NASH | ENGR 2333 | EQUATIONS

IDEAL GASES

ISENTROPIC: $\Delta s = 0$, $Q = 0$, $\Delta u = w$

- $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$
- $\Delta u = C_v(\Delta T) = w$ (V OR P)
- $s_2^\circ = s_1^\circ + R\ln\left(\frac{P_2}{P_1}\right)$
- $\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$
- $\frac{V_2}{V_1} = \frac{V_{r2}}{V_{r1}}$
- $s_2^\circ = s_1^\circ + R\ln\left(\frac{P_2}{P_1}\right)$ ⟵ VAR SPEC. HT
- $\eta = \frac{u_{2s}-u_1}{u_{2A}-u_1} = \frac{T_{2s}-T_1}{T_{2A}-T_1}$ I.E. DIESEL
- $C_p\ln\left(\frac{T_2}{T_1}\right) = R\ln\left(\frac{P_2}{P_1}\right)$

ISOTHERMAL $\Delta T = 0$, $\Delta u = 0$, $W = Q$

- $\Delta s = -R\ln\left(\frac{P_2}{P_1}\right) = -R\ln\left(\frac{V_1}{V_2}\right)$
- $q = T\Delta s = w$
- $q_i = T_H\Delta s$ (ON APPLICABLE PROCESS)
- $q_o = T_L\Delta s$ (ON APPLICABLE PROCESS)
- $w = TR\ln\left(\frac{V_1}{V_2}\right) = -TR\ln\left(\frac{P_2}{P_1}\right) = q$
- $P_1V_1 = P_2V_2$

ISOCHORIC $\Delta V = 0$, $W = 0$, $\Delta u = Q$

- $Q = C_v(\Delta T) = \Delta u$
- $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- $\Delta s = C_v\ln\left(\frac{T_2}{T_1}\right) = -R\ln\left(\frac{P_2}{P_1}\right)$

ISOBARIC $\Delta P = 0$

- $W = P\Delta V$
- $\Delta u = Q - W$
- $\Delta u = C_p(\Delta T)$
- $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
- $\Delta s = C_p\ln\left(\frac{T_2}{T_1}\right)$

1ST LAW: $m\left(\frac{\vec{V}_2^2}{2} - \frac{\vec{V}_1^2}{2}\right) + mg(z_2 - z_1) + m(u_2 - u_1) = Q - W$

2ND LAW: $S_2 - S_1 = \sum \frac{Q_k}{T_k} + S_{GEN}$

GENERAL

- $C_v(\Delta T) = \Delta u$
- $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- $s_2 - s_1 = C_v\ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{V_2}{V_1}\right)$
- $s_2 - s_1 = C_p\ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$

$\}$ ~ CONSTANT SPECIFIC HEAT

- $s_2 - s_1 = s_2^\circ - s_1^\circ - R\ln\left(\frac{P_2}{P_1}\right)$ ~ VARIABLE SPECIFIC HEAT
- $PV = RT$ / $PV = mRT$; $m = \frac{PV}{RT}$
- $\sum \dot{m}_i = \sum \dot{m}_o$
- $r = \frac{V_{max}}{V_{min}}$
- $W_N = q_N$ (CYCLES)
- $\eta = \frac{W_N}{q_i}$
- NO IRREVERSIBILITIES = REVERSIBLE ⟹ $\Delta S = 0$, $Q = 0$
- REVERSIBLE / ISOTHERMAL: $Q = \Delta S \cdot T$

SPECIFIC CASES

(FOR REFERENCE, ALL COME FROM EQN'S ON LEFT)

OTTO CYCLE:

- $\eta_{TH} = 1 - \frac{1}{r^{k-1}} = \frac{W_{NET}}{q_i} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{q_o}{q_i}$
- $r = \frac{V_{max}}{V_{min}}$
- $MEP = \frac{W_N}{V_1 - V_2} = \frac{W_N}{V_1(1 - \frac{1}{r})}$
- $W_N = q_N = q_i - q_o$

DIESEL CYCLE:

- $q_i = P_2(V_3 - V_2) + (u_3 + u_2) = h_3 - h_2 = C_p(T_3 - T_2)$
- $r_{c/o} = \frac{V_3}{V_2}$
- $MEP = \frac{W_N}{V_{max} - V_{min}}$
- $q_o = u_1 - u_4 = -C_v(T_4 - T_1)$
- $\eta_{TH} = \frac{W_N}{q_i} = 1 - \frac{T_4 - T_1}{k(T_3 - T_2)}$
- $\frac{V_3}{V_4} = r_{c/o}\left(\frac{1}{r}\right)$
- $\eta_{TH} = 1 - \frac{1}{r^{k-1}}\left(\frac{r_{c/o}^k - 1}{k(r_{c/o} - 1)}\right)$

STIRLING CYCLE

- $\eta_{TH} = 1 - \frac{T_L}{T_H}$
- $q_{SP,ADD} = RT_H\ln\left(\frac{V_H}{V_L}\right)$
- $q_{RECOVERED/STORED} = C_v(T_3 - T_2)$
- $q_{REJECT} = RT_L\ln\left(\frac{V_H}{V_L}\right)$

DUAL CYCLE

- $r_{c/o} = \frac{V_x}{V_3}$ $r_p = \frac{P_x}{P_2}$
- $\eta_{TH} = 1 - \frac{T_H}{T_L}$ ⟵ IF $r_p \simeq 1$, USE DIESEL η

ERICSSON CYCLE

- 1→2: q_i / q_{ADDED}
- 3→4: q_o / q REJECTED
- $\eta_{TH} = 1 - \frac{T_L}{T_H}$
- 2→3: q TRANSFERRED TO 4→1
- $q_i = T_H(S_2 - S_1) = T_H\left(-R\ln\left(\frac{P_2}{P_1}\right)\right) = RT_H\ln\left(\frac{P_1}{P_2}\right)$
- $q_o = T_L(S_4 - S_3) = T_L\left(-R\ln\left(\frac{P_4}{P_3}\right)\right) = RT_L\ln\left(\frac{P_4}{P_3}\right)$

BRAYTON CYCLE

- $\eta_{TH} = 1 - \frac{q_o}{q_i} = 1 - \frac{C_p(T_4 - T_1)}{C_p(T_3 - T_2)} = 1 - \frac{1}{r_p^{(k-1)/k}}$
- $r_p = \frac{P_2}{P_1}$

GAS TURBINE

- $\eta_{TH} = \frac{W_N}{q_i} = \frac{W_o - W_i}{q_{PRIM} + q_{REHEAT}} = \frac{2(h_6 - h_7) - 2(h_2 - h_1)}{(h_6 - h_4) + (h_8 - h_7)}$

★ AS # OF COMPRESSION AND EXPANSION CYCLES IS CREATED, η APPROACHES $1 - \frac{T_L}{T_H}$ AKA CARNOT

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

STEAM TABLE MATERIAL

VAPOR (H_2O)

- $\eta_{TURB} = \frac{h_3 - h_{4A}}{h_3 - h_{4s}}$
- $\eta_{PUMP} = \frac{h_{2s} - h_1}{h_{2A} - h_1}$
- $q = \Delta h$
- $w = \Delta u$

$W = v(\Delta P)$ (COMPRESSED)

$W = P(\Delta V)$ (ISOBARIC)

$\eta_{NOZ} = \frac{\vec{V}_{2A}^2}{\vec{V}_{2s}^2}$

$h = h_f + v_f(P - P_{sat})$ (SUBCOOLED)

$\Delta s = m \cdot C\ln\left(\frac{T_2}{T_1}\right)$

REFRIGERATION:

$COP_R = \frac{1}{\frac{T_H}{T_L} - 1}$

$COP_{HP} = \frac{1}{1 - \frac{T_L}{T_H}}$

$\}$ CARNOT

$COP_R = \frac{Q_L}{W_N} = \frac{h_1 - h_4}{h_2 - h_1}$

$COP_{HP} = \frac{Q_H}{W_N} = \frac{h_2 - h_3}{h_2 - h_1}$

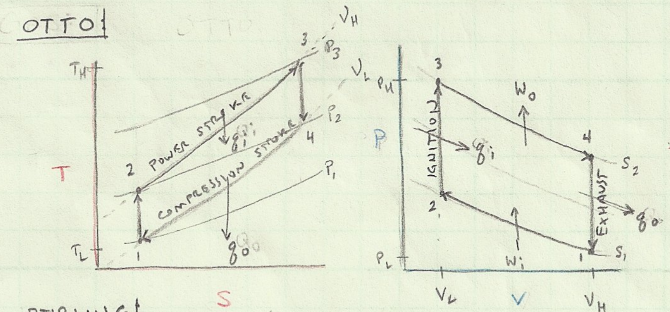
MISC

$\Delta V = 0$ IN TANK

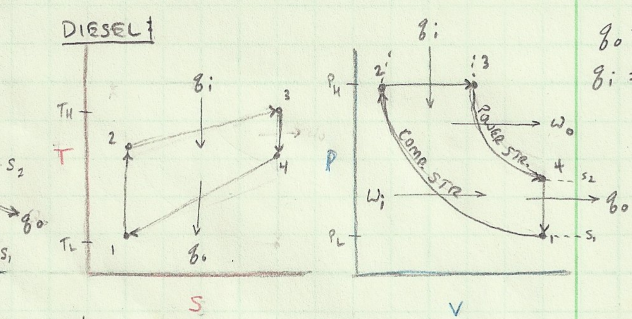
CYCLES:

GAS POWER CYCLES

OTTO



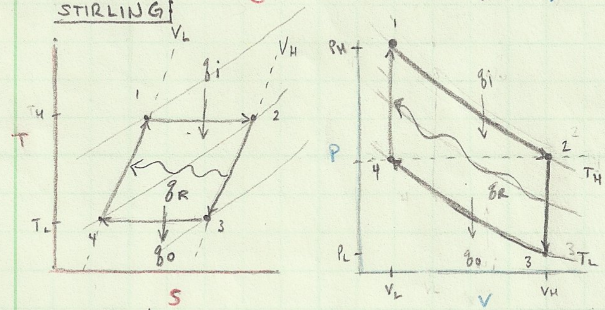
DIESEL



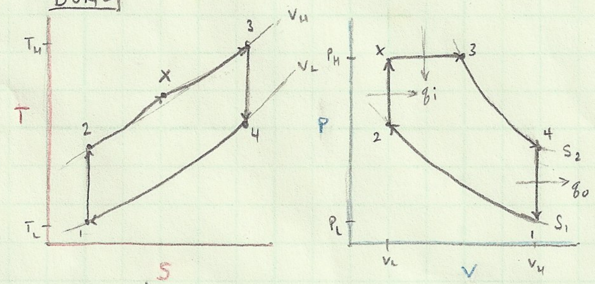
$q_o = q_H$

$q_i = q_L$

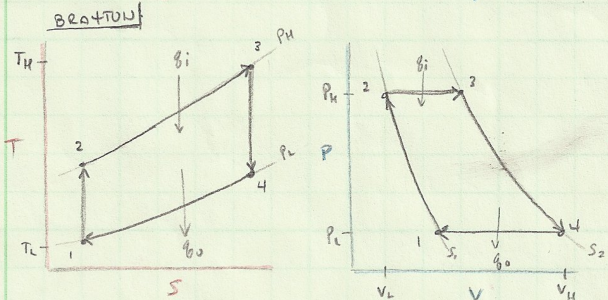
STIRLING



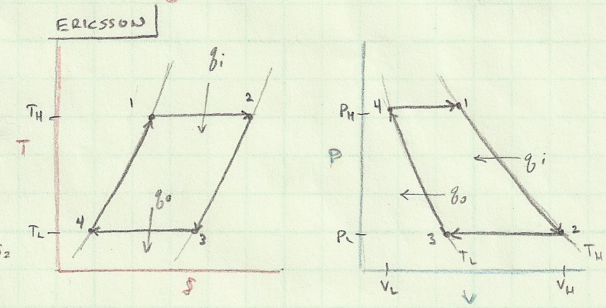
DUAL



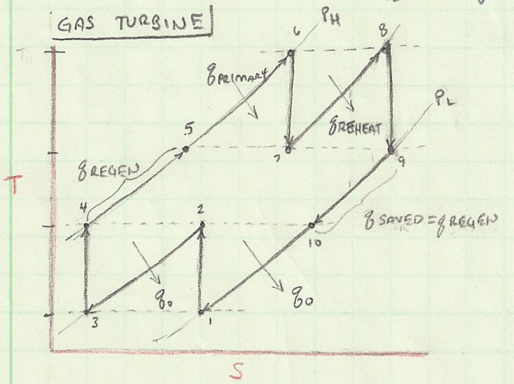
BRAYTON

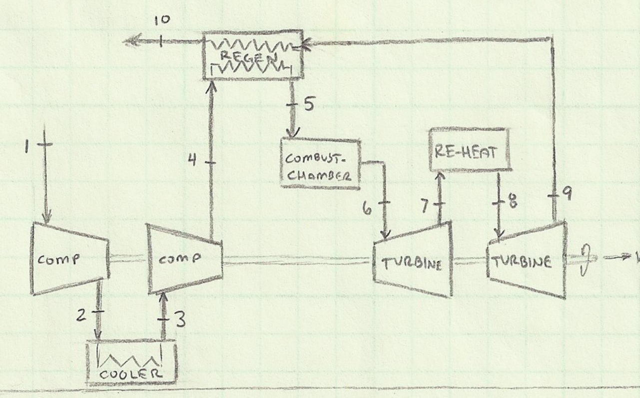


ERICSSON



GAS TURBINE





$T_6 = T_8 = T_H$

$T_5 = T_7 = T_9$

$T_4 = T_2 = T_{10}$

$T_3 = T_1 = T_L$

$P_4 = P_5 = P_6 = P_H$

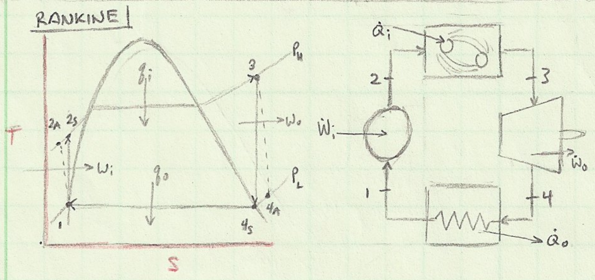
$P_3 = P_2$

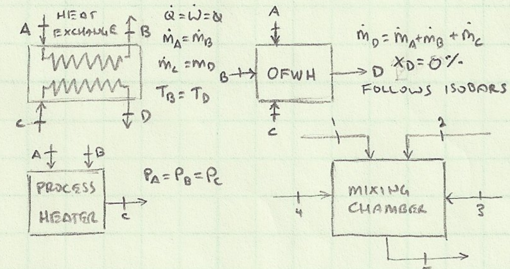
$P_7 = P_8$

$P_1 = P_9 = P_{10} = P_L$

STEAM POWER CYCLES

RANKINE





$\dot{Q} = \dot{W} = 0$

$\dot{m}_A = \dot{m}_B$

$\dot{m}_C = \dot{m}_D$

$T_B = T_D$

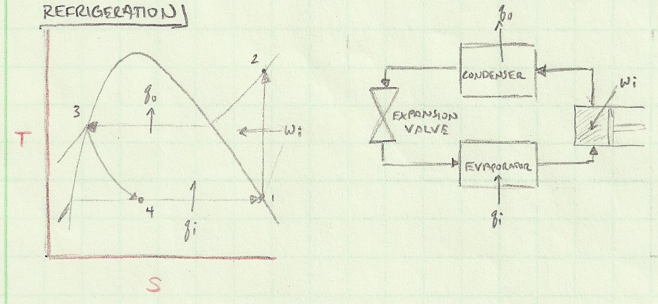
$P_A = P_B = P_C$

$\dot{m}_D = \dot{m}_A + \dot{m}_B + \dot{m}_C$

$x_D = 0\%$

FOLLOWS ISOBARS

REFRIGERATION



$\dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_3 h_3 + \dot{m}_4 h_4 = \dot{m}_5 h_5$

$\dot{m}_1 + \dot{m}_2 + \dot{m}_3 + \dot{m}_4 = \dot{m}_5$

$h_1 + h_2 + h_3 + h_4 = h_5$

$\sum \dot{m}_i = \sum \dot{m}_o$

$\sum \dot{E}_i = \sum \dot{E}_o$