Chamber of Mines of South Africa

MEMORANDUM

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – INTERMEDIATE CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 2	**EXAMINER:** F. NADARAJU **MODERATOR:** N. KRUGER
SUBJECT CODE: **COMIMEC**	
EXAMINATION DATE:	**TOTAL MARKS:** 100
TIME: 14:30 – 17:30	**PASS MARK:** 60

NUMBER OF PAGES:

SPECIAL REQUIREMENTS:
THIS IS **NOT** AN OPEN BOOK EXAMINATION. THERE IS **NO** FORMULA HANDOUT

INSTRUCTIONS TO CANDIDATES:

1. Answer all questions **legibly** in English.
2. Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in. **Psychrometric charts at 85 kPa, 115 kPa and 120 kPa are provided**

NB: Your name **must not** appear on any answer book or loose sheets.

3. Show all calculations **and check calculations on which the answers are based.**
4. Hand-held electronic calculators may be used for calculations.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. Answers must be given to an accuracy which is typical of practical conditions.
   NB Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used. (even if the calculated value is correct).
8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

1.1 Define the term Occupational Hygiene in terms of MHSA (29 of 1996). (2)

Means the anticipation, recognition (½), evaluation and control (½) of conditions (hazards) at the mine (½), that may cause illness or adverse health effects (½) to persons.

1.2 Define Natural Acclimatization Underground [NAU]. (2)

Workers that are heat tolerant after Heat Tolerance Screening spend twelve shifts underground in their normal working environment [27.5 to 32.5°C wet-bulb] on day-shift only, not working overtime and on a 60/15 minute work/rest cycle. Drinking water to be freely available and workers must consume approximately 500 ml during the rest cycle.

IMEC Workbook 2, Pg 39

1.3 Define wet-bulb globe temperature [WBGT] and state the formula to calculate WBGT. (2)

An index that takes into account the wet- and dry-bulb temperatures, air velocity, humidity and radiant heat to give an indication of the potential for heat stress in a working area.

$WBGT = 0.7\ T_{wb} + 0.2\ T_g + 0.1\ T_{db}$

IMEC Workbook 2, Pg 79-80

1.4 Define wind-chill equivalent temperature [WCET] and state the formula to calculate WCET. (2)

An index that takes into account the air temperature and air speed to give an indication of the rate of heat exchange between a person and a cold environment.

$WCET = 33 - \{ [(10.45 + 10\sqrt{V} - V) \times (33 - T)] / 22.04 \}$

IMEC Workbook 2, Pg 89,94

1.5 Define the terms Dust and Gas. (2)

Dust – finely divided solid matter generated during the handling, grinding, crushing, rapid impact, blasting, etc. of organic and inorganic substances such as rock, ore , metal, wood, etc. (1)

Gas – formless fluids that expand to fill the space they are in. They can be transformed into a liquid or solid by varying the temperature or pressure. (1)

IMEC Workbook 2, Pg 168

[10]

QUESTION 2

2.1 Give four hazards of over exposure to heat stress and briefly explain each condition. (4)

- Heat stroke (½) – is the most serious heat illness. It must be immediately recognised and treated correctly to minimise permanent damage or death (½)
- Heat exhaustion (½) – is the most common and a result of a decline in the circulating volume of blood as the result of dehydration (½)
- Dehydration (½) – is the loss of water and salts (sweat) during physical activities, which are brought to the skin. Heat is lost when sweat evaporates (½)
- Body / muscle cramps (½) – are spontaneous, involuntary painful, and prolonged muscle contraction (½)
- Heat rash (½) – occurs when working in hot environments with continuous perspiration on the skin. The pores become clogged resulting in infection (½)
- Heat syncope (½) – temporary loss of consciousness caused by a drop in blood pressure (½)

Any four, IMEC Workbook 2, Pg 74-75

2.2 Heat flow from rock is a major source of heat in mines. How would you go about minimising the heat-flow from rock into the workings (5)

- Keep downcast shafts dry – seal off water fissures, maintain shaft water columns, ensure skips are sealed, minimise water usage at the station, drainage rings in shaft (1)
- Shaft stations, intake airways and cross-cuts to be kept dry as possible (1)
- Cover drains in haulages and cross-cuts to prevent evaporation and maintain drains to prevent overflowing. (1)
- Minimise water wastage through standards/procedures for dust suppression [watering down] (1).
- Maintain water pipes and minimise leakage of water from pipes (1).

IMEC Workbook 2, Pg 36

2.3 Heat stress can impact on the health of workers, reduce productivity and increase accident rates. State ways in which heat stress can be controlled (4)

- Engineering controls – reduce air temperature [dilute with ventilation, cooling], reduce humidity [cooling via refrigeration], increased air velocity [improve evaporative/convective cooling of body]. (1)
- Administrative controls –sharing of work, work schedules. (1)
- Training – introduction to heat stress, recognition and treatment of heat related disorders, heat stress hygiene practices, heat stress policy and guidelines. (1)
- Heat stress hygiene practices – fluid replacement, work pacing, health status, acclimatization
- Medical surveillance – work and medical history, physical examination, assessment to use of medication/drugs. (1)

Any four– IMEC Workbook 2, Pg 76

2.4 List four reasons or objectives for sampling airborne pollutants. (4)

- To detect any working place / areas with unhealthy conditions (1).
- To determine the cause of air contamination by airborne pollutants (1).
- To indicate the necessary control measures (1).
- To determine the effectiveness of suppression methods (1).
- To confirm that satisfactory conditions have been obtained (1).
- To comply with legislation (1).
- To supply records for medical surveillance (1).
- For various research purposes (1).

IMEC Workbook 2, Pg 172-173

Any four

2.5 A risk assessment of an underground pump station has identified noise as one of the hazards. What hierarchy of controls would you use to limit the workers' exposure to noise? Give an example of each control measure. (3)

- Engineering controls (½) – maintenance, replace machines, reduction of vibrating surfaces, sound barriers, absorptive materials (½)
- Administrative controls (½) – Change work schedules, machine operating times, transfer workers from high noise areas to low noise areas (½)
- PPE (½) – suitable haring protection devices [ear plugs] (½)

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QUESTION 3

3.1 Give three reasons for sampling mine water. (3)

- To determine the amount of total dust present in the water [Workbook states "silica dust"]
- Bacteriological analysis
- Chemical analysis for dissolved and suspended solids, toxic metallic and chemical compounds
- To determine the pH value of the water
- To determine the amount of free chlorine in water
- For radioactive analysis
- For legal compliance

Any three, IMEC Workbook 2, Pg 195

3.2 Name and describe three routes of entry of toxic substances into the human body. (3)

- Inhalation (½) – The respiratory route is the most common and probably the most important route of absorption in the workplace, because the worker inhales the air for the duration of his entire shift. (½)
- Ingestion (swallowing) (½) – This route of entry is mostly the result of accidental swallowing a hazardous substance and being regarded as being of minor importance. (½)
- Skin absorption (½) – Some hazardous substances, upon contact with the skin, are absorbed into the skin or bloodstream and transported to other parts of the body (½)

IMEC Workbook 2, Pg 266-277

3.3 Silica and coal dust are generally classified according to the particle size. Define "inhalable" and "respirable" dust and the potential health risk of each type of dust on workers. (4)

- Inhalable dust – particles smaller than 50 microns but larger than 7 microns that precipitate on the mucous membranes nose, throat and windpipe. (1) Lower risk compared to respirable dust since the body will "flush" it out by the fine hairs of the nose; coughed up when collected in the windpipe or excreted by the body if swallowed. (1)
- Respirable dust – particles smaller than 7 micron that penetrate into the deepest sections of the lungs and end up in the alveoli. (1) Prolonged exposure can lead to pneumoconiosis [thickening and hardening of the tissues] resulting in shortness of breath, decreased chest expansion, lessened capacity for physical work and increased susceptibility to tuberculosis (1)

IMEC Workbook 2, Pg 171, 267

3.4 Supply the required properties and hazards of the following gases: Record the answers in your book from item (a) to (l). (10), 1 each; Table with letters will be provided

Gas	Sources of gas	Dangers	Explosive range	Occupational Exposure limit (OEL)
Ammonia		(1) Arrested breathing results in oedema [flooding of lungs]		
Carbon monoxide	(2) Incomplete combustion, blasting, fires, diesel equipment			(3) 30 ppm or 0.0003%
Carbon dioxide		(4) Oxygen deficiency [simple asphyxia]		
Hydrogen		(5) Highly explosive	(6) 4 to 74%	
Methane	(7) Decay of organic and vegetable matter		(8) 5 to 15%	
Nitrous fumes	(9) Blasting fumes and diesel exhaust			(10) 3 ppm or 0.00003%

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QUESTION 4

4.1 What is the depth at which the virgin rock temperature is 38.6°C? The thermal gradient is 0.023°C per metre and the surface rock temperature is 23.7°C. (2)

IMEC Workbook 2, Pg 49;

VRT = surface rock temp + depth x temp gradient = 38.6 = 23.7 + 0.023 x depth

Depth = [38.6 – 23.7] / 0.023 = 647.83 m, say 648 m

4.2 At a deep-level mine, ice is produced on surface and sent to an ice-melting dam underground. The cooling capacity of the ice when it melts and supplies chilled water at 5.3°C is 10.0 MW. What quantity of ice is produced on surface? Ignore the effects of autocompression and the heat loss through the shaft pipes. (2)

Combined sensible and latent heat – IMEC Workbook 2, Pg 58

Cooling capacity = m x Lf + mCpΔT = m x [335 + 4.187 x 4.8] = 10 000 kW [10 MW]

Therefore, m = 10 000 / [335 + 4.187 x 4.8] = 28 kg/s

4.3 At a mine the underground cooling required is 15 000 kW; chilled water will be produced on surface and sent to underground bulk air coolers and cooling cars.

4.3.1 Calculate the outlet water temperature if the total chilled water flow sent underground is 245 l/s and the temperature of the water entering the underground coolers is 8.4°C. (2)

Duty = mCpΔT = 245 x 4.187 (T – 8.4) = 15 000 kW; T= 23.02°C

IMEC Workbook 2, Pg 53

4.3.2 If the chilled water on surface is 5.0°C, at what depth will the underground coolers be installed? Ignore the heat loss through the shaft pipes. (2)

Heat increase due to Joule-Thomson effect = Loss in potential energy

m Cp ΔT = m g h

h = Cp ΔT / g = 4187 x (8.4 – 5) / 9.81 = 1 451.2 m

Environmental Engineering in South African Mines (1982), Pg 596 (Black book)

Ventilation and Occupational Environment Engineering in Mines (2014), Pg 507 (Blue book)

4.4 Water at a flow of 75 l/s enters a bulk air cooler at 6.1°C and leaves at 16.2°C. What is the cooling duty of the air cooler? (2)

Duty = mCpΔT = 75 x 4.187 (16.2 – 6.1) = 3171.7 kW

IMEC Workbook 2, Pg 53

4.5 The air velocity downstream of a surface bulk air cooler was measured at 18 km/hour at a temperature of 5.0 / 6.5 °C. Calculate the Wind chill equivalent temperature (WCET). (3)

WCET = 33 – {(10.45 + 10√V – V) x (33-T)} / 22.04

Note: T = dry bulb V = 18 x 1000 / 3600 = 5.0 m/s (1)

Thus = 33 – {(10.45 + 10√5 – 5) x (33 – 6.5)} / 22.04 (1)

= 33 – {(27.81 x 26.5)} / 22.04

= –0.44°C (1)

IMEC Workbook 2, Pg 94

4.6 A worker in an open pit is exposed to a temperature of 27.8 / 35.1°C and a globe temperature of 31.6 °C. Calculate the WBGT index. (2)

WBGT = 0.7 Twb + 0.2 Tg + 0.1 Tdb

= (0.7 x 27.8) + (0.2 x 31.6) + (0.1 x 35.1) (1)

= 19.46 + 6.32 + 3.51

= 29.29°C (1)

IMEC Workbook 2, Pg 80

4.7 The wet kata reading in a stope is 7.3 and the temperature of the air flowing across the stope face is 31.5 / 32.5°C, what is the air velocity? (2)

$H = 0.7\theta + \theta\sqrt{v}$

$v = \{(H - 0.7\theta) / \theta\}^2$

$= \{(7.3 - 0.7 \times 5.0) / 5.0\}^2$

= 0.58 m/s

$\theta = 36.5 - WB$

= 36.5 – 31.5

= 5.0

IMEC Workbook 2, Pg 49

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QUESTION 5

5.1 150 m^3/s of air enters an underground condenser cooling tower [CCT] at 28.0 / 30.0°C [barometric pressure 120 kPa] and is designed to reject 9 500 kW of condenser heat. The air leaves the top of the tower on a level where the barometric pressure is 115 kPa. The condenser water flow is 300 l/s and leaves the condenser at 42.0°C. Calculate the following:

5.1.1 The temperature of the air leaving the CCT (4)

Psychrometric properties of inlet air: 28/30°C 120 kPa

ASH = 19.46 g/kg

ASV = 0.747 m3/kg

Sigma heat in = 77.61 kJ/kg (1)

Mass flow of air through CCT = Q / ASV = 150 / 0.747 = 200.67 kg/s (1)

Sigma heat out = Sigma heat in + CCT duty / mass flow = 77.61 + 9500 / 200.67 = 124.95 kJ/kg (1)

Assume saturated conditions leaving CCT, RH = 100%

From Psychrometric chart at 115 kPa, Air temp out = 37.1°C wb/db (1)

5.1.2 The air quantity leaving the CCT. (2)

Mass flow of air through CCT = 200.67 kg/s [remains constant]

ASV = 0.819 m3/kg [at Twb = 37.1°C and RH = 100%] (1)

Air flow = Mass flow x ASV = 200.67 x 0.819 = 164.4 m^3/s (1)

5.1.3 The amount of water evaporated or condensed in litres per day (3)

Evaporation takes place in a CCT [temperature increases from 28/30°C to 37.1/37.1°C] (1)

Moisture content of air in = 19.46 g/kg [ASH]

Moisture content of air out = 36.32 g/kg

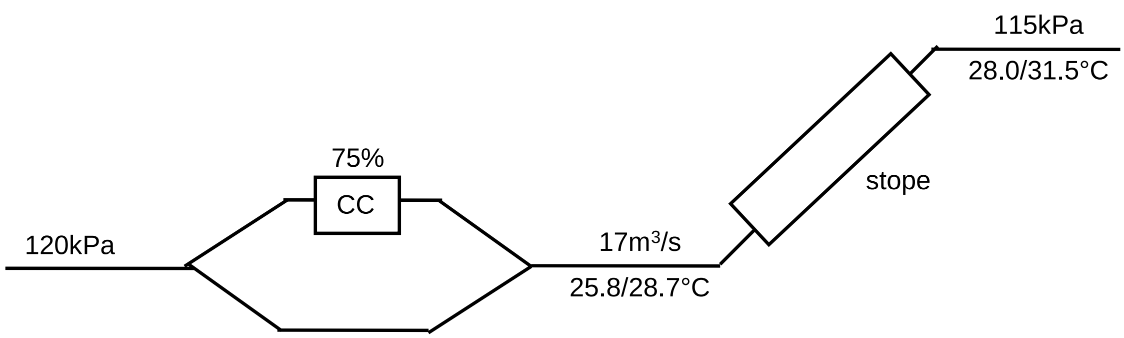
Water evaporated = Mass flow x [ASH out – ASH in] = 200.67 x [36.32 – 19.46] = 3.4 l/s (1)

Water evaporated in litres per day = 3.4 x 60 x 60 x 24 = 292 317 l/day (1)

5.1.4 The water temperature leaving the CCT. (2)

Water temp out = CCT duty / water flow / Cp + Water temp in = 42 – 9500/4.187/300 = 34.44°C

5.2 17 m^3/s of air enters a stope at a temperature of 25.8/28.7°C on a level where the barometric pressure is 120 kPa and exits the stope on a level where the barometric pressure is 115 kPa. A cooling car is installed upstream of the stope and cools 75% of the air that enters the stope. A sketch is provided below.



5.2.1 Calculate the heat added to the air if the temperature of the air leaving the stope is 28.0/31.5°C. Ignore the effects of autocompression. (6)

	Air entering stope (1½)	Air leaving stope (1½)

Barometric pressure	120 kPa	115 kPa
Temperature	25.8/28.7°C	28.0/31.5°C
Sigma heat	69.32 kJ/kg	79.83 kJ/kg
ASV	0.741 m^3/kg	0.784 m^3/kg

Mass flow of air = Q / ASV = 17 / 0.741 = 22.94 kg/s (1)

Heat added = Mass flow x (S out – S in) = 22.94 x (79.83 – 69.32) = 241.2 kW (2)

5.2.2 Calculate the air temperature leaving the cooling car if the air temperature upstream of the cooler is 27.3/29.4°C. (4)

	Air onto cooler	Air entering stope (1½)
Barometric pressure	120 kPa	120 kPa
Temperature	27.3/29.4 °C	25.8/28.7°C
Sigma heat	74.89 kJ/kg	69.32 kJ/kg

75% cooled: 22.94 x 0.75 = 16.06 kg/s; uncooled = 22.94 – 16.06 = 6.88 kg/s (½)

Air mixing calculation: air leaving cooling car + uncooled air = air entering stope

Sigma H (cc) = [mass flow (stope) x sigma H (stope) – mass flow (uncool) x sigma H (uncool)] / mass flow (cc)

= [22.94 x 69.32 – 6.88 x 74.89] / 16.06 = 66.93 kJ/kg (1)

RH = 100% - saturated air leaving cooling car, from Psychrometric 120 kPa chart,

Temperature leaving cooling car = 25.1 / 25.1 °C wet-bulb/dry-bulb (1)

5.2.3 Calculate the cooling car duty. (2)

Duty = massflow x [sigma in – sigma out] = 16.06 x [74.89 – 66.93] = 127.8 kW

5.2.4 6.0 l/s of chilled water at 7.0°C is supplied to the cooling car. Calculate the temperature of the water leaving the cooling car. (2)

Duty = m Cp ΔT = 6 x 4.187 x (Tout – 7) = 127.8; Tout = 12.08°C

5.3 A surface bulk air cooler (design duty of 7.5 MW) cools 300 m^3/s of ambient air at 18.0/30.0°C before being sent down the main shaft. The barometric pressure is 85 kPa.

5.3.1 What is the temperature of the air leaving the bulk air cooler? (4)

	Ambient air	Air leaving stope (1½)

Barometric pressure	85 kPa	85 kPa
Temperature	18/30°C	9.0/9.0°C
Sigma heat	56.31 kJ/kg	30.29 kJ/kg
ASV	1.041 m^3/kg	0.966 m^3/kg
ASH	10.55 g/kg	8.56 g/kg
Relative humidity	33.3%	100%

Mass flow of air = Q / ASV = 300 / 1.041 = 288.24 kg/s (½)

Duty = massflow x [sigma in – sigma out] = 288.24 x [56.31 – Sout] = 7500 kW

Sout = 56.31 – 7500 / 288.24 = 30.29 kJ/kg (1)

Air out = 9.0/9.0 °C [RH = 100%, sigma heat = 30.29 kJ/kg] (1)

5.3.2 Will condensation or evaporation take place in the bulk air cooler? Confirm this with a calculation. (2)

Condensation; water condensed = mass flow x [ASH in – ASH out]
= 288.24 x [10.55 – 8.56] = 0.574 kg/s

5.3.3 If the temperature of the chilled water supplied to the bulk air cooler is 5.1°C and the warm water leaves at 11.1°C, what is the water flow leaving the bulk air cooler? (2)

Duty = m Cp ΔT = m x 4.187 x (11.1 – 5.1) = 7500 kW; m = 298.54 kg/s

Water leaving BAC = 298.54 + 0.574 = 299.12 kg/s

[33]

TOTAL MARKS: [100]