REPUBLIC OF THE PHILIPPHNES
BATANGAS STATE UNIVERSITY
THE NATIONAL ENGINEERING UNVERSITY
ALANGILAN CAMPUS
COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

ME 425 - POWER PLANT DESIGN WITH RENEWABLE ENERGY

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PROBLEM

A NUCLEAR POWER PLANT OPERATES WITH A REACTOR COOLING SYSTEM THAT TRANSFERS HEAT FROM THE REACTOR TO THE BOILER USING LIQUID WATER AT A COOLANT PRESSURE OF 20 MPa. THE REACTOR COOLANT LEAVES THE REACTOR AT 300°C AND RUTURNS AT 260 °C AFTER TRANSFERRING HEAT TO THE BOILER, WHICH IS PART OF A SIMPLE RANKINE CYCLE SYSTEM AS SHOWN BELOW. COOLING WATER FOR THE CONDENSER ENTERS AT 15 °C AND EXITS AT 35°C. THE TURBINE GENERATES 100 MW OF SHAFT POWER AND THE CONDENSATE PUMP REQUIRES 1MW OF INPUT POWER TO CIRCULATE THE CONDENSED WATER BACK TO THE BOILER. THE THERMAL EFFICIENCY OF THE RANKINE CYCLE IS 30%

BASED ON THE INFORMATION, ANALYZE THE SYSTEM AND COMPUTE THE FOLLOWING:

A.) THE REACTOR COOLANT MASS FLOW RATE(IN MW)

B.) THE CONDENSER COOLING WATER MASS FLOW RATE (KG/SEC)

C.) THE HEAT INPUT TO THE RANKINE CYCLE FROM THE BOILER (IN MW)

D.) THE HEAT REJECTION BY THE CONDENSER(IN MW)

GIVEN:

$P_1 = 20\,MPa$ $\quad \eta_{TH} = 30\%$

$T_1 = 300°C$

$T_2 = 260°C$

$T_3 = 15°C$

$T_4 = 35°C$

$W_T = 100\,MW$

$W_P = 1\,MW$

REQUIRED:

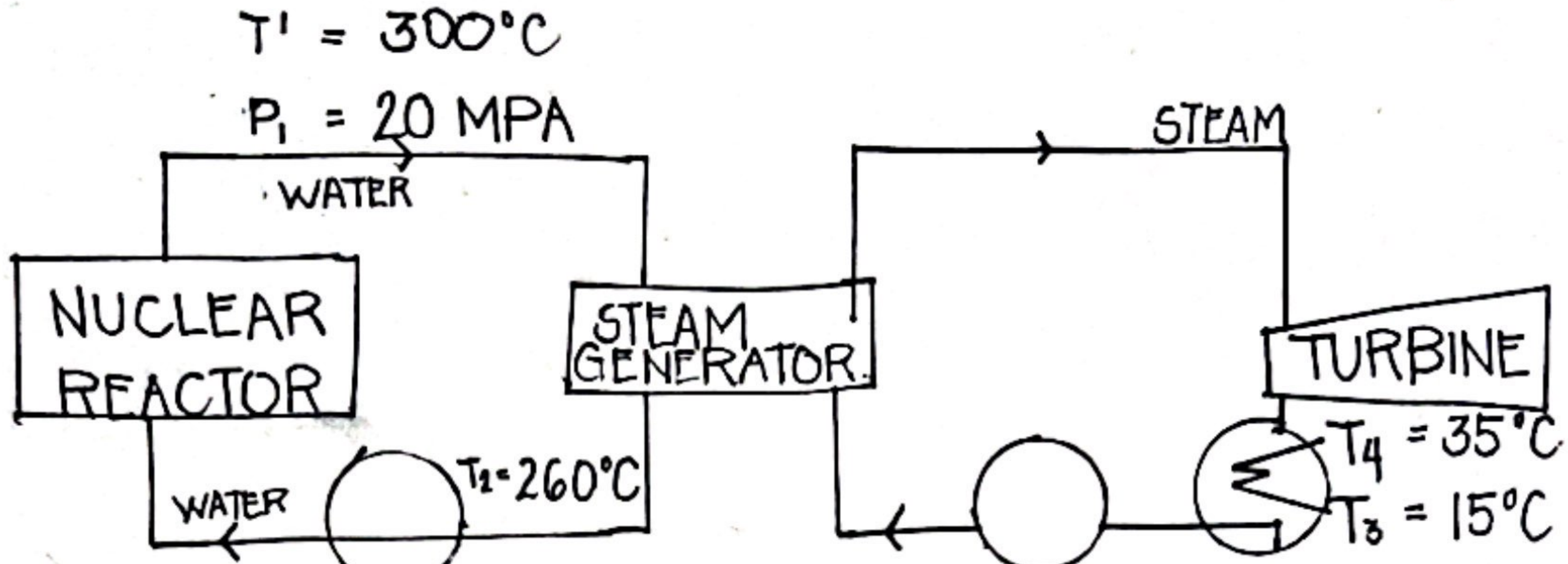
A.) m_C

B.) m_W

C.) Q_{IN}

D.) Q_{OUT}

SCHEMATIC DIAGRAM :



SOLUTION : CIRCULATING PUMP FEED WATER PUMP

AT STATE POINT A 1

$P_1 = 20$ MPa

$T_1 = 300°C$

FROM TABLE 2 : $T_{SAT} = 365.81°C$

SINCE $T_1 < T_{SAT}$, THEN SABCOOLED LIQUID

FROM TABLE 4

$h_1 = 1333.3$ KJ /KG

AT STATE POINT 2

$P_2 = P_1 = 20$ MPa

$T_2 = 260°C$

FROM TABLE 2: $T_{SAT} = 365.81°C$

SINCE $T_2 < T_{SAT}$, THEN SUBCOOLED LIQUID

FROM TABLE 4

$h_2 = 1133.5$ KJ/KG

SOLVING FOR W_{NET}

$W_{NET} = W_T - W_P$

$W_{NET} = 100\,MW - 1\,MW$

$W_{NET} = 99\,MW$

A) SOLVING FOR m_c

$Q_{IN} = m_c (h_1 - h_2)$

FOR Q_{IN}

$\eta_{TH} = \frac{W_{NET}}{Q_{IN}}$; $Q_{IN} = \frac{W_{NET}}{\eta_{TH}} = \frac{99 \text{ MW}}{0.30} = 330 \text{ MW}$

FOR m_c

$m_c = \frac{Q_{IN}}{h_1 - h_2} = \frac{330 \text{ MW} (1000 \text{ kJ/s} / 1 \text{MW})}{(1333.3 - 1133.5) \text{ kJ/kg}}$

$\boxed{m_c = 1651.651652 \text{ kg/s}}$

B) SOLVING FOR m_w

$Q_{OUT} = m_w C_{Pw} (T_4 - T_3)$

FOR Q_{OUT} =

$Q_{OUT} = Q_{IN} - W_{NET} = 330 \text{ MW} - 99 \text{ MW} = 231 \text{ MW}$

FOR MW

$m_w = \frac{Q_{OUT}}{C_{Pw}(T_4 - T_3)} = \frac{231 \text{ MW} (1000 \text{ kJ/s} / 1 \text{MW})}{(4.187 \text{ kJ/kg}\cdot\text{K})(35 - 15) \text{ K}}$

$\boxed{m_w = 2758.538333 \text{ kg/s}}$

C) SOLVING FOR QIN

$\eta_{TH} = \frac{W_{NET}}{Q_{IN}}$; $Q_{IN} = \frac{W_{NET}}{\eta_{TH}} = \frac{99 \text{ MW}}{0.30}$ $\boxed{Q_{IN} = 330 \text{ MW}}$

D) SOLVING FOR Q_{OUT}

$Q_{OUT} = Q_{IN} - W_{NET} = 330 \text{ MW} - 99 \text{ MW}$

$\boxed{Q_{OUT} = 231 \text{ MW}}$

DISCUSSION

BASED ON THE GIVEN DATA, THE REQUIRED FLOW RATE OF THE REACTOR COOLANT TO TRANSFER 330 MW OF HEA IS CALCULATED TO BE 1651.651652 kg/s. MEANWHILE, THE CONDENSER COOLING WATER NEEDS A FLOW RATE OF 2758.538333 kg/s TO DISSIPATE 231 MW OF WASTE HEAT.