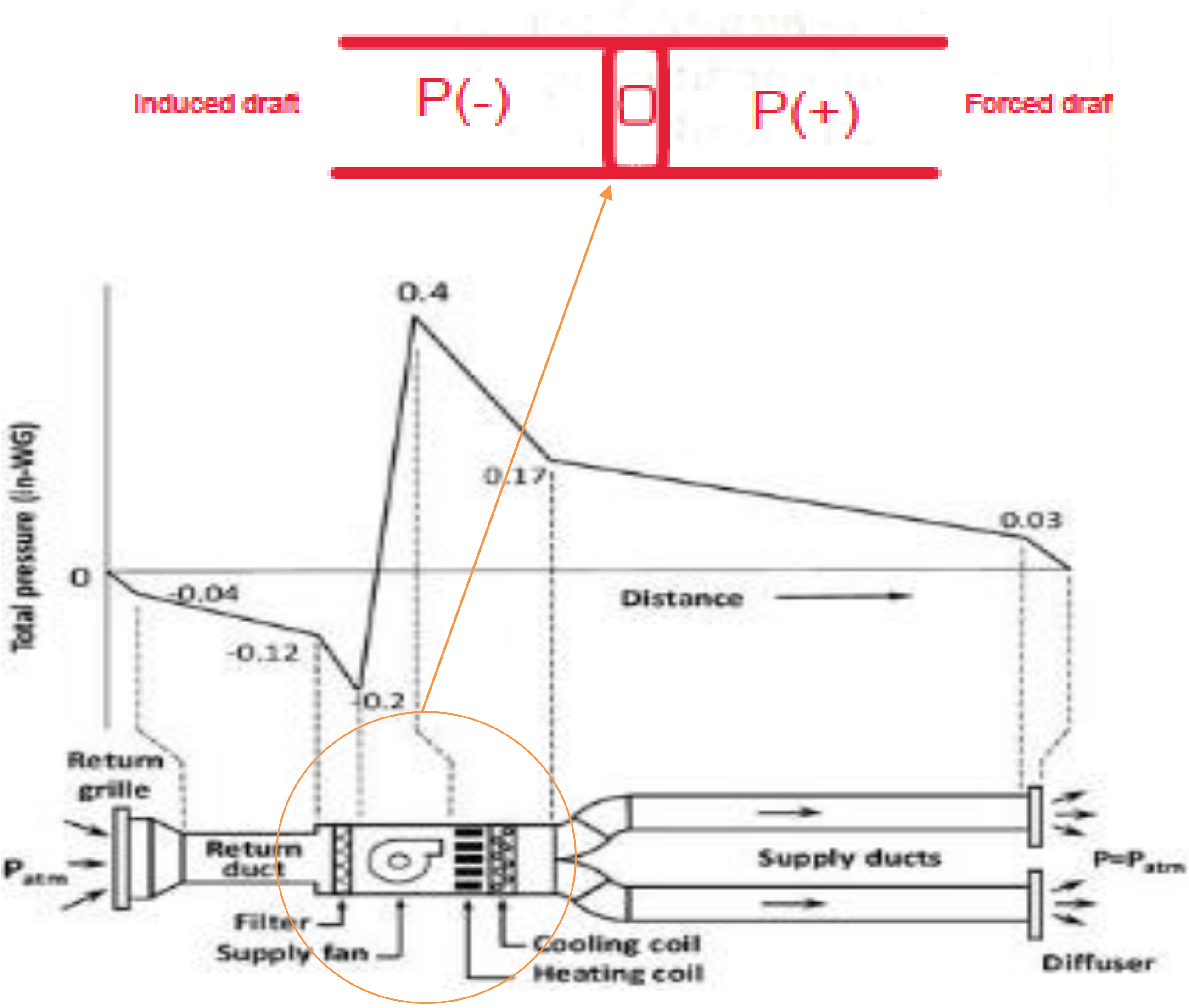
Fans

Fan is a kind of pump which is used for pumping or circulating the air through the entire duct system and the conditioned space.

The air may be moved by either creating an above atmospheric pressure (*i.e.* positive pressure) or a below-atmospheric pressure (*i.e.* negative pressure). All fans produce both the conditions. The air at inlet to the fan is below atmospheric pressure while at the exhaust or outlet of the fan is above atmospheric pressure. The air feed into a fan is called **induced draft** while the air exhaust from a fan is called **forced draft.**



Q/What is the difference between the Fan and Blower?

A fan develops pressure head below 0.07 bar while the blower develops more pressure head than fans. Blowers are high pressure fans

Types of Fans

The fans may be classified into the following:

1-Centrifugal or radial flow fans: The air enters the impeller axially and is discharged radially from the impeller.

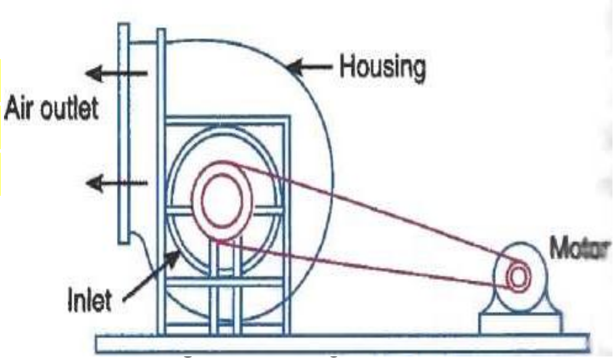
2. Axial flow fans: When the air flows parallel to the axis of impeller.

3- Utility fan and

4- Industrial fan.

Centrifugal Fans

The centrifugal fans are widely used for duct air conditioning system, because they can efficiently move large or small quantities of air over a greater range of operating pressures. All centrifugal fans have an impeller or wheel mounted in a scroll type of housing, as shown in **Fig.1**.



The fan impeller may have the following three types of blades

1-Radial or straight blades,

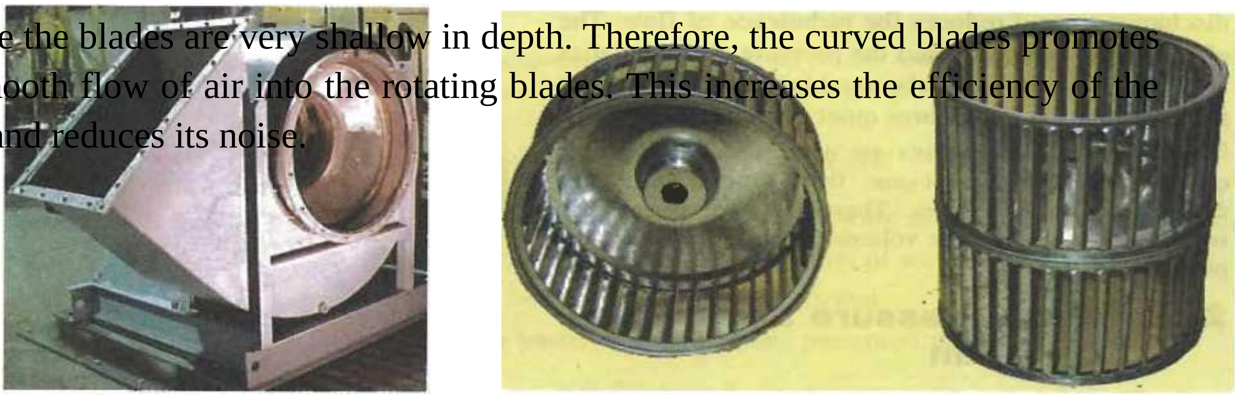
2. Forward curved blades, and

3. Backward curved blades

Fig. 2. Three types of fan impeller blades

Q/A large number of centrifugal fans installed in air conditioning systems have impellers forward curved blades? (As shown in **Fig.2 (b))**

Since the blades are very shallow in depth. Therefore, the curved blades promotes a smooth flow of air into the rotating blades. This increases the efficiency of the fan and reduces its noise.



(a) Radial centrifugal fans **(b)Centrifugal blowers.**

Fig. 3. (a)Radial centrifugal fans (b)Centrifugal blowers.

The number of impeller blades varies in centrifugal fans:

■The radial blade impellers seldom have more than 8 to 10 blades.

■The forward curved impellers usually have 24 to 64 blades

■The backward curved impeller usually have 10 to 16 blades.

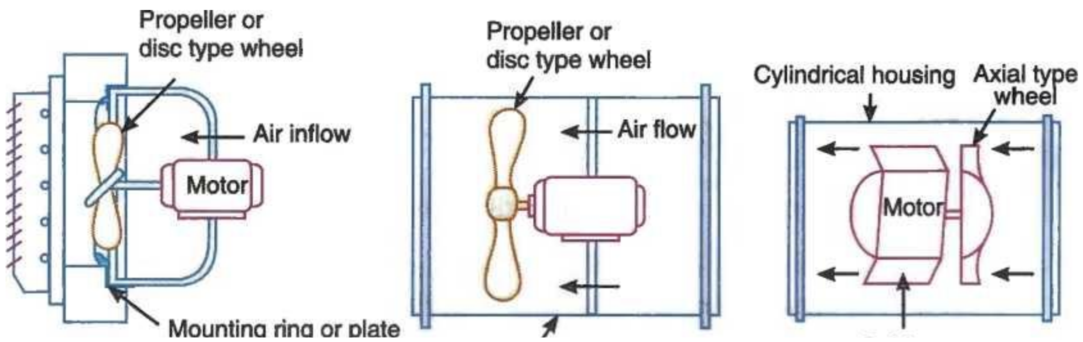
Q/What are the difference between the forward, Radial and Backward curved?

Item	Forward curved	Radial	Backward curved
Efficiency	Medium	Medium	High
Stability of operation	Poor	Good	Good
Space requirement	Small	Medium	Medium
Tip speed for a given pressure rise	Low	Medium	High
Resistance to abrasion	Poor	Good	Medium
Noise Characteristics	Poor	Fair	Good

Axial Flow Fans

The axial flow fans are divided into the following three groups :

1. **Propeller fan.** A propeller type of axial flow fan consists of a propeller or disc type wheel which operates within a mounting ring as shown in Fig.4 (a). The propeller fans are used only when the resistance to air movement is small. They are useful for the ventilation of attic spaces, lavatories and bathrooms, removal of cooking odours from kitchens and many other applications where little or no duct work is involved.



(a)Propeller fan (b) Tube axial fan (c) Vane axial fan

Fig. 4. Types of axial flow fans.

2. **Tube axial fan.** A tube axial fan, consists of a propeller wheel housed in a simple cylinder as shown in Fig.4 (b). These fans are easily installed in round ducts. They are more efficient than propeller fans. The air discharge from tube axial fan follows a spiral path as it leaves the cylindrical housing.

3. **Vane axial fan.** A vane axial fan combines a tube axial fan wheel mounted in a cylinder

with a set of air guide vanes, as shown in Fig.4 (c). The efficiency of operation and the pressure characteristics are better than those of tube axial fan.

Q/The axial flow fans are never used for duct air conditioning system?

Because they are incapable of developing high pressures. they are suitable for handling large volumes of air relatively low pressures.

Total Pressure Developed by a Fan:

We have already discussed the static pressure, velocity pressure and total pressure of air in ducts. In case of a fan, the **fan static pressure** (P_{SF}) is the pressure increase produced by a fan. The **fan velocity pressure** (P_{VF}) is the velocity pressure corresponding to the mean velocity of air at the fan outlet based on the total outlet area without any deductions for motors, fairings, or other bodies. The total pressure created by a fan or the fan **total pressure** (P_{TF}) is the algebraic difference between the total pressure at the fan outlet and the total pressure at the fan inlet. Mathematically, fan total pressure,

$$p_{TF} = p_{T2} - p_{T1}$$

where p_{T2} = Total pressure at fan outlet

= Static pressure at fan outlet + Velocity pressure at fan outlet

$= p_{S2} + p_{V2}$, and

p_{T1} = Total pressure at fan inlet

= Static pressure at fan inlet + Velocity pressure at fan inlet

$= p_{S1} + p_{V1}$

We know that the total pressure at a point is the sum of static pressure and velocity pressure at that point. Thus, for a fan,

Fan total pressure = Fan static pressure + Fan velocity pressure

i.e.

$$p_{TF} = p_{SF} + p_{VF}$$

Since the fan velocity pressure (p_{VF}) is the velocity pressure at the fan outlet (p_{V2}), therefore

$$p_{TF} = p_{SF} + p_{V2}$$

Notes:

1- If the fan has a suction duct and apparatus such as filters and coils. In such a system, the total pressure at the fan inlet is always equal to the total frictional resistance in that part of the system. Also, the total pressure at the fan inlet in such a system is always negative and it is numerically less than the static pressure at the fan inlet.

2. If the fan has no discharge duct (Ie. the fan delivers air directly into a free open space), the discharge static pressure is zero (i.e. $P_{s2} = 0$). Thus the total pressure at the fan outlet is equal to the velocity pressure (i.e. $P_{T2}= P_{V2}$). In an actual system, the fan has a discharge duct. In such a system, the total pressure at the fan outlet is equal to the velocity pressure at the point of discharge plus all pressure losses in the path taken by air to reach that point.

Fan Air Power

The power output of a fan is expressed in terms of air power and represents the work done by the fan. Mathematically, total fan air power (based on fan total pressure, p_{TF}),

$$P_{at} = \frac{9.81\,Q \times p_{TF} \times K_P}{60} \text{ (in watts)}$$

where Q = Total quantity of air flowing at the fan inlet in m³/min,

p_{TF} = Fan total pressure in mm of water, and

K_P = Compressibility coefficient.

Similarly, static fan air power based on the fan static pressure (p_{SF}) ,

$$P_{as} = \frac{9.81\,Q \times p_{SF} \times K_P}{60} \text{ (in watts)}$$

Note : If Q is expressed in m^3/s and p_{TF} and p_{SF} are in N/m^2, then total fan air power (in watts),

$$P_{at} = Q \times p_{TF} \times K_P$$

and static fan air power,

$$P_{as} = Q \times p_{SF} \times K_P$$

Fan Efficiencies

The ratio of the total fan air power to the driving power (or brake power) required at the fan shaft is known as total fan efficiency. It is also called mechanical efficiency of the fan.

$$\eta_{TF} = \frac{\text{Total fan air power } (P_{at})}{\text{Input or brake power } (B.P.)}$$

Similarly, static fan efficiency,

$$\eta_{SF} = \frac{\text{Static fan air power } (P_{as})}{\text{Input or brake power } (B.P.)}$$

Example 1: A centrifugal fan has a circular inlet duct 450 mm diameter and a rectangular duct of 450 mm x 375 mm. The static pressure at the fan inlet is - 125 Pa and a static pressure at the fan outlet is 250 Pa when the delivers 110 m^3/min and absorbs power of 1 kW.

Assume standard air, calculate

(1) Total pressure at fan inlet and outlet

(2) Fan total pressure and fan static pressure

(3) Fan total and fan static efficiency.

(a) *Total pressure at fan inlet and outlet*

Let p_{T1} = Total pressure at fan inlet, and

p_{T2} = Total pressure at fan outlet.

Cross-sectional area of circular inlet duct,

$$A_1 = \frac{\pi}{4} \times D^2 = \frac{\pi}{4}(0.45)^2 = 0.16 \text{ m}^2$$

∴ Velocity of air in the inlet duct,

$$V_1 = \frac{Q}{A_1} = \frac{115}{0.16} = 718.7 \text{ m}^3/\text{min} = 11.98 \text{ m}^3/\text{s}$$

We know that velocity pressure in the inlet duct,

$$p_{v1} = \left(\frac{V_1}{4.04}\right)^2 = \left(\frac{11.98}{4.04}\right)^2 = 8.8 \text{ mm of water}$$

∴ Total pressure at fan inlet,

$$p_{T1} = p_{S1} + p_{v1} = -12.5 + 8.8 = -3.7 \text{ mm of water} \quad \textbf{Ans.}$$

Cross-sectional area of rectangular outlet duct,

$$A_2 = a \times b = 0.45 \times 0.375 = 0.17 \text{ m}^2$$

∴ Velocity of air in the outlet duct,

$$V_2 = \frac{Q}{A_2} = \frac{115}{0.17} = 676.5 \text{ m}^3/\text{min} = 11.3 \text{ m}^3/\text{s}$$

We know that velocity pressure in the outlet duct,

$$p_{v2} = \left(\frac{V_2}{4.04}\right)^2 = \left(\frac{11.3}{4.04}\right)^2 = 7.8 \text{ mm of water}$$

∴ Total pressure at fan outlet,

$$p_{T2} = p_{S2} + p_{v2} = 25 + 7.8 = 32.8 \text{ mm of water} \quad \textbf{Ans.}$$

(b) *Fan total pressure and fan static pressure*

We know that fan total pressure,

$$p_{TF} = p_{T2} - p_{T1} = 32.8 - (-3.7) = 36.5 \text{ mm of water} \quad \textbf{Ans.}$$

and fan static pressure, $p_{SF} = p_{TF} - p_{v2} = 36.5 - 7.8 = 28.7$ mm of water **Ans.**

(c) *Fan total efficiency and fan static efficiency*

We know that fan air power,

$$P_{at} = \frac{9.81\, Q \times p_{TF} \times K_P}{60} = \frac{9.81 \times 115 \times 36.5 \times 1}{60} \text{ W}$$

$$= 686.3 \text{ W} = 0.6863 \text{ kW}$$

and static fan air power,

$$P_{as} = \frac{9.81\,Q \times p_{SF} \times K_P}{60} = \frac{9.81 \times 115 \times 28.7 \times 1}{60}\ \text{W}$$

$$= 539.6\ \text{W} = 0.5396\ \text{kW}$$

∴ Fan total effciency,

$$\eta_{TF} = \frac{P_{at}}{B.P.} = \frac{0.6863}{1} = 0.6863 \text{ or } 68.63\% \quad \textbf{Ans.}$$

and fan static efficiency, $$\eta_{SF} = \frac{P_{as}}{B.P.} = \frac{0.5396}{1} = 0.5396 \text{ or } 53.96\% \quad \textbf{Ans.}$$

Fan Performance Curves منحنيات الأداء للمراوح

Fan characteristics can be described by fan performance curves as shown in Fig. 5. Different parameters are presented such as: Volume flow rate, Pressure, Power and Efficiency

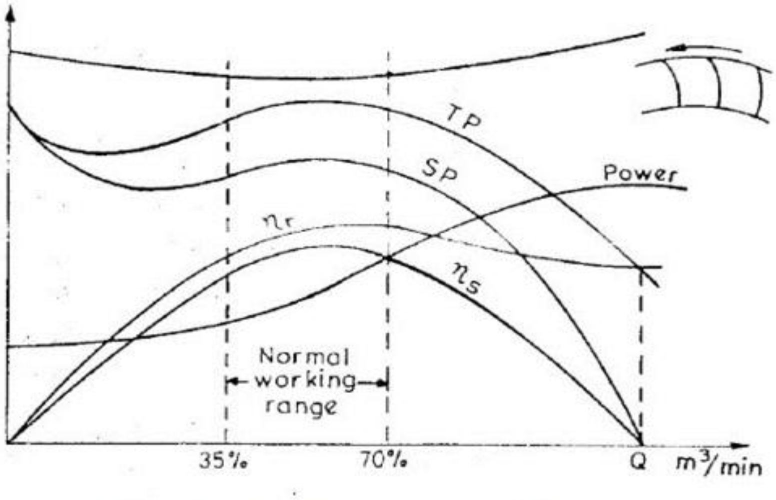


Fig. (5):Fan performance curve for Forward curve fan

From this figure it can be seen that, between 35% to 70% wide open volume, maximum pressure are developed along with maximum total efficiency. The sound level is also minimum at this openings.

FAN Selection اختيار المراوح

Fans are usually selected from **fan manufacturer's catalogs** which provide separate tables for each diameter of fan they manufacture. To make comparisons and selection as easy as possible, fan manufactures provide multi-rating performance tables for each wheel diameter manufactured.

عادةً ما يتم اختيار المراوح من كتالوجات الشركات المصنعة للمراوح والتي توفر جداول منفصلة **لكل قطر** من المروحة التي يقومون بتصنيعها. لذلك توفر الشركات المصنعة للمراوح جداول أداء متعددة التصنيفات لكل قطر عجلة تم تصنيعه.

Multirating table				*Fan wheel dia = 675 mm*				*Fan class I*	
Static Presssure		*259 Pa*		*312.5 Pa*		*375 Pa*		*437.5 Pa*	
L/S	σVm	RPM	BKW	RPM	BKW			RPM	BKW
1557	4.0	600	0.55						
1770	4.6	616	0.61	673	0.77	741	1.04		
1982	5.1	632	0.69	689	0.86	756	1.14	804	1.34
2195	5.7	651	0.77	705	0.96				

Note: The first requirement for the fan selection is that the fan must deliver the necessary air volume to ventilate, heat or cool the space being served.

ملاحظة: الشرط الأول لاختيار المروحة هو أن المروحة يجب أن توفر حجم الهواء اللازم لتهوية أو تسخين أو تبريد المساحةا.

Fans in Series

Sometimes it is necessary to use more than one fan in conjunction with a given system. The fans may be used in series that is the outlet of the first fan is connected to the inlet of second fan and outlet of the second fan is connected to the inlet of the third fan and so on, as shown in Fig.

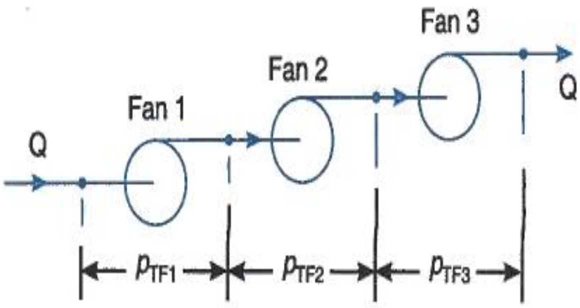


Fig. 21.11. Fans in series.


Series centrifugal fans.

When the fans are connected in series, then

1. the volume flow rate (Q) through each fan is same, *i.e.*

$$Q = Q_1 = Q_2 = Q_3$$

2. the overall fan total pressure (p_{TF}) is equal to the sum of the fan total pressures developed by the individual fans, *i.e.*

$$p_{TF} = p_{TF1} + p_{TF2} + p_{TF3}$$

Fans in Parallel

The fans may be used in parallel that is the inlets and outlets of the fans are connected together, as shown in Fig. 21.12.

When the fans are connected in parallel, then

1. the fan total pressure of each fan is the same *i.e.*

$$p_{TF1} = p_{TF2} = p_{TF3}$$

2. the total volume delivered (Q) is equal to the sum of the volumes delivered by the individual fans, *i.e.*

$$Q = Q_1 + Q_2 + Q_3$$

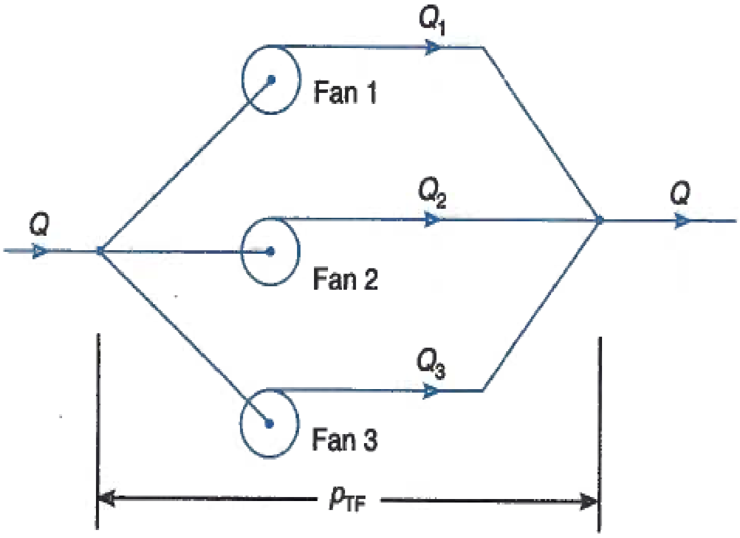


Fig. 21.12. Fans in parallel.

Dual fans:

Sometimes dual fans are used either in series or parallel. When comparing the fan characteristics of a single fan and dual fans in series (all identical) the pressure is doubled for a given volume flow rate.

When the system curve is plotted on the same graph the new operating point can be determined and compared with pressure that of a single fan as shown in fig. 1. The same applies with parallel fans where the volume flow rate is doubled for a given pressure. As shown in fig. 2.

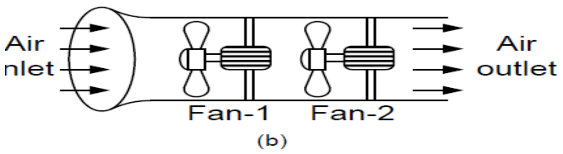


Fig. 1. two fans in series

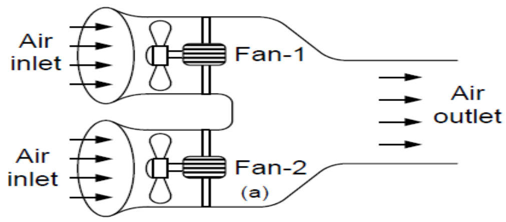
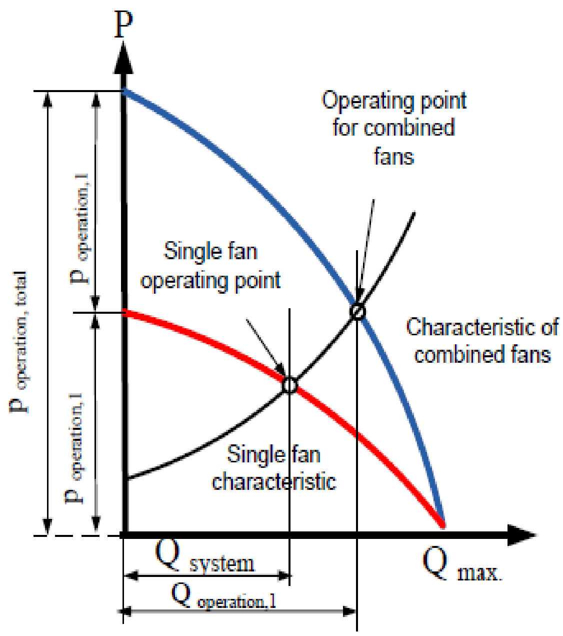
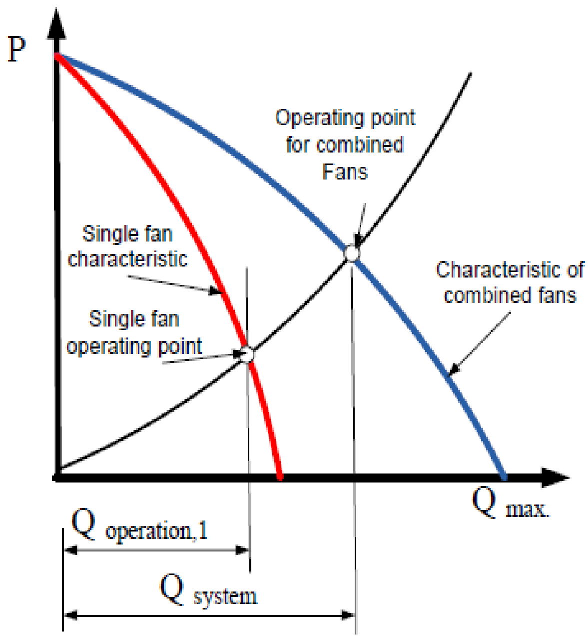


Fig. 2. two fan in parallel





سؤال وزاري مهم

Q/ What is the function of the fan in an air conditioning system. Also describe the centrifugal fan with drawing.