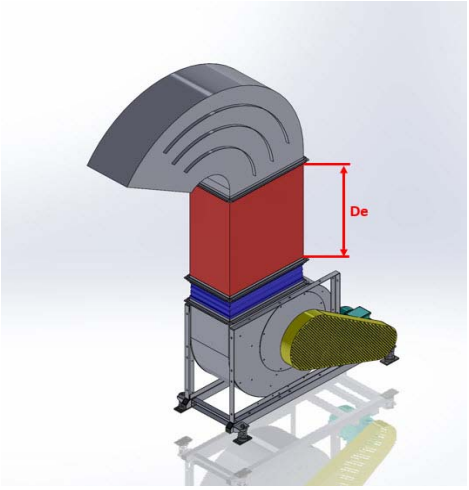


82

Fault



Fixed

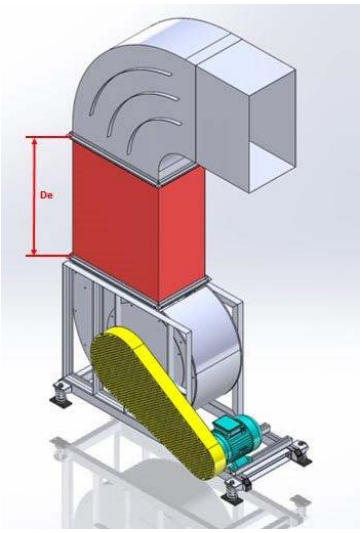


83

Fault



Fixed

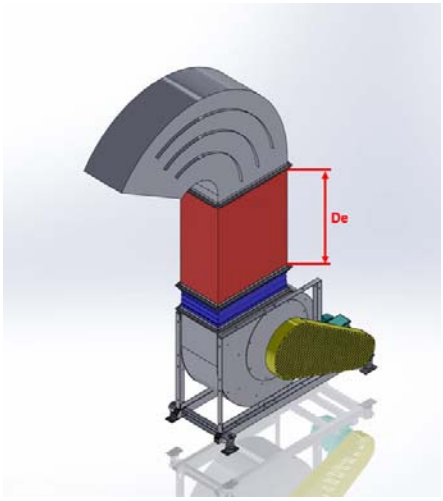


84

Fault



Fixed

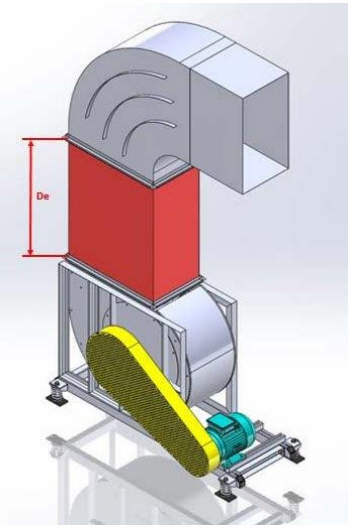


85

Fault



Fixed

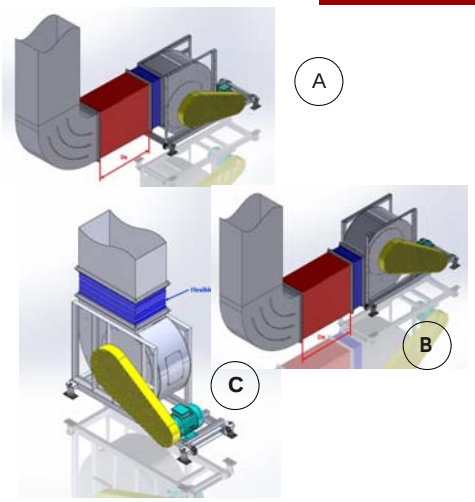


86

Fault



Fixed

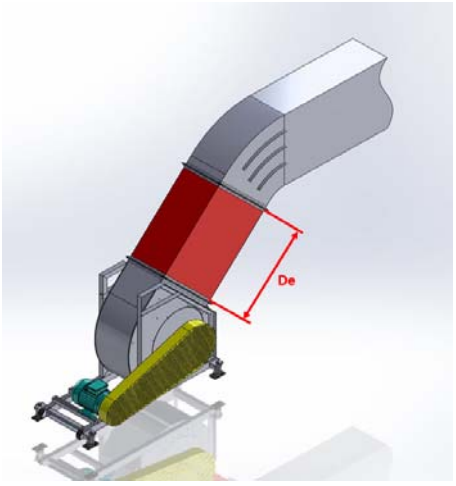


87

Fault



Fixed

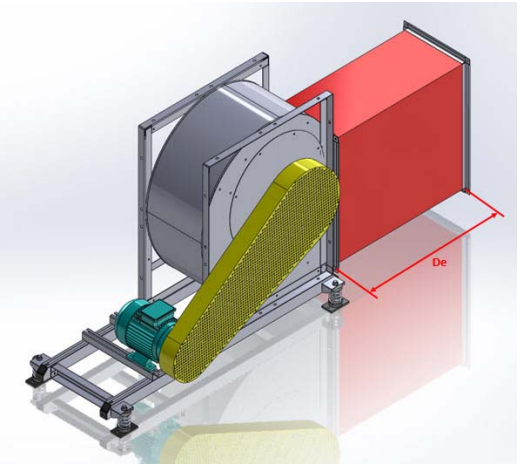


88

Fault



Fixed

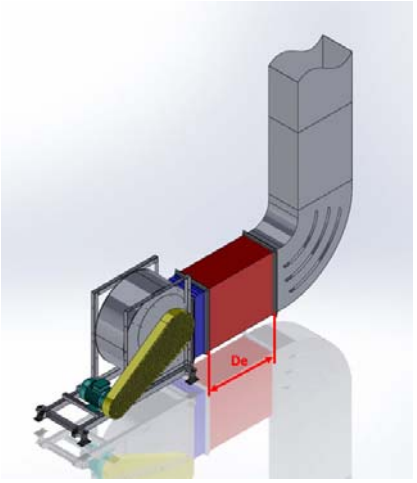


89

Fault

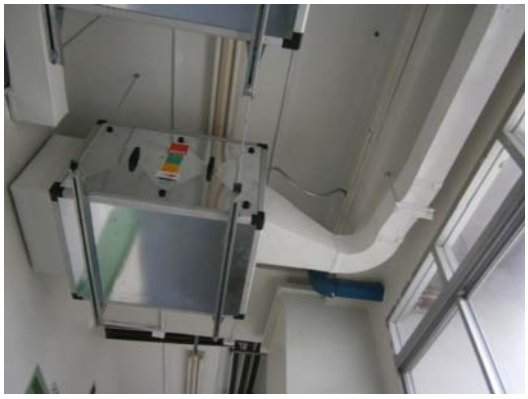


Fixed

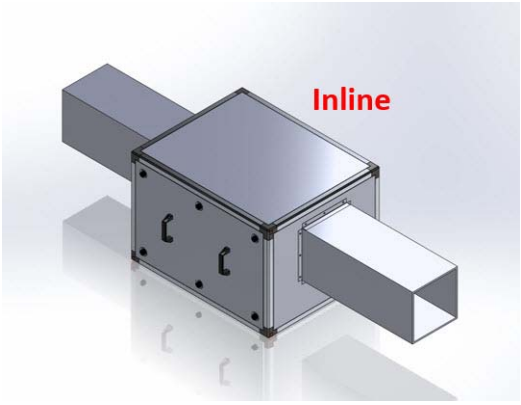


90

Fault



Fixed

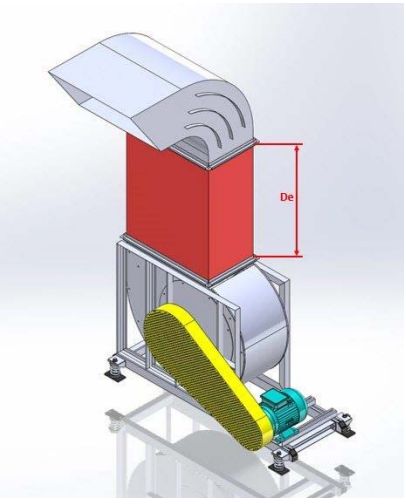


91

Fault



Fixed

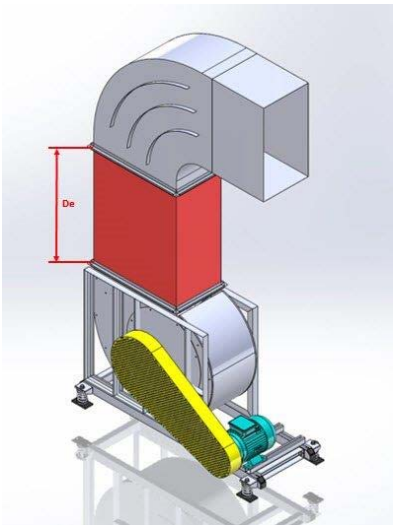


92

Fault



Fixed

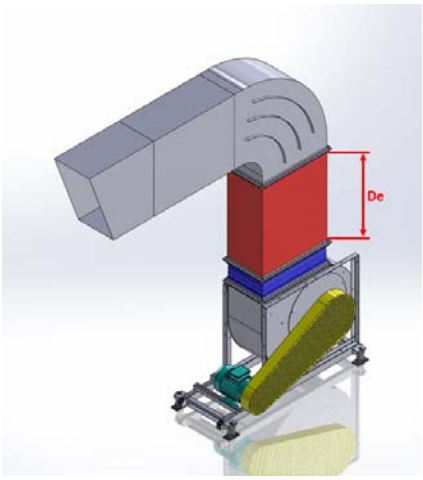


93

Fault



Fixed

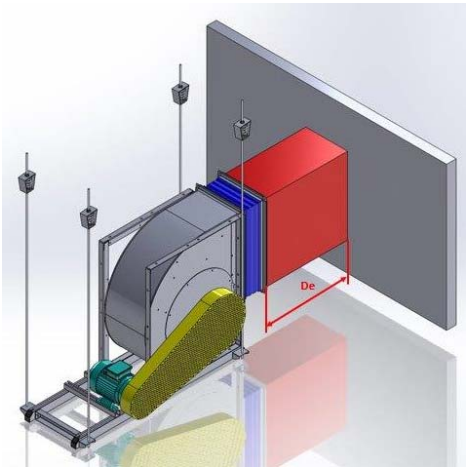


94

Fault



Fixed

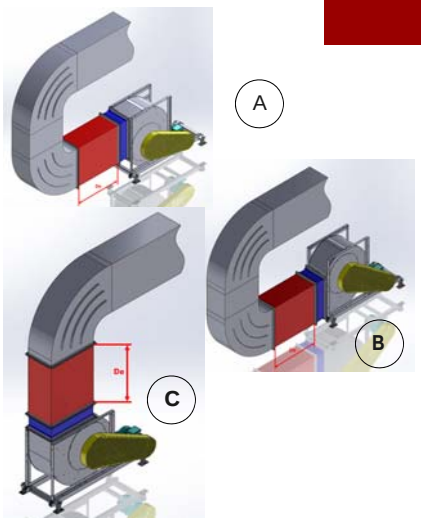


95

Fault



Fixed

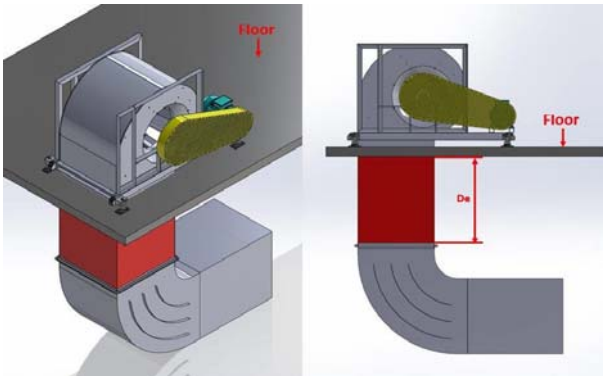


96

Fault



Fixed

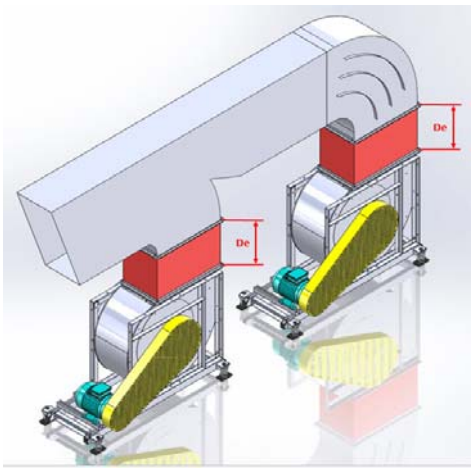


97

Fault



Fixed

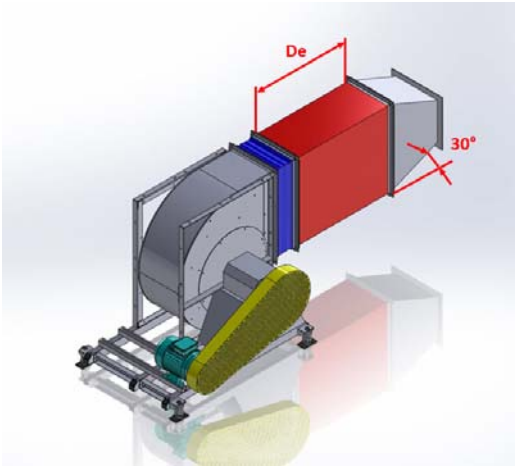


98

Fault



Fixed

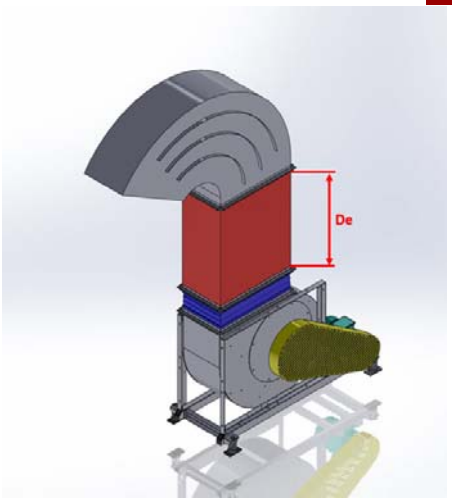


99

Fault



Fixed

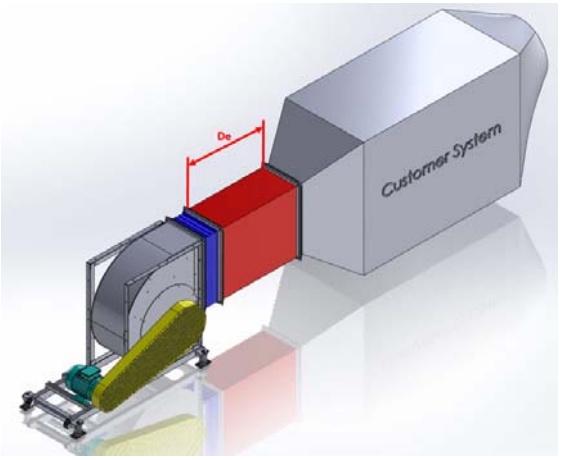


100

Fault



Fixed

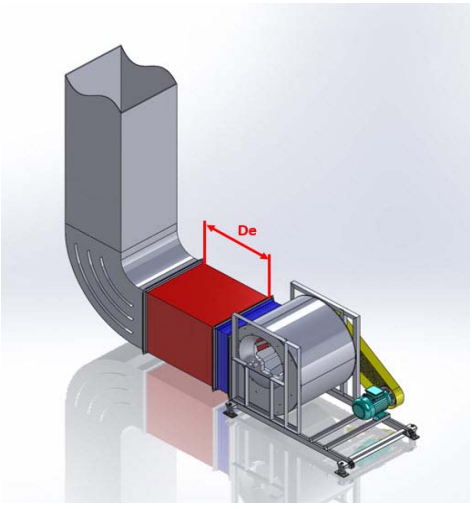


101

Fault

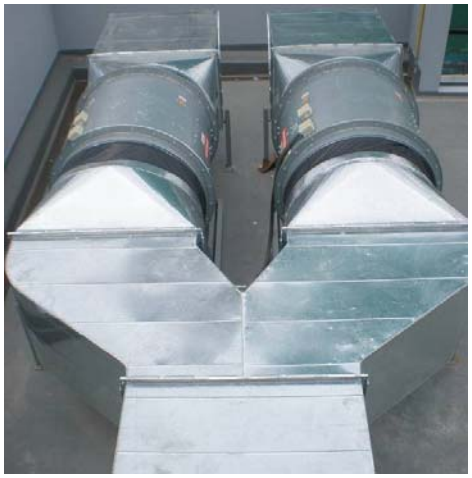


Fixed

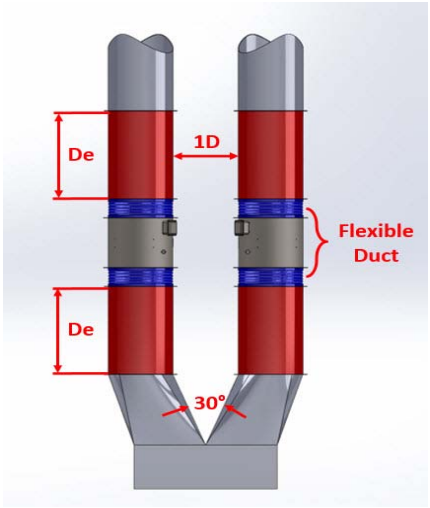


102

Fault



Fixed

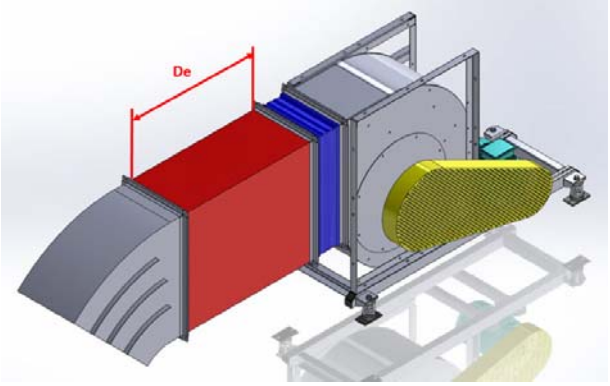


103

Fault



Fixed



104

Before

After





Air flow less designed 15%

Equal designed air flow

105

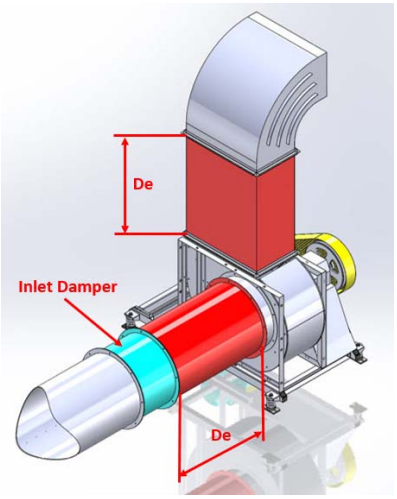
Poor Inlet

106

Fault



Fixed

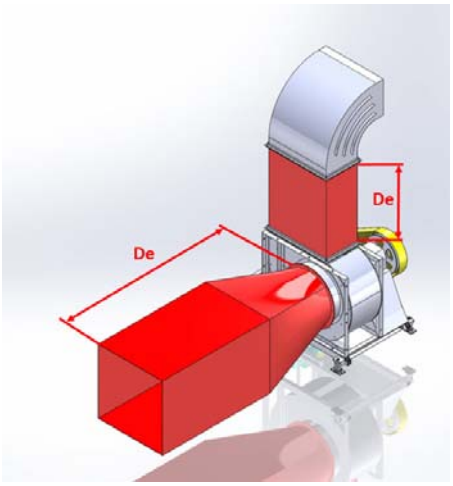


107

Fault



Fixed

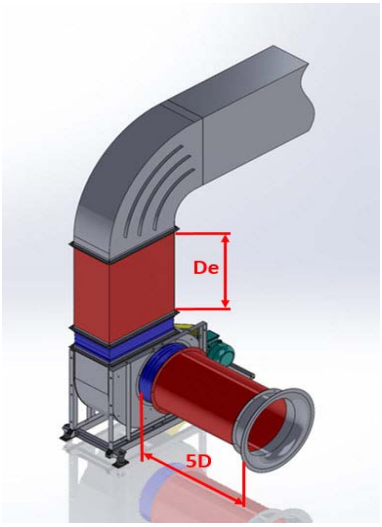


108

Fault



Fixed

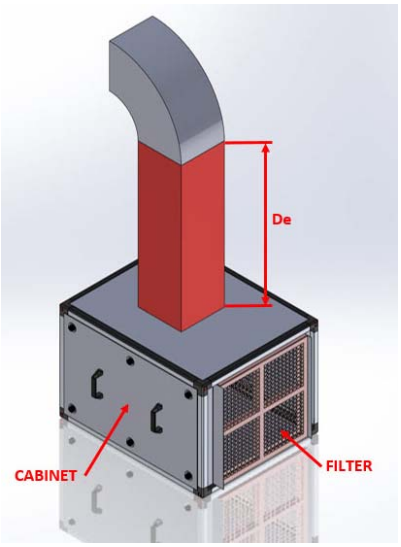


109

Fault



Fixed

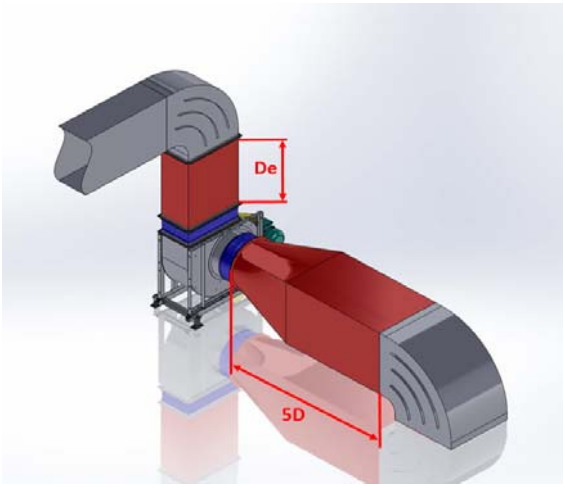


110

Fault



Fixed

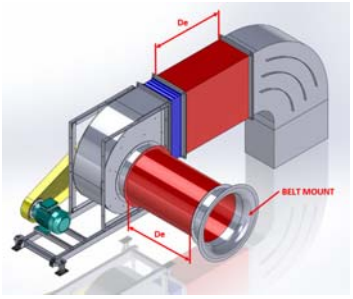


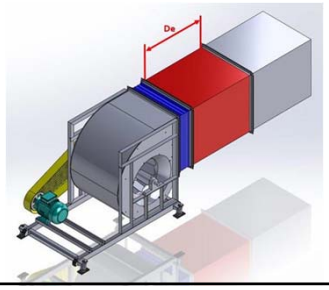
111

Fault



Fixed



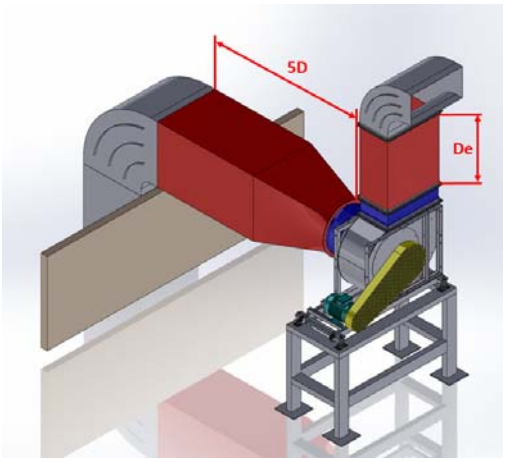


112

Fault



Fixed

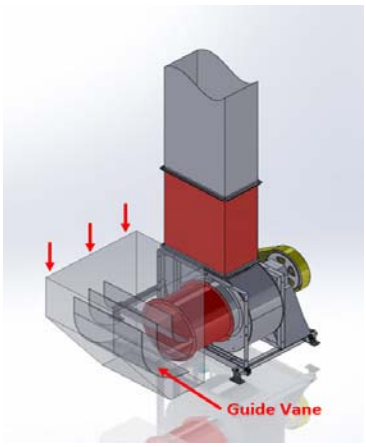


113

Fault

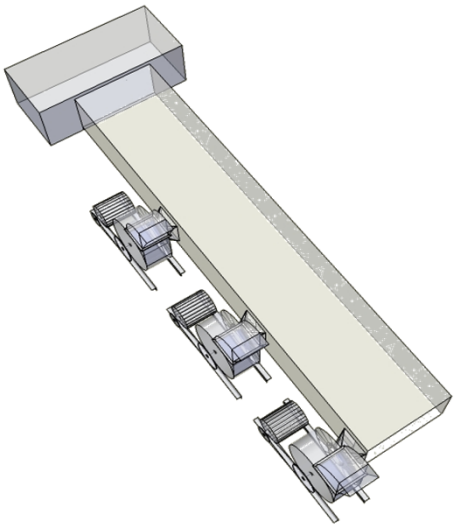


Fixed



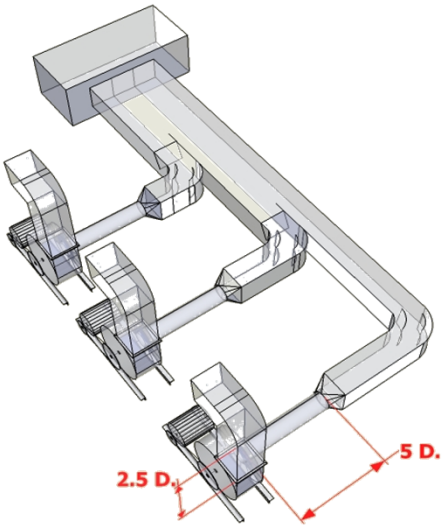
114

Not Recommended



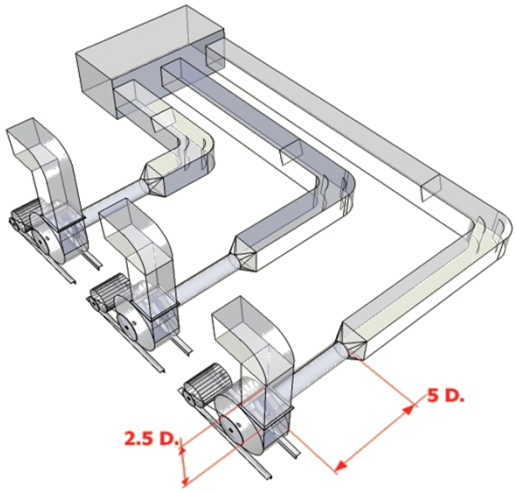
115

Recommended



116

Recommended



117

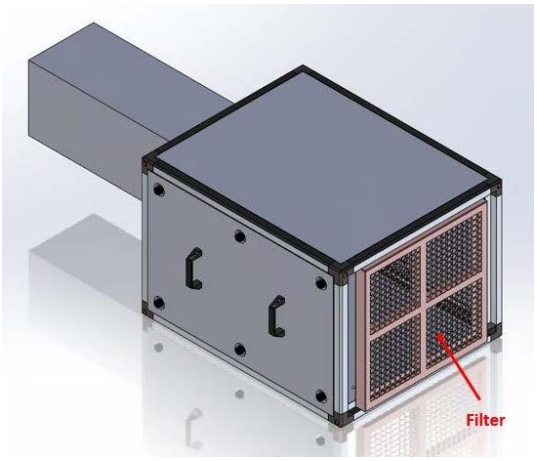
Poor Inlet & Poor Outlet

118

Fault



Fixed

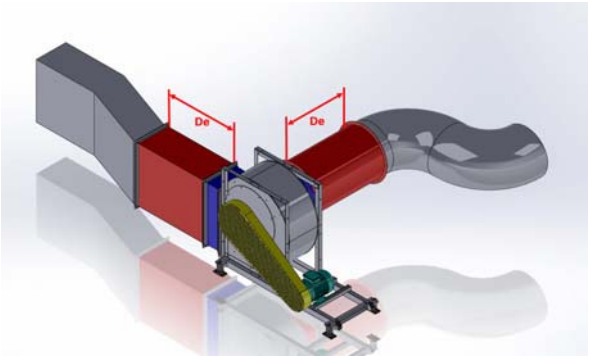


119

Fault



Fixed

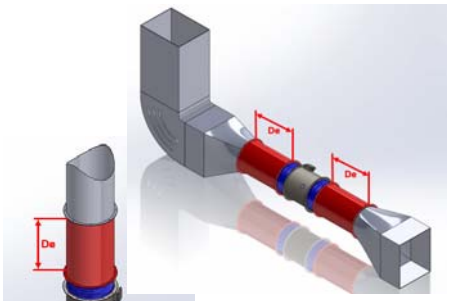


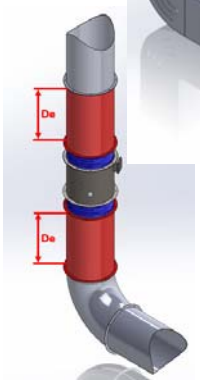
120

Fault



Fixed



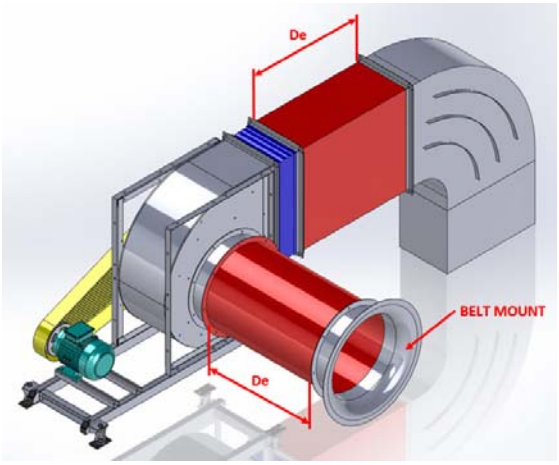


121

Fault



Fixed

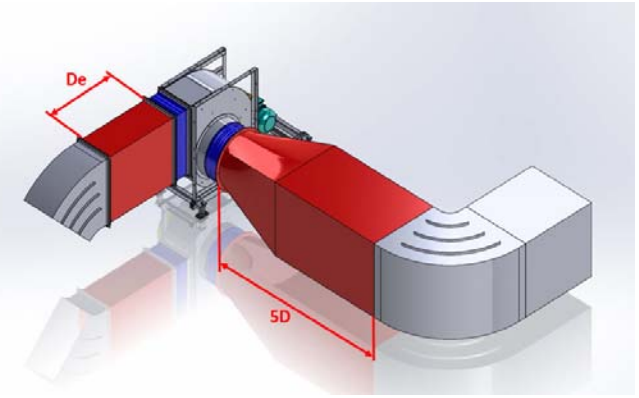


122

Fault



Fixed

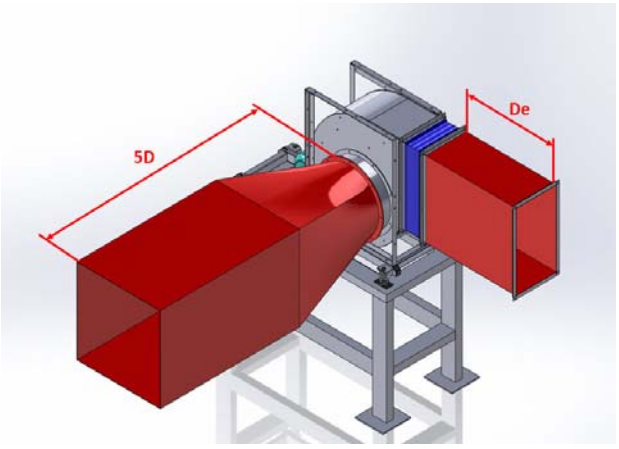


123

Fault



Fixed

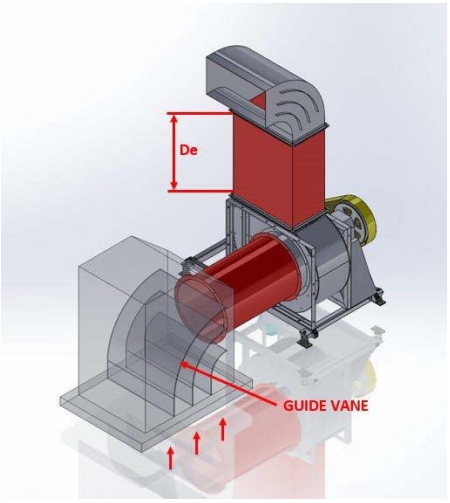


124

Fault



Fixed



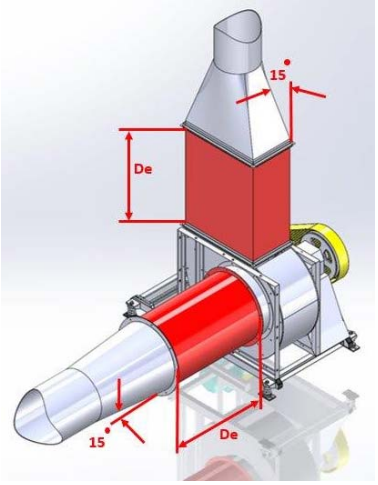
125

Fault





Fixed

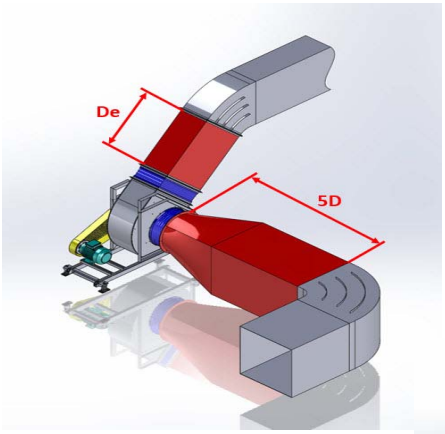


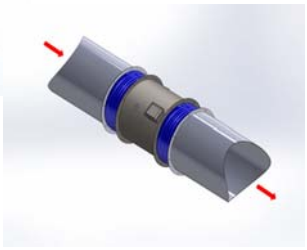
126

Fault



Fixed



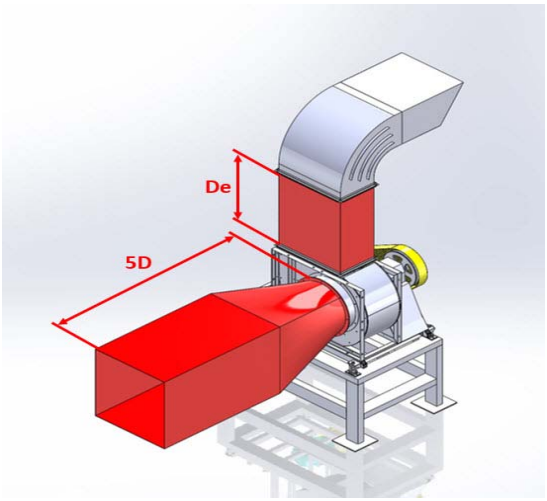


127

Fault



Fixed

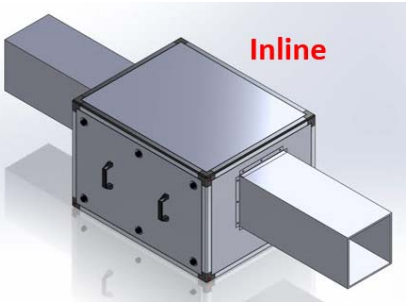


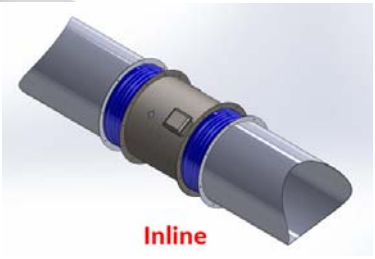
128

Fault



Fixed





129

Fair Installation

130



131

Good Installation

132



133



134



135



136



137



138



139



140



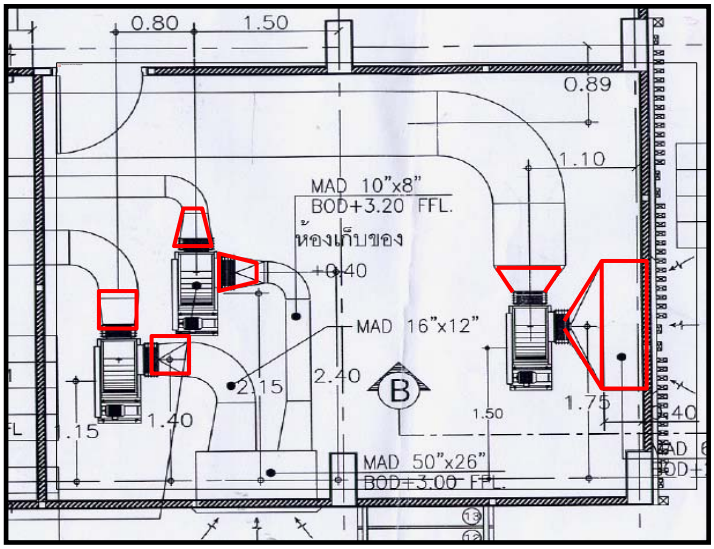
141



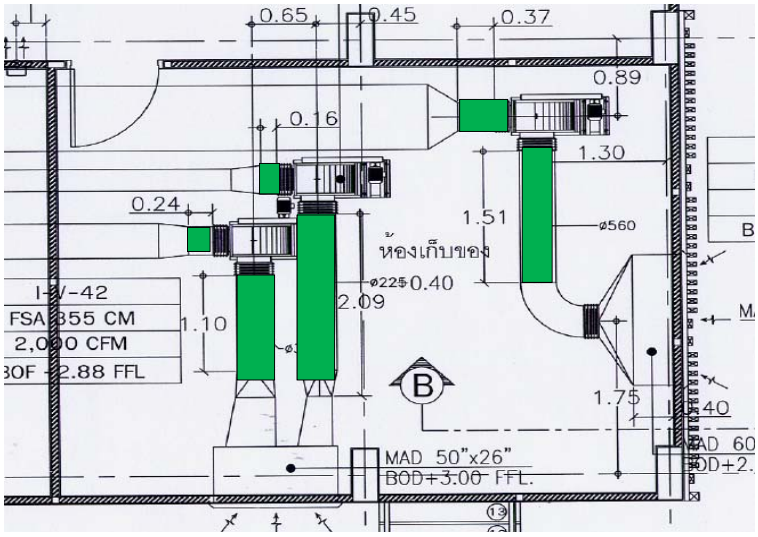
142



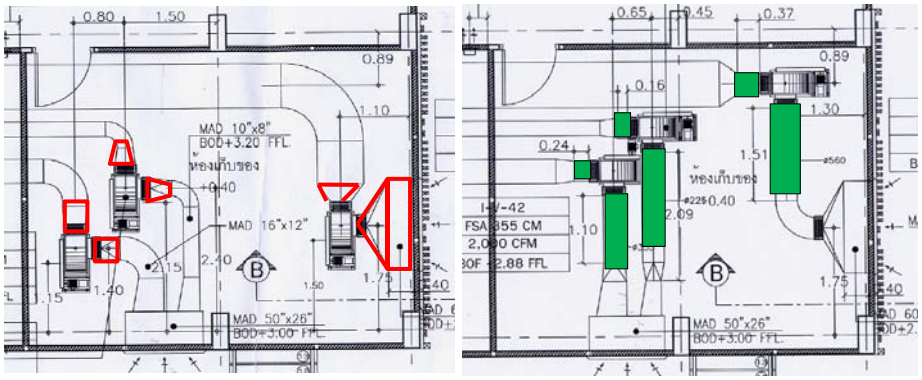
143


0.80
1.50
0.89
1.10
MAD 10"x8"
BOD+3.20 FFL.
ห้องเก็บของ
+0.40
MAD 16"x12"
2.40
2.15
B
1.40
1.50
1.75
MAD 50"x26"
BOD+3.00 FFL.

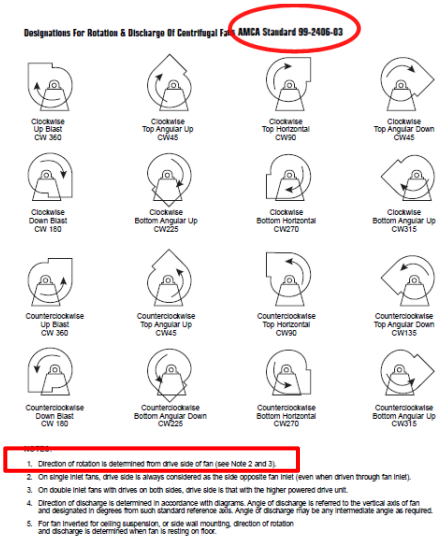
144

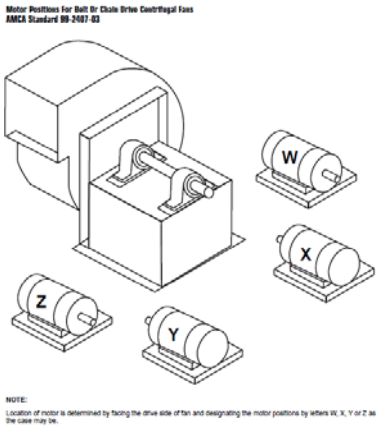

0.65
0.45
0.37
0.89
0.16
1.30
0.24
1.51
ø560
ห้องเก็บของ
ø225
0.40
2.09
1.10
B
1.75
MAD 50"x26"
BOD+3.00 FFL.

145


0.80
1.50
0.89
1.10
MAD 10"x8"
BOD+3.20 FFL.
ห้องเก็บของ
+0.40
MAD 16"x12"
2.15
2.40
B
1.40
1.75
MAD 50"x26"
BOD+3.00 FFL.
0.65
0.45
0.37
0.16
1.30
0.24
1.51
ø560
ø225
0.40
2.09
1.10
1.75

146





147

Energy conservation strategy

Energy conservation in fan is just a part of the system energy conservation:

1. High efficient fan
2. Wide product range – to meet different operation
3. Technical support – to ensure a good match of fan and system
4. Proper system design and TAB

148

Thank you