# Ventilation Strategies and the use of Trackless equipment


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# OBJECTIVES

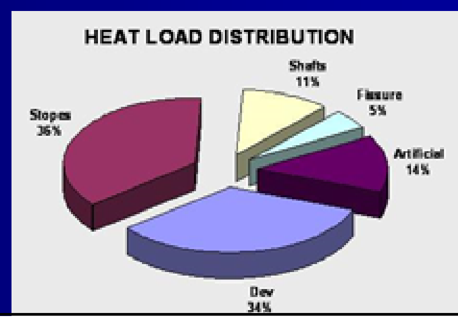
- INTRODUCTION.
  - PAST REFLECTIONS. (Implementations and achievements?)
- PLANNING METHODOLOGIES (Conceptual, pre-feasibility, etc.)
- Ventilation design criteria
  - Contaminant removal, diesel equipment req., blasting requirements, regulatory requirements, heat removal, etc.
- Where does the heat come from (Trackless equipment)
- Ambient air temperature changes
- Ventilation & Cooling requirements
- Ventilation & Control systems

- INTRODUCTION.

# THE LAST CENTURY ....

- Mining in the early 20th century
- Mining depth
- Underground conditions
- Heat loads
- Cooling systems

- Underground heat becomes an issue
- Refrigeration




- INTRODUCTION.

# THE LAST CENTURY ....

- Mining in the early 20th century
- Mining depth
- Underground conditions
- Heat loads

- Underground heat becomes an issue
- First Refrigeration plant

***Morro Velho (Brazil)***

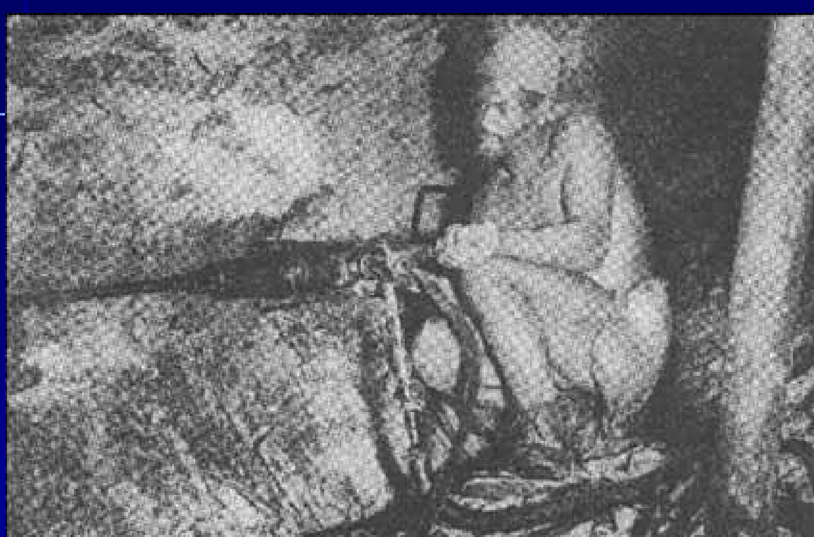
INTRODUCTION.

## *Depths reached in Witwatersrand at the end of 1944*

| MINE | METRES BELOW SHAFT COLLAR |
|---|---|
| City Deep, 4C Incline | 2730 |
| Crown Mines, R2 Incline | 2647 |
| Robinson Deep, 47 – 3 Winze (Turf section) | 2630 |
| East Rand Proprietary Mine, Angelo Tertiary Incline | 2494 |
| Durban Roodepoort Deep, 5A Shaft | 2395 |
| Consolidated Main Reef, 3C Incline | 2306 |
| Simmer & Jack, East Tertiary | 2262 |

INTRODUCTION.

## THE FIRST REFRIGERATION PLANT FOR S.A.

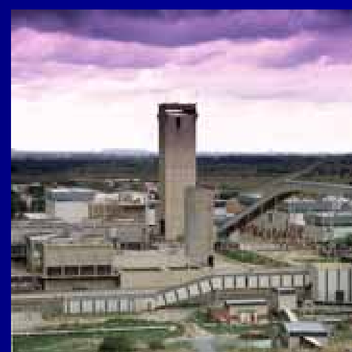


Turf shaft, Robinson Lake (1934)

❑ INTRODUCTION.

# 100 YEARS LATER……

- Large Mines
- Deep level mining
- Increased heat loads
- Large Refrigeration Plants



# Future ……

Initial steps that could be followed when designing a ventilation and cooling system for a new or an existing underground mine.

# Planning ......

**1. DETERMINE THE METHOD & RATE OF PRODUCTION**

This is an mining engineering function but the Ventilation Engineer must know the different mining methods to plan and design Ventilation and Refrigeration systems in an effective and practical manner.

# Planning ......

**2. DEFINE ACCEPTABLE ENVIRONMENTAL STANDARDS**

This usually involves the design of layout and a statement concerning the ventilation and refrigeration design parameters such as:

- Rock properties
- Ventilation requirements, i.e. trackless mining, conventional mining, etc.
- Up-and-Downcast shaft requirements.
- Airways
- Conveyor belt airways
- Auxiliary and main fans, etc.

## Planning ......

**OTHER PARAMETERS**

1)Rock thermal conductivity (K – W/mK))
2)VRT (°C)
3)Rock density (p – kg/$m^3$)
4)Rock thermal capacity (C – kJ/kg °C)
5)Airway length (m)
6)Air quantity ($m^3$/s)
7)Airway size (m)
8)Pressure (kPa)
9)Years age airway
10)Airway friction factor
11)Insulation thickness (mm)
12)K-Insulation (W/mK)
13)Refrigeration Capital cost (i.e. $ 1,415/kW) installed
14)Electrical Power Cost (i.e. $ 170 TO $ 264/kW) (30% of heat refrigerated)
15)Owning cost time period (i.e. 20 years).
16)Percentage interest used (i.e. 10%)
17)Haualge insulation cost per $m^3$
18)Psychometric properties (air WB and DB; Barometric pressure, etc.)

## Planning ......

**3. CALCULATE HEAT LOAD, GAS EMISSIONS AND DUST PRODUCTION**

a) **Heat load calculations**:

Stopes (Rock)
Fissure water (Fluids)
Electrical equipment (Inefficiency)
Diesels (Gases & fumes)
Auto compression (Potential energy)

b) **Gas emission** (EQI & Quantity)

c) **Dust production** (Air velocity/dilution)

# Planning ......

**4. CALCULATE AIR AND REFRIGERATION REQUIREMENTS**

The most favourable requirements are determined from a procedure considering 3 major and 2 minor cost functions

a) Major costs
- Ventilation costs
- Refrigeration costs
- Productivity costs

b) Minor costs
- Acclimatisation costs
- Dust levy costs
- Quantity of air per stope, stope face velocity, cooling and amount of refrigeration required.

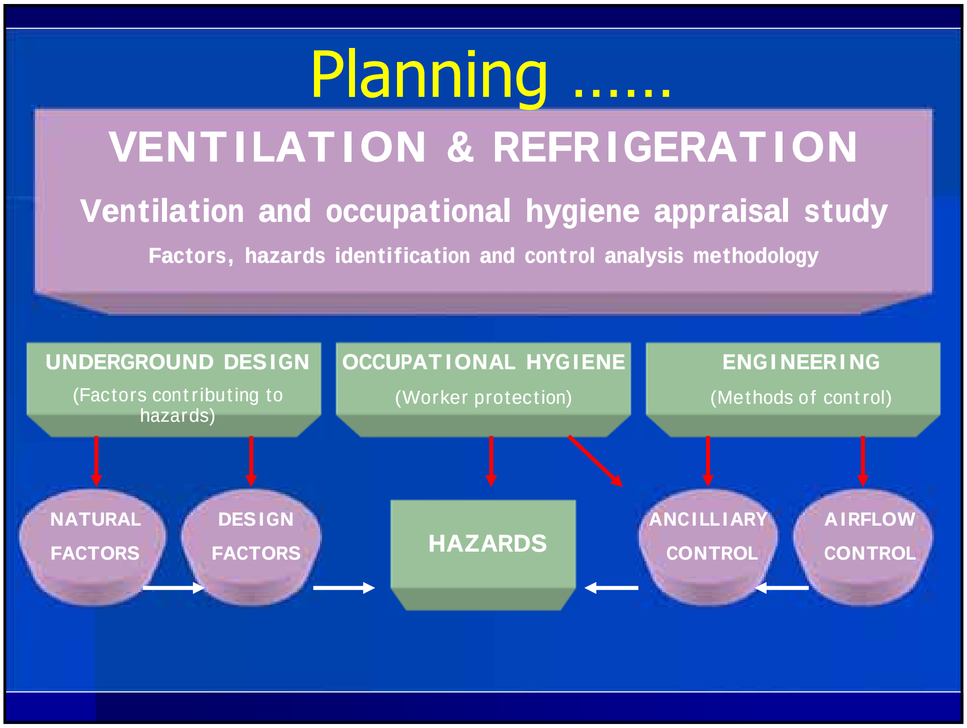
# Planning ......

**5. OPTIMISE ALTERNATIVES**

**6. SELECT SYSTEM**

Refrigeration plants can be situated both on surface and underground. What is the fundamental issue when planning a deep underground mine in relation to the location of the plant/s that are needed ?

- Mining depth
- Lateral mining distance from the shaft
- Mining area (VRT related)
- UG plant has low COP
- Use BAC on surface for DC air cooling
- Use UG plant for deep UG cooling distribution




# PLANNING PHASES

**A) Conceptual**

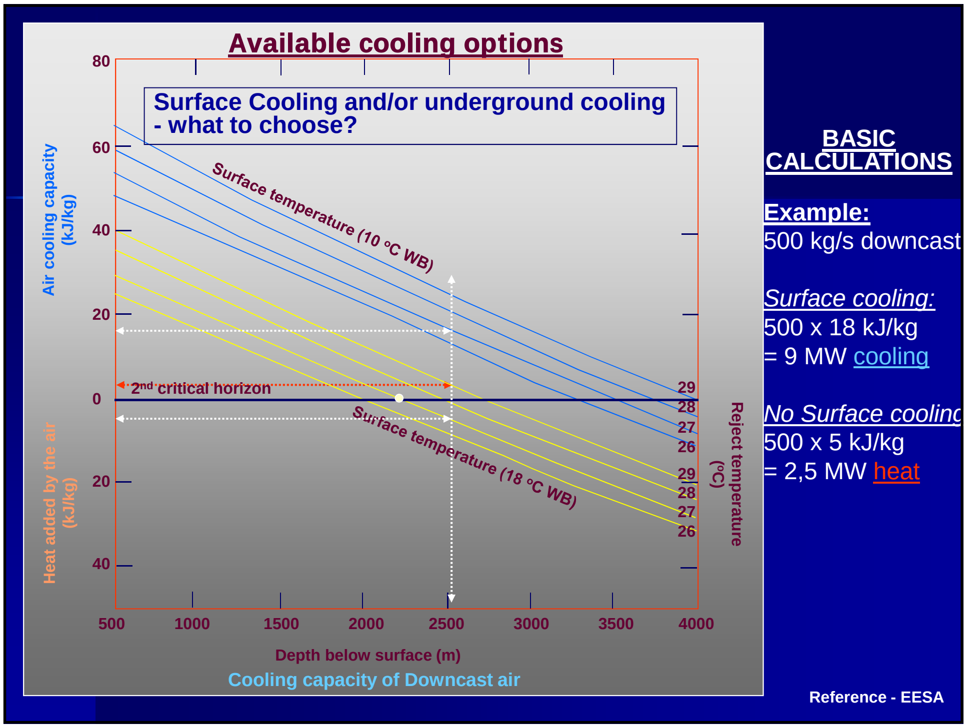
- Basic calculations & design – no detail

**B) Pre-feasibility**

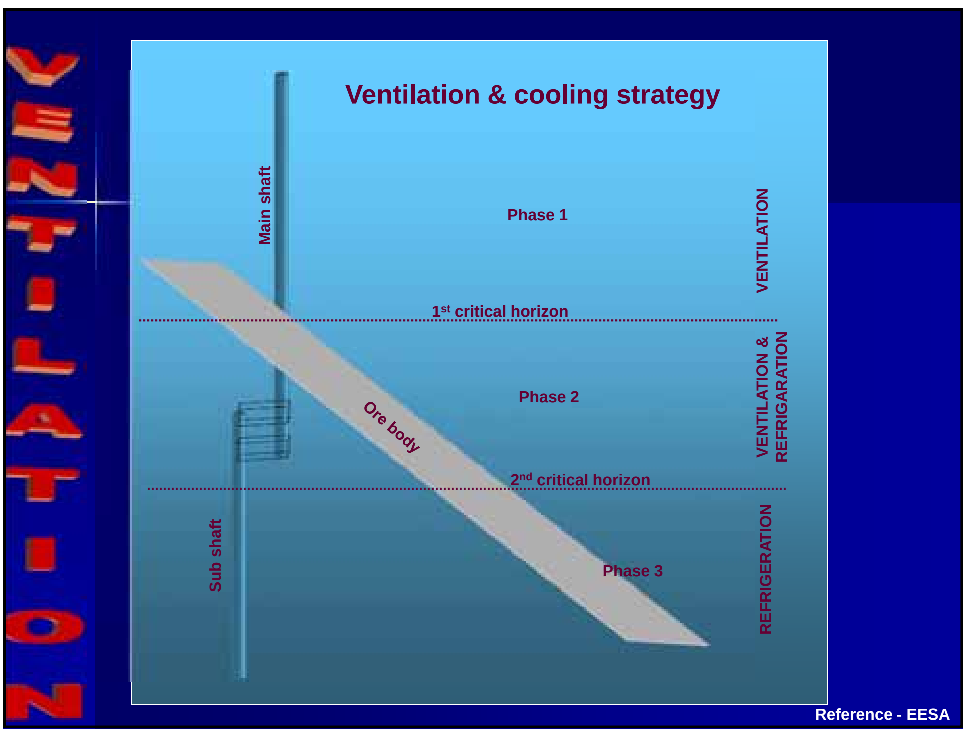
- Evaluate alternative designs
- Detail systems
- Preliminary cost

**C) Feasibility**

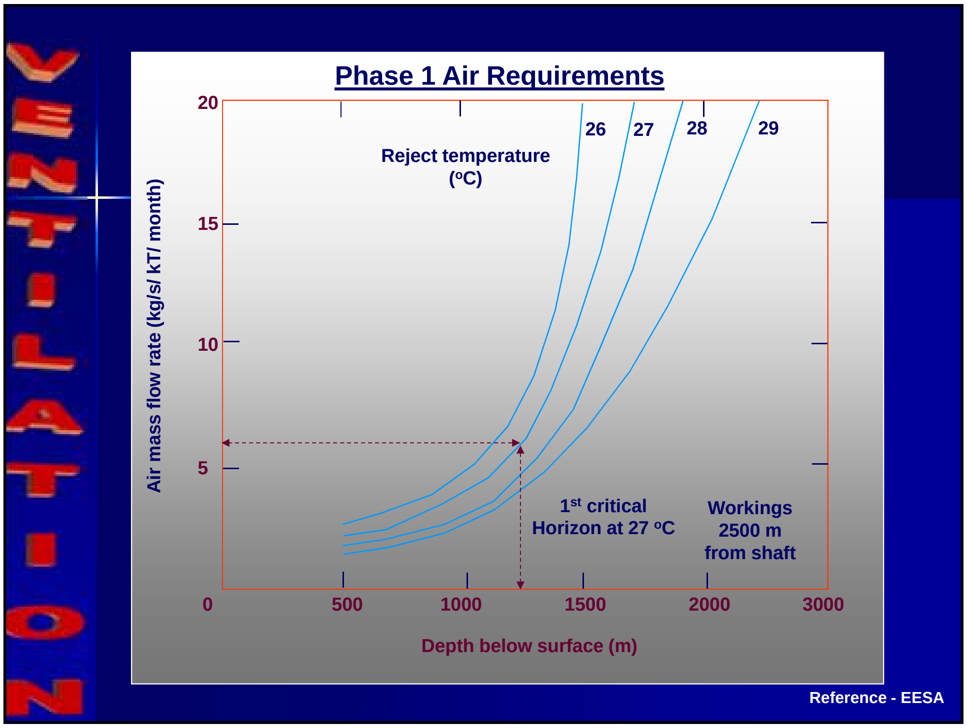
- Concentrate on preferred design
- Optimize
- Detail design & cost

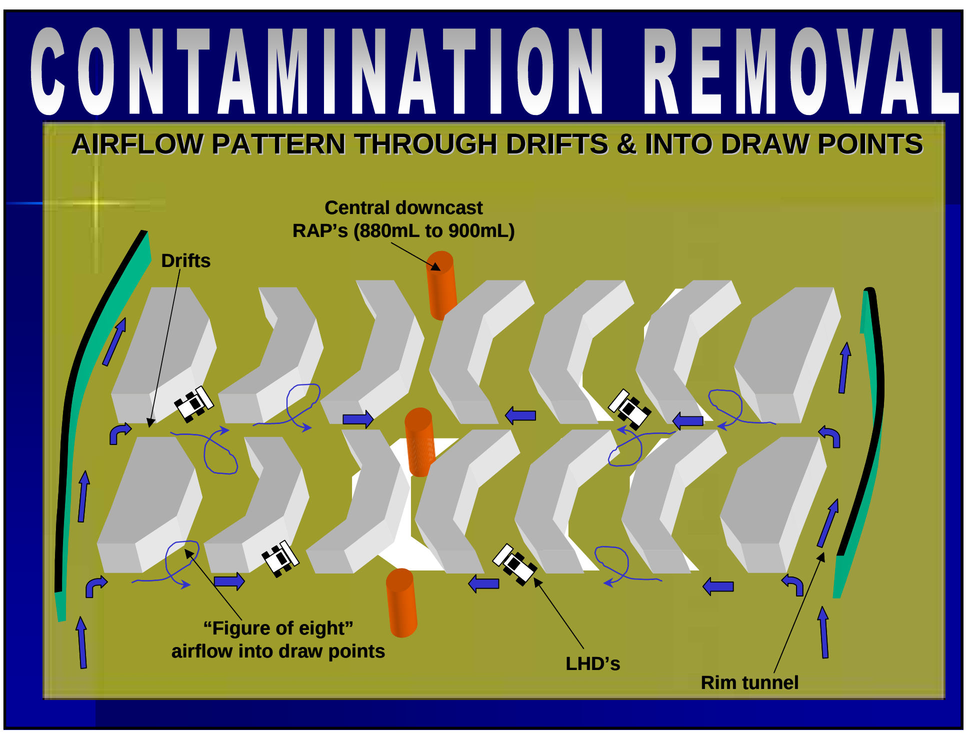


Available cooling options
Surface Cooling and/or underground cooling - what to choose?
Surface temperature (10 °C WB)
Surface temperature (18 °C WB)
2nd critical horizon
Air cooling capacity (kJ/kg)
Heat added by the air (kJ/kg)
Reject temperature (°C)
Depth below surface (m)
Cooling capacity of Downcast air
BASIC CALCULATIONS
Example:
500 kg/s downcast
Surface cooling:
500 x 18 kJ/kg
= 9 MW cooling
No Surface cooling
500 x 5 kJ/kg
= 2,5 MW heat
Reference - EESA

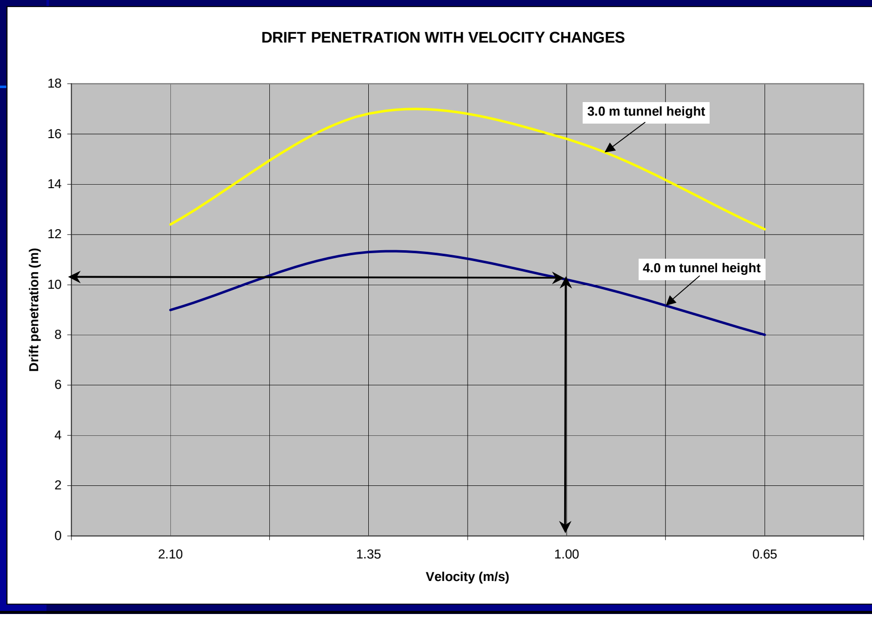



VENTILATION
Ventilation & cooling strategy
Main shaft
Phase 1
VENTILATION
1st critical horizon
Phase 2
Ore body
VENTILATION & REFRIGARATION
2nd critical horizon
Sub shaft
Phase 3
REFRIGERATION
Reference - EESA


VENTILATION
Phase 1 Air Requirements
Reject temperature
(°C)
26
27
28
29
Air mass flow rate (kg/s/ kT/ month)
20
15
10
5
0
500
1000
1500
2000
3000
1st critical
Horizon at 27 °C
Workings
2500 m
from shaft
Depth below surface (m)
Reference - EESA


CONTAMINATION REMOVAL
AIRFLOW PATTERN THROUGH DRIFTS & INTO DRAW POINTS
Central downcast
RAP's (880mL to 900mL)
Drifts
"Figure of eight"
airflow into draw points
LHD's
Rim tunnel

# AIR VELOCITY




DIESELS

**THE USE OF TRACKLESS EQUIPMENT & IMPLICATIONS THEREOF**

- Evaluating trackless equipment underground

## ACKNOWLEDGE THE SYSTEMS THAT INFLUENCE YOUR MINE

### WHAT INFLUENCES OUR ENVIRONMENT ?

- OREBODY (Depth below surface ? (5000 mbc)
- REGULATIONS ? (Dust, Gases, Surface Impact)
- INTERNATIONAL COMPETITION (Globalization)
- TECHNOLOGY (i.e. Trackless Equipment)

**Control:** to direct an activity.

***Control*** is considered to be **any** process whereby the hazard is managed to reduce and maintain the risks at acceptable levels. Here, once again, guidance as to the process should be taken from the MH&SA, Section 11 where the employer is instructed to assess and respond to risk. In so responding he must, as per Section 11(2):
"determine all measures, including changing the organisation of work and the design of safe systems of work, necessary to eliminate any recorded risk; control the risk at source; minimise the risk; and in so far as the risk remains – provide for personal protective equipment; and institute a programme to monitor the risk to which employees may be exposed."

The role and duty of the occupational hygienist (Section 12) is therefore to devise appropriate measurement systems which will provide the manager with information which can be used to determine measures or systems which are applied to **eliminate, control and minimise** health risks and hazards [see sub-section 2(a) and (b)].

## ACKNOWLEDGE THE SYSTEMS THAT INFLUENCE YOUR MINE

WHAT INFLUENCES OUR ENVIRONMENT ?

- TECHNOLOGY (i.e. Trackless Equipment)
  YES !!
  In what respect ?
  All industries are effected – improved & more effective ways of providing a productive environment – how ?
  Diesel/trackless equipment !
  Electronic equipment !

**WHAT DOES THIS MEAN IN OUR STRATEGY ?**

Why Ventilation and refrigeration planning?

## Overview

- VENTILATION

Mine ventilation is the continuous supply of *adequate* and *qualitative* air to all parts of a mine underground, where people are required to travel or work. This continuous supply of air is required to:

- Supply *oxygen for breathing purposes* and must be above 19% by volume.
- Remove heat and *provide comfortable working* conditions and hence improve production.
- To *dilute and remove noxious and flammable gases* that may be encountered during mining operations.
- To *dilute and remove hazardous airborne pollutants* created by various mining operations underground. (e.g. dust, fumes, aerosols, vapours etc.)

All these reasons above are to create and maintain an underground working environment that is conducive to the productivity, health, and safety of people.

**2.** Overview of current ventilation and refrigeration planning strategies.

## Overview

- REFRIGERATION

Refrigeration is a process of cooling, whereby heat is removed from a substance (air), where it is not wanted (working places), and put back where it does not affect workers (return airways). It is important to remember that heat is a form of energy and cannot be destroyed, but however can be transferred from one form into another.

In South Africa, refrigeration was introduced for the first time into the gold mines in the 1930's (Turfontein) and the first real increase in capacity occurred during the early 1960's. A dramatic increase in capacity occurred during the mid 1970 - 80's, when refrigeration started to become an integral part of South African modern and ultra deep mining. For example a mine in Free State utilises ± 105 Mega-watt (105 000 kW) of refrigeration in order to provide comfortable, safe and healthy conditions underground.

## Overview continue....

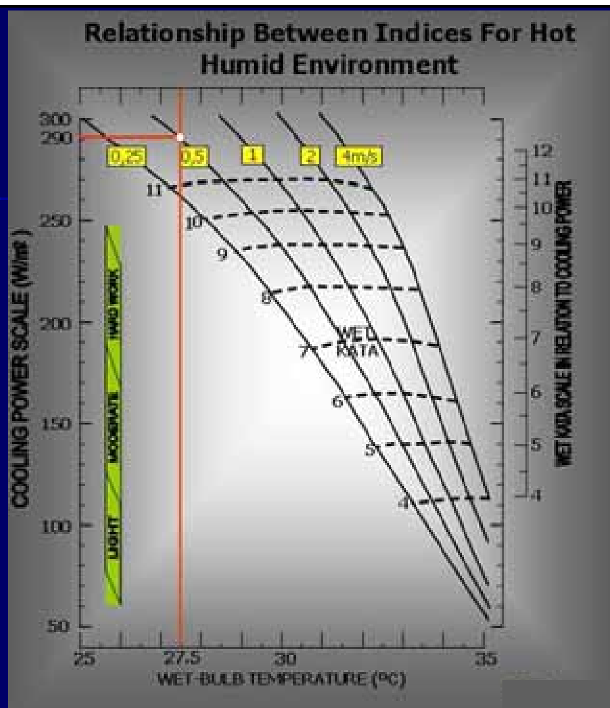
- REFRIGERATION

As a general guide in South African gold mines, it is possible to mine down to a VRT of approximately 40°C VRT (± 1250m) in most mines, without refrigeration. From 1250 m to ± 2000 m (40°C+ VRT) the ventilation air is supplemented by refrigeration and beyond 2000 m the air has no residual cooling effect and all the heat produced, must be removed by refrigeration.

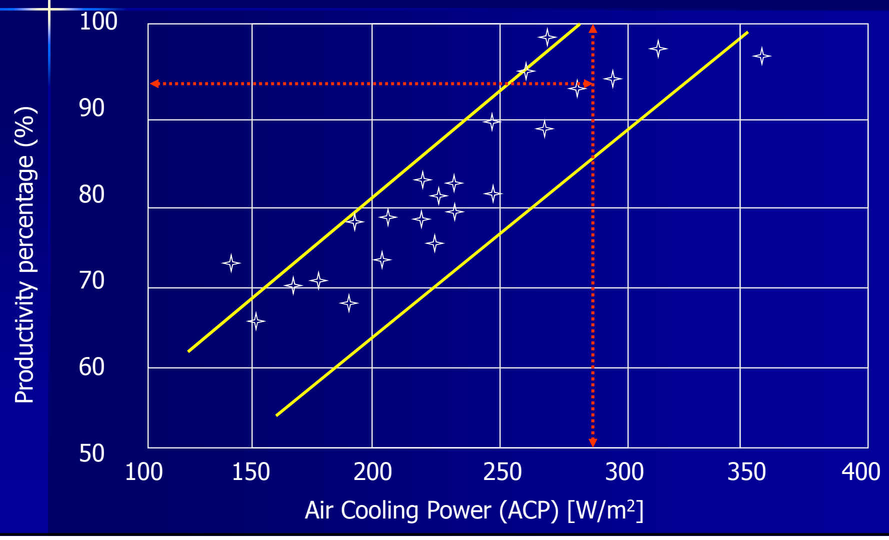
Another guide, which is purely arbitrary and is not based on any fundamental theory of heat exchange, is that 1 kW of refrigeration has the same effect as supplying an extra 0,03 $m^3/s$ of air. However, this relationship between air volume flow ($m^3/s$) and unit of refrigeration (kW) is a variable one, and is dependant upon the heat absorption capacity of the prevailing ventilation air. The deeper the higher the station temperature becomes, and under such conditions, refrigeration becomes an essential feature due to a decrease in the heat absorption capacity of the air.

# VENTILATION DESIGN CRITERIA

- DIESEL EQUIPMENT (i.e. 187 kW units)
- DUST AND FUMES (1 m/s)
- HEAT (27.5ºC reject)
- RE-ENTRY PERIODS (10 minutes)



# Effect of mine climate on productivity




## 2. Evaluating the Adverse Effects of Working within Hostile Conditions on Productivity.

- ❑ Understanding heat, fumes, and dust in different underground mining operations.

Where does the heat come from ?

# VENTILATION DESIGN CRITERIA


DIESELS

A method for calculating the quantity required for a diesel vehicle is the method used by CANMET for diesel engine certification. This method determines an Exhaust Quality Index (EQI). The calculations method is:

$$EQI = \frac{CO}{50} + \frac{NO}{25} + 3.7\left[\frac{DPM}{2}\right] + 1.5\left[\frac{SO_2}{3}\right] + 1.2\left[\frac{NO_2}{3}\right]$$

**Pollutants and related TLV's from diesel exhaust.**

| **Description** | **Threshold limit value (TLV)** |
|---|---|
| Carbon Monoxide (CO) | 50 ppm (parts per million) |
| Nitric oxide (NO) | 25 ppm |
| Sulphur dioxide ($SO_2$) | 3 ppm |
| Nitrogen dioxide ($NO_2$) | 3 ppm |
| Diesel particulate matter (DPM) | 2 mg/m$^3$ |

# Engines

- 'Nameplating' prevalent in developed world
- Consider engine choice

| Sulphur Level (ppm) | Minimum Air Rating ($m^3/s$ per kW) "Clean Engine" | Maximum Air Rating ($m^3/s$ per kW) "Dirty Engine" |
|---|---|---|
| Low Sulphur 500 ppm | 0.0327 | 0.0668 |
| High Sulphur 5000 ppm | 0.0654 | 0.1078 |

Figures from CANMET nameplate approvals – 150-250 kW range

# *DIESEL EQUIPMENT*

**Engine type: Detroit Diesel; DDEC 6043-GK32, 8.5l Series 50**
**LED air requirement: 0.0447 $m^3/s/kW$**
**HED air requirement: 0.0792 $m^3/s/kW$**

**Fresh Air Quantity (Q) = 187 kW x 0.06 $m^3/s/kW$ = 11.22 $m^3/s/LHD$**

| Engine Rating and Maximum Fuel Rate at Sea Level | Sulphur in Fuel - %wt. | Ventilation Prescription | |
|---|---|---|---|
| | | CFM | $m^3/s$ |
| (205 kW) 275 HP @ 2100 RPM 97.9 lb/hr | 0.05<br>0.10<br>0.20<br>0.25<br>0.50 | 18 400<br>20 100<br>23 300<br>25 000<br>33 100 | 8.7<br>9.5<br>11.0<br>11.8<br>15.6 |
| (187 kW) 250 HP @ 2100 RPM 91.0 lb/hr | **0.05**<br>0.10<br>0.20<br>**0.25**<br>0.30<br>0.50 | **17 600**<br>19 100<br>22 100<br>**23 600**<br>27 897<br>31 200 | **8.3**<br>9.0<br>10.4<br>**11.1**<br>13.2<br>14.7 |

**Diesel consumption for this type of LHD is given as 0.178 L per hour per rated power (kW). Table 3.1.1.2 shows the parameters used in the example.**

| Diesel usage (L/hour) | Calorific value (kJ/L) |
|---|---|
| 33.3 | 35000 |

The calculation procedure is:
Heat produced = Diesel usage x Calorific value of the diesel / 3600 seconds per hour
= **33.3 x 35000/3600 = 323.75 kW**

This is the total heat produced from the diesel machine and it was imposed that the combustion efficiency is 100%. The heat produced from diesel machinery comprises of both sensible and latent heat. The latent heat component could be calculated from the water produced after combustion at a mean of 1 litre per litre of fuel consumed . Given that the latent heat of evaporation of water is 2450 kJ/kg then the **latent heat** produced would be **22.7 kW**. The **sensible** component in this example is therefore (323.75 – 22.7) **301 kW**. The trackless equipment rated output power would be **187.1 kW**. The heat load factor imposed onto the surroundings would be 1.73.

Depending on the variable parameters used such as the diesel consumption for this specific LHD type, so will the heat load accordingly change. Electrical machinery has the advantage above that of diesel equipment that no latent heat is produced and therefore a reduced heat load component although versatility becomes a problem.

# HEAT

**Diesel fuel usage and parameters**

| Diesel usage (L/hour) | Calorific value (kJ/L) |
|---|---|
| 33.3 | 35000 |

- Heat produced = **323.75 kW (Total)**
- **The** latent heat = 22.7 kW.
- The sensible heat = 301 kW.
- The LHD rated output power = 187.1 kW.
- The heat load factor = 1.73.

The heat load calculated does not infer that all that heat is available as a source to the ambient surroundings. All would be available if the engine is operating at full capacity all the time, i.e. 100% power utilised constantly. This is generally not the case, and the operating time at full capacity should be monitored and the heat load contribution adjusted to the mean heat load value determined.

For this LHD it is important to determine what the intake WBT just before the LHD should be therefore not to allow the temperature to exceed the design reject temperature of 27.5°C. A simplistic psychrometric calculation is required:

**The following parameters are required:**
Barometric pressure (P) = 96 kPa
Exit temperature after the LHD: 27.5°C WB and say 33°C DB
Air mass flow ($M_2$) = 20 kg/s

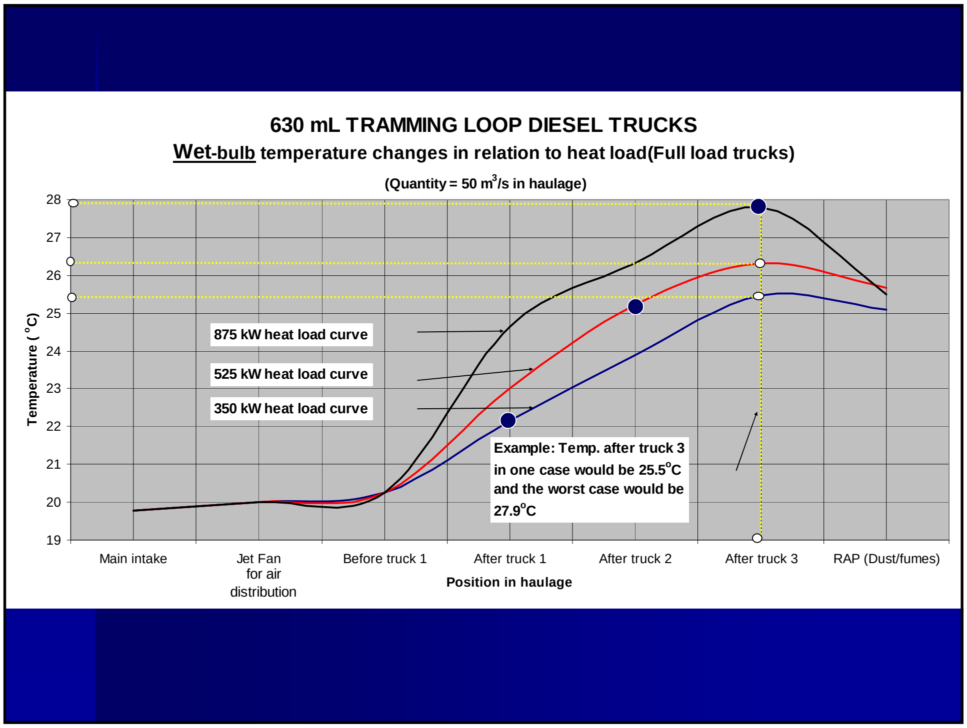
**Calculation results are:**
The sigma heat value is ($S_2$) = 88.15 kJ/kg
The energy content is ($Q_2$) = 1763 kJ/s

Therefore, the energy content on the LHD intake side should not exceed (1763 – 323) 1440 kJ/s. This intake energy content corresponds to a sigma ($S_2$) heat value of 72 kJ/kg. The WBT on the intake side of the LHD should therefore not exceed ***23.7°C***. A WBT above **23.7°C before** the LHD (LHD operating at maximum [100%] capacity) would increase the temperature above the design temperature of **27.5°C.**

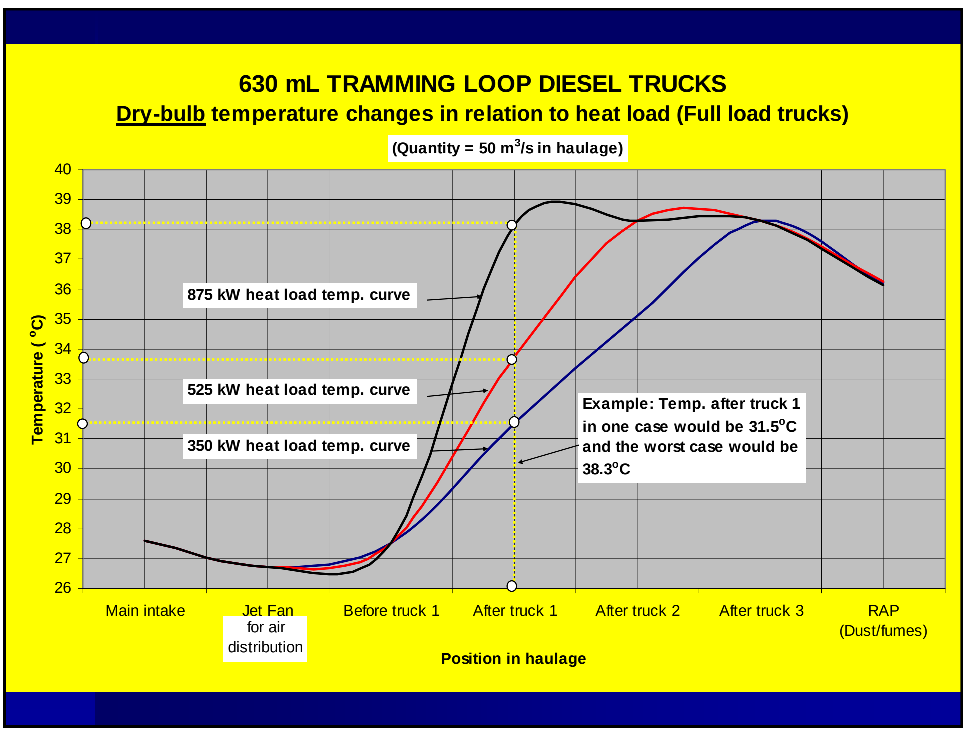
# HEAT CONT….

## TEMPERATURE BEFORE AND AFTER MECHANICAL EQUIPMENT

- REQUIRED TEMPERATURE AFTER THE LHD: 27.5°C WB
- **INTAKE WET BULB TEMPERATURE BEFORE LHD:** not to exceed ***23.7°C. (LHD operating at maximum [100%] capacity).***



630 mL TRAMMING LOOP DIESEL TRUCKS
Wet-bulb temperature changes in relation to heat load(Full load trucks)
(Quantity = 50 m3/s in haulage)
Temperature ( °C)
28
27
26
25
24
23
22
21
20
19
875 kW heat load curve
525 kW heat load curve
350 kW heat load curve
Example: Temp. after truck 3 in one case would be 25.5°C and the worst case would be 27.9°C
Main intake
Jet Fan for air distribution
Before truck 1
After truck 1
After truck 2
After truck 3
RAP (Dust/fumes)
Position in haulage

630 mL TRAMMING LOOP DIESEL TRUCKS
Dry-bulb temperature changes in relation to heat load (Full load trucks)
(Quantity = 50 m3/s in haulage)
Temperature ( °C)
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
875 kW heat load temp. curve
525 kW heat load temp. curve
350 kW heat load temp. curve
Example: Temp. after truck 1 in one case would be 31.5°C and the worst case would be 38.3°C
Main intake
Jet Fan for air distribution
Before truck 1
After truck 1
After truck 2
After truck 3
RAP (Dust/fumes)
Position in haulage

## ICE CALCULATION

An *example* is given to illustrate the unique application of Ice I as used in our mines. The use of ice involves three distinct phases namely (1) from ice at say -3°C to ice at 0°C, (2) when the ice melts at 0°C to form water and (3) the water phase (0°C to say 20°C). Using the specific heat of ice ($C_i$) as 2030 J/kg°C the energy transfer calculation is given as follows:

Ice mass ($M_i$) = 1 kg

Latent heat of melting ($L_i$) = 333 500 J/kg

Specific heat of water ($C_w$) = 4187 J/kg°C

$Q_{ice} = M_i C_i \Delta T$
= 1 x 2030 x 3
**= 6090 W**

$Q_L = L_i M_I$
= 333 500 x 1
**= 333 500 W**

$Q_w = M_w C_w \Delta T$
= 1 x 4187 x 20
**= 83 740 W**

$Q_{tot}$ = 6090 + 333 500 + 83 740
**= 423.33 kW per kg of ice**

The minimum amount of energy available from one kilogram of pure ice would be the latent energy component namely 333.5 kW. The mass of water required at a supply temperature of say 4°C and return water temperature of 20°C for the same energy transfer would be $\left(\frac{423330}{4187 \times 16}\right)$ 6.3 kg. A ratio of between 1:5 to 1:6 would be general for ice to water mass flow comparisons.

## COST TO COUNTER AN LHD's HEAT LOAD

1. The capital cost of a total refrigeration system is estimated at **$ 1,415 / kW(R)** and thus, constitutes a one-off payment of **$ 1,840 / kW** (1,415 x 1.3 = 1,840). (30% losses included)

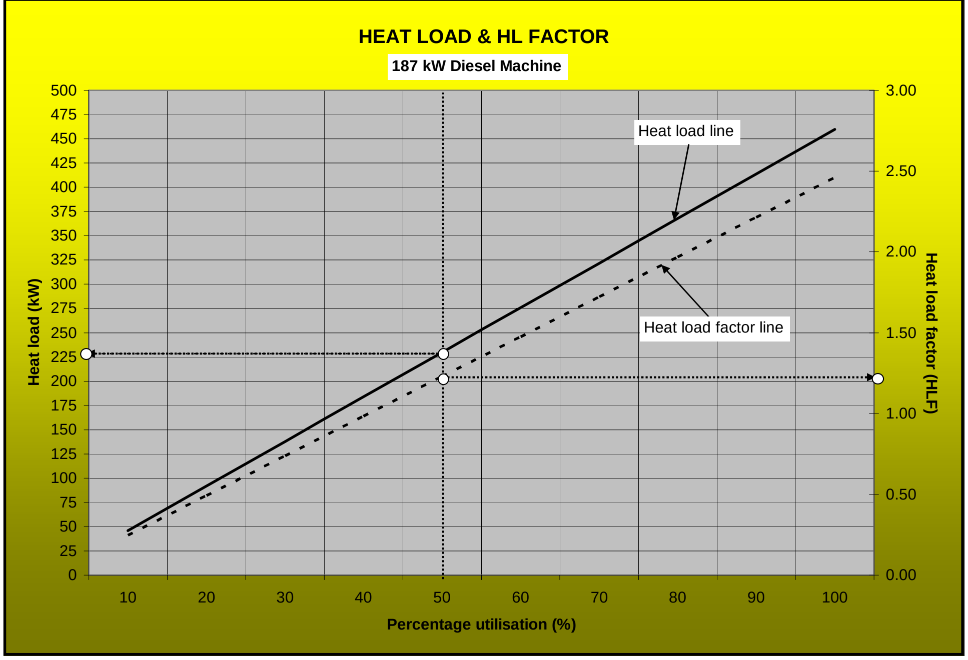
2. The electrical input power to generate 1.3 kW(R) = **0,39 kW(E)** (±30% of kW(R)).

3. The present value (PV) of this power cost over 20 years at 10% = 8.5
   Thus: the PV of running costs = (0,39 x 8.5 x $ 264) = **$ 875 / kW** (present day electrical power costs are $ 264/kW/annum including the mean maximum demand).

4. The total owning cost of one kW cooling required is thus, **$ 2,715 / kW** ($ 1,840 + $ 875).

5. For 323.75 kW cooling to be supplied to counter LHD heat the cost would be **$ 879,000** (323.75 x 2,715). Thus approximately 4,8L/s chilled water or 0.76kg ICE

## COST TO COUNTER THE LHD HEAT LOAD




## COST TO COUNTER THE LHD HEAT LOAD

- Re-examining the implications of ventilation and refrigeration planning & design for high productivity operations (deep level).
- Available air management strategies (How far can we go without cooling?)
  - Air is expensive
  - $P = RQ^2$ and $R = KCL/A^3$ at $\omega = 1.2$ kg/m$^3$
  - Air power = P x Q
  - Includes density changes

| | | |
|---|---|---|
| Diameter | 6.5 | m |
| Area | 33.18 | m² |
| K | 0.007 | Ns²/m⁴ |
| C | 20.420 | m |
| L | 2035 | m |
| Q | 650 | m³/s |
| **Velocity =** | **19.6** | **m/s** |
| **P (1) =** | **4036** | **Pa** |
| VP = | 192 | Pa |
| **P (2) tot =** | **4228** | **Pa** |
| **kW requirement (1)** | **4036** | **kW** |
| **kW requirement (2)** | **4862** | **kW** |

- Cost

Fan/s = $ 491 kW (installed)

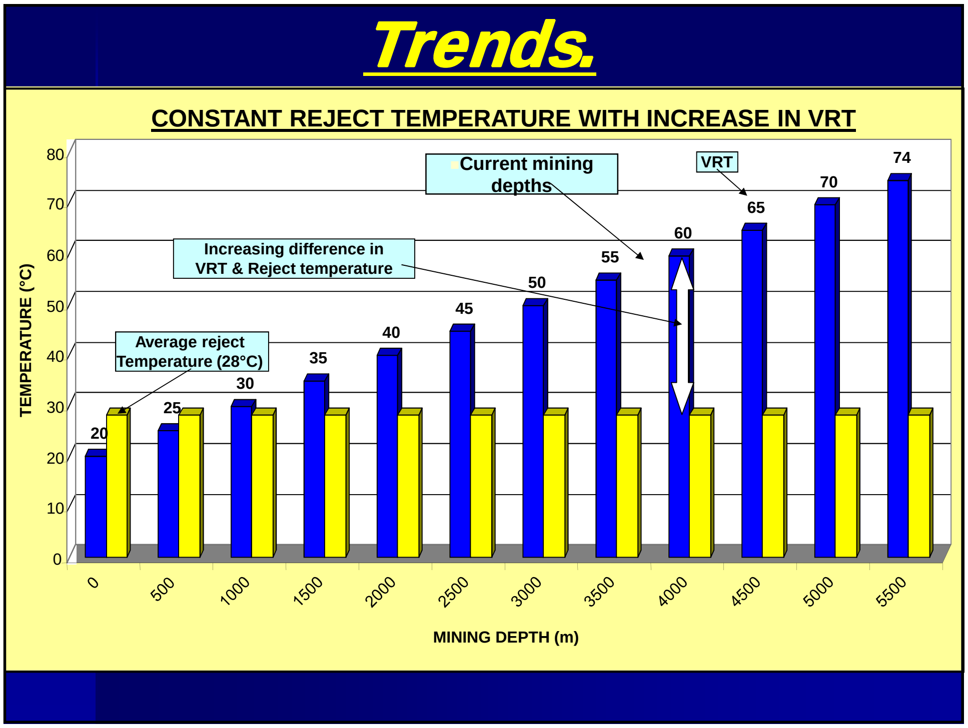
= $ 1,2 million / fan (2 x)

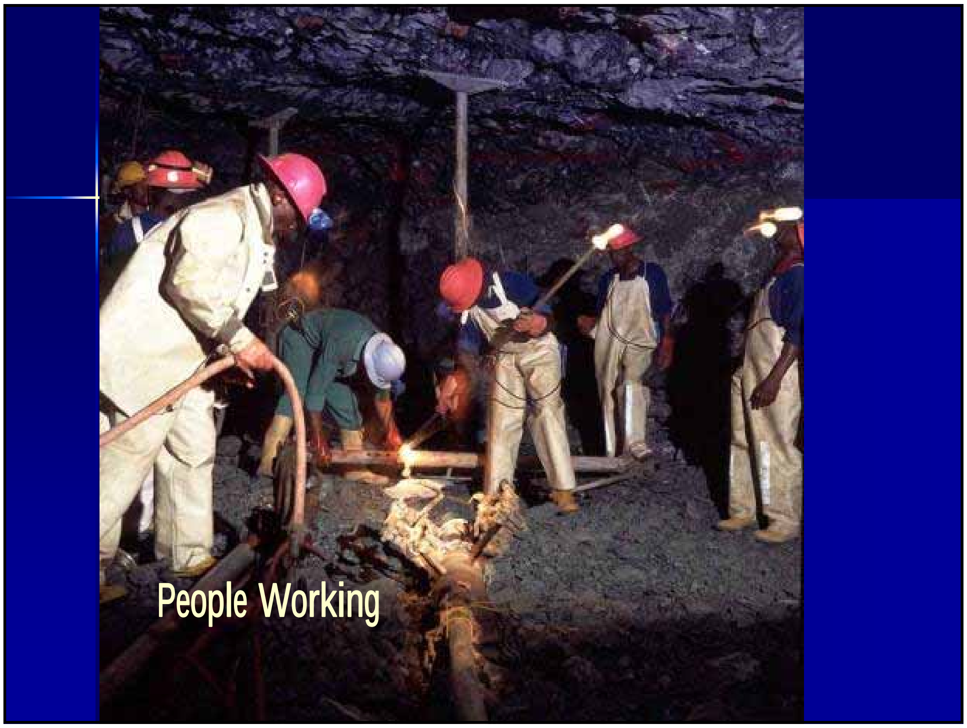
Electrical reticulation:

15 years ($ 264/kW/annum)

= $ 9,8 million


HEAT...............
Where does the heat come from?
Rock at depth

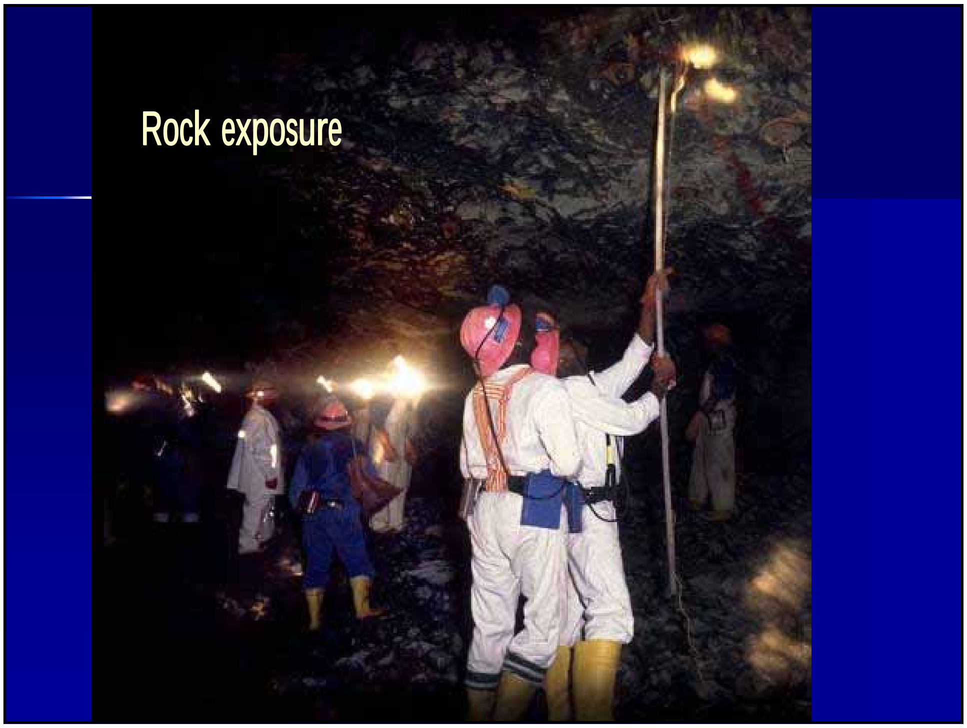

Trends.
CONSTANT REJECT TEMPERATURE WITH INCREASE IN VRT
TEMPERATURE (°C)
MINING DEPTH (m)
Current mining depths
VRT
Increasing difference in VRT & Reject temperature
Average reject Temperature (28°C)
0
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
20
25
30
35
40
45
50
55
60
65
70
74




## Metabolic rates for various activities

| Activity | Metabolic heat production (W) | $M (W/m^2)$ |
|---|---|---|
| Sleeping | 73 | 40 |
| Seated | 107 | 58.5 |
| Standing but relaxed | 128 | 70 |
| **Walking on the level at:** | | |
| 1 m/s | 238 | 130 |
| 1.4 m/s | 320 | 175 |
| 1.8 m/s | 403 | 220 |
| **Manual work** | | |
| Very light | 174 | 95 |
| Light | 265 | 145 |
| Moderate | 448 | 245 |
| Heavy | 622 | 340 |

Reference – McPherson (1992)


Rock exposure

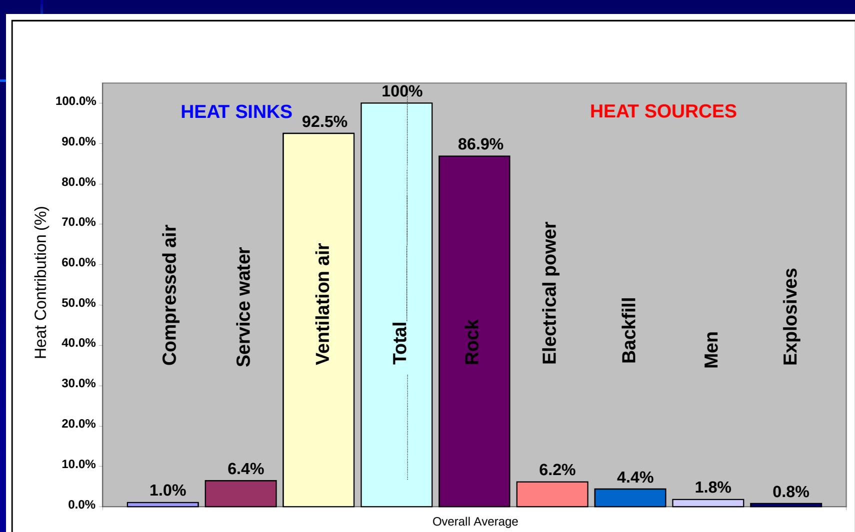

HEAT……………
Rock transport / development sections

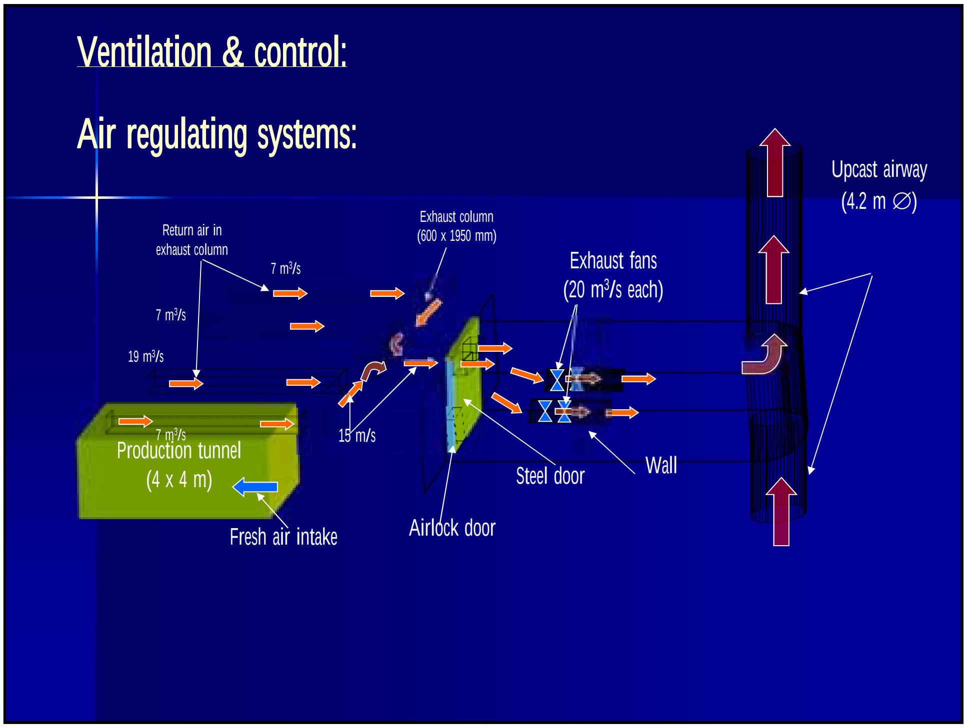
**Fissure water** is encountered generally in all mining operations, i.e. during shaft sinking, lateral development, etc. The temperature difference between the emitting fissure water and that of the ambient surroundings causes an additional heat load. It therefore makes economical sense and good practice to pipe all return water, i.e. fissure and service water, back to settling dams ready for pumping. An example would be where the difference in the discharge fissure water temperature and the arriving dam water temperature is (40 – 29) 11°C. The quantity of fissure water ($M_w$) is say 20 l/s. The heat ingress into the surroundings would be:

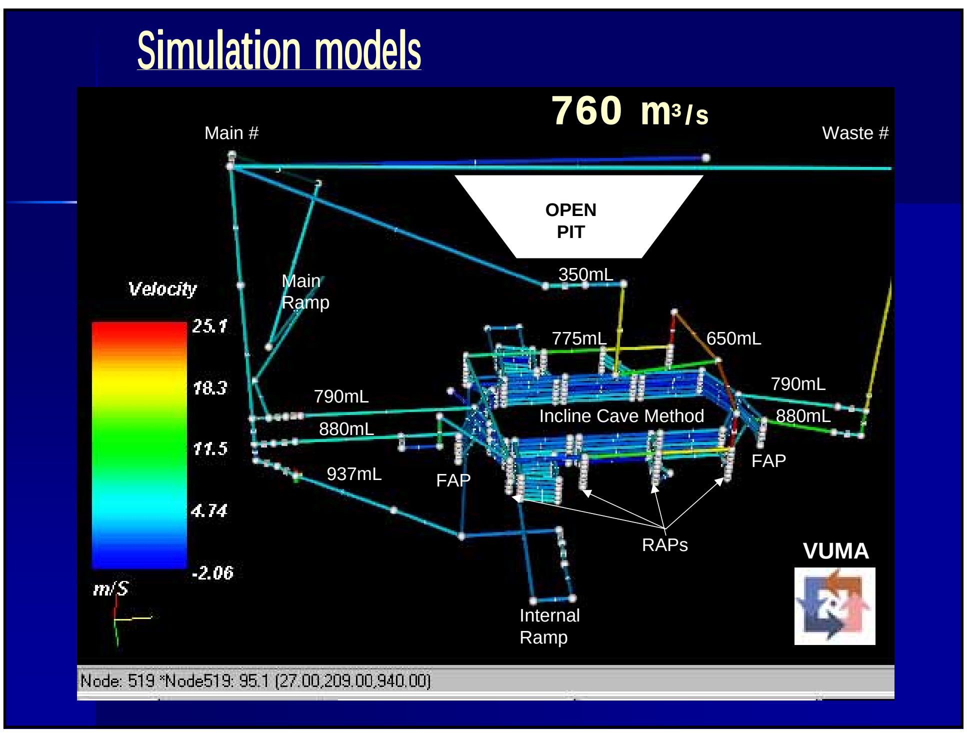
$$\begin{aligned} Q &= M_w C_p \Delta T \\ &= 20 \times 4.187 \times 11 \\ &= 921 kW \end{aligned}$$

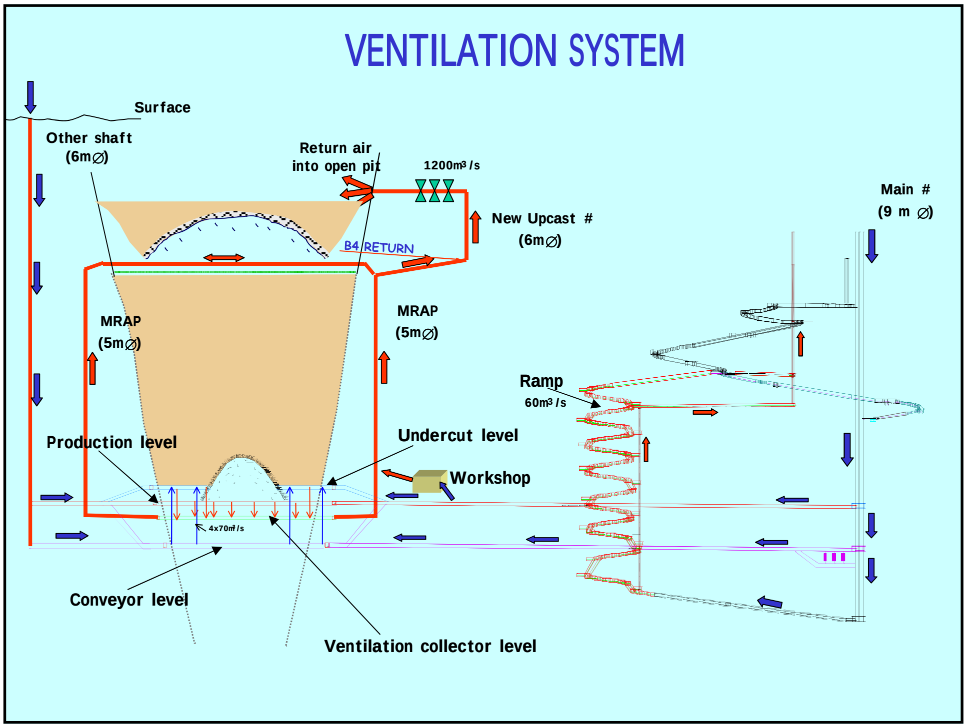
Water has a thermal capacity ($C_p$) of about 4.187 kJ/kg°C at a temperature of about 15°C.

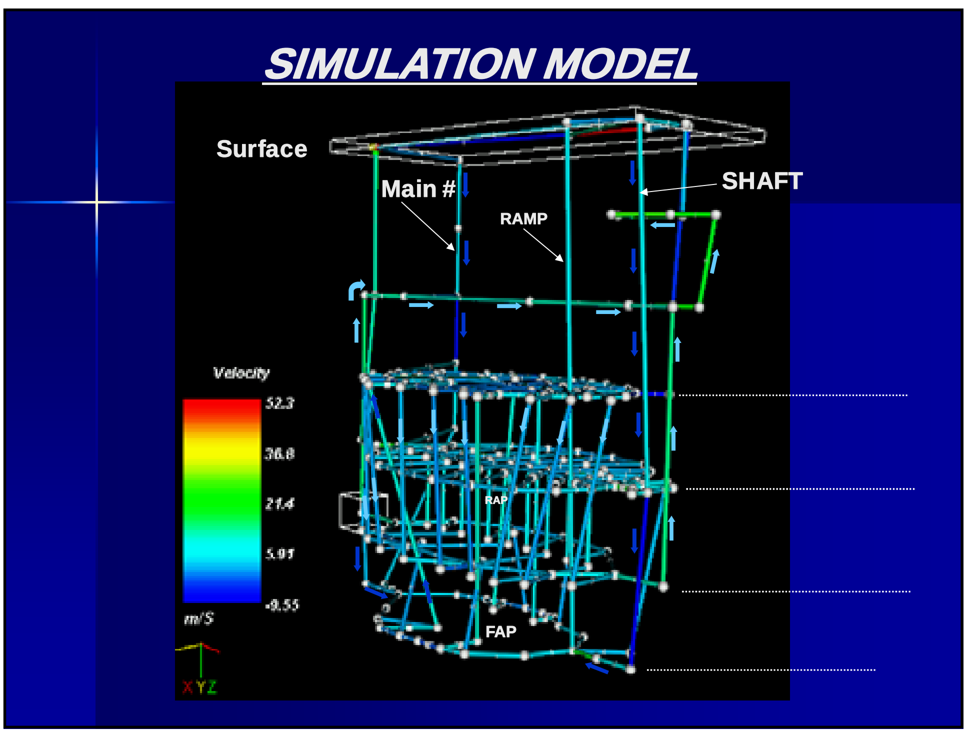
# Heat Sources & Heat Sinks

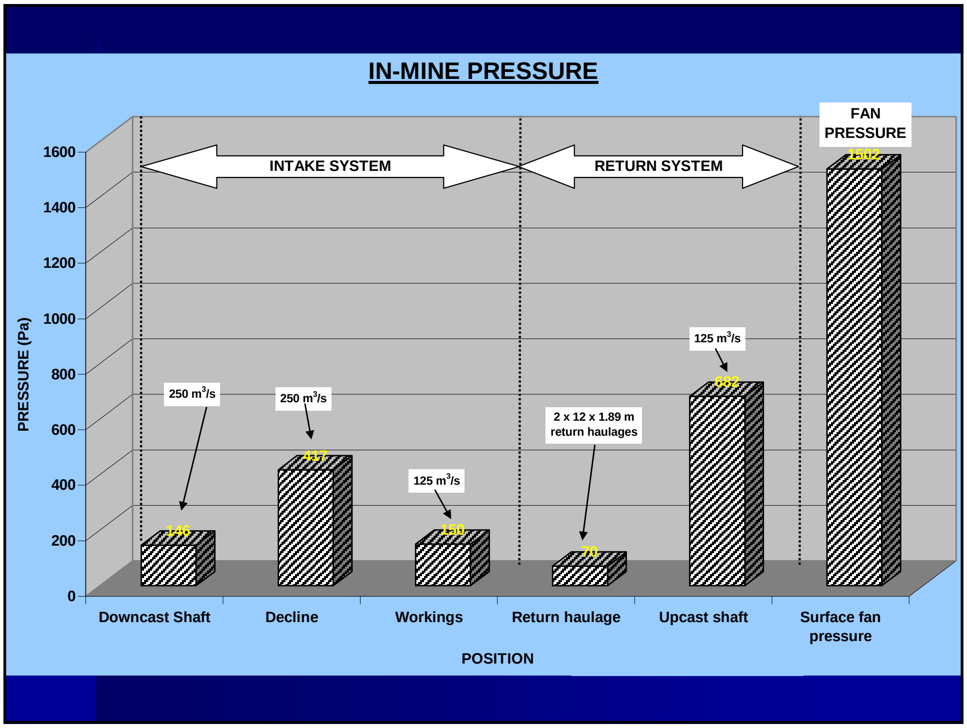


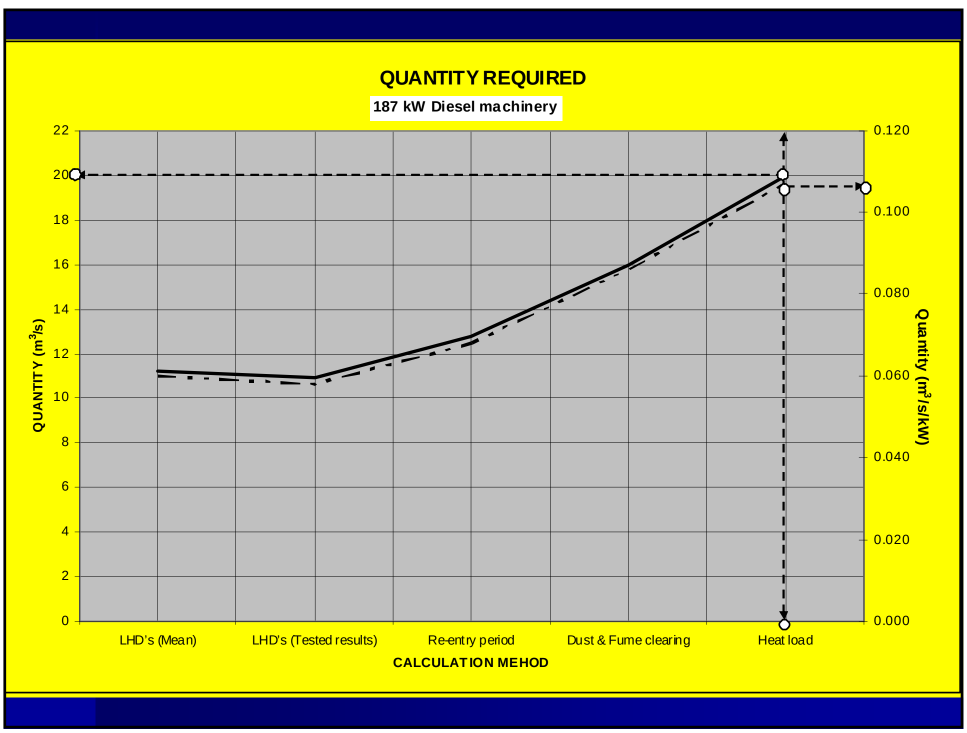

Ventilation & control:
Air regulating systems:
Return air in exhaust column
Exhaust column (600 x 1950 mm)
Exhaust fans (20 m³/s each)
Upcast airway (4.2 m ∅)
7 m³/s
7 m³/s
19 m³/s
7 m³/s
15 m/s
Production tunnel (4 x 4 m)
Fresh air intake
Airlock door
Steel door
Wall

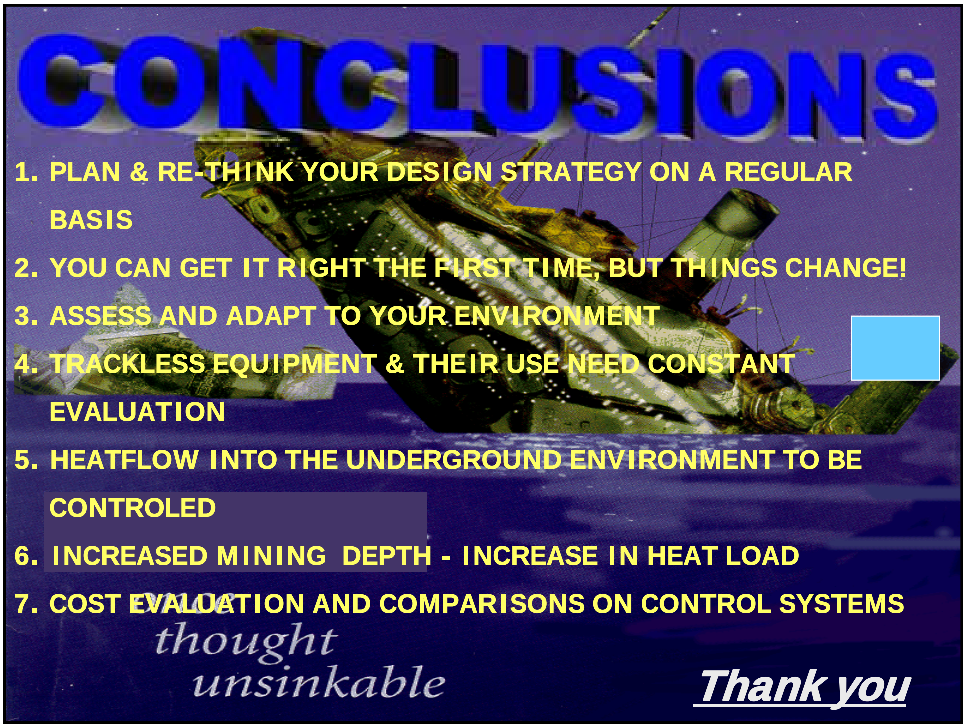

Simulation models
760 m³/s
Main #
Waste #
OPEN PIT
350mL
775mL
650mL
Main Ramp
Velocity
25.1
18.3
11.5
4.74
-2.06
m/S
790mL
880mL
937mL
Incline Cave Method
790mL
880mL
FAP
FAP
RAPs
Internal Ramp
VUMA
Node: 519 *Node519: 95.1 (27.00,209.00,940.00)


VENTILATION SYSTEM
Surface
Other shaft
(6m∅)
Return air
into open pit
1200m³/s
New Upcast #
(6m∅)
Main #
(9 m ∅)
B4 RETURN
MRAP
(5m∅)
MRAP
(5m∅)
Ramp
60m³/s
Production level
Undercut level
Workshop
4x70m³/s
Conveyor level
Ventilation collector level


SIMULATION MODEL
Surface
Main #
SHAFT
RAMP
Velocity
52.3
36.8
21.4
5.91
-9.55
m/S
RAP
FAP
XYZ


IN-MINE PRESSURE
FAN PRESSURE
1502
INTAKE SYSTEM
RETURN SYSTEM
1600
1400
1200
1000
800
600
400
200
0
PRESSURE (Pa)
250 m³/s
146
250 m³/s
417
125 m³/s
150
2 x 12 x 1.89 m return haulages
70
125 m³/s
682
Downcast Shaft
Decline
Workings
Return haulage
Upcast shaft
Surface fan pressure
POSITION


QUANTITY REQUIRED
187 kW Diesel machinery
22
20
18
16
14
12
10
8
6
4
2
0
QUANTITY (m³/s)
0.120
0.100
0.080
0.060
0.040
0.020
0.000
Quantity (m³/s/kW)
LHD's (Mean)
LHD's (Tested results)
Re-entry period
Dust & Fume clearing
Heat load
CALCULATION MEHOD


CONCLUSIONS
1. PLAN & RE-THINK YOUR DESIGN STRATEGY ON A REGULAR BASIS
2. YOU CAN GET IT RIGHT THE FIRST TIME, BUT THINGS CHANGE!
3. ASSESS AND ADAPT TO YOUR ENVIRONMENT
4. TRACKLESS EQUIPMENT & THEIR USE NEED CONSTANT EVALUATION
5. HEATFLOW INTO THE UNDERGROUND ENVIRONMENT TO BE CONTROLED
6. INCREASED MINING DEPTH - INCREASE IN HEAT LOAD
7. COST EVALUATION AND COMPARISONS ON CONTROL SYSTEMS
thought
unsinkable
Thank you