Final1

Equations

Mass flow rates

$$\dot{m}_1 = 206.6 \ \text{[kg/s]} \quad (1)$$

$$\dot{m}_2 = 206.6 \ \text{[kg/s]} \quad (2)$$

$$\dot{m}_3 = 206.6 \ \text{[kg/s]} \quad (3)$$

$$\dot{m}_4 = 206.6 \ \text{[kg/s]} \quad (4)$$

$$\dot{m}_5 = 43.5 \ \text{[kg/s]} \quad (5)$$

$$\dot{m}_6 = 163.1 \ \text{[kg/s]} \quad (6)$$

$$\dot{m}_7 = 163.1 \ \text{[kg/s]} \quad (7)$$

$$\dot{m}_8 = 163.1 \ \text{[kg/s]} \quad (8)$$

$$\dot{m}_9 = 163.1 \ \text{[kg/s]} \quad (9)$$

$$\dot{m}_{10} = 163.1 \ \text{[kg/s]} \quad (10)$$

$$\dot{m}_{11} = 163.1 \ \text{[kg/s]} \quad (11)$$

$$\dot{m}_{12} = 163.1 \ \text{[kg/s]} \quad (12)$$

$$\dot{m}_{13} = 163.1 \ \text{[kg/s]} \quad (13)$$

$$\dot{m}_{14} = 4.8 \ \text{[kg/s]} \quad (14)$$

$$\dot{m}_{15} = 4.8 \ \text{[kg/s]} \quad (15)$$

$$\dot{m}_{16} = 4.8 \ \text{[kg/s]} \quad (16)$$

$$\dot{m}_{17} = 4.8 \ \text{[kg/s]} \quad (17)$$

$$\dot{m}_{18} = 4.8 \ \text{[kg/s]} \quad (18)$$

$$\dot{m}_{19} = 38.7 \ \text{[kg/s]} \quad (19)$$

$$\dot{m}_{20} = 38.7 \ \mathrm{[kg/s]} \tag{20}$$

$$\dot{m}_{21} = 38.7 \ \mathrm{[kg/s]} \tag{21}$$

$$\dot{m}_{22} = 38.7 \ \mathrm{[kg/s]} \tag{22}$$

Specific Enthalpy

$$h_1 = 116.8 \ \mathrm{[kJ/kg]} \tag{23}$$

$$h_2 = 142.3 \ \mathrm{[kJ/kg]} \tag{24}$$

$$h_3 = 1381 \ \mathrm{[kJ/kg]} \tag{25}$$

$$h_4 = 6574 \ \mathrm{[kJ/kg]} \tag{26}$$

$$h_5 = 6574 \ \mathrm{[kJ/kg]} \tag{27}$$

$$h_6 = 6574 \ \mathrm{[kJ/kg]} \tag{28}$$

$$h_7 = 5027 \ \mathrm{[kJ/kg]} \tag{29}$$

$$h_8 = 6587 \ \mathrm{[kJ/kg]} \tag{30}$$

$$h_9 = 5053 \ \mathrm{[kJ/kg]} \tag{31}$$

$$h_{10} = 2973 \ \mathrm{[kJ/kg]} \tag{32}$$

$$h_{11} = 2739 \ \mathrm{[kJ/kg]} \tag{33}$$

$$h_{12} = 116.7 \ \mathrm{[kJ/kg]} \tag{34}$$

$$h_{13} = 154.4 \ \mathrm{[kJ/kg]} \tag{35}$$

$$h_{14} = 30212 \ \mathrm{[kJ/kg]} \tag{36}$$

$$h_{15} = 3958 \ \mathrm{[kJ/kg]} \tag{37}$$

$$h_{16} = 11226 \ \mathrm{[kJ/kg]} \tag{38}$$

$$h_{17} = 3958 \ \mathrm{[kJ/kg]} \tag{39}$$

$$h_{18} = 20566 \ \mathrm{[kJ/kg]} \tag{40}$$

$$h_{19} = 1827 \ [\mathrm{kJ/kg}] \tag{41}$$

$$h_{20} = 1.641 \ [\mathrm{kJ/kg}] \tag{42}$$

$$h_{21} = 493.8 \ [\mathrm{kJ/kg}] \tag{43}$$

$$h_{22} = -187.1 \ [\mathrm{kJ/kg}] \tag{44}$$

Specific Entropy

$$s_1 = 0.4067 \ [\mathrm{kJ/kg \cdot K}] \tag{45}$$

$$s_2 = .4255 \ [\mathrm{kJ/kg \cdot K}] \tag{46}$$

$$s_3 = 3.289 \ [\mathrm{kJ/kg \cdot K}] \tag{47}$$

$$s_4 = 8.725 \ [\mathrm{kJ/kg \cdot K}] \tag{48}$$

$$s_5 = 8.725 \ [\mathrm{kJ/kg \cdot K}] \tag{49}$$

$$s_6 = 8.725 \ [\mathrm{kJ/kg \cdot K}] \tag{50}$$

$$s_7 = 8.999 \ [\mathrm{kJ/kg \cdot K}] \tag{51}$$

$$s_8 = 9.915 \ [\mathrm{kJ/kg \cdot K}] \tag{52}$$

$$s_9 = 10.2 \ [\mathrm{kJ/kg \cdot K}] \tag{53}$$

$$s_{10} = 7.947 \ [\mathrm{kJ/kg \cdot K}] \tag{54}$$

$$s_{11} = 9.003 \ [\mathrm{kJ/kg \cdot K}] \tag{55}$$

$$s_{12} = 0.4068 \ [\mathrm{kJ/kg \cdot K}] \tag{56}$$

$$s_{13} = 0.53 \ [\mathrm{kJ/kg \cdot K}] \tag{57}$$

$$s_{14} = 95.36 \ [\mathrm{kJ/kg \cdot K}] \tag{58}$$

$$s_{15} = 66.79 \ [\mathrm{kJ/kg \cdot K}] \tag{59}$$

$$s_{16} = 67.7 \ [\mathrm{kJ/kg \cdot K}] \tag{60}$$

$$s_{17} = 53.46 \ [\mathrm{kJ/kg \cdot K}] \tag{61}$$

$$s_{18} = 53.48 \ [\mathrm{kJ/kg{\cdot}K}] \tag{62}$$

$$s_{19} = 2.816 \ [\mathrm{kJ/kg{\cdot}K}] \tag{63}$$

$$s_{20} = 0.8453 \ [\mathrm{kJ/kg{\cdot}K}] \tag{64}$$

$$s_{21} = 493.8 \ [\mathrm{kJ/kg{\cdot}K}] \tag{65}$$

$$s_{22} = -187.1 \ [\mathrm{kJ/kg{\cdot}K}] \tag{66}$$

Temperatures

$$T_1 = 301 \ [\mathrm{K}] \tag{67}$$

$$T_2 = 302.8 \ [\mathrm{K}] \tag{68}$$

$$T_3 = 581.9 \ [\mathrm{K}] \tag{69}$$

$$T_4 = 2000 \ [\mathrm{K}] \tag{70}$$

$$T_5 = 2000 \ [\mathrm{K}] \tag{71}$$

$$T_6 = 2000 \ [\mathrm{K}] \tag{72}$$

$$T_7 = 1426.7 \ [\mathrm{K}] \tag{73}$$

$$T_8 = 2000 \ [\mathrm{K}] \tag{74}$$

$$T_9 = 1435.5 \ [\mathrm{K}] \tag{75}$$

$$T_{10} = 523.15 \ [\mathrm{K}] \tag{76}$$

$$T_{11} = 400 \ [\mathrm{K}] \tag{77}$$

$$T_{12} = 301 \ [\mathrm{K}] \tag{78}$$

$$T_{13} = 310 \ [\mathrm{K}] \tag{79}$$

$$T_{14} = 2000 \ [\mathrm{K}] \tag{80}$$

$$T_{15} = 300 \ [\mathrm{K}] \tag{81}$$

$$T_{16} = 800 \ [\mathrm{K}] \tag{82}$$

$$T_{17} = 300 \ [\mathrm{K}] \tag{83}$$

$$T_{18} = 1400 \ [\mathrm{K}] \tag{84}$$

$$T_{19} = 2000 \ [\mathrm{K}] \tag{85}$$

$$T_{20} = 300 \ [\mathrm{K}] \tag{86}$$

$$T_{21} = 800 \ [\mathrm{K}] \tag{87}$$

$$T_{22} = 91 \ [\mathrm{K}] \tag{88}$$

Work output of the high pressure turbine

$$W_{hpt} = \dot{m}_6 \cdot h_6 - \dot{m}_7 \cdot h_7 \tag{89}$$

$$\dot{m}_6 \cdot s_6 + s_{genHPT} = \dot{m}_7 \cdot s_7 \tag{90}$$

Work output of the medium pressure turbine

$$W_{mpt} = \dot{m}_8 \cdot h_8 - \dot{m}_9 \cdot h_9 \tag{91}$$

$$\dot{m}_8 \cdot s_8 + s_{genMPT} = \dot{m}_9 \cdot s_9 \tag{92}$$

Work output of the condensing turbine

$$W_{ct} = \dot{m}_{10} \cdot h_{10} - \dot{m}_{11} \cdot h_{11} \tag{93}$$

$$\dot{m}_{10} \cdot s_{10} + s_{genCT} = \dot{m}_{11} \cdot s_{11} \tag{94}$$

Solar Receiver

$$\dot{m}_3 \cdot h_3 + \dot{m}_7 \cdot h_7 + Q_{rv} = \dot{m}_3 \cdot h_4 + \dot{m}_7 \cdot h_8 \tag{95}$$

Solar Reactor

$\dot{m}$[5] * h[5] + Q$_{rc}$ = $\dot{m}$[14] * h[14] + $\dot{m}$[19] * h[19]

Heat Exchanger

$\dot{m}$[2] * h[2] + $\dot{m}$[9] * h[9] = $\dot{m}$[3] * h[3] + $\dot{m}$[10] * h[10]

$$\dot{m}_2 \cdot s_2 + \dot{m}_9 \cdot s_9 + s_{genhx} = \dot{m}_3 \cdot s_3 + \dot{m}_{10} \cdot s_{10} \tag{96}$$

Intercooler

$$\dot{m}_{11} \cdot h_{11} = \dot{m}_{12} \cdot h_{12} + Q_{cool} \tag{97}$$

$$\dot{m}_{11} \cdot s_{11} + s_{cool} = \dot{m}_{12} \cdot s_{12} + \frac{Q_{cool}}{T_{12}} \tag{98}$$

Intercooler 1

$$\dot{m}h2 \cdot h_{14} = \dot{m}h2 \cdot h_{15} + Q_{cool1} \tag{99}$$

$$\dot{m}_{14} \cdot s_{14} + s_{cool1} = \dot{m}_{15} \cdot s_{15} + \frac{Q_{cool1}}{T_{15}} \tag{100}$$

Compressor 1

$$\dot{m}h2 \cdot h_{15} + W_{c1} = \dot{m}h2 \cdot h_{16} \tag{101}$$

$$\dot{m}_{15} \cdot s_{15} + s_{genc1} = \dot{m}_{16} \cdot s_{16} \tag{102}$$

Intercooler 2

$$\dot{m}_{16} \cdot h_{16} = \dot{m}_{17} \cdot h_{17} + Q_{cool2} \tag{103}$$

$$\dot{m}_{16} \cdot s_{16} + s_{cool2} = \dot{m}_{17} \cdot s_{17} + \frac{Q_{cool2}}{T_{17}} \tag{104}$$

Compressor 2

$$\dot{m}h2 \cdot h_{18} + W_{c2} = \dot{m}h2 \cdot h_{17} \tag{105}$$

$$\dot{m}_{18} \cdot s_{18} + s_{genc2} = \dot{m}_{17} \cdot s_{17} \tag{106}$$

Intercooler 3

$$\dot{m}_{19} \cdot h_{19} = \dot{m}_{20} \cdot h_{20} + Q_{cool3} \tag{107}$$

$$\dot{m}_{19} \cdot s_{19} + s_{cool3} = \dot{m}_{20} \cdot s_{20} + \frac{Q_{cool3}}{T_{20}} \tag{108}$$

Compressor 3

$$\dot{m}_{20} \cdot h_{20} + W_{c3} = \dot{m}_{21} \cdot h_{21} \tag{109}$$

$$\dot{m}_{20} \cdot s_{20} + s_{genc3} = \dot{m}_{21} \cdot s_{21} \tag{110}$$

Liquification

$$\dot{m}_{21} \cdot h_{21} + W_{liq} = \dot{m}_{22} \cdot h_{22} \tag{111}$$

$$\dot{m}_{21} \cdot s_{21} + s_{genliq} = \dot{m}_{22} \cdot s_{22} \tag{112}$$

$\dot{m}$[21] * s[21] + s$_{genc3}$ = $\dot{m}$[22] * s[22]

Water Pump 1

$$\dot{m}_{12} \cdot h_{12} + W_{p1} = \dot{m}_{13} \cdot h_{13} \tag{113}$$

$$\dot{m}_{12} \cdot s_{12} + s_{genp1} = \dot{m}_{13} \cdot s_{13} \tag{114}$$

Water Pump 2

$$\dot{m}_1 \cdot h_1 + W_{p2} = \dot{m}_2 \cdot h_2 \tag{115}$$

$$\dot{m}_1 \cdot s_1 + s_{genp2} = \dot{m}_2 \cdot s_2 \tag{116}$$

Overall Energy Efficiency

0.2507= (η_{hpt} * W_{hpt} + η_{mpt} * W_{mpt} + η_{ct} * W_{ct} - η_{c1} * W_{c1} - η_{c2} * W_{comp2} - η_{c3} * W_{c3} - η_{p1} * W_{p1} - η_{p2} * W_{p2} +$\dot{m}$h2 * HHV + $\dot{m}$O2 * h_{O2})/(Q_{rv} + Q_{rc1})

$$\eta_{enoverall} = \frac{\eta_{hpt} \cdot W_{hpt} + \eta_{mpt} \cdot W_{mpt} + \eta_{ct} \cdot W_{ct} - \eta_{c1} \cdot W_{c1} - \eta_{c2} \cdot W_{c2} - \eta_{c3} \cdot W_{c3} - \eta_{p1} \cdot W_{p1} - \eta_{p2} \cdot W_{p2} + \dot{m}h2 \cdot HHV + \dot{m}O}{Q_{rv} + Q_{rc}}$$

Q_{rc1} = 210459 [kJ/s]

W_{comp2} = 80381 [kJ/s]

$$\eta_{hpt} = 0.8 \tag{118}$$

$$\eta_{mpt} = 0.8 \tag{119}$$

$$\eta_{ct} = 0.8 \tag{120}$$

$$\eta_{c1} = 0.8 \tag{121}$$

$$\eta_{c2} = 0.8 \tag{122}$$

$$\eta_{c3} = 0.8 \tag{123}$$

$$\eta_{p1} = 0.95 \tag{124}$$

$$\eta_{p2} = 0.95 \tag{125}$$

$$HHV = 141.8 \cdot 1000 \ \ [\text{kJ/kg}] \tag{126}$$

$$\dot{m}h2 = 4.8 \ \ [\text{kg/s}] \tag{127}$$

$$\dot{m}O2 = 38.7 \ \ [\text{kg/s}] \tag{128}$$

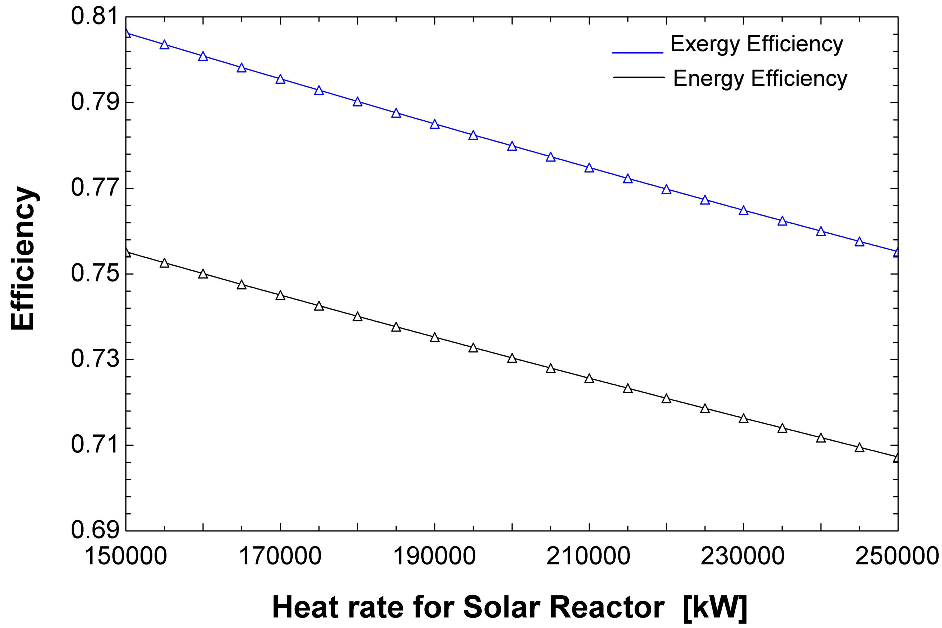
$$h_{O2} = -191 \ \ [\text{kJ/kg}] \tag{129}$$

$$\eta_{exoverall} = \frac{\eta_{hpt} \cdot W_{hpt} + \eta_{mpt} \cdot W_{mpt} + \eta_{ct} \cdot W_{ct} - \eta_{c1} \cdot W_{c1} - \eta_{c2} \cdot W_{c2} - \eta_{c3} \cdot W_{c3} - \eta_{p1} \cdot W_{p1} - \eta_{p2} \cdot W_{p2} + \dot{m}h2 \cdot ex_{h2} + \dot{m}O2}{Q_{rv} \cdot (1 - 298/2000) + Q_{rc} \cdot (1 - 298/2000)}$$

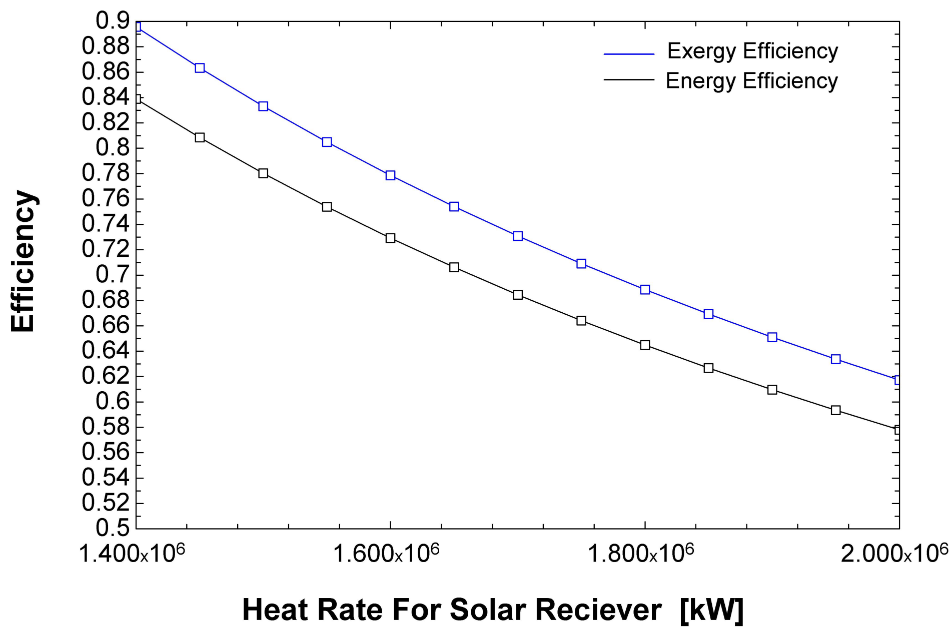
$$ex_{h2} = 118030 \ \ [\text{kJ/kg}] \tag{131}$$

$$ex_{O2} = 124.0625 \ \ [\text{kJ/kg}] \tag{132}$$

Plot Window 1: Efficiencies vs solar reactor heat rate



Plot Window 2: Efficiencies vs solar reciever heat rate



Plot Window 3: Efficiencies vs mass flow rate of hydrogen