Fan Engineering

Lesson 1

Fundamentals of Fan Engineering

Fundamentals of Fan Engineering

- Atmospheric air is a mixture of several gases, water vapor, and impurities

Table 3.1 - Dry Air Composition, Fraction

Component	Volume	Weight
Nitrogen	0.7809	0.7552
Oxygen	0.2095	0.2315
Argon	0.0093	0.0128
Carbon Dioxide	0.0003	0.0004
Also slight traces of neon, hydrogen, helium, krypton, ozone and others		

Fundamentals of Fan Engineering

- Volume Flow Rate is Defined as

- **The Air Velocity Multiplied by the Area of the Measuring Plane**

Velocity (m/s)

Area of Measuring Plane (m2)

Volume Flow Rate M3/S (CMS)

- **The Amount of Air passing a given point in a Given unit of Time**

Volume Flow Rate M3/HR (CMH)

Room (m3)

Air Change Per Hour

Fundamentals of Fan Engineering

Determine the Volume of the room for ventilation (m^3)

Length (m) x Width (m) x Height (m) = m^3

Determine the Air Change Required

Table 5 – Outdoor air supply for mechanical ventilation in non air-conditioned buildings or parts of buildings with no natural ventilation

Type of building/ occupancy	Minimum outdoor air supply air-change/h
Offices	6
Restaurants, canteens	10
Shops	6
Workshops, factories	6
Classrooms	8
(i) Car parks	6
(ii) Toilets, bathrooms	10
(iii) Lobbies , concourse, corridors, staircases and exits	4
Kitchens (commercial, institutional and industrial)	(iv) 20

Volume of the room for ventilation (m^3) x Air Change Required

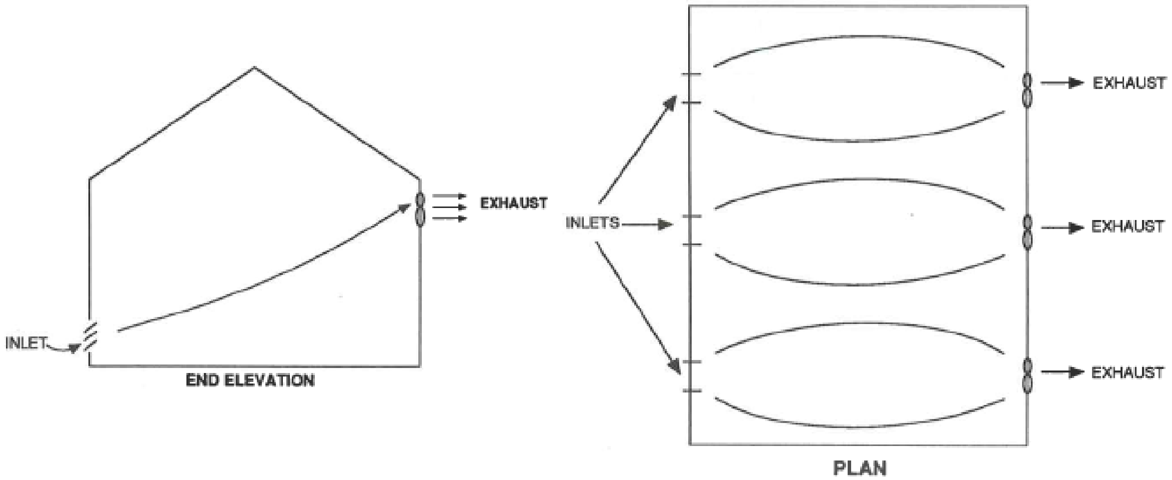
= Volume required for Ventilation

Fundamentals of Fan Engineering

Determine the Access for Fresh Air / Exhaust Air

Wall Mounted / Roof Mounted ?

If there are easy access to atmosphere



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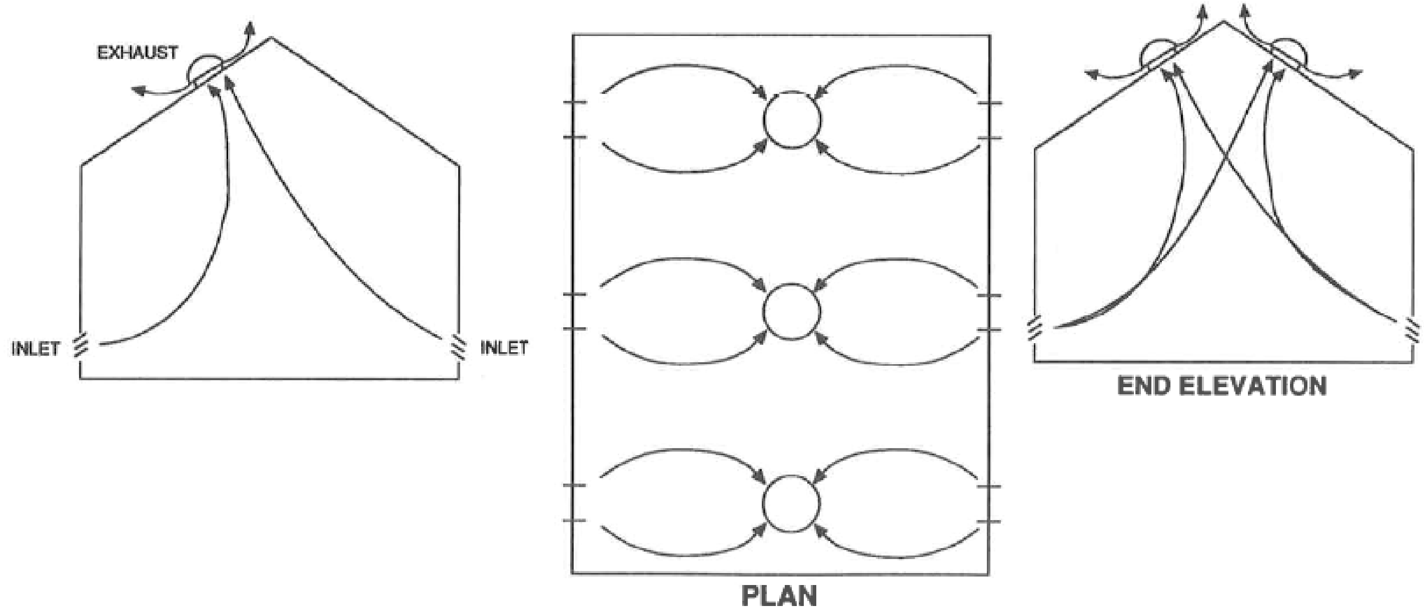
Determine the Access for Fresh Air / Exhaust Air

Wall Mounted / **Roof Mounted** ?

If there are easy access to atmosphere



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Wall Mounted / Roof Mounted

Wall Mounted Propeller

SCAW Series

(Wall mounted)

Roof Extractor series

TFA-R

(Roof mounted)

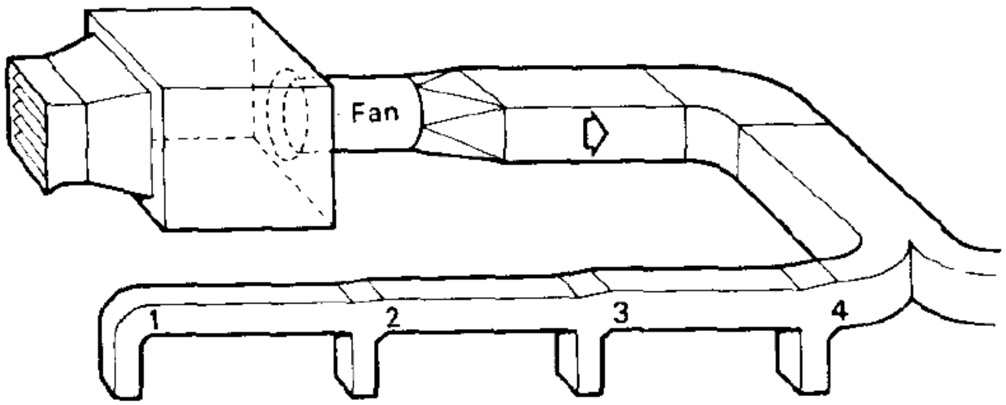
Fundamentals of Fan Engineering

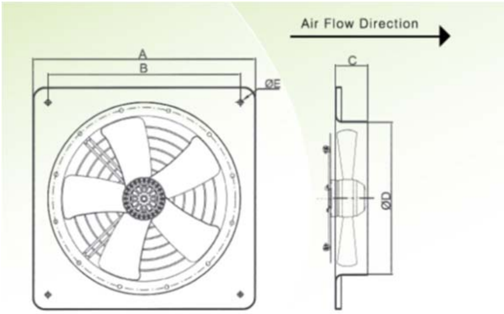
Ducted ?

⇒ To do static calculation (based on Ashrae or SMACNA) to get the pressure drop required to size the fan

Non Ducted?

=> To obtain the tested pressure drop through the ancillaries such as lourve shutter / grilles from the relevant suppliers

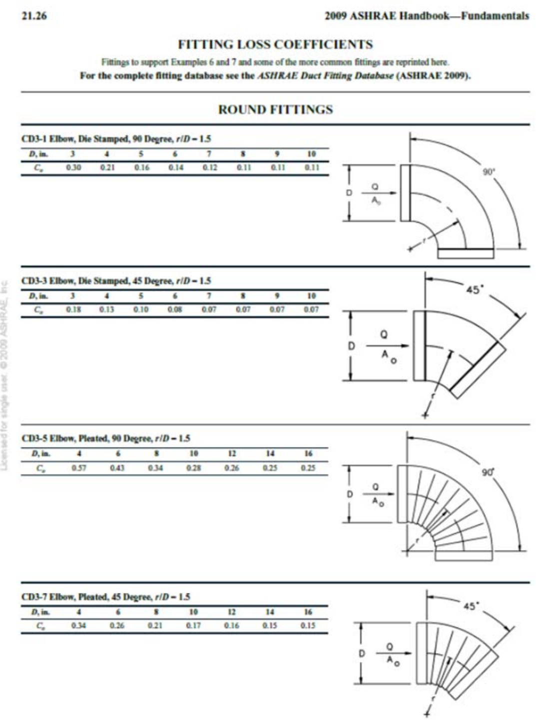




Fundamentals of Fan Engineering

Static Calculations

Loss Coefficients reference: **ASHRAE (**American Society of Heating, Refrigeration, and Air Conditioning Engineers) **or SMACNA (**Sheet Metal and Air Conditioning Contractors National Association)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FITTING LOSS COEFFICIENTS

Fittings to support Examples 6 and 7 and some of the more common fittings are reprinted here.
For the complete fitting database see the *ASHRAE Duct Fitting Database* (ASHRAE 2009).

ROUND FITTINGS

CD3-1 Elbow, Die Stamped, 90 Degree, $r/D = 1.5$

D, in.	3	4	5	6	7	8	9	10
C_o	0.30	0.21	0.16	0.14	0.12	0.11	0.11	0.11

CD3-3 Elbow, Die Stamped, 45 Degree, $r/D = 1.5$

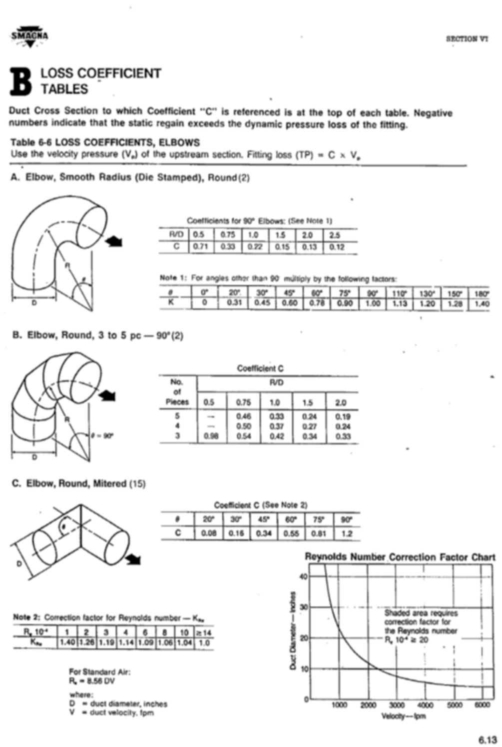
D, in.	3	4	5	6	7	8	9	10
C_o	0.18	0.13	0.10	0.08	0.07	0.07	0.07	0.07

CD3-5 Elbow, Pleated, 90 Degree, $r/D = 1.5$

D, in.	4	6	8	10	12	14	16
C_o	0.57	0.43	0.34	0.28	0.26	0.25	0.25

CD3-7 Elbow, Pleated, 45 Degree, $r/D = 1.5$

D, in.	4	6	8	10	12	14	16
C_o	0.34	0.26	0.21	0.17	0.16	0.15	0.15


SMACNA — SECTION VI

B LOSS COEFFICIENT TABLES

Duct Cross Section to which Coefficient "C" is referenced is at the top of each table. Negative numbers indicate that the static regain exceeds the dynamic pressure loss of the fitting.

Table 6-6 LOSS COEFFICIENTS, ELBOWS
Use the velocity pressure (V_p) of the upstream section. Fitting loss (TP) = C × V_p

A. Elbow, Smooth Radius (Die Stamped), Round (2)

Coefficients for 90° Elbows: (See Note 1)

R/D	0.5	0.75	1.0	1.5	2.0	2.5
C	0.71	0.33	0.22	0.15	0.13	0.12

Note 1: For angles other than 90° multiply by the following factors:

θ	0°	20°	30°	45°	60°	75°	90°	110°	130°	150°	180°
K	0	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

B. Elbow, Round, 3 to 5 pc — 90° (2)

Coefficient C

No. of Pieces	R/D 0.5	0.75	1.0	1.5	2.0
5	—	0.46	0.33	0.24	0.19
4	—	0.50	0.37	0.27	0.24
3	0.98	0.54	0.42	0.34	0.33

C. Elbow, Round, Mitered (15)

Coefficient C (See Note 2)

θ	20°	30°	45°	60°	75°	90°
C	0.08	0.16	0.34	0.55	0.81	1.2

Note 2: Correction factor for Reynolds number — K_{Re}

R_e 10^{-4}	1	2	3	4	6	8	10	≥14
K_{Re}	1.40	1.26	1.19	1.14	1.09	1.06	1.04	1.0

For Standard Air:
R_e = 8.56 DV

where:
D = duct diameter, inches
V = duct velocity, fpm

Reynolds Number Correction Factor Chart

6.13

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STATIC CALCULATIONS

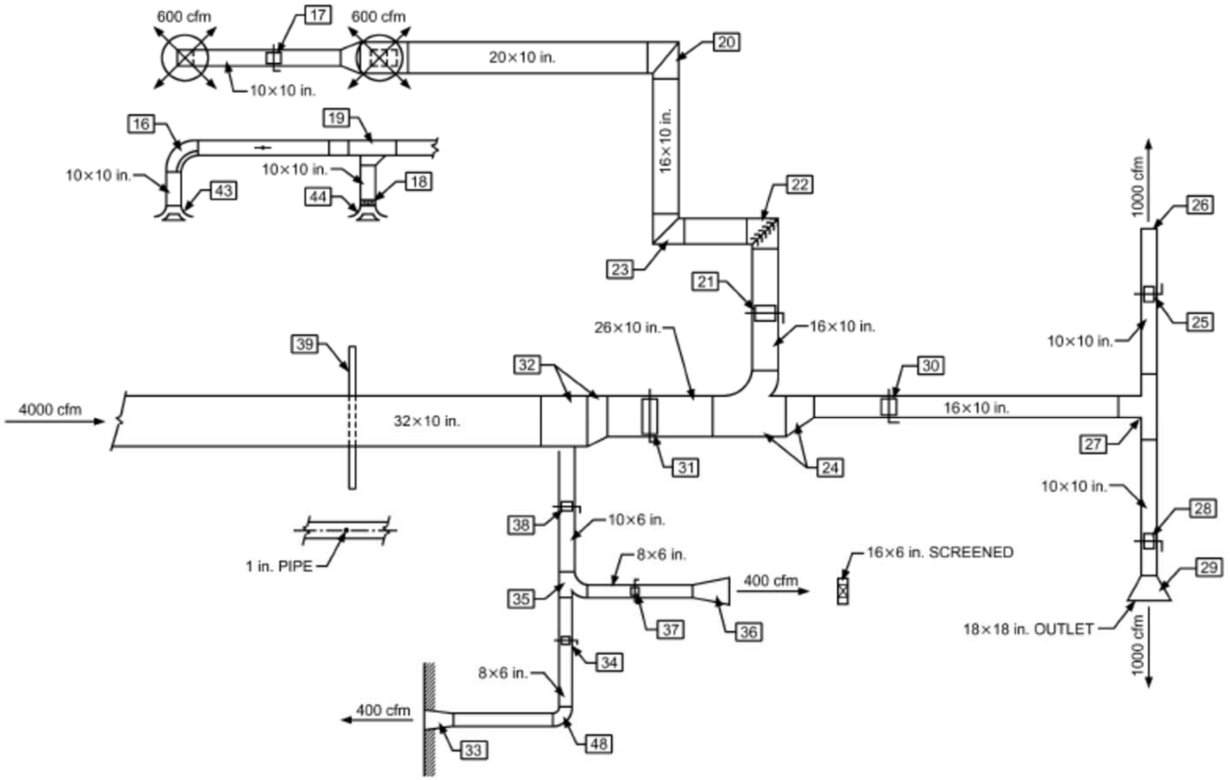

Fig. 15 Schematic for Example 6

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STATIC CALCULATIONS

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Table 9 Total Pressure Loss Calculations by Sections for Example 6

Duct Section[a]	Fitting No.[b]	Duct Element	Airflow, cfm	Duct Size (Equivalent Round)	Velocity, fpm	Velocity Pressure, in. of water	Duct Length,[c] ft	Summary of Fitting Loss Coefficients[d]	Duct Pressure Loss/100 ft,[e] in. of water	Total Pressure Loss, in. of water	Section Pressure Loss, in. of water
1	—	Duct	1500	12 in. ϕ	1910	—	15	—	0.40	0.06	
—	—	Fittings	1500	—	1910	0.23	—	0.74	—	0.17	0.23
2	—	Duct	500	8 in. ϕ	1432	—	60	—	0.39	0.23	
—	—	Fittings	500	—	1432	0.13	—	0.03	—	0.00	0.23
3	—	Duct	2000	12 in. ϕ	2546	—	20	—	0.69	0.14	
—	—	Fittings	2000	—	2546	0.40	—	1.00	—	0.40	0.54
4	—	Duct	2000	24 × 24 in. (26.2)	500	—	5	—	0.01	0.00	
—	—	Fittings	2000	—	500	0.02	—	0.90	—	0.02	
	9	Louver	2000	24 × 24 in.	—	—	—	—	—	0.10[f]	0.12
5	—	Duct	2000	14 in. ϕ	1871	—	55	—	0.32	0.18	
—	—	Fittings	2000	—	1871	0.22	—	2.37	—	0.52	0.70
6	—	Duct	4000	17 in. ϕ	2538	—	30	—	0.45	0.14	
—	—	Fittings	4000	—	2538	0.40	—	0.87	—	0.35	0.49
7	—	Duct	600	10 × 10 in. (10.9)	864	—	14	—	0.12	0.02	
—	—	Fittings	600	—	864	0.05	—	0.26	—	0.01	
	43	Diffuser	600	10 × 10 in.	—	—	—	—	—	0.10[f]	0.13
8	—	Duct	600	10 × 10 in. (10.9)	864	—	4	—	0.12	0.00	
—	—	Fittings	600	—	864	0.05	—	1.10	—	0.06	
	44	Diffuser	600	10 × 10 in.	—	—	—	—	—	0.10[f]	0.16
9	—	Duct	1200	20 × 10 in. (15.2)	864	—	25	—	0.08	0.02	
—	—	Fittings	1200	—	864	0.05	—	1.67	—	0.08	0.10
10	—	Duct	1200	16 × 10 in. (13.7)	1080	—	45	—	0.13	0.06	
—	—	Fittings	1200	—	1080	0.07	—	2.65	—	0.19	0.25
11	—	Duct	1000	10 × 10 in. (10.9)	1440	—	10	—	0.30	0.03	
—	—	Fittings	1000	—	1440	0.13	—	2.53	—	0.33	0.36
12	—	Duct	1000	10 × 10 in. (10.9)	1440	—	22	—	0.30	0.07	
—	—	Fittings	1000	—	1440	0.13	—	2.42	—	0.31	0.38
13	—	Duct	2000	16 × 10 in. (13.7)	1800	—	35	—	0.35	0.12	
—	—	Fittings	2000	—	1800	0.20	—	0.11	—	0.02	0.14
14	—	Duct	3200	26 × 10 in. (17.1)	1772	—	15	—	0.28	0.04	
—	—	Fittings	3200	—	1772	0.20	—	0.12	—	0.02	0.06

Ref: Ashrae HandBook – Chapter 21 – Duct Design

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STATIC CALCULATIONS

FITTING LOSS COEFFICIENTS

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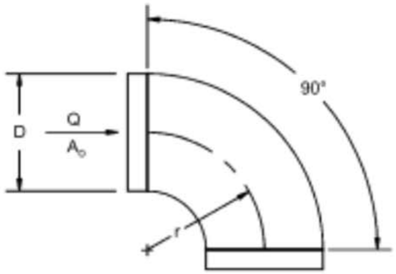
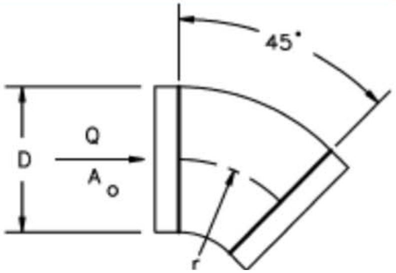


CD3-3 Elbow, Die Stamped, 45 Degree, $r/D = 1.5$

D, in.	3	4	5	6	7	8	9	10
C_o	0.18	0.13	0.10	0.08	0.07	0.07	0.07	0.07



Ref: Ashrae HandBook – Chapter 21 – Duct Design

Fundamentals of Fan Engineering

FAN LAW

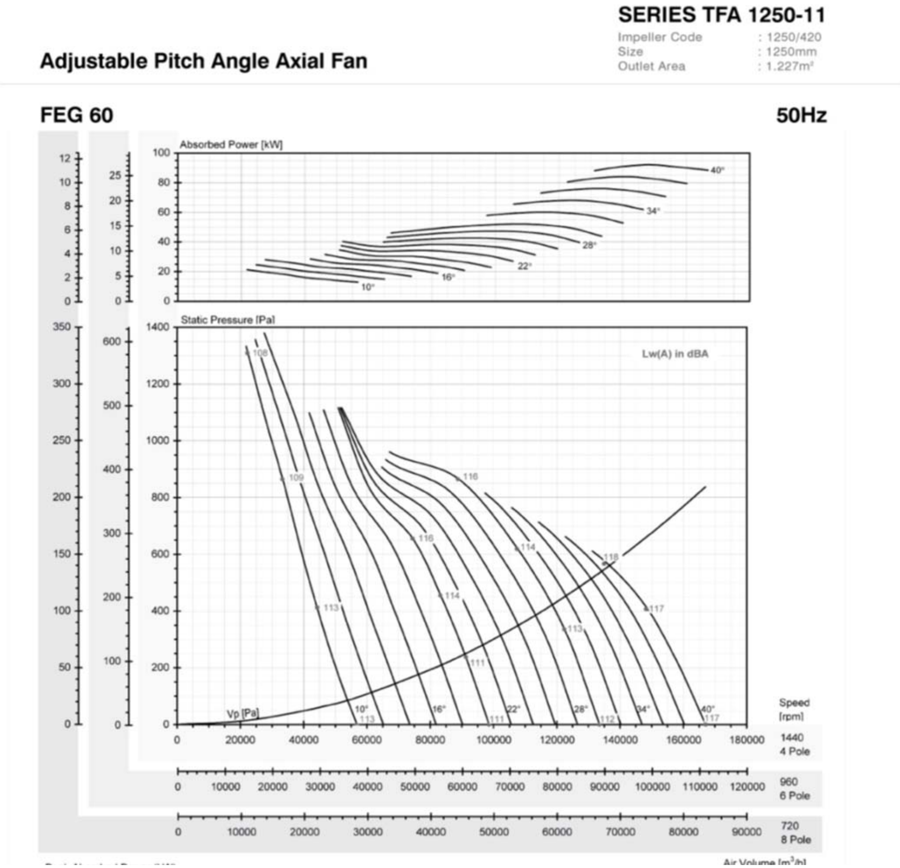
- **Fan Law 1**
  - **Air Flow is proportional to $(Speed)^1$**
- **Fan Law 2**
  - **Pressure is proportional to $(Speed)^2$**
- **Fan Law 3**
  - **Impeller Power is proportional to $(Speed)^3$**

Note

- Fan efficiency do not change at any speed
- Fan laws only applies to geometrically similar design

Fundamentals of Fan Engineering

FAN LAW



Note

- Fan efficiency do not change at any speed
- Fan laws only applies to geometrically similar design

Fundamentals of Fan Engineering

MULTI SPEED OPERATION

Required for dual purpose application due to space and usage

For example Emergency Mode and Normal Mode operation

- Staircase Pressurisation and Staircase Ventilation
- Carpark Fire and Normal operation

- Under Platform and Smoke Extraction operation (UPEF/SEF)

Few methods of multi speed control

- Dual Speed motors
- Variable Speed Drives
- Physically by have fans in parallel

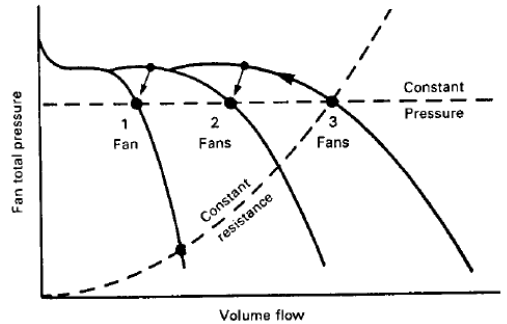


Fig. 9.1 Duty control by fans in parallel.

Fundamentals of Fan Engineering

MULTI SPEED OPERATION – HOW ?

A. Multi-speed motors

⇒ Motor itself have double winding or pole change configuration.

⇒ Usually in the form of 4/8, 2/4, 4/6 pole

⇒ Therefore 4pole = 1500rpm, 2pole = 3000rpm, 6pole = 1000rpm, 8pole = 750rpm

Fundamentals of Fan Engineering

MULTI SPEED OPERATION - HOW ?

A. MULTI-SPEED MOTORS

Specified Duty (20,000 / 8000 cmh @ 800 / 250 SPa)

1. Select 2 speed combination that is closest to the normal air flow requirement

   4/8 or 2/4 @ 0.5 ratio

   Fan Law 1 = Air Flow is proportional to Speed

   Therefore, the normal speed airflow is 20,000 x 0.5 = 10,000cmh (as compared to 8,000cmh)

   4/6 @ 0.667 ratio

   Fan Law 1 = Air Flow is proportional to Speed

   Therefore, the normal speed airflow is 20,000 x 0.667 = 13,333cmh (as compared to 8,000cmh)

Fundamentals of Fan Engineering

MULTI SPEED OPERATION - HOW ?

A. MULTI-SPEED MOTORS

Specified Duty (20,000 / 8000 cmh @ 800 / 250 SPa)

2. Determine what is the normal static pressure
   4/8 or 2/4 @ 0.5 ratio
   Fan Law 2 = Pressure is proportional to $(\text{Speed})^2$
   Therefore, the normal speed airflow is 800 x $(0.5)^2$ = 200SPa (as compared to 250 SPa)

There the 2 speed duty is 20000 / 10,000cmh @ 800 / 200 SPa (Specified 20,000 / 8000cmh @ 800 / 250 Spa)

Fundamentals of Fan Engineering

MULTI SPEED OPERATION – HOW ?

B. VARIABLE SPEED DRIVE

Specified Duty (20,000 / 8000 cmh @ 800 / 250 SPa)

1. Select the fan based on Full Speed of 50Hz (20,000 cmh @ 800 Spa)

   Fan Law 1 = Air Flow is proportional to Speed (in this case, Speed is proportional to Freq)

   Therefore, the frequency to achieve 8000cmh at normal mode is

   Thus the fan need to set at 8,000 x 50 / 20,000 **=> 20 Hz**

Fundamentals of Fan Engineering

MULTI SPEED OPERATION - HOW ?

B. VARIABLE SPEED DRIVE

Specified Duty (20,000 / 8000 cmh @ 800 / 250 SPa)

2. Determine what is the normal static pressure

   Fan Law 2 = Fan Law 2 = Pressure is proportional to $(\text{Speed})^2$

   Therefore, the frequency to achieve 8000cmh at normal mode is

   Thus the fan static at normal speed is **=> 128 SPa**

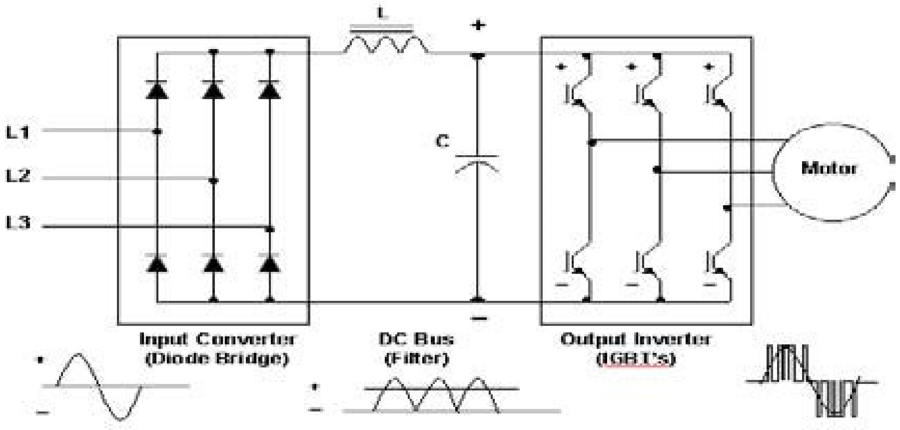
Thus using VSD 2 mode duty is 20000 / 8,000cmh @ 800 / 128 SPa (Specified 20,000 / 8000cmh @ 800 / 250 Spa)

Fundamentals of Fan Engineering

MULTI SPEED OPERATION – HOW ?

C. How does the VSD works

1. The supply voltage is firstly pass through a rectifier unit where in gets converted into AC to DC supply
2. The DC bus comprises with a filter section where the harmonics generated during the AC to DC conversion are filtered out.
3. An inverter section where the filtered DC supply is being converted to quasi sinusoidal wave of AC supply which is supply to the ac motor connected to it.



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MULTI SPEED OPERATION – HOW ?

D. ADVANTAGES OF USING VSD

- Energy Savings – No wastage
- Able to fine-tune the airflow during commissioning better

Fan Law 3
Power is proportional to $(\text{Speed})^3$

E. DISADVANTAGES OF USING VSD

- Overheating of general motor if the motor it run too slowly
    - Bearing and insulation life will be reduced

    Thus standard recommendations is for the motor to be running at 30Hz if using general purpose motors

- Voltage "chopping" that occurs in the drive will send high-voltage spikes (at the DC bus level) down to the motor. If the system has long cabling, reflected waves may occurs at the motor. This could double the voltage at the wire and end up with premature failure of the motor insulation
    - For critical systems with VSD operation, it is necessary to use Inverter Motors which are designed for higher voltage spikes without insulation failing

Question and Answer session