CLASS TEST

S.No.: 01SK_ABCDEFG_27072024

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POWER PLANT

MECHANICAL ENGINEERING

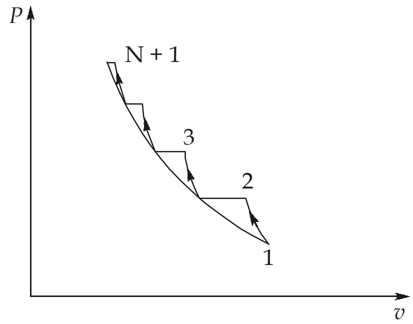
Date of Test : 27/07/2024

ANSWER KEY

1.	(a)	7.	(b)	13.	(a)	19.	(b)	25.	(c)
2.	(b)	8.	(c)	14.	(d)	20.	(b)	26.	(d)
3.	(a)	9.	(d)	15.	(a)	21.	(d)	27.	(b)
4.	(b)	10.	(b)	16.	(b)	22.	(c)	28.	(b)
5.	(b)	11.	(b)	17.	(a)	23.	(b)	29.	(a)
6.	(c)	12.	(a)	18.	(b)	24.	(a)	30.	(a)

DETAILED EXPLANATIONS

1. (a)



Let N be the number of stages.

$$P_1 = 1 \text{ bar}, T_1 = 27 + 273 = 300 \text{ K}$$
$$P_{N+1} = 150 \text{ bar}$$
$$T_2 = 160°\text{C} = 160 + 273 = 433 \text{ K}$$

For polytropic process, 1 – 2(n = 1.25)

$$\frac{T_2}{T_1} = \left(\frac{P_2}{1}\right)^{(1.25-1)/1.25}$$
$$P_2 = 6.2637 \text{ bar}$$

Now,
$$\frac{P_{N+1}}{P_1} = \frac{P_{N+1}}{P_N} \times \frac{P_N}{P_{N-1}} \ldots\ldots\ldots\ldots \frac{P_3}{P_2} \times \frac{P_2}{P_1}$$
$$\frac{P_{N+1}}{P_1} = \left(\frac{P_2}{P_1}\right)^N$$

$\Rightarrow$
$$\frac{150}{1} = \left(\frac{6.2637}{1}\right)^N$$
$$N = 2.731$$
$$N \simeq 3$$

2. (b)

Reheating results in increase in net work output, decrease in thermal efficiency (thermal efficiency is directly proportional to mean temperature of heat addition) and improvement in quality of wet steam at turbine exit. But reheating is mainly incorporated in power plant to limit the moisture content in the working fluid at turbine exit. Due to increase in specific output, mass flow rate required is less for the same power output, which results in reduction in plant size.

3. (a)

For maximum blade efficiency of Parson's turbine,

$$\text{Speed ratio, } \rho = \cos\alpha$$

4. **(b)**

Due to regeneration, mean temperature of heat addition increases resulting in increase in cycle efficiency and decrease in heat rate.

There is no change in mean temperature of heat rejection because of regeneration.

For same boiler output, net work output of cycle decreases.

5. **(b)**

Internal power developed $= m \times \Delta h_{i\,\text{sen}} \times \eta_{gs} = 15 \times 450 \times 0.9 = 6075$ kW

6. **(c)**

$$V_{w_2} = u_2 \quad \text{(Given)}$$

$$\text{Degree of reaction} = 1 - \frac{V_{w_2}}{2u_2}$$

$$= 1 - \frac{1}{2} = 0.5 = 50\%$$

7. **(b)**

$$\text{RF} = \frac{(h_1 - h_{2s}) + (h_2 - h_{3s'})}{(h_1 - h_{3s})}$$

$$= \frac{(2500 - 2000) + (2070 - 1900)}{(2500 - 1850)} = \frac{500 + 170}{650} = 1.030$$

8. **(c)**

$$\text{Heat rate} = \frac{Q}{W_T - W_P} = \frac{2500}{50 \times (19 - 1)} = 2.77$$

9. **(d)**

Various boiler mounting are as under:

1. Pressure gauge
2. Water level indicator
3. Fusible plug
4. Safety valve
5. Steam stop valve
6. Feed check valve
7. Blow off cock.

10. **(b)**

Approach of a cooling tower = $T_{\text{exit}} - T_{WBT}$

11. (b)

$$\frac{0.86}{12}C+\frac{0.14}{2}H_2+x(O_2+3.76N_2) = aCO_2 + bH_2O + cN_2$$

By comparing:

$$a = 0.07166$$
$$b = 0.07$$
$$c = x \times 3.76$$
$$x = a+\frac{b}{2} = 0.10666$$
$$c = 0.40104$$

$$\% \text{ of } CO_2 = \frac{a}{a+c} = \frac{0.07166}{0.07166+0.40104} = 0.15159 = 15.16\%$$

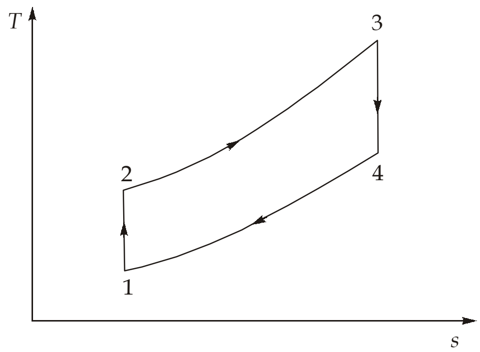
Note: for dry exhaust gas, H_2O will not be counted.

12. (a)

Pressure ratio, $r_p = 6$

$T_2 = 400 + 273 = 673$ K

$T_3 = 1200 + 273 = 1473$ K



Process 1–2 (Isentropic)

$$\frac{T_2}{T_1} = r_p^{\gamma-1/\gamma}$$

$$\frac{673}{T_1} = (6)^{(1.4-1)/1.4}$$

$$T_1 = 403.354 \text{ K}$$

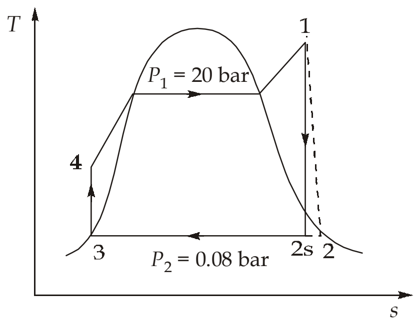
As we know,

$$\eta_{reg} = 1-\frac{T_1}{T_3}r_p^{\gamma-1/\gamma} = 1-\frac{403.354}{1473}\times 6^{(1.4-1/1.4)}$$

$$= 0.5431 = 54.31\%$$

13. (a)

$$h_1 = 3160 \text{ kJ/kg}$$



For isentropic process (1 – 2s)

$$s_1 = s_{2s}$$

$\Rightarrow$ $$6.992 = s_{f2} + x_2 s_{fg} = 0.5926 + x_2 \times 7.6371$$

$$x_2 = 0.8379$$

$$h_{2s} = h_f + x_2 h_{fg}$$
$$= 173.88 + 0.8379 \times 2403.1$$
$$h_{2s} = 2187.437 \text{ kJ/kg}$$
$$\text{Ideal work, } W_{ideal} = (h_1 - h_{2s}) = (3160 - 2187.437) = 972.563 \text{ kJ/kg}$$
$$\text{Brake efficiency, } \eta_b = \eta_{internal} \times \eta_{mechanical}$$
$$0.72 = \eta_{internal} \times 0.9$$
$$\eta_{internal} = \frac{0.72}{0.9} = 0.8$$

As we know,

$$\eta_{internal} = \frac{\text{Actual work}}{\text{Ideal work}}$$
$$0.8 = \frac{\text{Actual work}}{972.563}$$
$$\Rightarrow \quad \text{Actual work} = 0.8 \times 972.563 = 778.05 \text{ kJ/kg}$$

14. (d)

$$W_t = 120 \text{ kJ}, W_c = 60 \text{ kJ}, Q = 200 \text{ kJ}$$
$$\eta_1 = \frac{W_t - W_c}{Q_1} = 30\%$$

As regenerator would recover 40% of energy from exhaust. The overall thermal efficiency would be

$$\eta_2 = \frac{W_t - W_c}{Q_1 - 0.4(Q_1 - W_t)} = \frac{120-60}{200-0.4(200-120)} = \frac{60}{168} = 35.7\%$$

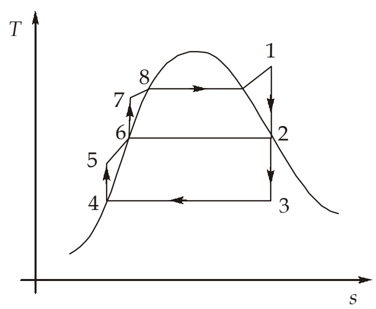
% increase in overall thermal efficiency

$$= \frac{\eta_2 - \eta_1}{\eta_1} \times 100 = \frac{35.7-30}{30} \times 100 = 19\%$$

15. (a)

Surface condensers are bulky and expensive.

17. (a)



$$h_7 - h_6 = 3 \text{ kJ/kg}$$
$$h_5 - h_4 = 1 \text{ kJ/kg}$$
$$h_1 = 3514 \text{ kJ/kg}$$
$$h_4 = 613 \text{ kJ/kg}$$
$$\text{Heat transferred in boiler} = (h_1 - h_4) - (h_7 - h_6) - (h_5 - h_4)$$
$$= (3514 - 613) - 3 - 1 = 2897 \text{ kJ/kg}$$

18. **(b)**
For maximum discharge of hot gases through the chimney height of hot gas column producing draught is equal to the height of the chimney.

19. **(b)**

$$h_3 = Xh_1 + (1 - X)h_2$$
$$720 = X \times 2800 + (1 - X)\,200$$
$$X = 0.2 = 20\%$$

20. **(b)**
Work developed in the turbine= $(h_5 - h_4) + (h_3 - h_2) + (1 - m)(h_2 - h_1)$

21. **(d)**
The Benson boiler feed pump feeds water to economizer from where it goes to radiant heating section here, most of the heat is transmitted and water gets heated almost to the critical temperature in the evaporative section the evaporation is completed and superheating super heating is done by convective super heater and radiation superheater after super heater the final temperature is obtained.

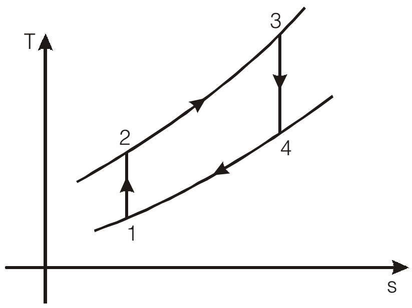
23. **(b)**

$$\text{Chimney efficiency, } \eta = \frac{gH_1}{C_{pg}\left(T_g - T_{ga}\right)} = \frac{9.81 \times 720}{900 \times (380 - 355)} = 31.39\%$$

24. **(a)**

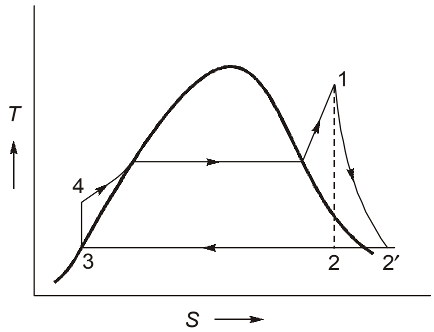
$$\text{Propulsive power of rocket} = \frac{\dot{m}_a\left(V_j^2 - V_a^2\right)}{2} = \frac{2.2 \times \left(600^2 - 550^2\right)}{2} = 63.25 \text{ kW}$$

25. **(c)**



$$P_3 = P_2 = 1200 \text{ kPa}$$
$$P_1 = 100 \text{ kPa}$$
$$T_3 = 1273 \text{ K}$$
$$T_1 = 293 \text{ K}$$
$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$
$$\frac{T_2}{293} = \left(\frac{1200}{100}\right)^{\frac{0.667}{1.667}}$$
$$T_2 = 791.898 \text{ k}$$
$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} = \frac{W_{net}}{Q_s} = \frac{W_{net}}{C_p(T_3 - T_2)}$$
$$0.63 = \frac{W_{net}}{0.5203(1273 - 791.893)}$$
$$W_{net} = 157.69 \text{ kJ}$$

26. (d)



$$h_1 = 2295 \text{ kJ/kg}$$
$$s_1 = 6.5422 \text{ kJ/kgK}$$
$$s_{3f} = 0.4763 \text{ kJ/kgK}$$
$$s_{2'} = 8.396 \text{ kJ/kgK}$$
$$s_2 = s_{3f} + x(s_{2'} - s_{3f})$$
$$s_2 = 0.4763 + x(8.396 - 0.4763)$$
$$s_1 = 6.5422$$

$\therefore$
$$x = \frac{6.5422 - 0.4763}{8.396 - 0.4763} = 0.7659$$

27. (b)

The cyclone separators collection efficiency increases with increasing:

1. Particle size
2. Particle density
3. Inlet gas velocity
4. Cyclone body length
5. Number of gas revolutions
6. Smoothness of cyclone walls

28. (b)

As
$$\eta_{th} = 0.333 \simeq \frac{1}{3} = \frac{W}{Q_{in}} \text{ or } Q_{in} = 3 \times 500$$

$\Rightarrow$ $Q_{in} = 1500$ MW, now heat rejected $Q_r = Q_{in} - W = 1000$ MW

As heat will be carried away by cooling water, so

$$m_w \times C_{PW} \times (\Delta T)_W = 1000 \times 10^3 \text{ kW}$$
$$m_w \times 4.2 \times 5 = 1000 \times 10^3 \text{ kW}$$

$\Rightarrow$ $m_w = 47.62 \times 10^3$ kg/s

or $m_w = 47.62$ tons/s

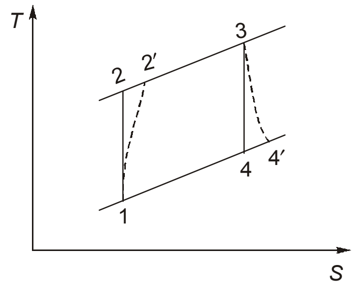
or $m_w = 47.62 \times 3600$ tons/hr

$m_w = 1.71 \times 10^5$ tons/hr

29. (a)

$$T_2 = T_1 \times (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$= 300 \times (5)^{\frac{0.4}{1.4}} = 475.15\text{K}$$



$$\eta_c = \frac{T_2 - T_1}{T_2' - T_1}$$

$$\Rightarrow \quad 0.8 = \frac{475.15 - 300}{T_2' - 300}$$

$$\Rightarrow \quad T_2' = 519 \text{ K}$$

Heat supplied, $Q_s = C_p(T_3 - T'_2)$ = 1.005 (1100 – 519) = 584 kJ/kg of air

As 10% of heating value is lost i.e. efficiency of heat is 90%. So, each kg of fuel contributes

$$0.9 \times 41800 = 37620 \text{ kJ}$$

$$\therefore \quad \text{Air fuel ratio} = \frac{37620}{584} = 64.4$$

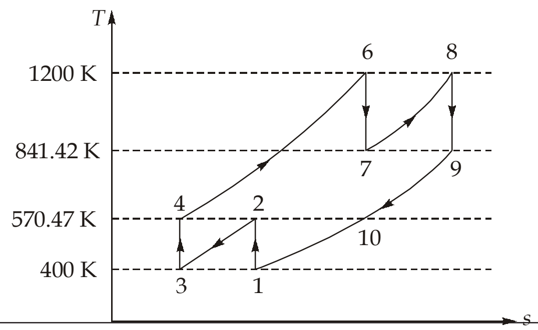
30. (a)

For perfect intercooler, $r_p = \frac{P_2}{P_1} = \frac{P_4}{P_3} = \sqrt{12} = 3.464,$

and $\frac{P_6}{P_7} = \frac{P_8}{P_9} = \sqrt{12} = 3.464,$

γ(air) = 1.4

C_p(air) = 1.005 kJ/kg· K



For ideal conditions, work output of each turbine and work input of each compressor would be same.

Now, $T_4 = T_2 = T_1 \left(r_p\right)^{\frac{\gamma-1}{\gamma}} = 400(3.464)^{\frac{1.4-1}{1.4}} = 570.47 \text{ K}$

and $T_9 = T_7 = \dfrac{T_8}{\left(r_p\right)^{\frac{\gamma-1}{\gamma}}} = \dfrac{1200}{(3.464)^{\frac{1.4-1}{1.4}}} = 841.42 \text{ K}$

Now, total compressor work $= 2\left(h_2 - h_1\right) = 2C_p\left(T_2 - T_1\right) = 2 \times 1.005 \times (570.47 - 400)$

$= 342.65$ kJ/kg

and total work of turbine $= 2(h_6 - h_7) = 2C_P(T_6 - T_7) = 2 \times 1.005\ (1200 - 841.42)$

$= 720.74$ kJ/kg

So, back work ratio $= \dfrac{W_C}{W_T} = \dfrac{342.65}{720.74} = 0.475$

■■■■