Answer Key

Steam Engines and Hydro Electric Power Plants

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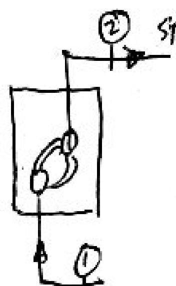

② STEAM
$m_s = 12\ kg/s$
$P_2 = 5\ MPa$
$t_2 = 400°C$

① FEEDWATER
$t_1 = 200°C$

$$DBH = \frac{m_s (h_s - h_f)}{35316}$$

$$Bohp = 35316\ kJ/hr$$

$$\dot{m}_s = kg/hr$$

from steam tables:

$$h_f = h_f @ 200°C = 852.45\ kJ/kg$$

$$h_s = h_s @ 5\ MPa\ \&\ 400°C = 3195.7\ kJ/kg$$

$$DBH = \frac{(12\ kg/s)\left(\frac{3600\ s}{1\ hr}\right)(3195.7 - 852.45)\ kJ/kg}{35316}$$

$$\boxed{DBH = 2866.36\ hp}$$

Percent Rating ; $\% R = \frac{DBH}{RBH} * 100\%$

(for water tube boiler)

$$RBH = \frac{HS}{0.91} = \frac{520\ m^2}{0.91}$$

$$RBH = 571.4286\ \text{Bo. hp}$$

Subst; $\% R = \frac{940\ \text{bo. hp}}{571.4286\ \text{Bo. hp}}$

$$\boxed{\% R = 164.5\%}$$

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Factor of Evaporation; $FE = 1.20$

$$m_s = 0.75\ \text{kg/s}$$

$$DBH = \frac{m_s(h_s - h_F)}{35316} \quad ; \quad FE = \frac{h_s - h_F}{2257}$$

$$1.20 = \frac{h_s - h_F}{2257}$$

$$h_s - h_F = 2708.4\ \text{kJ/kg}$$

Then;

$$DBH = \frac{\left(0.75\ \text{kg/s}\right)\left(\frac{3600\ s}{1\ hr}\right)\left(2708.4\ \text{kJ/kg}\right)}{35316}$$

$$\boxed{DBH = 207.0642\ \text{Bo. hp.}}$$

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$\%R = 210\%$

$F.E. = 1.15$

$HS = 310\ m^2$

$FE = \frac{h_s - h_F}{2257}$

$1.15 = \frac{h_s - h_F}{2257}$

$h_s - h_F = 2595.55\ KJ/kg$

For $\dot{m}_s$;

$DBH = \frac{m_s (h_s - h_F)}{35316}$; $\%R = \frac{DBH}{RBH}$

For water tube:

$RBH = \frac{HS}{0.91} = \frac{310\ m^2}{0.91}$

$RBH = 340.6593\ Bo.hp$

subst;

$2.10 = \frac{DBH}{340.6593\ Bo\ hp}$

$DBH = 715.3846\ Bo.hp$

therefore;

$715.3846\ Bo.hp = \frac{m_s (2595.55\ KJ/kg)}{35316}$

$\boxed{m_s = 9733.7838\ Kg/hr}$

Boiler Efficiency; $\eta_B = \dfrac{m_s(h_s - h_f)}{m_F\, HHV}$

Actual Specific Evaporation $= ASE = \dfrac{m_s}{m_F}$

$$\eta_B = \frac{ASE\,(h_s - h_f)}{HHV}$$

$$FE = \frac{h_s - h_f}{2257}$$

$$1.18 = \frac{h_s - h_f}{2257}$$

$$h_s - h_f = 2663.26 \text{ KJ/Kg}$$

therefore;

$$\eta_B = \frac{8.3\,(2663.26 \text{ KJ/g})}{26500 \text{ KJ/g}}$$

$$\boxed{\eta_B = 83.42\%}$$

$$\eta_{B_{NET}} = \frac{m_s(h_s - h_F) - \text{Auxiliaries}}{m_F\, HHV}$$

$$= \frac{25\,800\,325\ \text{kJ/hr} - (2.8\times10^3\ \text{kJ/s})\left(\frac{3600\,s}{1\,hr}\right)}{33\,000\,000\ \text{kJ/hr}}$$

$$\boxed{\eta_{B_{net}} = 47.64\,\%}$$

$$\text{Days of consumption} = \frac{160\,000 \text{ kg}}{(360+110) \text{ kg/hr}} = (340.4255 \text{ hrs})\left(\frac{1 \text{ day}}{24 \text{ hrs}}\right)$$

$$\boxed{\text{Days of consumption} = 14.1843 \text{ days}}$$

$$\eta_B = \frac{m_s(h_s - h_F)}{m_F\, HHV}$$

$$0.834 = \frac{\left(\frac{998000\text{ lb}}{5\text{ hr}}\right)(1380 - 255)\text{ Btu/lb}}{m_F\,(15980\text{ Btu/lb})}$$

$$\dot{m}_F = \left(16894.0849\ \frac{\text{lb}}{\text{hr}}\right)\left(\frac{1\text{ short ton}}{2000\text{ lb}}\right)\left(\frac{24\text{ hrs}}{1\text{ day}}\right)$$

$$\boxed{\dot{m}_F = 202.1862\text{ tons/day}}$$

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Steam Engine

Mechanical efficiency

$$\eta_m = \frac{BP}{IP}$$

$$0.85 = \frac{(70\ \text{bhp})\left(\frac{0.746\ \text{kW}}{1\ \text{hp}}\right)}{IP}$$

$$IP = 61.4353\ \text{kW}$$

Indicated engine efficiency

$$\eta_{ei} = \frac{IP}{m_s(h_1 - h_2)}$$

$$h_1 = h_g @ 1049.1\ \text{kPa} = 2779.9\ \text{kJ/kg}$$

$$h_2 = h_f @ 125.06\ \text{kPa} = 444.37\ \text{kJ/kg}$$

$$\eta_{ei} = \frac{61.4353\ \text{kW}}{\left(745.48\ \frac{\text{kg}}{\text{hr}}\right)\left(\frac{1\ \text{hr}}{3600\ \text{s}}\right)(2779.9 - 444.37)\ \text{kJ/kg}}$$

$$\boxed{\eta_{ei} = 12.70\%}$$

$$IP = P_{mI} V_D$$

$$V_D = 2\left[\frac{\pi D^2}{4}\,\frac{LN}{60}\right]$$

$$= 2\left[\frac{\pi}{4}(0.320\,m)^2(0.480\,m)\left(\frac{250\,rpm}{60}\right)\right]$$

$$V_D = 0.3217\ m^3/s$$

and;

$$IP = \left(4.8\ kg/cm^2\right)\left(\frac{9.81\ m/s^2}{1000\ \frac{kg-m}{kN-s^2}}\right)\left(\frac{100\,cm}{1\,m}\right)^2\left(0.3217\ m^3/s\right)$$

$$IP = (151.4821\ kW)\left(\frac{1\,hp}{0.746\ kW}\right)$$

$$\boxed{IP = 203.0591\ hp}$$

$$\eta_c = \frac{W_T}{Q_A} = \frac{IP}{Q_A} = \frac{h_1 - h_2}{h_1 - h_{f2}}$$

$h_1 = h$ @ 2.5 MPa and 240°C = 2851.7 kJ/kg

$S_1 = S$ @ 2.5 MPa & 240°C = 6.3536 kJ/kg-K

$S_1 = S_2 = S_f + x_2 S_{fg}$

S_f @ 0.18 MPa = 1.4944 kJ/kg-K

S_{fg} @ 0.18 MPa = 5.6679 kJ/kg-K

$6.3536\ \text{kJ/kg-K} = 1.4944\ \text{kJ/kg-K} + x_2(5.6675\ \text{kJ/kg-K})$

$x_2 = 85.73\%$

from;

$h_2 = h_f + x_2 h_{fg}$

h_f @ 0.18 MPa = 490.68 kJ/kg

h_{fg} @ 0.18 MPa = 2211.2 kJ/kg

$h_2 = 490.68\ \text{kJ/kg} + (0.8573)(2211.2\ \text{kJ/kg})$

$h_2 = 2386.3844\ \text{kJ/kg}$

$$\eta_c = \frac{(2851.7 - 2386.3844)\ \text{kJ/kg}}{(2851.7 - 490.68)\ \text{kJ/kg}} * 100\%$$

$\boxed{\eta_c = 19.71\%}$

exponential LEAP ONLINE REVIEW

$$\eta_m = \frac{BP}{IP} \quad ; \quad \eta_i = \frac{IP}{m_s(h_1 - h_2)}$$

$$0.70 = \frac{IP}{\left(\frac{3200}{3600}\right)\frac{kg}{sec}\left(2700 - 2200\right)\text{kJ/kg}}$$

$$IP = 311.11 \text{ kW}$$

Subst;

$$0.85 = \frac{BP}{311.11 \text{ kW}}$$

$$\boxed{BP = 264.44 \text{ kW}}$$

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$$N_s = \frac{0.2623 N \sqrt{kW}}{H^{5/4}} = \frac{0.2623 (460 \text{ rpm}) \sqrt{2000 \text{ kW}}}{(30 \text{ m})^{5/4}}$$

$$\boxed{N_s = 76.8545 \text{ rpm}}$$

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$$H_E = H_g - H_L$$

$$H_E = \frac{P}{\gamma} + \frac{v^2}{2g_o} + z = \frac{360\ kPa}{9.81\ kN/m^3} + \frac{(8.5\ m/s)^2}{2(9.81\ m/s^2)} + 3.2\ m$$

$$\boxed{H_E = 45.6185\ m}$$

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$$FP = \frac{2\pi TN}{60} = \frac{2\pi(0.550\ kN\text{-}m)(180\ rpm)}{60} = 10.3673\ kW$$

$$WP = Q\gamma H_E$$

$$H_E = 68\ m - \frac{(4.80\ m/s)^2}{2(9.81\ m/s^2)} = 66.8257\ m$$

$$WP = (0.85\ m^3/s)(9.81\ kN/m^3)(66.8257\ m)$$

$$WP = 557.226\ kW$$

Hence;

$$BP = WP - FP$$

$$= (557.226 - 10.3673)\ kW$$

$$\boxed{BP = 546.8587\ kW}$$

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$H_W = 620\ m$

$T_W = 500\ m$

$A = (3.8\ m)(0.50\ m) = 1.9\ m^2$

$v = 6.0\ m/s$

plant operation = 345 days/yr

$\eta_H = 80\%$

$\eta_g = 90\%$

$H_L = 5\%\ H_g$

Req'd : Energy required in kW-hr

$WP = Q \gamma_w H_E$

$H_E = H_g - H_L = 120m - (0.05)(120m)$

$H_E = 114\ m$

$WP = (1.9\ m^2)(6.0\ m/s)(9.81\ kN/m^3)(114\ m)$

$WP = 12749.076\ kW$

Hence;

$\eta_H \eta_g = \frac{BP}{WP}$

$(0.80)(0.90) = \frac{BP}{12749.076\ kW}$

$BP = (9179.3347\ kW)\left(\frac{24\text{-hrs}}{1\ day}\right)\left(345\ \frac{days}{yr}\right)$

$\boxed{BP = 76004891.48\ kW\text{-}hr}$

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exponential LEAP
ONLINE REVIEW

$$N_s = \frac{0.2623\, N \sqrt{kW}}{H^{5/4}}$$

$$80\text{ rpm} = \frac{0.2623\,(450\text{ rpm})\sqrt{120\text{ kW}}}{H^{5/4}}$$

$$H = 9.2642\text{ m}$$

Hence;

$$\#\text{ of turbines} = \frac{40\text{ m}}{9.2642\text{ m}}$$

$$\#\text{ of turbines} = 4.3177$$

$$\boxed{\text{use; 5 turbines}}$$

$$WP = Q \gamma_w H_E$$

$$= \left(28\ m^3/s\right)\left(9.81\ kN/m^3\right)\left(42\ m\right)$$

$$WP = 11536.56\ kW$$

Hence;

$$\eta_g \eta_H = \frac{BP}{WP}$$

$$(0.90)(0.85) = \frac{BP}{11536.56\ kW}$$

$$\boxed{BP = 8825.4684\ kW}$$