Chamber of Mines of South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 2 **SUBJECT CODE: COMMEC2** **EXAMINATION DATE: 11 OCTOBER 2017** **TIME:** 14:30 – 17:30	**EXAMINER:** E Botha **MODERATOR:** M Biffi **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 7

SPECIAL REQUIREMENTS:

FORMULA HANDOUT ARE ALLOWED.

THIS IS **NOT** AN **OPEN BOOK EXAMINATION**.

INSTRUCTIONS TO CANDIDATES:

1. Answer all **FOUR** 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.

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 At a deep level mine a new project is being developed. A computer simulation has confirmed that the calculated additional cooling load for this project to be 30000 kW. This being a long life (15 years) and deep project (max depth = 3600m), the decision has been taken to use ice to cater for the additional cooling load.

The water will leave the underground ice discharge dam at 3.0°C, arrive at the air cooling installations at 5°C and return to the same dam at 19.0°C.

Assuming that the water temperature leaving air cooling installations is the same as the water temperature returning to the melting dam (i.e. 19°C) and the IMF of ice is 80%,

1.1.1

a) Determine the chilled water flow rate (MF_W) through the air cooling installations to achieve 30 000 kW cooling. (1)

b) The heat energy (including line losses) transferred to the water circulated between the melting dam and the air cooling installations. (2)

c) Determine the flow rate of the ice/water mixture transported from surface to the melting dam. (3)

d) Determine the mass of solid ice being melted in the discharge dam (2)

1.1.2 If the 'melt' water is pumped to surface from the lowest level and the overall pumping efficiency is assumed to be 68%, determine the power required to return the 'melt' water back to surface. (2)

1.1.3 If ice were not used and all cooling water was generated from and pumped back to the surface refrigeration systems, assuming the same pump head and efficiency, how much power would be required to pump the required cooling water out of the mine?

[*Assume that the cooling water also reaches the air cooling installations exchanger at 5°C and that the required water flow is the same as that established in 1.1.1(a)]* (2)

1.1.4 Comment on the difference between your answers in 1.1.2 and 1.1.3 above in terms of infrastructure requirements (capital costs), operational costs and positional efficiencies. (3)

1.2 List at least 5 advantages and disadvantages of using ice as a medium for providing underground cooling in a deep mine. (10)

[25]

QUESTION 2

2.1 A quantity of 75m³/s of air enters a bulk cooler at 29.5/33.8°C. The barometric pressure is 112.5 kPa and the total heat energy transferred is 3 850 kW. The water flow rate through the bulk air cooler is 80 l/s and the temperature of the water entering the cooler is 9.5°C. Calculate:

2.1.1 The temperature of the air leaving the bulk air cooler (state any assumptions) (4)

2.1.2 The quantity of air leaving the bulk air cooler. (2)

2.1.3 The quantity of water, in litres per day, that has evaporated or condensed as the air flows through the bulk air cooler. (3)

2.1.4 The temperature of the water leaving the cooler. (1)

2.2 Briefly describe the process of auto-compression which occurs when ventilating air descends into a mine. In your description, explain why auto-compression of air is of greater significance in deep mines than in shallow mines. (5)

2.3 List 5 requirements of materials to be used for the insulation of chilled water piping. (5)

2.4 Give brief explanation of the following terms.

2.4.1 Partial pressure (1)

2.4.2 Superheat (1)

2.4.3 Wet-bulb globe index (1)

2.4.4 Enthalpy (1)

2.4.5 Isothermal process (1)

[25]

QUESTION 3

3.1 State typically thermal conductivity values of the following in the standard SI units

3.1.1 Copper

3.1.2 Steel

3.1.3 Plastic foam pipe insulation

3.1.4 Glass

3.1.5 Wood

3.1.6 UPVC

3.1.7 HDPE

3.1.8 Still water (8)

3.2.1 If still air has a conductivity of 0.028 W/m°C, how does this value compare to that of foam insulation? (2)

3.2.2 Considering your answer in 3.2.1 (above), briefly describe how thermal insulation materials works. (2)

3.3.1 Briefly describe the following heat transfer processes and list the factors that affect these.

a) Conduction (2)

b) Convection (2)

c) Radiation (2)

3.4 It takes a natural gas burner 30 minutes to heat 10kg of ice to water at 50°C. If the calorific heat value of the natural gas is 38.302GJ/m³, assuming that all the heat produced by the gas burner is used to heat the ice / water mixture, calculate the volumetric flow rate, in cubic centimetres per minute (cm³/min), of natural gas consumed in the gas burner. (5)

3.5 Briefly describe an adiabatic process (2)

[25]

QUESTION 4

4. The following measurements were made on an R134a refrigeration plant operating under full load conditions.

Evaporator

Water flow rate	75.5 l/s
Inlet water temperature	17.7°C
Outlet water temperature	3.5 °C
Evaporating temperature	0.5 °C

Condenser

Water flow rate	128 l/s
Inlet water temperature	42.8 °C
Outlet water temperature	54.5 °C
Condenser temperature	58.5 °C

Compressor

Motor current	114.6 A
Motor voltage	6 600 V
Electrical supply phases	3
Supply power factor	0.92
Calculated compressor motor efficiency	83%

Condenser cooling tower

Water flow rate	131 l/s
Inlet water temperature	55.8 °C
Outlet water temperature	43.9 °C
Condenser water pump input power	300 kW

Bulk air cooler

Water flow rate	106.2 l/s
Water temperature in	5.2 °C
Water temperature out	16.3 °C
Chilled water pump input power	230 kW

4.1 In a diagram, show the different energy transfer points in the 3 circuits described, clearly assigning the heat transfer values to each component derived from the data given above. (10)

4.2 With reference to the enclosed saturation point data sheet for refrigerant R134a, perform a heat balance on the refrigerant side of the circuit given that the compressor discharge refrigerant enthalpy is 320 kJ/kg. (5)
[*Hint: plot a rough (i.e. not to scale) p-H diagram of the cycle and enter the values obtained from the table below to help your analysis]*

Temperature °C	Pressure MPa	Vapour Volume m^3/kg	Liquid density kg/m^3	Enthalpy Liquid kJ/kg	Enthalpy Vapour kJ/kg	Entropy Liquid kJ/kgK	Entropy Vapour kJ/kgK
-80	0,00365	4,29	1524	-1,546	248,8	0,5623	1,858
-75	0,00545	2,94	1511	4,536	251,8	0,5934	1,841
-70	0,00795	2,07	1498	10,64	254,9	0,6238	1,826
-65	0,01135	1,48	1485	16,77	258,0	0,6536	1,613
-60	0,01587	1,08	1472	22,92	261,2	0,6828	1,801
-55	0,02179	0,803	1458	29,11	264,3	0,7114	1,790
-50	0,02942	0,606	1444	35,33	267,4	0,7400	1,780
-45	0,03908	0,465	1431	41,58	270,6	0,7673	1,771
-40	0,05118	0,361	1417	47,88	273,7	0,7946	1,763
-35	0,06612	0,284	1402	54,22	276,8	0,8214	1,756
-30	0,08436	0,226	1388	60,60	280,0	0,8479	1,750
-25	0,10640	0,181	1373	67,03	283,1	0,8740	1,745
-20	0,13270	0,147	1358	73,51	286,1	0,9000	1,740
-15	0,16390	0,121	1343	80,05	289,2	0,9252	1,735
-10	0,20050	0,100	1327	86,64	292,2	0,9504	1,732
-5	0,24320	0,083	1311	93,29	295,2	0,9753	1,728
0	0,29250	0,069	1295	100,0	298,1	1,000	1,725
5	0,34920	0,058	1278	106,8	301,0	1,024	1,723
10	0,41390	0,050	1261	113,6	303,9	1,049	1,721
15	0,48740	0,042	1244	120,5	306,6	1,073	1,718
20	0,57020	0,036	1226	127,5	309,3	1,096	1,717
25	0,66340	0,031	1207	134,6	312,0	1,120	1,716
30	0,76750	0,027	1188	141,8	314,5	1,144	1,713
35	0,88350	0,023	1168	149,0	317,0	1,167	1,712
40	1,01220	0,020	1147	156,4	319,2	1,190	1,710
45	1,15450	0,017	1125	163,8	321,3	1,214	1,709
50	1,31130	0,015	1103	171,4	323,3	1,237	1,707
55	1,48370	0,013	1079	179,1	325,1	1,260	1,705
60	1,67270	0,012	1053	187,0	326,6	1,283	1,702
65	1,88000	0,010	1026	195,1	327,8	1,307	1,699
70	2,10560	0,009	996,9	203,4	328,7	1,331	1,670
75	2,35230	0,008	964,7	212,0	329,1	1,355	1,691
80	2,62130	0,007	928,7	221,1	328,9	1,380	1,685
85	2,91470	0,006	887,3	230,7	32719	1,406	1,677
90	3,23480	0,005	837,3	241,3	325,6	1,434	1,666
95	3,58530	0,004	770,8	253,7	320,7	1,467	1,649
100	3,97200	0,003	645,5	272,7	307,0	1,517	1,609
101*	4,05500	0,002	509,1	289,4	289,4	1,561	1,561

*Critical point

MPa

Saturation points of Refrigerant 134 A

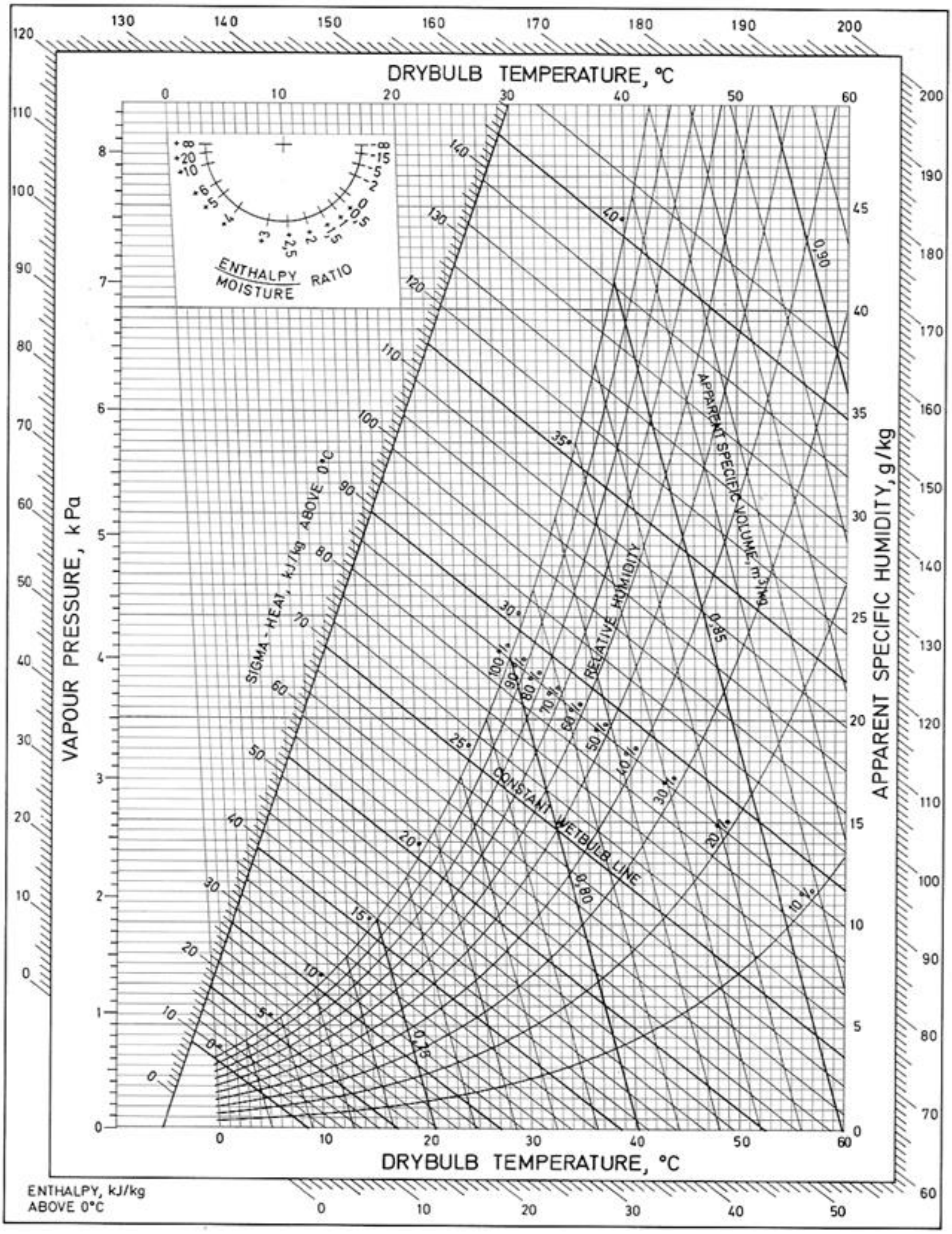
4.3 What is the refrigerant mass flow rate at the inlet to the compressor? (5)

4.4 What is the plant duty based on the refrigeration side calculations and what conclusions you draw regarding errors in the measurements obtained. (5)

[25]

TOTAL MARKS: 100

112,5 kPa



DRYBULB TEMPERATURE, °C
VAPOUR PRESSURE, kPa
APPARENT SPECIFIC HUMIDITY, g/kg
SIGMA - HEAT, kJ/kg ABOVE 0°C
ENTHALPY / MOISTURE RATIO
RELATIVE HUMIDITY
APPARENT SPECIFIC VOLUME, m³/kg
CONSTANT WETBULB LINE
ENTHALPY, kJ/kg ABOVE 0°C