IIT(BHU) VARANASI

STUDENTS' NOTES

UNDERGROUND MINE ENVIRONMENT

FIFTH SEMESTER

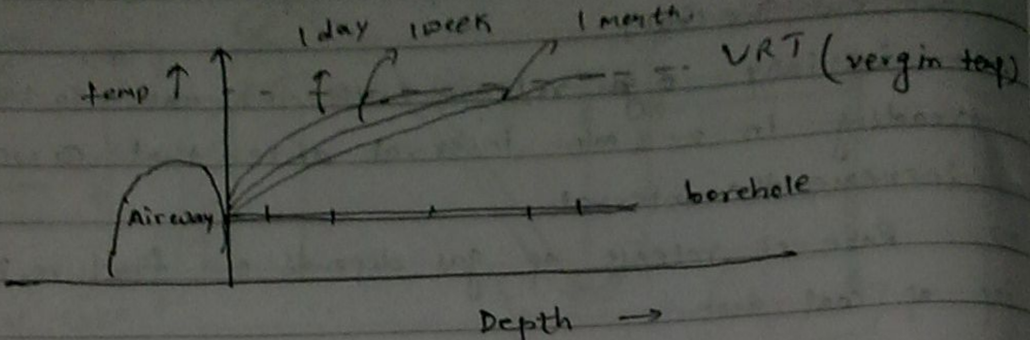
TOPIC-MINE FAN

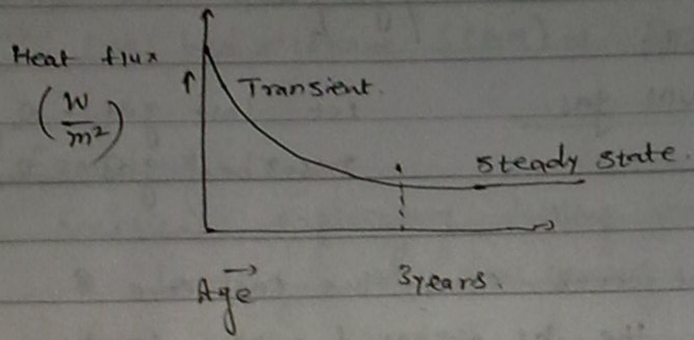
www.MINEPORTAL.in

20/9/2011

SASTRY

Rock to Air heat transfer →





Rate of heat flow from Rock to Air becomes constant After 3 years (general) (Heat flux)

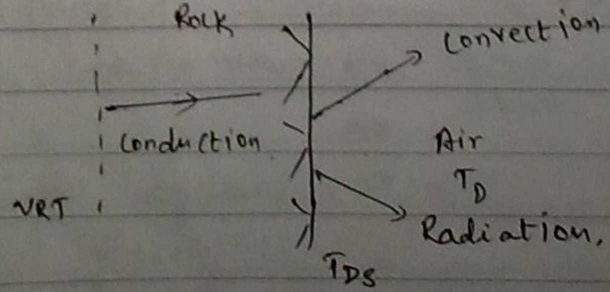
Factors Determining rock to air heat transfer –

1.) Surrounding Rock properties: VRT; Density, specific heat, Conductivity; geothermal gradient.

2.) Roadway properties → Dimensions; Age.

3.) Ventilation air properties : $\dot{m}$; psychrometric properties

4.) Rock to air interface properties: wetness of the surface.



Rock surface is dry than 2 types of heat transfer

① Convection ② Radiation, or Combined form Sensible heat

If wet surface than Evaporation take place.
& Surface temp. is ~~cases~~ known as T_{WS}.

→ If surface is rough than there is better heat transfer in comparison to smooth surface.

Methods of determining Rock to air heat transfer –

① Empirical Methods.

② Analytical Methods

<u>Empirical Method</u> → Assignment (Q. 4)

Convective heat flux.

Rock, | Air

T_D.

T_{DS}

$$Q_c \propto (T_{DS} - T_D)$$

$$= h_c (T_{DS} - T_D) \quad \text{—(1)}$$

h_c = Convective heat transfer coefficient

$$\frac{\text{Watt}}{m^2 \cdot {}^\circ C}$$

$$Q_c = \frac{\text{watt}}{m^2}$$

Radiant heat flux.

$$Q_r = h_r (T_{DS} - T_D) \quad \text{—(2)}$$

h_r = Radiant Heat Transfer coefficient.

Add ① & ②

Sensible heat Transfer = $h_s (T_{DS} - T_D)$

$h_s = h_r + h_c$ s: sensible heat

Rock | T_D

T_{ws}

Convective heat flux.

$$B_c \propto (T_{ws} - T_D)$$
$$= h_c (T_{ws} - T_D)$$

Radiant heat flux.

$$B_r = h_r (T_{ws} - T_D)$$

Evaporative heat flux.

$$B_e \propto (e_{ws} - e)$$

e_{ws} → Saturation vapor pressure at T_{ws}

e → Partial vapor pressure of atmosphere

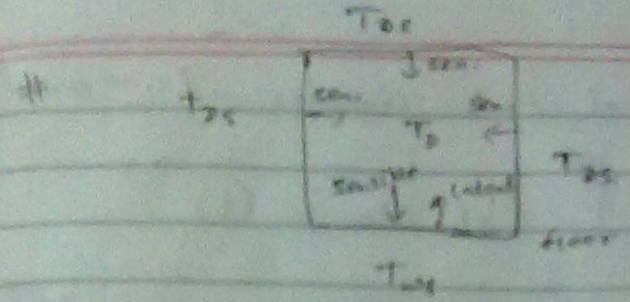
$$B_e = \frac{\beta . L . (e_{ws} - e)}{B}$$

β = Moisture Transfer coeff. $\left(\frac{kg}{m^2 s}\right)$

L = Latent heat of vaporization.

B = Barometric Pressure.

$$\underset{\frac{kg}{m^2 s}}{\beta} : 0.0007 . \underset{\frac{w}{m^2 . °c}}{h_c} \quad \text{(Empirical)}$$



latent heat = evaporating heat

Empirical Metods to estimate Rock to air heat Transfer

Ramsden Equation:

$$Q_r = 5.57\,(T_w + .2554)\,(VRT - T_D)\left(\frac{P}{12}\right)^{.437}\left(\frac{n}{3}\right)^{-.147}\left(\frac{k}{5.5}\right)^{.853}$$

Q_r = Heat Transfer (flow) in KW per 100 m length

f_w = function of ~~Roadway~~ Roadway Perimeter that is wet.

P = Perimeter, m

n = Age, Years

K = Rock Thermal Conductivity $\frac{W}{m.°C}$

$VRT \rightarrow T_{DE} \rightarrow T_D$

$47 \rightarrow 35.5 \rightarrow 35$

Whiller Equations →

1.) For Advancing Heading.

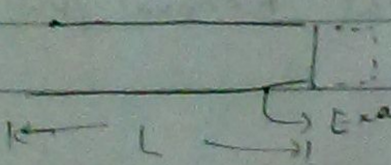
$$Q = 0.006\,K\,(L + 4\,DFA)\,(VRT - T_D)$$

Q → KW

K → Rock Thermal Conductivity

L = heading length m.

DFA = Daily ~~advance~~ face Advance



↳ Example Longwall gate road

2.) One Dimensional Heat Transfer → Ex. → stope

$$B = A \cdot (k \cdot \rho \cdot c)^{0.5} \, (VRT - T_2) \, (t)^{-0.5}$$

A → Surface Area.

B → watt

k → RTC (Rock Thermal conductivity) $\frac{w}{m \cdot °c}$

ρ → Rock Density kg/m^3

Rock → Rock specific heat $\frac{J}{kg \cdot °c}$

t → Age in seconds.

3.) Tunnel heat flow

$$B = 3.35 \cdot L \cdot k^{.554} \, (VRT - T_2)$$

B = watt

L = Tunnel length 'm'

k = RTC $\frac{w}{m \cdot °c}$

Air Cooling →

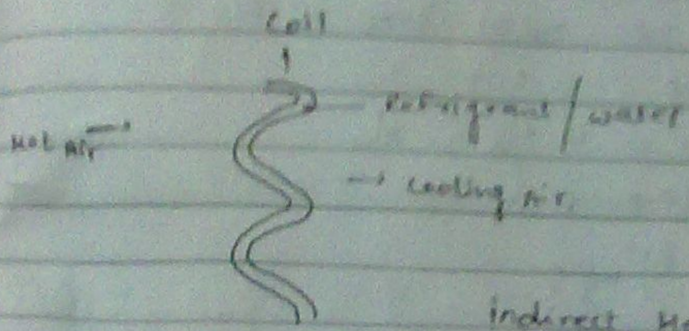
h_i → $\dot{m}$ → Heat Exchanger → cool Air

inlet air enthalpy — h_a Acceptable enthalpy

$$\dot{m} \, (h_i - h_a) = \text{Heat Removal (kw)}$$

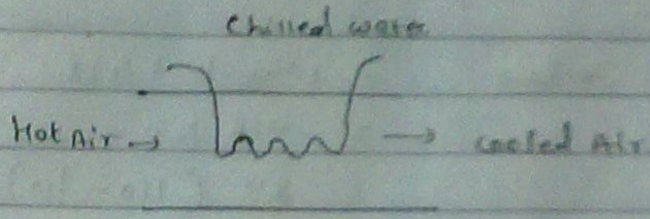
r → Ex. → stope
≈0.5
(t)
ity)
/m³
g.t
D)
ir.
ceptable enthalpy
w)

As a heat exchanger typically chilled water is used (5°C)

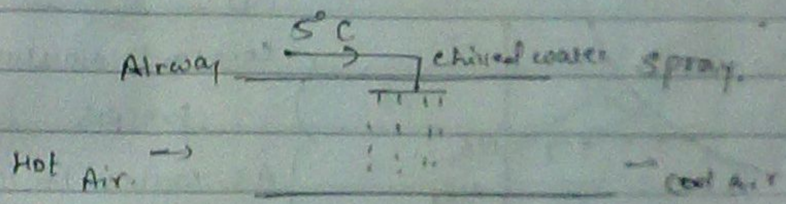


indirect Heat Exchanger

#



or



Direct Heat Exchange.

e.g. $\dot{m} = 20$ kg/s

$h_i = 110$ kJ/kg

$h_a = 90$

Water inlet temp = 5 °C

Water flow rate = 10 l/s.

Water outlet temp = ?

} coils

An. Heat lost by Air $= \dot{m}(h_i - h_a) = 400$ kW

Heat gained by water $= \dot{m}_w (T_{w_o} - T_{w_i}) C_{pw}$

water specific heat = 4.18 kJ/kg°C

Q.1 $\dot{m} = 20 \text{ kg/s}$

$h_i = 110 \; \cancel{kg} \text{ kJ/kg}$

$h_o = \; ? \rightarrow$ outlet temp. of Air ?

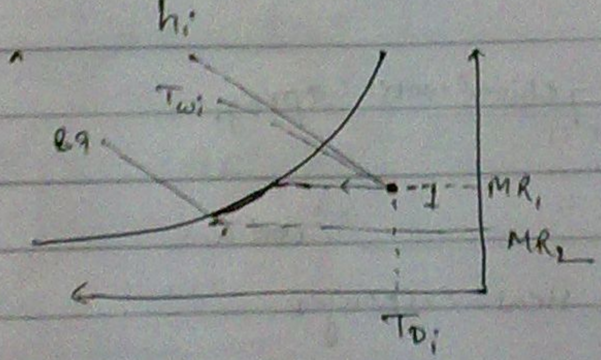
coils → { water inlet temp. = 5 °C
water flow rate = 10 l/s = $\dot{m}_w$
water outlet temp = 15 °C.
$C_{pw} = 4.18 \text{ kJ/kg °C}$ }

$B = 101.3 \text{ kPa}$

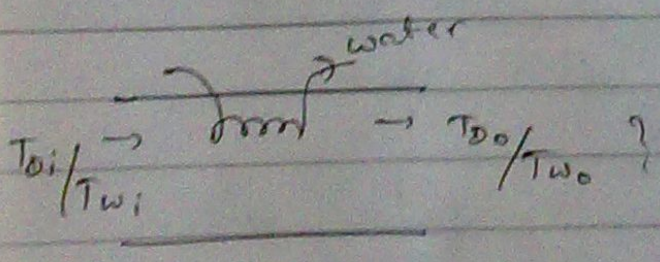
Ans.

$$\text{Heat exchange} = 10 \times 10 \times 4.18 = 418 \text{ kW} = 20\,(110 - h_o)$$

$$\Rightarrow h_o \simeq 89 \text{ kJ/kg}$$

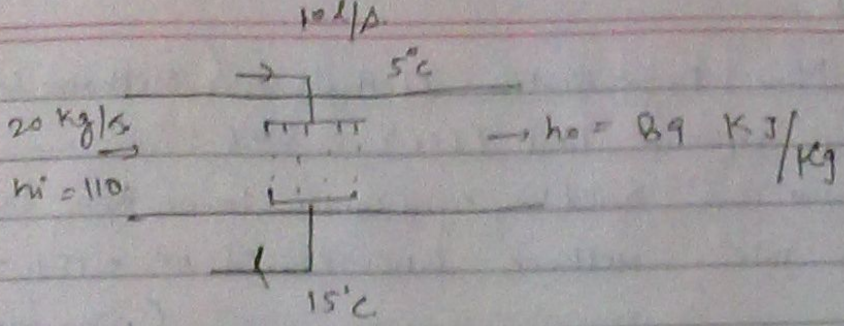


Constant moisture process
As water is in pipes.

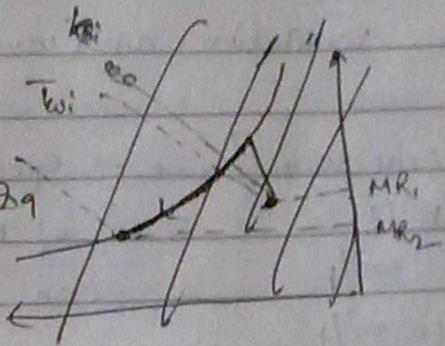


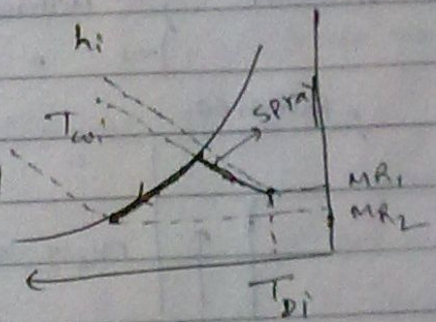
$$\underbrace{\dot{m}_a\,(MR_1 - MR_2)}_{\text{water condensed}}$$

#



Although h_o is same but process is diff.

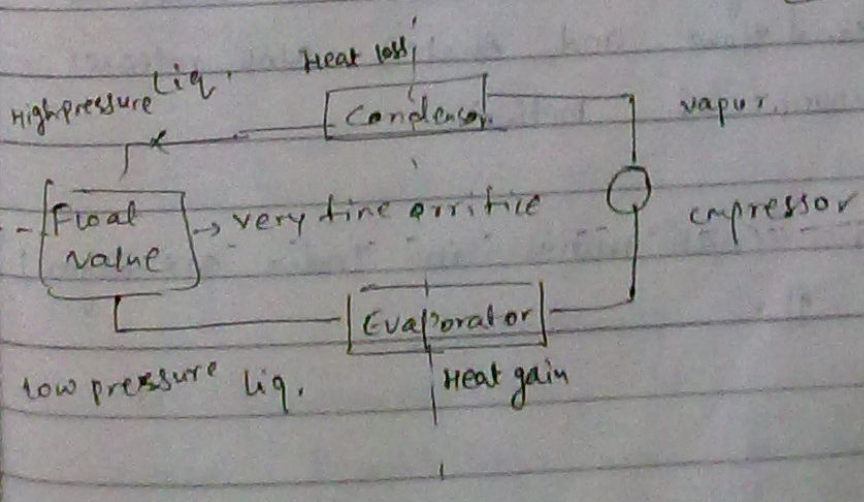




Evaporator
↓

Vapour Compression Refrigeration System } Removes heat from one location & physically transfers heat to Another location.

↓
condensor.



10/10/2011

Prusty

Mine Degasification Method → (Methane Drainage)

Lower explosive limit (LEL) = 5.4%

(Methane conc. should be significantly lower than LEL)

→ Indian rule - Methane conc. should be 0.75% → Anywhere (Mine Return)

Wherever methane emission conc. 1.25% → face area

→ Dilution with Ventilation air (usually works for deg I & deg II)

→ Gasiness of coal seam / mine → Specific methane emission rate

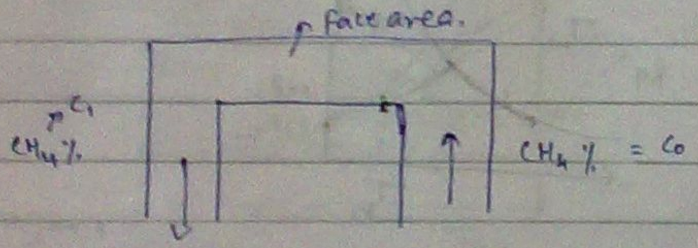
Degree I → < 1 m^3/t

Degree II 1 - 10 m^3/t

Degree III → > 10 m^3/t

$$\Rightarrow \frac{m^3 \text{ of methane emitted}}{\text{Coal production in 1 day}}$$

Measure { ⇒ Methane conc. in return air
⇒ " " " intake air



→ Specific methane emission can be higher than the gas content of coal seam as parting (sand stone and shale) also releases some amount of methane.

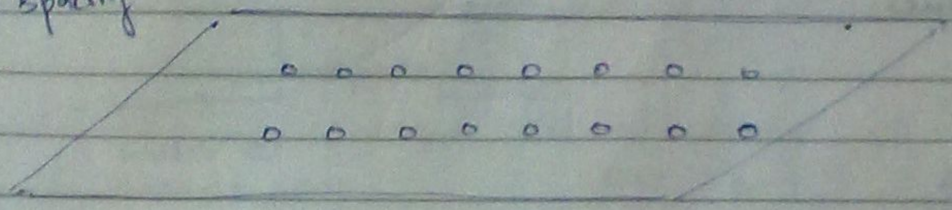
→ Most of coal mines in India are degree I and degree II.

→ Surface Technique → Vertical borehole with or without Hydraulic fracturing
→ GOAF well

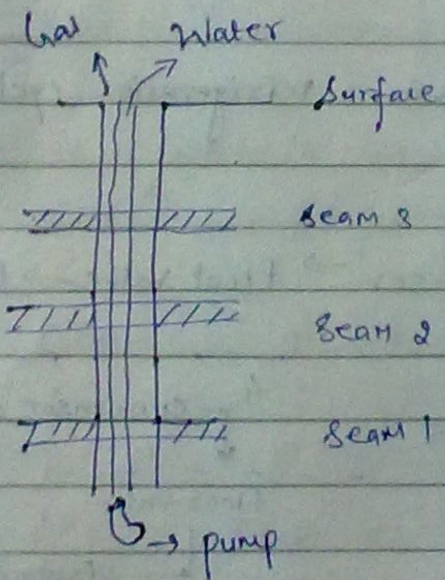
→ Underground Technique.
→ (a) Inseam Horizontal Borehole.
→ (b) Cross Measure Borehole.
→ (c) Superjacent Gallery (Hirschbach method)
→ (d) Packed Cavity Method

1) Vertical Borehole – Premining method

well spacing



2-10 years before mining



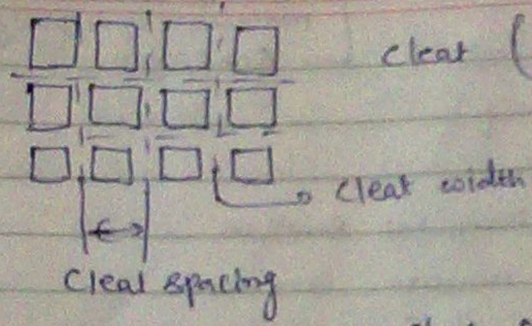
Reduce Hydrostatic pressure
(Reservoir / fluid pressure)
Dewatering

At a particular pressure gas starts coming out then pressure is known as Desorption Pressure

→ Coal permeability plays an important role in drainage of methane by this method.

Permeability > 5 milli darcy

→ If permeability is b/w 1 to 5 md then to increase permeability we ~~perform~~ apply Hydraulic fracturing
Hydraulic Stimulation Method.



Cleat Density = $\frac{\text{No. of Cleat}}{\text{Length (cm, in)}}$

Proppant

→ we can increase permeability 100 times, 1000 times.

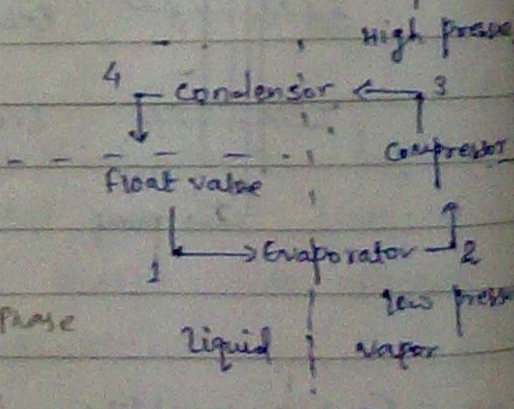
11/10/2011

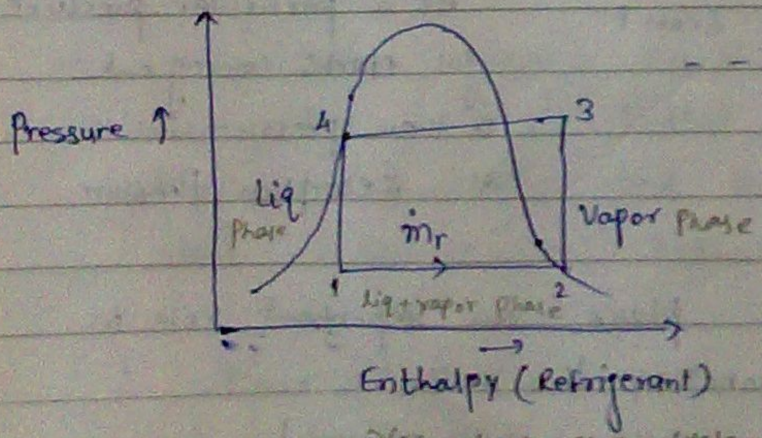
Sastry

How to cool air?

\# Using vapour compression refrigeration cycle.
4 - components -

compressor → condensor → Float valve → Evaporator





Vapor compression cycle

→ Refrigerant is normally in vapor state at room temp. & pressure.

pathway to flow
er)

No. of cleat
Length (cm, inch)

100 times, 1000

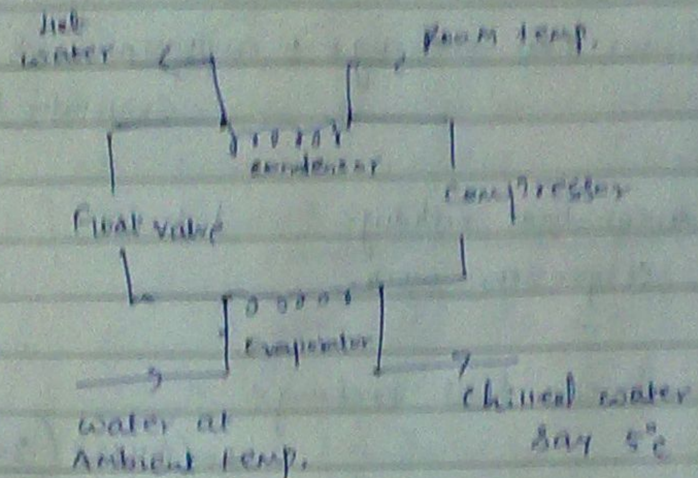
tion cycle.

alve → Evaporator
, High pressure
ndensor ← 3
compressor
lve
→ Evaporator — 2
low pressure
uid vapor

at room temp.

→ In condenser water is circulating. Due to circulation of water, heat exchange takes place in condenser.

→ Evaporator is also a heat exchanger.



Theoritical efficiency = Carnot cycle efficiency

COP: Coefficient of performance.

COP is constant for a particular refrigerator

COP ↑ Performance ↑

• $COP = \dfrac{\dot{m}_r (h_2 - h_1)}{\dot{m}_r (h_3 - h_2)} = \dfrac{\text{Heat Ex. at evaporator}}{\text{compressor output work}}$

$COP \simeq 3 - 5$ (Generally)

Ex.1 Condensor water flow rate = 30 kg/s

$T_{wi} = 25°c$ $T_{wo} = 34°c$

Plant COP = 4.0

Evaporation water flow rate = 15 kg/s

water inlet temp. = 25°c

what is the expected chilled water temp.?

les u assume heat exchange efficiency = 100%.

Ans.

$$h_3 - h_4 = h_3 - h_2 + h_2 - h_1$$

(Neglecting work)

$h_4 \simeq h_1$

Condensor heat exchange $\simeq$ compressor work + Evaporator heat Ex.

$$\Rightarrow \frac{\text{Condensor heat exchange}}{\text{compressor work}} = 1 + COP$$

$\left\{ \dot{m}_R (h_3 - h_1) \right\}$ = Condensor heat exchange =
ASSUME

$30 (4.183) (34 - 25)$ kW

kg/s kJ/kg°C °C

$= 1129.41$

$\Rightarrow$ Compressor work = ✓ 225.~~kw~~862

Evaporator heat Ex. = ✓

final temp. of chilled water = ✓

$\Rightarrow$ 1129.41 = 225.862 + Evaporator heat Ex.

$\Rightarrow$ = ~~2644.35~~ + Evaporator heat Ex.

Evaporator heat Ex. = ~~4514.64~~ 903.528

$\Rightarrow$ $15 \times 4.183 (T_f - 25) =$ ~~4514.64~~

~~T_f = 10.6°C~~

$T_f = 10.6°C$

#

water →

→ Hot

water at

cycle]

water

Twi →

Cool Air →

Fan

ID Fan.

(induced Draft

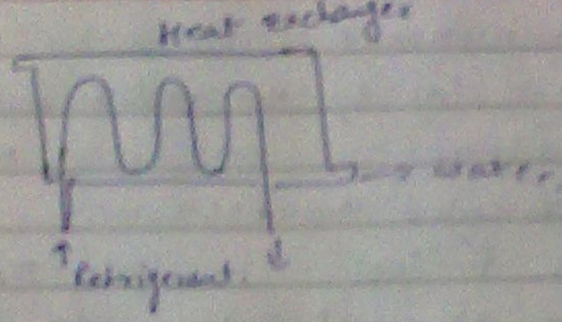
Water #

water.

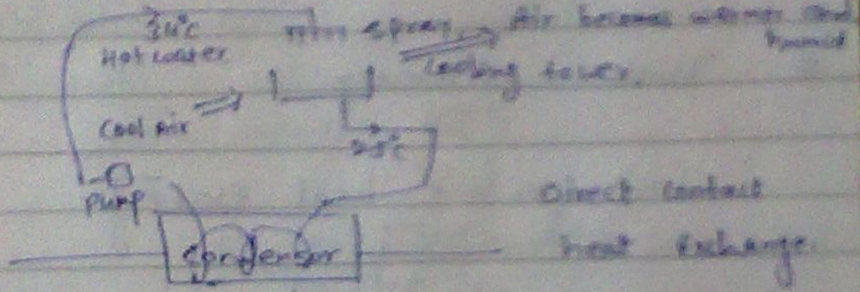
$\dot{m}$

Air

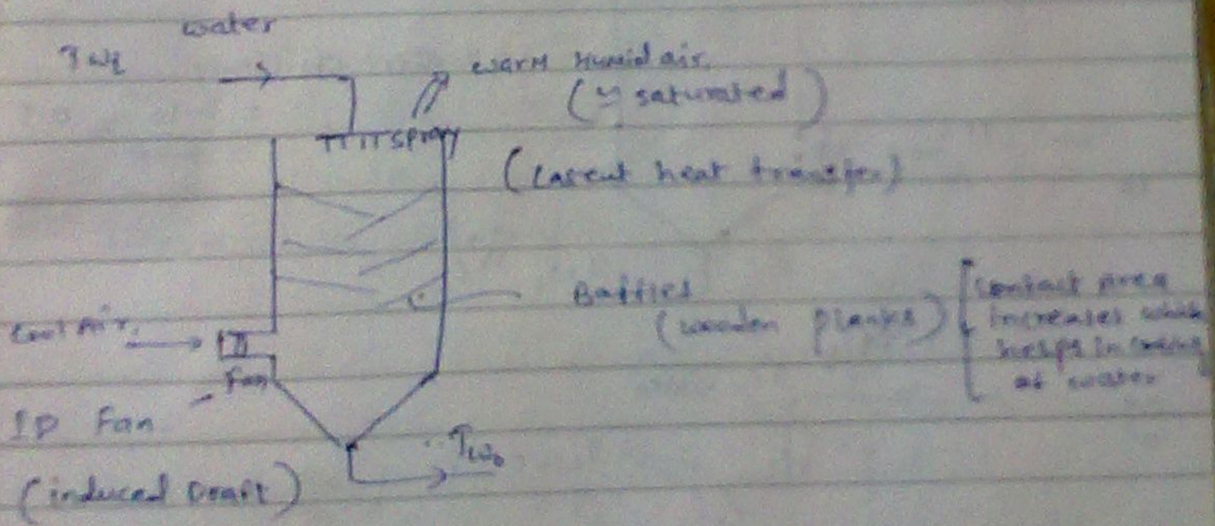
$\dot{m}_a$



→ Hot water at condenser outlet and chilled water at Evaporator outlet. [Outcome of the cycle]



Direct contact heat Exchange.



~~water~~ # Direct heat Exchangers -

Water.

$\dot{m}_w$, T_{wi}, T_{wo}

Air

$\dot{m}_a$ (Dry Air) ; T_{wbi} . T_{wbo}

Sigma heat is $= f(T_{wb})$

Enthalpy is $= f(T_{wb}, T_{db})$

but Enthalpy $\simeq$ Sigma heat (Approx.)

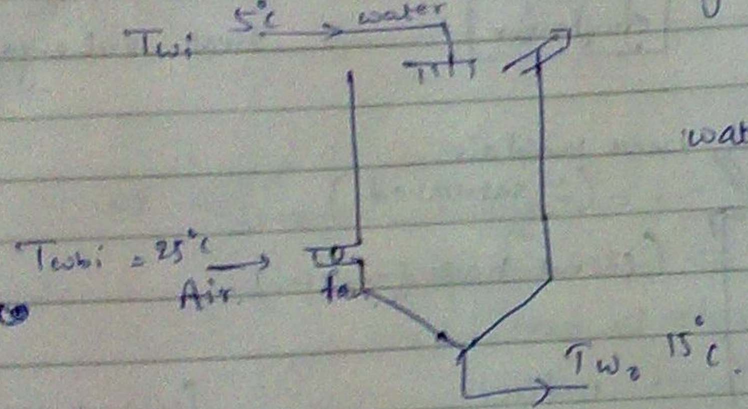
1st law of Thermodynamics =
Heat lost by one medium = Heat gained by other Medium

2nd law of Thermodynamics –
In a water cooled system
$T_{wo} \not< T_{wbi}$
in an air cooled system.
$T_{wbo} \not< T_{wi}$
} Thermodynamic Limits

eg.

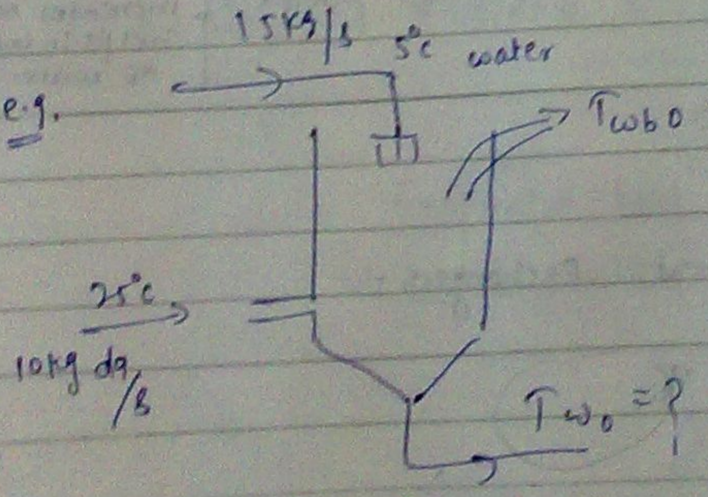
Water Efficiency = $\frac{T_{wi} - T_{wo}}{T_{wi} - T_{wbi}}$

Limit of the heat Exchange.



water efficiency
$= \frac{-10}{-20} = 0.5$

e.g.



→ factor of M
depends on { Size
Con
f
Empirically
Thermal Co
factor of
(Property o
R =

R
↓
Determined

Equivalent speci
heat of
(Air + wa

#
Water η ↑

→ Factor of Merit of a Direct Contact heat exchanger.

Depends on { Size of water droplets
Contact area
flow rate. etc.

Empirically Explained in terms of water efficiency and Thermal Capacity Ratio.

factor of Merit = f (water η : Thermal Capacity ratio)
(Property of Heat Exchanger)

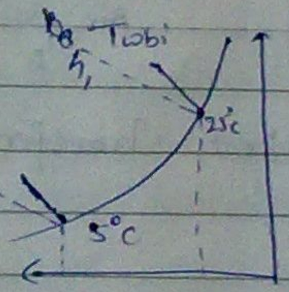
R = Thermal Capacity Ratio

$$= \frac{\text{Heat Exchange ability of water per °c}}{\text{Heat Exchange ability of air per °c}}$$

$$R = \frac{\dot{m}_w (4.183)}{\dot{m}_a \, c p_a'}$$

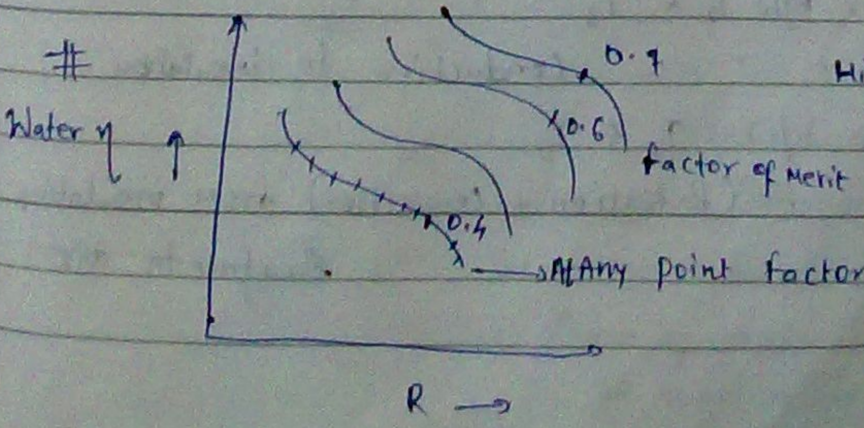
↓

Determined by inlet conditions.



Equivalent Specific heat of (Air + water vapor mix.) $= \dfrac{h_1 - h_2}{25-5} = Cp_a'$

#

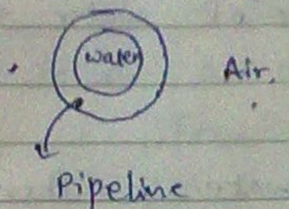


Higher factor of merit.
Better heat exchange

→ If for a tower factor of merit is known and ~~x~~ is calculated from inlet conditions, then we can estimate water η.

Indirect Heat exchange (coils)

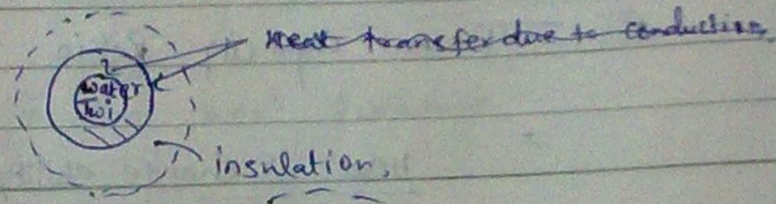
→

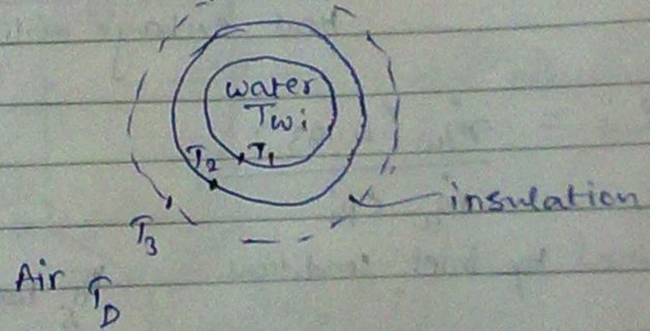


(Sensible heat transfer)

To prevent heat transfer insulate the pipeline

water
Twi





Heat Transfer b/w T_{wi} & T_1
= Convection b/w water and Metal Surface.

Heat transfer b/w T_1 & T_2
= Conduction in Metal

Heat transfer b/w T_2 & T_3
= Conduction in Insulation

Heat transfer b/w T_3 & T_D
= (Radiation + Convection) from insulation Surface to air

i) What
ii) wher

An
i) - It s

Laten

- It show
pressure
- It
- No
- En

13/10/2011 [Sma

→ 2 Types
① Axi

$U = \omega r$ [Backward blades ... Page ...]

V_R = Radial component of the absolute velocity of the ...

V_u = Tangential component of the absolute velocity ...

r_1 = Radius of the impeller inlet in m

r_2 = " " " " outlet in m.

Q = Quantity of air passing m^3/s.

ρ = Density of air

mass = $Q\rho$ = kg/s

Change of momentum from inlet to outlet :

$= Q\rho(V_2 - V_1)$

Change of moment of momentum from inlet to outlet

$= Q\rho(V_2 r_2 - V_1 r_1)$

$$T = Q\rho(V_{u2}r_2 - V_{u1}r_1)$$

Power P = $T \times \omega$ [ω = Angular vel.]

Total power = $Q\rho\omega(V_{u2}r_2 - V_{u1}r_1)$

$\Rightarrow$ Head $H = \dfrac{\text{Power}}{Q\rho g} = \dfrac{\omega(V_{u2}r_2 - V_{u1}r_1)}{g}$

$$= \frac{(V_{u2}U_2 - V_{u1}U_1)}{g}$$

For a special case of meridional entry (when there is no rotation of air), it ... is no prerotation of air

$$V_1 = V_{R_1} \quad \& \quad V_{u_1} = 0$$

$$H = \frac{V_{u_2} U_2}{g} \qquad V_{u_2} = U_2 - V_{R_2} \cot \beta_2$$

$$H = \frac{U_2 (U_2 - V_{R_2} \cot \beta_2)}{g} \quad \ldots \text{(Theoritical Head)}$$

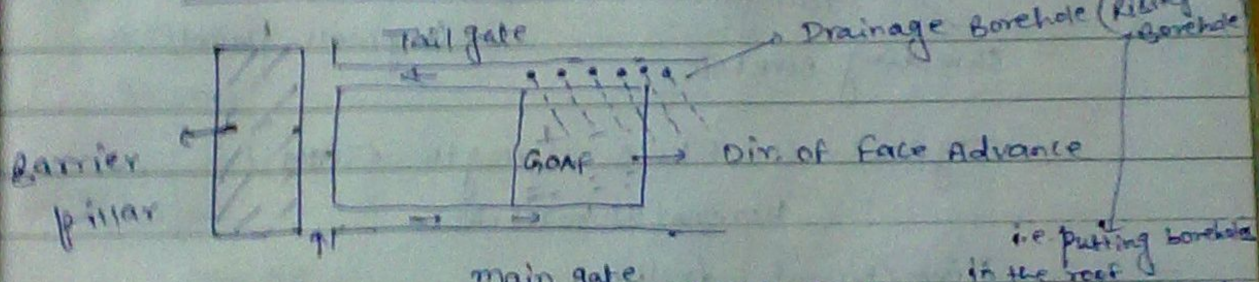
Also known as Euler's Head

⟹ for a Backward bladed centrifugal fan β_2 is always less than 90°. And it is eq. to 90° for radial bladed & greater than 90° for a forward bladed fan

17/10/2011

Drudy.

⟹ Cross-measure Borehole method –



(putting boreholes in the floor may create some problems as there is accumulation of water)

→ Drilling of borehole is being done before the formation of GOAF.

→ Angle of Drilling 30° – 50°

→ Generally we prefer drilling of borehole in tail gate side. But if seam is very gassy then we can also drill boreholes in main gate side.

→ Small Dia boreholes – 65 – 120 mm.

→ Spacing between 2 boreholes → 10 – 30 m.

Sometimes it may be upto 100 m – 150 m

→ Length of borehole → 25 – 40 m.

→ Angle – 20° – 60°

→ This method is followed in European mines.
→ for the Deep mines we prefer U/G method.

Horizontal Boreholes in advance of working –

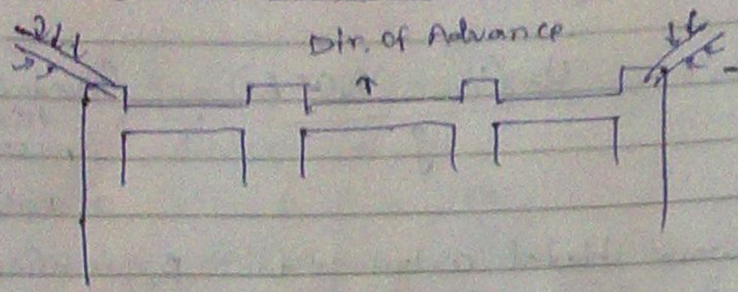


fig: for a Bord & Pillar working.

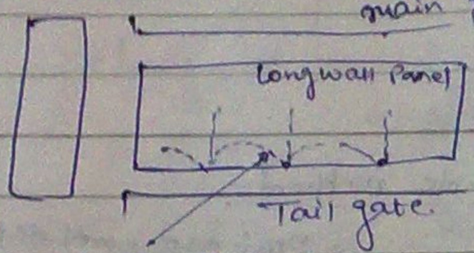


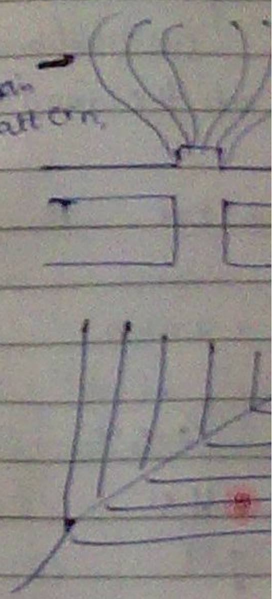
fig: Horizontal Boreholes in Longwall panels.

Typical short hole (Length < 300m) Horizontal boreholes.

→ Directional drilling.
→ Now Advancement in drilling. We can create a horizontal borehole upto a 1500m dist. This type of boreholes are known as Long Horizontal borehole.
→ Also known as Inseam borehole Technique.
→ Pocahontas no. 3 coalbed of pennsylvania USA.
→ Drainage efficiency = 30% - 60%.
→ Lead time → 6 to 18 months.

After putting boreholes How much time it is getting for drainage of gas. is known as Lead time. Depends on face advancement rate.

– Examples of ho[...]



→ Horizonta[...]
methane [...]
expensive.

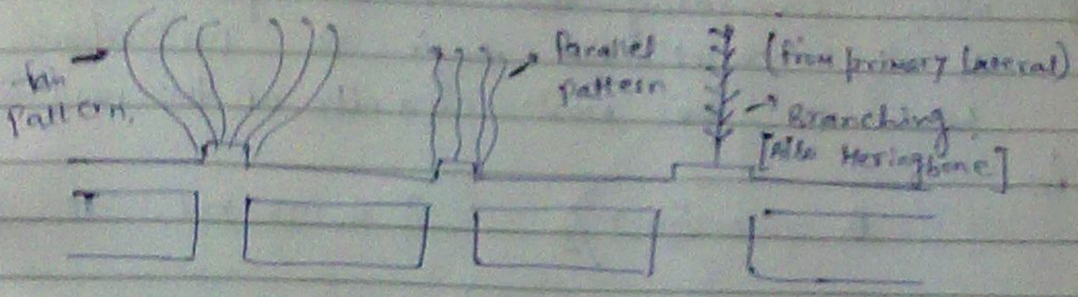
18/10/2011

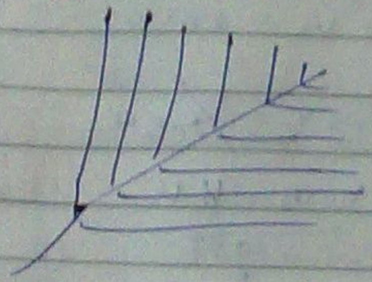
He [...]

At Max theori[...]

Ex.1 The [...]
fan ha[...]
1200 m[...]
theoritic[...]
rotatin[...]
Meridia[...]

- Examples of horizontal drilling -





Pinnate Drilling (Leaf Shape)

→ Horizontal borehole is most effective as far as methane drainage is concerned. But it is more expensive.

18/10/2011

Samantha

$$H_e = \frac{u_2^2 - u_2 V_{R_2} \cot\beta_2}{g}$$

$u_2 = \omega_2 r_2 = 2\pi n r_2$ (n → r.p.s.)

$V_{R_2} = \frac{Q}{2\pi r_2 b_2}$

b_2 = width of the fan

At Max theoritical fan capacity

$$V_{R_2} = u_2 \tan\beta$$

Ex.1 The impeller of a backward bladed centrifugal fan has a diameter of 2500 mm & a width of 1200 mm at the outlet. Calculate the maximum theoritical head the fan will develop when rotating at a speed of 280 r.p.m. Assume Meridional entry into the impeller. What will

At MAXIMUM fan capacity $V_{R_2} = U_2 \tan\beta$

be the theoritical head developed by the fan when circulating $50\,m^3$ of air per second. If the outlet fan angle is 1.13 radian. What is the Max^m capacity of the fan. (Theoretical)

Ans.

$Q_3 = 50\,m^3/s$ $\qquad \beta = 1.13$ rad.

$n = \frac{280}{60}$ r.p.s. $\Rightarrow U_2 = 2\pi r_2 n$

diameter at outlet = 2500 mm

width = 1200 mm $\Rightarrow V_{R_2} = Q_3 / 2\pi r_2 w$

$\Rightarrow$ MAXIMUM theoritical head $= \dfrac{V_{U_2}U_2 - V_{U_1}U_1}{g}$

for meridional condition $V_{U_1} = 0$ & $V_{R_1} = V_1$

$\therefore H = \dfrac{V_{U_2}U_2}{g}$

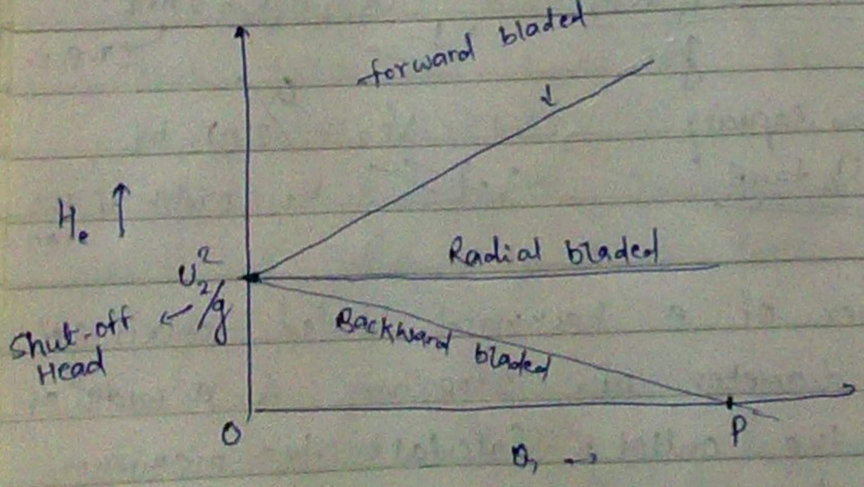
$\Rightarrow$ (1) Max. theoritical head $= \dfrac{U_2^2 - \cancel{U_2 V_R \cot\beta_2}}{g} = \dfrac{\left(2\times\pi\times\frac{2.5}{2}\times\frac{280}{60}\right)^2}{g}$

$= 137.07$ m

(2) Theoritical head developed $= \dfrac{U_2^2 - U_2 V_{R_2}\cot\beta}{g} =$

(3) fan capacity $= V_{R_2} = U_2 \tan\beta$

Head vs Quantity curve →



OP - Max Capacity of a backward bladed fan.

→ At the 'O' quantity fan (Backward bladed) produces max. head.

$\beta_2 \le 90°$
$\beta_2 = 90°$
$\beta_2 \ge 90°$

Shut-off
is know

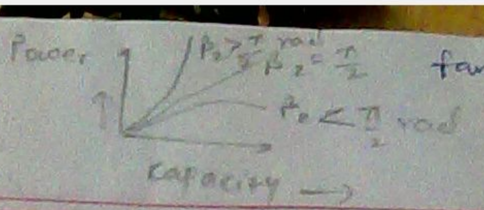
Various
There
i) Hyd
ii) M
bearing
iii) Lea
between
machine.

Losses
impeller,
losses
attribute

ii) Mechan

Input Pow

η_{me}



fan Power output = PQ

$\beta_2 \leq 90°$ for Backward bladed. ⇒

$\beta_2 = 90°$ for Radial bladed

$\beta_2 \geq 90°$ for forward bladed.

at 0 quantity $V_{R_2} = 0$.

Shut-off Head → at '0' quantity head developed is known as shut-off head.

$Q = 0$ at shut-off head

Various losses in fan →

There are 3 type of losses-

i) Hydraulic Losses

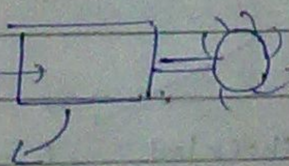
ii) Mechanical losses of power due to friction at bearings & disc friction.

iii) leakage losses - leakage through clearances between the rotating and stationary points of a turbo-machine. (Volumetric Efficiency)

when Air passes through the fan blades then loss due to friction b/w fan blade & Air is known as skin friction

Losses due to skin friction and diffusion in the impeller, and losses due to eddy and separation losses at the impeller inlet & outlet. This loss attributed to the head loss.

ii) Mechanical losses →

Input Power →  → output power = PQ

$\eta_{mech.}$

Air power = P.Q.

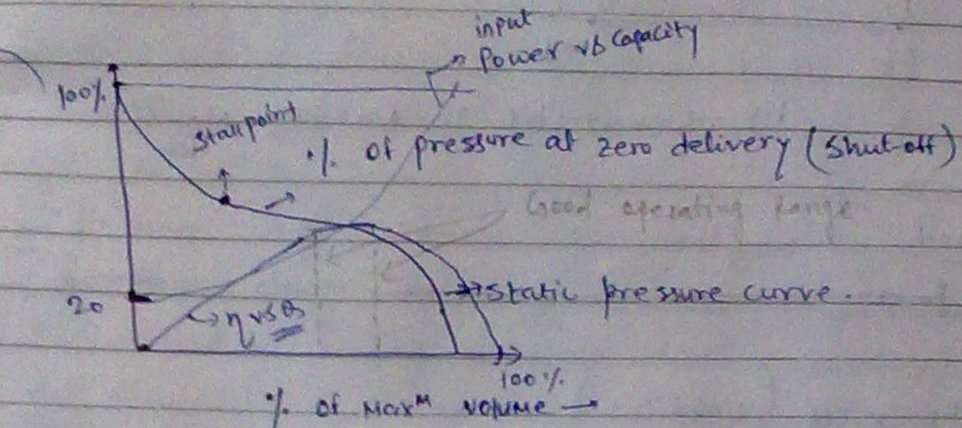
Actual power = $\frac{PQ}{\eta_{mech.}}$

→ ~~Different the quantity at output~~

→ ~~Velocity~~

Fan Characteristics →

i) Head - Capacity characteristics
ii) Power - Capacity (Q)
iii) Efficiency - Capacity



Max. efficiency ≈ 60-70%

fig: forward Bladed characteristics

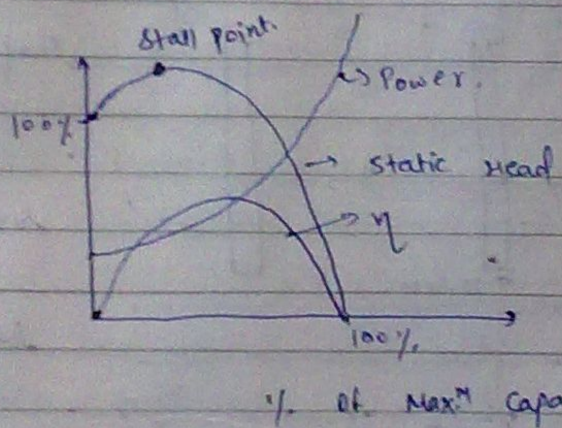


fig: Radial bladed fan charateristics

Stall point → fan generally opreates below the Stall point. At Stall point there is generation of max sound and lot of disturbances & ultimately lead to decrease in efficiency.

In all types fan, the operating point should be fixed to the right of the aerodynamics stall point 'p' which is point of reverse flexure, for at capacities less than this the performance of the fan becomes unstable and occurs fluctuation of air velocity characterized by throbbing and noise.

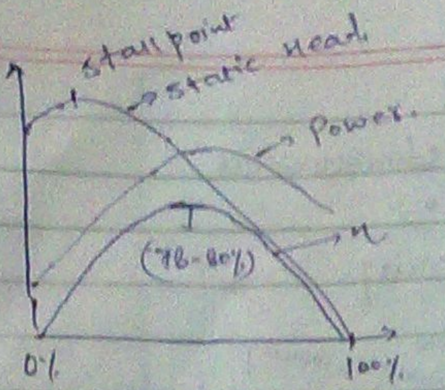
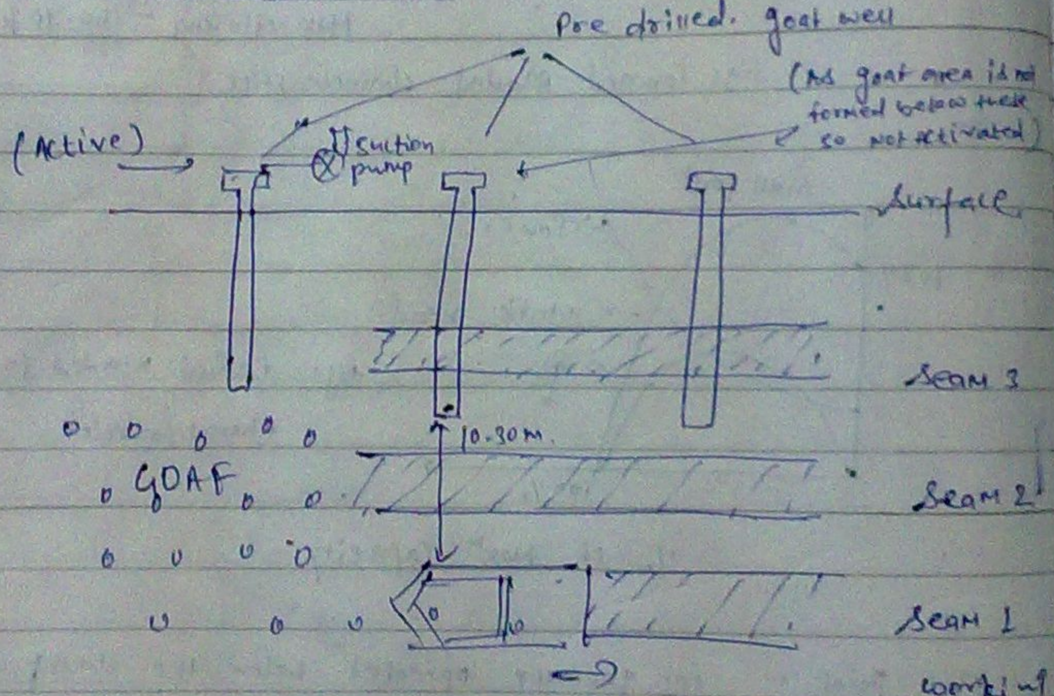


fig. characteristic of backward bladed fan

24/10/2011

Prusty.

Goaf Well (vertical) :-



permeability increases (orders of magnitude 10^n)

$n = 1, 2, 3, \ldots$

→ Life of the Bore hole is not so long. (Life 2-3...

→ Open hole completion (No casing is required as Life span is short)

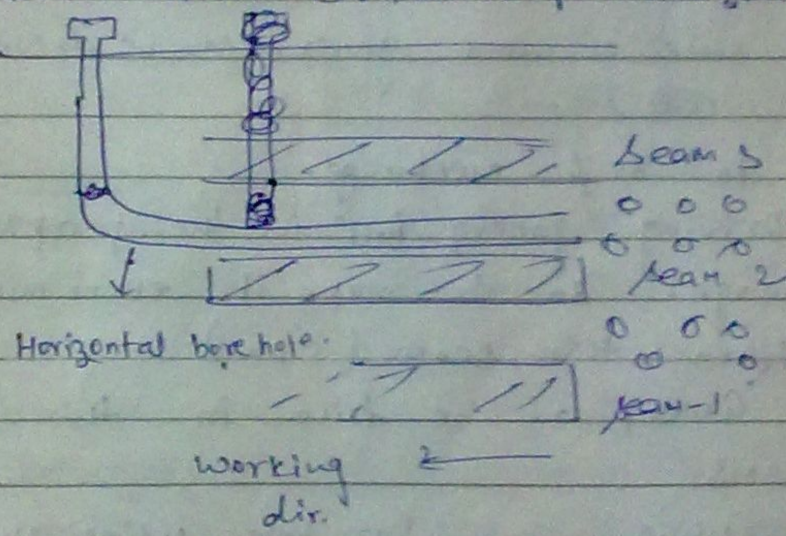
→ Mostly used in Mines of low to moderate depth.

→ Boreholes are
coal seam
caved zone
fracture z
→ Quality of g
But beyond
30%. th
→ As life
To make it
bore hole ch
Instead of
is sufficient
is being done.
Hor
- This t
(Bulli s
→ To m
make

→ Boreholes are not to be bring to working coal seam as
caved zone → 3 times coal seam thickness.
fracture zone → 50 times coal seam thickness.

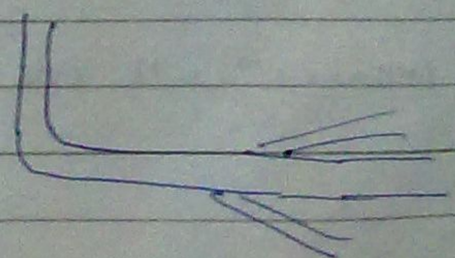
→ Quality of gas → Initially quality is upto 70%. But beyond that it deteriorates & go below to 30%. thats why life span is very short.

→ As life span is very short it is more costly. To make it profitable horizontal drilling is used and borehole changes to as shown in figure.
Instead of using multiple borehole only 1 borehole is sufficient & after certain depth Horizontal drilling is being done.



→ This technique is used very much in Australia (Bulli Seam Mine)

→ To make drainage more efficient we can make multiple lateral.

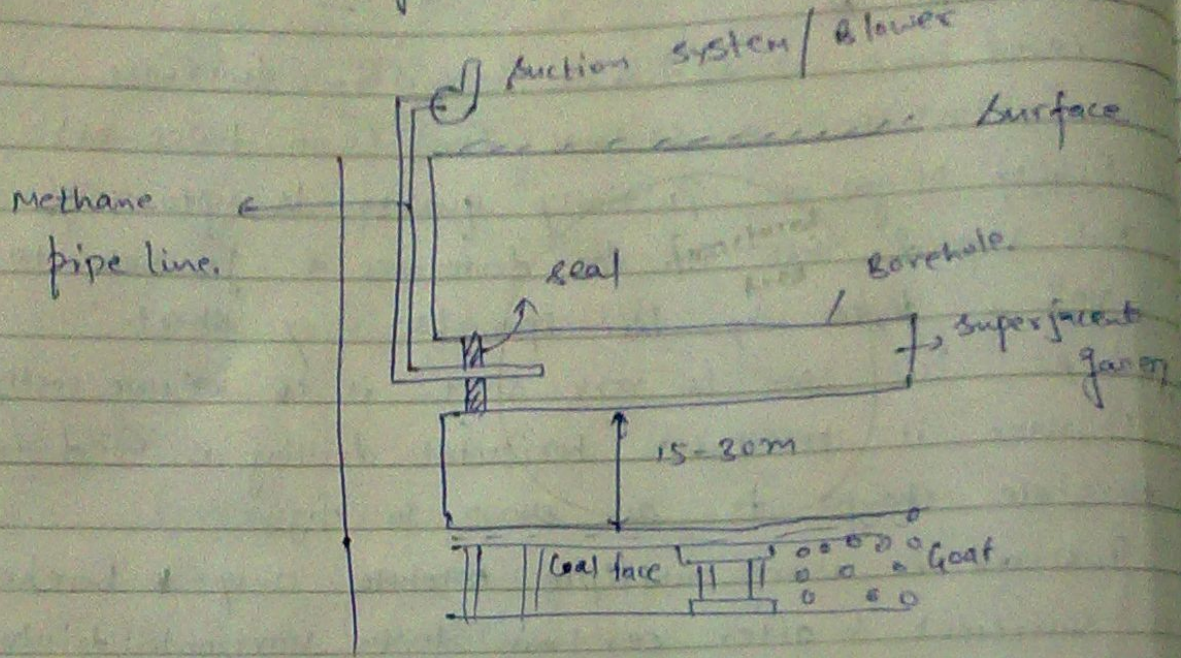


Assignment

Discuss the technological ~~adv~~ aspects of ...

25/10/2011

Superjacent gallery / Hirschbach Method →



→ In some of cases gallery can be driven below the coal seam.

→ 70 - 80 % methane.

→ Driving gallery just for the purpose of methane drainage. so to make it economical -

~~→ When thin seam (< 1m)~~

(a) Gallery can be driven in thin (< 1m) coal seams.

(b) using 2-3 bore hole using Horizontal drilling.

(c) By using unused gallery or preexisting gallery

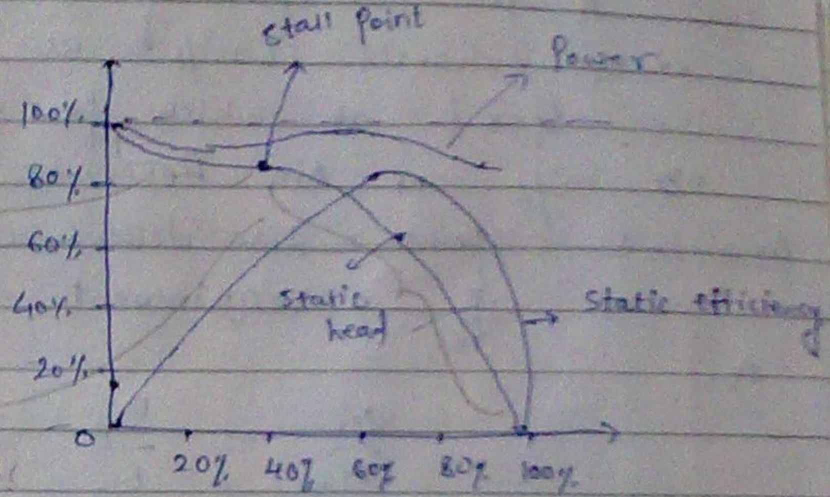
Highly gassy mines of europe (Germany, France

Use of methane → i) CNG ii) Power production

25/10/...

Samantha

Axial flow Fan → In India Axial flow fan is used generally. As it takes less space in installation as compare to centrifugal fan.
Also it is easier to change blade angle of axial fan ~~so that~~ and hence fan characteristics can be changed.



Axial flow fans are high (m/c with) capacity, low head & very high specific speed

fig: characteristics ~~of a~~ curve of a Axial flow fan

Fan Laws →

i) Fan speed
ii) fan diameter

} ⇒ Fan characteristics can be changed, if we change anyone ~~param~~ of these parameters.

a) When fan diameter is kept constant and fan speed changes, then

(capacity) Quantity $\propto$ ω (Angular velocity)
Head $\propto$ ω^2
Power $\propto$ ω^3

→ b) When speed is constant (specific speed) then (D = diameter)

$H \propto D^2$

$Q \propto D^3$

$P \propto D^5$

Ex:1 A fan is operating at a speed of 1000 rpm which exhausts 66 m^3/s at 171 Pa. Determine the speed at which fan should run to exhaust 83 m^3/s of Air. Determine the new pressure at this point. Also determine the additional power requirement.

Ans.

$$\frac{N_1}{N_2} = \frac{Q_1}{Q_2}$$

$$\Rightarrow \frac{1000}{N_2} = \frac{66}{83}$$

$$\Rightarrow N_2 = \frac{83000}{66} \text{ rpm}$$

$$\Rightarrow P_2 = \frac{\left(\frac{83000}{66}\right)^2}{(1000)^2} \times 171$$

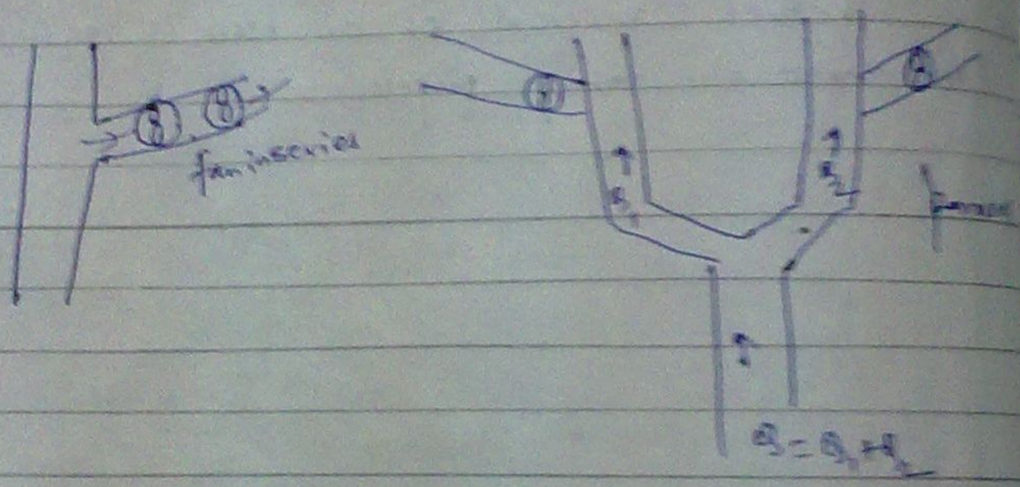
$$\Rightarrow \text{Power} = \frac{\left(\frac{83000}{66}\right)^3}{(1000)^3} \times [171 \times 66]$$

Multiple fans → if ~~fans can be put in series~~ [...]
→ ~~fan parallel (when quantity is more)~~

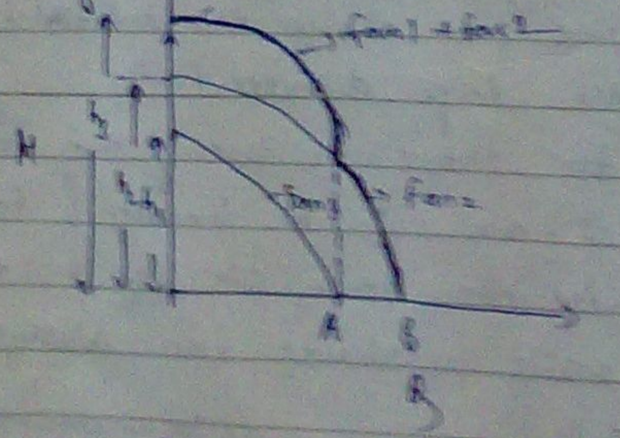
Combination of mine fan –

(a) fan in series → Each fan in series handles amount of current and the req. pressure to overcome the resistance is shared by both of them.
[Quantity is same & pressure of different fans are added]

(b) Fan in parallel → Each fan will operate in same pressure but handles different amount of air current.



Operating characteristics curve (fan in series) –

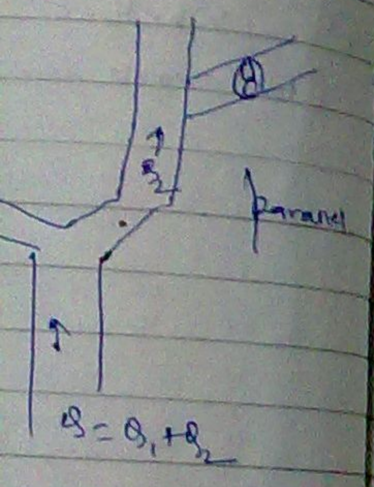


Quantity remains same & Head will add
$h_3 = h_1 + h_2$

If quantity is b/w A & B then fan 1 & 2 will increase resistance.

...be put in series [when ... req. ...]
...et (when quantity ... more)

...an in series handles the ...
...q. pressure to overcome
... both of them.
...ht fans are added]
...perate in same pressure
... air current.

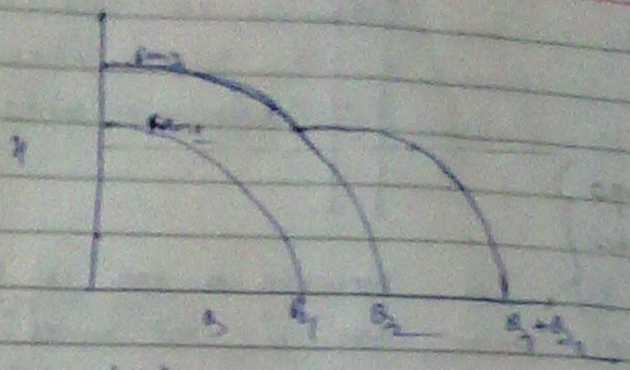


...re (fan in series) →

Quantity remains same & Head will adding
$h_3 = h_1 + h_2$

...en fan 1 & ... will

fan in parallel

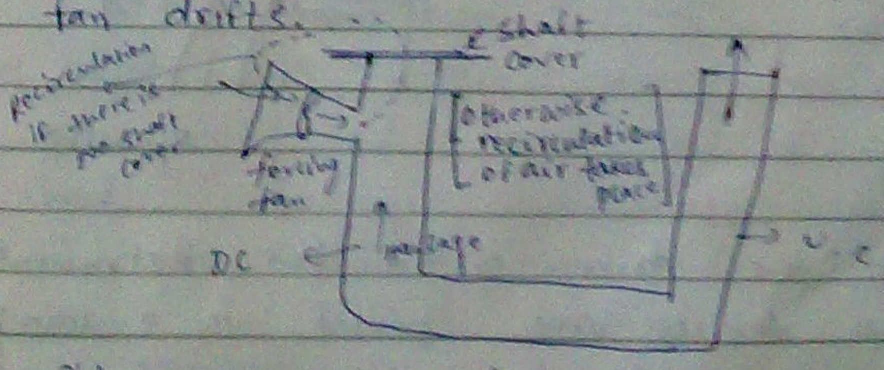


Quantity added up.

27/10/2011 Samantha.

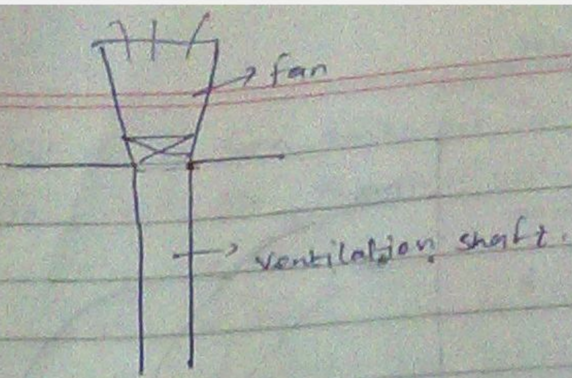
Installation of Mine fan →

Main mine fans are installed at the surface. They can be directly mounted over the shaft with their axis vertical. or horizontally on the ground connected to the shaft by a suitable bend. The later is essential in coal mines with the fan being located at least 5m away from the shaft in order to protect it from possible explosion. Where separate ventilation shaft can not be provided and fans have to be installed on operating shaft they are connected to the shaft by well designed fan drifts.



→ If shaft is only for ventilation purpose then we do not use fan drift. If shaft is for ventilation & transfer of men & mat. purpose then fan drift is used.

*



This type of Mounting of fan is being done only in Metal Mine Not in Coal Mines. As Coal Mines are pron to Explosion if there is an explosion then Explosion pressure will rise and will damage the fan.

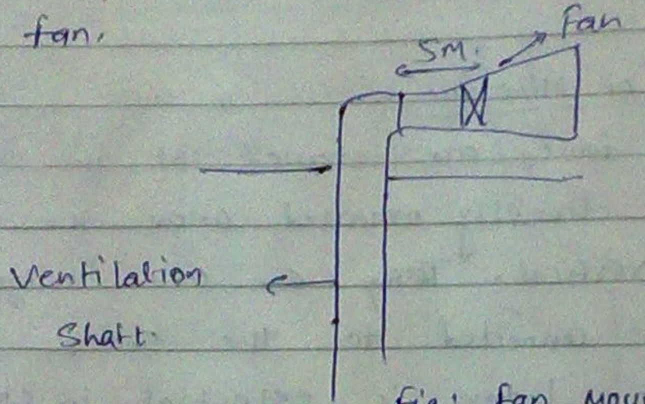
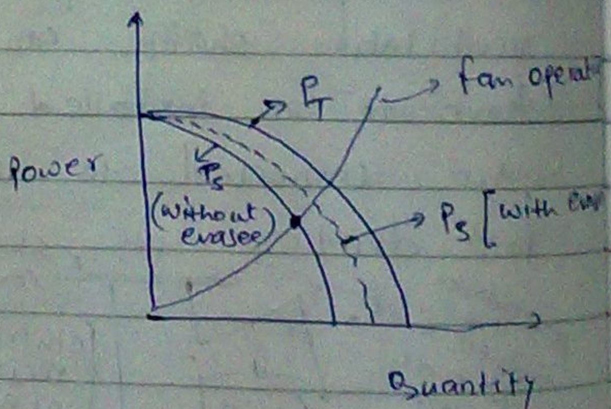


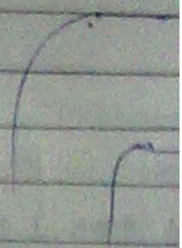
Fig: fan Mounting in ventilation shaft in Coal Mines.

Note: Use of Evasee



Normally the drive of the fan, instrument & controll devices are housed in a rain proof dust proofed & fire proofed building provided locking arrangement, lightening Arrestor.

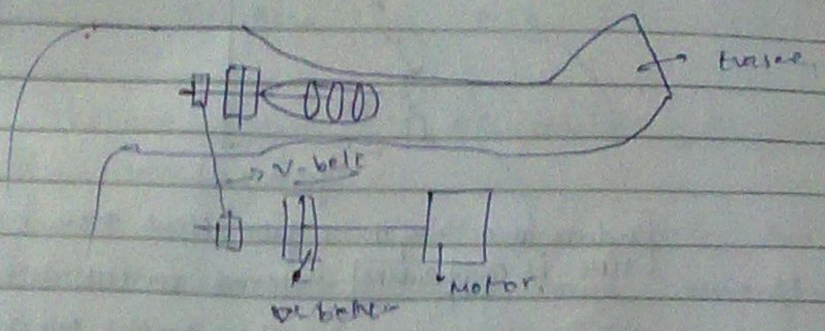
The to
A the
covered



Sur

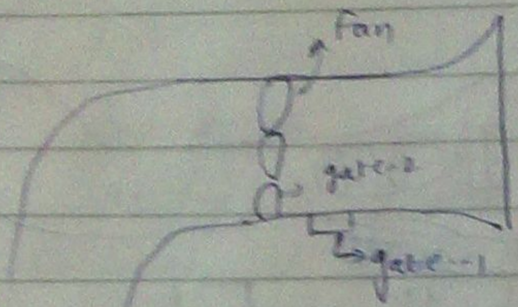
Main
it has to
are rea
~~are~~ or
and Mo
find
fan.
until
of axial
on sp
head.
is
Main
Or
hand

The top of the evaser in an exhaust fan & the fan inlet in a forcing fan are covered by a protective wire netting.



Surface vs Underground installation ->

Main fans at collieries are req. by law than it has to installs fans at surface. So that they are readily accessible in the event of ~~threats~~ floods, fires ~~are~~ or explosives. They are easier & cheaper to install and maintain. Besides it may be difficult to find a suitable u/g site for a main fan. U/g fans can not be installed untill the workings are ready to recieve them. They are usually of axial flow type. owing to the restriction on space. and hence are of limited head. Another disadvantage with u/g fan is they usually require air locks on main level which becomes a constant source of leakage and recirculation. On the other hand u/g fans avoid leakage at surface air locks and shaft collars. leakage at surface air locks can amount to 10-20% Quantity circulated by fans.



[2 doors at a time is called airlocks] → if 1 gate opens another gets closed automatically

u/g fans are commonly used in metal mines. where separate fans for diff. levels may be chosen for a ~~texi~~ more flexible control of ventilation. Also where all the openings are req. for active operation, it may be better practice to install fans u/g, rather than that have air locks at the top of the shafts.

s. leakage ~~of~~
mount to 10-20%.

opens another gets
~~o~~ automatically.
metal mines.
ff. levels may
more flexible
where all
active
ter practice to
than that have
the shafts.

Prosity

Methane Layering → expressed
Specific gravity of gas → ^ In terms of Air density

Air density = 1.2 m^3/kg
Sp. gravity = 0.56

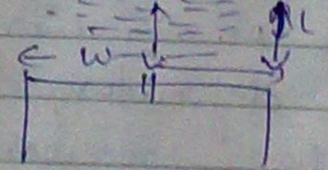
Methane tend to accumulate at the roof & forms layer.

→ Ascensional ventilation → fresh air from lower level to upper level through a drift.

→ Descensional ventilation → fresh air from upper level to lower level.

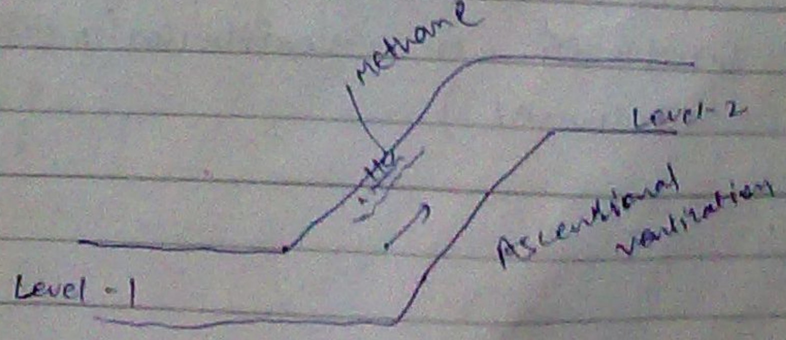
Normally ~~Metal~~ Methane emitted mixed with Air by diffusion.

→ Any Accumulation of methane in the roof where conc. of Methane is more than 5.4% is called Methane layer. & Minimum length of the methane accumulation should be more or equal to the width of the ~~Source~~ roadway.



$L \geq \frac{W}{2}$

#



Less Relative vel. → Less turbulent mixing.

$$\boxed{\text{Methane layer 'L'} = \frac{v}{\left(4.37\ V/w\right)^{1/3}}}$$

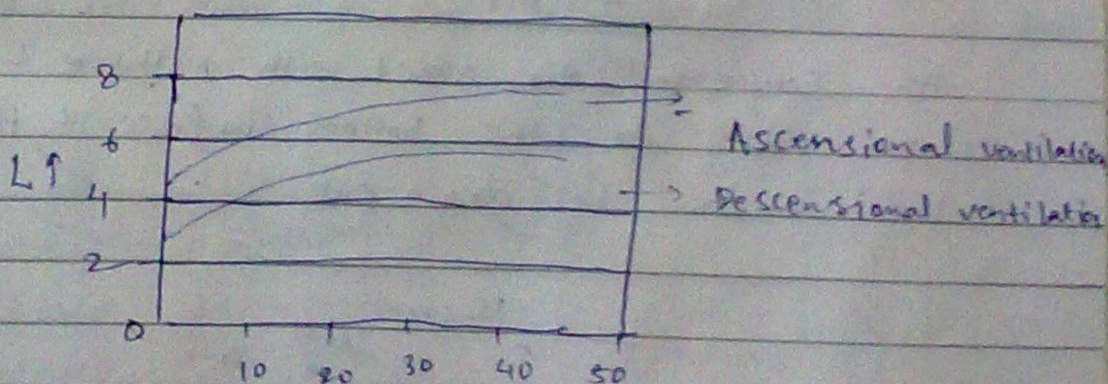
L = Methane layer No.

It will suggest that whether there will be formation of Methane layer or not.

For a Horizontal roadway -

L	
≤ 1	Buoyancy dominates, Pronounced Methane layering.
< 2	No turbulent mixing
> 10	No layering / Rapid mixing

If Roadways are inclined -



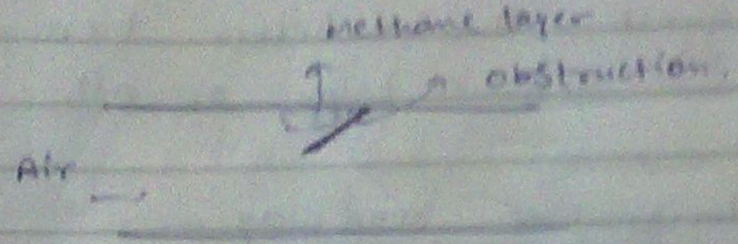
Roadway inclination, deg. →

→ Turbulent Mixing is starting around '2' for Descensional ventilation & there is no Methane layering beyond '6'.

→

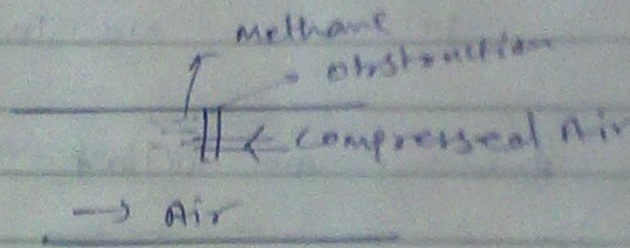
Dispersal of Methane layer →

1. Mixing baffle
2. Compressed air Ejection



Due to obstruction eddy current generates turbulent mixing started. However Resistance to air flow increases.

Compressed air →



Compressed Air Mixed with Methane & comes down to the bottom surface & thus Methane can be drain out.

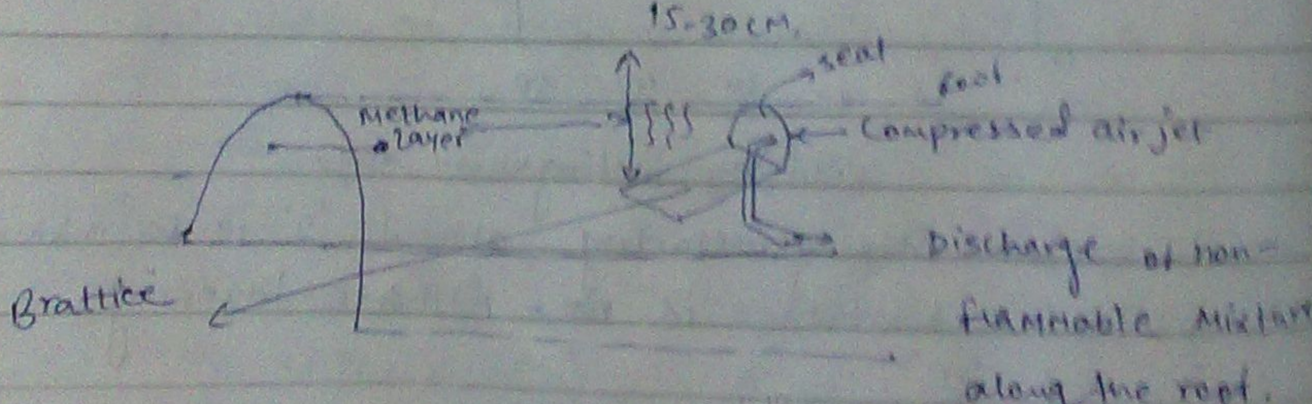


fig: Removal of Methane layer ~~...~~ from roof by compressed Air ejection

rent generated &
wever Resistance

r

l Air

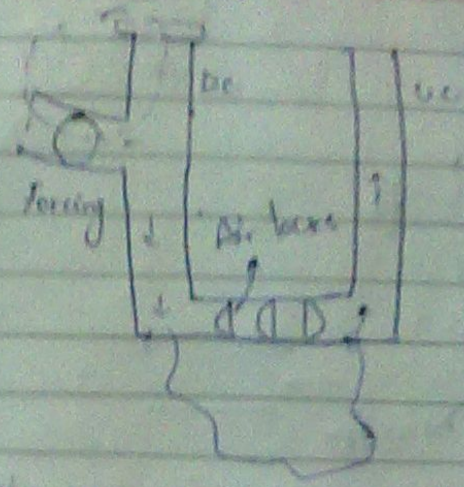
methane &
face & thus

ed air jet

arge of non-
irable Mixture
g the roof.
e from roof

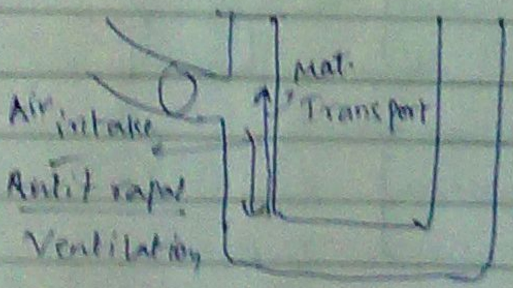
1/11/2021

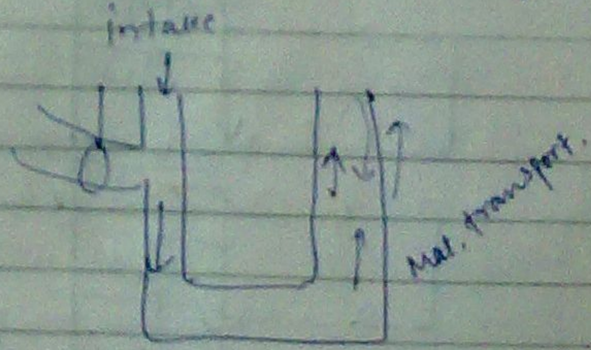
Samantha



- Generally material is transported through ~~the~~ the D.C. A lot of Air circulation / ~~loss~~ leakage takes place.
- ~~So~~ If we transport material through U.C then we have to ~~to~~ open or close air locks again & again & the air ~~dire~~ won't go to the face.
- Forcing types of fans are used in metal mines.
- Exhaust types of fans are used in coal mines.

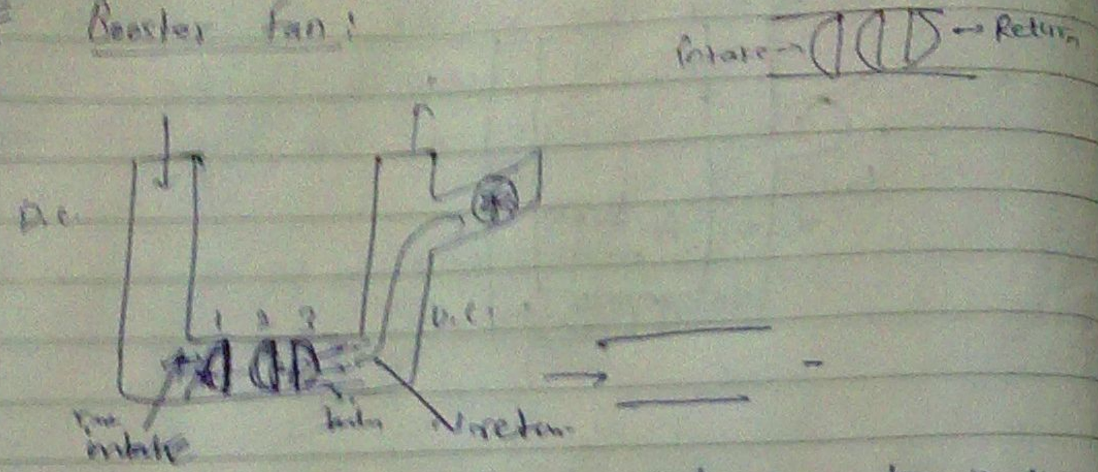
[As if forcing type of fans are used then ~~to~~ at the face there will be accumulation of methane]





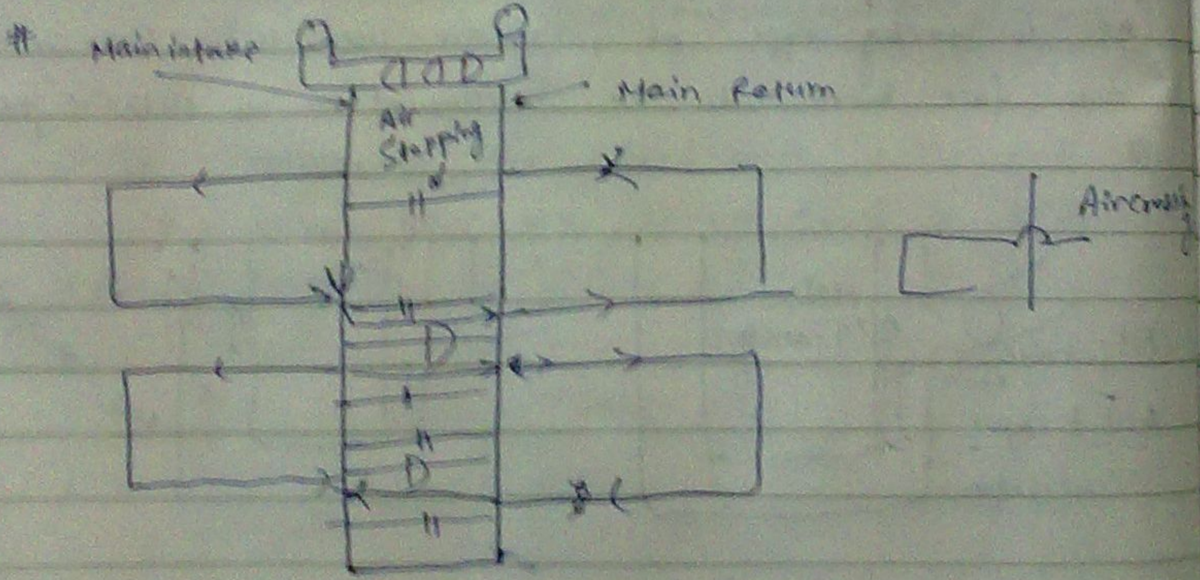
→ In Antitrapal ventilation a lot of dust generated. while in Homotrapal ventilation dust generated is less in comparison to Antitrapal.
So generally Homotrapal is preferred.

Booster fan :



→ 3 doors are provided. As ~~the~~ if there is 1 doors then ~~it~~ due to high pressure diff. at 2 sides of the doors it will be difficult to open the door.
3rd doors is provided only ~~for Air~~ if there is Air Reversal takes place.

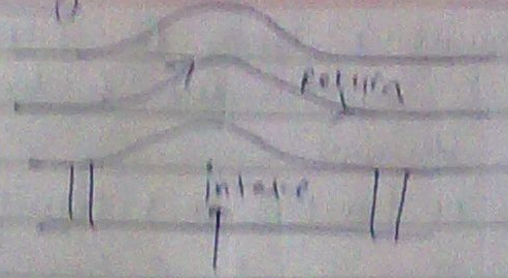
#



– Main intake & Main Return roadways are also known as trunk airway.

→ Air crossing

Air crossing



Regulator

Main controlling devices

(a) Air locks
(b) Air crossing
(c) Stopping
(d) gates.
(e) Regulator

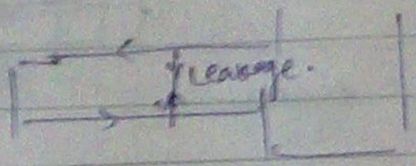
If Q_2 is less than the amount which is needed then there are some alternatives to increase Q_2.

(a) By increasing power of the main fan.
(b) By putting regulator in path-1. But by putting regulator there will be a lot of energy consumption.
(c) Booster fan. → Generally in coal mines is not recommended [Due to gassiness nature]
In ~~metal mines also~~ it is ~~not recommended~~. methane circulation & there may be a possibility of explosion.

Page 466
Ex.7.3

→ ~~Also~~ After installation of booster fan pressure diff across 'I' & 'O' ~~also~~ Decreases, & hence quantity in path-I decreases.

→ After installation of booster stars leakage also increases.



Critical pressure - Pressure of the booster fan at which quantity flow in other split (ventilation distr.) become zero. That pressure of booster fan is known as critical pressure.

→ Booster fan is generally installed in the return airway of the panel. [Because in entry airway it also hindre the transportation]

→ ~~Even if~~ ~~installation~~ selection ~~of Booster fan in the return~~ ~~airway~~ Booster fan is installed at neutral point in the airway. Neutral point is chosen in such a way that there ~~is cert~~ should be the least leakage

Ex.1 Two parallel split A & B have a pressure of 500 pa acting across them causing a flow 15 m³/s in split 'A' & 10 m³/s in split 'B'. It is desired to reduce the quantity in split 'A' to 10 m³/s by

8/11/2011

7.5
Ex.2 A
600 Pa w
25 m³/s
Consist
15 m³/s
to In
15 m³/s
Calculate
resistance
is 0.2

Ans.

R_A = R

=> R_B =

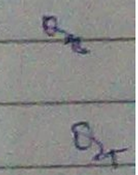
R_T =

P_B

Q_{2A}

Q_{2B}

Q_{2T}



Split

Before instanation of booster fan.

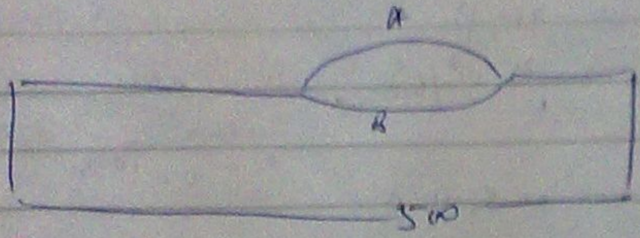
$$500 = R_T \times 25^2 + R_A \times 15^2 + R_B \times 10^2$$

$$R_A = 1.67$$

$$R_B = 3.57$$

After installation of booster fan.

[After instanation of booster fan not only quantity in B increased but also total quantity flowing through system increased]



$$500 = R_T Q_T^2 + R_A (Q_T - Q_B)^2 + R_B Q_B^2$$

$$= 0.2\, Q_T^2 + 1.67 \,(Q_T - 15)^2 + 3.57 \times 15^2$$

$$Q_T = 29 \text{ m}^3/s$$

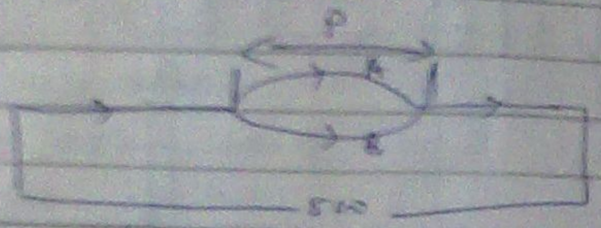
Now Considering flow in split B

$$500 + P_B = R_B Q_B^2 + R_T Q_T^2$$

$$= 3.57 \times 15^2 + 0.2 \times 29^2$$

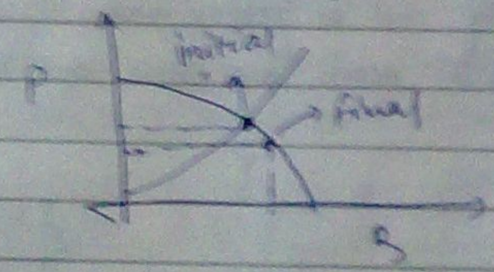
$$P_B = \underline{\underline{512 \text{ Pa}}} \quad \text{Ans.}$$

→ After installation of booster fan quantity across split [illegible] splits decreases.

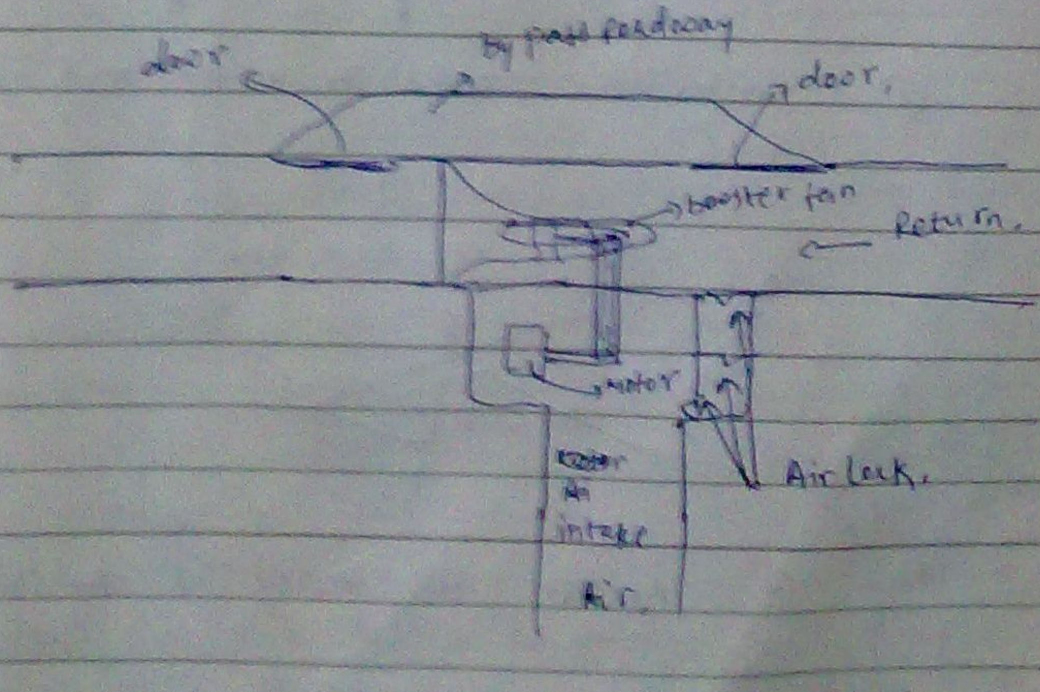


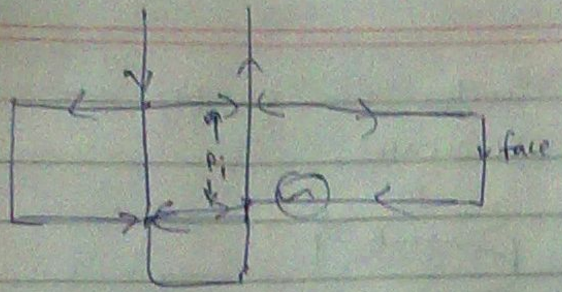
$P_{initial} > P_{final}$

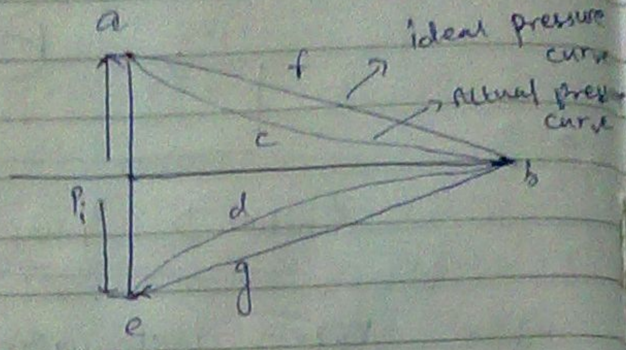
→ After installation of booster fan, main fan characteristics also changes. (As quantity increases)
In solving above question we have assumed that fan operating characteristics is same.



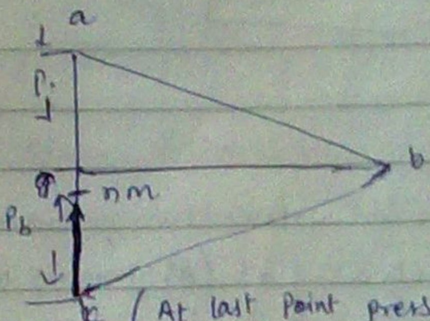
Installation of Booster fan –







a) Before installing booster fan

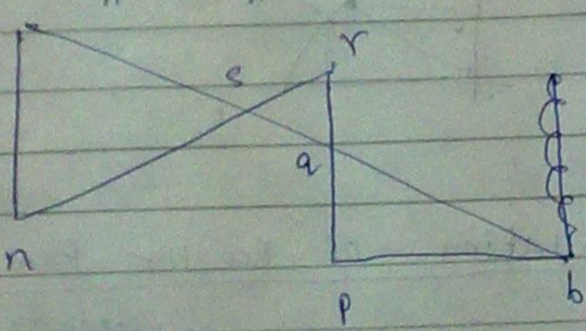


(At last point pressure has increased by P_b)

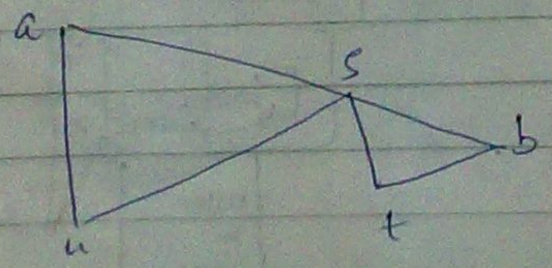
(b) After installation of booster fan at outby end of return Road

P_j = Pressure diff. Across the split due to main fan

P_b = " " " " " " " Booster fan.



(c) Booster fan located in return road near the face



(d) Booster fan located at neutral point

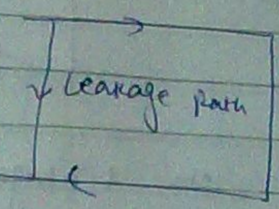
Leakage quantity $Q \propto P$

$P = RQ$

Q is very small

So we can assume leakage as laminar flow of air

& hence $P \simeq RQ$



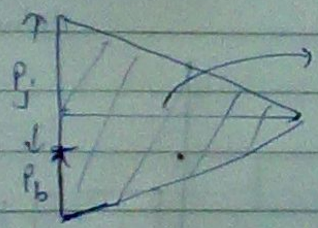
$\Rightarrow \quad Q = P/R$

& $R \propto$ ~~Length~~ $1/L$ for Leakage path.

[As length increases leakage path increases & more parallel leakage path generated hence total resistance decreases]

Case B

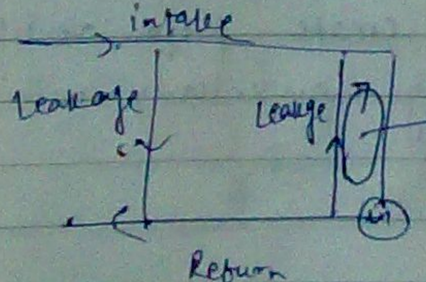
$Q \propto P, L$

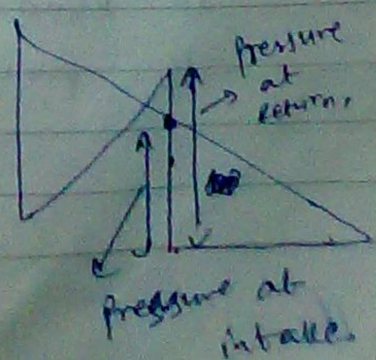


Area will show Total leakage

Case-C

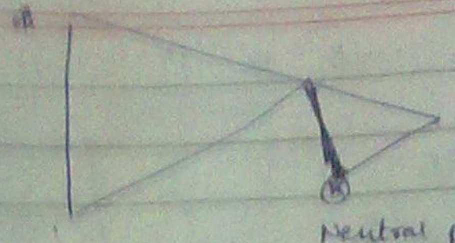
As near face pressure will be high so there may be recirculation of Air.





→ Leakage from Return to intake which is dangerous.

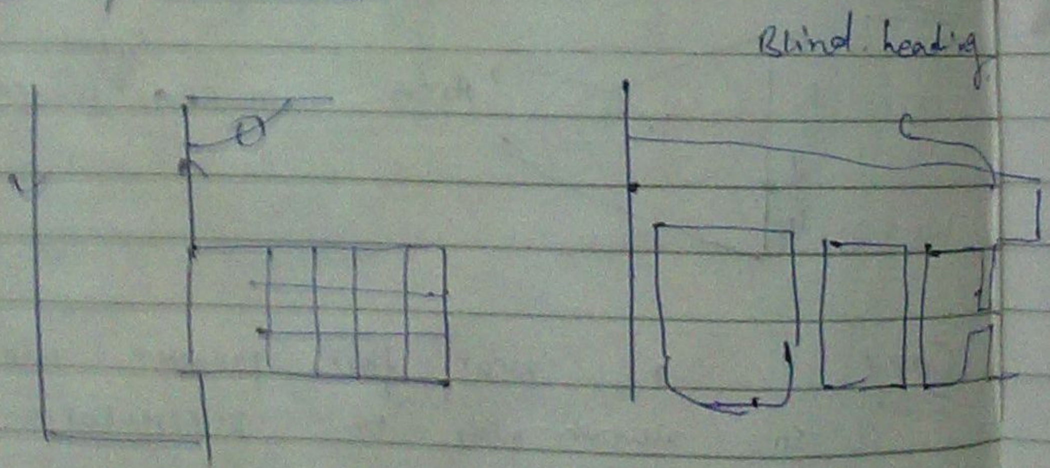
ideal pressure curve
Actual pressure curve
b
...alling booster fan
to main fan
" Booster fan.
road near the
neutral point



No leakage & No recirculation of Air.

Maximum possible leakage saved by using a booster is half the total leakage when the booster position 'b' is halfway in the return. Also the pressure of booster is same as that due to main fan. For other booster pressure however the position of the neutral point as well as the amount of leakage saved will vary.

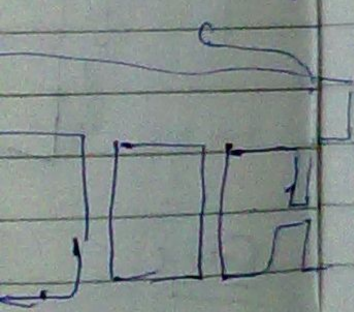
Auxiliary ventilation -



To create proper ventilation at Blind ~~ea~~ heading auxiliary ventilation is provided.

...n of Air.

... using a
...e when the
...y in the
... booster
...ain fan.
...wever the
...oint as well
... saved will



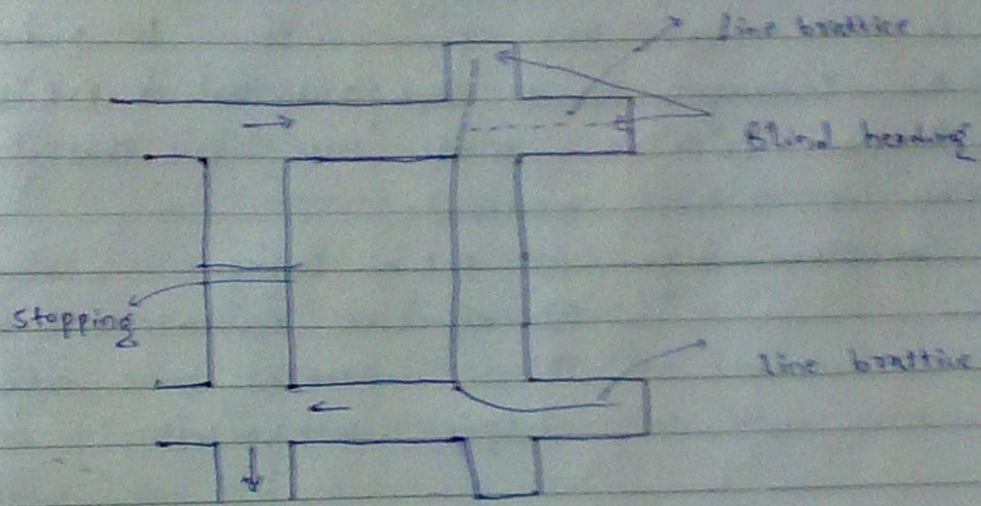
...er ventilation
...y ventilation.

15/11/2011

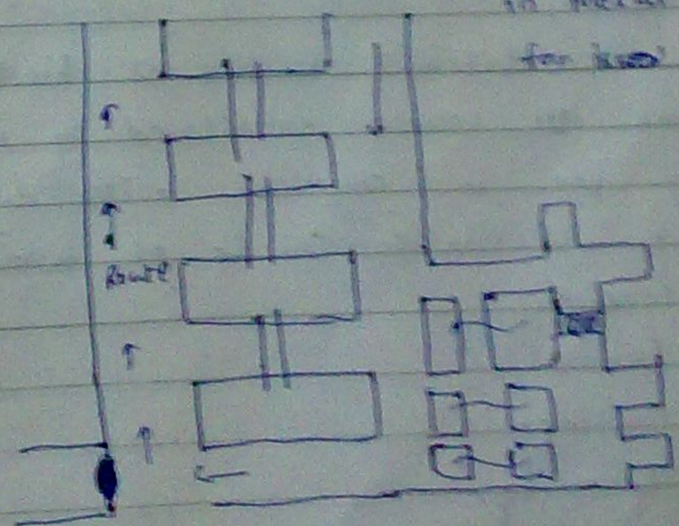
Samanta

Ventilation at a heading (Auxiliary Ventilation)

- Line brattice
- Auxiliary fan with ducting



Brattice is mainly used in coal mines while in metal mine Auxiliary fan is used.



a screen or curtain

of hessian cloth.
heading.
th is just pasting

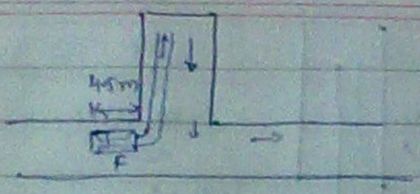
cloth.
@ 1.5m interval
th is not more than 20-50m
attice cloth is that
so to reduce
brised & PVC coated
PVC coated hessian

eakage
resistance increases
ised mine effective
be less.

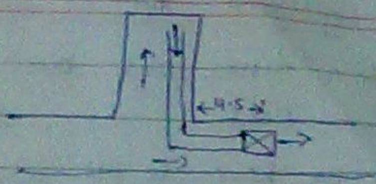
en auxiliary fan

headings & drifts
by means of
ith ducting.
following types -

→ Generally we place at 4.5 m from the heading gately to prevent recirculation of air.



Forcing fan



Exhausting fan

[Preferablly 1/2 ~~or~~ 1/3 of air should be circulated to the heading by the fan.]

→ ~~Broom~~

Advantages of forcing fans -

① It delivers fresh dry air at the face.

② In forcing system air travels to the face at higher velocity

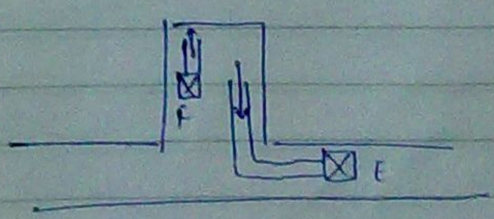
③ In forcing system, air directly impinch to the body. therefore it is more comfortable in heat and humid conditions.

④ In forcing systems the fan and motor is placed in ~~at face~~ fresh intake air hence corrosion to the fan and motor is less.

Advantages of Exhaust System -

① Clearence of dust, fumes, and gases are very effective in Exhaust system.

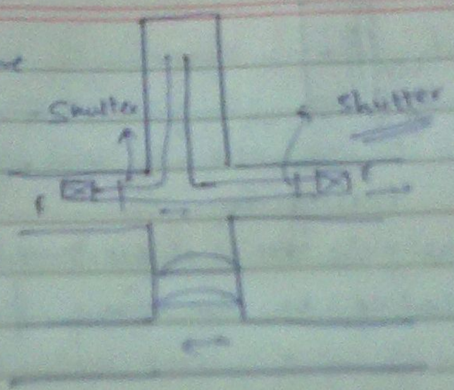
Overlapping fans :



Reversible ~~fan~~ System →

At a time only one fan acts.

If we have to use forcing then we put shutter before the exhaust fan and vice versa.



Flexible and Rigid Duct [Page no. 479 GB Mishra] – ducts for auxiliary fans.

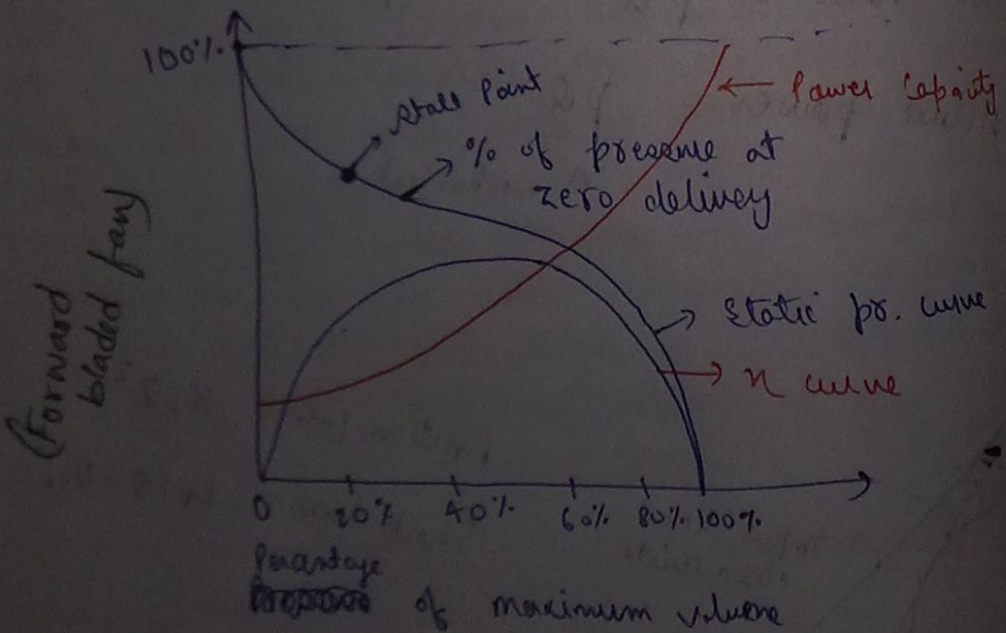
Mine V

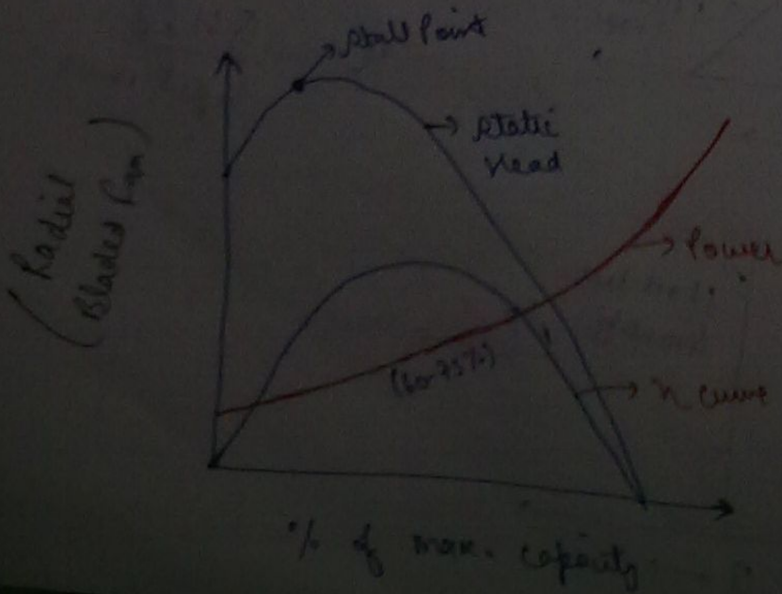
Steps in v

$H = AQ^2 + BQ + C$

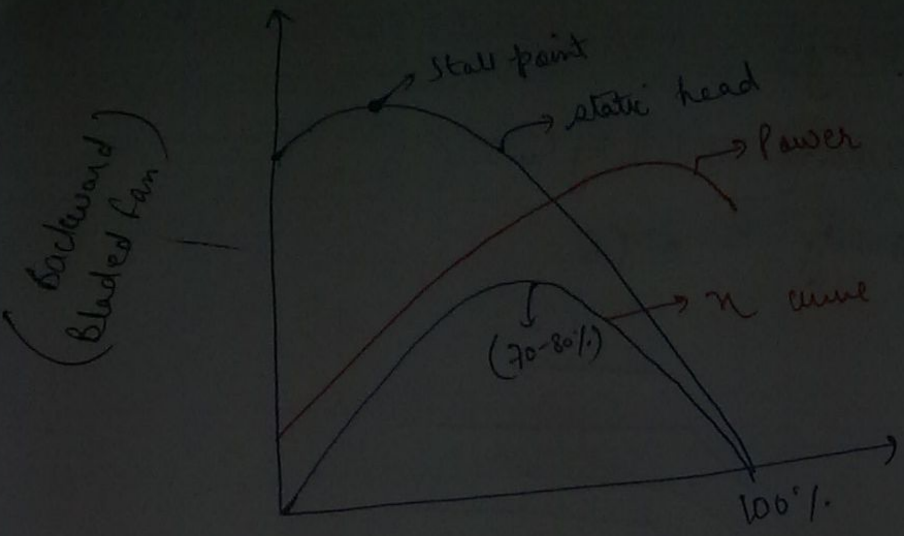
Fan Characteristics

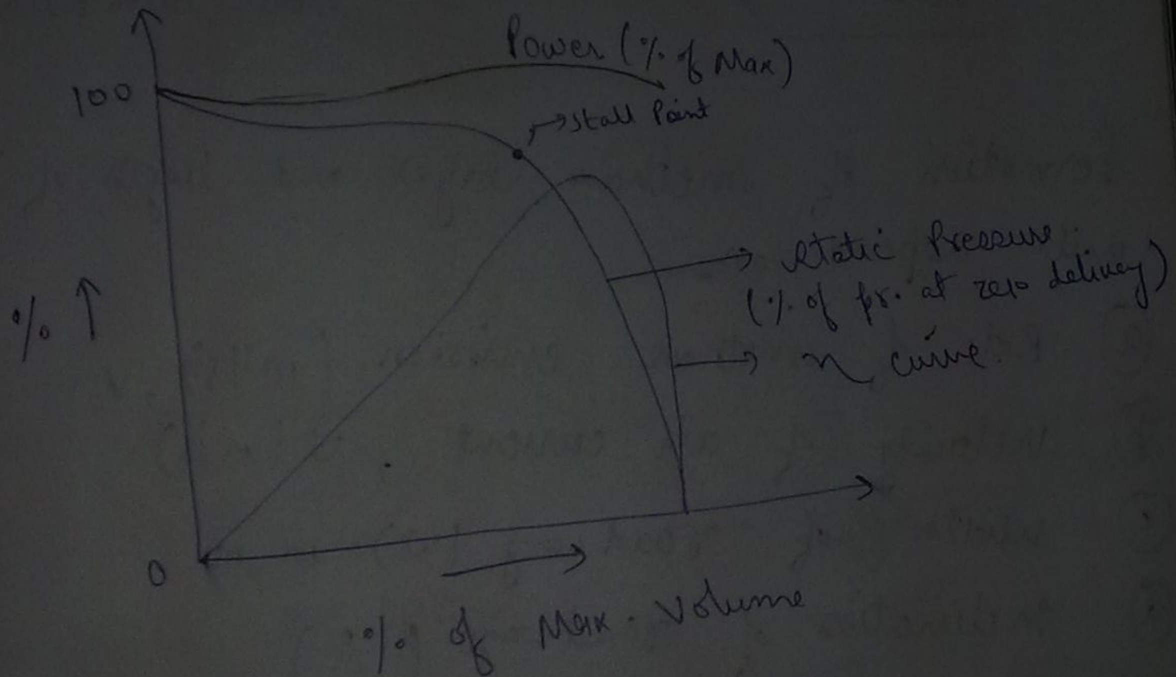
1. Head (H) - Capacity (Q) Characteristic
2. Power (P) - Capacity
3. Efficiency (η) - Capacity (Q)





* fan needed to be run after stall point for smooth functioning and less noise





Characteristics of Axial flow fans

① Selection of Mine fan (9 points)
② Combination of fans