HARD ROCK MINE VENTILATION

REFRIGERATION AND REFRIGERATION STRATEGIES

BY

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MINE REFRIGERATION REQUIRED = MINE HEAT LOAD – COOLING CAPACITY OF THE AIR

MINE HEAT LOAD

- Auto-compression
- Heat from rock surfaces
- Equipment – diesel and electric
- Fissure water and broken rock
- Miscellaneous
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COOLING CAPACITY OF THE AIR = COOLING CAPACITY OF AIR AT DESIGN CONDITION – COOLING CAPACITY OF THE AIR ON SURFACE

DESIGN CONDITIONS

- Wet bulb 32.5°C – Stop work
- Wet bulb 30.5°C – Modified conditions
- Wet bulb 28.0°C – Optimum productivity
Design wet bulb temperatures
CRITICAL DEPTH

- The depth at which the residual cooling power of the air is zero.
- It is mainly a function of surface temperature and depth of workings (auto-compression).
- Heat flow from rock is not normally important at about 10% of the total heat load.
- Equipment heat is usually constant and depends on production rate except for a decline haulage.
- Hot fissure water may be dominant.
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TYPICAL CRITICAL DEPTHS

- Argyle/Ranger 2 – 700 to 800 m
- Mount Isa/Telfer/Granites – 1000 to 1100 m
- Leinster/Wiluna – 1300 to 1400 m
- Kalgoorlie/CSA – 1500 to 1600 m
- Olympic Dam/ Broken Hill – 1800 to 2000 m

This is not necessarily the depth at which refrigeration is required and illustrates the effect of surface conditions and depth.
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ORDER OF MAGNITUDE ESTIMATES

DEPTH – 0.5°C WB increase per 100 m

DECLINE HAULAGE – 450 kW per Mtpa.km (i.e. 5400 kW from 1.5 Mtpa and 1000 m at 1:8)

HEAT/WB CONVERSION – 4.5 kW/m³/s per °C

EQUIPMENT WB’s – No diesels 1.0 to 1.5°C
  - diesels 3.0 to 4.5°C

(thermal flywheel effect and design conditions)
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Vapour compression

Diagram showing the components of a vapour compression system:
- Condenser
- Compressor
- Evaporator
- Expansion valve
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INCREASED CONDENSING TEMPERATURE RESULTS IN INCREASED INPUT POWER

Heat rejection (condensing) on surface depends on the ambient wet bulb temperature and U/G depends on the mine exhaust wet bulb.

Surface wet bulbs are always lower than U/G exhaust wet bulb temperatures and surface plants result in significant power savings.
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WET OR DRY CONDENSING

Wet bulb temperature is always equal to or less than the dry bulb temperature therefore wet condensing has lower power requirement.

Wet condensing does however require water to offset evaporation and a mine in the Tanami, required about **9.0 MI per MWR per summer.**

When operating dry, the shortfall in cooling was **12.5%** and power was **40%** greater.
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LOWER EVAPORATING TEMPERATURES REDUCE THE CAPACITY OF THE COMPRESSOR BUT INCREASE THE AMOUNT OF COOLING THAT CAN BE TRANSFERRED BY THE SECONDARY COOLANT (USUALLY WATER).

\[ \text{Heat transfer} = m c_p \Delta t \]

Limited by freezing point of water.

If return water is 28 °C and supply is 1 °C, each kg (litre)/s of water transfers 113 kW.
ADVANTAGE OF USING ICE – INCREASED CAPACITY OF SECONDARY COOLANT

Latent heat of fusion of ice is 334 kJ/kg i.e. if ice is used as a secondary coolant, the mass of water/ice is only 25% of water alone.

Relevant to deep mines with large refrigeration requirements i.e. ERPM in South Africa.

Plant produces 6000 t of ice per day which provides 31 MWR (Hemp, 1988).
SOME MINING AREAS SUCH AS CANADA HAVE COLD WINTERS AND, WHERE DEEP MINES REQUIRE COOLING IN THE SUMMER, ICE STORAGE SYSTEMS ARE POSSIBLE.

This is not a new concept in that the forming of ice was used as mine air heating process. If cold air is passed through water sprays, the water will be frozen by the coolth taken from the air which as a consequence is heated.

Sometimes known as ice stopes i.e. Creighton
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1.0 m$^3$/s of air over a winter will produce about 650 t of ice by heating air to -4 °C. Mine air heating cost saving is about $4000/m$^3$/s.

Depending on the design intake wet bulb temperature, the cooling of 1.0 m$^3$/s requires between 200 t and 450 t of ice.

Ice storage costs are site specific and, in the glacial till (clay) at Kidd Creek, the cost was approximately $75/t or equivalent to the capital cost of mechanical refrigeration.
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Plan view

- Anchored sheetpile wall
  - Volume = 12 000 m²
- Sump
- Concrete wall
- Walers
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At a similar mine (climate and location), an open pit had a potential ice storage volume of about 500 000 t with an equivalent cooling capacity of just over 30 MWR. The cost was about two thirds that of a conventional plant.

The use of ice for both cooling and heating is still limited to old stopes or caved areas.

Kidd Creek avoided installing a further 6 MWR compressor set by enlarging the cold stope ice storage volume underground.
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INTAKE AIR HEATING OR COOLING

REFRIGERATION PLANT

EXHAUST AIR HEAT RECOVERY
HEAT RECOVERY SYSTEM USING REFRIGERATION PLANT

Additional capital cost of mine refrigeration plant is about $2.5 million.

Annual saving in heating costs less operating power and maintenance of the heat recovery system is about $0.8 million.