Minerals Council South Africa

EXAMINATION MEMORANDUM

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – INTERMEDIATE CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 2	**EXAMINER:** JJ PIENAAR
SUBJECT CODE: COMIMEC2	**MODERATOR:** N. KRUGER
EXAMINATION DATE: 13 MAY 2019	**TOTAL MARKS:** 100
TIME: 14:30 – 17:30	**PASS MARK:** 60

NUMBER OF PAGES: 12

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

INSTRUCTIONS TO CANDIDATES:

1. Answer all questions **legibly** in English.

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 87.5 kPa and 115.0 kPa, are provided for Question 3.**

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

2. Show all calculations **and check calculations on which the answers are based.**
3. Hand-held electronic calculators may be used for calculations.
4. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
5. Illustrate your answers by means of sketches or diagrams wherever possible.
6. 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).
7. In answering the questions, full advantage should be taken of your practical experience as well as data given.
8. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
9. Cell phones are **NOT** allowed in the examination room.

QUESTION 1 **(Definitions)**

1.1. Define Wet Bulb Globe Temperature Index. (2)

It is an index that combines the influence of air temperature (wet and dry bulb) (½), radiant heat (globe temperature) (½), humidity and air velocity into a single reading (½) which is a measure of the safety and comfort level that the environment provides. (½)

1.2. Define the term Wind Chill Equivalent Temperature. (2)

In the environment of a working area two climatic factors influence the rate of heat exchange between a person and the environment (½), namely air temperature (°C) (½) and air speed (m/s) (½). The combined effect causes a condition called wind chill (½). To account for both factors (temp & vel), the wind chill equivalent temperature (WCET) was developed, also known as wind chill index / factor.

1.3. Define the term Heat Stress. (2)

Heat stress can be defined as environment measurements of air temperature (½), airflow rate (½), the level of radiant heat exchange (where applicable) and the evaluation of a person's metabolic heat production rate (½) from exercise and/or work. Excessive heat affects the health of workers (½), his productivity and decrease production rates.

1.4. Define the term Thermal Capacity. (2)

Is the amount of heat required (½) to raise or lower the temperature of a substance (½) having a mass of one kilogram by one degree Celsius (½), expressed in kJ/kg°C. (½)

1.5. Define Psychrometry. (1)

Psychrometry is the Science that studies the physical properties (½) of an air- water vapour mixture. (½)

1.6. Define and give the formula of Boyle`s Law. (3)

This law states, that at a constant temperature (½), the volume of a given mass of a gas (½) is inversely proportional (½) to the absolute pressure exerted on it (½).

$P1V1 = P2V2$ (at constant temperature) (½)

P = Absolute pressure (kPa) V = Volume (m^3, m^3/s, m^3/kg) (½)

1.7. Define "Exposure" as per toxicology Principles. (3)

Is the potential contact (½) at a worker's exchange boundaries (½) with chemical (½), physical (½) or biological (½) pollutants whilst at the workplace. (½)

1.8. Define the term "Fibre". (2)

A fibre is any particle having parallel sides (½) of which the length to diameter ratio is more than three to one (½), which is more than 5 micrometers long (½) and which has a diameter of less than 3 micrometers. (½)

1.9. Define Natural Acclimatization Underground (NAU). (2)

Workers that are heat tolerant after Heat Tolerance Screening (½) spend twelve shifts underground in their normal working environment (27.5 to 32.5°C wet-bulb) on day-shift only (½), not working overtime and on a 60/15 minute work/rest cycle (½). Drinking water to be freely available and workers must consume approximately 500 ml during the rest cycle. (½)

1.10. Define Heat intolerant employees. (1)

Heat intolerant employees are those individuals whose oral temperature are in excess of 37.6°C (½) and should not be allowed to work in areas conducive to heat illness (27.5°C and above) (½)

Total Marks: (20)

QUESTION 2 **(Theory)**

2.1. Supply the required properties and hazards of the following gases: Record the answers in your answer sheet from item (1) to (10). (10)

Answer:

Gas	Sources of gas	Dangers	Explosive range	Occupational Exposure limit (OEL)
Hydrogen		(1) Highly explosive	(2) (4%- 74%)	
Ammonia	(3) Blasting Excessive liming of settlers Refrigerants			(4) 25ppm
Carbon monoxide	(5) Incomplete combustion Fires, Blasting and Diesel equipment		(6) Yes 12.5% – 74.2%	
Carbon dioxide		(7) Oxygen deficiency - Asphyxia		
Methane			(8) Yes 5.0% – 15.0%	
Hydrogen Cyanide	(9) Cyanide process in gold recovery. Back-filling. Burning plastics.	(10) Poisonous. Explosive (5.6 - 40%). Can be absorbed through the skin		

2.2. State the Thermal Capacity of water including the SI Unit. (1)

4.187kJ/kg°C (1)

2.3. State the Thermal Capacity of ice including the SI Unit. (1)

2.094kJ/kg°C (1)

2.4. List the six major sources of heat in underground mines. (3)

Heat flow from rock (½)
Auto-compression of air (½)
Heat from machinery (½)
Men / employees (½)
Oxidation of timber / materials (½)
Explosives (½)

2.5. State six control measures before exposure to cold stress conditions. (6)

Any Six of the following:

a) Supply protective / insulating dry clothing. Otherwise wear several layers of clothing if the air temperature is below 4.0°C. In this way air, which is the weakest conductor of heat, will be trapped between the layers, ensuring better insulation. (1)

b) Protection of a person's head is of utmost importance. (1)
c) Clothing worn, must allow the evaporation of perspiration. (1)
d) Shoes with foam rubber soles must be avoided as they absorb moisture and could freeze to the floor. (1)
e) If protective clothing must be worn, ensure that circulation is not restricted. (1)
f) Use gloves when metal tools are used or alternatively use tools with wooden handles, when possible. (1)
g) No less than two persons should work together in a cold area. (Buddy - buddy system). (1)

2.6. List and describe the three types of defective vision. (6)

a) Long-sightedness (Hyperopia/Farsightedness): (1)
Is difficulty seeing objects which are nearby. (1)

b) Near-sightedness (Myopia/Short-sightedness): (1)
Is an error of visual focusing that makes distant objects appear blurred. (I.e. this type of eye can see nearby objects very clearly, but objects at a distance are unclear. (1)

c) Presbyopia: (1)
Is an age associated progressive loss of the focusing power of the lens caused by loss of elasticity of the eye lens, occurring especially in middle and old age people - the process of adjusting to near-vision becomes extremely difficult. (1)

2.7. List and describe the four types of noise. (8)

a) Continuous noise: - is a noise whose intensity remains constant for a considerable period of time, for example permanent fan installations, electric motors, pumps, refrigeration plants, compressors etc. (2)

b) Fluctuating noise:- is a noise whose intensity varies considerably over a given period of time, for example a diesel locomotive transporting ore, a LHD busy loading ore, or any engine running at different speeds, depending on its load it has to carry. (2)

c) Interrupted noise: - is a noise that produces great variations in sound intensity from a given background noise that is interrupted at intervals, for example the switching on and off of equipment. (2)

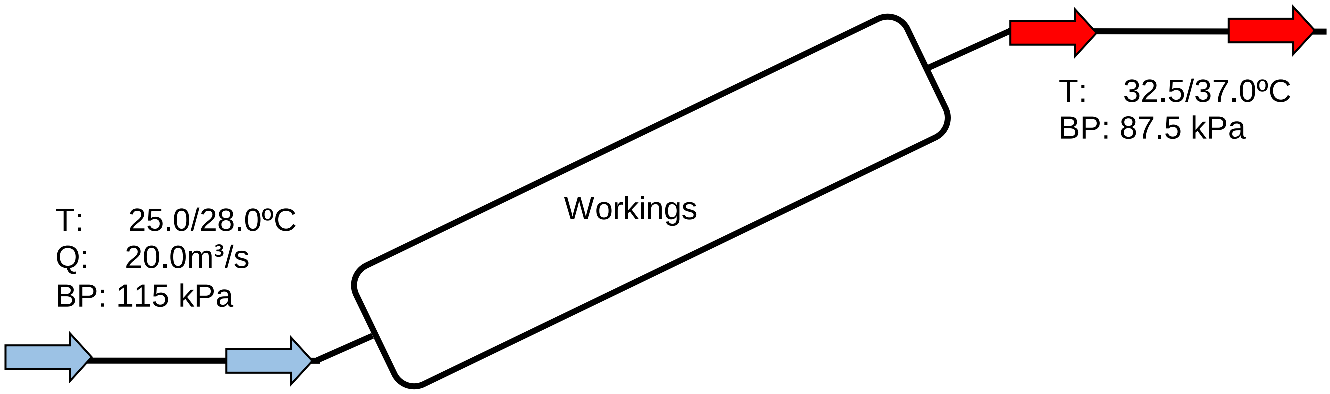
d) Impulse noise:- is a momentary noise having a duration of less than 0,5 seconds, for example a hammer blow, an explosion, a single loud explosive sound like a rifle or canon shot, etc. (2)

Total Marks: (35)

QUESTION 3 **(Psychrometry)**

NOTE! - Ensure that the correct units of measure (SI unit) are recorded as answers will be marked wrong if the incorrect unit is used, even if the value calculated is correct.

3.1 The sketch below represents an underground working section.



a) By using psychrometric charts determine how much heat is produced in the workings. Ignore the effects of auto-compression. (3)

b) If in-stope cooling of 500 kW is installed in the workings, determine what will be the expected wet-bulb and dry-bulb temperatures in the return airway. Assume the Relative Humidity in the return airway increased to 80%. (3)

c) State if the cooling will be adequate to reduce the temperature to below 28.5°C wet bulb. (2)

a) Sigma Heat of return air from Workings = 121.8 kJ/kg (87.5 kPa chart at 32.5 / 37.0)
Sigma Heat of intake air to Workings = 68.1 kJ/kg (115 kPa chart at 25.0 / 28.0)

Sigma Heat from workings = ΣH return air – ΣH intake air
= 121.8 – 68.1
= 53.7 kJ/kg (1)

Thus Heat from workings = Massflow x Δ Σ Heat
= 25.9 x 53.7
= 1 391.0 kW (1)

Massflow = (20 / 0.771)
= 25.9 kg/s (1)

b) New heat from workings = Total heat – Cooling
= 1 391 – 500
= 891 kW (1)

Δ Σ Heat = New Heat / Massflow
= 891 / 25.9
= 34.4 kJ/kg (1)

New Return Σ H = Intake ΣH + ΔΣH
= 68.1 + 34.4
= 102.5 kJ/kg (1)

Thus new temperature = 29.2 / 32.0ºC (from 87.5 kPa chart at 102.5 kJ/kg and 80% RH)

c) No, the wet bulb temperature is still above 28.5 °C (29.2°C wb). (1)
Heat Tolerance Screening can only be stopped if all workings and other areas are consistently below 27.5°C wet bulb and approved by the DMR. (1)

3.2. A Bulk Air Cooler (BAC) was installed in the main intake to an underground section. An air volume of 100 m^3/s enters the BAC at 27.5 / 33.0 °C. The barometric pressure is 115 kPa and the total heat removed from the air is 3 200 kW. The water flow rate through the BAC is 90 l/s and the temperature of the water entering the BAC is 10 °C.

Calculate the following:

a) The temperature of the air leaving the BAC (state assumptions). (4)
b) The air quantity leaving the BAC. (2)
c) Has water evaporated or condensed. (1)
d) How much water has evaporated or condensed in litres per 24 hour day. (3)
e) The temperature of the water leaving the cooler (state assumptions). (2)

a) Mass-flow of air through the BAC

M = Q / ASV — Q = 100 m^3/s
= 100 / 0.786 — ASV = 0.786 m^3/kg (115kPa at 27.5 / 33.0°C)
= 127.2 kg/s (1)

But total heat = Mass-flow x Delta Sigma Heat
TH = M x ΔΣH
…ΔΣH = TH / M — TH = 3 200 kW
= 3 200 / 127.2
= 25.2 kJ / kg (1)
…ΣH removed from the air = 25.2 kJ/kg

Sigma Heat of air entering BAC = 77.6 kJ/kg (115 kPa chart at 27.5 / 33.0)
…ΣH of air leaving = 77.6 – 25.2
= 52.4 kJ/kg (1)

Assume that the air leaving the BAC is saturated.
On 115 kPa chart and ΣH of 52.4 kJ/kg, read off the wet-bulb temp.
Thus, Temp of air leaving BAC = 20.2 / 20.2 °C (saturated). (1)

b) Mass-flow of air entering = 127.2 kg/s
But mass-flow remains constant and mass-flow of air leaving cooler = 127.2 kg/s.
ASV of air leaving BAC at 20.2 °C saturated from 115 kPa chart = 0.748 m^3/kg (1)
Now M = Q / ASV
…Q = M x ASV
= 127.2 x 0.748
= 95.1 m^3/s
Qty leaving the BAC = 95.1 m^3/s (Note the qty has decreased) (1)

c) Water has condensed out of the air, because the air temperature has decreased from 27.5 / 33.0°C to 20.2 / 20.2°C. (1)

d) Moisture content of air intake the BAC = 18.2 g/kg (115kPa at 27.5 / 33.0 °C)
Moisture content of air out of the BAC = 13.1 g/kg (115 kPa at 20.2 / 20.2 °C)
Thus Delta Moisture Content = MC in – MC out
ΔMC = 18.2 – 13.1
= 5.1 g/kg (1)

…The amount of water condensed = M x ΔMC / 1000
= 127.2 x 5.1 / 1000 Massflow = 127.2 kg/s
= 0.65 l/s (1)

Amount of water condensed in litres per day.
= 0.65 x 60 x 60 x 24
= 56 049 l/day (1)

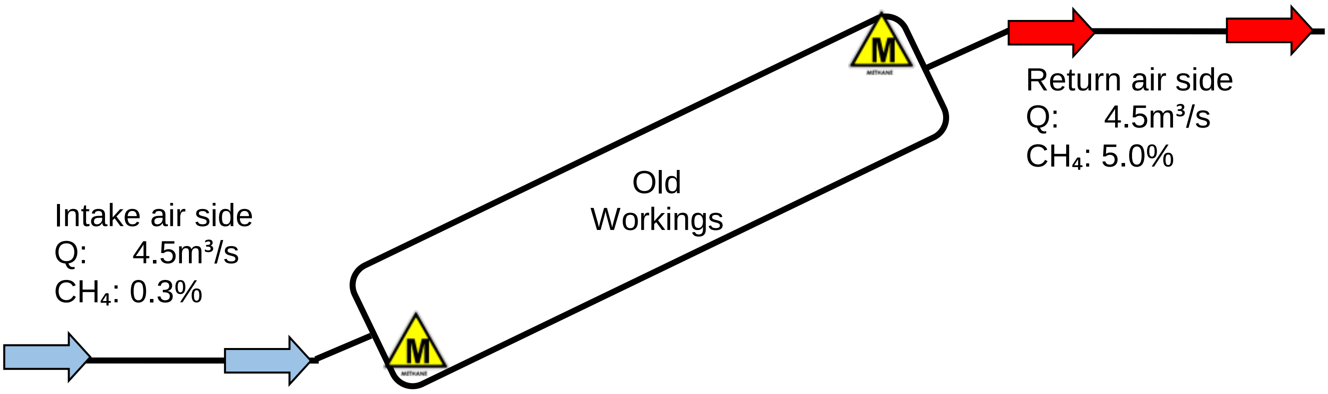
e) Heat removed from the air = 3 200 kW = Heat added to the water (Assumed)
q = M x Cp x ΔT Cp = 4.187 KJ/kg °C
…ΔT = q / (M x Cp) q = 3 200 kW
= 3 200 / (90 x 4.187) M = 90 l/s
= 8.5 °C (1)

Thus Temp of water leaving the BAC = Water Temp in + Delta Temp
Tout = 10.0 + 8.5 Water in = 10 °C
= 18.5 °C (1)

Total Marks: (20)

QUESTION 4 **(General Calculations)**

4.1 An air volume of 4.5m³/s is returning from old workings and contains 5% flammable gas (CH4) and the intake air contains 0.3% flammable gas (CH4). What must the intake air volume be changed to, to ensure that the flammable gas (CH4) on the return side of the old workings do not exceed the legal limit of 1.4%? (See sketch). (4)



4.1 (Q1 x G1) + (Q2 x G2) = (Q1+Q2) G3 (1)

(Q1 x 0.3) + (4.5 x 5) = (Q1 + 4.5) x 1.4 (1)

0.3 Q1 + 22.5 = 1.4 Q1 + 6.3 (1)

22.5 – 6.3 = 1.4Q1 – 0.3Q1

Q1 = 14.7 m³/s (1)

New intake Q = 14.7 m³/s

4.2. A quantity of 585 m³/s enters a downcast shaft of a mine at a barometric pressure of 88.2kPa and a temperature of 20.0/27.5°C. At the bottom of the shaft the barometric pressure is 115.8kPa and the temperature is 25.3/36.2°C. Assuming no leakage, calculate the quantity at the bottom of the shaft. (4)

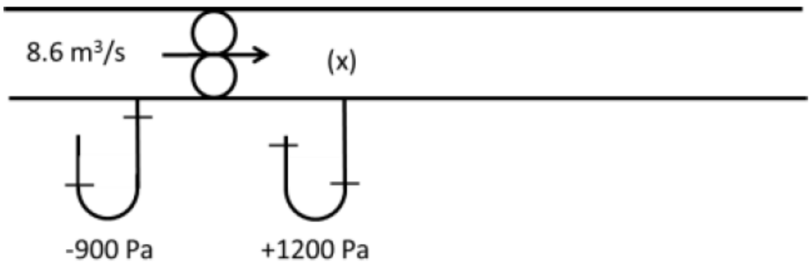
4.2 $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$ (1)

Thus: $$V2 = \frac{P_1V_1T_2}{T_1P_2}$$ (2)

$$= \frac{88.2x585x(273+36.2)}{115.5x(273+27.5)}$$

= 458.5m³/s (1)

4.3. An axial flow fan is installed in a vent column, with the static pressure readings taken by means of a vertical manometer. The measured barometric pressure at the locality of this installation is 102.5kPa. If the fan intake quantity is 8.6 m³/s calculate the quantity at the fan discharge (x), assuming the temperature remains constant. (4)



4.3. Absolute pressure at fan intake (P1) = BP - Gauge Pressure (vacuum)

$= 102.5 - 0.9$

$\therefore P1 = 101.6\ kPa$ (1)

Absolute pressure at fan discharge (P2) = BP + Gauge Pressure

$= 102.5 + 1.2$

$\therefore P2 = 103.7\ kPa$ (1)

$P_1V_1 = P_2V_2$ (1)

$$V_2 = \frac{P_1V_1}{P_2}$$

$$= \frac{101.6 \times 8.6}{103.7}$$

$= 8.43 m^3/s$ (1)

4.4. A filter bag filter has to be installed at a tip. The tip is 4 m long and 2 m wide. Each of the bags is 2 m long and has a diameter of 200 mm. Determine the number of bags required for the filter. (8)

4.4. Area of tip = length x width

$= (4 \times 2)\ m^2$

$= 8\ m^2$ (1)

Recommended velocity down tip = 0.5 m/s

Air quantity down tip = Area x velocity

$= (8 \times 0.5)\ m^3$

$= 4.0\ m^3/s$ (1)

Surface area of one bag = $(\pi \times D \times L) + (\pi \times r^2)$ (1)

$= (3.14 \times 0.2 \times 2) + (3.14 \times 0.1 \times 0.1)$

$= (1.257) + (0.031)$

$= 1{,}288\ m^2$ (1)

Recommended velocity through bag = 0.1 m/s (1)

Air quantity through one bag = (area x velocity)

$= (1.288 \times 0.1)\ m^3/s$

$= 0.1288\ m^3/s$ (1)

$$\text{Number of Bags} = \frac{\text{air quantity down tip}}{\text{air quantity through one bag}}$$ (1)

$$= \frac{4.0}{0.1288}$$

= 31.1 bags

Number of bags required for filter unit = 32 bags (1)

4.5. A worker in a shaft timber yard is exposed to a wet bulb temperature of 28,5°C, a dry bulb temperature of 32,5°C and a globe temperature of 30,6°C. Calculate the WBGT index and comment. (2)

4.5. $WBGT = 0.7\ T_{wb} + 0.2T_g + 0.1T_{db}$ (½)

$= 0.7(28.5) + 0.2(30.6) + 0.1(3.25)$

$= 19.95 + 6.12 + 3.25$

$= 29.3°C$ (½)

Comment: Acceptable. WBGT not to exceed 30.0°C (OHSAct 85 of 1993) (1)

4.6. Air enters a surface downcast shaft at an average velocity of 50km/h and a temperature of 0.0 / 5.0°C. Calculate the wind chill equivalent temperature (wind chill factor). (2)

4.6. Air enters a surface downcast shaft at an average velocity of 50km/h and a temperature of 0.0 / 5.0°C. Calculate the wind chill equivalent temperature (wind chill factor).

Given that $V = \frac{50000}{3600}$

$= 13.9 m/s$ (1)

$T = 5.0°C$ dry bulb.

Then $WCET = 33 - \frac{(10.45 + 10\sqrt{V} - V) \times (33 - T)}{22.04}$ (1)

$= 33 - \frac{(10.45 + 10\sqrt{13.9} - 13.9) \times (33 - 5)}{22.04}$

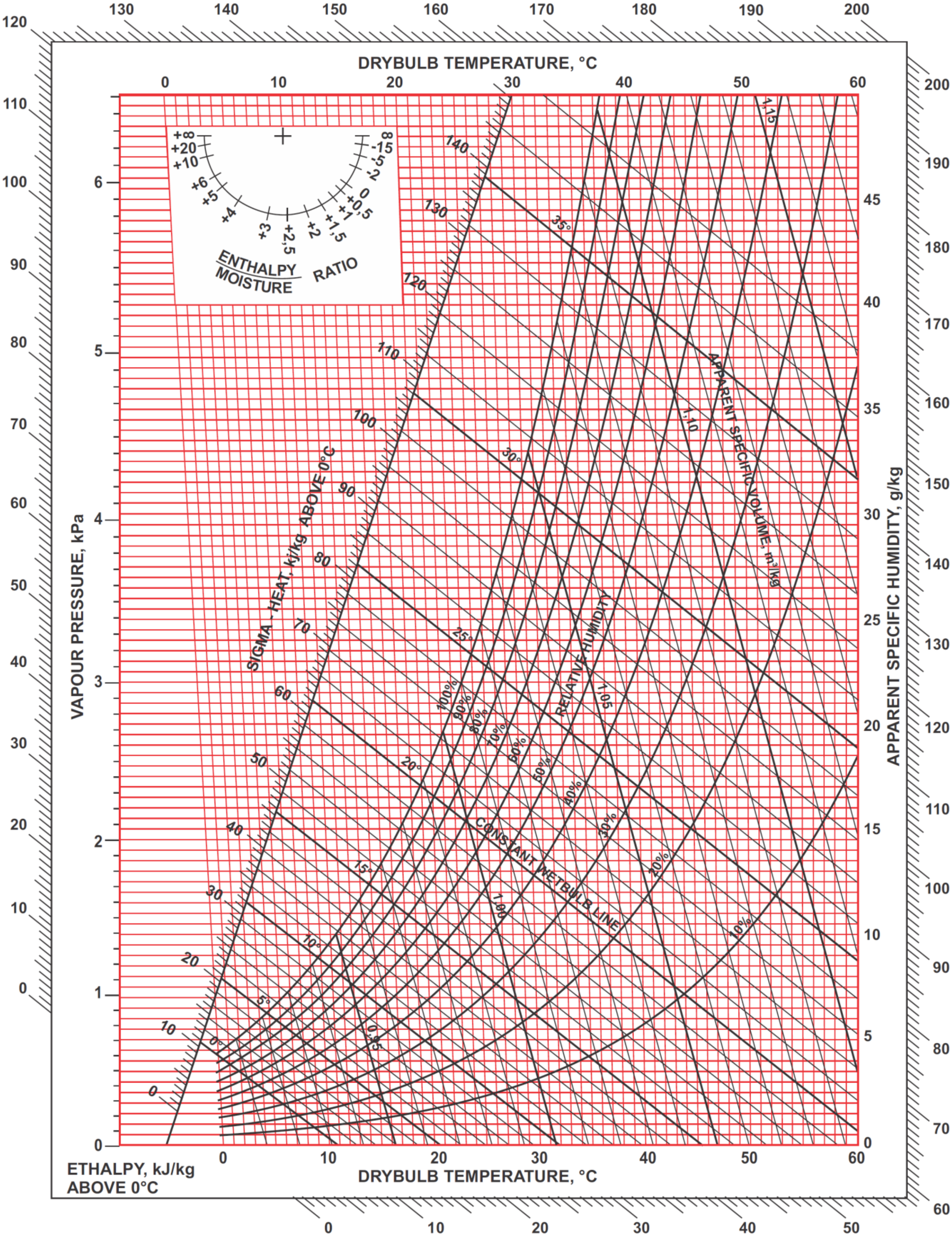
$= 33 - \frac{(33.8 \times 28)}{22.04}$

$= 33 - 43$

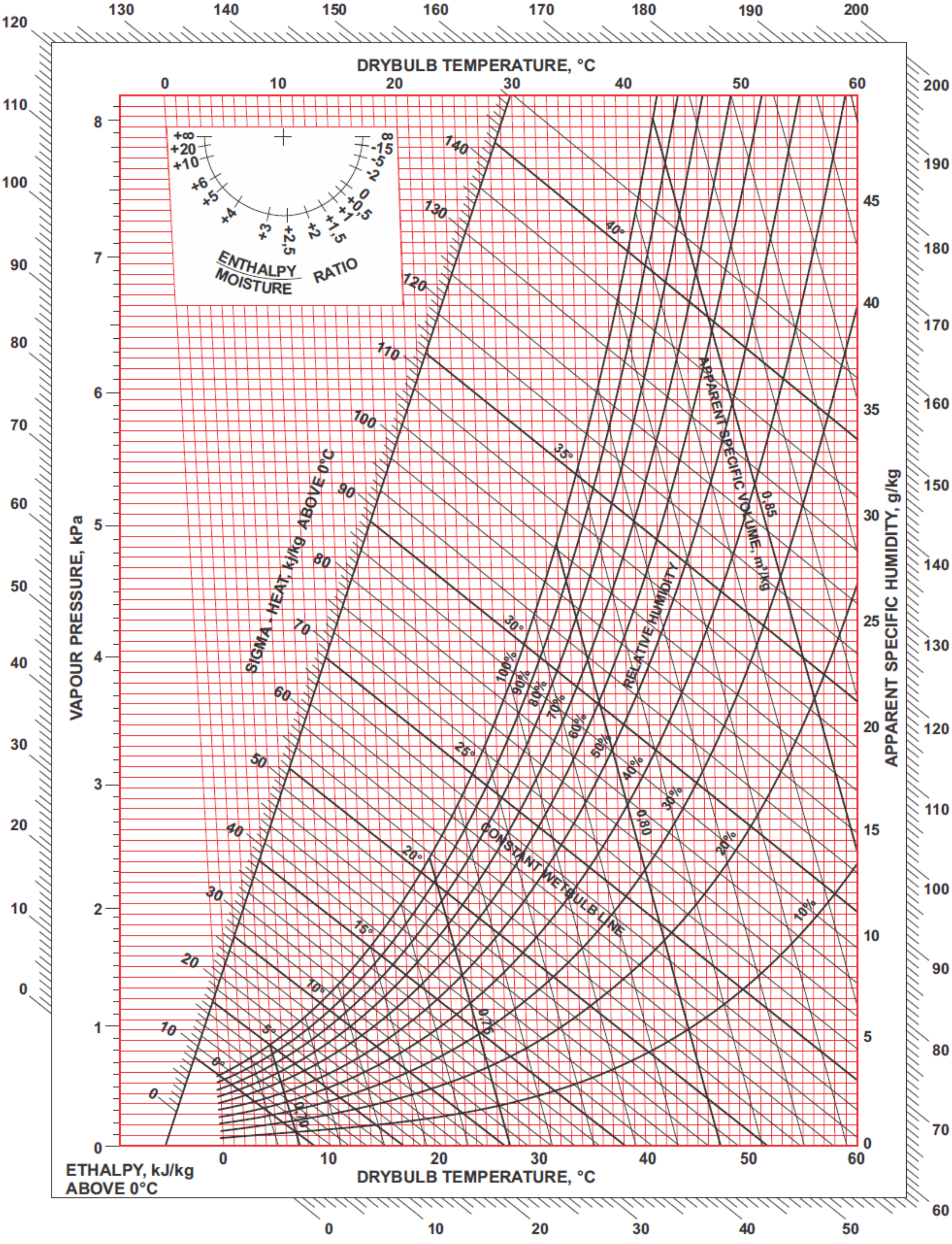
$= -10°C$ (1)

Total Marks: (25)

PSYCHROMETRIC CHART
87,5 kPa



PSYCHROMETRIC CHART
115,0 kPa



A.W.T.B.

CHART NO 16
115,0 kPa