



GWANDA STATE UNIVERSITY
FACULTY OF ENGINEERING AND THE ENVIRONMENT
DEPARTMENT OF METALLURGICAL ENGINEERING
EMG 3203 PYROMETALLURGY – NON FERROUS
Part III Second Semester Examination Paper
2025

This examination paper consists of 4 printed pages

Time Allowed: 3 hours

Total Marks: 100

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INSTRUCTIONS

1. Answer ALL questions in section A and any 2 from 3 in section B
2. Use of calculators is permissible.

Additional Requirements

MARK ALLOCATION

Section A	50 Marks
Section B	50 Marks
Part Questions	As shown in each part question
Total Attainable	100

SECTION A (50 MARKS)

ANSWER ALL QUESTIONS

Question 1

Matabeleland South Province is home to one of the largest national cement clinker production plant, PPC Colleen Bawn. Clinker production is one of the major contributors to the world CO₂ emissions, 8% in 2020.

The plant produces clinker at a rate of 6.944kg/s. A rotary kiln is used to produce clinker from limestone and montmorillonite clay. Coal is used as fuel to heat up the kiln to the clinker formation temperature of 1450°C. Exhaust gases have CO₂ from combustion of coal and decomposition of CaCO₃ to CaO.

Assuming steady state conditions in the kiln, complete decomposition of CaCO₃ and with the data below estimate the

- minimum amount of coal to be charged to the kiln [20]
- and the amount of CO₂ generated per tonne of clinker produced. [20]
- In what ways can the amount of coal required by the kiln be reduced? [10]

Inputs	Outputs
Limestone (CaCO ₃) - 1.65 tonnes	Clinker - 1 tonne
montmorillonite ((Na,Ca) _{0.33} (Al, Mg) ₂ (Si ₄ O ₁₀)(OH) ₂ .nH ₂ O) - 0.4 tonnes	Exhaust gases
Coal	

	Limestone and Montmorillonite	Coal	Clinker	Exhaust Gases
CaCO ₃	75.34%			
CaO			64.58%	
C		80%		
CO ₂				60%

Element	Atomic mass
Ca	40 g/mol
C	12 g/mol
O	16 g/mol

Heat Inputs	Heat Outputs
Coal Combustion $Q = m_c H_c$ where $H_c = 30600 \text{ kJ/kg}^\circ\text{C}$ and m_c is the mass of coal in kg	Sensible heat of coal is $1.15 \text{ kJ/kg}^\circ\text{C}$ fed at 25°C
	Sensible heat of limestone mixed with montmorillonite is $0.86 \text{ kJ/kg}^\circ\text{C}$
	Endothermic clinker formation heat is $1795 \text{ kJ/kg-clinker}$
	Heat lost in exhaust gases $Q = m_{eg} C_{eg} T_{eg}$ Where $C_{eg} = 1.071 \text{ kJ/kg}^\circ\text{C}$ $T_{eg} = 315^\circ\text{C}$ m_{eg} is the mass of exhaust gases
	Heat loss from the kiln surface to the surroundings $Q = \sigma \varepsilon A_{kiln} (T_s^4 - T_\infty^4) / (1000 m_{clinker})$ Where $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$ $\varepsilon = 0.78$ $A_{kiln} = 565 \text{ m}^2$ $T_s = 581 \text{ K}$ $T_\infty = 300 \text{ K}$ $m_{clinker} = 6.944 \text{ kg/s}$

SECTION B (50 MARKS)

ANSWER ANY TWO QUESTIONS

Question 2

Roasting of Cobalt-Copper Sulphide concentrates is done to produce a soluble Sulphate Calcine. The roasting temperature is maintained between 695-705°C to avoid formation of insoluble oxide.

- a. How many degrees of freedom does this Cobalt-Copper Sulphide system have? [2]
- b. What type of furnace can be used for this roasting? [2]
- c. With your choice of furnace, you stated above in (b) how will the roasting residence time be varied? [2]
- d. With your choice of furnace, you stated above in (b) what will be the ideal feed particle size and justify your answer? [4]
- e. State two effects to the roasting process of operating the furnace at a temperature lower than 500°C. [2]
- f. What is the difference between drying, roasting and smelting? [3]
- g. In what four ways can the temperature of the roasting furnace be regulated to stay within the 695-705°C range? [8]
- h. State two effects to the roasting process of operating the furnace at a temperature higher than 900°C. [2]

Question 3

Bindura Nickel Cooperation has a Nickel smelting plant. In smelting of sulphide ore a matte of base metals and sulphide soluble precious metals are also collected in the matte.

- a. State and explain five different ways this smelting furnace can pollute the Bindura environment. [10]
- b. For each of the ways of pollution stated above in (a) highlight the form/type of pollution it is. [5]
- c. For each of the ways stated in (a) explain how the pollution can be minimised in furnace design and/or operation? [5]
- d. State any three social benefits that comes with / were brought by, having a smelting plant in Bindura [3]
- e. State any two social negatives that can be/were brought about by having a smelting furnace in Bindura. [2]

Question 4

Zimbabwe has one of the world fourth largest reserves of Platinum Group Metals (PGMs) and the world's third largest producer after South Africa and Russia.

- a. Describe the basic flow sheet for processing of ROM ore with PGMs associated with sulphide minerals to independent Platinum Group Metals. Highlight typical machinery you would use in each stage of the flowsheet. [6]
- b. In PGM sulphide mineral separation from oxide materials how can recovery be improved if some of the PGMs occur as native metals in micro-particle sizes of 25 μ m sizes. [3]
- c. Give four reasons why PGMs ores need to first be prepared into concentrates by mineral processing before feeding to the smelter furnace. [4]
- d. What is the purpose of converting PGMs smelter matte before sending it to the refinery? [2]
- e. Give two reasons why PGMs concentrate should be dried before being fed to the smelter. [2]
- f. Describe the drying process and equipment you would use to dry smelter feed that is transported as slurry to the smelter. [4]
- g. What two factors limit the erection of a PGMs refinery plant in Zimbabwe. [2]
- h. State any two uses of PGM materials. [2]

END OF QUESTION PAPER