Mine Ventilation

- Introduction - General Aspects
- Physical Influences on Mine Air
- Movement of Mine Air
- Generation of Mine Air Movement
- Distribution of Air Inside the Mine
- Air Conditioning

Terms

Mine ventilation:
sufficient supply of mine openings with fresh air

Mine air:
all gas mixtures, which occur in mines

Fresh (good) air:
composition of atmospheric air

Dead or choke damp:
air, containing e.g. carbon acid gas (CO_2), nitrogen, methane or hydrogen; little or not suited for human respiration

Toxic air (stinkdamp, whitedamp or bad air):
air containing additions of carbon monoxide, nitric oxides, hydrogen sulfide

Fire damp:
explosive mixtures of flammable gas, especially methane and air

Wet and hot air:
air containing high quantity of vapour and hot air, reducing physical and mental performance

Tasks in mine ventilation

Supply of sufficient quantities of fresh air

+

Dilution of hazardous gases (CO, CH_4 (4,5-14 %Vol explosible), etc.)

+

Creation of a reasonable or tolerable climate

Requirements of mine air

People — **1 - 6 m^3/man x min**

Decisive aspects:

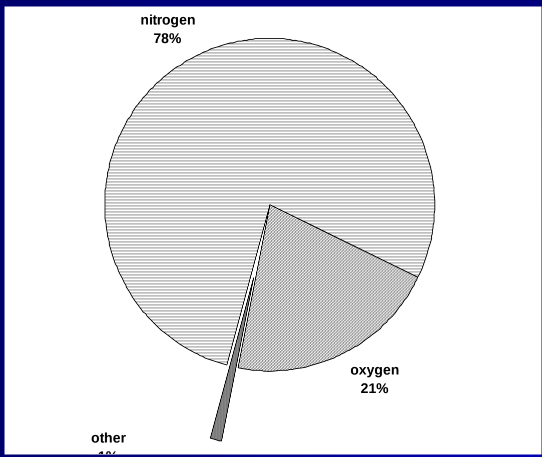
- air requirement of a hard working human (60-100 l/min)
- mixing of fresh and expired air
- tolerable climate

Engines — **3 - 6 m^3/PS x min**

Decisive aspects:

- CO-content of engine fumes
- mixing of fumes and fresh air

Composition of atmospherical air



- **carbon acid gas**
- **rare gases**
  - argon
  - neon
  - helium
  - krypton
  - xenon
- **hydrogen**

Natural change of condition

$$R_W = \frac{R_A + x \cdot R_V}{1 + x}$$

$$\rho = \frac{1}{v} = \frac{p}{R_w \cdot T} \qquad \left[\frac{N \cdot kg \cdot K}{m^2 \cdot N \cdot m \cdot K} = \frac{kg}{m^3}\right]$$

Density of air:

ρ density of wet air [kg/m³]
v specifical volume [m³/kg]
p barometric pressure [Pa]
R_W gas constant of wet air [J/(kg · K)]

R_A gas constant of dry air [= 287 J/(kg · K)]
R_V gas constant of vapour [= 462 J/(kg · K)]
x vapour content [kg/kg or g/kg]

T absolute temperature [K] (= 273 °C + t)
t temperature [°C]

E.g. at normal physical condition:

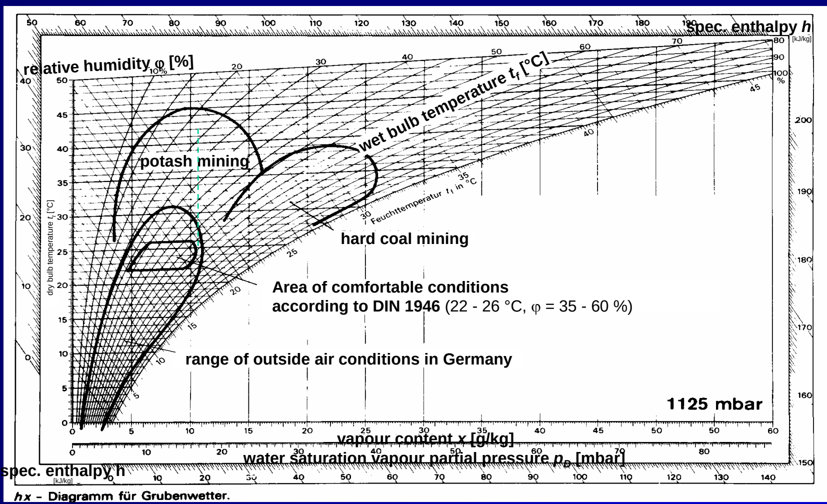
p 101.324 Pa (= 1013,24 mbar)
T 273,15 K

ρ = 1,293 kg/m³

e.g.

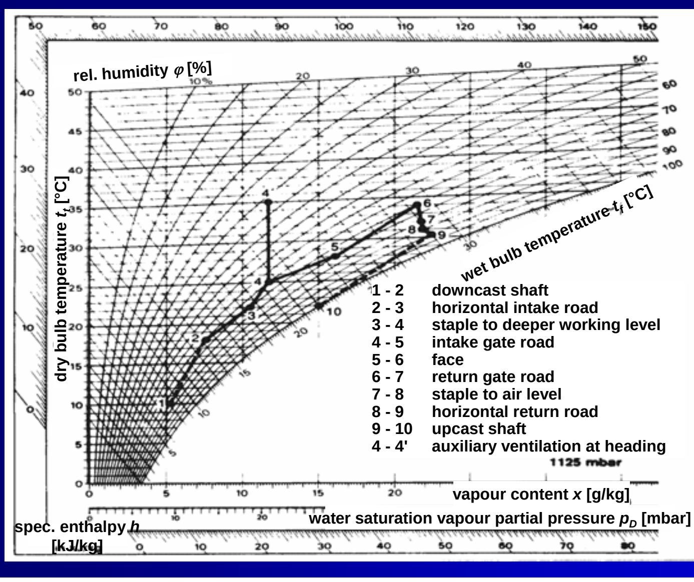
high pressure → high density
high temperature → low density
high humidity → low density

Mine climate



Range of comfort in h,x-diagram

Plotting of climatic conditions



Ventilation basic equations

pressure drop in airways with circular cross section:

$$\Delta p = \lambda \cdot \frac{L}{D} \cdot \frac{\rho}{2} \cdot v^2$$

$$\dot{V} = A \cdot v$$

$$\Delta p = \underbrace{\lambda \cdot \frac{L}{D} \cdot \frac{\rho}{2} \cdot \frac{1}{A^2}}_{R} \cdot \dot{V}^2$$

$$\Delta p = R \cdot \dot{V}^2$$

$$\Rightarrow R = \frac{\Delta p}{\dot{V}^2}$$

=> R of roadways

$$A^2 = \pi^2 \cdot \frac{D^4}{8}$$

$$\Delta p = \underbrace{\frac{\rho}{2} \cdot \frac{16}{\pi^2}}_{C} \cdot \lambda \cdot \frac{L}{D^5} \cdot \dot{V}^2$$

$$\Delta p = c \cdot \lambda \cdot \frac{L}{D^5} \cdot \dot{V}^2$$

$$D = \frac{4 \cdot A}{Perimeter}$$

=> for noncircular roadways

$\dot{V}$	volume flow	D	diameter of tube [m]
Δp	total drop of pressure [Pa]	ρ	density of flowing medium [kg/m³]
λ	coefficient of friction [1]	v	velocity [m/s]
L	length of tube [m]	A	area of airways cross section [m²]
D	diameter of tube [m]	R	*Resistance*

Volume flow, Diameter, Power, Pressure losses

		Volume flow	
		$\dot{V}$	$2 \, x \, \dot{V}$
Diameter	D	Δp, P	Δp x 2^2, P x 2^3
	2 x D	Δp x 2^{-5}, P x 2^{-5}	Δp x 2^{-3}, P x 2^{-2}

$$P = \dot{V} \cdot \Delta p \qquad \Delta p = R \cdot \dot{V}^2 \qquad \Rightarrow \quad P = \dot{V}^3 \cdot R$$

$$P = Ventilation \; Power$$

Mine Ventilation

Overhead 10.11

20/02/2006

Calculation of mine air movement:

Coefficient of friction

Relationship between coefficient of friction (lamda) and condition of air way:

$\lambda = f(Re)$	for hydraulically smooth tubes
$\lambda = f\left(\frac{k}{D}\right)$	for hydraulically rough tubes
$\lambda = f\left(Re, \frac{k}{D}\right)$	for an intermediate section

Re	Reynold´s number
k	average height of roughness [m]
D	road diameter [m]

Reynold´s number Re:

$$Re = \frac{w \cdot D}{\upsilon_L}$$

Inside mine openings: Re ≈ 10^5 ... $5 \cdot 10^6$

w	velocity of mine air [m/s]
D	(hydraulical) diameter [m]
υ_L	kinematic viscocity of air ($\upsilon_L \approx 15 \cdot 10^{-6}$ m²/s)

Mine Ventilation

Overhead 10.12

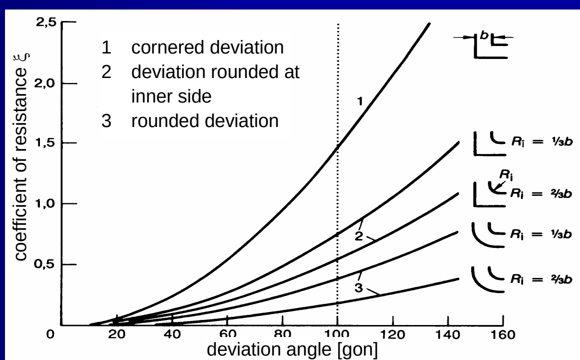
20/02/2006

Calculation of mine air movement:

Pressure drops caused by deviations

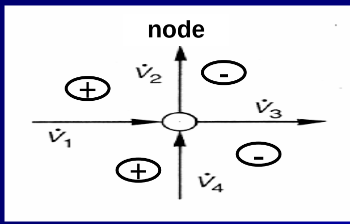
$$\Delta p = \xi \cdot \frac{\rho}{2} \cdot w^2$$

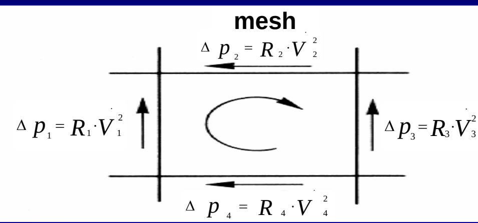
ξ coefficient of resistance due to geometric shape of deviation and deviation angle (see diagram)



Calculation of mine air movement:

Rules of node and mesh





$$\sum_{i=1}^{n} \dot{V}_i = 0$$

$$\sum_{i=1}^{n} \Delta p_i = 0$$

"The flow rates of all air flows towards (pos. sign) or away from (neg. sign) a node sum up to zero."

"The pressure losses of all air flows, which behave homotropal (pos. sign) or antitropal (neg. sign.) to a counting direction determined before, sum up to zero."

e.g.:

$$\dot{V}_1 - \dot{V}_2 - \dot{V}_3 + \dot{V}_4 = 0$$

e.g.:

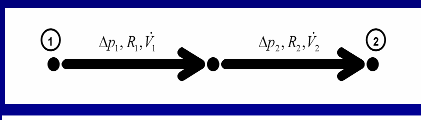
$$\Delta p_1 - \Delta p_2 - \Delta p_3 + \Delta p_4 = 0$$

$$R_1 \cdot \dot{V}_1^{\,2} - R_2 \cdot \dot{V}_2^{\,2} - R_3 \cdot \dot{V}_3^{\,2} + R_4 \cdot \dot{V}_4^{\,2} = 0$$

Calculation of mine air movement:

Distribution of flow rate and pressure I

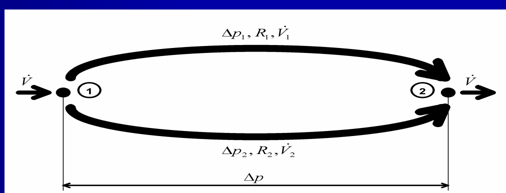
Serially connected air ways:



total resistance:

$$R_g = R_1 + R_2 + R_3 + \ldots + R_n = \sum_{i=1}^{n} R_i$$

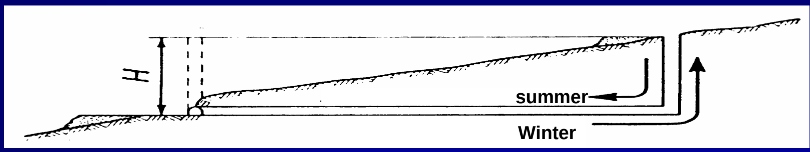
Parallely connected air ways:



total resistance:

$$\frac{1}{\sqrt{R_g}} = \frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}} + \frac{1}{\sqrt{R_3}} + \ldots + \frac{1}{\sqrt{R_n}} = \sum_{i=1}^{n} \frac{1}{\sqrt{R_i}}$$

Natural Ventilation



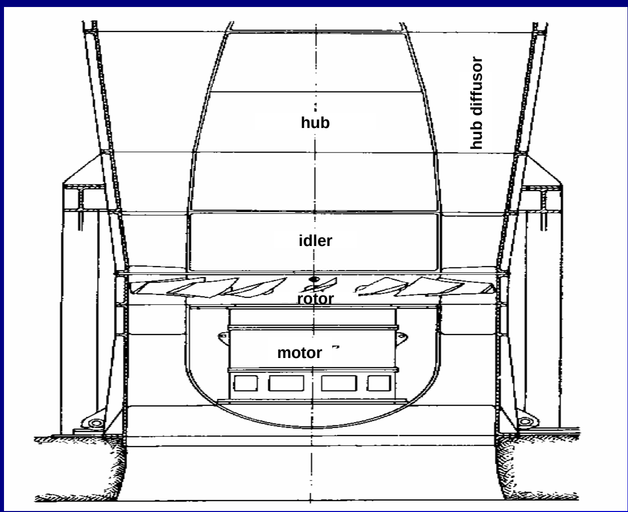
$$\Delta p_R = \Delta p_L \mp \Delta p_N$$

Δp_r total drop of pressure [Pa]
Δp_L generation of pressure by fan [Pa]
Δp_N natural buoyancy [Pa]

Axial fan

$$\dot{V} = A \cdot v$$

if A increases
⇒ v decreases
⇒ Δp increases

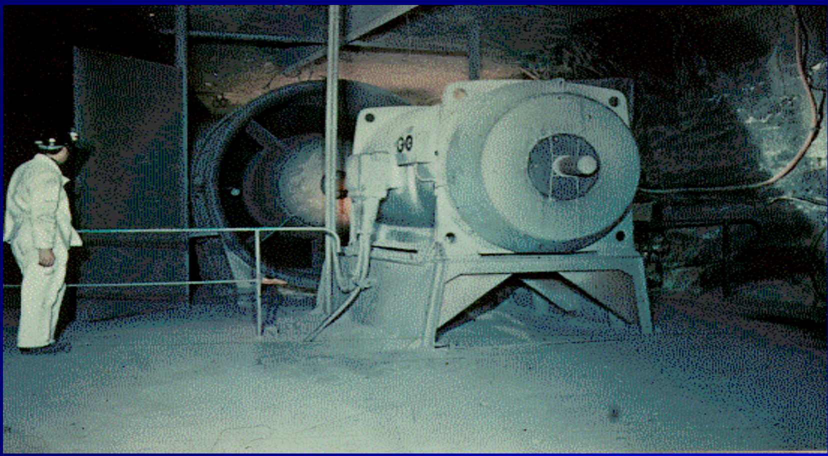


Mine Ventilation

Overhead 10.17

20/02/2006

Axial fan underground



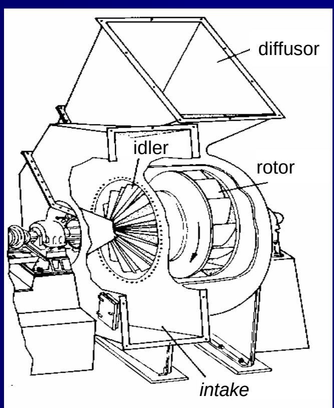
Axial fan underground (Wintershall potash mine)

Mine Ventilation

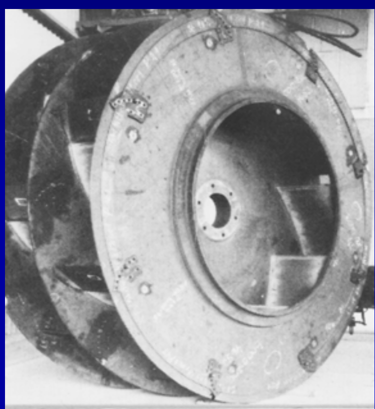
Overhead 10.18

20/02/2006

Centrifugal fan

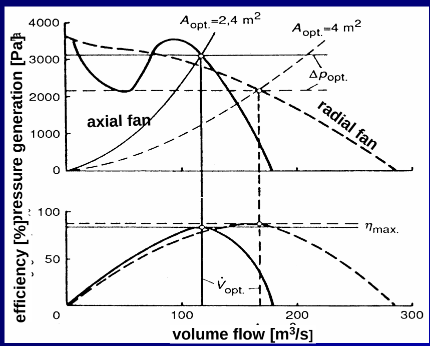


Single flow centrifugal fan



Rotor of a double flow centrifugal fan with adjustable rotor blades

Characteristic curves and efficiency



——— characteristic curves of axial fan

- - - - - - - characteristic curves of radial fans

Efficiency of ventilation device:

$$\eta_{VD} = \eta_F \cdot \eta_G \cdot \eta_M$$

η_{VD} efficiency of ventilation device

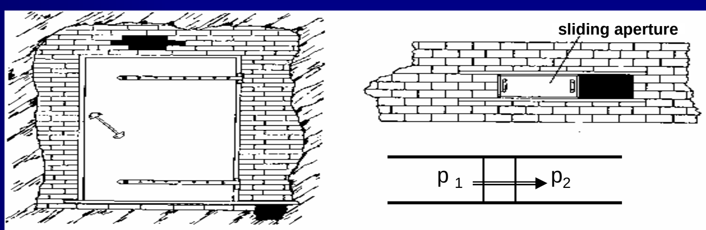
η_F efficiency of fan

η_G efficiency of gear

η_M efficiency of motor

air throttle

Air throttle door:



Throttling losses

$$P_D = \Delta p_D \cdot \dot{V} \quad [W]$$

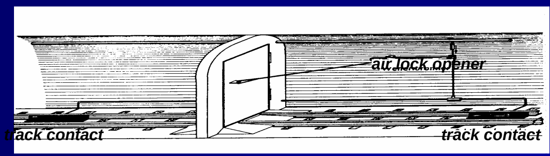
P_D performance losses due to throttling [W]

Δp_D pressure drop due to throttling [N/m² = Pa]

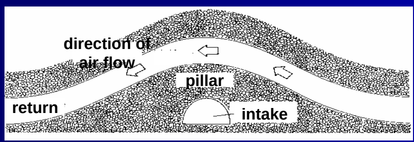
$\dot{V}$ volume flow [m³/s]

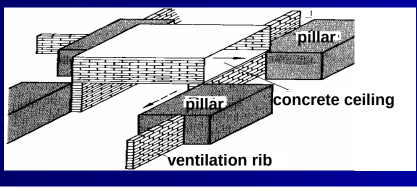
Separation of air flows

Automatical air lock:

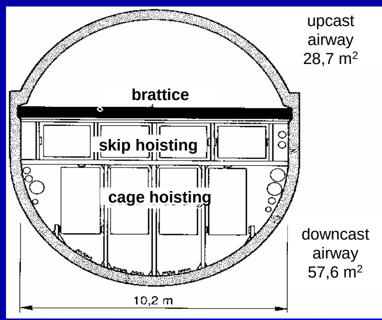


Air bridge :



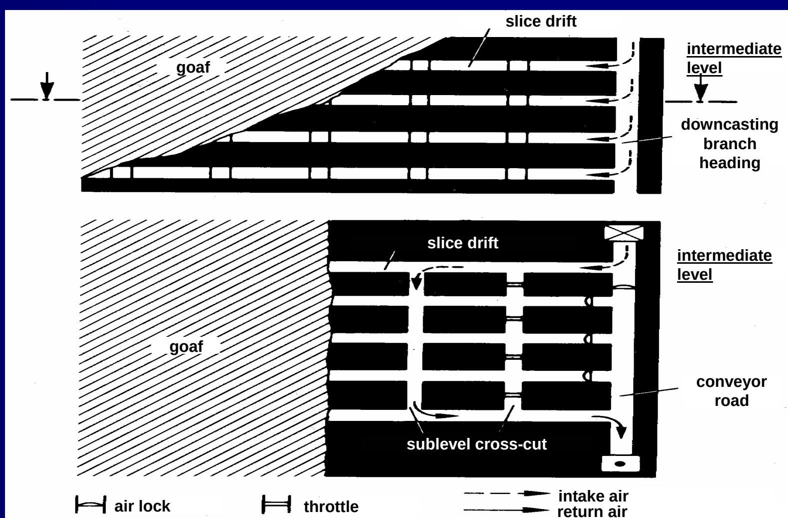


Brattice:



Examples of mine ventilation systems:

Sublevel caving



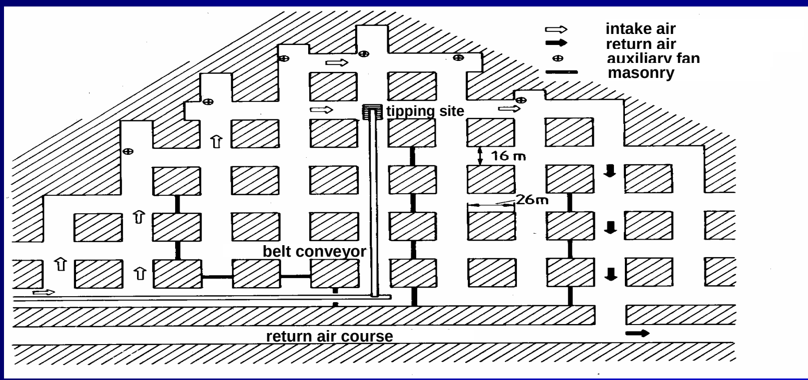
Mine Ventilation

Overhead 10.23

20/02/2006

Examples of mine ventilation systems:

Room and pillar mining



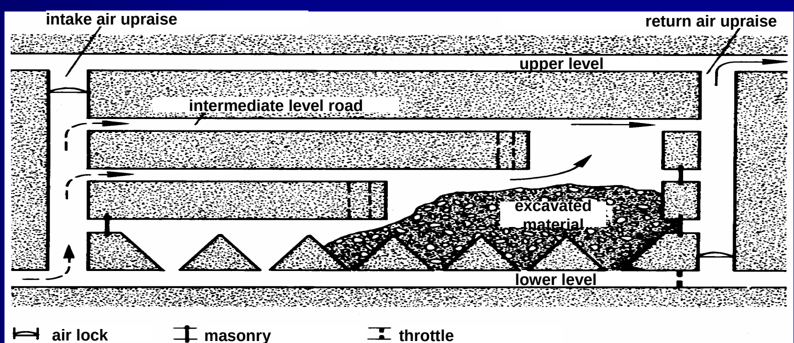
Mine Ventilation

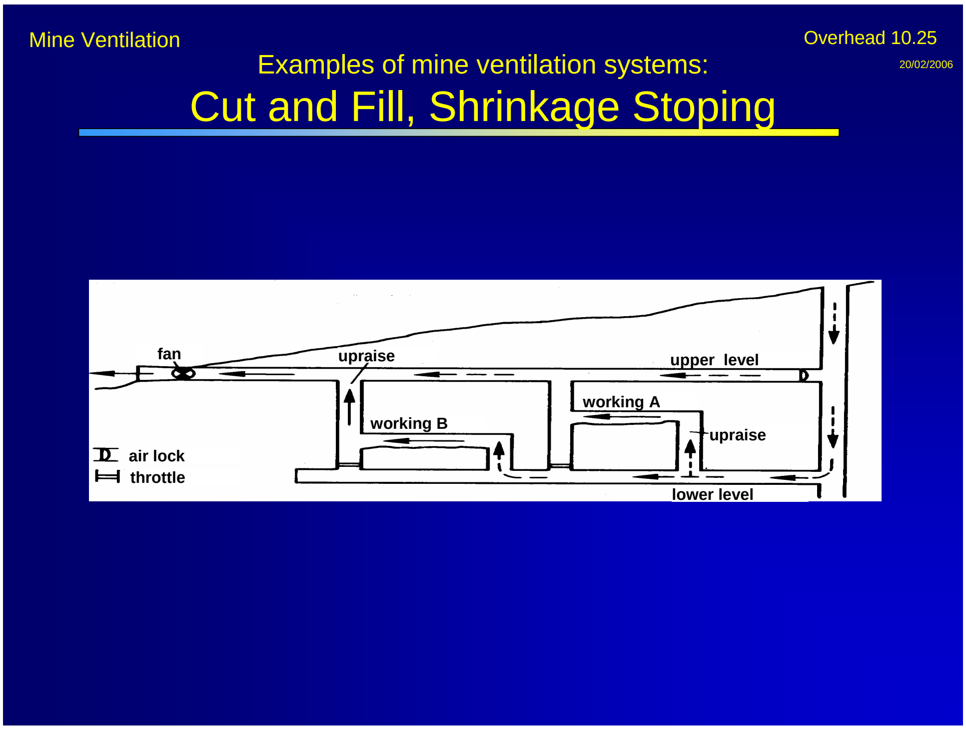
Overhead 10.24

20/02/2006

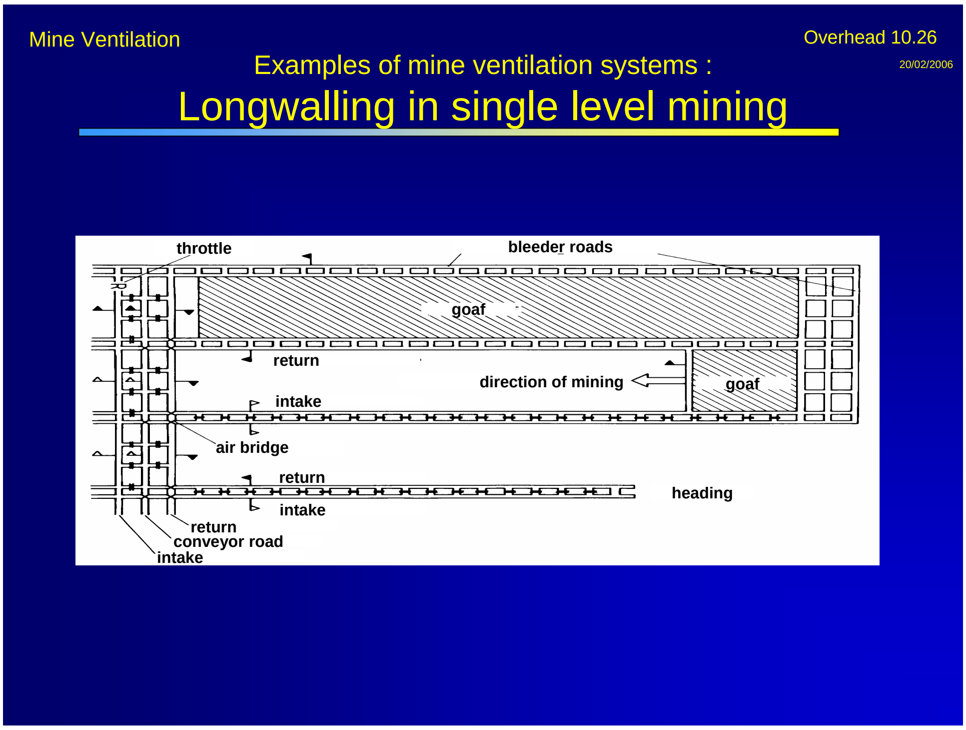
Examples of mine ventilation systems:

Sublevel Stoping





Mine Ventilation
Overhead 10.25
20/02/2006
Examples of mine ventilation systems:
Cut and Fill, Shrinkage Stoping
fan
upraise
upper level
working A
working B
upraise
air lock
throttle
lower level



Mine Ventilation
Overhead 10.26
20/02/2006
Examples of mine ventilation systems :
Longwalling in single level mining
throttle
bleeder roads
goaf
return
direction of mining
goaf
intake
air bridge
return
heading
intake
return
conveyor road
intake

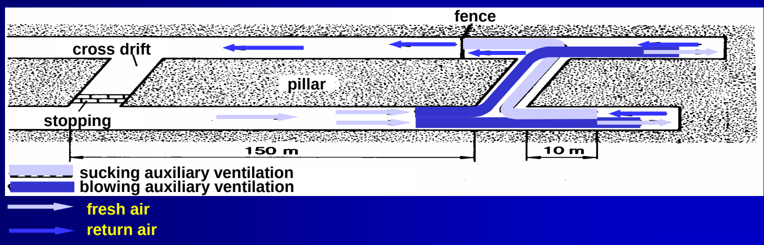
Mine Ventilation

Overhead 10.27

20/02/2006

Other methods of auxiliary ventilation:

Double heading



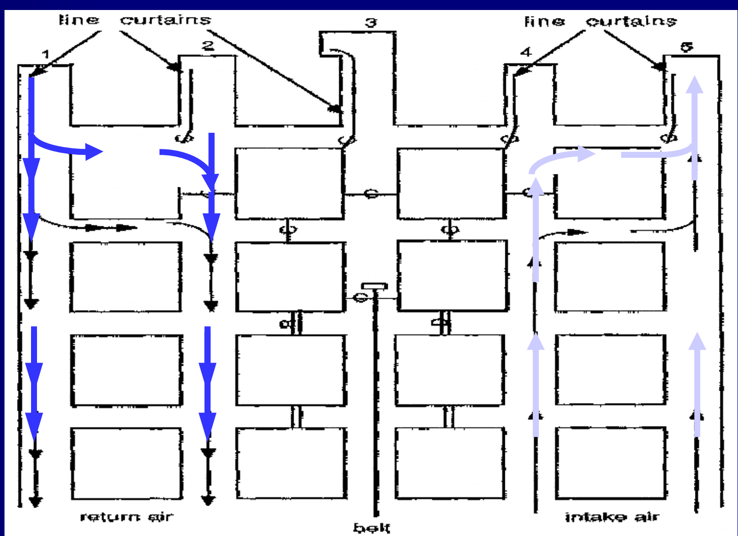
Mine Ventilation

Overhead 10.28

20/02/2006

Other methods of auxiliary ventilation:

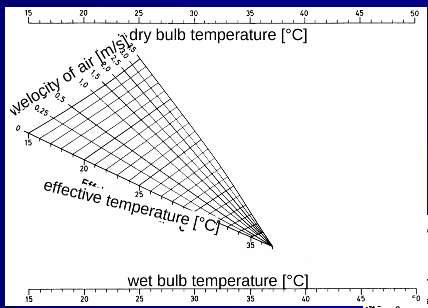
Auxiliary ventilation by line curtain

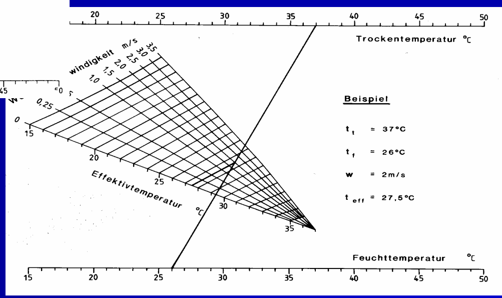


Measure for climate:

Effective temperature

Yaglou-diagram for distinguishing the effective temperature from dry and wet bulb temperature:





Example of application:

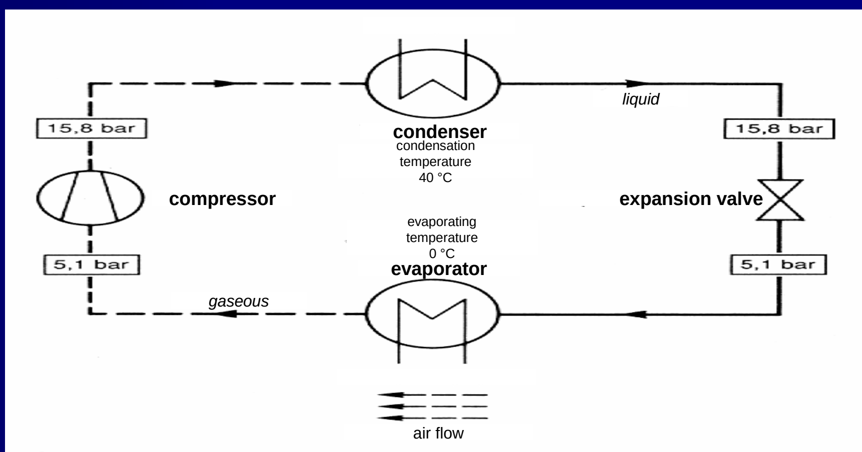
measured:

t_t 38,0 °C
t_f 32,0 °C
w 1,0 m/s

diagram value:

t_{eff} 32,5 °C

Refrigator Curcuit

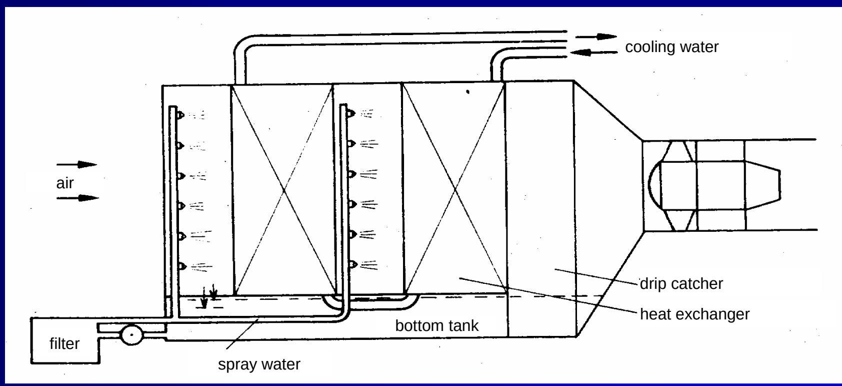


Mine Ventilation

Overhead 10.31

20/02/2006

Recooling



Mine Ventilation

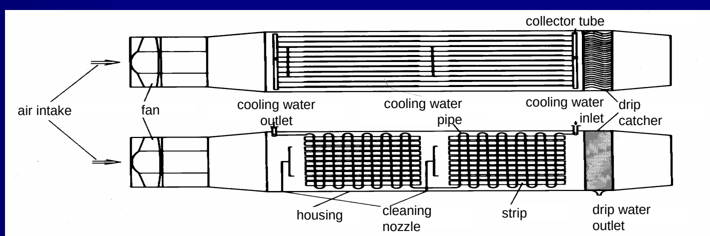
Overhead 10.32

20/02/2006

Types of air coolers:

Mobile air cooling systems

Surface cooler:



Spray type cooler: