higher education & training

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REFRIGERATION TRADE THEORY N3

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
REFRIGERATION TRADE THEORY N3
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Write neatly and legibly.

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QUESTION 1

1.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (1.1.1–1.1.5) in the ANSWER BOOK.

1.1.1 A refrigerant should have a boiling point.

1.1.2 The specific enthalpy of vaporisation of a refrigerant should be high.

1.1.3 The critical temperature of a refrigerant should be high.

1.1.4 A refrigerant should have a high specific volume.

1.1.5 A refrigerant should be easily condensable.

(5 × 1) (5)

1.2 FIGURE 1 shows three forms of a main component of a common pump used in the refrigeration industry.

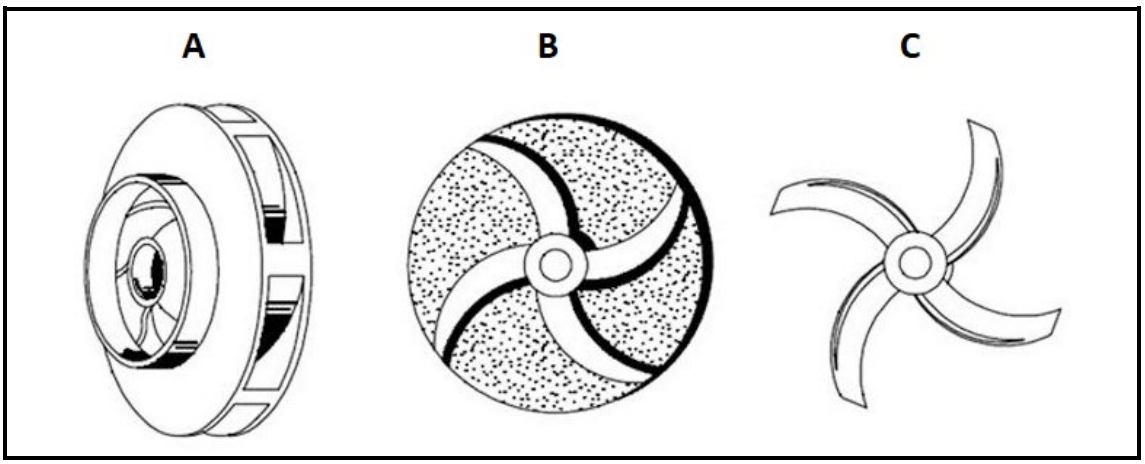

FIGURE 1

1.2.1 Name the type of pump in which this component is used. (1)

1.2.2 Identify each form in FIGURE 1 by writing the name next to the letter (A–C) in the ANSWER BOOK. (3)

1.3 The form of the component in FIGURE 1 that should be used in the pump is determined by the material or substance pumped.

Choose a component from FIGURE 1 to use for each substance below and write only the letter (A–C) next to the question number (1.3.1–1.3.3) in the ANSWER BOOK.

1.3.1 Clear liquids

1.3.2 Large amount of suspended solids

1.3.3 Small amounts of suspended liquids

(3 × 1) (3)

1.4 Choose the correct term from those in brackets. Write only the answer next to the question number (1.4.1–1.4.4) in the ANSWER BOOK.

1.4.1 A small part to protect closed water-heating systems and domestic hot-water systems from excessive pressure is called a/an (valve/expansion tank.)

1.4.2 Mechanical device designed to help protect the system from harmful or undesirable effects of solid and fluid impurities. It filters out solid debris in the water system. It is called a/an (air-vent/strainer).

1.4.3 Plumbing device used to release trapped air automatically from a heating system is called a/an (air-vent/valve).

1.4.4 Mechanical device blocking a pipe, either partially or completely, to change the amount of fluid passing through it is called a/an (expansion tank/valve).

(4 × 2) (8)

1.5 Name TWO commonly used valves. (2)

[22]

QUESTION 2

2.1 A compressor is an important component in the refrigeration cycle and as such it is important to control its capacity.

2.1.1 What variable is used to determine whether capacity control in a compressor is being achieved? (1)

2.1.2 Briefly explain compressor capacity control when each of the following is used:

(a) Hot-gas bypass (3)

(b) Cylinder unloading (3)

2.1.3 State ONE other method also used to control capacity besides the two methods given in QUESTION 2.1.2. (2)

2.1.4 What type of compressor mainly uses the methods of capacity control named in QUESTIONS 2.1.2 and 2.1.3? (1)

2.2 Explain the operating principle of an absorption refrigerator system. Include the THREE main stages, namely evaporation, absorption and regeneration, used in this system in the explanation. (3 × 2) (6)

2.3 State TWO main advantages of using an absorption refrigeration system. (4)

[20]

QUESTION 3

3.1 Natural-draft cooling towers play an important role in the refrigeration industry.

3.1.1 Briefly describe the natural-draft cooling tower. (2)

3.1.2 Name the other type of cooling tower commonly used. (1)

3.1.3 List ONE advantage of a natural-draft cooling tower. (2)

3.1.4 List ONE disadvantage of a natural-draft cooling tower. (2)

3.1.5 List ONE method to control capacity of a cooling tower. (2)

3.2 Briefly describe the operating method of each of the following control devices:

3.2.1 Evaporator pressure regulator (4)

3.2.2 Nonreturn or check valve (4)

3.3 Give ONE reason why the air circulation should be evenly distributed over a coil in a cold room. (3)

[20]

QUESTION 4

4.1 Briefly define the term *flash gas*. (3)

4.2 A four-cylinder compressor rotating at 20 revolutions per second has a bore of 30 mm and a stroke length of 50 mm. The refrigerant inlet pressure is 250 Kpa and it delivers the refrigerant vapour at a rate of 0,0025 m³/s and 1500 Kpa.

Calculate each of the following regarding the compressor:

4.2.1 Volumetric efficiency (6)

4.2.2 Clearance volume (2)

4.2.3 Compression ratio (3)

4.3 Give THREE advantages of a centrifugal compressor. (6)

[20]

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QUESTION 5

5.1 FIGURE 2 shows an automatic expansion valve.

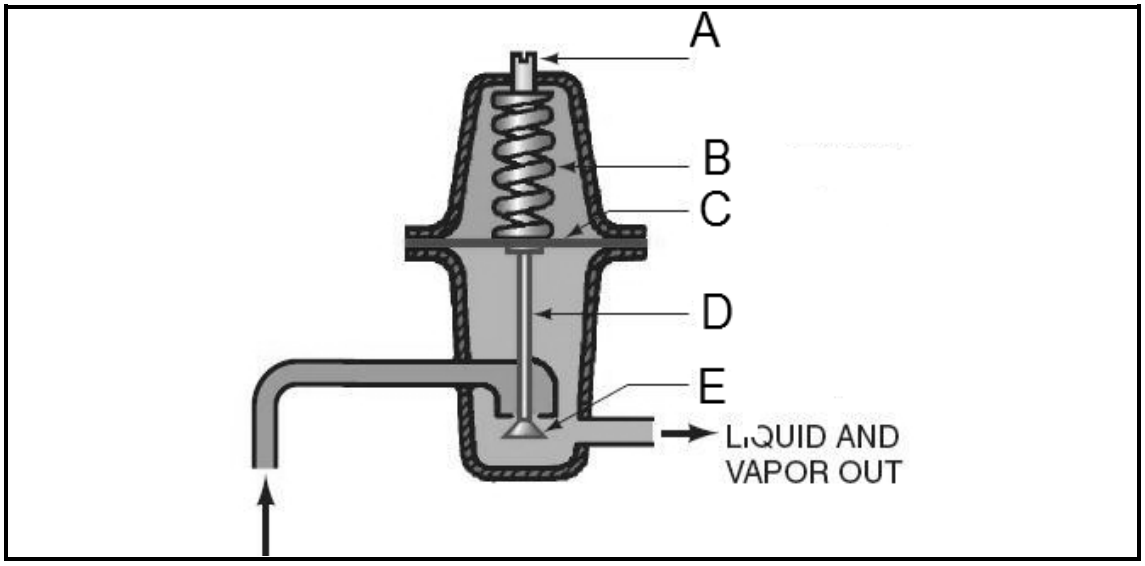

FIGURE 2

5.1.1 Label the indicated parts by writing the answer next to the letter (A–E) in the ANSWER BOOK. (5)

5.1.2 Name TWO other types of expansion valves that operate on the variable restriction principle. (2)

5.1.3 Give THREE symptoms of failure of an expansion valve in the air-conditioning system of a motor vehicle. (3)

5.2 List THREE routine maintenance activities done on an air-cooled reciprocating compressor every 40 hours or weekly. (6)

5.3 Why is a filter drier installed in a refrigeration system? (1)

5.4 In which line is the filter drier in QUESTION 5.3 fitted? (1)

[18]

TOTAL: 100

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FORMULA SHEET

REFRIGERATION TRADE THEORY N3

1. $Density = \frac{mass}{volume} \quad \therefore \rho = \frac{m}{v}\ kg/m^3$

   also $\rho = \frac{1}{v}\ kg/m^3 \quad (v = specific\ volume)$

2. $Specific\ volume\ (v) = \frac{1}{density} = \frac{1}{\rho}\ m^3/kg$

3. Greek symbols: $\eta = efficiency\ (neta)$
   $\rho = density\ (rho)$

4. $Mass\ flow\ rate: \left(\dot{m}\right)$

   $\dot{m} = \dot{V} \times \rho \quad Kg/S$

   $OR \quad \dot{m} = \dot{V} \times \frac{1}{v} \quad \therefore \quad \dot{m} = \frac{\dot{V}}{v} \quad kg/s$

5. $(Quantity\ of\ heat\ (Q) for\ a\ change\ in\ temperature)$
   $Q = mC\Delta T\ \ kJ$
   $For\ a\ chnge\ of\ phase)$
   $Q = m.hfg$
   $(hfg = latent\ heat\ required)$
   $when\ the\ heat\ transfered\ reteis\ required\ the\ formula\ changes\ to:$
   $\dot{Q} = \dot{m}\ .\ hfg\ KJ/s\ or\ KW$

6. $Specific\ enthalphy\ (h)$

   To calculate the total energy transfer

   $\dot{Q} = \dot{Q}.\Delta h\ \ kJ/s\ or\ kW$

7. $Boyle's\ law$:

   $P_1V_1 = P_2V_2\ (at\ constan\ temperature)$

8. $Charles's\ law$:
   $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

9. $Ideal\ gas\ law$:

   $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

10. $The\ gas\ constant\ (R)$

    $R = \frac{Pv}{T}\ \ J/Kg.K$

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11. $Comperssor\ efficiency = \frac{Actual\ displacement(V)}{Thermal\ displacement(V\rho)}$

$\eta = \frac{V}{V\rho} \times \frac{100}{1} = \%$

12. $Theoretical\ displacement$:

$V\rho = \frac{\pi \times D^2 \times L \times n \times N}{4}\ m^3/min$

$OR\ = \frac{\pi \times D^2 \times s \times N \times R}{4}\ m^3/min$

$NOTE: (\pi = 3.142)$

13. $Evaporator\ capacity$:

(a) $The\ quantity\ of\ sensible\ heat\ transferred\ in\ watt$

$(evaporator\ sensible\ capacity)\ \left(\overset{\circ}{Q}\right)$

$\overset{\circ}{Q}\ = U\ .A\ .\Delta t\ watts$

(b) $Overall\ heat\ transfer\ coefficient$ (U-factor)

$U = \frac{1}{R}\ \ W/m^2.℃$

(c) $Resistance\ of\ surface\ to\ heat\ flow\ (R)$

$R = \frac{1}{U} = \frac{1}{h_0} + \frac{x}{k} + \left(\frac{Ao}{A_1} + \frac{1}{h_1}\right)\ \ m^2.℃/W$

(d) $Log\ mean\ temperature\ difference\ (LMTD)$

$LMTD = \frac{(te-tr)-(t\ell-tr)}{\log n\left(\frac{te-tr}{t\ell-tr}\right)}\ ℃$

14. $Condenser\ \ load$:

(a) $Total\ heat\ rejected\ of\ condenser\ in\ KW(THR)$

$THR = \overset{\circ}{Qe} + \overset{\circ}{Q}i$ KW

$Also\ THR = refrigeration\ capacity \times heat\ rejected\ factor$

(b) $Condenser\ capacity\ \left(\overset{\circ}{Q}\right)$

$\overset{\circ}{Q} = U\ .A\ .\Delta t\ \ \ kW$

(c) $LMTD = \frac{(tr-t\ell)-(tr-te)}{log\ n\left(\frac{tr-t\ell}{tr-te}\right)}$

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15. *The pressure enthalphy diagram*:

(a) *Refrigeration effect* (Re)
$Re = h_1 - h_4 \quad kJ/kg$

(b) *Heat of compression* (WD)
$WD = h_2 - h_1 \quad kJ/kg$

(c) *Heat rejection* (THR)
$THR = h_2 - h_3 \quad kJ/kg$

(d) *Coefficient of performance* (COP):
$COP = \frac{Re}{WD}$ $(cooling)$
$COP = \frac{THR}{WD}$ *(heat pump)*

(e) *Refrigerant mass flow* $\left(\dot{m}\right)$
$\dot{m} = \frac{Load}{Re} \; kg/s$

(f) *Plant capacity* $= \dot{m} \times Re \quad kW$

(g) *Theoretical power* $= \dot{m} \times WD \quad kW$

(h) *Actual power* $= \frac{\dot{m} \times WD}{\eta} \quad kW$

(i) *Total heat rejected in kW* (THR)
$THR \text{ in } kW = \dot{m} \times THR \text{ in } kJ/kg \; kW$

(j) *The efficiency of a comressor*:
$\% = \frac{Theoretical\ power\ input}{Actual\ power\ input} \times 100$
OR
$\% = \frac{h_2 - h_1}{h_{1_2} - h_1} \times 100$

16. *Cooling load calculations*:

(a) *Basic heat transfer formula*
$Q = U \,.\, A \,.\, \Delta T \; watts \; (J/S)$

(b) *To calculate total resistance against heat flow*

$Rt = \frac{1}{h_0} + \frac{d_1}{k_1} + \frac{d_2}{k_2} \cdots + \frac{1}{h_1} \; m^2.℃/W$

(c) *heat transfer coefficient* (U)
$U = \frac{1}{R_1} \; W/m^2.℃$

(d) *Resistance against heat flow* (R)
$\mathrm{R} = \frac{d}{k} \; m^2.℃/W$

(e) *Total air change in cold room* $\left(\dot{V}\right)$
$\dot{V} = \frac{V \times f}{86400} \quad m^3/s$

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(f) *Total air change load* $\left(\overset{\circ}{Q}\right)$

(i) $\overset{\circ}{Q} = \overset{\circ}{V} \times \rho \times (h_2 - h_1) \times 1000$ *watts*

or when using the table for the number of air changes:

(ii) $\overset{\circ}{Q} = \frac{V \times f \times \rho \times \Delta h}{86.4}$ *watts*

The above formula is the combination of the 2 formulae given in (e)*and* $(f)(i)$

(g) *The product load*:

(i) *Sensible heat*:

$\overset{\circ}{Q} = \frac{\overset{\circ}{m} \cdot C \cdot \Delta t}{86.4}$ *watts*

(ii) *Latent heat*:

$\overset{\circ}{Q} = \frac{\overset{\circ}{m} \Delta h}{86.4}$ *watts*

(iii) *Heat respiration*:

$\overset{\circ}{Q} = \overset{\circ}{m} \cdot \Delta h$ *Watts*

(h) *Miscellaneous loads*:

(i) *Eqiupment load* $= \frac{\text{Equipment output} \times \text{hours of operation}}{24}$ *watts*

NB: Loadand output must be given in watts

(ii) *Lighting load* $= \frac{\text{Wattage of lighting} \times \text{hours of operation}}{24}$ *watts*

NB: When lighting is by means of fluorescent light, add 25% to the lighting load.

(iii) *Occupancy load*:

$\overset{\circ}{Q} = \frac{\text{Heat equivalent per person} \times \text{number of persons} \times \text{hours}}{24}$ *watts*

17. Ventilation and air conditioning:

(a) *Removal of latent heat*:

$\overset{\circ}{Q} = \overset{\circ}{Q} \times \Delta g \times hfg$ *kW*

$\overset{\circ}{m} = \frac{\overset{\circ}{V}}{v}$ *kg/s*

$\therefore \overset{\circ}{Q} = \frac{\overset{\circ}{V} \times \Delta g \times hfg}{v}$

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(b) *Room sensible heat factor* $(RSHF)$:

$$RSHF = \frac{RSH}{RSH+RLH} = \frac{RSH}{RTH}$$

(c) *Efficiency of an evaporative cooler*:

$$\eta = \frac{ta-tc}{ta-tb}$$

(d) *Cooling and dehumidification*:

$$\dot{Q} = \dot{m}\ [\Delta h - hfg(\Delta g)]\ kW$$

(e) $\dot{V}$ *of the return air*

$$\dot{V}ra = \dot{V}ra - \dot{V}fa\ m^3/s$$

(f) *Air temperature of mixture in the front of coil*

$$T = \frac{\left(\dot{V}fa \times tdbfa\right) + \left(\dot{V}ra \times tdbra\right)}{\dot{V}sa} \quad ℃$$

(g) *Quantity of air*:

$$\dot{V} = \frac{\dot{Q}}{C \times \rho \times \Delta t}\ m^3/s$$

(h) *Amount of air forced through an opening by wind*:

$$\dot{V} = E \times A \times v \quad m^3/s$$

(i) *Volume flow due to temperature difference*:

$$\dot{V} = kA\sqrt{h(\Delta t)}\ m^3/s$$

(j) *Air changes per hour* (f):

$$f = \frac{\dot{V} \times 3600}{V}\ changes/hour$$

(k) *Volume air low per* m^2 *opening*:

$$\dot{V} = \frac{\dot{V}}{A} \quad m^3/s/m^2$$

(l) *Free area of an opening* (A):

$A = total\ area \times \eta\ m^2$

(m) *Louvre size for given air speed*:

$$= \frac{\dot{V} \times 100}{Number\ of\ inlets \times inlet\ speed \times \%\ A}\ m^2$$

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18. Fans:

(a) *Fan total pressure* (Pt)

$$Pt = Ps + Pv \ \ kPa$$

(b) *Theoretical power of fan* :

$$= \overset{\circ}{V} \times Pt \ \ kW$$

(c) True power of fan:

$$= \frac{\overset{\circ}{V} \times Pt}{\eta} \ kW$$

(d) *Air power* (Ap)

$$Ap = \frac{\overset{\circ}{Q} \times Pt}{N} \ \ kW$$

(e) *Brake power* (Bp)

$$Bp = \frac{\overset{\circ}{Q} \times pt}{\eta\, t} = \frac{\overset{\circ}{Q} \times ps}{\eta\, t}$$

$$\therefore Bp = \frac{Pt}{\eta\, t} = \frac{Ps}{\eta\, s} \ \ (for\ the\ same\ volume)$$

19. Fan laws:

(a) $\frac{VOL_1}{VOL_2} = \frac{N_1}{N_2} \times \frac{(DIA_1)^3}{(DIA_2)^3}$

(b) $\frac{P_1}{P_2} = \frac{(N_1)^2}{(N_2)^2} \times \frac{(DIA_1)^2}{(DIA_2)^2} \times \frac{\rho_1}{\rho_2}$

(c) $\frac{kW_1}{kW_2} = \frac{(N_1)^3}{(N_2)^3} \times \frac{(DIA_1)^5}{(DIA_2)^5} \times \frac{\rho_1}{\rho_2}$

$$\frac{DIA_1}{DIA_2} = \frac{N_1}{N_2}$$

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