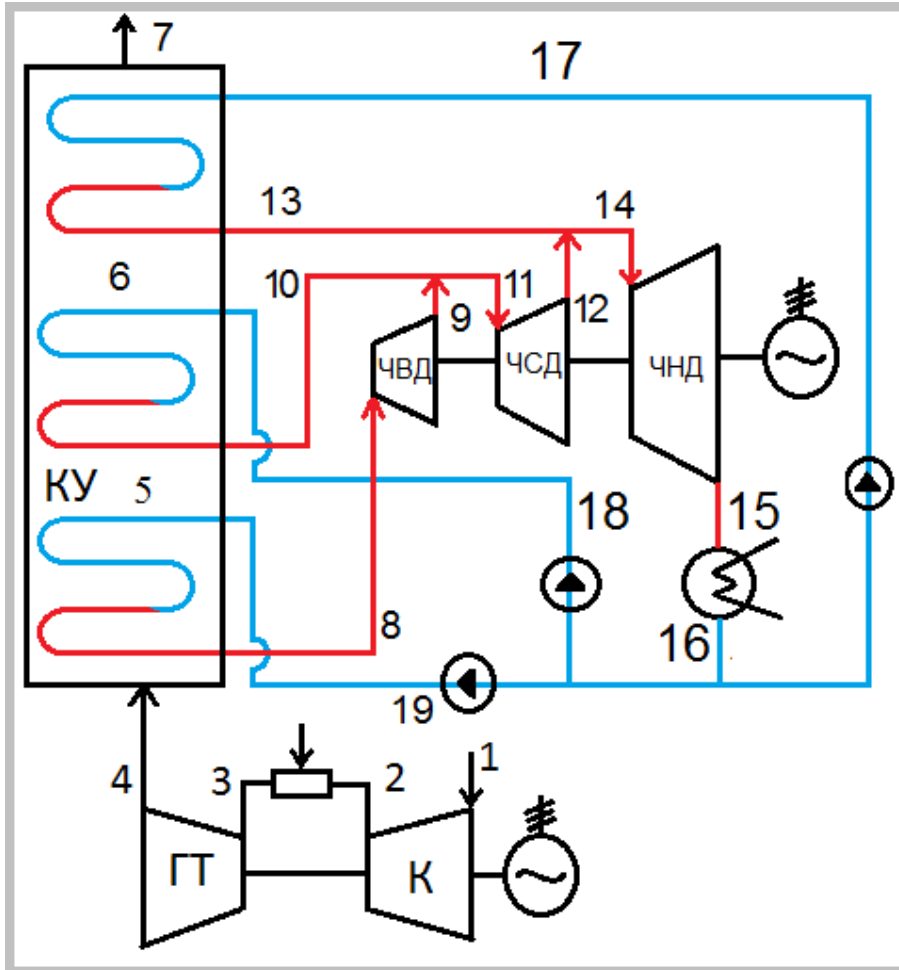


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Обозначения:
 ГТУ - газотурбинная установка
 к - компрессор
 кс - камера сгорания
 гт - газовая турбина
 ПТУ - паротурбинная установка
 ЧВД - часть высокого давления
 паровой турбины
 ЧСД - часть среднего давления
 паровой турбины
 ЧНД - часть низкого давления
 паровой турбины
 ку - котел-утилизатор
 пт - паровая турбина
 к-р - конденсатор
 н - питательный насос
 ПГУ - парогазовая установка
 q - отношение расхода пара в
 указанных точках

Start

```
[> restart
[> with(Units[Standard]) :
[> with(ThermophysicalData) :
[> Digits := 20 :
```

```
[ :
[> p8 := 9 MPa :
[> p9 := 0.5 MPa :
[> p10 := 3 MPa :
[> p12 := 0.1 MPa :
```

- > $p_{15} := 5 \text{ kPa} :$
- > $t_8 := 480 \text{ degC} :$
- > $t_{10} := 240 \text{ degC} :$
- > $t_{13} := 120 \text{ degC} :$
- > $q_{19}/q_{16} := 0.2 :$
- > $q_{18}/q_{16} := 0.3 :$
- > $q_{17}/q_{16} := 1 - q_{19}/q_{16} - q_{18}/q_{16} :$
- > $\eta_{\text{чВД}} := 0.73 :$
- > $\eta_{\text{чСД}} := 0.80 :$
- > $\eta_{\text{чНД}} := 0.87 :$



:

> $h_8 := \text{Property}(\text{enthalpy, pressure} = p_8, \text{temperature} = t_8, \text{water})$

$3336,43 \frac{\text{kJ}}{\text{kg}} \quad (2.1)$

:

> $h_9 := \text{wspHEXPANSIONPTPEFF}(p_8, t_8, p_9, \eta_{\text{чВД}})$

$2836,47 \frac{\text{kJ}}{\text{kg}} \quad (2.2)$

:

> $I_{\text{чВД}} := h_8 - h_9$

$499,96 \frac{\text{kJ}}{\text{kg}} \quad (2.3)$

:

> $T_9 := \text{Property}(\text{temperature, enthalpy} = h_9, \text{pressure} = p_9, \text{water}) : T_9 - 273.15 \text{ K}$

$191,01 \text{ }^\circ\text{C} \quad (2.4)$

1 0 :

> $p_{10} := p_9$

$p_{10} := 0.5 \text{ MPa} \quad (2.5)$

> $h_{10} := \text{Property}(\text{enthalpy, pressure} = p_{10}, \text{temperature} = t_{10}, \text{water})$

$2940,21 \frac{\text{kJ}}{\text{kg}} \quad (2.6)$

9 1 0 :

> $h_{11} := \frac{h_{10} + h_9 \cdot (q_{19}/q_{16})}{1 + (q_{19}/q_{16})}$

$2922,92 \frac{\text{kJ}}{\text{kg}} \quad (2.7)$

C :

$$\begin{aligned} > p_{11} := p_9 \\ & \qquad \qquad \qquad p_{11} := 0.5 \text{ MPa} \end{aligned} \quad (2.8)$$

$$\begin{aligned} > T_{11} := \text{Property}(\text{temperature, enthalpy} = h_{11}, \text{pressure} = p_{11}, \text{water}) : T_{11} - 273.15\text{K} \\ & \qquad \qquad \qquad 231,72 \text{ }^\circ\text{C} \end{aligned} \quad (2.9)$$

$$\begin{aligned} & \text{C} : \\ > h_{11} := \text{Property}(\text{enthalpy, pressure} = p_{11}, \text{temperature} = T_{11}, \text{water}) \\ & \qquad \qquad \qquad 2922,92 \frac{\text{kJ}}{\text{kg}} \end{aligned} \quad (2.10)$$

$$\begin{aligned} & \text{C} : \\ > h_{12} := \text{wspHEXPANSIONPTPEFF}(p_{11}, T_{11}, p_{12}, \eta_{qCD}) \\ & \qquad \qquad \qquad 2676,66 \frac{\text{kJ}}{\text{kg}} \end{aligned} \quad (2.11)$$

$$\begin{aligned} & \text{C} : \\ > I_{qCD} := h_{11} - h_{12} \\ & \qquad \qquad \qquad 246,27 \frac{\text{kJ}}{\text{kg}} \end{aligned} \quad (2.12)$$

$$\begin{aligned} & \text{C} : \\ > T_{12} := \text{Property}(\text{temperature, enthalpy} = h_{12}, \text{pressure} = p_{12}, \text{water}) : T_{12} - 273.15\text{K} \\ & \qquad \qquad \qquad 100,43 \text{ }^\circ\text{C} \end{aligned} \quad (2.13)$$

$$\begin{aligned} & \text{1 3} : \\ > p_{13} := p_{12} \\ & \qquad \qquad \qquad 0.1 \text{ MPa} \end{aligned} \quad (2.14)$$

$$\begin{aligned} > h_{13} := \text{Property}(\text{enthalpy, pressure} = p_{13}, \text{temperature} = t_{13}, \text{water}) \\ & \qquad \qquad \qquad 2716,64 \frac{\text{kJ}}{\text{kg}} \end{aligned} \quad (2.15)$$

$$\begin{aligned} & \text{1 2} \quad \text{1 3} \\ > h_{14} := \frac{h_{13} + h_{12} \cdot (q18/q16)}{1 + (q18/q16)} \\ & \qquad \qquad \qquad 2707,41 \frac{\text{kJ}}{\text{kg}} \end{aligned} \quad (2.16)$$

$$\begin{aligned} & : \\ > p_{14} := p_{12} \\ & \qquad \qquad \qquad 0.1 \text{ MPa} \end{aligned} \quad (2.17)$$

$$\begin{aligned} > T_{14} := \text{Property}(\text{temperature, enthalpy} = h_{14}, \text{pressure} = p_{14}, \text{water}) : T_{14} - 273.15\text{K} \\ & \qquad \qquad \qquad 115,44 \text{ }^\circ\text{C} \end{aligned} \quad (2.18)$$

$$\begin{aligned} & \text{H} : \\ > h_{15} := \text{wspHEXPANSIONPTPEFF}(p_{14}, T_{14}, p_{15}, \eta_{qHD}) \\ & \qquad \qquad \qquad 2326,96 \frac{\text{kJ}}{\text{kg}} \end{aligned} \quad (2.19)$$

:
:

$$I_{qHD} := h_{14} - h_{15}$$

$$380,45 \frac{\text{kJ}}{\text{kg}} \quad (2.20)$$

$$x_{15} := \text{wspXEXPANSIONPTPEFF}(p_{14}, T_{14}, p_{15}, \eta_{qHD})$$

$$85,49\% \quad (2.21)$$

$$T_{15} := \text{wspTSP}(p_{15}) :$$

$$T_{15} := \text{Property}(\text{temperature}, \text{pressure} = p_{15}, Q = 0, \text{water}) : T_{11} - 273.15 \text{ K}$$

$$231,72 \text{ }^\circ\text{C} \quad (2.22)$$

$$h_{16} := \text{wspHSWT}(T_{15}) :$$

$$h_{16} := \text{Property}(\text{enthalpy}, \text{temperature} = T_{15}, Q = 0, \text{water})$$

$$137,75 \frac{\text{kJ}}{\text{kg}} \quad (2.23)$$

$$p_{19} := p_8$$

$$p_{19} := 9 \text{ MPa} \quad (2.24)$$

$$p_{16} := p_{15}$$

$$5 \text{ kPa} \quad (2.25)$$

$$T_{16} := T_{15}$$

$$306,02 \text{ K} \quad (2.26)$$

$$h_{19} := \text{wspHCOMPRESSIONPTPEFF}(p_{16}, T_{16}, p_{19}, 0.75)$$

$$149,78 \frac{\text{kJ}}{\text{kg}} \quad (2.27)$$

$$i_{nu1} := h_{19} - h_{16}$$

$$12,03 \frac{\text{kJ}}{\text{kg}} \quad (2.28)$$

$$p_{18} := p_{10}$$

$$0.5 \text{ MPa} \quad (2.29)$$

$$h_{18} := \text{wspHCOMPRESSIONPTPEFF}(p_{16}, T_{16}, p_{18}, 0.73)$$

$$138,43 \frac{\text{kJ}}{\text{kg}} \quad (2.30)$$

$$i_{nu2} := h_{18} - h_{16}$$

$$,68 \frac{\text{kJ}}{\text{kg}} \quad (2.31)$$

$$\begin{aligned}
 & \text{73 \%}) : \\
 & > p_{17} := p_{13} \\
 & \qquad \qquad \qquad 0.1 \text{ MPa} \qquad \qquad \qquad (2.32)
 \end{aligned}$$

$$\begin{aligned}
 & > h_{17} := \text{wspHCOMPRESSIONPTPEFF}(p_{16}, T_{16}, p_{17}, 0.73) \\
 & \qquad \qquad \qquad 137,88 \frac{\text{kJ}}{\text{kg}} \qquad \qquad \qquad (2.33)
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > i_{m3} := h_{17} - h_{16} \\
 & \qquad \qquad \qquad ,13 \frac{\text{kJ}}{\text{kg}} \qquad \qquad \qquad (2.34)
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > \eta := \left((q_{19}/q_{16}) \cdot I_{q_{BD}} + (1 + (q_{18}/q_{16})) \cdot I_{q_{CD}} + (1 + (q_{17}/q_{16})) \cdot I_{q_{BD}} - (i_{m1} \cdot (q_{19}/q_{16})) - (i_{m2} \cdot (q_{18}/q_{16})) - (i_{m2} \cdot (q_{17}/q_{16})) \right) / \left((h_8 - h_{19}) \cdot (q_{19}/q_{16}) + (h_{10} - h_{18}) \cdot (q_{18}/q_{16}) + (h_{13} - h_{17}) \cdot (q_{17}/q_{16}) \right) \\
 & \qquad \qquad \qquad 42,20\% \qquad \qquad \qquad (2.35)
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > t_1 := (15 + 273.15) \text{ K} :
 \end{aligned}$$

$$\begin{aligned}
 & > p_1 := 0.1 \text{ MPa} :
 \end{aligned}$$

$$\begin{aligned}
 & > p_2 := 1 \text{ MPa} :
 \end{aligned}$$

$$\begin{aligned}
 & > t_3 := (1100 + 273.15) \text{ K} :
 \end{aligned}$$

$$\begin{aligned}
 & > t_7 := 80 \text{ degC} :
 \end{aligned}$$

$$\begin{aligned}
 & > p_7 := 9 \text{ MPa} :
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > h_1 := \text{Property}(\text{enthalpy}, \text{pressure} = p_1, \text{temperature} = t_1, \text{air}) \\
 & \qquad \qquad \qquad 414,38 \frac{\text{kJ}}{\text{kg}} \qquad \qquad \qquad (3.1)
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > s_1 := \text{Property}(\text{entropy}, \text{pressure} = p_1, \text{temperature} = t_1, \text{air}) \\
 & \qquad \qquad \qquad 3849,95 \frac{\text{J}}{\text{kg K}} \qquad \qquad \qquad (3.2)
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > s_2 := s_1 :
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > t_2 := \text{Property}(\text{temperature}, \text{pressure} = p_2, \text{entropy} = s_2, \text{air}) : t_2 - 273.15 \text{ K} \\
 & \qquad \qquad \qquad 279,46 \text{ }^\circ\text{C} \qquad \qquad \qquad (3.3)
 \end{aligned}$$

$$\begin{aligned}
 & : \\
 & > h_2 := \text{Property}(\text{enthalpy}, \text{pressure} = p_2, \text{temperature} = t_2, \text{air})
 \end{aligned}$$

$$683,60 \frac{\text{kJ}}{\text{kg}} \quad (3.4)$$

$$:> p_3 := p_2 :$$

$$:> s_3 := \text{Property}(\text{entropy, pressure} = p_3, \text{temperature} = t_3, \text{air})$$

$$4,867 \frac{\text{kJ}}{\text{kg K}} \quad (3.5)$$

$$:> h_3 := \text{Property}(\text{enthalpy, pressure} = p_3, \text{temperature} = t_3, \text{air})$$

$$1\,610,34 \frac{\text{kJ}}{\text{kg}} \quad (3.6)$$

$$:> p_4 := p_1 :$$

$$:> s_4 := s_3 :$$

$$:> t_4 := \text{Property}(\text{temperature, pressure} = p_4, \text{entropy} = s_4, \text{air}) : t_4 - 273.15\text{K}$$

$$498,01 \text{ }^\circ\text{C} \quad (3.7)$$

$$:> h_4 := \text{Property}(\text{enthalpy, pressure} = p_4, \text{temperature} = t_4, \text{air})$$

$$916,82 \frac{\text{kJ}}{\text{kg}} \quad (3.8)$$

$$:> q_1 := h_3 - h_2$$

$$926,74 \frac{\text{kJ}}{\text{kg}} \quad (3.9)$$

$$:> I_{IT} := h_3 - h_4$$

$$693,52 \frac{\text{kJ}}{\text{kg}} \quad (3.10)$$

$$:> I_K := h_2 - h_1$$

$$269,23 \frac{\text{kJ}}{\text{kg}} \quad (3.11)$$

$$:> \eta_{ITV} := \frac{I_{IT} - I_K}{q_1}$$

$$45,78\% \quad (3.12)$$



- :

> $h_7 := \text{Property}(\text{enthalpy, pressure} = p_7, \text{temperature} = t_7, \text{air}) :$

$$> m1 := \frac{(h_8 - h_{19})}{h_4 - h_7} \quad 7,1 \quad (4.1)$$

$$> m2 := \frac{(h_{10} - h_{18})}{h_4 - h_7} \quad 6,2 \quad (4.2)$$

$$> m3 := \frac{(h_{13} - h_{17})}{h_4 - h_7} \quad 5,7 \quad (4.3)$$

$$m = \frac{m1 \cdot q19 + m2 \cdot q18 + m3 \cdot q17}{q16} :$$

$$> m := m1 \cdot (q19/q16) + m2 \cdot (q18/q16) + m3 \cdot (q17/q16) \quad 6,2 \quad (4.4)$$

, :

$$> q_1 := (h_3 - h_2) \cdot m \quad 5708,45 \frac{\text{kJ}}{\text{kg}} \quad (4.5)$$

:

$$> I_{ГТΥ} := (h_3 - h_4) - (h_2 - h_1) \quad 424,30 \frac{\text{kJ}}{\text{kg}} \quad (4.6)$$

:

$$> I_{ИТΥ} := (h_8 - h_9) \cdot (q19/q16) + (h_{11} - h_{12}) \cdot (q18/q16) + (h_{14} - h_{15}) \cdot 1 - (h_{19} - h_{16}) \cdot (q19/q16) - (h_{18} - h_{16}) \cdot (q19/q16) - (h_{17} - h_{16}) \cdot (1 - (q19/q16) - (q18/q16)) \quad 551,71 \frac{\text{kJ}}{\text{kg}} \quad (4.7)$$

:

$$> \eta_{ИТΥ} := \frac{I_{ИТΥ} + I_{ГТΥ} \cdot m}{q_1} \quad 55,45\% \quad (4.8)$$