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higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N5

29 NOVEMBER 2019

This marking guideline consists of 9 pages.

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QUESTION 1

1.1
- Must be designed and manufactured according to the code of practice
- Must be approved by the inspector if no code exists for such a boiler
- Must be manufactured under supervision of an inspection authority (3 × 2) (6)

1.2
- More work done is achieved due to greater expansion of steam.
- Water in the circuit can be treated to reduce scale formation in the boiler.
- The pressure can be operated below atmospheric pressure. (Any 2 × 2) (4)

[10]

QUESTION 2

$V_1 = 0,15\ m^3$ $T_1 = 40\ °C$
$P_1 = 310\ kPa$ $m = 0,5\ kg$
$P_2 = 680\ kPa$ $C_v = 0,718\ kJ/kg.K$

2.1
$$P_1V_1 = mRT_1$$
$$R = \frac{P_1V_1}{mT_1} \checkmark$$
$$= \frac{310 \times 0.15}{0.5 \times 313} \checkmark$$
$$= 0,297\ kJ/kg.K \checkmark$$
(3)

2.2
$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}$$
$$T_2 = T_1\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \checkmark$$
$$= \sqrt{313}\ \left(\frac{\sqrt{680}}{310}\right)^{\frac{1.35-1}{1.35}}$$
$$= 383,698\ \ K \checkmark$$
(3)

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2.3 $P_2V_2 = mRT_2$

$V_2 = \frac{mRT_2}{P_2}$ ✓

$= \frac{0{,}5 \times 0.297 \times 383{,}698}{680}$ ✓

$= 0{,}084\, m^3$ ✓

OR

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1}$

$V_2 = \frac{V_1}{\left(\frac{T_2}{T_1}\right)^{\frac{1}{n-1}}}$ ✓

$= \frac{0{,}15\ \surd}{\left(\frac{383{,}698}{313}\right)^{\frac{1}{1.35-1}}\ \surd}$

$= 0{,}084\ m^3$ ✓ (3)

2.4 $WD = \frac{P_1V_1 - P_2V_2}{n-1}$

$= \frac{(310 \times 0.15) - (680 \times 0{,}084)}{1{,}35 - 1}$ ✓✓✓

$= -30{,}343\ kJ$ ✓

OR

$WD = \frac{mR(T_1 - T_2)}{n-1}$

$= \frac{0.5 \times 0{,}297\ (313 - 383{,}698)}{1{,}35 - 1}$ ✓✓✓

$= -29{,}996\ kJ$ ✓ (4)

2.5 $\Delta U = mC_v(T_2 - T_1)$

$= (0{,}5)(0{,}718)(313 - 383{,}698)$ ✓✓

$= -25{,}381$ kJ ✓ (3)

2.6 $Q = \Delta U + WD$

$= -25{,}381 + (-29{,}996)$ ✓✓

$= -55{,}377$ kJ ✓✓ (4)

[20]

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QUESTION 3

3.1
$$x = \frac{M}{M+m}$$
$$= \frac{1,5\checkmark}{1,5+0,15\checkmark}$$
$$= 0,909\checkmark$$
(3)

3.2
$$P = (B_m + M_m)\frac{101,325}{760}$$
$$= (775+652)\frac{101,325}{760}\checkmark$$
$$= 190,25 \text{ kPa}\checkmark$$
$$\approx 190 \text{ kPa}$$

At $P = 190$ kPa
$h_f = 498$ kJ/kg✓
$h_{fg} = 2\,206$ kJ/kg✓

3

At 120 kPa, $t_{ss} = 110\,°C$✓
$h_g = 2\,683$ kJ/kg✓
$t_s = 104,8\ °C$ √
+

Enthalpy before throttling = Enthalpy after throttling
$$h_1 \text{ at } 190\ kPa = h_2 \text{ at } 120\ kPa$$
$$h_f + xh_{fg} = h_g + c_p(t_{ss} - t_s)$$
$$498 + x(2206) = 2683 + 2,1(110 - 104,8)$$
$$x = 0,995\checkmark$$
(9)

3.3
$$x = x_1 \times x_2\checkmark$$
$$x = 0,909 \times 0,995$$
$$x = 0,904\checkmark$$
(4)

3.4
$$V = xV_g$$
$$V = 0,904 \times 0,929\checkmark$$
$$V = 0,8398\frac{\text{m}^3}{\text{kg}} \times 3 \text{ kg}\checkmark$$
$$V = 2,519 \text{ m}^3\checkmark$$
(4)
[20]

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QUESTION 4

4.1 4.1.1

$$p = (B_m - M_m)\frac{101,325}{760}$$
$$= (760-660)\frac{101,325}{760}\checkmark$$
$$= 13,332\ kPa\ \checkmark$$
$$\approx 13\ kPa$$

(2)

4.1.2 At P = 13 kPa $h_f = 214$ kJ/kg $h_{fg} = 2\,380$ kJ/kg

$h_c = 192$ kJ/kg at $t_c = 45,8$ °C

heat emitted by steam = heat absorbed by water

h_1 At 13 kPa $= h_2$

$$m_s\left[h_f + xh_{fg} - h_c\right] = mc_p\Delta T$$
$$8\,500\left[214 + (0,85\times 2\,380) - 192\right] = m\times 4,2\times(38-20)$$
$$m = 229\,927,249\ \frac{\text{kg}}{\text{h}}\checkmark$$

ALTERNATIVE METHOD:

At P = 13 kPa $h_{fg} = 2\,380$ kJ/kg

$$h_c = c_p(t_{ss} - t_c)$$
$$h_c = 4,2(51,1-45,8)\checkmark$$
$$h_c = 22,26\ \text{kJ/kg}\checkmark$$

heat emitted by steam = heat absorbed by water

$$h_1 = h_2$$
$$m[xh_{fg} + h_c] = m\times c_p\times(t_2 - t_1)$$
$$8\,500[(0,85\times 2380) + 22,26] = m\times 4,2\times(38-20)$$
$$m = 229\,956,482\ \frac{\text{kg}}{\text{h}}\ \checkmark$$

(6)

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4.1.3 At $t_c = 45{,}8\ ^\circ\text{C}$, $P_s = 10\ \text{kPa}$ √

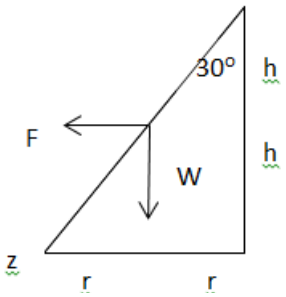
$$P_T = P_a + P_s$$
$$P_a = 13{,}332 - 10$$
$$= 3{,}332\ \text{kPa} ✓$$

$$T_a = 273 + 45{,}8$$
$$= 318{,}8\ ^\circ\text{C} √$$

$$P_a V_a = mRT_a$$
$$V_a = \frac{mRT_a}{P_a}$$
$$= \frac{0{,}25 \times 0{,}3 \times 318{,}8}{3{,}332} √$$
$$= 7{,}176\ \frac{\text{m}^3}{\text{s}} √ \times \frac{60\ \text{s}}{1\ \text{min}} √$$
$$= 430{,}56\ \text{m}^3/\text{s} ✓$$

(5)

4.2 $h = 0{,}28 \cos 30^o$ √
$h = 0{,}242m$ ✓
$r = 0{,}28 \sin 30^o$ √
$r = 0{,}14m$ ✓



Take moments about z :

$$F \times h = W \times r$$
$$F \overset{✓}{\times} 0{,}242 = (1{,}2 \overset{✓}{\times} 9{,}81) \times 0{,}14$$
$$F = \frac{1{,}2 \times 9{,}81 \times 0{,}14}{0{,}242} ✓$$
$$F = 6{,}81\ \text{N} ✓$$

(7)
[20]

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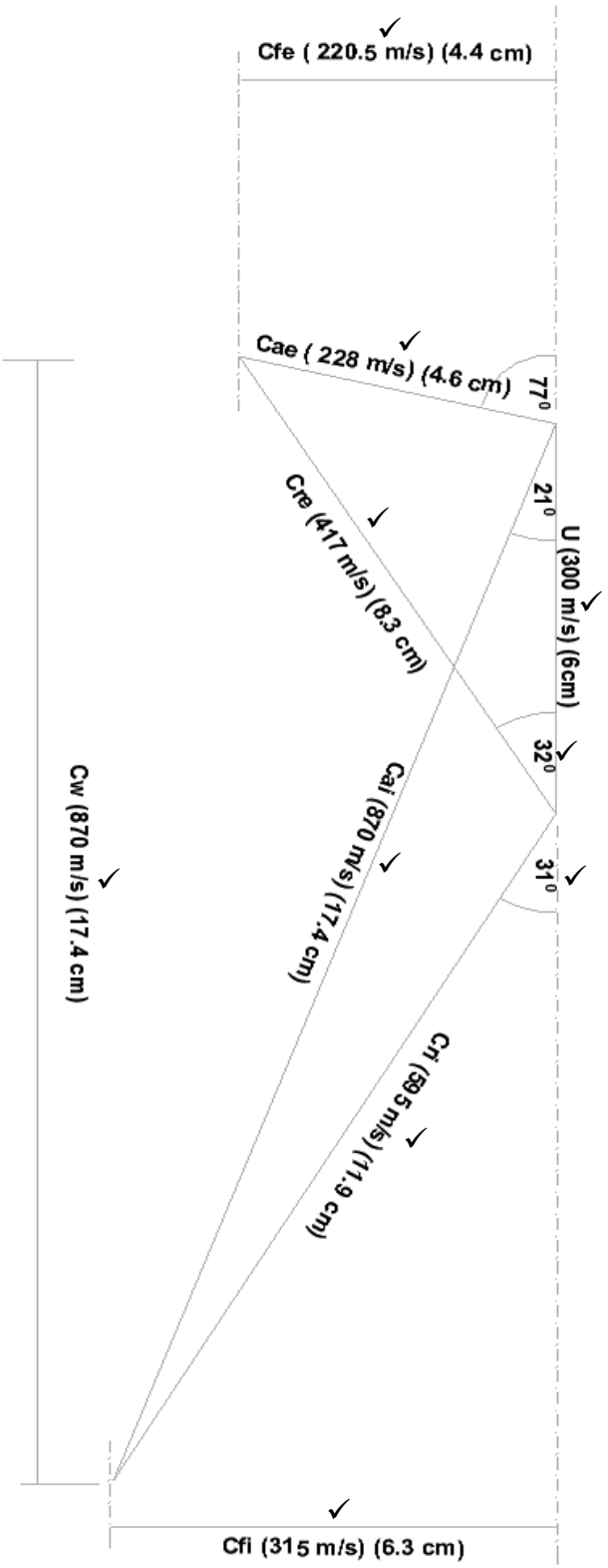
QUESTION 5

5.1



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5.2 5.2.1 $\alpha = 25^{o}$

5.2.2 $Cfe = 220{,}5 \text{ m/s}$

(2 × 1) (2)

5.3 $$\eta = \frac{mU[(Cwi)-(Cwe)]}{Cai^2}$$ ✓

$$= \frac{2 \times 300 \times 870}{870^2} \times 100$$ ✓

$$= 68{,}965\%$$ ✓

(3)
[15]

QUESTION 6

6.1 $$HCV = (CV_C.C) + CV_{H_2}.\left(H_2 - \frac{O_2}{8}\right) + (CV_s.S)$$

$$HCV = (34 \times 0{,}85) + (145)(0{,}07 - \frac{0{,}02}{8}) + (9 \times 0{,}06)$$ (√ ✓ √)

$$HCV = 39{,}228 \text{ MJ/kg}$$ ✓

(3)

6.2 $$LCV = HCV - h_{fg}(9H_2)$$

$$LCV = 39{,}228 - (2{,}424)(9 \times 0{,}07)$$ (✓ ✓)

$$LCV = 37{,}701 \text{ MJ/kg}$$ ✓

(3)

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6.3

$$M_{air} = \frac{100}{23}\left[\left(\frac{8}{3} \times 0,85\right) + (8 \times 0,07) + 0,06 - 0,02\right]$$

$$M_{air} = 12,463\ kg\ air / kg\ fuel \checkmark$$

Mass of dry products :

$CO_2 = 3,667 \times 0,85$

$= 3,117$ kg CO_2/kg fuel✓

$SO_2 = 2 \times 0,06$

$= 0,12$ kg SO_2/kg fuel✓

$N_2 = \frac{77}{100} \times 12,463$

$= 9,597$ kg N_2/kg fuel✓

Total mass $= 3,117 + 0,12 + 9,597$✓

$= 12,894$ kg products/kg fuel√

$$AHV = LCV - mC_p(t_2 - t_1)$$

$$AHV = 37,701 - \frac{12,894 \times 1,045 \times (230 - 36)}{1\,000\ \surd} \checkmark$$

$$AHV = 37,701 - 2,614 \checkmark$$

$$AHV = 35,087\ \text{MJ/kg} \checkmark$$

(9)
[15]

TOTAL: 100

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