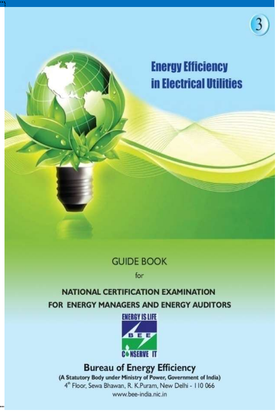
OPTC TRAINING COURSE

BOOK 3 – ENERGY EFFICIENCY IN ELECTRICAL UTILITIES
Brief Contents



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Chapter-5 Fans and Blowers
Contents

Learning Objectives

- ✓ Fan types and application
- ✓ Factors affecting efficiency
- ✓ Selection of Fan
- ✓ Flow control strategies
- ✓ Performance assessment and Energy saving opportunities

1 Introduction

Purpose : Fans and blowers provide air for ventilation and industrial process requirements.

- *Supply air / exhaust air system*
- *Boilers, furnaces, PROCESS*

How air is flowing? **Fans generate a pressure to move air** / gases against a resistance caused by ducts, dampers in a fan system. The fan rotor receives energy from a rotating shaft and transmits it to the air

What is the Difference between fans, blowers and compressors ?

Equipment	Specific Ratio	Pressure rise (mmWc)
Fans	Up to 1.11	1136
Blowers	1.11 to 1.20	1136 – 2066
Compressors	more than 1.20	-

As per ASME, the specific pressure, i.e, the ratio of the discharge pressure over the suction pressure

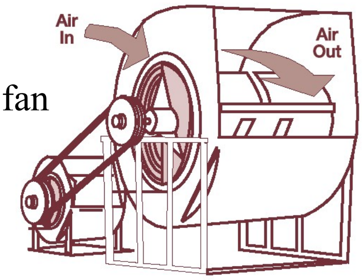
2 Fan types

Fans are classified into two general categories: **centrifugal flow and axial flow.**

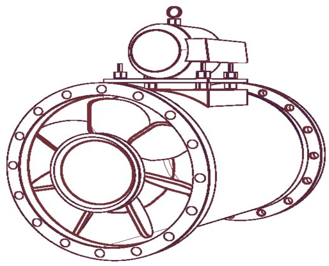
In centrifugal flow, airflow changes direction twice - once when entering and second when leaving ***(forward curved, backward curved or inclined, radial)***

In axial flow, air enters and leaves the fan with no change in direction (propeller, tube-axial, vane- axial)

Centrifugal fan



Axial fan



Centrifugal Fan: Types

Three types of centrifugal fans

- **Radial fans – used for** high static pressures (upto 1400 mm WC) and ability to handle contaminated air streams. Radial fans are suited for high temperatures
- **Forward-curved fans are used** in clean environments and operate at lower temperatures and best suited for moving large volumes of air against low pressures.
- **Backward-inclined fans** are more efficient than forward-curved fans. Backward-inclined fans are known as "**non-overloading" because** changes in static pressure do not overload the motor High Pr, Boiler FD

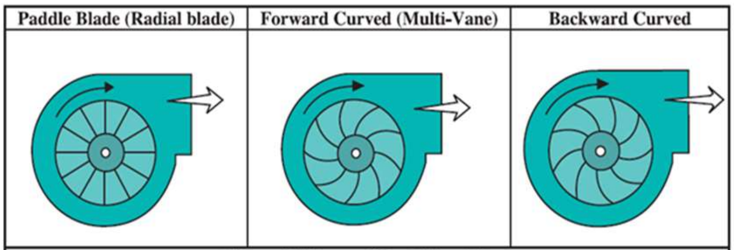


Figure 5.3 Types of Centrifugal Fans

Axial Flow Fan: Types

Three types of Axial Flow Fans

Tube-axial fans have a wheel inside a cylindrical housing. The wheel turn faster than propeller fans.

Used for 250 – 400 mm WC.

Vane-axial fans are similar to tubeaxials, but guide vanes provided for directing and straightening the flow.
used upto 500 mmWC.

Propeller fans usually run at low speeds and used indoors as exhaust fans.Handle large volumes of air at low pressure or free delivery.

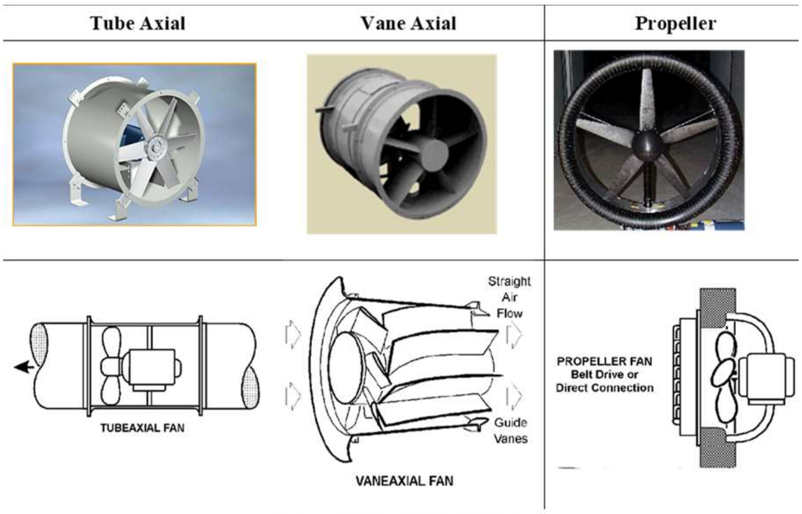


Figure 5.4 Types of Radial Fans

Fan Types and Efficiencies

Common Blower Types

- Blowers can achieve much higher pressures than fans, as high as **1.20 kg/cm²**.
- It is also used to produce negative pressures for industrial **vacuum systems.**
- Major types are **centrifugal and positive-displacement blower.**

Centrifugal blowers rotates as fast as 15,000 rpm. Operate against pressures of **0.35 to 0.70 kg/cm²**, but can achieve higher pressures.

Positive-displacement blowers have rotors, which "trap" air and push it through housing. It is a constant volume of air even if the system pressure varies. Used up to **1.25 kg/cm²**

Fan Efficiencies	
Type of fan	
Centrifugal Fan	
Airfoil, backward curved/inclined	79-83
Modified radial	72-79
Radial	69-75
Pressure blower	58-68
Forward curved	60-65
Axial fan	
Van-axial	78-85
Tube-axial	67-72
Propeller	45-50

5.3 Fan Performance Evaluation and Efficient System Operation

"**system resistance**" is used to refer he static pressure. The system resistance is a function of ***ducts, pickups, elbows and the pressure drops across equipment- for example bagfilter or cyclone***

The system resistance increases as the volume of air flowing through the system increases; **square of air flow.**

Conversely, resistance decreases as flow decreases. To determine what volume the fan will produce, In existing systems, the system resistance can **be measured.**

System characteristics curve

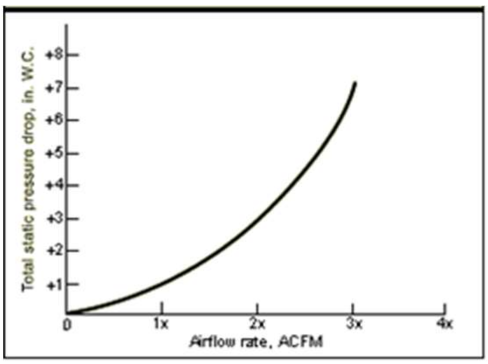
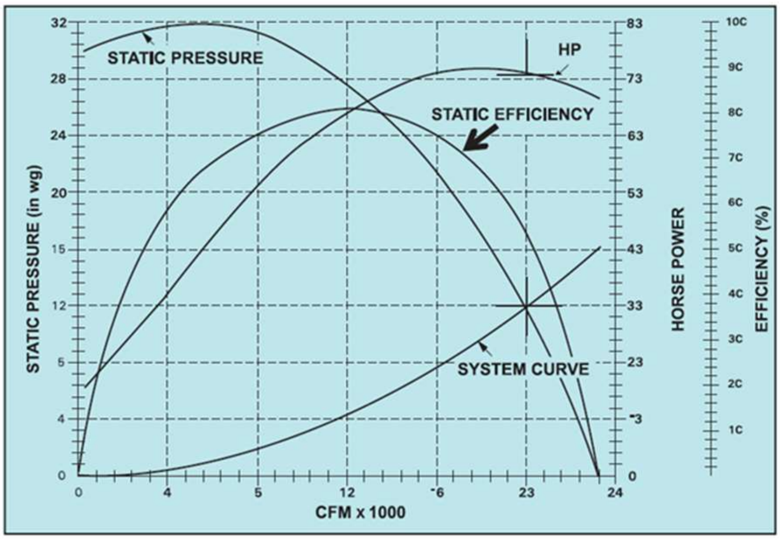


Figure 5.5 System Characteristics

Fan Characteristics

Fan curves is developed for a given set of conditions “ fan volume, system static pressure, fan speed, and horsepower required to drive the fan efficiency
under the stated conditions.
The curve static pressure (SP) vs. flow is especially important



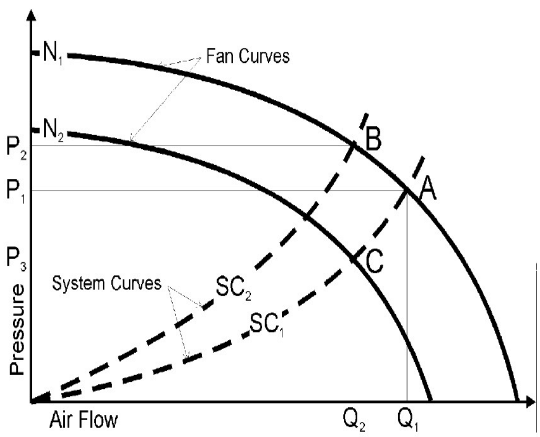
System characteristics and Fan curves

Two methods can be used to reduce air flow from Q1 to Q_2:

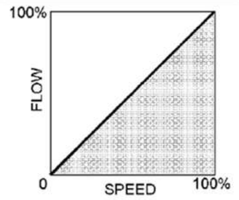
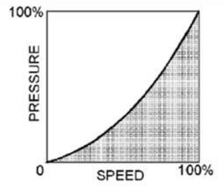
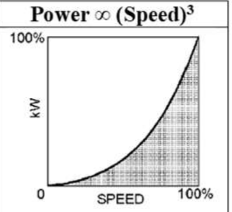
First method is by partially closing a damper in the system. The fan will now operate at "B" to provide the reduced air flow Q_2 against higher pressure P_2.

Second method is by reducing the speed from N_1 to N_2, keeping the damper fully open. The fan would operate at "C" to provide the same Q_2 air flow, but at a lower pressure P_3.

Thus, reducing the fan speed is a much more efficient method.



Fan Laws

Flow ∞ Speed	Pressure ∞ (Speed)^2	Power ∞ (Speed)^3
		
$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$	$\frac{SP_1}{SP_2} = \left(\frac{N_1}{N_2}\right)^2$	$\frac{kW_1}{kW_2} = \left(\frac{N_1}{N_2}\right)^3$
Varying the RPM by 10% decreases or increases air delivery by 10%.	Reducing the RPM by 10% decreases the static pressure by 19% and an increase in RPM by 10% increases the static pressure by 21%.	Reducing the RPM by 10% decreases the power requirement by 27% and an increase in RPM by 10% increases the power requirement by 33%.

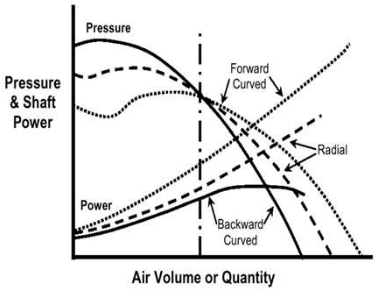
5.4 Fan Design and Selection Criteria

Air-flow and required outlet pressure are most important in proper selection of fan type and size

- **Air flow depends upon** requirement such as heat transfer rates, combustion air, flue gas quantity etc.
- **System pressure depends upon** pressure drop across length, bends, contractions, expansions, branch lines, bag filters, process pressure
- etc.

Once flow and pressure requirements are determined, the fan and impeller type are selected from manufacturer specific fans.

Fan Static Pressure and Power Requirements for Different Fans



Fan Performance Characteristics Based on Fans/ Impellers

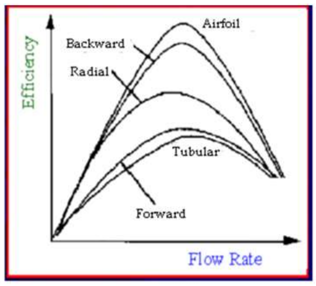
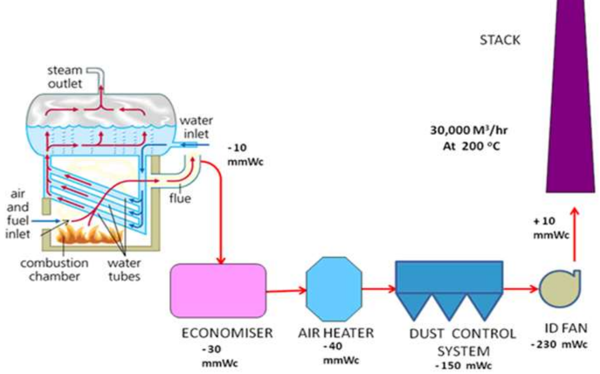


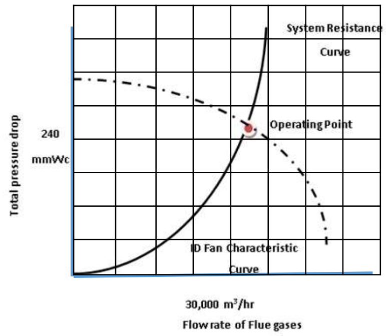
Figure 5.9 Fan Performance Characteristics Based

Safety margin can be 5 % over the maximum requirement on flow rate.

- For boilers induced draft (ID) fan - safety margin of 20 % on volume and 30 % on head.
- For forced draft fans and primary air fans , Generally zero but safety margins of 10 % on volume and 20 % on pressure are maintained for FD and PA fans.

System Resistance and Pressure Drop





System resistance also changes depending on the process. (*Ex formation of the coatings / erosion ducts, Replacement equipment's or duct modifications.)* Hence, the system resistance has to be periodically checked,

The overall resistance (pressure drop) to be build up by the ID fan is the difference between the outlet pressure and the inlet pressure [i.e. 10 – (-230) = 240 mmWc].

5 Flow Control Strategies

- Fan is designed for operating at constant speed. But practically, there may be need for increase in flow or decrease in flow.
- Various strategies are
  1. **Pulley change**
  2. **Damper controls**
  3. **Inlet guide vanes,**
  4. **Variable speed drives**
  5. **Series and parallel operation**

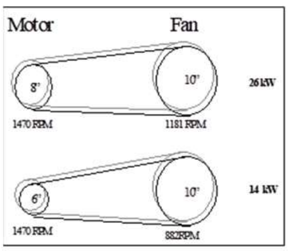


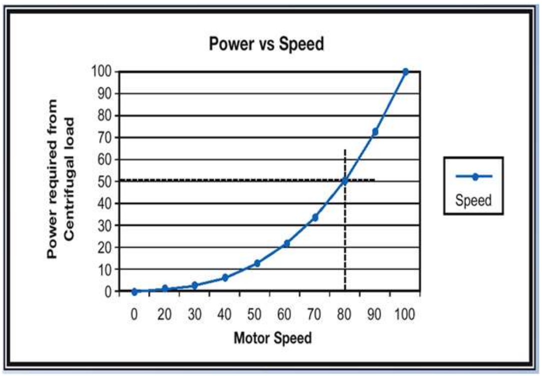
Figure 5.12 Pulley Change

Figure 5.13 Damper change

Figure 5.14 Inlet Guide Vanes

Variable Speed Drives

- Provide infinite variations in speed control
- Fans laws are applicable: power input changes as the cube of the flow
- Economical for system with frequent flow variations
- For assessing power consumption, efficiency of control system should be taken in account



Series and Parallel operation

- Parallel operation
  - Two fans operating in parallel ideally will result in doubling of flow at free delivery
  - Higher the system resistance, less increase in flow with parallel fan operation
- Series operation
  - Two fans operating in series ideally will result in doubling of static pressure at given flow
  - Higher the system resistance, better the result

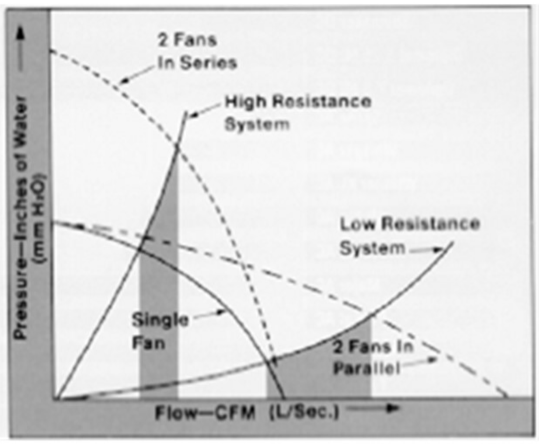


Figure 5.15 Series and Parallel Operation

6. How to do Fans Performance Assessment

By measurement of flow, head and temperature on the **fan side** and kW input on the **motor side**.

Static pressure: Potential energy put into the system by the fan

Velocity pressure: Pressure arising from air flowing through the duct. This is used to calculate velocity

Total pressure : (Static pressure + velocity pressure.)Total pressure remains constant unlike static and velocity pressure

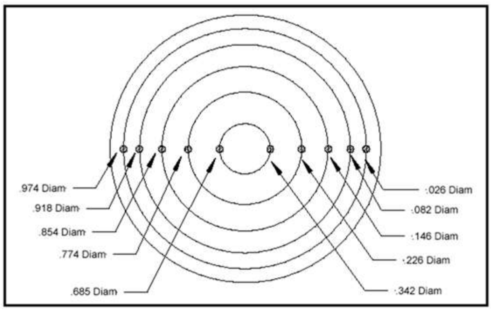
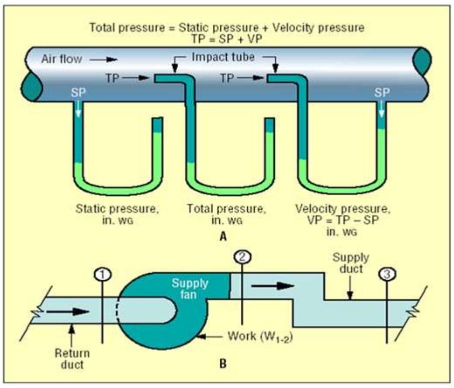
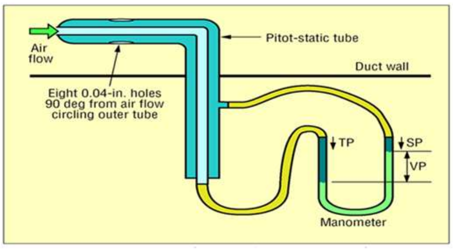


Figure 5.17 Traverse Points for Circular Duct

Traverse points for velocity measurement





Calculation of

$$Gas\ \ Density\ \ (\gamma) = \frac{273\ \ x\ 1.293}{273\ \ +\ t^{o}C}$$

$$\text{Velocity v, m/s} = \frac{C_p\ \ x\ \ \sqrt{2 \times 9.81 \times \Delta p \times \gamma}}{\gamma}$$

Volumetric flow (Q), m^3/s = Velocity, m/s x Area(m^2/s)

$$Fan\ Mechanical Efficiency(\eta_{mechanical}),\% = \frac{Volume in\ m^3/\sec * \Delta p\,(total\ pressure)\ in\ mmWC}{102 * power input to\ fan shaft in\ kW} x\ 100$$

$$Fan\ \ Static\ Efficiency\ (\eta_{static}),\% = \frac{Volume\ in\ m^3/\sec * \Delta p\,(static\ pressure)\ in\ mmWC}{102 * power\ input\ to\ fan\ shaft\ in\ kW} x\ 100$$

7 Energy Saving Opportunities

- Avoid unnecessary demand- excess air reduction, idle running, arresting leaks
- Match fan capacity to demand – downsizing, pulley change, VSD, impeller de-rating
- Reduce pressure drops – remove redundant drops, modify ducts with minimum bends
- Drive system- direct drive, V belt by Flat belt, two speed motors
- Replace with energy efficient fan, impeller
- Change to hallow FRP impeller
- Inlet guide vane in place of discharge damper control

8 Case Study on pressure drop reduction across the bag filter

Problem One of the Cement filter bag house is experiencing high Differential Pressure (DP) across the bag house while producing one particular type of cement.
This high DP is resulting in high power consumption and **puffing from the bag house**.

Upon examination it has been found that particle size distribution for this particular type of Cement associated with the fineness is creating high DP. The results of this replacement are given

Application	Bag Filter for Cement Mill	
Problem	High DP across the bag house while producing one particular type of Cement Product	
Reason for the Problem	Characteristics of particle size distribution associated with its fineness is creating high DP across the bag house	
Solution	Replace the existing filter bags with PTFE Membrane filter bags	
Results	(a) Reduction of 50mm WC in DP across the bag house (b) Reduction of 5kWh in power consumption	
Parameter	Existing Bag	Bag with membrane
Gas Volume m3/hr	40000	41600
Temperature in ^{o} C (IL/OL)	96.8/86.9	98.2/88.7
Type of Filter bags	Mixed Felt	Mixed Felt with PTFE membrane
DP across the bag house mm WC	165	115
ID Fan power consumption kWh	51	46
Conclusion	by changing the filter fabric significant performance improvement of the bag house	

5.9 Computational Fluid Dynamics

Application of CFD in a Fan System for Energy Efficiency

This case study describes the optimization of the induced draught flow of a double-inlet fan using CFD.
The very sharp-edged transitions at inlet side affect the smooth flow.
The black circles indicate that too sharp-edged prevent the flow from following the contours, resulting in turbulence and pressure drops and thus leads to additional electrical energy consumption.
Optimization of the geometry involved redesigning the critical points highlighted in Figure that the cross-section transitions were smooth
The mean pressure drop saving of 275 Pa at a volume flow of 5,00,000 m³/h significantly reduces the power consumption.
The resultant power saving was of the order of 49 kW.

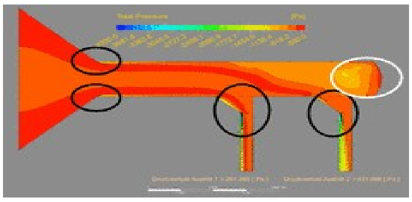


Figure 5.22 Total pressure profile with original design

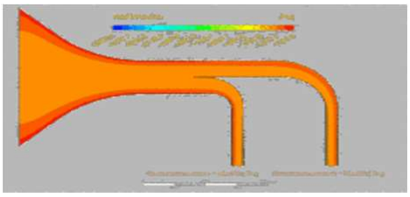


Figure 5.23 Total pressure profile after optimizing design

Solved Example:

A V-belt centrifugal fan is supplying air to a process plant. The performance test on the fan gave the following parameters.
Find out the static fan efficiency.

Density of air at 0 °C	1.293 kg/m³
Ambient air temperature	40 °C
Diameter of the discharge air duct	0.8 m
Velocity pressure measured by Pitot tube in discharge duct	45 mmWC
Pitot tube coefficient	0.9
Static pressure at fan inlet	- 20 mmWC
Static pressure at fan outlet	185 mmWC
Power drawn by the motor coupled with the fan	75 kW
Belt transmission efficiency	97 %
Motor efficiency at the operating load	93 %

Ans:

Air temperature	40 °C
Diameter of the discharge air duct	0.8 m
Velocity pressure measured by Pitot tube	45 mmWC
Static pressure at fan inlet	- 20 mmWC
Static pressure at fan outlet	185 mmWC
Power drawn by the motor	75 kW
Transmission efficiency	97%
Motor efficiency	93 %
1. Area of the discharge duct	3.14 x 0.8 x 0.8 x 1/4
	0.5024 m^2
Pitot tube coefficient	0.9
2.Corrected gas density	(273 x 1.293) / (273 + 40) = **1.1277**

3.Volume	$\frac{C_p \times A \sqrt{2 \times 9.81 \times \triangle p \times \gamma}}{\gamma}$
	$\frac{0.9 \times 0.5024 \times \text{Sq rt.}(2 \times 9.81 \times 45 \times 1.1277)}{1.1277}$
	12.65 m³/s
4.Power input to the shaft	75 x 0.97 x 0.93
	67.65 kW
Static Fan Efficiency % = $\frac{\text{Volume in } m^3 / \text{Sec} \times \text{total static pressure in mmwc}}{102 \times \text{Power input to the shaft in (kW)}}$	
5.Fan static Efficiency	$\frac{12.65 \times (185 - (-20))}{102 \times 67.65}$
	37.58 %

QUESTIONS	
Objective Type Questions	
1.	In a textile mill, two 150 cfm belt driven reciprocating compressors are seen to be working constantly with a loading time of 20 seconds and unloading time of 30 seconds. The best economic option for energy savings would be: a) switch off one compressor b) switch off one compressor and reduce motor pulley size of the other compressor appropriately c) adopt variable speed drive for one of the compressors d) none of the above
2.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by a) discharge pressure/suction pressure b) suction pressure/discharge pressure c) discharge pressure/ (suction pressure + discharge pressure) d) suction pressure/ (suction pressure + discharge pressure)
3.	The efficiency of backward-inclined fans compared to forward curved fans is__ a) lower b) higher c) same d) none of the above
4.	For centrifugal fans, the relation between shaft input Power (kW) and Speed (N) is given by a) = b) = c) = d) none of the above
5.	Parallel operation of two identical fans in a ducted system a) will double the flow b) will double the fan static pressure c) will increase flow by more than two times d) will not double the flow

Thank You

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Save energy and water for Sustainable Life

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