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{ The combined Brayton/Ranking power plan shown in the figure has a gas-turbine and steam-turbine cycle. The following data
  are known for the gas-turbine cycle: air enters the compressor at 100 kPa, 25 degrees celsius, the compressor pressure ratio is
  11, the heater input rate is 40 MW; the turbine inlet temperature is 1300 degrees celsius, the exhaust pressure is 100 kPa; the
  cycle exhaust temperature from the heat exchanger is 150 degrees C. The following data are known for the steam-turbine
  cycle. The pump inlet state is saturated liquid at 100 kPa, the pump exit pressure is 17 MPa. Assume compression pressure
  ratio of 11, isentropic efficiencies are: 80% for the gas compressor and 85% for the gas turbine; 83% for the steam turbine, 78%
  for the pump, heat exchanger effectiveness 0.70. Use "Steam_IAPWS" as your working fluid (this is a more accurate model for
  water).}

{ Givens }
$ifnot parametricTable
Pr = 11 "compressor pressure ratio. compression ratio is the same for both gas-turbine and steam-turbine cycles. this is P2/P1"
$endif
r_c = 11
Q_dot_H = 40*convert(MW,kW) "heater input rate"
eta_c_gas = 0.8 "isentropic gas compressor efficiency"
eta_t_gas = 0.85 "isentropic gas turbine efficiency"
eta_t_steam = 0.83 "isentropic steam turbine efficiency"
eta_p_steam = 0.78 "isentropic steam pump efficiency"
e_he = 0.70 "heat exchanger effectiveness"

{ ------ State 1 through State 4 are the Brayton Gas Turbine with Air ------ }
{ State 1 - Compressor Inet }
T1 = 25 [C] "temperature at compressor inlet"
P1 = 100 [kPa] "pressure at compressor inlet"
v1 =volume(Air,T=T1,P=P1)
h1=enthalpy(Air,T=T1)
s1=entropy(Air,T=T1,P=P1)

{ State 2 - Heater Inlet }
P2 = Pr*P1
s2 = s1 "isentropic compressor"
T2=temperature(Air,s=s2,P=P2)
h2=enthalpy(Air,T=T2)

{ State 3 - Gas Turbine Inlet }
T3 = 1300 [C] "turbine inlet temperature"
P3 = P2 "Constant pressure heat addition"
h3=enthalpy(Air,T=T3)
s3=entropy(Air,T=T3,P=P3)

{ State 4 - HX Inlet }
P4 = P3*(1/Pr)
s4 = s3
T4 = temperature(Air, s=s4, P=P4)
h4 = enthalpy(Air, T=T4)

{ State 5 - Rejected }
P5 = P4
T5 = T4
h5=enthalpy(Air,T=T5)

{ ---- States 6 through 10 are the Steam Rankine cycle ---- }

{ State 7 - Steam Turbine Inlet }
P7 = P6
T7 = T4
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h7=enthalpy(Steam_IAPWS,T=T7,P=P7)
s8=entropy(Steam_IAPWS,T=T7,P=P7)

{ State 8 - Condensor Inlet }
P8 = P7*(1/r_c)
s8 = s7
T8=temperature(Steam_IAPWS,P=P8,s=s8)
h8 = enthalpy(Steam_IAPWS, T=T8, P=P8)

{ State 9 - Pump Inlet (Saturated Liquid) }
P9 = 100 [kPa] "given"
T9 = 99.63 [C] "from table since we know sat liquid"
h9 =enthalpy(Steam_IAPWS,T=T9,P=P9)
s9=entropy(Steam_IAPWS,T=T9,P=P9)

{ State 6 - Pump exit }
P6 = 17*convert(MPa,kPa)
s6 = s9
T6=temperature(Steam_IAPWS,P=P6,s=s6)
h6=enthalpy(Steam_IAPWS,T=T6,P=P6)

{ mass flow rates }
m_dot_air = Q_dot_H/(h3-h2)
m_dot_water = m_dot_air*((h4-h5)/(h7-h6))

{ devices }
w_c = h2 - h1
w_t_gas = h3-h4
w_p = h6-h9
w_t_steam = h7-h8
qsmall_dot_h = Q_dot_H/m_dot_air

{ Powers }
W_dot_brayton =  m_dot_air*(w_t_gas - w_c)
W_dot_rankine = m_dot_water*(w_t_steam - w_p)
W_dot_net = m_dot_air*(w_t_gas - w_c) + m_dot_water*(w_t_steam - w_p)

{ efficiency }
eta_brayton = W_dot_brayton/Q_dot_H
eta_th = W_dot_net/Q_dot_H

{ANSWERS}
{PART 1}
"As the pressure ratio (Pr) increases, the efficency of the cycle increases as well. The output of the gas turbine results in a lower
 temperature as efficiency increases"

{PART 2}
"The performance of the plan can be improved by further inreasing the pressure ratio of the devices in the Brayton cycle."
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$r_c = 11$

$\dot{Q}_H = 40 \cdot \left| 1000 \cdot \frac{kW}{MW} \right|$ *heater input rate*

$\eta_{c,gas} = 0.8$ *isentropic gas compressor efficiency*

$\eta_{t,gas}$ = 0.85 *isentropic gas turbine efficiency*

$\eta_{t,steam}$ = 0.83 *isentropic steam turbine efficiency*

$\eta_{p,steam}$ = 0.78 *isentropic steam pump efficiency*

e_{he} = 0.7 *heat exchanger effectiveness*

T1 = 25 [C] *temperature at compressor inlet*

P1 = 100 [kPa] *pressure at compressor inlet*

v1 = **v** [Air , T = T1 , P = P1]

h1 = **h** [Air , T = T1]

s1 = **s** [Air , T = T1 , P = P1]

P2 = Pr · P1

s2 = s1 *isentropic compressor*

T2 = **T** [Air , s = s2 , P = P2]

h2 = **h** [Air , T = T2]

T3 = 1300 [C] *turbine inlet temperature*

P3 = P2 *Constant pressure heat addition*

h3 = **h** [Air , T = T3]

s3 = **s** [Air , T = T3 , P = P3]

$$P4 = P3 \cdot \frac{1}{Pr}$$

s4 = s3

T4 = **T** [Air , s = s4 , P = P4]

h4 = **h** [Air , T = T4]

P5 = P4

T5 = T4

h5 = **h** [Air , T = T5]

P7 = P6

T7 = T4

h7 = **h** [$Steam_{IAPWS}$, T = T7 , P = P7]

s8 = **s** [$Steam_{IAPWS}$, T = T7 , P = P7]

$$P8 = P7 \cdot \frac{1}{r_c}$$

$$s8 = s7$$

$$T8 = \mathbf{T}\left[\text{Steam}_{IAPWS}, P = P8, s = s8\right]$$

$$h8 = \mathbf{h}\left[\text{Steam}_{IAPWS}, T = T8, P = P8\right]$$

$P9 = 100$ [kPa] *given*

$T9 = 99.63$ [C] *from table since we know sat liquid*

$$h9 = \mathbf{h}\left[\text{Steam}_{IAPWS}, T = T9, P = P9\right]$$

$$s9 = \mathbf{s}\left[\text{Steam}_{IAPWS}, T = T9, P = P9\right]$$

$$P6 = 17 \cdot \left|1000 \cdot \frac{kPa}{MPa}\right|$$

$$s6 = s9$$

$$T6 = \mathbf{T}\left[\text{Steam}_{IAPWS}, P = P6, s = s6\right]$$

$$h6 = \mathbf{h}\left[\text{Steam}_{IAPWS}, T = T6, P = P6\right]$$

$$\dot{m}_{air} = \frac{\dot{Q}_H}{h3 - h2}$$

$$\dot{m}_{water} = \dot{m}_{air} \cdot \left[\frac{h4 - h5}{h7 - h6}\right]$$

$$w_c = h2 - h1$$

$$w_{t,gas} = h3 - h4$$

$$w_p = h6 - h9$$

$$w_{t,steam} = h7 - h8$$

$$qs\dot{m}all_h = \frac{\dot{Q}_H}{\dot{m}_{air}}$$

$$\dot{W}_{brayton} = \dot{m}_{air} \cdot \left[w_{t,gas} - w_c\right]$$

$$\dot{W}_{rankine} = \dot{m}_{water} \cdot \left[w_{t,steam} - w_p\right]$$

$$\dot{W}_{net} = \dot{m}_{air} \cdot \left[w_{t,gas} - w_c\right] + \dot{m}_{water} \cdot \left[w_{t,steam} - w_p\right]$$

$$\eta_{brayton} = \frac{\dot{W}_{brayton}}{\dot{Q}_H}$$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_H}$$

As the pressure ratio (Pr) increases, the efficency of the cycle increases as well. The output of the gas turbine results in a lower temperature as efficiency increases

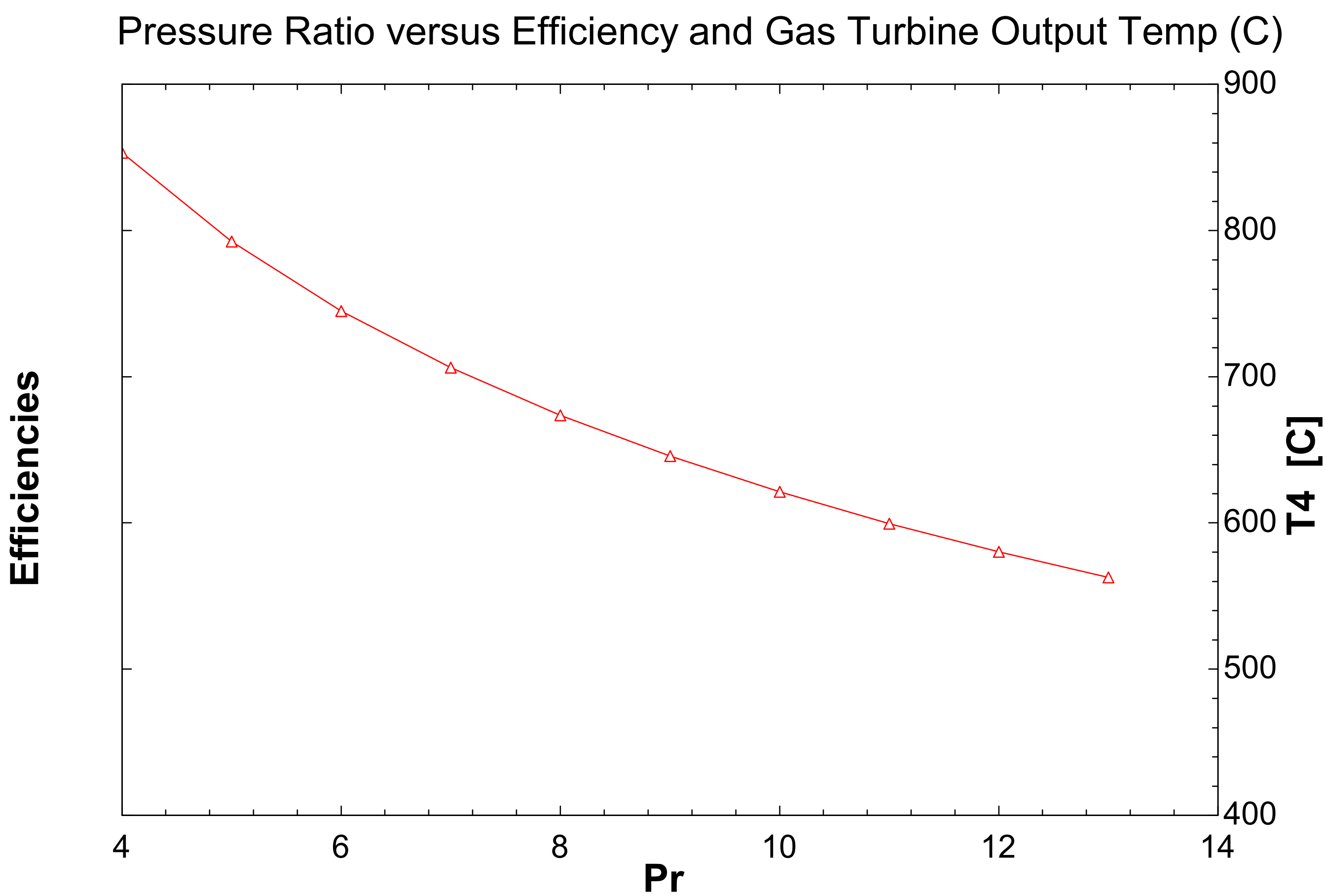
The performance of the plan can be improved by further inreasing the pressure ratio of the devices in the Brayton cycle.

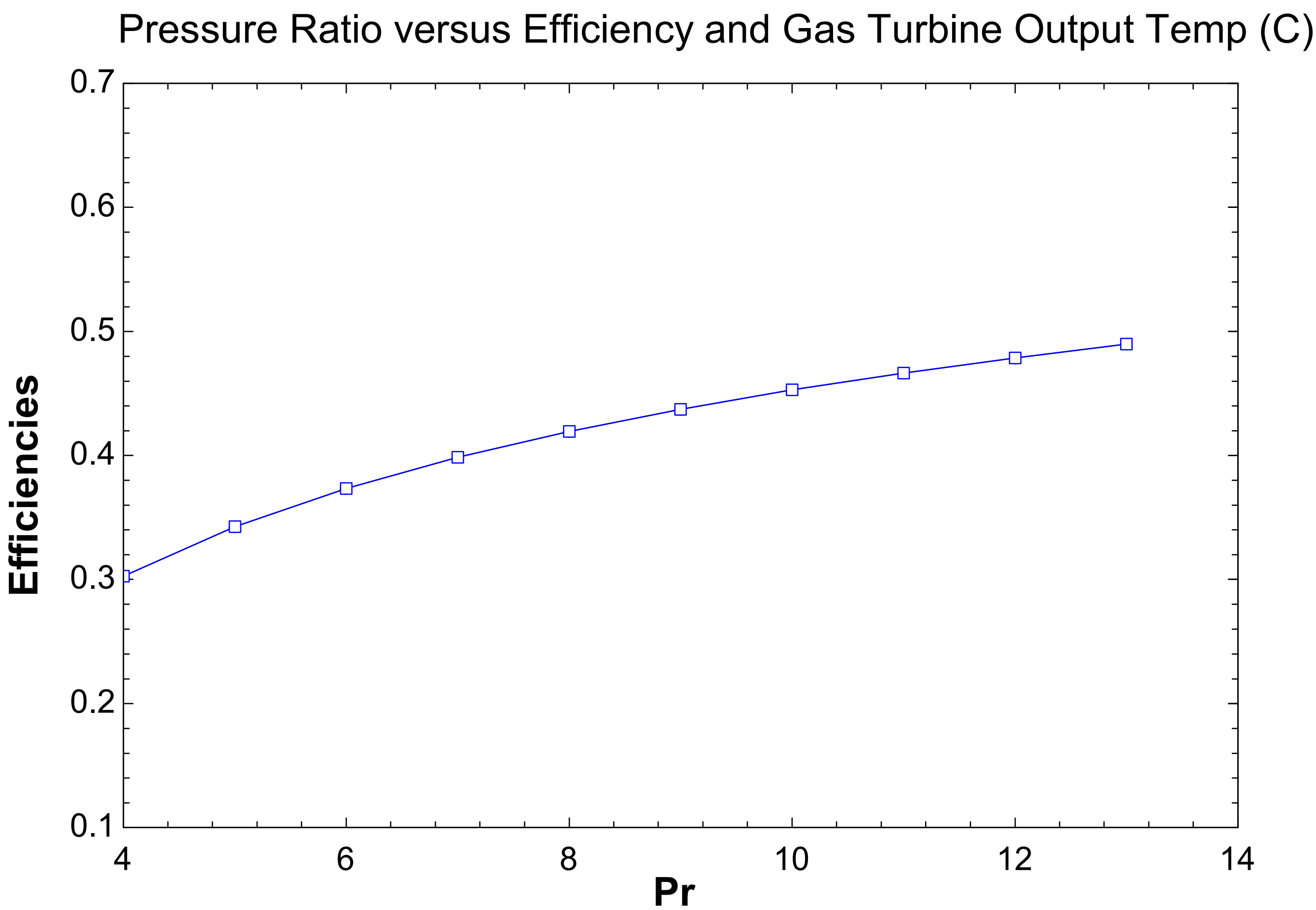
Uncompiled equations within $IF conditional statements

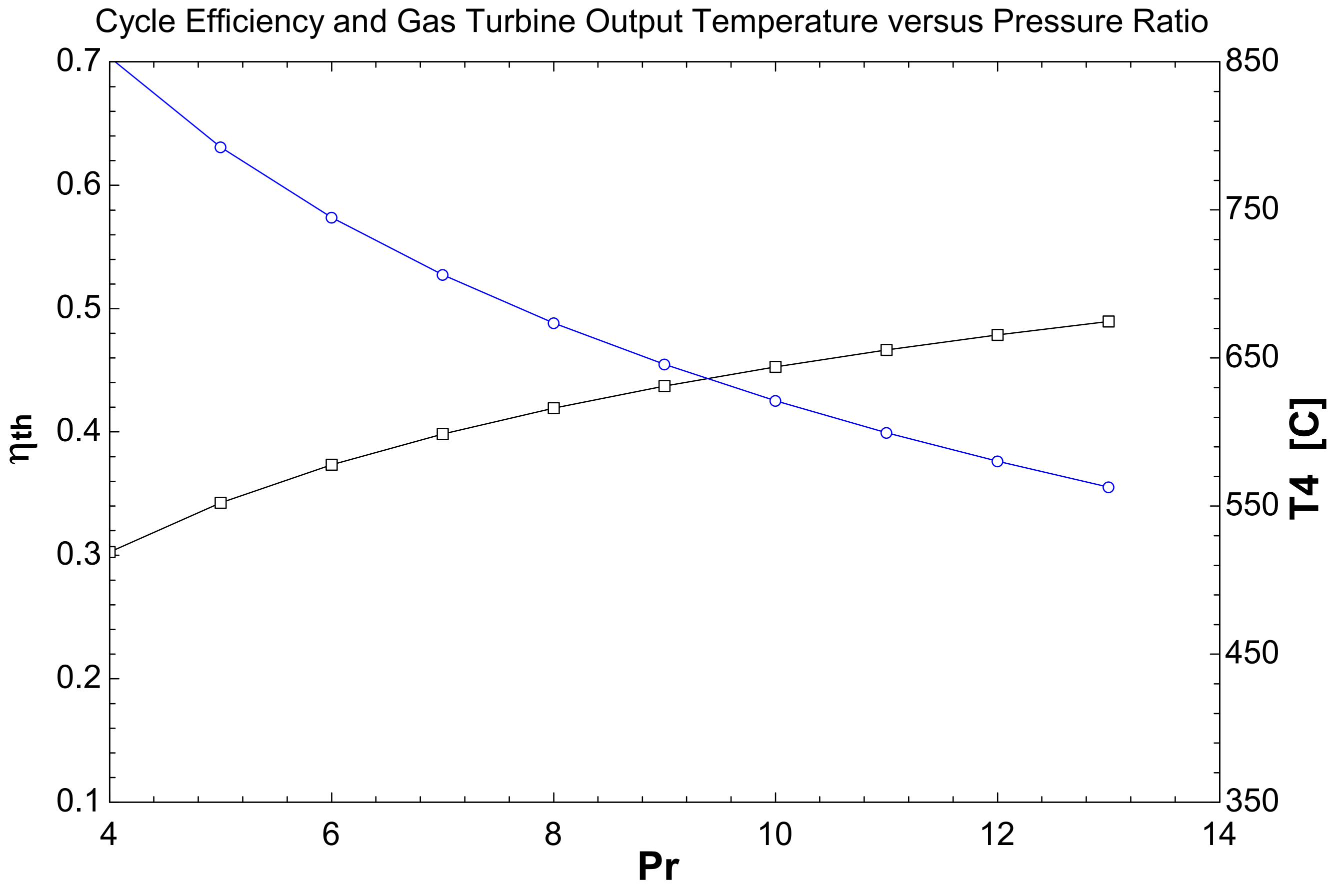
Pr = 11 "compressor pressure ratio. compression ratio is the same for both gas-turbine and steam-turbine cycles. this is P2/P1"

Parametric Table: Table 1

	Pr	η_{th}	$\eta_{brayton}$	T4 [C]
Run 1	4	0.3027	0.3027	853
Run 2	5	0.3425	0.3425	792.4
Run 3	6	0.3734	0.3734	744.9
Run 4	7	0.3984	0.3984	706.1
Run 5	8	0.4194	0.4194	673.6
Run 6	9	0.4372	0.4372	645.6
Run 7	10	0.4528	0.4528	621.2
Run 8	11	0.4665	0.4665	599.5
Run 9	12	0.4787	0.4787	580.1
Run 10	13	0.4897	0.4897	562.6




Pressure Ratio versus Efficiency and Gas Turbine Output Temp (C)
Efficiencies
Pr
0.1
0.2
0.3
0.4
0.5
0.6
0.7
4
6
8
10
12
14


Cycle Efficiency and Gas Turbine Output Temperature versus Pressure Ratio
0.7
0.6
0.5
0.4
0.3
0.2
0.1
ηth
850
750
650
550
450
350
T4 [C]
4
6
8
10
12
14
Pr