Esercizi - Cicli

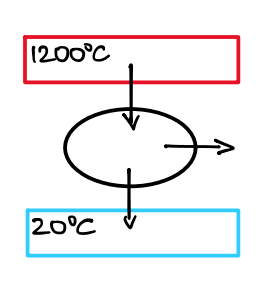
Thursday, 13 January 2022 15:06

ES 1

IRREVERSIBILE

$T_S = 1200°C$ $T_1 = 20°C$

$Q_S = 100\ KW$ $\eta_{II} = 0.5$



POTENZA PRODOTTA DALLA MACCHINA

CICLO IDEALE (REVERSIBILE)

$$\eta_{ID} = \eta_{CARNOT} = 1 - \frac{T_1}{T_2} = 0.801$$

T_1, T_2 IN [K]

RENDIMENTO DEL II PRINCIPIO

$$\eta_{II} = \frac{W_{RE}}{W_{ID}} = \frac{Q_S \cdot \eta_{RE}}{Q_S \cdot \eta_{ID}} = \frac{\eta_{RE}}{\eta_{ID}}$$

$$\eta_{RE} = \eta_{ID}\, \eta_{II} = 0.4$$

POTENZA REALMENTE PRODOTTA

$$\eta_{RE} = \frac{W_{RE}}{Q_S} \rightarrow W_{RE} = Q_{IN} \cdot \eta_{RE} = 40\ KW$$

ES 2

TURBINA A GAS

CICLO SB-APERTO $\beta = 6$ (RAPPORTO DI COMPRESSIONE)

MM (ARIA) = 28.9 Kg/KmoL MODIFICA CHIMICA TRASCURABILE

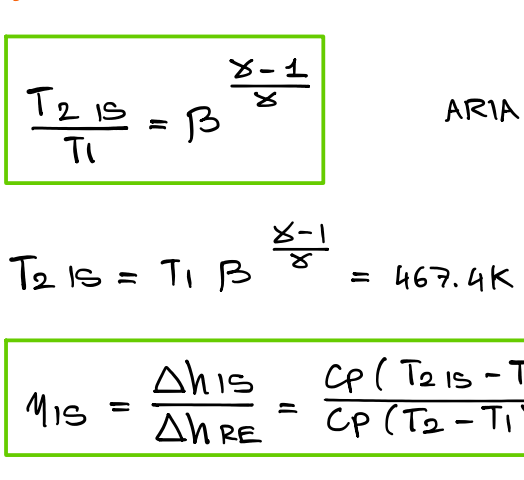
$T_1 = 280\ K$ $T_3 = 1250\ K$

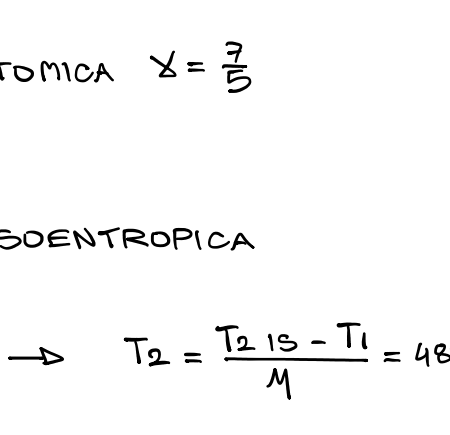
CESSIONE/INTRODUZIONE CALORE ISOBARE

η_{ISO} (COMPRESSORE) = 0.90 η_{ISO} (TURBINA) = 0.92

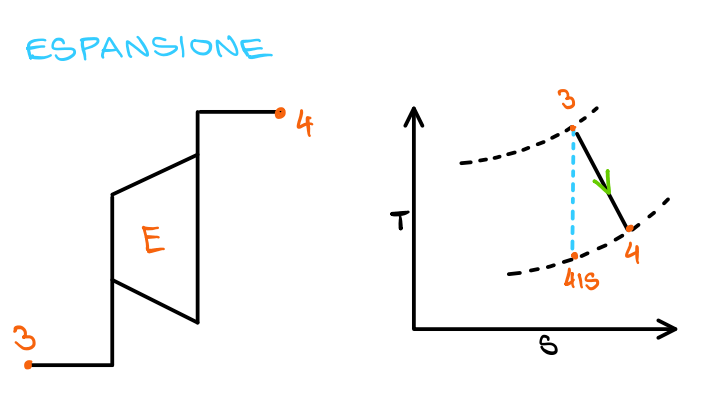
$T_3, T_4, \eta, \frac{L_{EXP}}{L_{COMP}}$?

DIAGRAMMA TS





COMPRESSORE

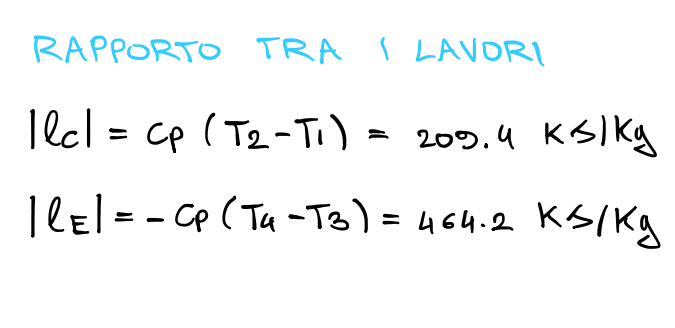


$$\frac{T_{2IS}}{T_1} = \beta^{\frac{\gamma-1}{\gamma}}$$ ARIA BIATOMICA $\gamma = \frac{7}{5}$

$$T_{2IS} = T_1\, \beta^{\frac{\gamma-1}{\gamma}} = 467.4\,K$$ ISOENTROPICA

$$\eta_{IS} = \frac{\Delta h_{IS}}{\Delta h_{RE}} = \frac{c_p (T_{2IS} - T_1)}{c_p (T_2 - T_1)} \rightarrow T_2 = \frac{T_{2IS} - T_1}{\eta} = 488\,K$$

ESPANSIONE



$$\frac{T_3}{T_{4IS}} = \beta^{\frac{\gamma-1}{\gamma}}$$ ARIA BIATOMICA $\gamma = \frac{7}{5}$

$$T_{4IS} = T_1\, \beta^{-\frac{\gamma-1}{\gamma}} = 749\,K$$ ISOENTROPICA

$$\eta_{IS} = \frac{\Delta h_{IS}}{\Delta h_{RE}} = \frac{c_p (T_3 - T_4)}{c_p (T_3 - T_{4IS})} \rightarrow T_4 = T_3 - \eta (T_3 - T_{4IS}) = 789\,K$$

RAPPORTO TRA I LAVORI

$|l_C| = c_p (T_2 - T_1) = 209.4\ KJ/Kg$

$|l_E| = -c_p (T_4 - T_3) = 464.2\ KJ/Kg$

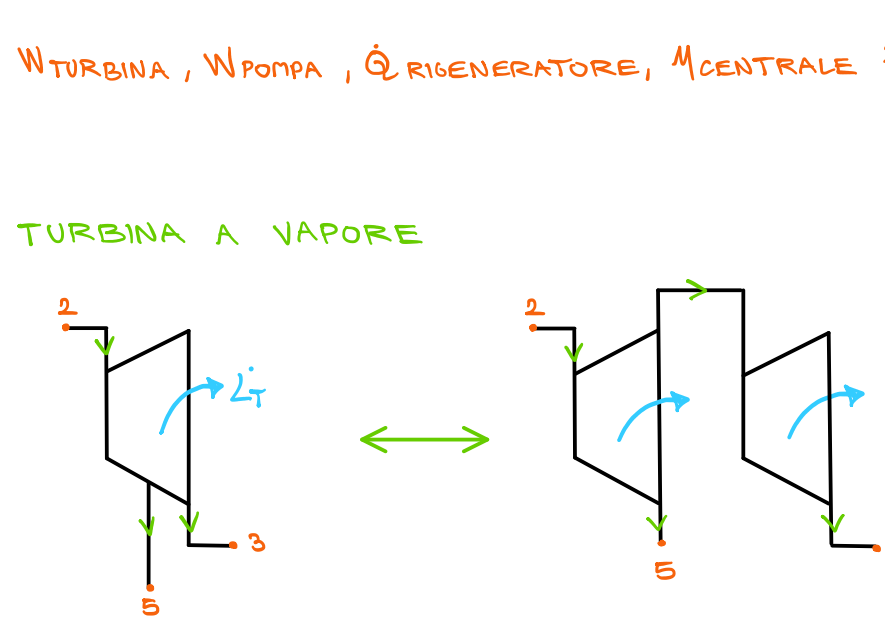
$c_p = \frac{7}{2} R^*$ $R^* = \frac{R}{MM}$

RENDIMENTO DEL CICLO

$$\eta_I = \frac{l_{NETTO}}{Q_1} = \frac{l_E - l_C}{c_p (T_3 - T_2)} = 33.21\%$$

ES 3

CENTRALE TERMOELETTRICA
CICLO RANKINE RIGENERATIVO



$\dot m_1 = 45\ Kg/s$ $\eta_{GV} = 94\%$

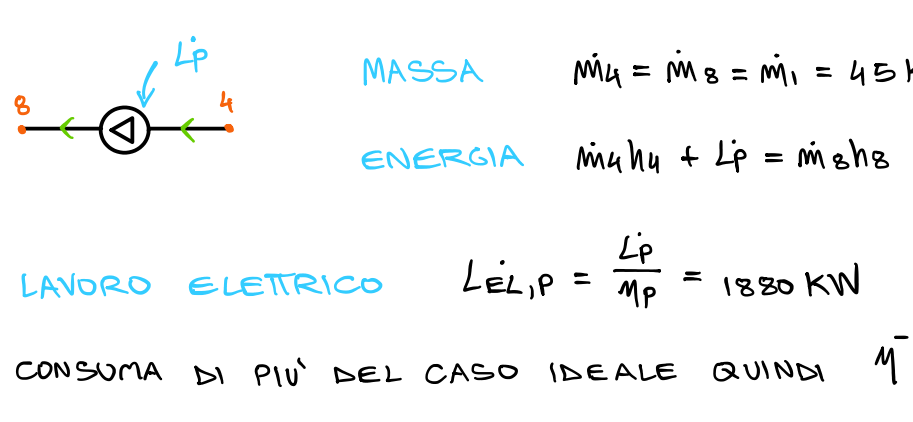
$\dot m_5 = 5\ Kg/s$ $\eta_{POMPA} = 89\%$

$\eta_{EL} = 99\%$ $\eta_{TURBINA} = 91\%$

$\dot W_{AUSILIARI} = 400\ KW$ $h_{1,2,\dots,8}$

$W_{TURBINA}, W_{POMPA}, \dot Q_{RIGENERATORE}, \eta_{CENTRALE}$?

TURBINA A VAPORE

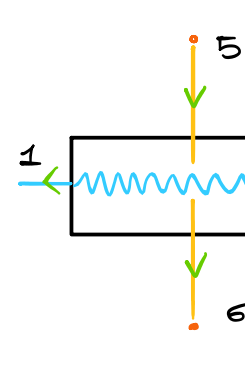


MASSA | $\dot m_2 = \dot m_3 + \dot m_5 \rightarrow m_3 = 45 - 5 = 40\ Kg/s$

ENERGIA | $\dot m_2 h_2 = \dot m_3 h_3 + \dot m_5 h_5 + L_T \rightarrow \dot L_T = 47755\ KW$

LAVORO ELETTRICO $\dot L_{EL,T} = \dot L_T\, \eta_T = 43457\ KW$

POMPA



MASSA $\dot m_4 = \dot m_8 = \dot m_1 = 45\ Kg/s$

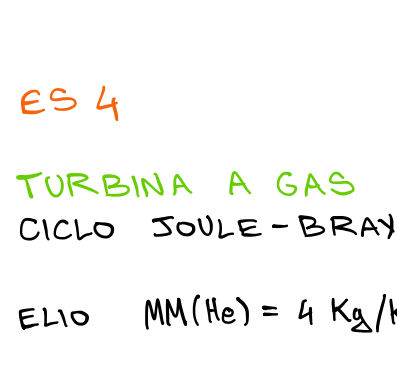
ENERGIA $\dot m_4 h_4 + \dot L_P = \dot m_8 h_8 \rightarrow \dot L_P = \dot m_1 (h_8 - h_4) = 1602\ KW$

LAVORO ELETTRICO $\dot L_{EL,P} = \frac{\dot L_P}{\eta_P} = 1880\ KW$

CONSUMA DI PIU' DEL CASO IDEALE QUINDI $\eta^{-1} > 1$

RIGENERATORE A SUPERFICIE (NON MIXER)

IN UN R. A SUPERFICIE LA PORTATA DI VAPORE SPILLATA NON SI MISCELA CON L'ACQUA DI ALIMENTO



MASSA 1 $\dot m_8 = \dot m_1 = 45\ Kg/s$

MASSA 2 $\dot m_5 = \dot m_6 = 5\ Kg/s$

ENERGIA $\dot m_5 h_5 + \dot m_8 h_8 = \dot m_1 h_1 + \dot m_6 h_6$

$\rightarrow \dot Q_{RIG} = \dot m_5 (h_5 - h_6) = \dot m_8 (h_1 - h_8) = 12623\ KW$

IMPIANTO TERMOELETTRICO

$$\eta_{EL,NETTO} = \frac{\dot L_{NETTO}}{\text{SPESA ENERGETICA}} = \frac{(L_{EL,T} - L_{EL,P} - L_{AUX})\,\eta_{TRASF}}{\dot Q_{IN}/\eta_{GV}} = 0.29$$

$\dot Q_{IN} = \dot m_1 (h_2 - h_1) = 133368\ KW_t$

ES 4

TURBINA A GAS
CICLO JOULE-BRAYTON CHIUSO

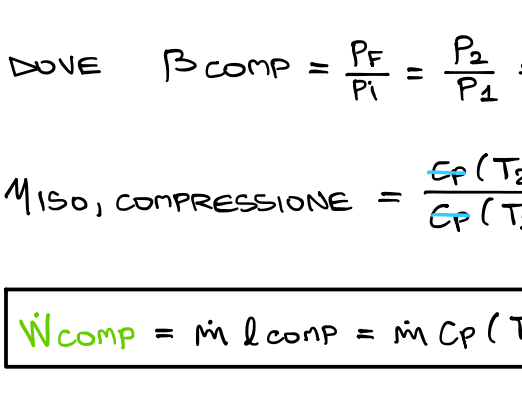
ELIO MM(He) = 4 Kg/KmoL c_p, c_v COST $\gamma = \frac{5}{3}$ MONOATOMICO

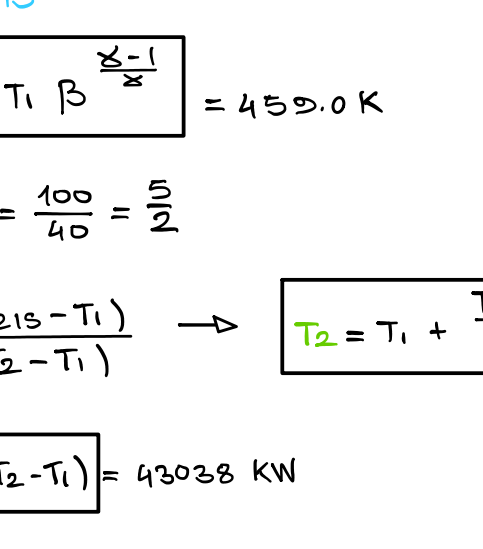
$T_1 = 45°C$ $P_1 = 40$ BAR $\dot m = 50\ Kg/s$
$T_3 = 1000°C$ $P_3 = 100$ BAR

η_{ISO} (COMP) = η_{ISO} (EXP) = 0.85

$T_C, \dot L_C, T_E, \dot L_E, \dot Q_{IN}, \dot L_{NET}, \eta$

CICLO TERMODINAMICO





COSTANTE R^*

$$R^* = \frac{R}{MM(He)}$$

TRASFORMAZIONE 1 → 2IS

$$\frac{T_{2IS}}{T_1} = \beta^{\frac{\gamma-1}{\gamma}} \rightarrow T_{2IS} = T_1\, \beta^{\frac{\gamma-1}{\gamma}} = 459.0\,K$$

DOVE $\beta_{COMP} = \frac{P_F}{P_I} = \frac{P_2}{P_1} = \frac{100}{40} = \frac{5}{2}$

$$\eta_{ISO,COMPRESSIONE} = \frac{c_p (T_{2IS} - T_1)}{c_p (T_2 - T_1)} \rightarrow T_2 = T_1 + \frac{T_{2IS} - T_1}{\eta_{ISO}} = 483.86\,K$$

$$\dot W_{COMP} = \dot m\, l_{COMP} = \dot m\, c_p (T_2 - T_1) = 43038\ KW$$

TRASFORMAZIONE 3 → 4IS

$$\Delta S = 0 = c_p \ln \frac{T_F}{T_I} - R^* \ln \frac{P_F}{P_I}$$

$$c_p \ln \frac{T_{4IS}}{T_3} = R^* \ln \frac{P_4}{P_3}$$ $\beta_{EXP} = \frac{40}{100} = \frac{2}{5}$

$$\frac{T_{4IS}}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{R^*}{c_p}} = \beta_{EXP}^{\frac{\gamma-1}{\gamma}} \rightarrow T_{4IS} = T_3\, \beta_{EXP}^{\frac{\gamma-1}{\gamma}} = 882.48\,K$$

$$\eta_{ISO,ESPANSIONE} = \frac{c_p (T_3 - T_4)}{c_p (T_3 - T_{4IS})} \rightarrow T_4 = 941.15\,K$$

$$\dot W_{EXP} = \dot m\, l_{EXP} = -\dot m\, c_p (T_3 - T_4) = 86257\ KW$$

POTENZA TERMICA IN INGRESSO

$\dot Q_{IN} = \dot m\, c_p (T_3 - T_2) = 205083\ KW$

POTENZA NETTA

$\dot W_{NET} = \dot W_E - \dot W_P = 43219\ KW$

RENDIMENTO

$$\eta = \frac{\dot W_{NET}}{\dot Q_{IN}} = 21.07\%$$

CICLO JB IDEALE

$$\eta_{ID} = 1 - \beta^{1-\theta} = 0.3069$$

ES 5

CICLO RANKINE

$\dot W_{NET} = 600\ MW$

FLUIDO DI LAVORO = ACQUA

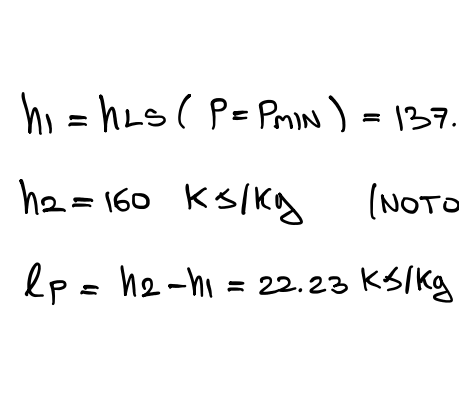
$P_{MIN} = 0.05$ BAR $P_{MAX} = 150$ BAR

$T_{MAX} = 600°C$ $h_2 = 160\ KJ/Kg$

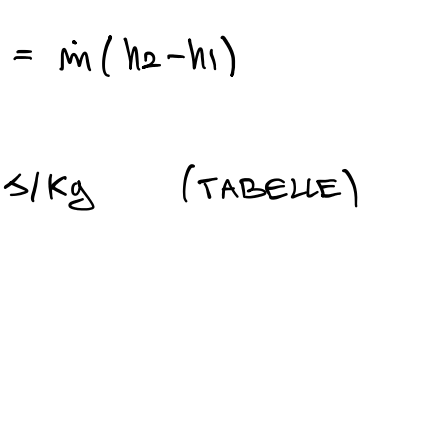
TURBINA (ESPANSIONE ISOS) $\eta_{IS} = 1$

$\eta_{CICLO}, \dot m$?

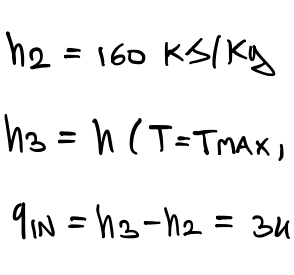
SCHEMA IMPIANTO



CICLO IN T-S



1 → 2 ISOS POMPA



MASSA $\dot m_1 = \dot m_2 = \dot m$

ENERGIA $\dot m h_1 + \dot L_P = \dot m h_2$

$\rightarrow \dot L_P = \dot m (h_2 - h_1)$

$h_1 = h_{LS} (P = P_{MIN}) = 137.72\ KJ/Kg$ (TABELLE)

$h_2 = 160\ KJ/Kg$ (NOTO)

$l_P = h_2 - h_1 = 22.23\ KJ/Kg$

2 → 3 ISO P GENERATORE DI VAPORE

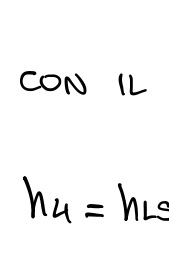
ENERGIA $\dot Q_{IN} = \dot m (h_3 - h_2)$

$h_2 = 160\ KJ/Kg$ (NOTO)

$h_3 = h (T = T_{MAX}, P = P_{MAX}) \cong 3600\ KJ/Kg$ (GRAFICI)

$q_{IN} = h_3 - h_2 = 3440\ KJ/Kg$

3 → 4 ISOS TURBINA



MASSA $\dot m_3 = \dot m_4 = \dot m$ NO SPILLAMENTO

ENERGIA $\dot m h_3 = L_T + \dot m h_4 \rightarrow L_T = \dot m (h_3 - h_4)$

$h_3 = h (T = T_{MAX}, P = P_{MAX}) \cong 3600\ KJ/Kg$

h_4 = ? SI TROVA INTERNO ALLA CURVA DI SATURAZIONE

ISOS → $S_3 = S_4 \cong 6.7\ KJ/KgK$

$S_4 = S_{LS} (1 - x_4) + S_{VS}\, x_4$ | $S_{LS} = S_{LS} (P = P_{MIN})$

$S_4 = S_{LS} - x_4 S_{LS} + x_4 S_{VS}$ | $S_{VS} = S_{VS} (P = P_{MIN})$

$$x_4 = \frac{S_4 - S_{LS}}{S_{VS} - S_{LS}} = \frac{6.7 - 0.47626}{8.396 - 0.47626} = 0.78585$$

CON IL TITOLO ORA POSSIAMO CALCOLARE L'ENTALPIA

$h_4 = h_{LS} (1 - x_4) + h_{VS}\, x_4$ | $h_{LS} = h_{LS} (P = P_{MIN})$

$= \dots = 2042.54\ KJ/Kg$ | $h_{VS} = h_{VS} (P = P_{MIN})$

$l_T = -(h_4 - h_3) = 1547.46\ KJ/Kg$

LAVORO NETTO

$$\dot W_{NET} = \dot m (L_T - L_P) \rightarrow \dot m = \frac{\dot W_{NET}}{L_T - L_P} = 393.4\ Kg/s$$

RENDIMENTO DEL CICLO

$$\eta_{NET} = \frac{L_{NET}}{\dot Q_{IN}} = 44.5\%$$