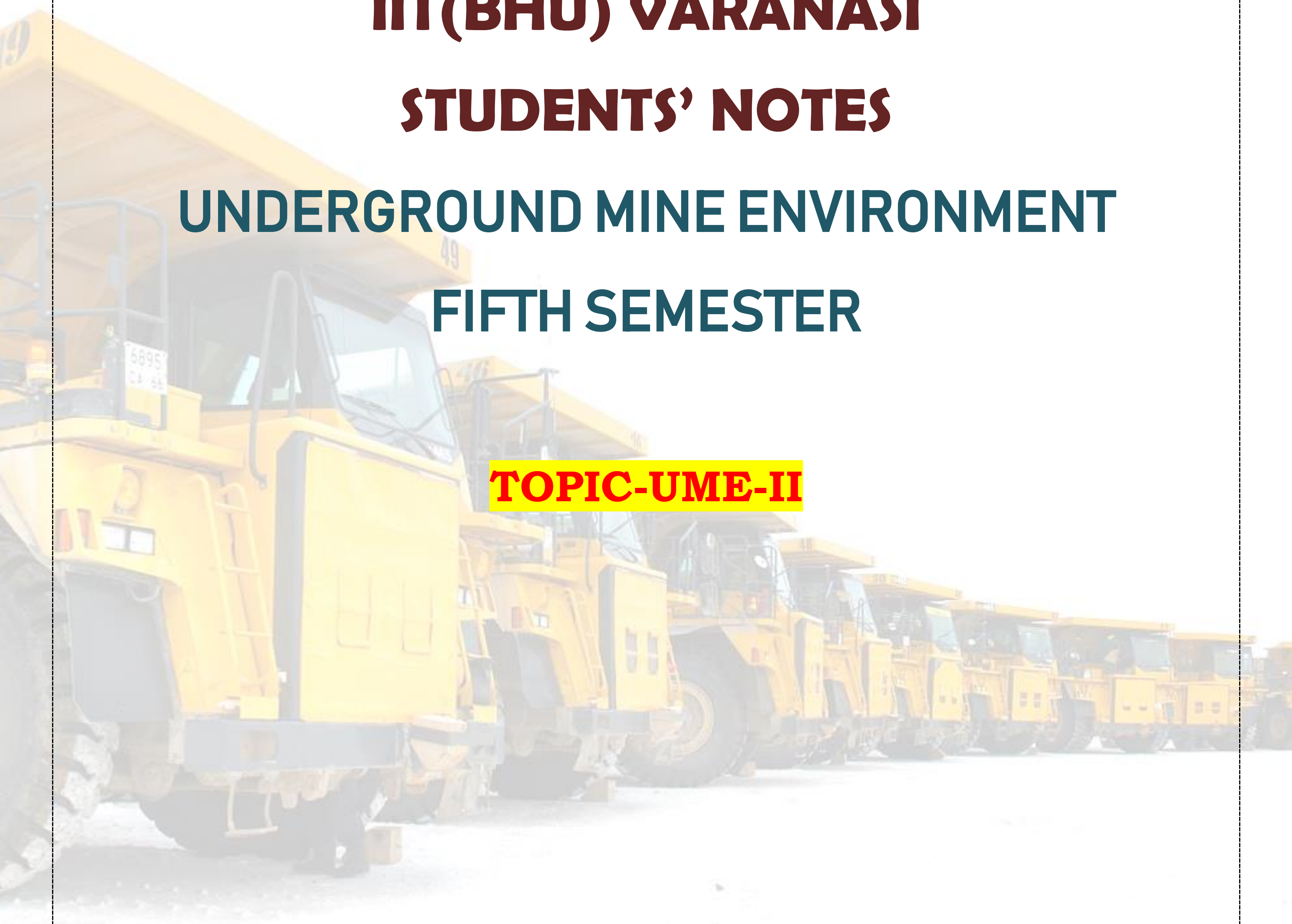
IIT(BHU) VARANASI

STUDENTS' NOTES

UNDERGROUND MINE ENVIRONMENT

FIFTH SEMESTER



TOPIC-UME-II

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Mechanical Ventilators

- Main Mine Fan : main mechanical ventilator of u/g mine that handles total flow of mine air or of a major circuit

- Booster Fan : A mechanical ventilator used for below ground for boosting whole current of air passing along the intake or return airway of a mine or ventilating district.
  Note : A booster fan passes the whole of the air circulating in district or the districts concerned and it works without ventilation ducting

- Auxiliary Fan : A forcing or an exhausting fan, used below ground wholly or mainly for ventilating one or more faces forming part of a ventilating district

Depending on function and position of fan with reference to airway circuit it is designated as Exhausting Fan and Forcing Fan

Based on design and principle of working fan are grouped as
- Centrifugal or radial-flow fan
- Air Screw or axial-flow fan

• Ventilation Screw District means such part of a mine below ground as has an independent intake airway commencing from a main intake airway and an independent return airway terminating at a main return airway

Increase of Air Quality

- By installing a regulator in the neighbouring split
- By enlarging the airway
- By increasing the speed of the fan without undue rise of w-g, with consequent loss of power in regulator of loss resistance splits and increased air leakage
- By installing a new mine fan with a large peripheral speed
- $6m^3$/min/person is required in normal shift or $2.5m^3$/tonne/min

CH4 0.75 % in return air
and 1.25% anywhere

Date 4/8/14
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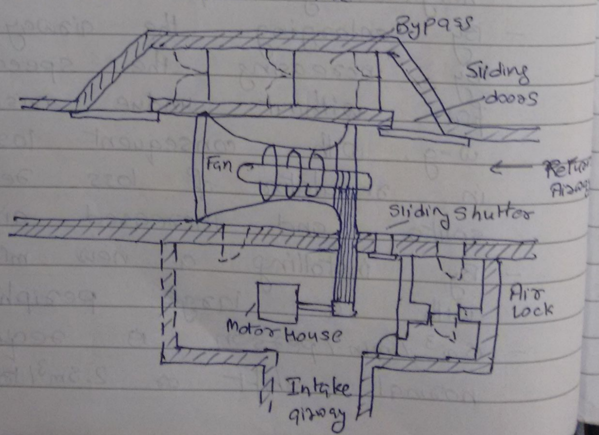
Purpose of Booster Fan Installation

Primary objectives of a booster fan are -

- To enhance or maintain adequate airflow in area of the mine that are difficult or uneconomic to ventilate by main fan

- To improve the working condition in deep hot mines by speeding up the air and increasing the cooling power

- To redistribute the pressure pattern such that air leakage or the risk of spontaneous heating is minimised and the



$\therefore$ 30.5 °C should be maximum temperature if the air vel. = 1 m/s

Joint operation of main & booster fan

Depending on the power of the booster fan, the result of it's installation may be :

- The required distribution of air between splits
- An excessive increase of the flow in one split at the expense of the others
- A reduced or even a reversal of the air flow in the splits which have no booster

In both the last instances, it is neccessary

- To reduce, if possible the resistance of common sections
- to increase the resistance of splits containing booster
- To reduce the rpm of booster or to increase that of the main fan.

Operation of booster fan in split

Result of installation

(i) The required distribution of air between the splits

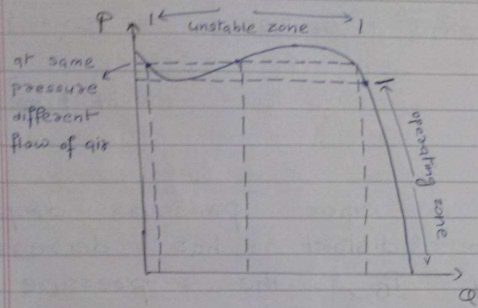
(ii) An excessive increase of flow in one split at the expense of the others

(iii) A reduction or even reversal of the air flow in the splits which have no booster

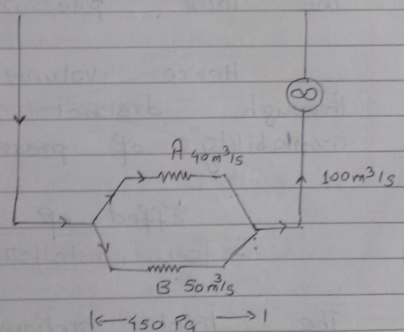
Ques1. Two splits A & B pass 40 m^3/s and 60 m^3/s of air respectively with a pressure of 450 Pa across them when the main fan pressure is 850 Pa. Calculate the pressure of booster fan required to increase the flow in split A to 50 m^3/s and flow in split B after installation of booster assuming

a) main fan pressure remains constant at 850 Pa

b) main fan pressure follow the equation $P = 1650 - 8Q$ in the operating zone where Q is the quantity delivered by fan



Ans



$R_a = \frac{450}{40^2} = 0.28125$

$R_b = \frac{450}{50^2} = 0.125$

$R_T = \frac{400}{(100)^2}$

After installation of booster let Q be new volume.

$$R_T Q^2 + (Q - 850)^2\, 0.125 = 850$$

and

$$R_T Q^2 + 0.28125 \; 50^2 = 850 + P_{Booster}$$

$$\Rightarrow P_B = 100.3797 \; N/m^2$$

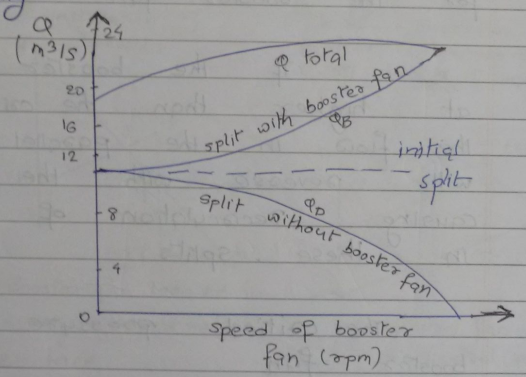
Since pressure drop in district has decreased by P_B, the pressure in common district increases as the total pressure is constant

Hence volume will decrease through district due to less availability of pressure

Effect of booster fan installation

- The total airflow in mine increases
- The airflow in split which need more air can be increased through the installation of the booster fan in it and air flow in other split will decrease

- The increase in airflow of booster split is much more than the reduction in airflow in the un-boosted split
- If we go on increasing the speed of booster fan hence the pressure developed by it, time will come when all the air will flow through boosted split only



Critical pressure of Booster Fan

If booster fan selected is of such high capacity or operates at a high pressure that the whole of the main fan quantity is drawn into the booster split the resistance of the main fan pressure is consumed to overcome the resistance of the shaft & trunk airways. The flow in the parallel splits then becomes zero. The pressure of booster fan in the situation is known as ~~split~~ critical pressure for the booster fan

If the booster fan opera at higher than the critical press the flow in the parallel split will reverse with the booster causing recirculation of the air in these splits

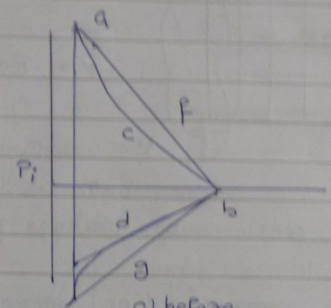
The critical pressure of a booster fan

$$P_b = \frac{R_a}{R_t} \cdot P_{total}$$

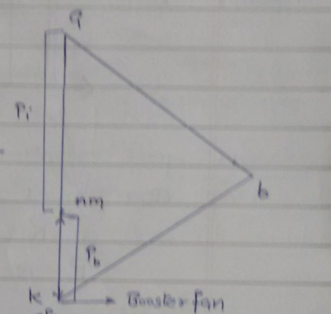
where R_a is the resistance of the high resistance split A, B is the resistance of the trunk airway and P is the pressure developed by main fan

Recirculation - return to intake

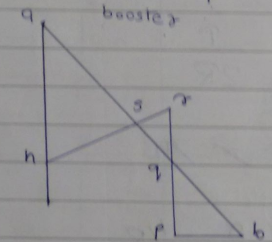
Proper Siting of a Booster Fan



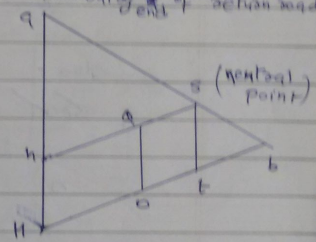
a) before installation of booster



b) after installation of booster at outby end of return road



c) Booster fan located in return road near the face

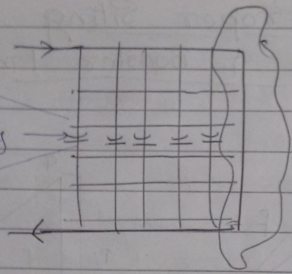


d) Booster fan located at neutral point

Criteria for selection:-

- Maximum setting saving of leakage air
- No recirculation of air

Press.
Difference stopping



$P = RQ_L$

R = resistance of continuous leakage path

Q_L = Leakage quantity

$Q_L = \frac{P}{R}$

P is average (as decreasing)

$\therefore$ $Q_L = \frac{P}{2R}$

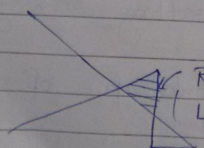
also

~~area~~ $\Delta = \frac{PL}{2}$

$\therefore$ $L \propto 1/R$

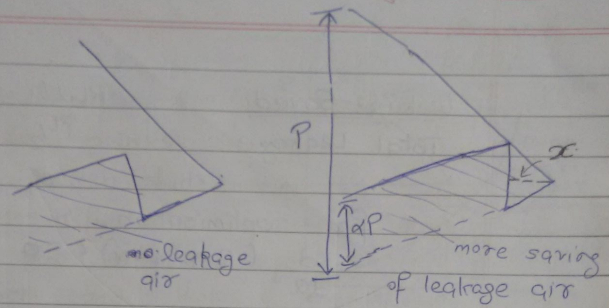
or, $R \propto 1/L$

as $Q_L \propto \frac{PL}{2}$

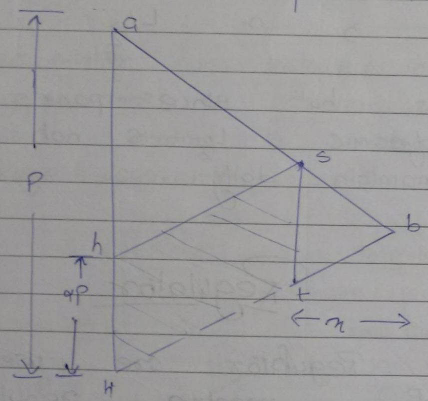


(Return Leakage) : creates recirculation

$\because$ as return press is more than intake



αP press. is available from booster
$(1-\alpha)P$ is available from main fan.



$$\frac{x}{L} = \frac{ts}{Ha} = \frac{\alpha P}{P} \quad \Rightarrow \quad x = \alpha L$$

$$\text{Area } tshH = \frac{1}{2}PL - \frac{1}{2}LP(1-\alpha)(1-\alpha) - \frac{1}{2}\alpha^2 PL$$

$$= \frac{1}{2}PL\left[1-(1-\alpha)^2-\alpha^2\right]$$

$$= \frac{PL}{2}(1-\alpha)\left[(1+\alpha)-(1-\alpha)\right]$$

$$= \frac{PL}{\cancel{2}}(1-\alpha)\cancel{2}\alpha$$

$$\frac{\text{Leakage Saved}}{\text{Total Leakage}} = \frac{PL\alpha(1-\alpha)}{PL/2} = 2\alpha(1-\alpha)$$

for optimisation,

$$\frac{d}{d\alpha}\{2\alpha(1-\alpha)\} = 0$$

$$\Rightarrow \alpha = 1/2$$

$$\Rightarrow x = L/2$$

but since panels are dynamic $L/2$ is not possible to maintain daily

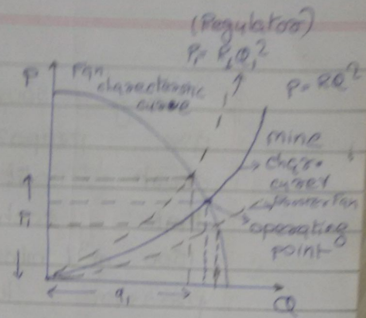
Regulator

Regulator are used in term of negetive regulation.

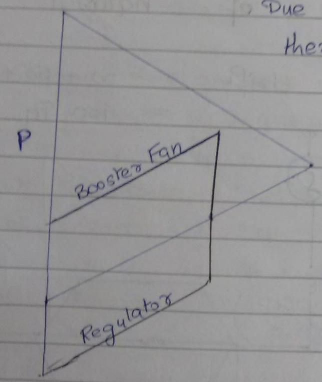
If a regulator is put then effective resistance increases hence volume decrease in mine

It is used to increase air flow in high resistance district of mine

Regulator are wooden planks with a wooden shutter to satisfy the air flow in other district and the shutter is locked with a suitable attachment



Regulator is installed in return airway and a suction zone is created leading to increase in leakage current

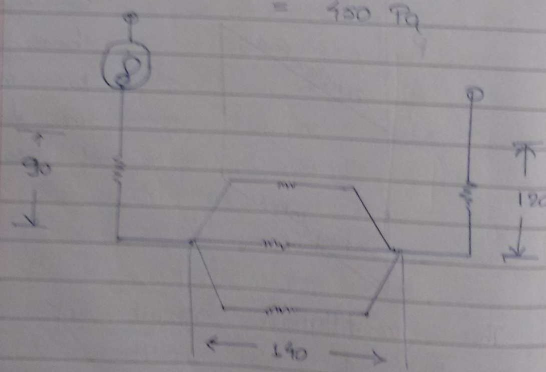


Due to leakage there is chance of auto oxidation ie spontaneous heating leading to increase in the rate of auto oxidation

Q. The ventillation circuit of a mine consist of 3 splits, 2 being 1600 m long each and 3rd one being 300 m long. The resistance are proportional to length. The short split is regulated so that each split recieves 1500 m^3/min of air. The pressure loss due to friction in each shaft is 50 Pa, in main intake, 90 Pa, in main return 120 Pa and across district pressure gauge is 140 Pa. If regulator is removed what quantity of air will flow. Assuming fan drift water gauge remain unchanged & neglect effect of natural ventillation

Ans Fan drift = 50 + 50 + 140 + 120 + 90

= 450 Pa



$R Q^2 = P$

$\Rightarrow R = \dfrac{450}{(4500/60)^2} = 0.08\ Ns^2m^{-8}$

R of 1600 m dist $= \dfrac{140}{(1500/60)^2} = 0.224\ Ns^2m^{-8}$

Effective R of all 8 districts $= \dfrac{0.224}{9} = 0.0249\ Ns^2m^{-8}$

After removal of resistance in form of regulator

$\dfrac{1}{R_{new}} = \left(\dfrac{2}{\sqrt{0.0249}} + \dfrac{1}{\sqrt{0.0128}}\right)^2 Ns^2m^{-8}$

$= 0.192\ Ns^2 m^{-8}$

Change $= 0.0249 - 0.0192$

$= 0.0057\ Ns^2m^{-8}$

New Resistance of mine $= 0.08 - 0.0057$

$= 0.0743\ Ns^2m^{-8}$

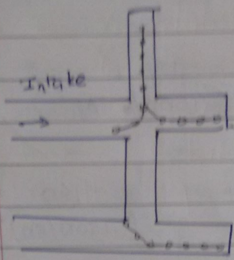
New $Q = \left(\dfrac{450}{0.743}\right)^{1/2}\ m^3/s$

and

$Q_1 : Q_2 : Q_3 = \dfrac{1}{\sqrt{1600}} : \dfrac{1}{\sqrt{1600}} : \dfrac{1}{\sqrt{800}}$

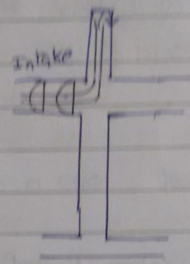
Ventilation of headings

Case 1



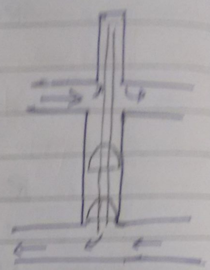
ventilation of heading with line brattice

Case 2



Forcing ventilation with duct

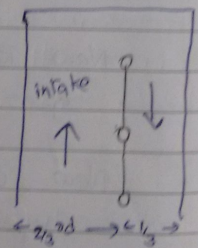
Case 3.



Exhaust ventilation with duct

(i) line Brattice - Treated Hessian Cloth and are flexible hence are to be nailed at wooden block ~~cloths~~ / props ~~B~~. erected at interval of 1 - 1.5m ~~Ru~~ Hessian clothes are rubberised PVC coated fire treated

Since intake is used for man & movement & to avoid dust in circuit the intake is given 2/3 rd width of gallery when brattice is erected.



Brattice is very leaky from roof & floor and upto 30m only 5% air is left hence 20m is maximum limit for using brattice.

Since it divides area it can't be used for mechanised mines as continuous miner need enough space for movement.

In metal mine, the actual metal drive (gallery) is 2 - 2.5 m only and the roof & floor are hard the leakage is more and effect of blasting (more in metal mines) will tear-up the brattice and heading are very long (few 100 m), hence brattices are not used.

Instead of hessian clothes brick wall can be erected but it is permanent & time consuming and few inches thick.

classmate
Date
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(2) Ventilation Tube - In case of large pressure difference ie availability of intake & return air way near the face it is used.

It is of 2 types
(i) Forcing (Case 2)
(ii) Exhausting (Case 3)

In forcing system the total air has to be passed to next face which is returning from 1st Face and the doors will increase the mine resistance.

In exhaust the face 2 will recieve fresh air as well as face 1. Also the doors are not in the path of direct intake path.

Types of ventillation using auxiliary fan

(i) Forcing or blowing system
(ii) Exhaust System
(iii) Overlapping system
(iv) Reversible system

Exhaust system with forcing overlap | Forcing system with exhaust overlap

Use of Auxiliary Ventilation

Auxiliary ventilation system are used to supply air to the sinking shaft, drifts, tunnels and other working face of blind drivages particularly in metal mines where the small size of opening does not permit bratticing. They are also used in short heading of coal mines where large scale mechanisation prohibits the use of brattice. Ventillation of dead-end working place is most important application of auxiliary the primary means of assuring the standards of air quality and quantity in the face. The dilution of dust and gases and the

NOXs and Dust to be removed.

removal of heat are primary reason for applying auxiliary ventilation.

Classification of Auxiliary ventilation

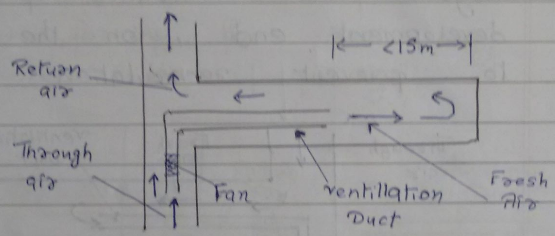
(A) - Forcing or Blowing system of ventilati
(B) - Exhaust system of auxiliary ventilation
(C) - Overlap system
  a) Forcing system with exhaust overlap.
  b) Exhaust system with forcing overlap
(D) - Reversible system

A) Forcing system of ventilation.

With this system the fresh air the through airway is forced into face through a ventilation du by a fan and this air returns via the development face end. The intake to the duct must be extend well into the upstream portion

Booster - District
Auxiliary - Face (Part of a district)

the fresh air stream (at least 4.5m), otherwise there is a danger of the used air which flow out of the face entering the duct and thus being recirculated. The fan should be in the part of the duct which extends into fresh air

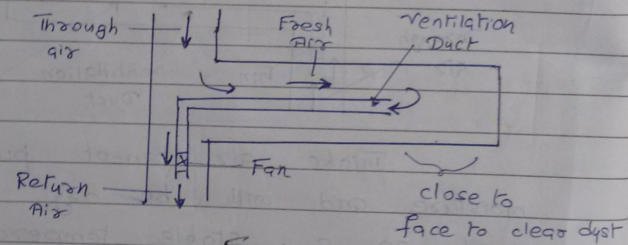


Intake air cannot pick-up the moisture and will be dry which is good as a stable temperature is obtained. And intake air is relative cold as surrounding is duct not hot ~~cold~~

In case of long headings, q/A is very less, hence it may take hours to clear the fume.

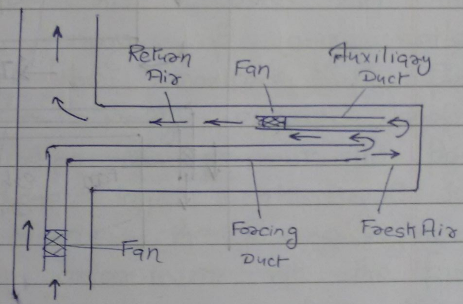
B) Exhaust system of Auxiliary Ventilation

The heading in this case is used as intake and the air duct as the return. The ventilation duct discharge the return air well beyond the entrance of the development end, on the down side to prevent recirculation.



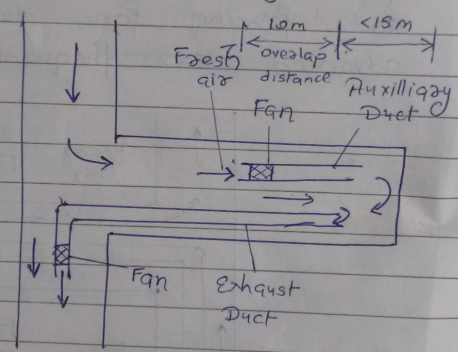
(C) a) ~~Exhausting~~ Forcing system with ~~forcing~~ exhausting overlap

In this system, the forcing fan sends a quantity of air a part of which goes to the exhaust overlap duct and the rest overlap travels out bye through the heading. After the overlap zone, the exhaust fan delivers the air in the heading, (directly or through a dust filter) and the combined air now goes out through the rest of the heading, the exhaust overlap duct has to be extended periodically to keep up with the progress of face but exhaust fan (and the dust filter where fitted) and forcing fan duct may be advanced less frequently.

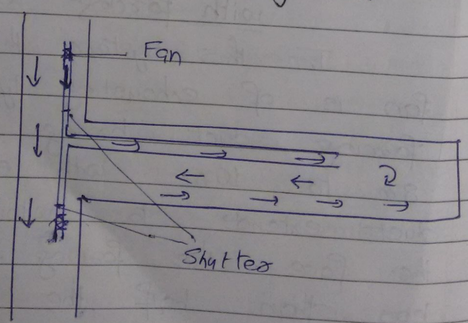


(c) b) Exhausting system with forcing overlap

In this system the basic auxilliary fan is of exhausting type. A short forcing duct having an overlap of 8m to 10m with the exhaust duct extends to within 3m from the face. the forcing fan handles less than half the air drawn by the exhaust fan to avoid risk of re-circulation. The exhaust fan is usually fitted with a duct filter at its outlet end. Quick clearing of shot firing fumes where blasting is adopted and a brisk air vel. at the face is the two advantages of the system.



D) Reversible System



To choose type of ventilation, parameters are
a) Gas
b) Dust
c) Heat.

1. The higher velocity air stream emerging from the face end of a forcing duct gives a scouring effect as the air sweeps across the face. This assists in the turbulent mixing of any methane that may be emitted from fragment rock or newly exposed surface. It also helps to prevent the formation of methane layer at roof level. In hot mines, the forcing system provides cooler air at the face. This results in a cooling effect by lowering the effective temperature.

2. The major disadvantage of forcing system is that pollutants added to the air at the face affect the full length of the heading as air passes back, relatively slow along it.

3. Where duct is main hazard, an exhaust system is preffered the polluted air (containing freed dust and blasting fumes) is drawn directly into their duct at the face - end allowing fresh air to flow through the length of the heading and the heading is kept clear for person working and travelling therein.

4. With the forcing system, the methane emitted out bye in the heading is carried away from the face. with an exhausing system, it is taken in to face area where there is the greatest danger of ignition.

5. With the forcing system the air reaching the face usually take up less heat, moisture and as the air is carried to the face end at high velocity by a duct therefore it cannot pick up heat moisture or dust on its journey to the face. Therefore forcing system of auxilliary

ventilation is particularly suitable for wet headings where the rock temperature is high.

6. Leaks in the duct are more easily detected in forcing system.

7. An advantage of forcing ventilation is that, because the fan handles intake air, its electric motor can be mounted safely in air stream and this results in a compact fan unit.

Exhaust fan ventilation is also unsuitable for headings in which there is sustaintial emission of firedamp. Apart from difficulty of inefficiently ventilating the face area, the high concentration of gases with exhaust ventilation occurs at face where "shortfiring" is carried out and where there are often electrically driven machines. There is also the further objection that if auxiliary fan is stopped as will happen time to time, firedamp may accumulated in high concentration in heading.

without passing through fan which is most undesireable.

Characteristics of Auxiliary Fans

The pressure required for an auxiliary fan depends on the length of drift. The fan should be so selected that it should operate to right of stall point when used with the longest ducting i.e. maximum system resistance. For this reason it is preferable to have a continuously operating dropping pressure chara. of the fan. When operating with short ducting, the fan will have a tending to overloading and that is why it is essential to select a type of fan for auxiliary ventillation which not only has a non-overloading but also have a fairly flat power characteristics.

Auxiliary Ventilation :

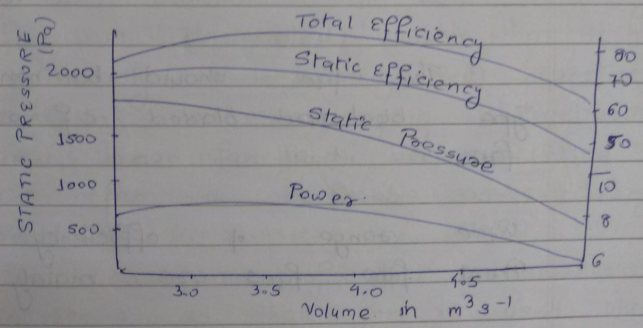
i) Sinking shafts
ii) Development ends
iii) Ventilating Districts
iv) Drifts
v) In metal mine where drivage is too long

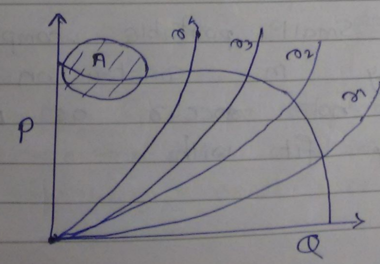
$0.5\ m^3/s$

Large scale mechanisation: $(1.0 - 2.5)\ m^3/s$

Q of air should reach the face for deep & hot mine

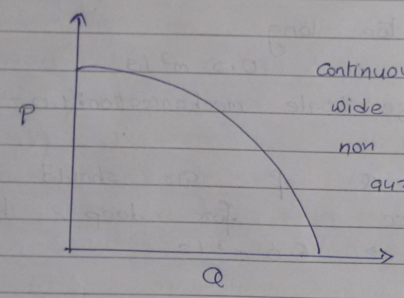
$Q \rightarrow 6.0\ m^3/s$.





$R_4 > R_3 > R_2 > R_1$

Region A is not applicable for operation because for same pressure difference different quantities flow hence hammering operation takes place. This is a stall zone.



Continuous by drop
wide range effi
non loading
auxiliary fan
characteristic
of auxiliary
ventillation

The fan should be non-overloading type backward bladed c.f or auxiliary fan.

Wide range of efficiency characteristic
Axial flow fans are mainly used

→ Small portable compact and sturdy in construction, shock loss will not occur as it can easily fit with

When the tunnel length is more, in deep vertical shaft where more resistance is to be faced to create a large pressure, c.fans are used.

Capacity control feature is generally absent in normal auxilliary fan as it will make it large & heavy.

Inlet vane Damper Control } can control quantity delivered by fan when

To eliminate stall zone auxilliary fan is designated such that it has continuously decreasing P-Q characteristics Due to non-overloading characteristics axial flow fan and backward blade C.F fan is preferable as auxilliary ventilator.

Since resistance of duct is continuously increasing so that fan is used which has wide range of efficiency char. flatter

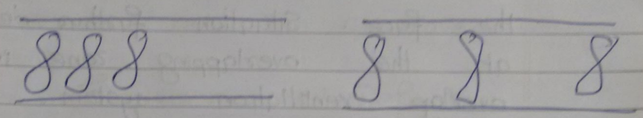
Axial flow fan are compact, portable and sturdy in construction; Also axis flow fan is most suitable.

For long heading / tunnel C.F (backward bladed) is used as it develops large pressure. Auxilliary fa should have continuously decreasing P-Q char. and flatter η-Q and P... char.

- For Quantity control we use inlet vane and damper control attachment. Normally single stage axial flow fans are used (450 - 750 mm ϕ). Their head characterstic is almost a st. line. which develops a press of 1 kPa at high efficiency to 2 kPa at low efficiency
- For operating at high pressure we use a multiple no of fan installation or two stage axial flo fan or ~~concent~~ contra - rotating axial flow fan
- For multiple installation, leakage of air is kept in mine and the is nowhere pressure in the duct less than outside pressure.

Auxilliary ventilator is run by squirrel cage induction motor of ...

2900 rpm, 50 Hz supply



Overlapping Ventilation System

Controlled Partial Recirculation

- Recirculation - The movement of the same or more than once past a given point is reffered as re-circulation.

CMR 137-(1) prohibits recirculation of air by auxilliary fan and DGMS circular No 82 of 1963 recommends that quantity of air taken by an auxilliary fan shall not exceed 50% of quantity in current from which the air passing through the fan is drawn.

- Reason for prohibition - Fear that it may lead to a buildup of firedamp or may cause dangerous build up of other pollutant concentration. But restriction of air quantities handled by auxilliary fan. often lead to low air velocities at the face. Situation further deteriorated at the overlapping zone in an overlap ventilation system.

- Investigation or Recirculation - Theoritical investigation. carried out by leach Slack and Bakke at Safety of mine Research Establishment UK on recirculation showed that re-circulation in auxilliary ventilation system could offer benefits and that it could be safety used if properly applied and controlled.

- Conclusion of investigation on recirculation - The conc of firedamp in any ventilated place is determined solely by 2 factors the rate at which firedamp is given off into the place and the flow rate of fresh air into the place. It doesnot depend on on recirculation that may be taking place provided that the recirculation doesnot reduce the flow rate of fresh air into the place being ventilated and recirculated air is not in a closed loop.

Conclusion and Defination

$$\frac{\text{General body gas conc.}}{} = \frac{\text{Flow of gas into region}}{\text{Flow of fresh air passing through the region}}$$

Defination : A system of controlled partial recirculation is one in which a controlled fraction of air returning from a work area is passed back into the intake while at same time, the volume flow of air, passing through the region is mentioned to ensure that it remains greater than a predetermined minimum

Controlled Recirculation in Heading

A must wide spread application of controlled recirculation has been in headings. One of the disadvantage of the conventional overlap system is the reduction in general body air velocity

... because of ...
sturdiness and long life.

Steel ducts are usually made of hot-rolled mild steel sheets of 1.6 mm thickness; they are made 2m - 3m or 4m sections.

Ventillation Survey

Scope & Importance:- A survey giving idea about quantity as well as quality of air a... gives a clear picture of ambient working environment in mine.

- Scopes
- Concentration of noxious and inflammable gases in mine air. (CO, CH_4, NO, CO_2)
- Conc. of pathogenic dust.
- Dry & wet bulb temperature. (Humidity)
- Barometeric pressure
- Velocity of air.

- Quality of air.
- Pressure Drop.

• Regulations in CMR and Statutory Requirement of measurment

a) Sub Reg 133(4), CMR (1957) - For Gasy seam of Deg - I and max Temp 30°C the survey has to be done every 30 days.

For Deg - II and III gasy seam, survey has to be done every 14 day

b) Sub Reg 132(1) · Before installation of booster fan a detailed survey of pressure drop has to done

c) Sub Reg 130(2)(v) - The conc. of inflamable noxious gases, temperature & humidity every 30 day in working place

d) Sub Reg 145-(2) - Regional Inspector of mine will specify environmental parameters at different places like temp. humidity in every 30 days

Air Quantity Survey

Direct Method
(Tracer Gas Technique)

Indirect Met
(measure velocity and cross-sectional

- Principle of working of airflow measuring Instruments.

(i) Mechanical Effect of air on obj in contact with the air stream - Vane Anemometer, Velometer, Smoke

(ii) Pressure effect produced by mov air - Pitot Tube, Orifice Plates & Ventu meter

(iii) Effect of air velocity on the co rate of hot body placed in air stream - Hot wire anemometer, Kata - Thermometer

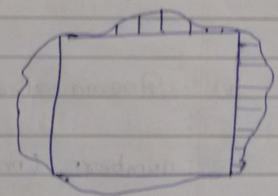
(iv) Formation of vortices on the downs of obstacle placed in the air stream - Vortex - Shadding anemometer

Measurement of Cross - Sectional Area

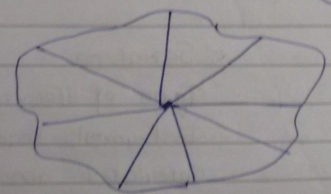
(i) Tapping Method
(ii) Offset Method
(iii) Profilometer Method
(iv) Photographic Method

- Tapping Method - If airway is of rectangular as cross-section but in airway boundries which is generally irregular and so offset are measured.

- Offset Methods - Offset are measured normally at 0.3 - 0.5m interval. NCB of UK suggest for measurement of atleast 20 reading for a rectangular cross section.



- Profilor Methods -



- Photographic Method - Photograph is taken of airway by painting ground survey station by white colours.

Measurement of Cross - Sectional Area

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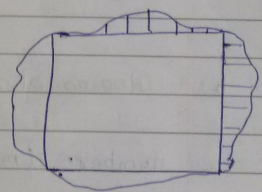
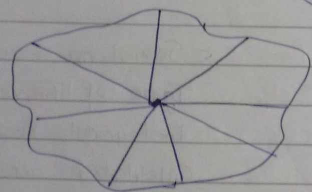


- Profiler Methods -



- Photographic Method - Photograph is taken of airway by painting Ground Survey station by white colours.

Booking of the air quantity measurement

Bookings are made under by sections

a) General Information -

Location of stations (permanent location) . Date & type of measurement . Name of pe[rson] taking the reading of Hygro[meter] reading

b) Anemometer Readings -

Anemometer identification number (modal & make)

- Serial no.
- Type of Traverse
- Instrument Reading
- Calculated air Velocity
- Remark

Observed air velocity
Calibrated Conversion } Calculated air velocity
Corrected air velocity

- Remarks : Movement of cars, disturbance of steady flow, if any roof fall if any etc.

c) Cross - Section Area -

- Rough sketch of airway important dimension (height and width) and other dimensions if cross - section is not rectangular

- Type of obstruction (effective airway cross - section)

- Remarks on the measurement

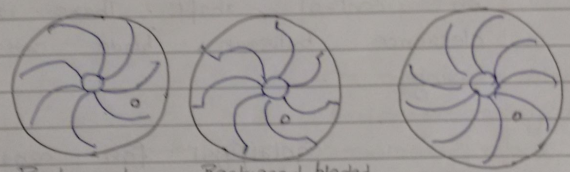
- Measured air quantity ($Q = Av$)

Mechanical Ventillation

- Fan → It is a mechanical device which develops pressure difference to cause airflow

Types of fan are
a) Centrifugal - Air rotates along the blade and it creates high Pressure difference but low volume

Centrifugal
→ Backward Bladed
→ Radial Tip Bladed
→ Forward Bladed



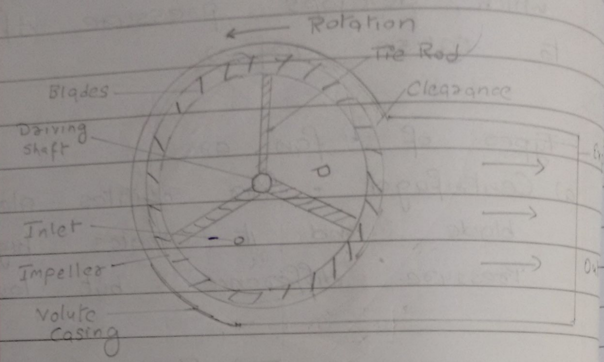
Backward

Backward bladed fan but near tip it gets straighten (Radial)

Forward

b) Axial - It generates low pressure but cause large volume. mines need more volume hence it is prefferred

- Constructional Features :-



A centrifugal fan co of impeller. Impeller is boun on central shaft. There is clearance between blade and v casing

Centrifugal fan consist impellor mounted on tie rod known as Hub.

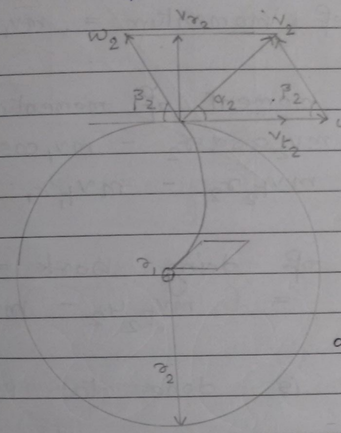
- Theoritical Head Developed by a Centrifugal Fan

$$P \; \rho = \rho g h$$

P = pressure (N/m^2 or Pa)
h = head (m)
ρ = quantity (kg/m^3)

We shall derive the formula on the basis of velocity diagram

Assuming ideal conditions that infinite no of blades is placed in a finite place and no frictional loss.



inlet : 1
outlet : 2

β = angle of blade at tip wrt tangential direction

α = angle of blade peripheral velocity and resultant velocity

ω = relative velocity of air wrt blade tip
u_2 = peripheral speed
v = absolute vel. of air
v_r = radial component of absolute vel.
v_t = tangential component of abs. velocity

Let Q be quantity of air flow (m^3/s)
ρ is density in kg/m^3

momentum of m kg of air at inlet $= mv_1$

component along tangential direction $= mv_1\cos$

Moment of momentum $= mv_1 \cos\alpha_1$

Change of moment of momentum

$= mv_2\cos\alpha\, r_2 - mv_1\cos\alpha\, r_1$

$\tau = mv_{t_2} r_2 - mv_{t_1} r_1 \quad kg\,m^2$

Rate of doing work $= \tau$

$= mv_{t_2} u_2 - mv_{t_1} u_1$

This is done to increase pressure Ques 1

$mgH = mv_{t_2} u_2 - mv_{t_1} u_1$

$\Rightarrow \boxed{H = \frac{1}{g}\left[u_2 v_{t_2} - u_1 v_{t_1}\right]}$

Euler Head

Meridinal Entry → entry of is radial

ie $v_{t_1} = 0$

$$H = \frac{1}{g} u_2 v_{t_2}$$

$$\boxed{H = \frac{1}{g} u_2 \left[u_2 - v_{r_2} \cot\beta_2 \right]}$$

$$Q = 2\pi r_2 \cdot \underbrace{B}_{\text{width}} \cdot v_{r_2}$$

so,

$$H_e = \frac{u_2}{g}\left[u_2 - \frac{Q}{2\pi r_2 B} \cot\beta_2 \right]$$

$$H_e = \frac{u_2^2}{g} - \frac{u_2 Q \cot\beta_2}{2\pi r_2 B g}$$

Ques.1 Air power vs Q when curve
(PQ)

$\beta_2 < 90^\circ$

$\beta_2 = 90^\circ$

$\beta_2 > 90^\circ$

12/08/2014

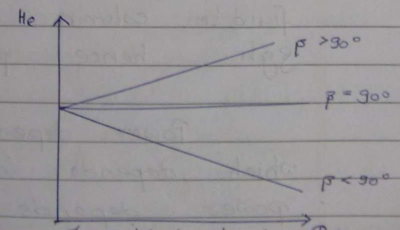
$$H_e = \frac{u_2^2}{g} - \frac{u_2 \cot\beta_2}{2\pi r_2 B g} Q$$

in form of

$y = -mx + c$

actually

$y = -m\cot\beta_2 x + c$



Theoritical characters curve

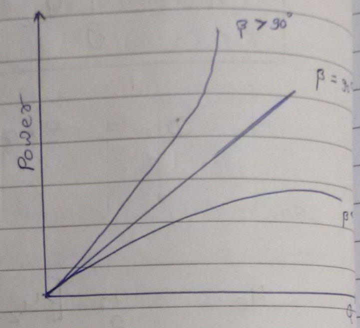
Fan characteristic always measured w.r.t Q.

Power = (Hegg) Q

⇒ Power = $k_1 \cot\beta_2 Q^2 + k_2 Q$

in form of

$y = ax^2 + bx$



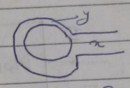
Meridonal entry - is done avoid shock loss. Head devel may not be maximum. Head is more for forwa bladed non-meridonal fan

Head developed is indep of density of fluid and he is expressed in height of fluid (m) column by pressure ρgh, hence pressure varies.

Power depends on pressu which depends on density so power depends on density

Fan Losses

Types of losses are
- Skin Friction
- Conversion of K.E to Pr.E (MSD nice captain of C.Super King)
- Direction change
- Shock Loss
- Mechanical Loss
- Volumetric loss



$P_x > P_y$

$$\eta_{hyd} = \frac{\text{Available pr. head}}{\text{input head}} = \frac{P(\text{actual P develop})}{P + \text{Losses}}$$

power absorbed by impellor

friction converted into head

$$\eta_{vol} = \frac{V_{delivered}}{V + \Delta V}$$

$$\eta_{mech} = \frac{\text{Power absorbed by input}}{\text{Power applied to fan}}$$

$$= \frac{bhp - \text{mech. loss}}{bhp}$$

BHP = Break Horse Power is power required to apply breaks to stop a machine

$$\boxed{\eta_{comb} = \eta_h \times \eta_v \times \eta_{mech}}$$

Since vel. of air is different for different outlet, manufacturers use static power

$$\eta_{static} = \frac{\text{Static Air Power } (P_s \ldots}{\text{Input Power}}$$

$$\eta_{total} = \frac{\text{Air Power } (P_t Q)}{\text{Input Power}}$$

$$\text{Input} \xrightarrow{I} \boxed{\text{Motor}} \xrightarrow{I_1} \boxed{\text{Drive}} \longrightarrow \boxed{\text{Fan}} \xrightarrow{I_2} \text{A.P.}$$

$$\eta_{overall} = \frac{\text{Air Power}}{\text{Input Power}}$$

$$= \eta_m \cdot \eta_D \cdot \eta_F = \frac{I_1}{I} \cdot \frac{I_2}{I_1} \cdot \ldots$$

where

$$\eta_F = \eta_h \cdot \eta_v \cdot \eta_{mech}$$

$$\Rightarrow \eta_{overall} = \eta_m \cdot \eta_d \cdot \eta_h \cdot \eta_v \cdot \eta_{mech}$$

Losses

i) Skin Friction & Diffusion loss - By the walls the passage

ii) Eddy loss - By loss of ... nature

iii) Separation loss

Shock loss

$$P_{friction} = k_1 Q^2$$

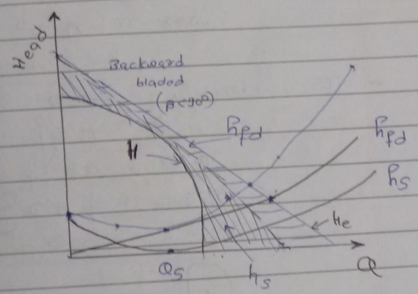
$h_d = k_2 Q^2 \Rightarrow h_{fd} = h_f + h_d = k_3 Q^2$

Shockless Quantity - Quantity for which shock is minimum is Q_S

$$h_s \propto (Q - Q_s)^2 = k_4 (Q - Q_s)^2$$

Total loss $= h_{fd} + h_s$

Actual Head
$$(H) = H_e - k_3 Q^2 - k_4 (Q - Q_s)^2$$



Various Laws of fan

- When speed of a given fan is changed (n)

$$H \propto n^2$$
$$Q \propto n$$
$$Power \propto n^3$$

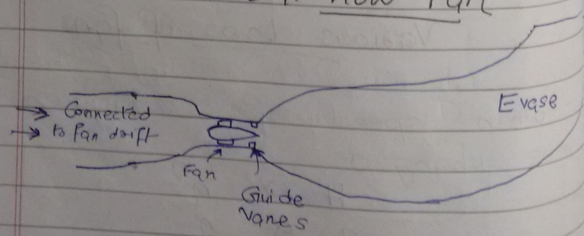
Geometrical similar
(all dimensions same
except D)

- If size of two geometr similar impellor operating at same speed then, (ie diamet
$H \propto D^2$
$Q \propto D^3$
$Power \propto D^5$

- If both speed & size c changed for geometrically sim fan.
$H \propto n^2 D^2$
$Q \propto n D^3$
$Power \propto n^3 D^5$

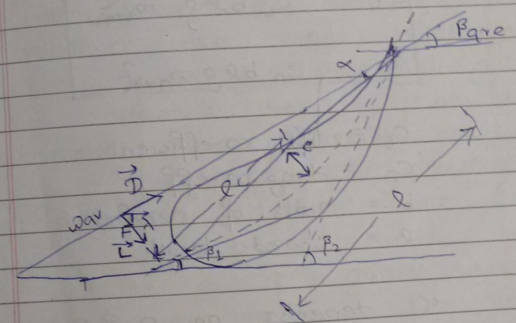
- If density, speed & size ch
$H \propto n^2 D^2$
$Q \propto n D^3$
$Power \propto n^3 D^5 \rho$

Axial Flow Fan



Axial fan have high capacity, low head & high speed. They are of single stage. Though for high pressure 2 - 3 stage fan are used to limit side

Aerofoil Design - Strength is needed for high speed
- Weight is also important factor



An aerofoil consist of a certain thickness of material concen-trated about a mean line shown as dotted. Max distance from mean line to chord (ℓ) is known as Vane Cambre. ℓ_c is distance from nose to vane Cambre.

α = angle of attack

The direction of ave. rel.

D = Drag Force (loss)
L = Lift (effective)

$\vec{F}$ is divided into $\vec{D}$ & $\vec{L}$

λ is known a Gliding a

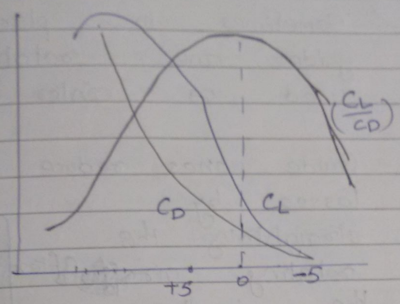
$$\boxed{\begin{aligned} L &= C_L\, b\, l\, \rho\, \omega_{ave.}^2 \\ D &= C_D\, b\, l\, \rho\, \omega_{ave.}^2 \end{aligned}}$$

C_L = lift co-efficient
C_D = drag co-eff
b = width of aerofoil
l = chord length

α depends on β_1 & β_2

To get max efficiency = $\left(\frac{L}{D}\right)$ ratio has to max

Casing are meant for expanding contraction

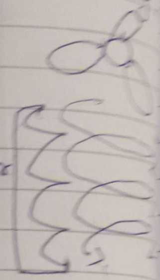


Fan casing are provided with fixed outlet guide vanes, neccesary for converting tangential component of absolute vel. of air leaving impellor into pressure energy by straightning the direction of flow to axial one.

The no. of guide vanes vary 5-8, smaller no. for smaller fan. In addition to

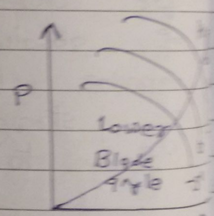
Casing is of diverging nature for reducing velocity and kinetic energy is converted into pressure energy at Evasee.

Sometimes in place of fi...
guide vane, rotating vane
used as counter rotating



Guide vanes reduce
losses by
straightning the
rotating air after
the impellor.

Adjustable blade
angle is also used as
alters the char. curve.
but all the
blades has to
be changed as
not doing so
would lead to
disbalance and
vibration of fan.



This is one of main
resons for using axial
variable angle blade fa...
(pitch)

Arrangement for reversal of mine ventilation