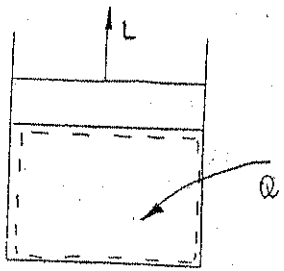
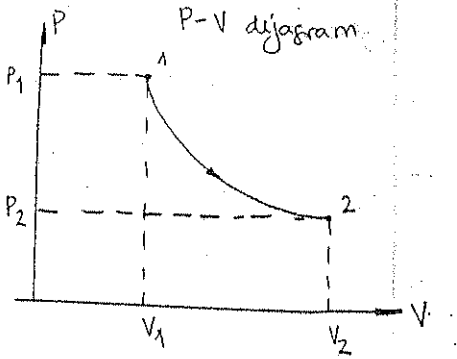
Zadatak ① 2-2-8

Promjena pritiska idealnog plina u zatvorenom sistemu, cilindar sa klipom koji se kreće bez trenja, vrši se prema zakonu $P = 9,6 V^{-1} + 3,5$ bara, od volumena $1,5\ m^3$ do volumena $3,5\ m^3$. Odrediti rad promjene volumena i u P-V dijagramu označiti površinu koja je proporcionalna radu. Odrediti količinu topline koju je potrebno dovesti plinu ili odvesti od plina da bi njegova unutarnja energija ostala ista nakon navedenog procesa.

$P = 9,6 \cdot V^{-1} + 3,5$ [bara]

$1,5\ m^3 \longrightarrow 3,5\ m^3$




Rad promjene volumena je:

$$L_{12} = \int_{V_1}^{V_2} P\,dV = \int_{V_1}^{V_2} \left[\left(3,5 + \frac{9,6}{V}\right)\right] \cdot 10^5\,dV$$

$$L_{12} = \left[\int_{V_1}^{V_2} 3,5\,dV + \int_{V_1}^{V_2} \frac{9,6}{V}\,dV\right] \cdot 10^5$$

$$L_{12} = \left[3,5\,V \cdot \Big|_{V_1}^{V_2} + 9,6\,\ln V \Big|_{V_1}^{V_2}\right] \cdot 10^5$$

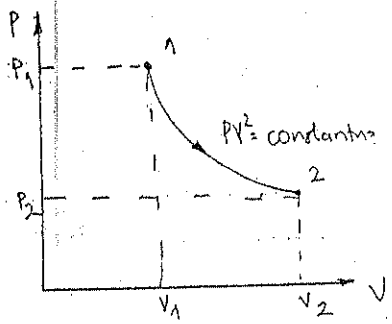
$$L_{12} = \left[3,5 \cdot (V_2 - V_1) + 9,6 \ln \frac{V_2}{V_1}\right] \cdot 10^5$$

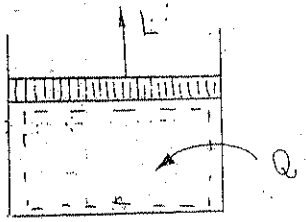
$$L_{12} = \left[3,5 \cdot (3,5 - 1,5) + 9,6 \cdot \ln \frac{3,5}{1,5}\right] \cdot 10^5$$

$$\boxed{L_{12} = 15,134 \cdot 10^5\ J} = 1513,4\ kJ$$

Zadatak ② 2-2-15

U cilindru sa pokretnim klipom nalazi se plin čije je početno stanje definirano pritiskom 100 psia, temperaturom 355°F i volumenom 1,1 ft³. Plin je podvrgnut kvazistatičnom procesu koji se odvija prema jednadžbi $pV^2 = \text{konstanta}$. Pritisak plina u zadnjem (krajnjem) stanju je 25 psia. Utvrditi da se plinu tokom procesa dovede količina topline od 5,3 Btu. Odrediti promjenu unutarnje energije plina u KJ.




$P_1 = 100\ psi = 100 \cdot \frac{101,325}{14,696}\ kPa = 689,47\ kPa = 6,89\ bar$

$t_1 = 355°F = \frac{5}{9}(355 - 32) = 179,44°C$

$V_1 = 1,1\ ft^3 = 1,1 \cdot 0,02832 = 0,0312\ m^3$

$P_2 = 25\ psi = 25 \cdot \frac{101,325}{14,696} = 172,368\ kPa = 1,72\ bar$

$Q = 5,3\ Btu = 5,3 \cdot \frac{1}{0,9478} = 5,59\ KJ$

$Q - L = \Delta U$

$L_{12} = \int_1^2 p\,dV$

$p \cdot V^2 = C$

$p = \frac{C}{V^2} = \frac{670,7}{V^2}$

$C = p_1 V_1^2 = 6,89 \cdot 10^5 \cdot (0,0312)^2 = 670,7\ Pam^6$

$L_{12} = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{C}{V^2}\,dV = \int_{V_1}^{V_2} \frac{670,7}{V^2}\,dV = 670,7 \int_{V_1}^{V_2} \frac{dV}{V^2}$

$L_{12} = 670,7 \left(-\frac{1}{V}\right)\Big|_{V_1}^{V_2} = 670,7 \left(\frac{1}{V_1} - \frac{1}{V_2}\right)$

$P_2 V_2^2 = C = 670,7$

$V_2 = \sqrt{\frac{670,7}{P_2}} = \sqrt{\frac{670,7}{1,72 \cdot 10^5}} = 0,0624\ m^3$

$L_{12} = 670,7 \left(\frac{1}{0,0312} - \frac{1}{0,0624}\right) = 10748\ J$

$\boxed{L_{12} = 10,748\ KJ}$

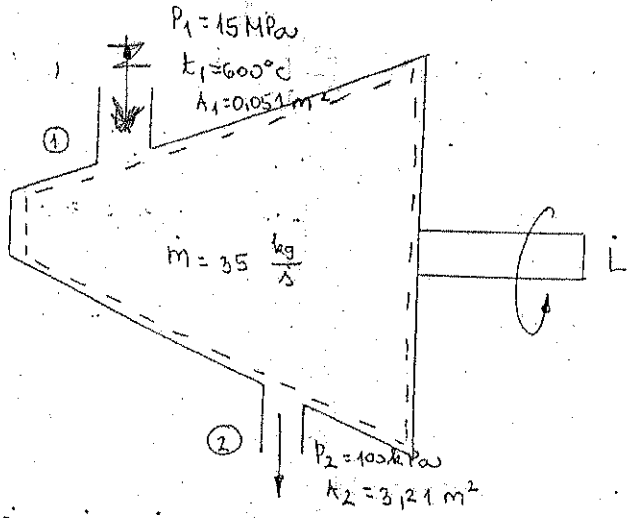
$Q - L = \Delta U$

$\Delta U = U_2 - U_1 = 5,59 - 10,748 = -5,518\ KJ$

Zadatak ③ 3-2-12

Na ulazu u turbinu vodena para ima pritisak 15 MPa i temperaturu 600°C, a na izlazu iz turbine para je suho zasićenog stanja na pritisku 100 kPa. Površina poprečnog presjeka toka pare na ulazu u turbinu je 0,051 $m^2$ a na izlazu 3,21 $m^2$. Ravnomjeran maseni protok pare kroz turbinu je 35 kg/s.

Uko. je zanemaren prenos toplote iz sistema u okolinu. Izračunati osovinski rad turbine u jedinici vremena.




$\dot{m}_1 = \dot{m}_2 = \dot{m}$

$\dot{Q} - \dot{L} = \dot{m}\left[h_2 - h_1 + \frac{w_2^2 - w_1^2}{2} + g\cdot(z_2 - z_1)\right]$

($\dot{Q}$: nema toplote; $z_2 - z_1$: zanemarujemo)

$-\dot{L} = \dot{m}\left[h_2 - h_1 + \frac{w_2^2 - w_1^2}{2}\right]$

Stanje 1.

$P_1 = 15$ MPa $= 150$ bar
$t_1 = 600°C$
$\Rightarrow h_1 = 3581{,}2\ \frac{kJ}{kg}$
$v_1 = 0{,}1024\ m^3/kg$

Stanje 2.

$P_2 = 100$ kPa $= 1$ bar
$\Rightarrow h_2 = h_{pare} = 2675\ \frac{kJ}{kg}$
$v_2 = v_{pare} = 1{,}694\ m^3/kg$

$$\dot{m} = \rho \cdot w_2 \cdot A = \frac{\dot{W}\cdot A}{v}$$

$$w_1 = \frac{\dot{m}\cdot v_1}{A_1} = \frac{35\cdot 0{,}02489}{0{,}051} = 17{,}08\ \frac{m}{s}$$

$$w_2 = \frac{\dot{m}\cdot v_2}{A_2} = \frac{35\cdot 1{,}694}{3{,}121} = 18{,}47\ \frac{m}{s}$$

$$-\dot{L} = 35\left[(2675 - 3581)\cdot 10^3 + \frac{18{,}47^2 - 17{,}08^2}{2}\right]$$

$$-\dot{L} = -906175\ W \longrightarrow \dot{L} = 906{,}175\ kW$$

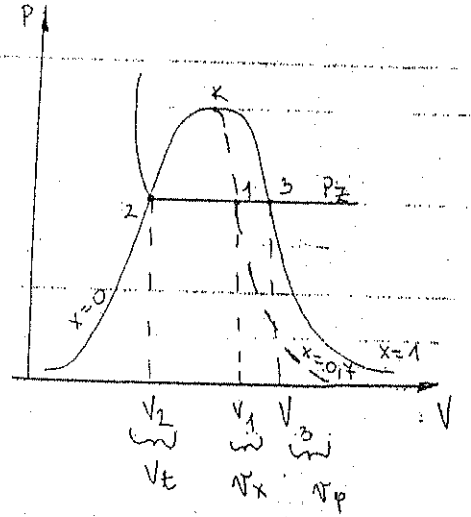
Zadatak ④ ~~4-2-dig~~ ✳

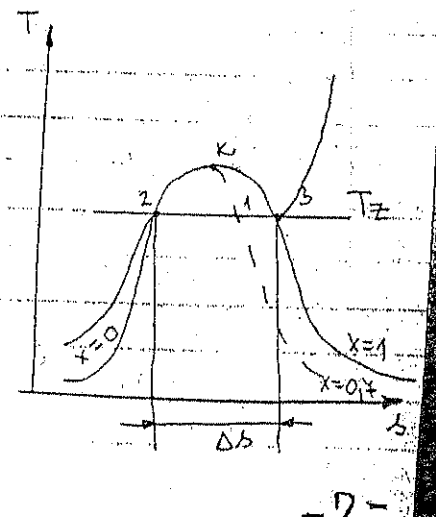
Stanje vlažne vodene pare je definirano pritiskom zasićenja 760 mmHg i stepenom vlažnosti $x = 0{,}7$.

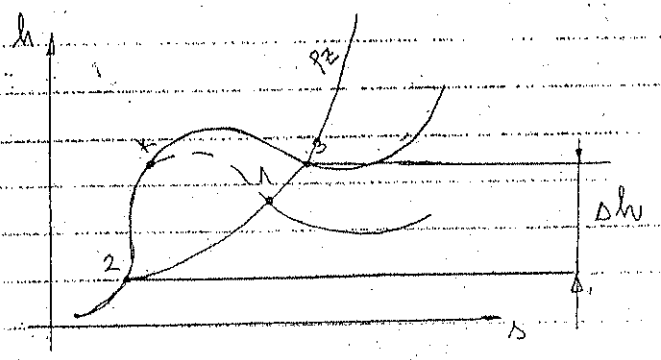
Odrediti: a) specifični volumen vlažne pare $v = ?$

b) promjenu entalpije za proces njene potpune kondenzacije $\Delta h = ?$

c) promjenu entalpije za proces od zasićene tečnosti do zasićene pare.



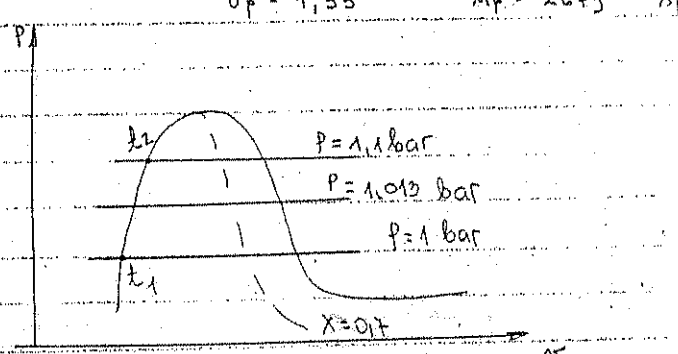



$1\ kPa = 7,501\ mmHg$

$1\ mmHg = \frac{1}{7,501}\ kPa = 0,1333224\ Pa$

$p_z = 760 \cdot 0,1333224 = 101,325\ kPa = 1,013\ bar$

| | p [bar] | v $\left[\frac{m^3}{kg}\right]$ | h $\left[\frac{kJ}{kg}\right]$ | s $\left[\frac{kJ}{kg}\right]$ |
|---|---|---|---|---|
| stanje 1. | 1 | $v_k = 0,001043$ | $h_k = 417,4$ | $s_k = 1,3026$ |
| | | $v_p = 1,694$ | $h_p = 2675$ | $s_p = 7,36$ |
| stanje 2. | 1,1 | $v_k = 0,001045$ | $h_k = 428,9$ | $s_k = 1,3327$ |
| | | $v_p = 1,55$ | $h_p = 2679$ | $s_p = 7,328$ |




a)

Stanje 2.

$$v_2 = v_{ta} + \frac{v_{tb} - v_{ta}}{p_b - p_a}(p_z - p_a)$$

$$v_2 = 0,00143 + \frac{0,001045 - 0,00143}{1,1 - 1}(1,103 - 1)$$

$$\boxed{v_2 = 0,00104326\ \frac{m^3}{kg}}$$

Stanje 3.

$$v_3 = v_{pa} + \frac{v_{pb} - v_{pa}}{p_t - p_a}(p = p_a)$$

$$v_1 = v_2 + x \cdot (v_3 - v_2)$$

$$\boxed{v_1 = 1,0984\ \frac{m^3}{kg}}$$

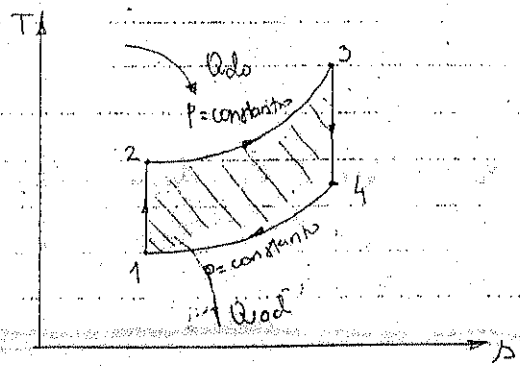
b)

$$s_2 = s_{ta} + \frac{s_{tb} - s_{ta}}{p_b - p_a}(p_z - p_a)$$

$$s_{fx} = s_2 = 1,0326 + \frac{1,3327 - 1,0326}{1,1 - 1}(1,014 - 1) = 1,3065\ \frac{kJ}{kg}$$

Zadatak (5)

U idealnom Braytonovom ciklusu radnom mediju se dovodi 1,65 mega J/kg topline. Radni medij ulazi u kompresor s temperaturom 30 °C i pritiskom 0,12 Pa, a odnos pritiska prije i poslije kompresije je 8. Koliko je radni medij može odredeti termički koeficijent korisnog djelovanja ciklusa.




$$\frac{p_2}{p_1} = \frac{p_3}{p_4} = 8$$

Stanje 1.

$T_1 = 303\ K$

Stanje 2.

$$T_2 = T_1 \cdot \left(\frac{P_2}{P_1}\right)^{\frac{\varkappa-1}{\varkappa}} = 303 \cdot 8^{\frac{1,4-1}{1,4}} = 548,87\ K$$

Stanje 3. P = constantno (izobarna)

$$q_{do} = c_p \cdot (T_3 - T_2)$$

$$T_3 = T_2 + \frac{q_{do}}{c_p} = 548,87 + \frac{1,65 \cdot 10^5}{1010} = 2182,53\ K$$

Stanje 4.

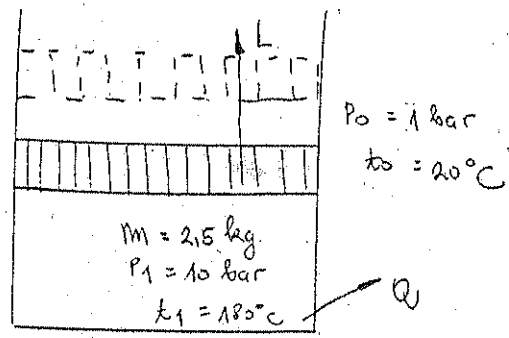
$$T_4 = T_3 \left(\frac{P_4}{P_3}\right)^{\frac{\varkappa-1}{\varkappa}} = 2182,53 \cdot \left(\frac{1}{8}\right)^{\frac{1,4-1}{1,4}} = 1204,85\ K$$

$$\eta_t = 1 - \frac{Q_{od}}{Q_{do}} = 1 - \frac{m \cdot c_p (T_4 - T_1)}{m \cdot c_p (T_3 - T_2)}$$

$$\eta_t = 1 - \frac{1204,85 - 303}{2182,53 - 548,87} = 0,447 \quad (44,7\ \%)$$

Zadatak (6.) 6-2-22

Odrediti maksimalni jednokratni i tehnički rad koji se može dobiti od 2,5 kg amonijaka ako je njegovo početno stanje definirano pritiskom 10 bara i temperaturom 180°C. Stanje okoline je pritisak 1 bar i temperatura 20°C, $R = 0,4265\ \frac{kJ}{kg}$ i $\varkappa = 1,32$.




Maksimalni jednokratni rad:

$$L_{max_K} = m \cdot [(u_1 - u_0) - T_0 \cdot (s_1 - s_0) + p_0 \cdot (v_1 - v_0)]$$

$$u_1 - u_0 = c_v \cdot (T_1 - T_0)$$

$$u_1 - u_0 = \frac{R}{\varkappa - 1}(T - T_0) = \frac{0,4265}{1,32 - 1}(453 - 293)$$

$$u_1 - u_0 = 213,25\ \frac{kJ}{kg}$$

$$s_1 - s_0 = c_p \cdot \ln\frac{T_1}{T_0} - R \cdot \ln\frac{p_1}{p_0}$$

$$s_1 - s_0 = \frac{\varkappa R}{\varkappa - 1} \ln\frac{T_1}{T_0} - R \ln\frac{p_1}{p_0}$$

$$s_1 - s_0 = \frac{1,32 \cdot 0,4265}{1,32 - 1} \cdot \ln\frac{453}{293} - 0,4265 \cdot \ln\frac{10}{1}$$

$$s_1 - s_0 = -0,5463\ \frac{kJ}{kgK}$$

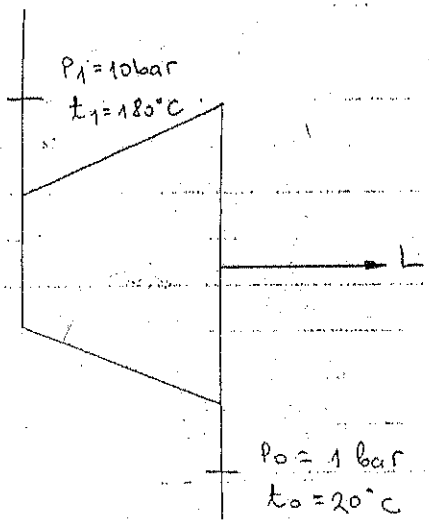
$$v_1 - v_0 = \frac{RT_1}{p_1} - \frac{R \cdot T_0}{p_0} = 0,4265 \cdot \left(\frac{453}{10 \cdot 10^2} - \frac{293}{1 \cdot 10^2}\right)$$

$$v_1 - v_0 = -1,056\ \frac{m^3}{kg}$$

$$L_{max_K} = 2,5 \cdot [213,25 - 293 \cdot (-0,5463) + 1 \cdot 10^2 \cdot (-1,056)]$$

$$L_{max_K} = 669,28\ kJ$$

Tehnički rad:




$$L_t = m \cdot [h_1 - h_0 - T_0 \cdot (s_1 - s_0)]$$

$$h_1 - h_0 = c_p \cdot (T_1 - T_0) = \frac{\varkappa R}{\varkappa - 1} (T_1 - T_0)$$

$$h_1 - h_0 = \frac{1{,}32 \cdot 0{,}4265}{1{,}32 - 1} (453 - 293)$$

$$h_1 - h_0 = 281{,}49 \ \frac{kJ}{kg}$$

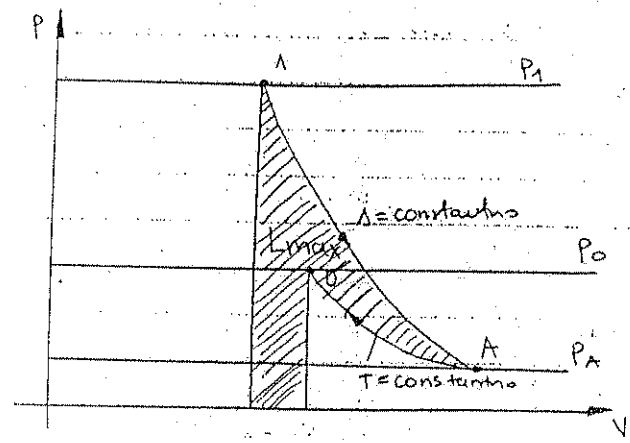
$$L_t = 2{,}5 \cdot [281{,}49 - 293 \cdot (-0{,}5462)]$$

$$\boxed{L_t = 1103{,}88\ kJ}$$

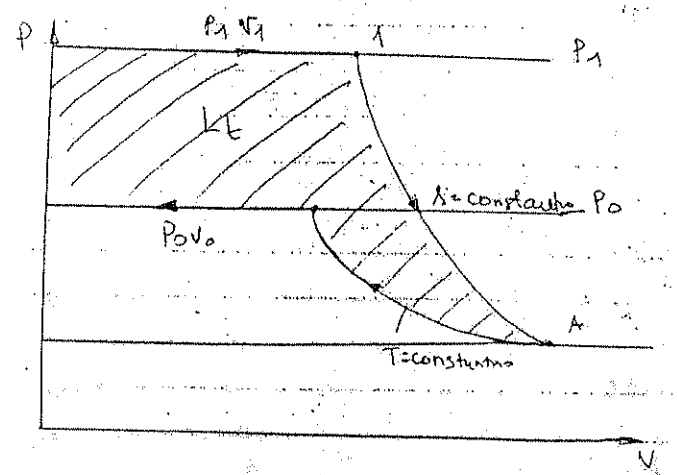
Predstavljanje procesa u p-v dijagramu

a) I slučaj - max jednokratni rad
b) II slučaj - tehnički rad

a) Maximalan jednokratni rad




b) Tehnički rad




Zadatak 2-2-2

$V_1 = 0{,}1\ m^3$
$V_2 = 89{,}9\ m^3$
$p_1 = 200\ kPa$

$p = 300 + p_1$
$p = 300 + 200$
$p = 500\ kPa$
$U = ?$

$V = 0,1 + 99,9 = 100\ m^3$

$U_1 = p_1 V_1 = 200 \cdot 10^3 \cdot 100 = 200 \cdot 10^6\ [J]$

$U_2 = p_2 V_2 = 300 \cdot 10^3 \cdot 100 = 500 \cdot 10^6\ [J]$

$U = U_2 - U_1$

$U = 500 \cdot 10^5 - 200 \cdot 10^5 = 300 \cdot 10^5\ [J]$

Zadatak 2-2-3

$m = 2,5\ kg$

$v = 20\ \frac{km}{h}$

$E_K = ?$

$E_K = \frac{m \cdot v^2}{2}$

$E_K = \frac{2,5 \cdot \left(\frac{20 \cdot 1000}{3600}\right)^2}{2} = 38,5\ [J]$

Zadatak 2-2-4

$m = 150\ grama = 0,15\ kg$

$v = 100\ \frac{km}{h}$

$E_K = ?$

$E_K = \frac{m \cdot v^2}{2}$

$E_K = \frac{0,15 \cdot \left(\frac{100 \cdot 1000}{3600}\right)^2}{2} = 57,83\ [J]$

Zadatak 2-2-5

$m = 14,5\ kg$

$h = 120\ m$

$v_1 = 25\ \frac{m}{s}$

$g = 9,81\ \frac{m}{s^2}$

$v_2 = ?$

$\Delta E_p = m \cdot g \cdot h$

$\Delta E_p = 14,5 \cdot 9,81 \cdot 120 = 17052\ [J]$

$\Delta E_K = \Delta E_p = 17052\ [J]$

$\Delta E_K = m \cdot (v_2^2 - v_1^2)/2$

$v_2 = \sqrt{\frac{2 \Delta E_K}{m} + v_1^2} = \sqrt{\frac{2 \cdot 17052}{14,5} + 25^2}$

$v_2 = 54,56\ \frac{m}{s}$

Zadatak 2-2-6

$m = 80\ tona$

$v = 900\ \frac{km}{h}$

$h = 10\,000\ m$

$g = 9,5\ \frac{m}{s^2}$

$v_1 = 10\% \cdot v = 0,1 \cdot 900 \cdot \frac{1000}{3600} = 25\ \frac{m}{s}$

$v_2 = ?$

$\Delta E_p = m \cdot g \cdot h$

$\Delta E_p = 80 \cdot 10^3 \cdot 9,5 \cdot 10\,000 = 760 \cdot 10^7\ [J]$

$\Delta E_p = \Delta E_K = 760 \cdot 10^7\ [J]$

$\Delta E_K = \frac{v_2^2 - v_1^2}{2} \cdot m$

$v_2 = \sqrt{\frac{2 \Delta E_K}{m} + v_1^2} = \sqrt{\frac{2 \cdot 760 \cdot 10^7}{80000} + 25^2}$

$v_2 = 436,6\ \left[\frac{m}{s}\right]$

Zadatak 2-2-7

$V_1 = 0,14\ m^3$

$p_1 = 9\ bara$

$T = 41\ ^\circ C = 41 + 273,15 = 314,15\ [K]$

$p_2 = 2,6\ bara$

$L_{12} = ?$ $\quad n = 1,25$

$Q_{12} = ?$

$T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}$

$T_2 = 314,15 \cdot \left(\frac{2,6}{9}\right)^{\frac{1,25-1}{1,25}} = 298,7\ [C]$

$$L_{12} = \frac{RT_1}{n-1} \cdot \left(1 - \frac{T_2}{T_1}\right)$$

$$L_{12} = \frac{287 \cdot 314{,}15}{1{,}25 - 1} \left(1 - \frac{298{,}7}{314{,}15}\right) = 17736{,}6\ [J] = 17{,}7366\ [kJ]$$

$P_{zraka} = 287\ \left[\frac{J}{kgK}\right]$

$L_{12} = Q_{12} - \Delta U$

$Q_{12} = L_{12} + \Delta U$

$\Delta U = U_2 - U_1$

$\Delta U = p_2 V_2 - p_1 V_1 = 2{,}6 \cdot 10^5 \cdot 0{,}146 - 9 \cdot 10^5 \cdot 0{,}14 = -0{,}064 \cdot 10^5$

$\Delta U = -6{,}4\ [kJ]$

$p_1 V_1 = mRT_1$

$p_2 V_2 = mRT_2$

$$\frac{p_1 V_1}{p_2 V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = \frac{p_1 V_1}{p_2 V_2} \cdot T_2 = \frac{9{,}5 \cdot 0{,}14 \cdot 298{,}7}{2{,}6 \cdot 10^5 \cdot 314{,}15} = 0{,}146\ m^3$$

$Q_{12} = 17{,}7366 + (-6{,}4) = 11{,}3366\ [kJ]$

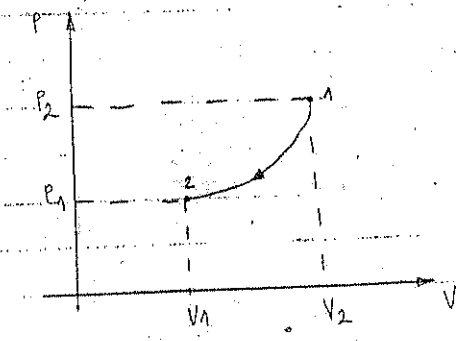
Zadatak 3-2-11

$V_1 = 0{,}1\ m^3$

$V_2 = 0{,}3\ m^3$

$p = 7{,}4 + 40V + 60V^2$

$L_{12} = ?$




$$L_{12} = \int_{V_1}^{V_2} p\,dV$$

$$L_{12} = \int_{V_1}^{V_2} (7{,}4 + 40V + 60V^2)\,dV = \left(7{,}4V + \frac{40V^2}{2} + \frac{60V^3}{3}\right)\Big|_{V_1}^{V_2}$$

$L_{12} = (7{,}4V + 20V^2 \cdot 0{,}3^2 + 20 \cdot 0{,}3^3) - (7{,}4 \cdot 0{,}3 + 20 \cdot 0{,}3^2 + 20 \cdot 0{,}3^3)$

$L_{12} = 3{,}6 \cdot 10^5\ [J] = 360\ kJ$

Zadatak 3-2-13

$p_1 = 730\ mmHg = 730 \cdot 0{,}1333224 = 97{,}325\ kPa$

$p_2 = 765\ mmHg = 765 \cdot 0{,}1333224 = 101{,}991\ kPa$

$h = ?$

$p_2 - p_1 = \rho g h$

$$h = \frac{p_2 - p_1}{\rho \cdot g} = \frac{(101{,}991 - 97{,}325) \cdot 10^3}{1{,}29 \cdot 9{,}81} = 368{,}71\ [m]$$

Zadatak 3-2-4

$p = 1{,}5\ MPa = 1{,}5 \cdot 10^6\ \frac{N}{m^2} = 15 \cdot 10^5\ \frac{N}{m^2}$

$t = 90°C = 363\ K$

$\dot{m} = 150\ \frac{kg}{min} = 150 \cdot \frac{kg}{60s} = 2{,}5\ \frac{kg}{s}$

$\rho = 3{,}4843 \cdot 10^{-3}\ pT^{-1}\ \left[\frac{kg}{m^3}\right] = 3{,}4843 \cdot 10^{-3} \cdot 15 \cdot 10^6 \cdot \frac{1}{363} = 14{,}398\ \frac{kg}{m^3}$

$v_{sr} \leq 250\ \frac{m}{s}$

$\dot{V}_{sr} \leq \dot{m} \cdot \rho \cdot A$

$\dot{V}_{sr} \leq \dot{m} \cdot \rho \cdot d^2 \pi$

$$d^2 \geq \frac{\dot{V}_{sr}}{\dot{m} \cdot \rho \cdot \pi} = \frac{250}{2{,}5 \cdot 14{,}398 \cdot \pi} = 2{,}21$$

$d \geq \sqrt{\phantom{x}}$

Zadatak: ~~3-2-43~~

$p_1 = 100\ kPa = 10^5\ Pa = 1\ bar$

$t_1 = 20°C$

$p_2 = 240\ kPa = 2{,}4\ bar$

$t_2 = 70°C$

$\dot{m} = 1{,}5\ \frac{kg}{s}$

$q = 19\ \frac{kJ}{kg}$

$w_1 = 60\ \frac{m}{s}$

$w_2 = 120\ \frac{m}{s}$

$L = ?$

(a)

$L = l \cdot \dot{m}$

$q_{12} - l_{12} = (h_2 - h_1) + \left(\frac{w_2^2 - w_1^2}{2}\right) + g \cdot (z_2 - z_1)$ → $0$

$q_{12} - l_{12} = (h_2 - h_1) + \left(\frac{w_2^2 - w_1^2}{2}\right)$

Vršimo interpolaciju P-5-1

$p = 1\ bar$

$t_1 = 273{,}15 + 20 = 293{,}15$

| T | 250 | 300 | K |
|---|---|---|---|
| h | 503,4 | 553,7 | $\frac{kJ}{kg}$ |

$h_1 = 503{,}4 + \frac{553{,}7 - 503{,}4}{300 - 250}\ (293{,}15 - 250)$

$h_1 = 503{,}4 + 1{,}006 \cdot 43{,}15$

$\boxed{h_1 = 546{,}8089\ \frac{kJ}{kg}}$

(b) $T_2 = 343{,}15\ K$

$p = 2{,}4\ bar$

Imamo tablice za: $p_1 = 1\ bar$

$p_2 = 10\ bar$

Za: $p_1 = 1\ bar$

| T | 300 | 350 | K |
|---|---|---|---|
| h | 553,7 | 604,1 | $\frac{kJ}{kg}$ |

$h^* = 553{,}7 + \frac{604{,}1 - 553{,}7}{350 - 300}\ (343{,}15 - 300)$

$h^* = 553{,}7 + 1{,}008 \cdot 43{,}15$

$\boxed{h^* = 597{,}195\ \frac{kJ}{kg}}$

Za: $p_2 = 10\ bar$

| T | 300 | 350 | K |
|---|---|---|---|
| h | 551,6 | 602,6 | $\frac{kJ}{kg}$ |

$h^{**} = 351{,}6 + \frac{602{,}6 - 551{,}6}{350 - 30} \cdot 43{,}15$

$h_2 = h^* + \frac{h^{**} - h^*}{p_2 - p_1}\ (p - p_1)$

$h_2 = 597{,}195 + \frac{595{,}613 - 597{,}195}{10 - 1} \cdot 1{,}4$

$\boxed{h_2 = 596{,}948\ \frac{kJ}{kg}}$

© $\Delta h = h_2 - h_1$

$\Delta h = 596{,}948 - 546{,}8089 = 50{,}1391 \ \frac{kJ}{kg}$

$q_{12} - l_{12} = (h_2 - h_1) + \frac{w_2^2 - w_1^2}{2}$

$l_{12} = q_{12} - (h_2 - h_1) - \frac{w_2^2 - w_1^2}{2}$

$\frac{w_2^2 - w_1^2}{2} = \frac{(120)^2 - (60)^2}{2} = 5400 \ \frac{m^2}{s^2} = 5{,}4 \ \frac{kJ}{kg}$

$l_{12} = 19 - 50{,}1351 - 5{,}4 = -36{,}539 \ kJ/kg$

Snaga: $L = \dot{m} \cdot l$

$L = 1{,}5 \ kg/s \cdot 36539 \ J/kg$

$L = 54808{,}5 \ W$

$L = 54{,}808 \ KW$

Zadatak 4-2-19 (nastavak) ✱

$\Delta p_x = \Delta p_a + \frac{\Delta_b - \Delta_{pa}}{P_b - P_a} (P_2 - P_a)$

$\Delta p_x = 7{,}36 + \frac{7{,}328 - 7{,}36}{1{,}1 - 1} (1{,}013 - 1) = 5{,}15245 \ \frac{kJ}{kgK}$

$\Delta_x = \Delta_1 = \Delta t_x + x \cdot (\Delta p_x - \Delta t_x) = 1{,}3065 + 0{,}7 \cdot (7{,}33216 - 1{,}3065)$

$\Delta_x = \Delta_1 = 5{,}15245 \ \frac{kJ}{kgK}$

$\Delta s = s_2 - s_1 = 1{,}3065 - 5{,}15265 = 4{,}21796 \ \frac{kJ}{kgK}$

c) $h_{tx} = h_{ta} + \frac{h_{tb} - h_{ta}}{P_b - P_a} (P_x - P_a)$

$h_{tx} = 417{,}4 + \frac{428{,}9 - 417{,}4}{1{,}1 - 1} (1{,}013 - 1) = 418{,}895 \ \frac{kJ}{kg}$

$h_{px} = h_{pa} + \frac{h_{pb} - h_{pa}}{P_b - P_a} (P_x - P_a)$

$h_{px} = 2675 + \frac{2679 - 2675}{1{,}1 - 1} (1{,}013 - 1)$

$h_{px} = 2675{,}52 \ \left[\frac{kJ}{kg}\right]$

$\Delta h = h_{px} - h_{tx} = 2675{,}52 - 418{,}895 = 2256{,}625 \ \frac{kJ}{kg}$

Zadatak 4-2-20

$P = 0{,}1 \ bar$

$x = 0{,}9$

Za $P = 0{,}1 \ bar$

$t_z = 45{,}84 \ °C$

$v_t = 0{,}0010103 \ \frac{m^3}{kg}$

$v_p = 14{,}68 \ \frac{m^3}{kg}$

$h_t = 191{,}9 \ \frac{kJ}{kg}$

$h_p = 2584 \ kJ/kg$

$s_t = 0{,}649 \ kJ/kgK$

$s_p = 8{,}15 \ kJ/kgK$

Specifični volumen vlažne pare

$v_x = (1 - x) \cdot v_t + x v_p = (1 - 0{,}9) \cdot 0{,}0010103 + 0{,}9 \cdot 14{,}68$

$v_x = 13{,}212$

$s_2 = s_t = 0{,}649 \left[\frac{kJ}{kgK}\right]$

$s_1 = s_x = (1-x)s_t + x \cdot s_p = (1-0{,}9)\cdot 0{,}649 + 0{,}9 \cdot 8{,}15$

$s_1 = 7{,}399 \ kJ/kgK$

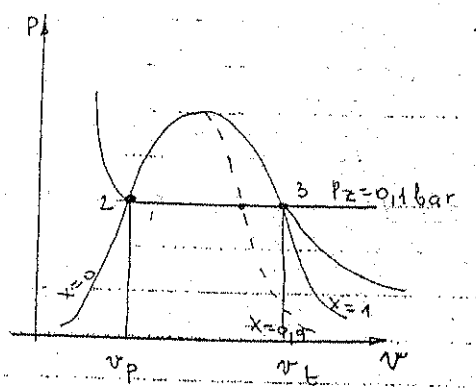
$|\Delta s| = s_2 - s_1 = 0{,}649 - 7{,}399 = 6{,}750 \ \frac{kJ}{kgK}$

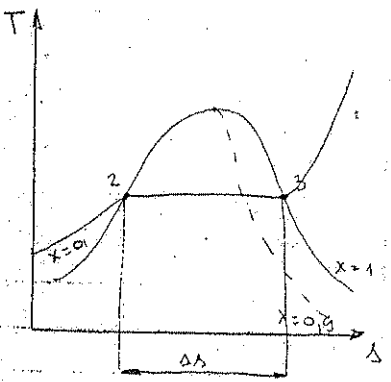
$\Delta s = 6{,}750 \ kJ/kg$

$h_t = 191{,}9 \ \frac{kJ}{kg}$

$h_p = 2584 \ kJ/kg$

$\Delta h = h_p - h_t = 2584 - 191{,}9 = 2392{,}1 \ kJ/kg$




Zadatak 5-2-1

$m = 1{,}5$ kg

$p_1 = 0{,}125$ MPa $= 1{,}25$ bar

$V_1 = 1$ litar $= 1 \cdot 10^{-3} \ m^3$

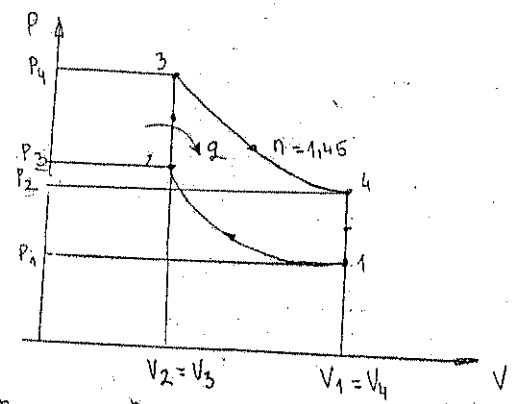
$V_2 = 0{,}12$ litara $= 0{,}12 \cdot 10^{-3} \ m^3$

$p_3 = 4{,}5$ MPa $= 45$ bar

$n = 1{,}45$

$R = 287 \ \frac{J}{kgK}$ } zad. zrak

$\varkappa = 1{,}4$




$p_1 V_1^n = p_2 V_2^n$

$p_2 = p_1 \cdot \left(\frac{V_1}{V_2}\right)^n = \left(\frac{1}{0{,}12}\right)^{1{,}45} \cdot 1{,}25 = 27$ bar

$p_3 V_3^n = p_4 V_4^n$

$p_4 = p_3 \cdot \left(\frac{V_3}{V_4}\right)^n = \left(\frac{0{,}12}{1}\right)^{1{,}45} \cdot 45 = 2{,}079$ bar

$L_{12} = m \cdot \frac{R}{n-1}(T_1 - T_2) = \frac{mRT_1}{n-1}\left(1 - \frac{T_2}{T_1}\right)$

$L_{12} = \frac{mRT_1}{n-1}\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right] = \frac{p_1 V_1}{n-1}\left[\left(1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]\right.$

$L_{12} = \frac{1{,}25 \cdot 10^5 \cdot 1 \cdot 10^{-3}}{(1{,}45-1)}\left[1 - \left(\frac{27}{1{,}25}\right)^{\frac{1{,}45-1}{1{,}45}}\right] = -442{,}94 \ [kJ]$

$L_{23} = m\,p\,(V_3 - V_2) = 0$

$$L_{34} = \frac{mR}{n-1}\left[T_3 - T_4\right] = \frac{mRT_3}{n-1}\left[1 - \frac{T_4}{T_3}\right]$$

$$L_{34} = \frac{mRT_3}{n-1}\left[1 - \left(\frac{P_4}{P_3}\right)^{\frac{n-1}{n}}\right]$$

$$L_{34} = \frac{P_3V_3}{n-1}\left[1 - \left(\frac{P_4}{P_3}\right)^{\frac{n-1}{n}}\right] = \frac{45\,10^5 \cdot 0{,}12 \cdot 10^{-3}}{1{,}45-1}\left[1 - \left(\frac{2{,}097}{45}\right)^{\frac{1{,}45-1}{1{,}45}}\right]$$

$$\boxed{L_{34} = 737{,}81 \ [kJ]}$$

$$\boxed{L_{41} = 0}$$

$$Q_{12} = m \cdot c_v \cdot \frac{n-\varkappa}{n-1}\left[T_2 - T_1\right]$$

$$Q_{12} = \frac{m \cdot c_v \cdot (n-\varkappa) \cdot T_1}{n-1}\left[\frac{T_2}{T_1} - 1\right] = \frac{1}{\varkappa-1} \cdot \frac{(n-\varkappa)}{n-1} \cdot mRT_1\left[\frac{T_2}{T_1} - 1\right]$$

$$Q_{12} = \frac{n-\varkappa}{(\varkappa-1)(n-1)} P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = \frac{1{,}45-1{,}4}{(1{,}4-1)(1{,}45-1)} \cdot 1{,}25 \cdot 10^5 \cdot 1 \cdot 10^{-3}\left[\left(\frac{27}{1{,}25}\right)^{\frac{1{,}45-1}{1{,}45}} - 1\right]$$

$$\boxed{Q_{12} = 55{,}37 \ kJ}$$

$$Q_{23} = m\,c_v\,(T_3 - T_2) = \frac{1}{\varkappa-1} m \cdot R \cdot T_2\left[\frac{T_3}{T_2} - 1\right]$$

$$Q_{23} = \frac{1}{\varkappa-1} \cdot P_2V_2\left[\left(\frac{P_3}{P_2}\right) - 1\right] = \frac{1}{1{,}4-1} \cdot 27 \cdot 10^5 \cdot 0{,}12 \cdot 10^{-3}\left[\left(\frac{45}{27}\right) - 1\right]$$

$$\boxed{Q_{23} = 540 \ kJ}$$

$$Q_{34} = m \cdot c_v \cdot \frac{n-\varkappa}{n-1}\left[T_4 - T_3\right] = \frac{(m \cdot c_v) \cdot (1-\varkappa)}{n-1} \cdot T_3 \cdot \left[\frac{T_4}{T_3} - 1\right]$$

$$Q_{34} = \frac{1}{\varkappa-1} \cdot \frac{n-\varkappa}{n-1} m \cdot R \cdot T_3\left[\frac{T_4}{T_3}\right]$$

$$Q_{34} = \frac{1}{\varkappa-1} \cdot \frac{n-\varkappa}{n-1} P_3V_3\left[\left(\frac{P_4}{P_3}\right)^{\frac{n-1}{n}} - 1\right]$$

$$Q_{34} = \frac{1}{1{,}4-1} \cdot \frac{1{,}45-1{,}4}{1{,}45-1} \cdot 45 \cdot 10^5 \cdot 0{,}12 \cdot 10^{-3} \cdot \left[\left(\frac{2{,}097}{45}\right)^{\frac{1{,}45-1}{1{,}45}} - 1\right]$$

$$Q_{34} = -92{,}226 \ [kJ]$$

$$Q_{41} = m \cdot c_v \cdot (T_4 - T_1) = \frac{1}{\varkappa-1} \cdot m \cdot R \cdot T_1\left(\frac{T_4}{T_1} - 1\right)$$

$$Q_{41} = \frac{1}{\varkappa-1} P_1V_1\left[\left(\frac{P_4}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$Q_{41} = \frac{1}{1{,}4-1} \cdot 1{,}25 \cdot 10^5 \cdot 1 \cdot 10^{-3}\left[\left(\frac{2{,}097}{1{,}25}\right)^{\frac{1{,}45-1}{1{,}45}} - 1\right]$$

$$\boxed{Q_{41} = 207{,}25 \ [kJ]}$$

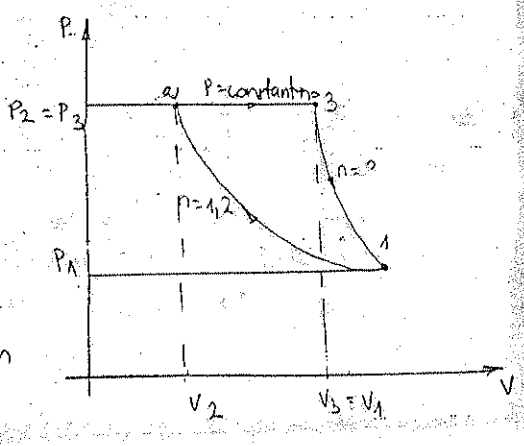
$$L_{korisno} = Q_{12} + Q_{23} + Q_{34} + Q_{41}$$

$$L_{korisno} = 55{,}37 + 540 - 92{,}226 + 207{,}25$$

$$\boxed{L_{korisno} = 710{,}394 \ [kJ]}$$

Zadatak 5-2-2

$m = 2\,kg$
$V_1 = 0{,}11\ m^3$
$P_1 = 0{,}105\ MPa = 6{,}5\ bar$
$V_2 = 0{,}015\ m^3$
$n = 1{,}2$
$V_3 = 0{,}06\ m^3$
$R = 319{,}6\ \frac{kJ}{kgK}$ } za acetilen
$\varkappa = 1{,}25$



$P_1 \cdot V_1^{n_1} = P_2 V_2^{n_2}$

$P_3 = P_2 = P_1 \left( \frac{V_1}{V_2} \right)^{n_1}$

$P_3 V_3^{n_2} = P_1 V_1^{n_2} \quad / \log$

$\log P_3 + n_2 \log V_3 = \log P_1 + n_2 \log V_1$

$n_2 \log V_3 - n_2 \log V_1 = \log P_1 - \log P_3$

$n_2 (\log V_3 - \log V_1) = \log P_1 - \log P_3$

$$n_2 = \frac{\log P_1 - \log P_3}{\log V_3 - \log V_1} = \frac{\log(0{,}15) - \log(71)}{\log(0{,}106) - \log(0{,}11)} = \frac{-1{,}038}{-0{,}2632}$$

$\boxed{n_2 = 3{,}943}$

$L_{12} = \frac{mR}{n-1} (T_1 - T_2)$

$L_{12} = \frac{mR}{n-1} T_2 \left( \frac{T_1}{T_2} - 1 \right) = \frac{P_2 V_2}{n-1} \left[ \left( \frac{P_1}{P_2} \right)^{\frac{n-1}{n}} - 1 \right]$

$L_{12} = \frac{71 \cdot 0{,}015}{1{,}12 \cdot 1} \left[ \left( \frac{6{,}5}{71} \right)^{\frac{1{,}12-1}{1{,}12}} - 1 \right] = -174{,}44^{8} \text{ [KJ]}$

$\boxed{L_{12} = -174{,}44 \text{ [KJ]}}$

$Q_{12} = m \cdot c_v \cdot \frac{n-\varkappa}{n-1} (T_2 - T_1)$

$Q_{12} = \frac{1}{\varkappa - 1} \cdot \frac{n-\varkappa}{n-1} mRT_1 \left[ \frac{T_2}{T_1} - 1 \right] = \frac{n-\varkappa}{(\varkappa-1)(n-1)} P_1 V_1 \left[ \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$

$Q_{12} = \frac{1{,}12 - 1{,}25}{(1{,}25-1)(1{,}12-1)} \cdot 6{,}5 \cdot 10^5 \cdot 0{,}11 \cdot \left[ \left( \frac{7}{6{,}5} \right)^{0{,}166} - 1 \right]$

$\boxed{Q_{12} = -34{,}833 \text{ [KJ]}}$

2234,56

$L_{23} = m \cdot c_p \cdot (V_3 - V_2) = m \cdot R (T_3 - T_2)$

$L_{23} = 71 \cdot 10^5 (0{,}106 - 0{,}1015) \cdot 2 = 639 \text{ [KJ]}$

$\boxed{L_{23} = 639 \text{ [KJ]}}$

$Q_{23} = m \cdot c_p (T_3 - T_2) = m \cdot c_p \cdot T_2 \left( \frac{T_3}{T_2} - 1 \right)$

$Q_{23} = \frac{m \cdot R T_2}{\varkappa - 1} \left( \frac{T_3}{T_2} - 1 \right) = \frac{P_2 V_2}{\varkappa - 1} \left( \frac{V_2}{V_3} - 1 \right)$

$Q_{23} = \frac{71 \cdot 0{,}1015}{1{,}25 - 1} \left[ \frac{0{,}1015}{0{,}106} - 1 \right] = -319{,}6 \text{ [KJ]}$

$\boxed{Q_{23} = -319{,}6 \text{ [KJ]}}$

$L_{31} = m \frac{R}{n-1} (T_3 - T_1)$

$L_{31} = \frac{mR}{n-1} T_1 \left[ \frac{T_3}{T_1} - 1 \right] = \frac{P_1 V_1}{n-1} \left[ \left( \frac{P_3}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$

$L_{31} = \frac{6{,}5 \cdot 0{,}11}{1{,}12 - 1} \left[ \left( \frac{71}{6{,}5} \right)^{0{,}166} - 1 \right]$

$\boxed{L_{31} = 1770 \text{ [KJ]}}$

$Q_{31} = m \cdot c_v \cdot \frac{n-\varkappa}{n-1} (T_1 - T_3) = \frac{1}{\varkappa - 1} \cdot \frac{n-\varkappa}{n-1} mRT_3 \left[ \frac{T_1}{T_3} - 1 \right]$

$Q_{31} = \frac{1}{\varkappa - 1} \cdot \frac{n-\varkappa}{n-1} P_3 V_3 \left[ \left( \frac{P_1}{P_3} \right)^{\frac{n-1}{n}} - 1 \right]$

$\boxed{Q_{31} = 354{,}3 \text{ [KJ]}}$

$-Q_1 + Q_2 + Q_3 =$

Zadatak 5-2-3

$m = 3\ kg$

$V_1 = 120\ litara = 120 \cdot 10^{-3}\ m^3$

$p_1 = 0{,}765\ MPa = 7{,}65\ bara$

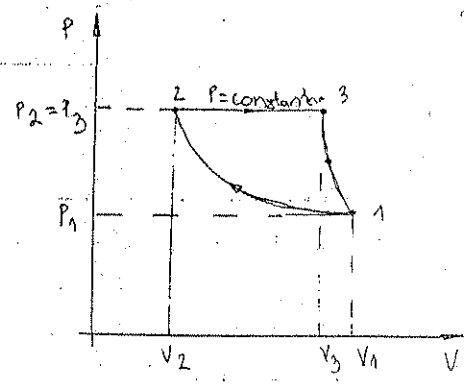
$V_2 = 0{,}015\ m^3$

$n_2 = 1{,}23$

$V_3 = 0{,}064\ m^3$

$R = 260\ \frac{kJ}{kg\,K}$

$\varkappa = 1{,}4$




$$p_1 \cdot V_1^{n_1} = p_2 \cdot V_2^{n_1}$$

$$p_3 = p_2 = p_1 \cdot \left(\frac{V_1}{V_2}\right)^{n_1} = 7{,}65 \cdot \left(\frac{0{,}12}{0{,}015}\right)^{1{,}23} = 98{,}79\ bara$$

Stanje 1-2:

$$L_{12} = \frac{m \cdot R}{n-1}(T_1 - T_2) = -244{,}75\ kJ$$

$$Q_{12} = c_v \cdot \frac{n-\varkappa}{n-1} \cdot m \cdot (T_2 - T_1)$$

$$Q_{12} = \frac{R}{\varkappa - 1} \cdot \frac{n}{n-1} \cdot m \cdot (T_2 - T_1) = 104{,}01\ [kJ]$$

Stanje 2-3:

$$L_{23} = m \cdot p \cdot (V_3 - V_2) = 1451{,}3\ kJ$$

$$Q_{23} = m \cdot c_p \cdot (T_3 - T_2)$$

$$Q_{23} = \frac{\varkappa}{\varkappa - 1} \cdot m \cdot R \cdot T_3 \left[1 - \frac{T_2}{T_3}\right]$$

$$Q_{23} = \frac{\varkappa}{\varkappa - 1} \cdot p_3 V_3 \left[1 - \frac{T_2}{T_3}\right]$$

$$Q_{23} = \frac{\varkappa}{\varkappa - 1} \cdot p_3 V_3 \cdot \left[1 - \frac{V_2}{V_3}\right]$$

$$Q_{23} = \frac{1{,}4}{1{,}4 - 1} \cdot 98{,}79 \cdot 10^5 \cdot 0{,}064 \left[1 - \left(\frac{0{,}015}{0{,}064}\right)\right]$$

$$Q_{23} = 1093{,}233\ kJ$$

Stanje 3-1: $n = 4{,}067$

$$L_{31} = m \cdot \frac{R}{n-1}(T_3 - T_1)$$

$$L_{31} = \frac{m R T_1}{n-1}\left[\frac{T_3}{T_1} - 1\right] = \frac{p_1 V_1}{n-1}\left[\left(\frac{V_1}{V_3}\right)^{n-1} - 1\right] = 175{,}85\ [kJ]$$

$$Q_{31} = m\ c_v \cdot \frac{n-\varkappa}{n-1} \cdot [T_1 - T_3]$$

$$Q_{31} = \frac{n-\varkappa}{(\varkappa-1)\cdot(n-1)} \cdot m \cdot R \cdot T_3 \left[\frac{T_1}{T_3} - 1\right] = \frac{n-1}{(\varkappa-1)(n-1)} \cdot p_3 V_3 \left[\left(\frac{V_1}{V_3}\right)^n\right]$$

$$Q_{31} = -1350{,}10\ kJ$$

$$Q_K = Q_{12} + Q_{23} + Q_{31} = 239{,}109\ kJ$$

$$L_K = Q_K$$

Zadatak 5-2-7

$m = 2{,}5\ kg$

$p_1 = 1{,}05\ bar$

$T_1 = 294{,}15\ K$

$p_3 = p_2 = 1{,}7\ bara$

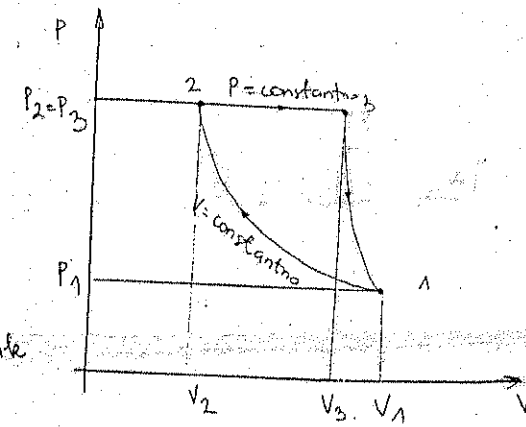
$T_3 = 70°C = 343\ K$

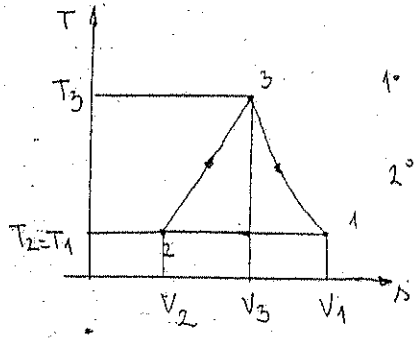
$u_1 = 213{,}1\ \frac{kJ}{kg}$

$R = 4125\ J/kgK$

$\varkappa = 1{,}407$

} zrak vodonik






1° $U_1 = m u_1 = 2{,}5 \cdot 213{,}1 = 532{,}75$ kJ

2° $U_2 - U_1 = C_v \cdot \Delta T$

$U_2 = U_1 + m \cdot C_v \cdot \Delta T = 8112{,}43$ kJ

$s_2 - s_1 = R \cdot C_v \cdot m \cdot \frac{V_1}{V_2} = 1987{,}59 \frac{kJ}{kg}$

$s_2 - s_1 = m \cdot (1987{,}59) = 4968{,}95 \frac{kJ}{kg}$

3° $U_3 - U_2 = C_p \cdot (T_3 - T_2)$ $\quad s_3 - s_2 = C_p \, m \, \frac{T_3}{T_2} = 2{,}224$

$U_3 - U_2 = \frac{nR}{n-1} (T_3 - T_2)$

$U_3 - U_2 = 1767{,}5$ kJ

$V_1 = \frac{R T_1}{P_1} = 11{,}55 \frac{m^3}{kg}$

$P_1 V_1 = P_2 V_2$

$V_2 = V_1 \cdot \frac{P_1}{P_2} = 7{,}1338 \; m^3/kg$

$T_2 = \frac{P_2 V_2}{R} = 293{,}99 \; K$

$V_3 = \frac{R T_3}{P_3} = 8{,}322 \frac{m^3}{kg}$

$\frac{V_2}{T_2} = \frac{V_3}{T_3} \Rightarrow T_2 = \frac{V_2}{V_3} \cdot T_3 = 294$ K

Zadatak ~~5-2-9~~

$m = 2{,}5$ kg

$T_1 = 50°C + 273 = 323$ K

$T_1 = T_2 =$ constanta

$P_2 = 2{,}5$ bar

$R = 518{,}8$

$L_{12} = RT \cdot \ln \frac{V_2}{V_1} = RT \cdot \ln \frac{P_1}{P_2}$

$L_{12} = mRT \ln \frac{V_2}{V_1} = mRT \ln \frac{P_1}{P_2}$

$L_{12} = 2{,}5 \cdot 518{,}8 \cdot 323 \ln \frac{1}{2{,}5} = -383{,}86$ [KJ]

$L_{12} = -383{,}86$ [KJ]

Zadatak 5-2-11

$V_1 = 0{,}03 \; m^3$

$T_1 = 323$ K

$P_2 = P_1 = 150$ kPa $= 1{,}5$ bar

$V_2 = V_1 \cdot 2 = 0{,}06 \; m^3$

$V_3 = V_2 \cdot 2 = 0{,}06 \cdot 2 = 0{,}12 \; m^3$

$P_2 V_2 = P_3 V_3$

$P_3 = P_2 \frac{V_2}{V_3} = 1{,}5 \cdot \frac{0{,}06}{0{,}12} = 0{,}75$ bar.

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$T_3 = T_2 = \frac{V_2}{V_1} T_1 = \frac{0{,}06}{0{,}03} \cdot 323 = 646$ K

$$L_{12} = mR(T_2 - T_1) = mRT_1\left(\frac{T_2}{T_1} - 1\right)$$

$$L_{12} = P_1 V_1 \left(\frac{V_1}{V_2} - 1\right) = 1{,}5 \cdot 0{,}03 \cdot \left(\frac{0{,}03}{0{,}06} - 1\right) 10^5$$

$$\boxed{L_{12} = -2{,}25 \text{ kJ}}$$

$$L_{23} = mR \cdot T_3 \cdot \ln \frac{V_3}{V_2} = P_3 V_3 \cdot \ln \frac{V_3}{V_2}$$

$$L_{23} = 0{,}75 \cdot 0{,}12 \cdot 10^5 \cdot \ln \frac{0{,}12}{0{,}06}$$

$$\boxed{L_{23} = 6{,}238 \text{ kJ}}$$

Zadatak **5-2-12**

$T = 150°C + 273 = 423$ K

$P_1 = 340$ kPa $= 3{,}4$ bar

$P_2 = 1$ MPa $= 10$ bar

$V_1 = 1{,}3$ m$^3$

$R = 297$ J/kgK – za ugljenmonoksid

$L = ?$

$$m = \frac{P_1 V_1}{RT_1}$$

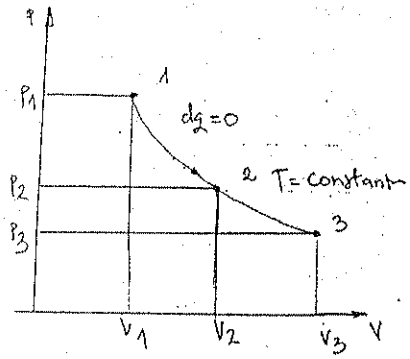
$$m = \frac{3{,}4 \cdot 10^5 \cdot 1{,}3}{297 \cdot 423} = 3{,}518 \text{ kg}$$

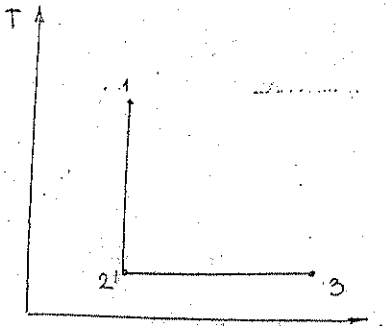
$$L = mRT \ln \frac{V_2}{V_1}$$

$$L = 3{,}518 \cdot 297 \cdot 423 \cdot \ln \frac{3{,}4}{10} = -476{,}82 \text{ kJ}$$

$$\boxed{L = -476{,}82 \text{ kJ}}$$

Zadatak **5-2-13**




$P_1 = 20$ MPa $= 200$ bar

$T_1 = 1100$ K

$P_3 = 2{,}1$ MPa $= 21$ bar

$V_1 = 1{,}2$ m$^3$

$R = 287$ [J/kgK] } za zrak

$\varkappa = 1{,}4$ }

$$m = \frac{P_1 V_1}{RT_1} = \frac{200 \cdot 10^5 \cdot 1{,}2}{287 \cdot 1100} = 76{,}02 \text{ kg}$$

$$P_1 V_1^{\varkappa} = P_2 V_2^{\varkappa}$$

$$P_2 V_2 = P_3 V_3$$

$$\frac{P_1 V_1^{\varkappa}}{V_2^{\varkappa}} = \frac{P_3 V_3}{V_2}$$

$$\frac{V_2}{V_2^{\varkappa}} = \frac{P_3 V_3}{P_1 V_1^{\varkappa}}$$

$$V_2^{1-\varkappa} = \left(\frac{P_3}{P_1} V_1^{\varkappa}\right) V_3$$

$$V_2 = \left(\frac{p_3}{p_1} \cdot V_1^{\varkappa}\right)^{\frac{1}{1-\varkappa}} \cdot V_3^{\frac{1}{1-\varkappa}}$$

Zadatak 5-2-14

$m = 3\ kg$

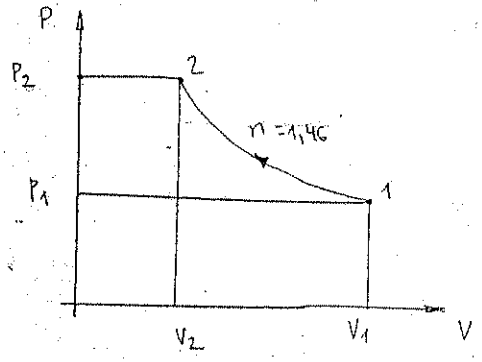
$p_1 = 310\ kPa = 3{,}10\ bar$

$T_1 = 327\ K$

$p_2 = 1{,}1\ MPa = 11\ bar$

$n = 1{,}46$

$R = 189\ J/kgK$




$$\frac{p_1^{n-1}}{T_1^{n}} = \frac{p_2^{n-1}}{T_2^{n-1}}$$

$$T_2 = \left(\frac{p_2}{T_1}\right)^{\frac{n-1}{n}} \cdot T_1 = 487{,}31\ K$$

$$V_1 = \frac{mRT_1}{p_1} = \frac{3 \cdot 189 \cdot 327}{3{,}1\ 10^5} = 0{,}1598\ m^3$$

$$V_2 = \frac{mRT_2}{p_2} = \frac{3 \cdot 189 \cdot 487{,}31}{1{,}1 \cdot 10^5} = 0{,}25118\ m^3$$

$$L_{12} = \frac{mR}{n-1}(T_1 - T_2) = -197{,}59\ kJ$$

Zadatak 5-2-15

$p_1 = 150\ kPa = 1{,}5 \cdot bar$

$T_1 = 313\ K$

$p_2 = 1{,}25\ MPa = 12{,}5\ bar$

$R = 287\ J/kgK$

$n = 1{,}4$

$$\frac{p_1^{n-1}}{T_1^{n}} = \frac{p_2^{n-1}}{T_2^{n-1}}$$

$$T_2 = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \cdot T_1 = 573{,}61\ K$$

$$L_{12} = \frac{R}{n-1}(T_1 - T_2) = \frac{287}{1{,}4-1}(313 - 573{,}61)$$

$$\boxed{L_{12} = -186{,}992\ kJ/kg}$$

Za $n = 1{,}2$

$$\frac{p_1^{n-1}}{T_1^{n}} = \frac{p_2^{n-1}}{T_2^{n}}$$

$$T_2 = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \cdot T_1 = 445{,}04\ K$$

$$L_{12} = \frac{R}{n-1}(T_1 - T_2) = \frac{287}{1{,}2-1}(313 - 445{,}04)$$

$$\boxed{L_{12} = -189{,}479\ kJ/kg}$$

Za izotermni proces:

$$L_{12} = RT \cdot \ln\frac{V_2}{V_1}$$

$$L_{12} = RT \cdot \ln\frac{p_1}{p_2}$$

$$L_{12} = 287 \cdot 313 \cdot \ln\frac{1{,}05}{12{,}5}$$

$$\boxed{L_{12} = -190{,}146\ \frac{kJ}{kg}}$$

Zadatak **5-2-16**

$p_1 = 2$ bar

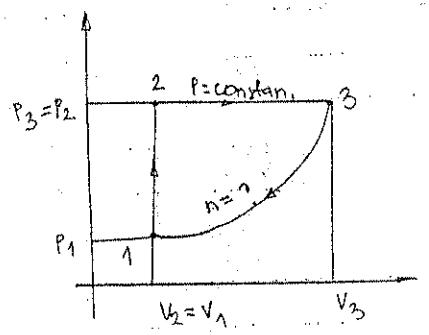
$T_1 = 323$ K

$\Delta h = 360$ kJ/kg

$\Delta U = 185$ kJ/kg

$R = 296{,}7$ J/kgK

$\varkappa = 1{,}4$




$$\Delta h = c_p \cdot (T_2 - T_1)$$

$$T_2 = T_1 + \frac{\Delta h}{c_p} = 323 + \frac{360 \cdot 10^3 (1{,}4 - 1)}{296{,}7 \cdot 1{,}4}$$

$$c_p = \frac{\varkappa \cdot R}{\varkappa - 1}$$

$$\boxed{T_2 = 669{,}670 \text{ K}}$$

$$\Delta U = c_v \cdot (T_3 - T_2)$$

$$T_3 = T_2 + \frac{\Delta U}{c_v} = 669{,}670 + \frac{185 \cdot 10^3 \cdot (1{,}4 - 1)}{296{,}7}$$

$$c_v = \frac{R}{\varkappa - 1}$$

$$\boxed{T_3 = 919{,}08 \text{ K}}$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2} = p \quad p_2 = \frac{T_2}{T_1} \cdot p_1 = 4{,}114 \text{ bar}$$

$$\boxed{p_3 = p_2}$$

$$V_1 = \frac{RT_1}{p_1} = 0{,}479 \text{ m}^3/\text{kg}$$

$$\boxed{V_2 = V_1}$$

$$V_3 = \frac{RT_3}{p_3} = 0{,}658 \text{ m}^3/\text{kg}$$

$$\frac{p_3^{n-1}}{T_3^n} = \frac{p_1^{n-1}}{T_1^n}$$

$$\frac{p_3}{p_1} = \left(\frac{T_3}{T_1}\right)^{\frac{n}{n-1}}$$

$$\log\left(\frac{p_3}{p_1}\right) = \frac{n}{n-1} \log\left(\frac{T_3}{T_1}\right)$$

$$\frac{n}{n-1} = \frac{\log \frac{p_2}{p_1}}{\log \frac{T_3}{T_1}} = \frac{0{,}3153}{0{,}4541} = 0{,}6956$$

$$n = 0{,}6956(n-1) = 0{,}6956 - 0{,}6956 \cdot n$$

$$n(1 - 0{,}6956) = -0{,}6956$$

$$n(0{,}3043) = -0{,}6956$$

$$\boxed{n = -2{,}285}$$

$$L_{31} = \frac{R}{n-1} (T_3 - T_1) = \frac{296{,}7}{-2{,}285 - 1} (919{,}08 - 323) = -137{,}63 \text{ kJ/kg}$$

$$Q_{31} = c_v \frac{n - \varkappa}{n - 1} (T_1 - T_3) = \frac{R}{\varkappa - 1} \cdot \frac{n - \varkappa}{n - 1} (T_1 - T_3)$$

$$Q_{31} = \frac{296{,}7 \cdot (-2{,}285 - 1{,}4)}{(1{,}4 - 1) \cdot (-2{,}285 - 1)} (323 - 919{,}08)$$

$$\boxed{Q_{31} = -304{,}510 \text{ kJ/kg}}$$

Zadatak **5-2-17**

$V_1 = 0{,}5 \text{ m}^3$

$p_1 = 0{,}98066 \cdot 10^6 \frac{N}{m^2} = 9{,}8066 \text{ bar}$

$p_2 = 0{,}1966 \cdot 10^6 \frac{N}{m^2} = 1{,}966 \cdot 10^5 \frac{N}{m^2} = 1{,}966 \text{ bar}$

$\varkappa = 1{,}4$

$L_{12} = m \cdot R \cdot T \cdot \ln \frac{V_2}{V_1}$

$L_{12} = \underbrace{mRT}_{p_1 V_1} \ln \frac{p_1}{p_2} = p_1 V_1 : \ln \frac{p_1}{p_2} = 9,8066 \cdot 10^5 \cdot 0,5 \cdot \ln \frac{9,8066}{1,966}$

$\boxed{L_{12} = 342,218 \text{ kJ}}$ za izotermni proces

$L_{12} = m \cdot c_v \cdot (T_1 - T_2)$

$L_{12} = m \cdot \frac{R}{\varkappa - 1} \cdot T_1 \cdot \left(1 - \frac{T_2}{T_1}\right) = \frac{p_1 V_1}{\varkappa - 1} \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{\varkappa - 1}{\varkappa}}\right] = 451,312 \text{ K}$

Zadatak 5-2-18

$m = 2 \text{ kg}$

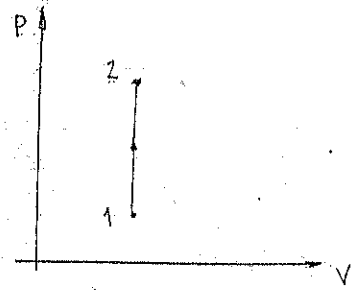
$V_1 = 0,17 \text{ m}^3$

$T_1 = 288 \text{ K}$

$T_2 = 408 \text{ K}$

$R = 0,29 \text{ kJ/kgK}$

$c_p = 0,72 \text{ kJ/kgK}$




$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$p_2 = \frac{T_2}{T_1} \cdot p_1$

$p_1 = \frac{mRT_1}{V_1} = \frac{2 \cdot 290 \cdot 288}{0,7} = 2,386 \text{ bar}$

$p_2 = \frac{408}{288} \cdot 2,386 = 3,380 \text{ bar}$

$q_{12} = c_v \cdot (T_2 - T_1) = 0,43 \cdot (408 - 288) = 51,6 \frac{\text{kJ}}{\text{kg}}$

$c_p - c_v = R$

$c_v = c_p - R = 0,72 - 0,29 = 0,43 \frac{\text{kJ}}{\text{kgK}}$

$Q_{12} = m \cdot q_{12} = 2 \cdot 51,6 = 103,2 \text{ kJ}$

Zadatak 5-2-19

$p_1 = 1,4 \text{ MN/m}^2 = 14 \cdot 10^5 \frac{\text{N}}{\text{m}^2} = 14 \text{ bar}$

$T_1 = 623 \text{ K}$

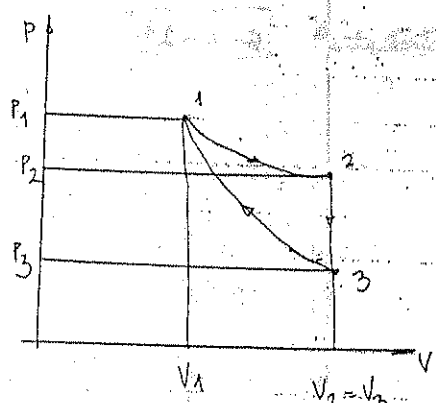
$p_2 = 100 \frac{\text{kN}}{\text{m}^2} = 1 \text{ bar}$

$T_3 = 623$

$p_3 = 220 \text{ kN/m}^2 = 2,2 \text{ bar}$

$m = 0,23 \text{ kg}$

$c_p = 1,0072 \text{ kJ/kgK}$




$\frac{p_2}{T_2} = \frac{p_3}{T_3}$

$T_2 = T_3 \cdot \frac{p_2}{p_3} = 623 \cdot \frac{1}{2,2} = 283,18 \text{ K}$

$\frac{p_1^{\varkappa - 1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa - 1}}{T_2^{\varkappa}} \quad / \log$

$\log \frac{p_1}{p_2} = \frac{\varkappa}{\varkappa - 1} \log \frac{T_1}{T_2}$

$\frac{\varkappa}{\varkappa - 1} = \log \frac{p_1}{p_2} / \log \frac{T_1}{T_2}$

$\varkappa = 1,426 \Rightarrow c_v = 0,706 \frac{\text{kJ}}{\text{kgK}}$

$u_2 - u_1 = c_v \cdot (T_1 - T_2) = 0,706 \cdot (623 - 283,18)$

$u_2 - u_1 = 239,9 \text{ kJ/kg}$

$u_2 - u_1 = m \cdot (u_2 - u_1) = 0,23 \cdot 239,9 = 55,179 \text{ kJ}$

## Zadatak 5-2-21

$p_1 = 150$ bar

$T_1 = 288$ K

$T_2 = 318$ K

$$p_1 V = m \cdot R T_1$$

$$p_2 V = m R T_2$$

$$V = \frac{m R T_1}{p_1}$$

$$V = \frac{m R T_2}{p_2}$$

$$\frac{m R T_1}{p_1} = \frac{m R T_2}{p_2}$$

$$p_2 = \frac{p_1 \cdot m \cdot R \cdot T_2}{m R T_1} = \frac{p_1 T_2}{T_1} = \frac{150 \cdot 318}{288}$$

$$\boxed{p_2 = 165{,}62 \text{ bar}}$$

$$m = \frac{p_1 V_1}{R T_1}$$

Nije dat volumen pa se zadatak ne može uraditi (greška u postavci zadatka)

## Zadatak 5-2-24

$V_1 = 0{,}8\ m^3$

$p_1 = 3$ bar

$T_1 = 300$ K

$p_2 = 1$ bar

$\varkappa = 1{,}4$

$$m = \frac{p \cdot V_1}{R T_1} = \frac{3 \cdot 10^5 \cdot 0{,}8}{285 \cdot 300} = 2{,}78 \text{ kg}$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2} \Rightarrow T_2 = \frac{p_2}{p_1} T_1 = 100 \text{K}$$

$$q_{12} = c_v \cdot (T_2 - T_1) = c_v \cdot T_1 \left(\frac{T_2}{T_1} - 1\right)$$

$$q_{12} = c_v \cdot T_1 \cdot \left(\frac{p_2}{p_1} - 1\right) = \frac{R T_1}{\varkappa - 1} \left(\frac{p_2}{p_1} - 1\right)$$

$$Q_{12} = m \cdot q_{12} = \frac{m \cdot R \cdot T_1}{\varkappa - 1} \left(\frac{p_2}{p_1} - 1\right)$$

$$Q_{12} = \frac{p_1 V_1}{\varkappa - 1} \left(\frac{p_2}{p_1} - 1\right) = -400 \text{ kJ}$$

## Zadatak 5-2-25

$m = 2{,}0$ kg

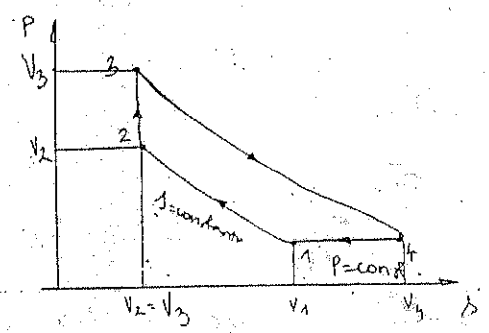
$p_4 = p_1 = 1$ bar

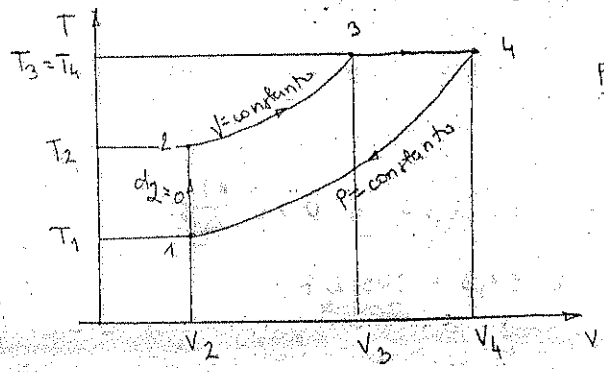
$T_1 = 313$ K

$\varkappa = 1{,}4$

$T_2 = 423$ K

$p_3 = p_{max} = 5{,}5$ bar




$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\downarrow$$

$$p_2 = \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa - 1}} \cdot p_1$$

$$\boxed{p_2 = 2{,}869 \text{ bar}}$$

$\frac{p_2}{T_2} = \frac{p_3}{T_3} \Rightarrow T_3 = \frac{p_3}{p_2} T_2 = 737,19\ K$

$\boxed{T_3 = T_4 = 737,19\ K}$

$V_1 = \frac{RT_1}{p_1} = 0,1998\ m^3/kg$

$V_2 = \frac{RT_2}{p_2} = 0,4231\ m^3/kg$

$\boxed{V_2 = V_3 = 0,423\ m^3/kg}$

$V_4 = \frac{RT_4}{p_4} = 2,115\ \frac{m^3}{kg}$

$\boxed{q_{12} = 0}$

$q_{23} = c_v (T_3 - T_2) = \frac{R}{\varkappa - 1} (T_3 - T_2)$

$\boxed{q_{23} = 225,431\ kJ/kg}$

$\underline{\underline{Q_{23}}} = q_{23} \cdot m = \underline{\underline{450,86}}\ kJ$

$q_{34} = RT \ln \frac{V_4}{V_3} = RT \ln \frac{p_3}{p_4} = 287 \cdot 737,19 \ln \frac{5,5}{1}$

$\boxed{q_{34} = 360,67\ kJ/kg}$

$\underline{\underline{Q_{34}}} = q_{34} \cdot m = \underline{\underline{721,359}}\ kJ$

$q_{41} = c_p (T_1 - T_4) = \frac{\varkappa R}{\varkappa - 1} (T_1 - T_4) = -426,098\ kJ/kg$

$\underline{\underline{Q_{41}}} = q_{41} \cdot m = \underline{\underline{-852,19}}\ kJ$

$Q_{do} = Q_{23} + Q_{34}$

$Q_{do} = 450,86 + 721,359 = 1172,219\ kJ$

$Q_{od} = Q_{41} = -852,19\ kJ$

$L_{neto} = Q_{do} - |Q_{od}| = 320,029\ kJ$

$\eta_t = \frac{L_{neto}}{Q_{do}} = 0,2730$

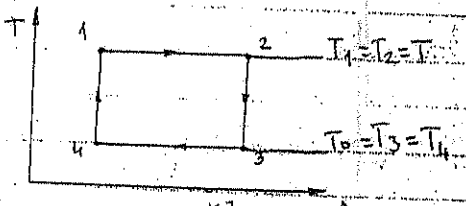
Zadatak 6-2-1

$T_{max} = 830 + 273 = 1103\ K$

$T_{min} = 273\ K$

$\eta_t = 1 - \frac{T_{min}}{T_{max}} = 1 - \frac{273}{1103} = 0,7524$

Zadatak 6-2-2




$T = 1123\ K$

$T_0 = 323\ K$

$Q_{do} = 1,2 \cdot 10^3\ MJ/h = \frac{1200000}{3600}\ \frac{kJ}{s} = 333,33\ \frac{kJ}{s}$

$\eta = \frac{L_{neto}}{Q_{do}} = \frac{Q_{do} - Q_{od}}{Q_{do}} = 1 - \frac{Q_{od}}{Q_{do}}$

$\eta_t = 1 - \frac{Q_{od}}{Q_{do}}$ $\quad \eta_{tc} = 1 - \frac{T_0}{T} = 1 - \frac{323}{1123} = 0,7123$

$Q_{od} = Q_{do} (1 - \eta_t) = 333,33 (1 - 0,7123)$

$\boxed{Q_{od} = 95,873\ kJ/s = 95,873\ kW}$

$L = Q_{do} \cdot \eta_{tc} = 237,43\ \frac{kJ}{s} = 237,43\ kW$

## Zadatak 6-2-3

$t_0 = 2°C = T_0 = 275\ K$

$t = 25°C = T = 273 + 25 = 298\ K$

$Q_{od} = 8\ MJ/h = \frac{8000}{3600} \cdot \frac{KJ}{s} = 2,22\ \frac{KJ}{s}$

$\varepsilon_h = 2,5$

$\varepsilon = \frac{Q_h}{L} \Rightarrow L = \frac{Q_h}{\varepsilon_h} = \frac{2,21}{2} = 1,105$

$\varepsilon = 1 + \frac{Q}{L}$

$\varepsilon = 1 + \frac{2,22}{1,105} = 3,0108$

$\varepsilon = \frac{T}{T - T_0} = \frac{275}{298 - 275} = 11,956$

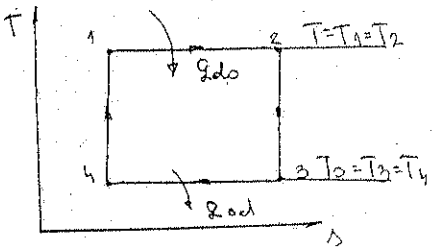
$N = Q_h \cdot \varepsilon = 5,55\ kW$

## Zadatak 6-2-4

$T = 1050\ K$

$T_0 = 420\ K$

$\Delta s_0 = 0,76\ KJ/kg$




$\Delta s_{sistema} = s_0 - s_i = -\Delta s_{okol} = -0,76\ KJ/kg$

$\Delta s = \frac{Q_0}{T_0}$

$q_0 = \Delta s \cdot T_0 = -0,76 \cdot 420 = -319,2\ KJ$

$\eta_{tc} = 1 - \frac{T_0}{T} = 0,6$

$\eta_{tc} = 1 - \frac{q_{od}}{q_{do}}$

$q_{do} \eta_{tc} = q_{do} - q_{od}$

$q_{do}(1 - \eta_{tc}) = -q_{od}$

$q_{do} = -\frac{q_{od}}{(1 - \eta_{tc})} = 798\ KJ/kg$

$l_k = \eta_{tc} \cdot q_{do} = 478,8\ KJ/kg$

## Zadatak 6-2-7

$m = 2,5\ kg$

$P_1 = 0,11\ MPa = 1,1\ bar$

$T_1 = 298\ K$

$T_2 = 598\ K$

$R = 287\ KJ/kgK$

$\varkappa = 1,4$

$P_1 = P_2$

$V_1 = \frac{RT_1}{P_1} = 0,8073\ m^3/kg$

$V_2 = \frac{RT_2}{P_2} = 1,62\ m^3/kg$

$s_2 - s_1 = c_p \ln \frac{T_2}{T_1} = \frac{\varkappa \cdot R}{\varkappa - 1} \ln \frac{T_2}{T_1} = 0,999\ KJ/kg$

$S_2 - S_1 = m \cdot (s_2 - s_1) = 2,5 \cdot 0,999 = 1,7490\ KJ/kg$

$h_2 - h_1 = c_p (T_2 - T_1) = \frac{\varkappa R}{\varkappa - 1} (T_2 - T_1) = 301,25\ KJ/kg$

$H_2 - H_1 = m \cdot c_p (T_2 - T_1) = 2,5 \cdot 301,25 = 782,223\ KJ$

## Zadatak 6-2-5

$V = 1{,}2\ m^3$

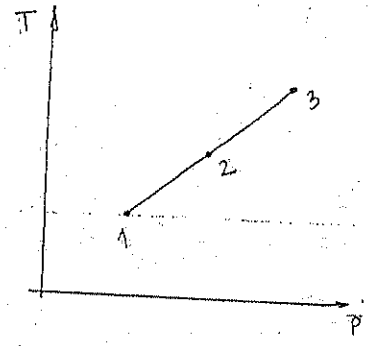
$p_1 = 0{,}95\ atm = 1{,}0665\ bar$

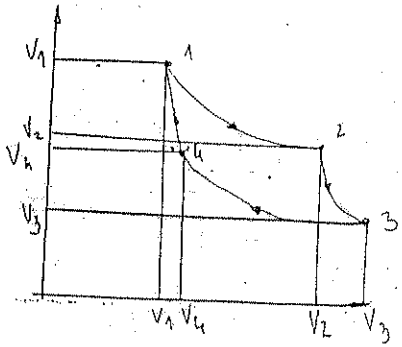
$T_1 = 20^\circ C = 293\ K$

$p_2 = 5\ atm = 0{,}102533\ bar$

$\varkappa = 1{,}4$

$R = 287\ J/kgK$




$$m = \frac{p_1 V_1}{RT_1} = \frac{1{,}0665 \cdot 1{,}2}{287 \cdot 293} = 1{,}5219\ kg$$

$$\frac{p_2^{\varkappa-1}}{T_2^{\varkappa}} = \frac{p_3^{\varkappa-1}}{T_3^{\varkappa}}$$

$$T_3 = \left(\frac{p_3}{p_2}\right)^{\frac{\varkappa-1}{\varkappa}} \cdot T_2 = 161{,}763\ K$$

$$\eta_t = 1 - \frac{T_0}{T} = 1 - \frac{161{,}763}{293} = 0{,}4479$$

$$\frac{p_4^{\varkappa-1}}{T_4^{\varkappa}} = \frac{p_1^{\varkappa-1}}{T_1^{\varkappa}}$$

$$p_4 = p_1 \left(\frac{T_4}{T_1}\right)^{\frac{\varkappa}{\varkappa-1}} = 1{,}0665 \cdot \left(\frac{161{,}763}{293}\right)^{3{,}5} = 0{,}1333\ bar$$

$$s_2 - s_1 = m \cdot c_v \cdot \ln\frac{p_2}{p_1} = m \cdot c_v \cdot \ln\frac{v_2}{v_1} = -1{,}8125\ kJ$$

$s_1 = s_4$ i $s_2 = s_3$

## Zadatak 6-2-8

$p_1 = 0{,}15\ MPa = 1{,}5\ bar$

$T_1 = 400\ K$

$p_2 = 0{,}25\ MPa = 2{,}5\ bar$

$T_2 = 750\ K$

$R = 296{,}7\ J/kgK$

$\varkappa = 1{,}4$

$$s_2 - s_1 = c_p \ln\frac{T_2}{T_1} - R \cdot \ln\frac{p_2}{p_1}$$

$$s_2 - s_1 = \frac{\varkappa - R}{\varkappa - 1} \ln\frac{T_2}{T_1} - R \cdot \ln\frac{p_1}{p_2}$$

$$s_2 - s_1 = \frac{1{,}4 \cdot 287}{1{,}4 - 1} \ln\frac{750}{400} - 287 \cdot \ln\frac{2{,}5}{1{,}5}$$

$$s_2 - s_1 = 0{,}6343 - 0{,}1466 = 0{,}4848\ \frac{kJ}{kg} = 484{,}8\ J/kg$$

## Zadatak 6-2-9

$T_1 = 299\ K$

$v_1 = 1{,}1\ m^3/kg$

$T_2 = 1048\ K$

$v_2 = 0{,}74\ m^3/kg$

$R = 297\ J/kgK$

$\varkappa = 1{,}4$

$c_v = 0{,}7454\ kJ/kgK$

$c_p = 1{,}0744\ kJ/kgK$

$$s_2 - s_1 = c_v \ln\frac{T_2}{T_1} + R \ln\frac{v_2}{v_1}$$

a) $c_v = 0{,}754\ kJ/kgK$

$R = 0{,}297\ kJ/kgK$

$$s_2 - s_1 = c_v \ln\frac{T_2}{T_1} + R \ln\frac{v_2}{v_1}$$

$$s_2 - s_1 = 0{,}754 \cdot \ln\frac{1048}{299} + 0{,}297 \cdot \ln\frac{0{,}74}{1{,}1}$$

$$s_2 - s_1 = 0{,}9456 + (-0{,}1177) = 827{,}9\ J/kg$$

b) $M \cdot R = R_0$

$$R = \frac{R_0}{M} = \frac{8314}{28,01} = 296,82 \ \frac{J}{kgK}$$

$$c_v = \frac{R}{\varkappa - 1} = \frac{296,82}{1,4 - 1} = 742,05 \ J/kgK$$

$$s_2 - s_1 = 742,05 \ \ln \frac{1048}{299} + 296,82 \ \ln \frac{0,74}{1,1}$$

$$s_2 - s_1 = 0,9306 + \ln \frac{1048}{299} + 296,82 \ \ln \frac{0,74}{1,1}$$

$$s_2 - s_1 = 0,9306 + (-0,1173) = 0,8132 \ \frac{kJ}{kg}$$

$$s_2 - s_1 = 813,2 \ J/kg$$

Zadatak 6-2-10

$m = 5 \ kg$
$p_1 = 0,12 \ MPa = 1,2 \ bar$
$T_1 = 320 \ K$
$p_2 = 0,15 \ MPa = 5 \ bar$
$T_2 = 620 \ K$

$R = 4125 \ J/kgK$
$c_p = 14,266 \ kJ/kgK$
$c_v = 10130 \ J/kgK$
$M = 2,016 \ kg/kmol$
$\varkappa = 1,407$

$$s_2 - s_1 = c_p \cdot \ln \frac{T_2}{T_1} + R \ln \frac{p_2}{p_1} = 14,266 \ln \frac{620}{320} - 4,125 \ln \frac{5}{1,2}$$

$$s_2 - s_1 = 9,4355 - 5,8868 = 3,548 \ kJ/kg$$

$$S_2 - S_1 = m \cdot (s_2 - s_1) = 5 \cdot 3,548 = 17,74 \ kJ$$

$$S_2 - S_1 = m \cdot c_p \cdot \frac{T_2}{T_1} - m R \ln \frac{p_2}{p_1}$$

$$S_2 - S_1 = 47,753 - 29,427 = 18,325 \ kJ$$

Zadatak 6-2-17

$Q_{do} = 20 \ MJ/s$
$T_1 = 550 \ K$
$T_o = 289 \ K$

$$\eta_t = 1 - \frac{T_o}{T_1} = 1 - \frac{289}{550} = 0,4745 \ \checkmark$$

$$E_x = Q \left(1 - \frac{T_o}{T_1 - T_o} \ln \frac{T_1}{T_o}\right) = 20 \left[1 - \frac{289}{550 - 289} \ln \frac{550}{289}\right]$$

$$E_x = 20 \left[1 - \frac{289}{261} \cdot 0,6434\right] = 5,7515 \ MJ/s$$

$Q = E_x + A_m$

$E_x = Q_{do} \cdot \eta = 20 \cdot 0,475 = 9,5$ ✓
$A_m = Q_{do} - E_x = 20 - 9,5 = 10,5$ ✓

$A_m = Q - E_x = 20 - 5,7515 = 14,248 \ MJ/s$

$E_v = \eta_t \cdot Q_{do} = 0,4745 \cdot 20 = 9,4 \ MJ/s$

Zadatak 6-2-18

$Q = 100 \ kJ$
$T = 979 \ K$
$T_o = 273 \ K$

$$E_x = Q \left(1 - \frac{T_o}{T_1 - T_o} \ln \frac{T}{T_o}\right) = 100 \left[1 - \frac{273}{979 - 273} \ln \frac{979}{273}\right]$$

$$E_x = 100 \left[1 - 0,4914\right] = 50,85 \ kJ$$

Sljedeći zadatak je za temperaturu $T = 773 \ K$

$$E_x = 100 \left[1 - \frac{T_o}{T_1 - T_o} \ln \frac{T_1}{T_o}\right] = 100 \left[1 - \frac{773}{979 - 773} \ln \frac{979}{773}\right]$$

$$E_x = 24,402 \ kJ$$

Zadatak 6-2-20

$m = 1\,kg$
$E_x = 470\ kJ/kg$ $\quad R = 287\ J/kgK$
$q_{do} = 193\ kJ/kg$ $\quad \varkappa = 1{,}4$
$p_o = 1\,bar$
$T_o = 293\ K$

$e_x = (h_1 - h_o) - T_o \cdot (s_1 - s_o)$
$h_1 - h_o = c_p \cdot (T_1 - T_o)$
$-T_o (s_o - s_1) = q$
$e_x = h_1 - h_o + q = c_p \cdot (T_1 - T_o) + q$

$$T_1 = T_o + \frac{e_x - q}{c_p} = 293 + \frac{(470-193)\cdot 10^3 (1{,}4-1)}{287 \cdot 1{,}4}$$

$\boxed{T_1 = 568{,}75\ K}$

$T_o (s_o - s_1) = q$
$T_o (s_o - s_1) = q$
$s_o - s_1 = \frac{q}{T_o}$

$$s_o - s_1 = c_p \cdot \ln \frac{T_o}{T_1} - R \cdot \ln \frac{p_o}{p_1}$$

$$q = T_o \left[ c_p \ln \frac{T_o}{T_1} - R \ln \frac{p_o}{p_1} \right] = T_o c_p \cdot \ln \frac{T_o}{T_1} - T_o R \cdot \ln \frac{p_o}{p_1}$$

$$T_o R \ln \frac{p_o}{p_1} = T_o \cdot c_p \ln \cdot \frac{T_o}{T_1} - q$$

$$T_o \cdot R \ln \cdot \frac{1}{p_1} = T_o : c_p \ln \frac{T_o}{T_1} - q$$

$$\ln \frac{1}{p_1} = \frac{c_p \cdot \ln \frac{T_o}{T_1}}{R} - \frac{q}{T_o R} = \frac{1004{,}5 \cdot \ln \frac{293}{568{,}7}}{287} - \frac{193 \cdot 10^3}{293 \cdot 287}$$

$$\ln \frac{1}{p_1} = -2{,}321 - 2{,}295 = -4{,}606$$

$$\frac{1}{p} = e^{-4{,}606}$$

$$\frac{1}{p} = 0{,}00999$$

$\boxed{p = 100\ bar}$

Zadatak 6-2-21

$V = 100\ Nm^3$
$p_1 = 6\ bar$
$p_o = 1\ bar$
$T_o = 288\ K$
$M = 28{,}95\ kg/kmol$

$$100\ Nm^3 = \frac{28{,}95}{22{,}41} \cdot 100 = 129{,}18\ kg$$

$e_x = h_1 - h_o - T_o (s_1 - s_o)$
$h_1 - h_o = 0$
$h_1 = h_o$
$e_x = -T_o (s_1 - s_o)$
$e_x = R\, T_o \ln \frac{p_1}{p_o} = 148{,}09\ kJ/kg$

$T_o (s_1 - s_o) = q$
$-T_o (s_o - s_1) = q$
$q = R T_o \ln \frac{p_1}{p_o}$

$E_x = m \cdot e_x = 129{,}18 \cdot 148{,}09 = 19{,}130\ MJ$

$$p_2 = p_1 \cdot \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa - 1}} = p_1 \cdot \left(\frac{T_o}{T_1}\right)^{\frac{\varkappa}{\varkappa - 1}} = 0{,}623\ bar$$

$e_x = h_1 - h_o - T_o (s_2 - s_o)$

$$h_1 - h_o = c_p (T_2 - T_o) = \frac{1{,}4 \cdot 287}{1{,}4 - 1} (550 - 288) = 263{,}172$$

$10^3 / 287$

$s_2 - s_1 = T_0 \cdot R \cdot \ln \frac{p_0}{p_2} = 287 \cdot 288 \cdot \ln \frac{1}{0{,}023} = 39{,}1135 \ \frac{kJ}{kg}$

$e_x = 263{,}179 - 39{,}1135 = 224{,}06 \ kJ/kg$

$E_x = m \cdot e_x = 28{,}944 \ MJ$

Zadatak 6-2-23

$m = 5 \ kg$

$h = 25 \ MJ/kg$

$T = 1823 \ K$

$T_0 = 288 \ K$

$E_x = Q \left(1 - \frac{T_0}{T_1 - T_0} \ln \frac{T_1}{T_0}\right) = m h \left[1 - \frac{T_0}{T_1 - T_0} \ln \frac{T_1}{T_0}\right]$

$E_x = 525 \cdot \left[1 - \frac{288}{1823 - 288} \ln \frac{1823}{288}\right] = 81{,}723 \ MJ$

$Q = E_x + A_m$

$A_m = Q - E_x = 5{,}25 - 81{,}723 = 43{,}275 \ MJ$

$\eta_{tc} = 1 - \frac{T_0}{T} = 0{,}842$

$E_x = \eta_{tc} \cdot Q = \eta_{tc} \cdot (m h) = 0{,}842 \ (5 \cdot 25) = 105{,}25 \ MJ$

$Q = E_x + A_m$

$\Rightarrow A_m = Q - E_x = 19{,}747 \ MJ$

Zadatak 6-2-24

$p_1 = 1 \ bar$

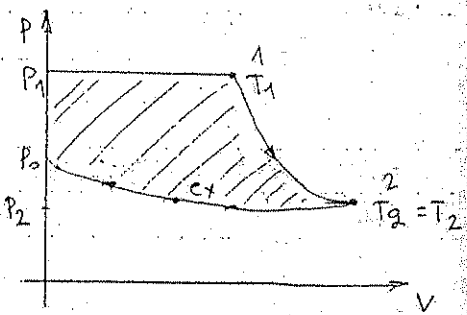
$T_1 = 873 \ K$

$p_0 = 1 \ bar$

$T_0 = 300 \ K$

$R = 287 \ J/kgK$

$\varkappa = 1{,}4$




$V_1 = \frac{R T_1}{p_1} = 2{,}505 \ \frac{m^3}{kg}$

$V_2 = \frac{R T_0}{p_0} = 0{,}861 \ \frac{m^3}{kg}$

$e_x = (h_1 - h_0) - T_0 (s_1 - s_0) = c_p (T_1 - T_0) - R T_0 \ln \frac{p_0}{p_2}$

$e_x = \frac{1{,}4 \cdot 287}{1{,}4 - 1} (873 - 300) - 287 \cdot 300 \ln \frac{1}{0{,}0238} = 253{,}73 \ \frac{kJ}{kg}$

$p_2 = p_1 \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa - 1}} = 0{,}0238 \ bar$

Zadatak 6-2-25

$m = 1 \ kg$

$p_1 = 1 \ atm = 101{,}325 \ kPa = 1{,}013 \ bar$

$T_1 = 823 \ K$

$p_0 = 1 \ atm = 1{,}013 \ bar$

$T_1 = 293 \ K$

$R = 259{,}9 \ J/kgK$

$\varkappa = 1{,}4$

$$V_1 = \frac{R T_1}{P_1} = 1{,}726 \ m^3/kg$$

$$V_2 = \frac{R \cdot T_2}{P_2} = 0{,}75173 \ m^3/kg$$

$$P_A = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa - 1}} = 0{,}0551 \ bar$$

$$T_o (s_o - s_1) = q$$

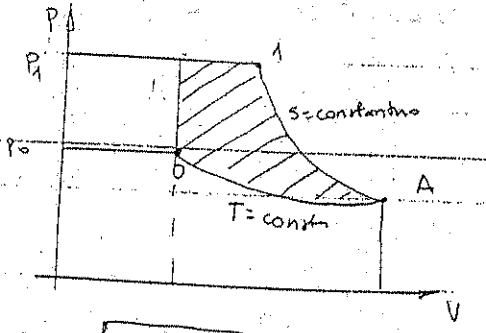
$$T_o (s_o - s_1) = R \cdot T_o \ln \frac{P_o}{P_2}$$

$$L_{max} = m \cdot [(u_1 - u_o) - T_o \cdot (s_1 - s_o) + P_o (V_1 - V_o)]$$

$$L_{max} = m \cdot [c_v \cdot (u_1 - u_o) - T_o (s_1 - s_o) + P_o (V_1 - V_o)]$$

$$L_{max} = 1 \cdot \left[\frac{259{,}9}{1{,}4 - 1} (673 - 293) - 259{,}9 \cdot 293 \ln \frac{1{,}073}{0{,}0551}\right] + 1{,}013 \cdot (1{,}726 - 0{,}75173) \cdot 10^5$$

$$L_{max} = 1 \cdot [246{,}905 - 221{,}914 + 98{,}696] = 123{,}887 \ kJ$$




Zadatak 6-2-26

$V = 300$ litara $= 300 \cdot 10^{-3} \ m^3$

$P_1 = 50$ atm $= 101{,}325$ kPa $= 50{,}6625$ bar

$T_1 = 293$ K

$P_o = 1$ atm $= 101{,}325$ kPa $= 1{,}0132$ bar

$T_o = 293$ K.

$$L_{max} = (u_1 - u_o) - T_o \cdot (s_1 - s_o) + P_o \cdot (V_1 - V_o)$$

$$L_{max} = c_v \cdot (T_1 - T_o) - T_o \cdot (s_1 - s_o) - V_1 \cdot (P_1 - P_o)$$

Zadatak 7-2-2

$T = 350 + 273 = 623$ K

$T_o = 323$ K

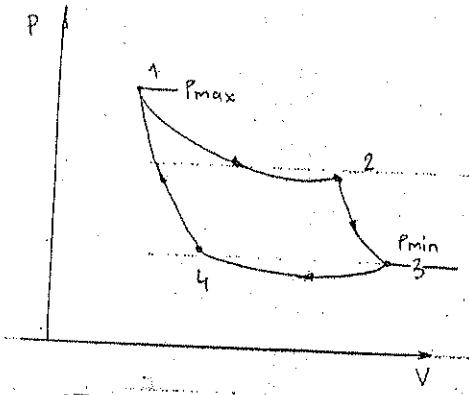
$L_{neto} = 2{,}033$ MJ

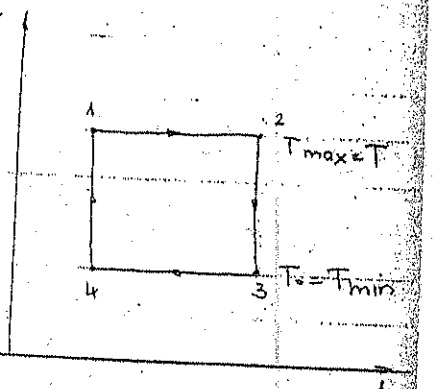
$P_1 = P_{max} = 4{,}34$ MPa $= 43{,}4$ bar

$P_3 = P_{min} = 0{,}12$ MPa $= 1{,}2$ bar

$R = 2079$ J/kgK

$\varkappa = 1{,}666$




$$V_1 = \frac{R T_1}{P_1} = 0{,}1984 \ m^3/kg$$

$$V_3 = \frac{R T_o}{P_3} = 5{,}595 \ m^3/kg$$

$$V_3 = P_4 V_4$$

$$V_4^{\varkappa} = P_1 V_1^{\varkappa}$$

$$P_3 = \frac{P_3 V_3}{V_4} \qquad P_4 = \frac{P_1 V_1^{\varkappa}}{V_4^{\varkappa}}$$

$$\frac{P_3 V_3}{V_4} = \frac{P_1 V_1^{\kappa}}{V_4^{\kappa}}$$

$$T_4^{\kappa-1} = \left(\frac{P_1}{P_3} \cdot \frac{1}{V_3}\right) \cdot V_1^{\kappa} = \left(\frac{P_1}{P_3} \cdot \frac{1}{V_3}\right)^{\frac{1}{\kappa-1}} \cdot V_1^{\frac{\kappa}{\kappa-1}} =$$

$$= \left(\frac{43,4}{1,2} \cdot \frac{1}{5,595}\right)^{\frac{1}{1,66-1}} \cdot (0,2984)^{\frac{1,66}{1,66-1}} =$$

$$= 16,9013 \cdot 0,04779 = 0,8073 \ \frac{m^3}{kg}$$

$$\frac{P_4^{\kappa-1}}{T_4^{\kappa}} = \frac{P_1^{\kappa-1}}{T_1^{\kappa}} = D$$

$$P_4 = P_1 \cdot \left(\frac{T_4}{T_1}\right)^{\frac{\kappa}{\kappa-1}} = 8,317 \text{ bar}$$

$$\eta_{tc} = 1 - \frac{T_0}{T} = 1 - \frac{323}{623} = 0,4815$$

$$l_{12} = R T \ln \frac{V_2}{V_1} = 2079 \cdot 623 \cdot \ln \frac{2,068}{0,2984} = 2507,41 \ \frac{kJ}{kg}$$

$$l_{23} = c_v (T_1 - T_2) = \frac{R}{\kappa-1}(T_1 - T_2) = 945 \ kJ/kg$$

$$l_{34} = R T \ln \frac{V_4}{V_3} = -1300 \ kJ/kg$$

$$l_{41} = c_v (T_1 - T) = \frac{R}{\kappa-1}(323 - 623) = -945 \ kJ/kg$$

$$P_1 V_1 = P_2 V_2$$

$$P_2 V_2^{\kappa} = P_3 V_3^{\kappa}$$

$$\frac{P_1 V_1}{V_2} = P_2$$

$$\frac{P_3 V_3^{\kappa}}{V_2^{\kappa}} = P_2$$

$$\frac{P_1 V_1}{V_2} = \frac{P_3 V_3^{\kappa}}{V_2^{\kappa}}$$

$$\frac{V_2^{\kappa}}{V_2} = \frac{P_2 V_3^{\kappa}}{P_1 V_1}$$

$$V_2^{\kappa-1} = \left(\frac{P_3}{P_1 V_1^{\kappa}}\right) \cdot V_3^{\frac{\kappa}{\kappa-1}}$$

$$V_2 = \left(\frac{P_3}{P_1 V_1}\right)^{\frac{1}{\kappa-1}} V_3^{\frac{\kappa}{\kappa-1}} = \left(\frac{1,2}{43,4} \cdot \frac{1}{0,2984}\right)^{\frac{1}{1,66-1}}$$

$$\cdot 5,595^{\frac{1,66}{1,66-1}}$$

$$V_2 = 0,02721 \cdot 75,996 = 2,068 \ m^3/kg$$

$$\frac{P_2^{\kappa-1}}{T_2^{\kappa}} = \frac{P_3^{\kappa-1}}{T_3^{\kappa}}$$

$$\Downarrow$$

$$P_2 = P_3 \left(\frac{T_2}{T_3}\right)^{\frac{\kappa}{\kappa-1}} = 3,246 \text{ bar}$$

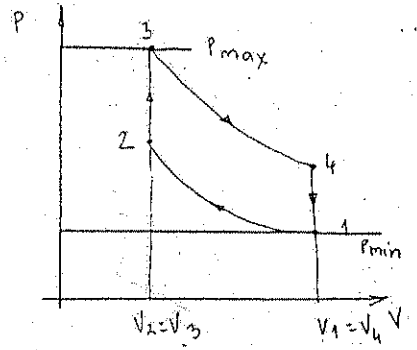
$$q_{12} = l_{12} = 2507,41 \ kJ/kg$$

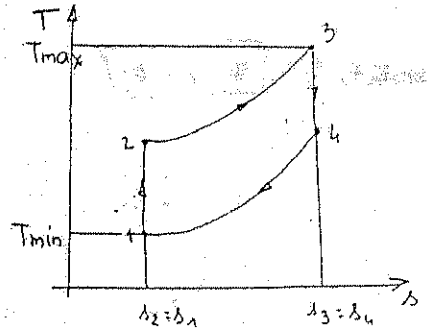
$$q_{23} = 0$$

$$q_{34} = l_{34} = -1300 \ kJ/kg$$

$$q_{41} = 0$$

## Zadatak 7-2-4




$V_1 = V_4 = 1{,}6 \text{ litar} = 1{,}6 \cdot 10^{-3} \text{ m}^3$

$\frac{V_1}{V_2} = 10$

$t_3 = 2100°C \Rightarrow T_3 = 2373 \text{ K}$

$p_1 = 1 \text{ bar}$

$t_1 = 28°C \Rightarrow T_1 = 301 \text{ K}$

$R = 287 \text{ J/kgK}$

$\varkappa = 1{,}4$

$V_3 = V_2 = 0{,}0016 \text{ m}^3/\text{kg}$

$T_1 V_1^{\varkappa-1} = T_2 \cdot V_2^{\varkappa-1}$

$T_2 = \left(\frac{V_1}{V_2}\right)^{\varkappa-1} \cdot T_1 = 763{,}1 \text{ K}$

$T_3 \cdot V_3^{\varkappa-1} = T_4 \cdot V_4^{\varkappa-1}$

$T_4 = \left(\frac{V_3}{V_4}\right)^{\varkappa-1} \cdot T_3 = \left(\frac{V_2}{V_1}\right)^{\varkappa-1} \cdot T_3$

$T_4 = \left(\frac{1}{10}\right)^{1,4-1} \cdot 2373 = 944{,}7 \text{ K}$

$l_{12} = c_v \cdot (T_1 - T_2) = \frac{R}{\varkappa - 1} (T_1 - T_2)$

$l_{12} = \frac{287 \cdot 10^{-3}}{1{,}4-1} (304 - 763{,}01) = -329{,}77 \text{ kJ/kg}$

$l_{23} = p \cdot (V_3 - V_2) = 0$

$l_{34} = c_v \cdot (T_3 - T_4) = \frac{R}{\varkappa - 1} (T_3 - T_4)$

$l_{34} = \frac{287 \cdot 10^{-3}}{1{,}4-1} (2373 - 944{,}708) = 1024{,}799 \text{ kJ/kg}$

$l_{41} = p \cdot (V_1 - V_4) = 0$

$q_{12} = 0$

$q_{23} = c_v \cdot (T_3 - T_2) = \frac{R}{\varkappa - 1} (T_3 - T_2) = 1154{,}737 \text{ kJ/kg}$

$q_{34} = 0$

$q_{41} = c_v \cdot (T_1 - T_4) = \frac{R}{\varkappa - 1} (T_1 - T_4) = -459{,}707 \text{ kJ/kg}$

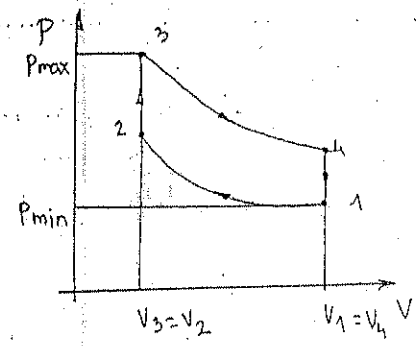
$L_{neto} = q_{do} - |q_{od}| = 1154{,}737 - 459{,}407 = 695{,}029 \text{ kJ/kg}$

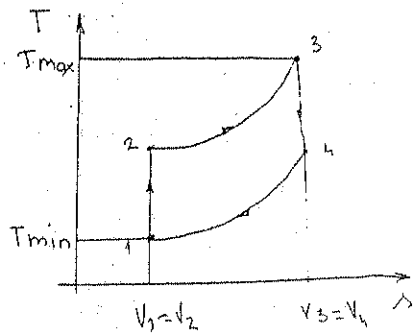
$\eta_t = \frac{L_{neto}}{q_{do}}$

$\eta_t = 1 - \frac{|q_{od}|}{q_{do}} = 1 - \frac{459{,}707}{1154{,}737}$

$\boxed{\eta_t = 0{,}6018}$

Zadatak 4-2-5




$t_1 = 14°C \Rightarrow T_1 = 287\ K$

$\frac{V_1}{V_2} = 9$

$q_{do} = q_{23} = 1200\ KJ/kg$

$R = 287\ J/kgK$

$\varkappa = 1,4$

$T_1 V_1^{\varkappa-1} = T_2 V_2^{\varkappa-1}$

$T_2 = \left(\frac{V_1}{V_2}\right)^{\varkappa-1} \cdot T_1 = 9^{1,4-1} \cdot 287 = 691,16\ K$

$q_{do} = c_v \cdot (T_3 - T_2) = \frac{R}{\varkappa-1}(T_3 - T_2)$

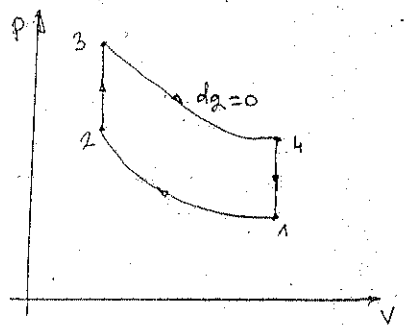
$T_3 = T_2 + \frac{q_{do} \cdot (\varkappa-1)}{R}$

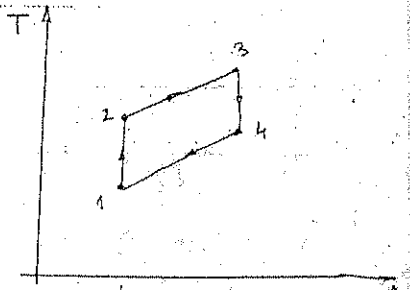
$T_3 = 691,16 + \frac{1200 \cdot 10^3 \cdot (1,4-1)}{287} = 2363,63\ K$

$T_3 V_3^{\varkappa-1} = T_4 \cdot V_4^{\varkappa-1}$

$T_4 = \left(\frac{V_3}{V_4}\right)^{\varkappa-1} \cdot T_3 = \left(\frac{V_2}{V_1}\right)^{\varkappa-1} \cdot T_3 = 981,482\ K$

Zadatak 7-2-6




$V_1 = V_4 = 550\ cm^3$

$\frac{V_1}{V_2} = 8$

$P_1 = 0,95\ bar$

$R = 287\ J/kgK$

$\varkappa = 1,4$

$T_3 = 1880 + 273 = 2153\ K$

$T_1 = 80 + 273 = 353\ K$

$m = \frac{P_1 V_1}{R T_1} = \frac{0,95 \cdot 10^5 \cdot 0,00055}{287 \cdot 353} = 0,000515$

$T_1 V_1^{\varkappa-1} = T_2 \cdot V_2^{\varkappa-1}$

$T_2 = \left(\frac{V_1}{V_2}\right)^{\varkappa-1} \cdot T_1 = 810,98\ K$

$V_1 = V_2 \cdot 8 \Rightarrow V_2 = \frac{V_1}{8}$

$V_2 = 68,75\ cm^3$

$V_2 = V_3 = 0,0000675\ m^3$

$$P_2 = \frac{mRT_2}{V_2} = \frac{0{,}000515 \cdot 287 \cdot 810{,}98}{0{,}00006875} = 17{,}442 \text{ bar}$$

$$\frac{P_2}{T_2} = \frac{P_3}{T_3} \Rightarrow P_3 = P_2 \frac{T_3}{T_2} = 46{,}320 \text{ bar}$$

$$T_3 \cdot V_3^{x-1} = T_4 \cdot V_4^{x-1}$$

$$T_4 = \left(\frac{V_3}{V_4}\right)^{x-1} \cdot T_3 = \left(\frac{V_2}{V_4}\right)^{x-1} \cdot T_3 = 937{,}14 \text{ K}$$

$$Q_{23} = m \cdot c_v \cdot (T_3 - T_2)$$

$$Q_{23} = \frac{mR}{x-1}(T_3 - T_2) = \frac{0{,}000515 \cdot 287}{0{,}4}(2153 - 810{,}98)$$

$$\boxed{Q_{23} = 0{,}4958 \text{ KJ}}$$

$$Q_{12} = 0$$

$$Q_{34} = 0$$

$$Q_{41} = c_v \cdot (T_1 - T_4) \cdot m = -0{,}2158 \text{ KJ}$$

$$\eta_t = 1 - \frac{|Q_{cd}|}{Q_{do}} = 1 - \frac{0{,}2158}{0{,}4958} = 0{,}5646$$

$$l_{12} = c_v (T_1 - T_2) = \frac{R}{x-1}(T_1 - T_2) = -328{,}16 \text{ KJ/kg}$$

$$l_{23} = R \cdot (V_3 - V_2) = 0$$

$$l_{34} = c_v \cdot (T_3 - T_4) = \frac{R}{x-1}(T_3 - T_4) = 872{,}37 \text{ KJ/kg}$$

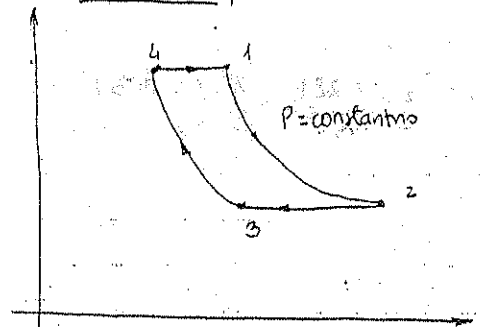
$$L_{12} = m \cdot l_{12} = -0{,}16922 \text{ KJ}$$

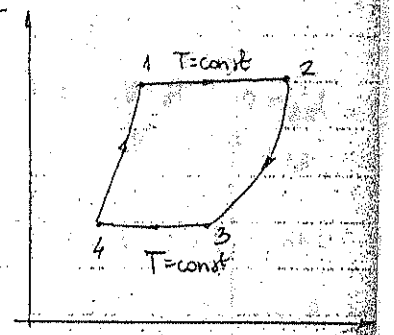
$$L_{34} = m \cdot l_{34} = 0{,}4492 \text{ KJ}$$

$$L_{neto} = 0{,}2802 \text{ KJ}$$

$$L_{neto} = \eta_t \cdot Q_{do} = 0{,}5646 \cdot 0{,}4958 = 0{,}2799 \text{ KJ}$$

Zadatak 7-2-7




$$T_1 = T_2 = 943 \text{ K}$$

$$T_3 = T_4 = 273$$

$$P_{max} = P_1 = P_4 = 3 \text{ MPa} = 30 \text{ bar}$$

$$P_{min} = P_2 = P_3 = 0{,}2 \text{ MPa} = 20 \text{ bar}$$

$$R = 287 \text{ J/kg.K}$$

$$x = 1{,}4$$

$$V_1 = 0{,}109021 \text{ m}^3/\text{kg}$$

$$V_2 = 0{,}1350 \text{ m}^3/\text{kg}$$

$$V_3 = 0{,}03991 \text{ m}^3/\text{kg}$$

$$V_4 = 0{,}0261 \text{ m}^3/\text{kg}$$

$$\eta_{tc} = 1 - \frac{T_{min}}{T_{max}} = 1 - \frac{273}{943} = 0{,}7104$$

$$q_{12} = l_{12} = R \cdot T \cdot \ln \frac{V_2}{V_1} = R \cdot T \cdot \ln \frac{P_1}{P_2} = 109{,}735 \text{ KJ/kg}$$

$$q_{23} = c_p (T_3 - T_2) = \frac{R \cdot x}{x-1}(T_3 - T_2) = -673{,}015 \text{ KJ/kg}$$

$$q_{34} = l_{34} = R \cdot T \cdot \ln \frac{V_4}{V_3} = R \cdot T \cdot \ln \frac{P_3}{P_4} = -31{,}768 \text{ KJ/kg}$$

$l_{23} = p \cdot (v_3 - v_2) = R \cdot (T_3 - T_2) = 287 \cdot (273 - 943) = -192,29 \ kJ/kg$

$l_{41} = p \cdot (v_1 - v_4) = R \ (T_1 - T_4) = 192,29 \ kJ/kg$

$q_{do} = q_{12} + q_{41} = 782,75$

$q_{od} = |q_{23}| + |q_{34}| = 704,783$

$l_{neto} = q_{do} - q_{od} = 77,90 \ kJ/kg$

~~Zadatak~~ 7-2-8

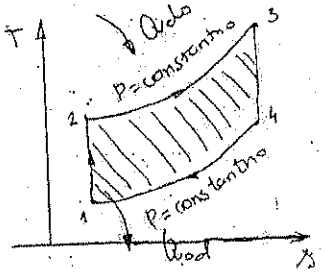
$q_{do} = 1,65 \ MJ/kg$

$t_1 = 30°C \Rightarrow T_1 = 303 \ K$

$p_1 = 0,12 \ MPa = 0,0012 \ bar$

$\frac{p_2}{p_1} = \frac{p_3}{p_4} = 8$

$R = 287 \ J/kgK \ , \ \varkappa = 1,4$




Stanje ①

$T_1 = 303 \ K$

Stanje ②

$T_2 = T_1 \cdot \left(\frac{p_2}{p_1}\right)^{\frac{\varkappa-1}{\varkappa}} = 303 \cdot 8^{\frac{1,4-1}{1,4}} = 548,87 \ K$

Stanje ③ $p = constantno$ (izobara)

$q_{do} = c_p \cdot (T_3 - T_2)$

$T_3 = T_2 + \frac{q_{do}}{c_p} = 548,87 + \frac{1,65 \cdot 10^6}{1010} = 2182,53 \ K$

Stanje ④

$T_4 = T_3 \cdot \left(\frac{p_4}{p_3}\right)^{\frac{\varkappa-1}{\varkappa}} = 2182,53 : \left(\frac{1}{8}\right)^{\frac{1,4-1}{1,4}} = 1204,85 \ K$

$\eta_t = 1 - \frac{Q_{od}}{Q_{do}} = 1 - \frac{m \cdot c_p \cdot (T_4 - T_1)}{m \cdot c_p \cdot (T_3 - T_2)}$

$\eta_t = 1 - \frac{1204,85 - 303}{2182,53 - 548,87} = 0,447 \ (44,7\%)$

~~Zadatak~~ 7-2-10

$T_1 = T_{min} = 299 \ K$

$p_1 = p_4 = 0,12 \ MPa = 1,2 \ bar$

$T_3 = T_{max} = 1389 \ K$

$p_3 = p_2 = 1,12 \ MPa = 11,2 \ bar$

$R = 287 \ J/kgK$

$\varkappa = 1,4$

$v_1 = \frac{R \, T_1}{p_1} = 0,0766 \ \frac{m^3}{kg}$

$v_3 = 3,322$

$\frac{p_1^{\varkappa-1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa-1}}{T_2^{\varkappa}} \Rightarrow T_2 = \left(\frac{p_2}{p_1}\right)^{\frac{\varkappa-1}{\varkappa}} \cdot T_1 = 565,99 \ K$

$\frac{p_3^{\varkappa-1}}{T_3^{\varkappa}} = \frac{p_4^{\varkappa-1}}{T_4^{\varkappa}} \Rightarrow T_4 = \left(\frac{p_4}{p_3}\right)^{\frac{\varkappa-1}{\varkappa}} \cdot T_3 = 733,77 \ K$

$q_{12} = 0$

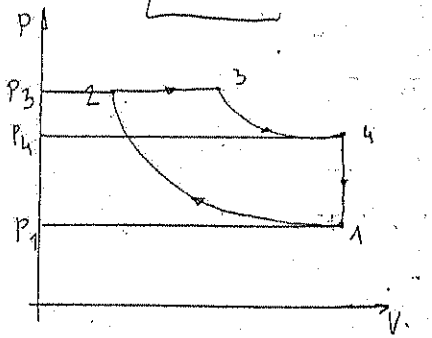
$q_{23} = c_p \cdot (T_3 - T_2) = \frac{R \cdot \varkappa}{\varkappa - 1} (T_3 - T_2) = 826,713 \ kJ/kg$

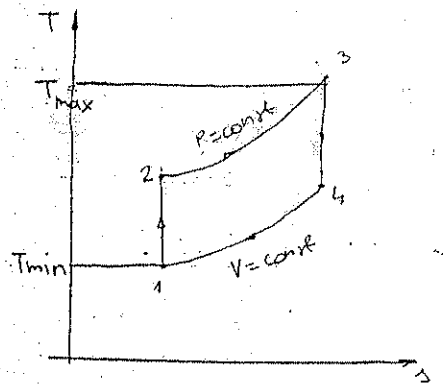
$q_{41} = c_p \cdot (T_1 - T_4) = \frac{\varkappa R}{\varkappa - 1} (T_1 - T_4) = -436,730 \ kJ/kg$

$l_{neto} = q_{do} - |q_{od}| = 816,713 - 436,730 = 389,983 \ kJ/kg$

$\eta_{tc} = \frac{l_{neto}}{q_{do}} = 0,4717$

Zadatak 7-2-11.




$\frac{V_1}{V_2} = 14$

$q_{23} = 1{,}8$ MJ/kg

$T_1 = 551$ K

$p_1 = 1$ bar

$R = 287$ J/kgK

$\varkappa = 1{,}4$

$v_4 = v_1 = \frac{RT_1}{p_1} = 1{,}581$ m³/kg

$v_2 = \frac{RT_2}{p_2} = 0{,}1129$ m³/kg

$v_3 = \frac{RT_3}{p_3} = 0{,}2407$ m³/kg

$T_1 v_1^{\varkappa-1} = T_2 v_2^{\varkappa-1}$

$T_2 = \left(\frac{v_1}{v_2}\right)^{\varkappa-1} \cdot T_1 = 1583{,}44$ K

$q_{23} = c_p (T_3 - T_2)$

$T_3 = T_2 + \frac{q_{23}(\varkappa-1)}{\varkappa R} = 3375{,}37$ K

$\frac{p_1^{\varkappa-1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa-1}}{T_2^{\varkappa}}$

$p_2 = \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa-1}} \cdot p_1 = 40{,}23$ bar

$p_2 = p_3 = 40{,}23$ bar

$T_3 \cdot v_3^{\varkappa-1} = T_4 \cdot v_4^{\varkappa-1}$

$T_4 = \left(\frac{v_3}{v_2}\right)^{\varkappa-1} \cdot T_3 = 1589{,}78$ K

$\frac{p_3^{\varkappa-1}}{T_3^{\varkappa}} = \frac{p_4^{\varkappa-1}}{T_4^{\varkappa}}$

$p_4 = \left(\frac{T_4}{T_3}\right)^{\frac{\varkappa}{\varkappa-1}} \cdot p_3 = 2{,}884$ bar

$q_{12} = 0$

$q_{23} = c_p (T_3 - T_2) = \frac{\varkappa R}{\varkappa-1} (T_3 - T_2) = 1799{,}99$ kJ/kg

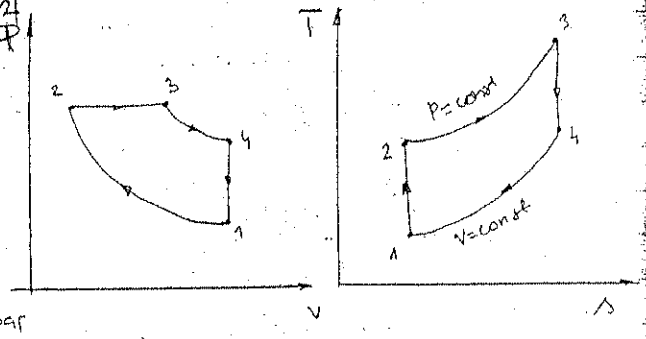
$q_{34} = 0$

$q_{41} = c_v (T_1 - T_4) = \frac{R}{\varkappa-1} (T_1 - T_4) = -745{,}324$ kJ/kg

$l_{neto} = q_{do} - |q_{od}| = 1054{,}66$ kJ/kg

$\eta_t = \frac{l_{neto}}{q_{dov}} = 0{,}5859$

## Zadatak 7-2-12







$\frac{V_1}{V_2} = 18$

$\frac{V_3}{V_2} = 2{,}8$

$R = 287 \ J/kgK$

$T_1 = 308 \ K$

$p_1 = 0{,}2 \ MPa = 2 \ bar$

$V_3 = V_2 \cdot 2{,}8 = 0{,}0686 \ m^3/kg$

$V_4 = V_1 = \frac{RT_1}{p_1} = 0{,}4419 \ m^3/kg$

$V_2 = \frac{R \cdot T_2}{p_2} = 0{,}0245 \ \frac{m^3}{kg}$

$T_1 \cdot V_1^{\varkappa-1} = T_2 \cdot V_2^{\varkappa-1}$

$T_2 = \left(\frac{V_1}{V_2}\right)^{\varkappa-1} \cdot T_1 = 978{,}72 \ K$

$\frac{p_1^{\varkappa-1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa-1}}{T_2^{\varkappa}} \Rightarrow p_2 = \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa-1}} \cdot p_1 = 114{,}39 \ bar$

$\frac{V_2}{T_2} = \frac{V_3}{T_3} \Rightarrow T_3 = \frac{V_3}{V_2} \cdot T_2 = 2740{,}416 \ K$

$p_2 = p_3 = 114{,}39 \ bar$

$T_3 \cdot V_3^{\varkappa-1} = T_4 \cdot V_4^{\varkappa-1} \Rightarrow T_4 = \left(\frac{V_3}{V_4}\right)^{\varkappa-1} \cdot T_3 = 1300{,}81 \ K$

$\frac{p_3^{\varkappa-1}}{T_3^{\varkappa}} = \frac{p_4^{\varkappa-1}}{T_4^{\varkappa}} \Rightarrow p_4 = \left(\frac{T_4}{T_3}\right)^{\frac{\varkappa}{\varkappa-1}} \cdot p_3 = 8{,}429 \ bar$

$q_{12} = 0$

$q_{23} = c_p \cdot (T_3 - T_2) = \frac{\varkappa R}{\varkappa - 1} \cdot (T_3 - T_2)$

$q_{23} = 1769{,}61 \ kJ/kg$

$q_{34} = 0$

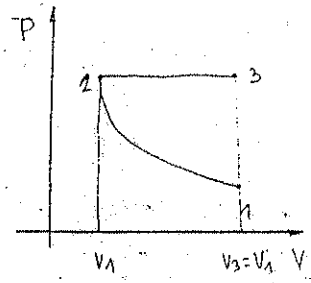
$q_{41} = -712{,}341 \ kJ/kg$

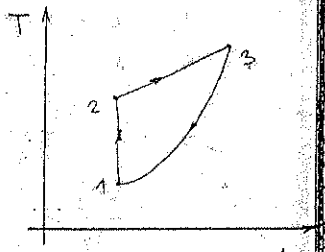
$l_{neto} = q_{do} - |q_{od}|$

$l_{neto} = 1057{,}26$

$\eta_t = \frac{l_{neto}}{q_{do}} = 0{,}597$

## Zadatak 7-2-15




$p_1 = 1 \ bar$

$t_1 = 20° \Rightarrow T_1 = 293 \ K$

$p_3 = p_2 = 18 \ bar$

$R = 287 \ J/kgK$

$\varkappa = 1{,}4$

$V_1 = V_3 = \frac{RT_1}{p_1} = 0{,}84091 \ m^3/kg$

$V_2 = \frac{RT_2}{p_2} = 0{,}1066 \ m^3/kg$

$\frac{p_1^{\varkappa-1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa-1}}{T_1^{\varkappa}} \Rightarrow T_2 = \left(\frac{p_2}{p_1}\right)^{\frac{\varkappa-1}{\varkappa}} \cdot T_1 = 669{,}112 \ K$

$\frac{V_2}{T_2} = \frac{V_3}{T_3} \Rightarrow T_3 = \left(\frac{V_3}{V_2}\right) T_2 = 5278{,}24 \ K$

$q_{12} = 0$

$q_{23} = c_p \cdot (T_3 - T_2) = \frac{\varkappa R}{\varkappa - 1} (T_3 - T_2) = 4629{,}86 \ \text{kJ/kg}$

$q_{31} = c_v \cdot (T_1 - T_3) = \frac{R}{\varkappa - 1} (T_1 - T_3) = -3576{,}909 \ \text{kJ/kg}$

$l_{neto} = q_{do} - |q_{od}| = 4629{,}86 - 3576{,}90 = 1052{,}95 \ \text{kJ/kg}$

$\eta_t = \frac{l_{neto}}{q_{do}} = 0{,}2274$

## Zadatak 7-2-16

$p_1 = p_4 = 8 \ \text{bar}$

$p_2 = p_3 = 1 \ \text{bar}$

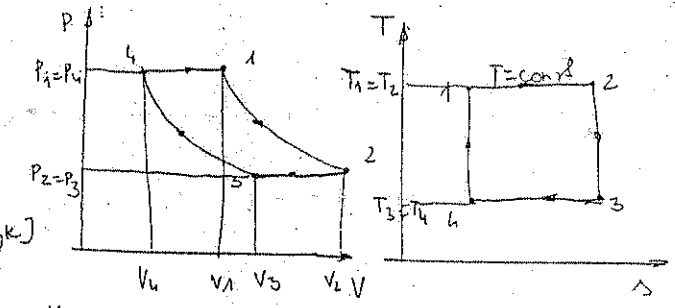
$T_1 = T_2 = 773 \ \text{K}$

$T_4 = T_3 = 293 \ \text{K}$

$m = 1 \ \text{kg}$

$R = 296{,}7 \ [\text{J/kgK}]$

$\varkappa = 1{,}4$




$Q_{12} = l_{12} = m R T \ln \frac{V_2}{V_1} = m \cdot R \cdot T \cdot \ln \frac{p_1}{p_2} = 476{,}918 \ \text{kJ}$

$Q_{34} = l_{34} = m R T \ln \frac{V_4}{V_3} = m \cdot R \cdot T \ln \frac{p_3}{p_4} = -180{,}772 \ \text{kJ}$

$Q_{23} = m \cdot c_p \cdot (T_3 - T_2) = m \cdot \frac{\varkappa R}{\varkappa - 1} (T_3 - T_2) = -498{,}48 \ \text{kJ}$

$Q_{41} = m \cdot c_p (T_1 - T_4) = m \cdot \frac{\varkappa R}{\varkappa - 1} (T_1 - T_4) = 498{,}456$

$L_{23} = m p (V_3 - V_2) = m \cdot R \cdot (T_3 - T_2) = -142{,}416 \ \text{kJ}$

$L_{41} = m p \cdot (T_1 - T_4) = m \cdot R \cdot (T_1 - T_4) = 142{,}416 \ \text{kJ}$

$l_{neto} = l_{12} + l_{34} + l_{23} + l_{41} = 180{,}772 \ \text{kJ}$

$L_{neto} = Q_{12} + Q_{23} + Q_{34} + Q_{41} = 180{,}772 \ \text{kJ}$

$\eta_t = 1 - \frac{T_{min}}{T_{max}} = 0{,}6203$

## Zadatak 7-2-21

$p_1 = 0{,}96 \ \text{bar}$

$T_1 = 300 \ \text{K}$

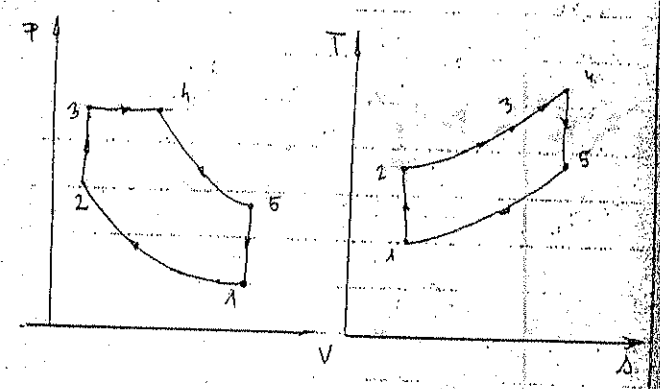
$\frac{V_2}{V_1} = 14$

$q_{23} = 370 \ \text{kJ/kg}$

$q_{34} = 1110 \ \text{kJ/kg}$

$R = 287 \ \text{J/kgK}$

$\varkappa = 1{,}4$




$V_5 = V_1 = \frac{R T_1}{p_1} = 0{,}8963 \ \text{m}^3/\text{kg}$

$T_1 \cdot V_1^{\varkappa - 1} = T_2 \cdot V_2^{\varkappa - 1}$

$T_2 = \left( \frac{V_1}{V_2} \right)^{\varkappa - 1} \cdot T_1 = 862{,}129 \ \text{K}$

$V_2 = \frac{R T_2}{p_2} = 0{,}064 \ \text{m}^3/\text{kg}$

$V_3 = 0{,}06406 \ \text{m}^3/\text{kg}$

$V_4 = \frac{R \cdot T_4}{p_4} = 0{,}11515 \ \text{m}^3/\text{kg}$

$q_{23} = c_v \cdot (T_3 - T_2) \Rightarrow T_3 = T_2 + \frac{q_{23}}{c_v} = T_2 + \frac{q_{23} \cdot (\varkappa - 1)}{\kappa} = 1377{,}8 \ \text{K}$

$q_{34} = c_p \cdot (T_4 - T_3) \rightarrow T_4 = T_3 + \frac{q_{34}}{c_p} = T_3 + \frac{q_{23} \cdot (\varkappa - 1)}{R \cdot \varkappa} = 2432{,}82 \ \text{K}$

$\frac{p_1^{\varkappa - 1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa - 1}}{T_2^{\varkappa}} \Rightarrow p_2 = \left( \frac{T_2}{T_1} \right)^{\frac{\varkappa}{\varkappa - 1}} \cdot p_1 = 38{,}62 \ \text{bar}$

$\frac{p_2}{T_2} = \frac{p_3}{T_3} \Rightarrow p_3 = \frac{T_3}{T_2} p_2 = 61{,}720 \ \text{bar}$

$p_3 = p_4 = 61{,}72 \ \text{bar}$

$$P_4 \cdot V_4^{\varkappa} = P_5 V_5^{\varkappa}$$

$$P_5 = \left(\frac{V_4}{V_5}\right)^{\varkappa} \cdot P_4 = 27{,}18 \text{ bar}$$

$$\frac{P_4^{\varkappa-1}}{T_4^{\varkappa}} = \frac{P_5^{\varkappa-1}}{T_5^{\varkappa}}$$

$$T_5 = \left(\frac{P_5}{P_4}\right)^{\frac{\varkappa-1}{\varkappa}} \cdot T_4$$

$$\boxed{T_5 = 1964{,}19 \text{ K}}$$

$$q_{12} = 0$$

$$q_{23} = c_v (T_3 - T_2) = \frac{R}{\varkappa - 1}(T_3 - T_2) = 369994 \text{ KJ/kg}$$

$$q_{34} = c_p (T_4 - T_3) = \frac{\varkappa R}{\varkappa - 1}(T_4 - T_5) = 1059767{,}8 \text{ KJ/kg}$$

$$q_{45} = 0$$

$$q_{51} = c_v (T_5 - T_1) = \frac{R}{\varkappa - 1}(T_5 - T_1) = 1194056{,}325 \text{ KJ/kg}$$

$$\eta_t = 1 - \frac{q_{od}}{q_{do}} = 1 - \frac{T_5 - T_1}{(T_3 - T_2) + \varkappa \cdot (T_4 - T_3)}$$

$$\eta_t = 1 - \frac{1664{,}19}{515{,}67 + 1105{,}02 \cdot 1{,}4} = 0{,}19319$$

Zadatak 7-2-24

$P_1 = 0{,}962$ bar

$T_1 = 18 + 273 = 291$ K

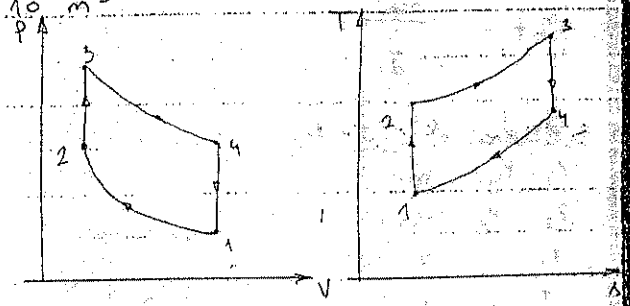
$V_1 = 2{,}18$ litara $= 2{,}18 \cdot 10^{-3}$ m$^3$

$\frac{V_1}{V_2} = 9$

$q_{do} = 4{,}51$ KJ

$R = 287$ J/kgK

$\varkappa = 1{,}4$




$$T_1 V_1^{\varkappa-1} = T_2 V_2^{\varkappa-1}$$

$$T_2 = \left(\frac{V_2}{V_1}\right)^{\varkappa-1} T_1 = 700{,}7 \text{ K}$$

$$\frac{P_1^{\varkappa-1}}{T_1^{\varkappa}} = \frac{P_2^{\varkappa-1}}{T_2^{\varkappa}}$$

$$P_2 = \left(\frac{T_2}{T_1}\right)^{\frac{\varkappa}{\varkappa-1}} \cdot T_1 = 20{,}185 \text{ Bar}$$

$$q_{do} = c_v (T_3 - T_2) \Rightarrow T_3 = T_2 + \frac{q_{do}}{c_v}$$

$$T_3 = T_2 + \frac{q_{do}(\varkappa - 1)}{R} = 707{,}06 \text{ K}$$

$$T_3 V_3^{\varkappa-1} = T_4 \cdot V_4^{\varkappa-1} \Rightarrow T_4 = \left(\frac{V_3}{V_4}\right)^{\varkappa-1} = \left(\frac{V_2}{V_1}\right)^{\varkappa-1} T_3 = 293{,}6 \text{ K}$$

$$\frac{P_2}{T_2} = \frac{P_3}{T_3} \Rightarrow P_3 = \left(\frac{T_3}{T_2}\right) P_2 = 21{,}039 \text{ bar}$$

$$\frac{P_3^{\varkappa-1}}{T_3^{\varkappa}} = \frac{P_4^{\varkappa-1}}{T_4^{\varkappa}} \Rightarrow P_4 = \left(\frac{T_4}{T_3}\right)^{\frac{\varkappa}{\varkappa-1}} = 0{,}970 \text{ bar}$$

$$\eta_t = 1 - \frac{|q_{od}|}{q_{do}} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{2{,}1}{3{,}36} = 0{,}591$$

$q_{12} = 0$

$q_{23} = c_v \cdot (T_3 - T_2) = \frac{R}{\varkappa - 1} (T_3 - T_2)$

$q_{34} = 0$

$q_{41} = c_v (T_1 - T_4) = \frac{R}{\varkappa - 1} (T_1 - T_4)$

## Zadatak ~~7-2-25~~

$q_{23} = 1600$ KJ/kg

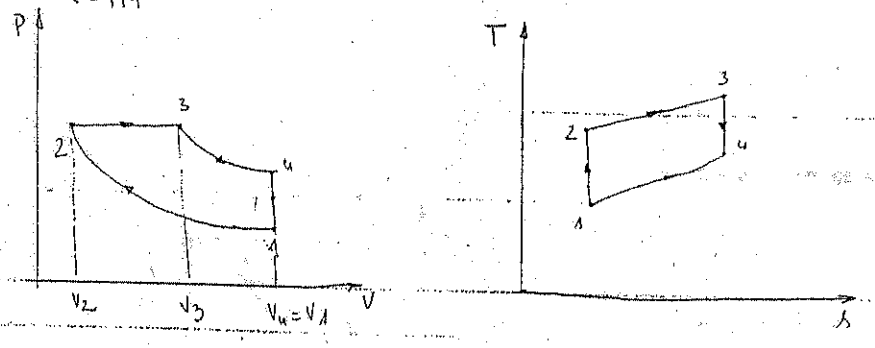
$p_1 = 0,955$ bar

$T_1 = 20 + 273 = 293$ K

$p_3 = p_2 = 3,55$ MPa $= 35,5$ bar

$R = 287$ KJ/kgK

$\varkappa = 1,4$




$V_4 = V_1 = \frac{R \cdot T_1}{p_1} = 0,880$ m³/kg

$V_2 = 0,00665$ m³/kg

$V_3 = 0,1953$ m³/kg

$\frac{p_1^{\varkappa-1}}{T_1^{\varkappa}} = \frac{p_2^{\varkappa-1}}{T_2^{\varkappa}} \Rightarrow T_2 = \left(\frac{p_2}{p_1}\right)^{\frac{\varkappa-1}{\varkappa}} T_1 = 823,15$ K

$q_{23} = c_p \cdot (T_3 - T_2) \Rightarrow T_3 = T_2 + \frac{q_{23}}{c_p} = T_2 + \frac{q_{23}(\varkappa - 1)}{R \cdot \varkappa} = 2415,9$ K

$T_3 \cdot V_3^{\varkappa-1} = T_4 \cdot V_4^{\varkappa-1}$

$T_4 = \left(\frac{V_3}{V_4}\right)^{\varkappa-1} \cdot T_3 = 1323,05$ K

$\frac{p_3^{\varkappa-1}}{T_3^{\varkappa}} = \frac{p_4^{\varkappa-1}}{T_4^{\varkappa}} \Rightarrow p_4 = \left(\frac{T_4}{T_3}\right)^{\frac{\varkappa}{\varkappa-1}} \cdot p_3 = 41,314$ bar

$q_{12} = 0$

$q_{23} = 1600$ KJ/kg

$q_{34} = 0$

$q_{41} = c_v \cdot (T_1 - T_4) = \frac{R}{\varkappa - 1} (T_1 - T_4) = -739,06$ KJ/kg

$\eta_{tc} = 1 - \frac{|q_{od}|}{q_{do}} = 1 - \frac{739,06}{1600} = 0,5380$

## Zadatak 7-2-26

$\frac{V_1}{V_2} = 15$

$p_1 = 0,95$ bar

$T_1 = 18 + 273 = 291$ K

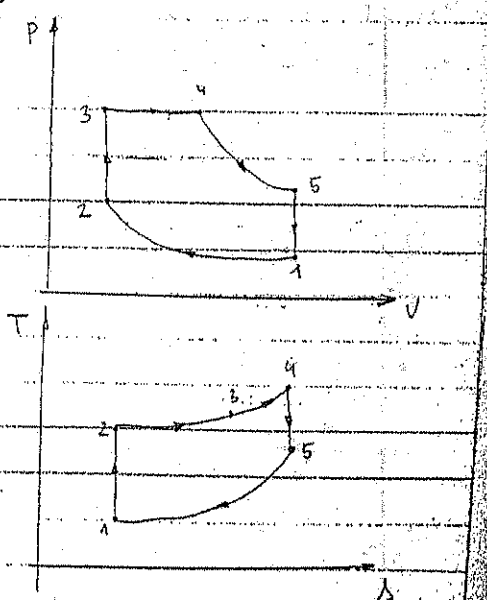
$V_1 = 3,7$ litara $= 3,7 \cdot 10^{-3}$ m³

$q_{23} = 11,8$ KJ

$q_{34} = 4,2$ KJ

$R = 287$ J/kgK

$\varkappa = 1,4$



$V_1 = \frac{3{,}17 \cdot 10^{-3}}{15} = 2{,}466 \cdot 10^{-3}\ m^3$

$m = \frac{P_1 \cdot V_1}{R T_1} = 0{,}004208\ kg$

$T_1 V_1^{\alpha-1} = T_2 V_2^{\alpha-1}$

$T_2 = \left(\frac{V_1}{V_2}\right)^{\alpha-1} \cdot T_1 = 859{,}605\ K$

$\frac{P_1^{\alpha-1}}{T_1^{\alpha}} = \frac{P_2^{\alpha-1}}{T_2^{\alpha}} \Rightarrow P_2 = \left(\frac{T_2}{T_1}\right)^{\frac{\alpha}{\alpha-1}} \cdot P_1 = 42{,}09$

$\boxed{P_2 = 42{,}09\ bar}$

$Q_{23} = c_v \cdot (T_3 - T_2) = \frac{R}{\alpha-1}(T_3 - T_2)$

$T_3 = T_2 + \frac{Q_{23}(\alpha-1)}{R} = 862{,}16\ K$

$Q_{34} = c_p \cdot (T_4 - T_3) \Rightarrow T_4 = T_3 + \frac{Q_{34} \cdot (\alpha-1)}{R \cdot \alpha} = 866{,}34\ K$

$\frac{P_2}{T_2} = \frac{P_3}{T_3} \Rightarrow P_3 = \frac{T_3}{T_2} \cdot P_2 = 42{,}21\ bar$

$V_5 = V_1 = \frac{R \cdot T_1}{P_1} = 0{,}87891\ m^3/kg$

$V_2 = \frac{R T_2}{P_2} = 0{,}058641\ m^3/kg$

$V_3 = \frac{R T_3}{P_3} = 0{,}05863\ m^3/kg$

$T_3 V_3 = T_4 \cdot V_4 \Rightarrow V_4 = \frac{T_3}{T_4} \cdot V_3 = 0{,}058504\ m^3/kg$

$T_4 \cdot V_4^{\alpha-1} = T_5 \cdot V_5^{\alpha-1}$

$T_5 = \left(\frac{V_4}{V_5}\right)^{\alpha-1} T_4 = 292{,}73\ K$

$Q_{12} = 0$

$Q_{23} = 1{,}8\ kJ$

$Q_{34} = 4{,}2\ kJ$

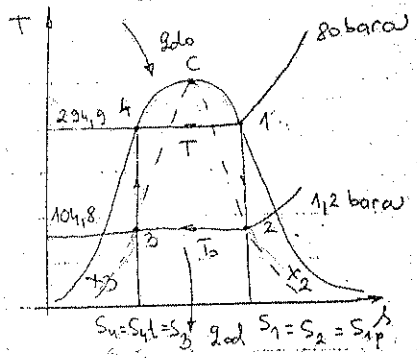
$Q_{45} = 0$

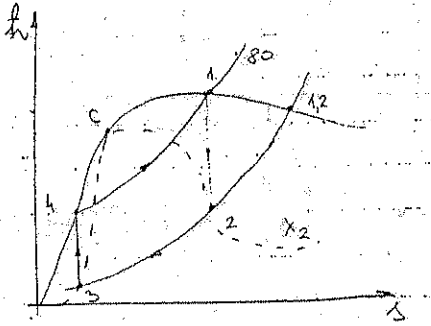
$Q_{51} = m\ c_v\ (T_5 - T_1) = 0{,}00512\ kJ$

$\eta_{tc} = 1 - \frac{T_5 - T_1}{T_3 - T_2 + \alpha(T_4 - T_3)} = 1 - \frac{1{,}73}{8{,}1376}$

$\boxed{\eta_{tc} = 0{,}7934}$

~~Tadatarea~~ 8-2-1




$m = 0{,}85\ \frac{kg}{s}$

$\eta_{tc} = 1 - \frac{T_0}{T} = 1 - \frac{377{,}8}{569{,}9} = 0{,}337$

Stanja ① (80 bar)

$S_p = S_1 = 5,745$ KJ/kgK

$h_1 = h_{1p} = 2758$ KJ/kg

$V_1 = V_{p1} = 0,02352$ KJ/kg

Stanja ②

$$x_2 = \frac{s_2 - s_{2t}}{s_{2p} - s_{2t}} = \frac{5,745 - 1,36}{7,298 - 1,36} = \frac{4,385}{5,938} = 0,7384$$

$h_2 = h_{2t} + x \cdot (h_{2p} - h_{2t}) = 2096,07$ kJ/kg

$h_{2p} = 2683$ KJ/kg

$h_{2t} = 439,4$ KJ/kg

$s_2 = 5,745$ KJ/kgK

Stanje ③

$s_3 = 3,208$ KJ/kg

$$x_3 = \frac{s_3 - s_{3t}}{s_{3p} - s_{3t}} = \frac{3,208 - 1,36}{7,298 - 1,36} = \frac{1,848}{5,938} = 0,3112$$

$h_3 = h_{3t} + (h_{3p} - h_{3t}) \cdot x = 1137,608$ KJ/kg

$h_{3p} = 2683$ KJ/kg

$h_{3t} = 439,4$ KJ/kg

Stanje ④

$S_4 = S_{4t} = 3,208$ KJ/kgK

$h_{4t} = 1317$ KJ/kg

$q_{do} = q_{41} = h_1 - h_4 - T \cdot (s_1 - s_4)$

$q_{do} = 2758 - 1317 = 1441$ KJ/kg

$q_{od} = q_{23} = h_3 - h_2 = T_o \cdot (s_3 - s_2)$

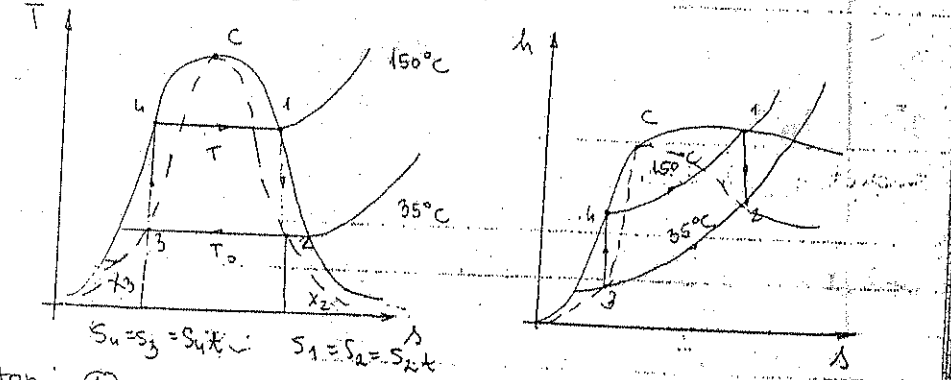
$q_{od} = 2096,07 - 1134,608 = 958,46$ KJ/kg

$N = m \cdot (h_1 - h_2) = 0,185 \cdot (2758 - 2096,07)$

$N = 562,64$ KW

$Q_{od} = m \cdot (h_3 - h_2) = 0,185 \cdot 958,46 = 814,691$ KJ/kg

8-2-2




Stanje ①

$S_1 = S_{1p} = 6,8383$ KJ/kgK

$h_{1p} = 2746$ KJ/kg

Stanje ②

$$x_2 = \frac{S_2 - S_{2t}}{S_{2p} - S_{2t}} = \frac{6,8383 - 0,5049}{8,3519 - 0,5049} = \frac{6,3334}{7,847} = 0,80706$$

$h_2 = h_{2t} + x \cdot (h_{2p} - h_{2t}) = 2098,24$ KJ/kg

Stanje ③

$s_3 = 1,8418 \ kJ/kgK$

$x_3 = \frac{s_3 - s_{3t}}{s_{r3} - s_{t3}} = \frac{1,8418 - 0,5049}{8,3519 - 0,5049} = \frac{1,3369}{7,847} = 0,1703$

$h_3 = h_{3t} + x_3 \cdot (h_{3p} + h_{3t}) = 568,459 \ kJ/kg$

Stanje ④

$s_4 = s_{4t} = 1,8418 \ kJ/kgK$

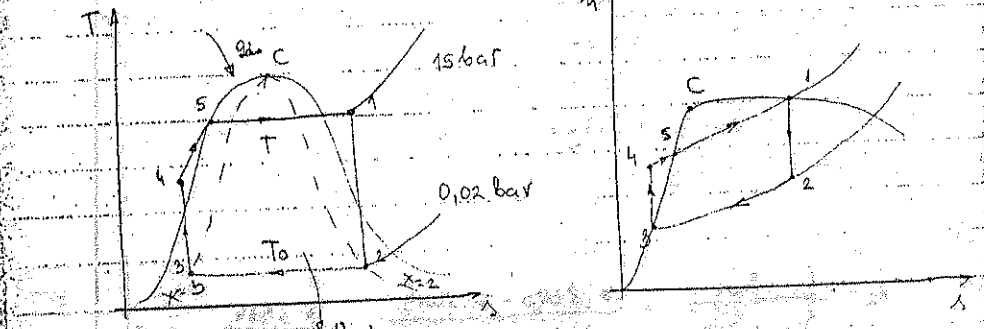
$h_4 = h_{t4} = 632,2 \ kJ/kg$

$q_{od} = h_3 - h_2 = T_0 \cdot (s_3 - s_2) = -1539,4 \ kJ/kg$

$q_{do} = q_{14} = h_1 - h_4 = 2113,8 \ kJ/kg$

$\eta_t = 0,2715$

Zadatak 8-2-4







Stanje ① (interpolacija)

$s_1 = s_{1p} = s_{p1} + \frac{p - p_1}{p_2 - p_1} (s_{p2} - s_{p1}) = 6,4669 + \frac{15 - 14}{16 - 14} (6,422 - 6,46) = 6,46 \ \frac{kJ}{kgK}$

$h_1 = h_{1p} = h_{1p} + \frac{p - p_1}{p_2 - p_1} (h_{p2} - h_{p1}) = 2790 + \frac{15 - 14}{16 - 14} (2793 - 2790) = 2791,5 \ kJ/kg$

Stanje ②

$s_2 = s_{1p} = s_1 = 6,46$

$x_2 = \frac{s_2 - s_{2t}}{s_{2p} - s_{2t}} = \frac{6,46 - 0,2609}{8,1722 - 0,2609} = 0,7326$

$h_2 = h_{2t} + x_2 (h_{2p} - h_{2t}) = 73,52 + 0,7326 (2533 - 73,52)$

$h_2 = 1875,23 \ kJ/kg$

Stanje ③

$s_3 = s_{3t} = 0,2609 \ kJ/kgK$

$h_3 = h_{3t} = 73,52 \ kJ/kg$

Stanje ④

$s_3 = s_4 = s_{2l} = 0,2609 \ kJ/kgK$

interpolacija

$T = T_1 + \frac{s - s_{t1}}{s_{t2} - s_{t1}} (T_2 - T_1) = 283 + \frac{0,2609 - 0,1509}{0,2960 - 0,1909} (293 - 283) = 293,5 \ K$

$h_4 = h_1 + \frac{T - T_1}{T_2 - T_3} (h_2 - h_3) = 75,184$

Stanje ⑤ (nije potrebno odrediti ali kao može)

$s_5 = s_{5t} = s_{t1} + \frac{p - p_1}{p_2 - p_1} (s_{t2} - s_{t1}) = 2,212 \ kJ/kgK$

$h_5 = h_{t1} + \frac{p - p_1}{p_2 - p_1} (h_{t2} - h_{t1}) = 844,75 \ kJ/kg$

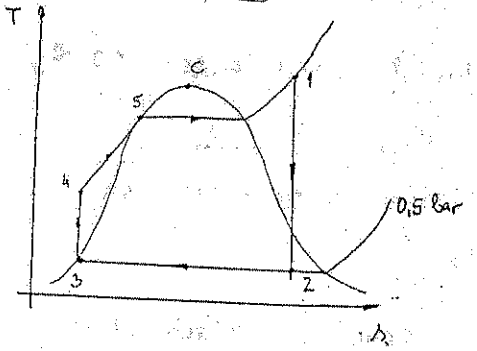
$q_{do} = q_{45} + q_{s1} = h_1 - h_4 = 2716,316 \ kJ/kg$

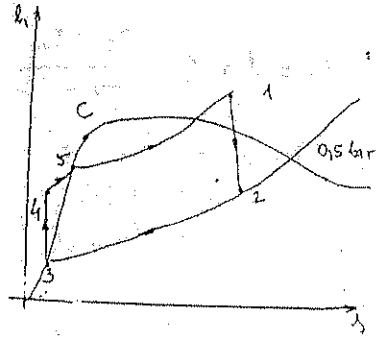
$q_{od} = q_{23} = h_3 - h_2 = -1801,81 \ kJ/kg$

$\eta_{tc} = \frac{l_{neto}}{q_{do}} = 1 - \frac{q_{od}}{q_{do}} = 0,336$

$l_{neto} = \eta_t \cdot q_{do} = 914,5$

Zadatak 8-2-10




Stanje (1.)

$s_1 = 7,5084$ kJ/kgK

$h_1 = 3681,5$ kJ/kg

Stanje (2)

$s_2 = s_1 = 7,593$ kJ/kgK

$$x_2 = \frac{s_2 - s_{2t}}{s_{2p} - s_{2t}} = \frac{7,5084 - 1,091}{7,593 - 1,091} = 0,9869$$

$$h_2 = h_{2t} + x \cdot (h_{2p} - h_{2t}) = 340,6 + 0,9869 \cdot (2645 - 340,6)$$

$h_2 = 2614,81$ kJ/kg

Stanje (3.)

$s_3 = s_{3t} = 1,091$ kJ/kgK

$h_3 = 340,6$ kJ/kg

Stanje (4)

$s_4 = s_3 = 1,091$ kJ/kgK

$$T = T_1 + \frac{s - s_{t1}}{s_p - s_{t1}} \cdot (T_2 - T_1) = 353 + \frac{1,091 - 1,0703}{1,1904 - 1,0703} \cdot (363 - 353)$$

$T = 354,51$ K

$$h_4 = h_{t1} - \frac{T - T_1}{T_2 - T_1} \cdot (h_2 - h_{t1}) = 343,642 \text{ kJ/kg}$$

Stanje (5.)

$s_5 = 2,106$ kJ/kgK

$h_5 = 1008,3$ kJ/kg

$l_{turbine} = l_{12} = h_1 - h_2 = 1066,69$ kJ/kg

$l_{pumpe} = l_{34} = h_4 - h_3 = 3,042$ kJ/kg

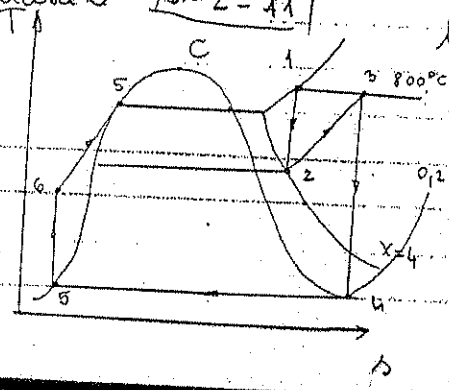
$q_{do} = q_{45} + q_{51} = h_1 - h_4 = 3337,21$ kJ/kg

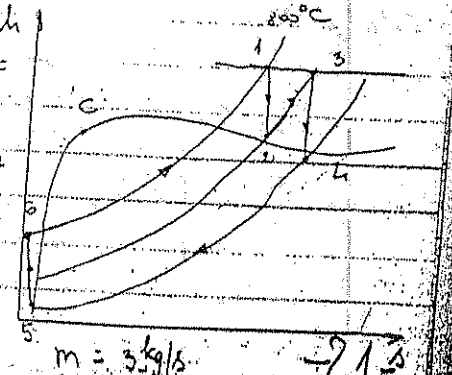
$q_{od} = q_{23} = h_3 - h_2 = 2274,21$ kJ/kg

$l_{neto} = l_{turbine} + l_{pumpe} = 1063,64$ kJ/kg

$$\eta_t = \frac{l_{neto}}{q_{do}} = \frac{1063,54}{3337,85} = 0,3186$$

Zadatak 8-2-11




$\dot{m} = 3$ kg/s

Stanje ① ($t = 800°C$, $p = 50$ bara)

$s_1 = 7,7427$ kJ/kgK

$h_1 = 4135,2$ kJ/kg

Stanje ② (10 bara)

$s_2 = s_1 = 7,7427$ kJ/kgK

$T_2 = T_1 + \frac{s - s_a}{s_b - s_a}(T_2 - T_1) = 480 \cdot \frac{7,7427 - 7,7061}{7,7624 - 7,7061}(500 - 480)$

$\boxed{T_2 = 493,04 \text{ K}}$

$h_2 = h_a + \frac{T_2 - T_1}{T_2 - T_1}(h_b - h_a) = 3436,1 + \frac{493,04 - 480}{500 - 480}(3472,3 - 3436,1)$

$\boxed{h_2 = 3463,26 \text{ kJ/kg}}$

Stanje ③ ($p = 10$ bar, $t = 800°C$)

$s_3 = 8,498$ kJ/kgK

$h_3 = 4151$ kJ/kg

Stanje ④ ($p = 0,2$ bar)

$s_4 - s_3 = 8,498$ kJ/kg

$T_4 = T_m + \frac{s_4 - s_a}{s_b - s_a}(h_b - h_a) = 2328,39$ kJ/kg

Stanje ⑤ ($p = 0,2$ bara)

$s_5 = 0,8321$ kJ/kgK

$h_5 = h_{sk} = 251,4$ kJ/kg

Stanje ⑥ ($p = 50$ bara)

$t = T_m + \frac{s_5 - s_a}{s_b - s_a}(T_n - T_m) = 60,30$ K

$h_6 = h_a + \frac{T_6 - T_m}{T_n - T_m}(h_b - h_a) = 256,551$ kJ/kg

$L_{turbine} = L_{12} + L_{34} = h_1 - h_2 + h_3 - h_4$

$L_{turbine} = 4135,2 - 3463,26 + 4151 - 2328,39$

$L_{turbine} = 2494,55$ kJ/kg

$\dot{L}_t = \dot{m} \cdot L_{turbine} = 3,15 \cdot 2494,55 = 7,857$ MW

$l_{pumpe} = h_6 - h_5 = 256,551 - 251,4 = 5,151$ kJ/kg

$\dot{L}_p = \dot{m} \cdot l_{pumpe} = 3,15 \cdot 5,151 = 16,22$ kW

$q_{23} = h_3 - h_2 = 4151 - 3463,26 = 687,74$ kJ/kg

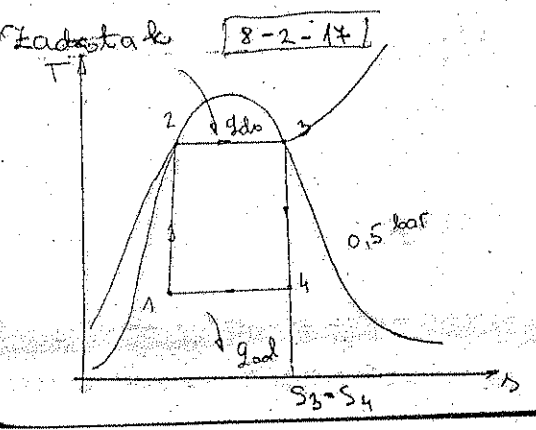
$q_{16} = h_1 - h_6 = 4135,2 - 256,551 = 3878,64$ kJ/kg

$\eta_t = \frac{L_{turbine} + L_{pumpe}}{q_{do}} = \frac{L_{t12} + L_{t34} - L_{pcs}}{q_{23} + q_{16}}$

$\eta_t = \frac{2489,33}{4566,36} = 0,545$

$x_4 = \frac{h_4 - h_t}{h_g - h_t} = \frac{2328,39 - 251,4}{2609 - 251,4} = 0,8809$

Zadatak 8-2-17



$$\eta_{tk} = \frac{L_{neto}}{q_{do}} = \frac{h_3 - h_4}{h_3 - h_1}$$

Stanje (3.)

$p_3 = 10$ bar } para
$h_3 = 2778$ KJ/kg
$s_3 = 6,586$ KJ/kgK

Stanje (1)

$p_1 = 0,15$ bar } $h_1 = 340,6$ KJ/kg
kečnost

Stanje (4)

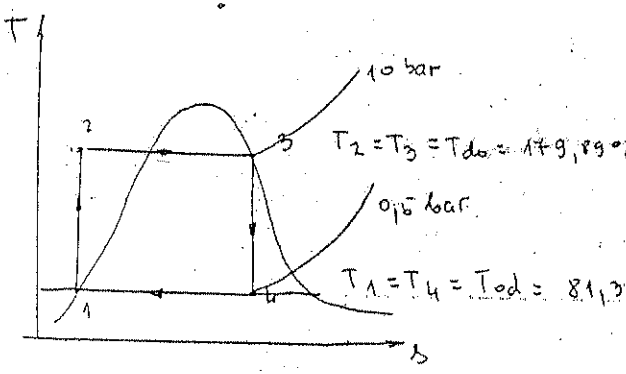
$p_4 = 0,15$ bar
$s_4 = s_3 = 6,586$ KJ/kgK } T. 5.32
$s_{t4} = 1,091$ KJ/kgK
$s_{p4} = 7,593$ KJ/kgK
$h_{t4} = 340,6$ KJ/kg
$h_{p4} = 2645$ KJ/kg

$$x_4 = \frac{s_4 - s_{t4}}{s_{p4} - s_{t4}} = \frac{6,586 - 1,091}{7,593 - 1,091} = 0,845$$

$$h_4 = h_{t4} + x_4 (h_{p4} - h_{t4}) = 340,6 + 0,845 (2645 - 340,6)$$

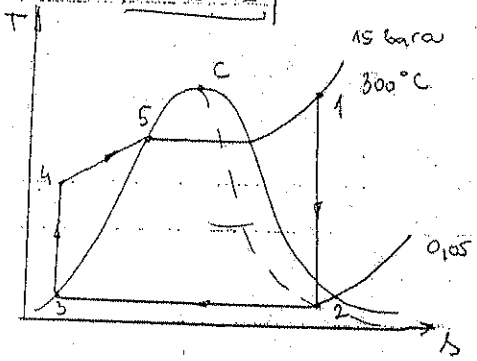
$$h_4 = 2287,818 \ \frac{KJ}{kg}$$

$$\eta_{tk} = \frac{2778 - 2287,818}{2778 - 340,6} = 0,2011$$




$$\eta_{tc} = 1 - \frac{T_{od}}{T_{do}} = 1 - \frac{81,32 + 273,15}{179,88 - 273,15} = 0,2176$$

Zadatak [8-2-19]




$$\dot{m} = 30 \text{ t/h} = \frac{30\,000}{3600} = 8,33 \frac{kg}{s}$$

Stanje (1.) ($t = 300$°C, $p = 15$ bar)

$s_1 = 6,9192$ KJ/kgK $= 6,7679$
$h_1 = 3037,9$ KJ/kg $= 3024,0$

Stanje (2.) ($p = 0,05$ bara)

$s_2 = s_p = s_1 = 6,9192$ KJ/kgK

$x_2 = h_t + x (h_p - h_t) = 137,83 + 0,913 (2561 - 137,83)$

$x_2 = 2107,86$ KJ/kg

Stanje ③ (P = 0,05 bara)

$s_3 = 0,4761$ KJ/kgK

$h_3 = h_{3t} = 137,83$ KJ/kg

Stanje ④ (P = 15 bara)

$s_4 = 0,4761$ KJ/kgK

$h_4 = h_m + \frac{T_4 - T_1}{T_2 - T_1}(h_n - h_m) = 127 + \frac{32,95-30}{40-30}(168 - 127)$

$\boxed{h_4 = 139,09 \text{ KJ/kg}}$

$T_4 = T_m + \frac{s_4 - s_a}{s_b - s_a}\cdot(T_n - T_m) = 30 + \frac{0,4761 - 0,436}{0,5715 - 0,436}(40-30)$

$\boxed{T_4 = 32,95 \text{ K}}$

$q_{do} = q_{45} + q_{51} = h_1 - h_4 = 2898,81$ KJ/kg

$Q_{do} = \dot{m} \cdot q_{do} = 8,33 \cdot 2898,81 = 24,14$ MW

$q_{od} = q_{23} = h_3 - h_2 = -1970,03$ KJ/kg

$Q_{od} = \dot{m} \cdot q_{od} = -16,41$ MW

$L_{neto} = q_{do} - |q_{od}| = 928,78$ KJ/kg

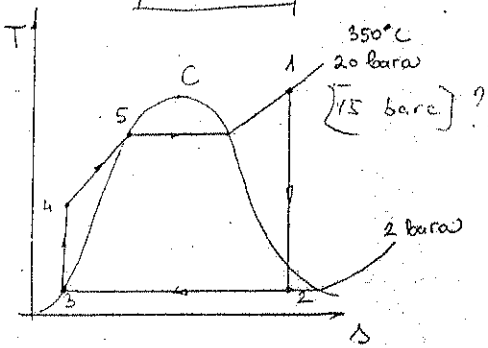
$L_{neto} = L_{turbina} - L_{pumpe} = h_1 - h_2 - (h_4 - h_3) = 927,28$ KJ/kg

$L_{turbina} = h_1 - h_2 = 930,04$ KJ/kg

$\dot{L}_t = \dot{m} \cdot L_{turbina} = 8,33 \cdot 930,04 = 7,747$ MW

$\eta_t = \frac{L_{neto}}{q_{do}} = 0,320$

Zadatak 8-2-20




Stanje ① (t = 350°C) (P = 20 bara)

$s_1 = s_m + \frac{T - T_1}{T_2 - T_1}(s_n - s_m) = 7,0674 + \frac{350-341}{360-340}(7,1372 - 7,0674) = 7,1023$ KJ/kgK

$h_1 = h_m + \frac{T - T_1}{T_2 - T_1}(h_n - h_m) = 3125 + \frac{350-340}{360-340}(3169 - 3125,9)$

$h_1 = 3147,55$ KJ/kg

Stanje ② P = 2 bar

$s_2 = s_1 = 7,1022$ KJ/kgK

$x_2 = \frac{s_2 - s_t}{s_p - s_t} = \frac{7,102 - 1,5302}{7,127 - 1,530} = \frac{5,5718}{5,597} = 0,995$

$h_2 = h_t + x \cdot (h_p - h_t) = 2695,98$ KJ/kg

Stanje ③ (P = 2 bara)

$s_3 = s_{3t} = 1,5302$ KJ/kgK

$h_3 = h_{3t} = 504,7$ KJ/kg

Stanje ④ P = 20 bara

$s_3 = s_4 = 1{,}5302$ kJ/kgK

$$T_4 = T_a + \frac{s - s_a}{s_b - s_a}(T_b - T_a) = 80 + \frac{1{,}5302 - 1{,}526}{1{,}757 - 1{,}526}(90 - 80)$$

$$\boxed{T_4 = 80{,}199\ K}$$

$$h_4 = h_a + \frac{T_4 - T_a}{T_3 - T_a}(h_b - h_a) = 506{,}69\ kJ/kg$$

$$q_{od} = q_{23} = h_3 - h_2 = -2191{,}18\ kJ/kg$$

Zadatak 8-2-23

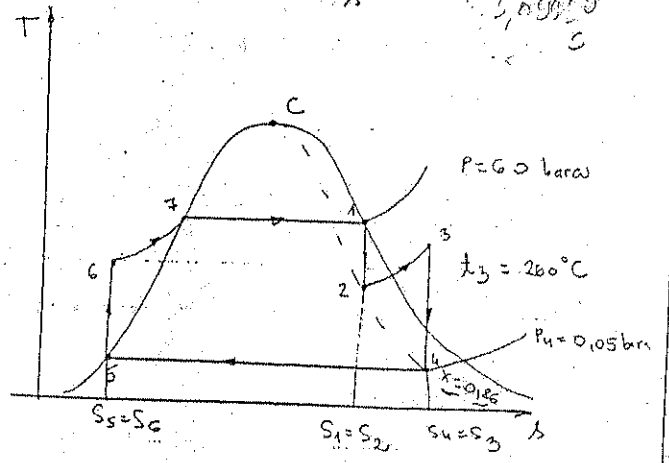
$N_{tc} = 400\ MW = 400 \cdot 10^6\ W = 400 \cdot 10^3\ \frac{kJ}{s}$

$P_1 = 60$ bara

$x_2 = 0{,}86$

$t_2 = 260°C$

$P_4 = 0{,}105$ bara




Stanje ①

P = 60 bara

$h_{p1} = 2785$ kJ/kg

$s_{t1} = 3{,}027$ kJ/kgK

$s_{p1} = 5{,}183$ kJ/kgK

$h_{t1} = 1213{,}9$ kJ/kg

$h_1 = 2785$ kJ/kg

Stanje ④

P = 0,105 bara

$h_{t4} = 137{,}83$ kJ/kg

$h_{p4} = 2561$ kJ/kg

$s_{t4} = 0{,}4761$ kJ/kgK

$s_{p4} = 8{,}393$ kJ/kgK

$h_4 = 2561$ kJ/kg

Stanje ③ $t_3 = 260°C$

$s_{p4} = s_3 = 8{,}393$ — T, P, 3

P = 0,15 bara

$h_3 = 2995{,}6$

$s_{t3} = 1{,}091$ kJ/kgK

$s_{p3} = 7{,}595$ kJ/kgK

$h_{t3} = 340{,}6$ kJ/kg

$h_{p3} = 2645$ kJ/kg

Stanje ②

P = 0,05 bara

$h_{2t} = 137{,}83$ kJ/kg

$h_{2p} = 2561$ kJ/kg

$x = 0{,}86$

$h_2 = h_{2t} + x \cdot (h_{2p} - h_{2t}) = 137{,}83 + 0{,}86\,(2561 - 137{,}83)$

$h_2 = 2221{,}756$ kJ/kg

Stanje ⑤

$h_5 = h_{t4} = 137{,}83$ kJ/kg

Stanje ⑥ $h_6 = h_{t1} = 1213{,}9$ kJ/kg

$q_{do} = (h_1 - h_6) + (h_3 - h_2) = (2785 - 1213,9) + (2995,6 - 2221,6)$

$q_{do} = 1571,1 + 773,844 = 2344,944 \ KJ/kg$

$N_{nukl.el} = q_{dov} \cdot \dot{m}$

$$\dot{m} = \frac{N_{nukl.el}}{q_{do}} = \frac{400 \cdot 10^3}{2344,944} = 170,5798 \ \frac{kg}{s}$$

$l_{turbine} = (h_1 - h_4) + (h_3 - h_4)$

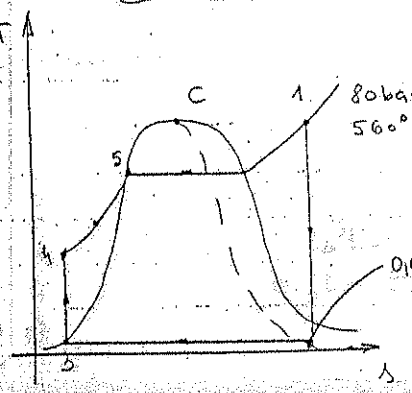
$l_{turbine} = (2785 - 2721,756) + (2995,6 - 2561) = 997,844 \ \frac{KJ}{kg}$

$$\eta_t = \frac{(h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)}{(h_1 - h_6) + (h_3 - h_2)}$$

$$\eta_t = \frac{997,844 - (1213,9 - 137,83)}{2344,944} = 0,033336$$

$N_{turbine} = l_{turbine} \cdot \dot{m} = 997,844 \cdot 170,5798 = 170212,03 \ \frac{KJ}{s}$

Zadatak 8-2-24




Stanje ① ($P = 80$ bara, $t = 560°C$)

$s_1 = 6,906 \ KJ/kgK$

$h_1 = 3545 \ KJ/kg$

Stanje ② ($P = 0,06$ bara)

$s_2 = s_1 = 6,906 \ KJ/kgK$

$$x_2 = \frac{s_2 - s_t}{s_p - s_t} = \frac{6,906 - 0,5207}{8,328 - 0,5207} = 0,817$$

$h_2 = h_t + x \cdot (h_p - h_t) = 151,5 + 0,817 \cdot (2561 - 151,5) = 2124,963 \ KJ/kg$

Stanje ③ ($P = 0,06$ bara)

$s_3 = 0,5207 \ KJ/kg$

$h_3 = h_{3t} = 151,5 \ KJ/kg$

Stanje ④ ($P = 80$ bara)

$s_3 = s_4 = 0,5207 \ KJ/kgK$

$$T_4 = T_m + \frac{s_4 - s_a}{s_b - s_a}(T_n - T_m) = 20 + \frac{0,5207 - 0,294}{0,1569 - 0,294}(40 - 20)$$

$T_4 = 36,48 \ K$

$$h_4 = h_a + \frac{T_4 - T_m}{T_n - T_m}(h_b - h_a) = 91,3 + \frac{36,48 - 20}{40 - 20}(174,5 - 91,3)$$

$h_4 = 159,85 \ KJ/kg$

$q_{do} = q_{45} + q_{51} = h_1 - h_4 = 3385,15 \ KJ/kg$

$q_{od} = q_{23} = h_3 - h_2 = -1973,46$

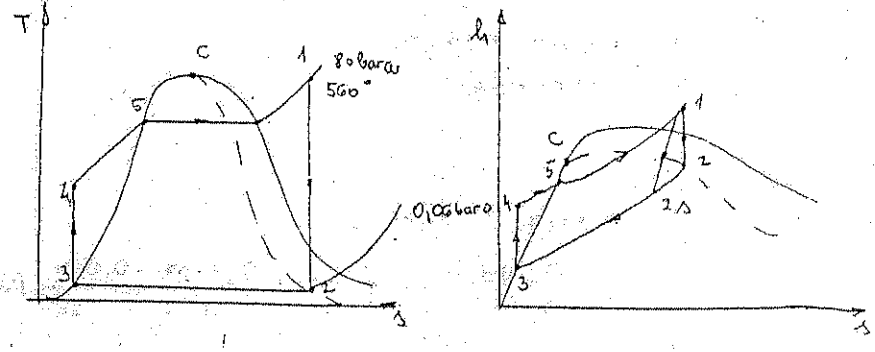
$l_{neto} = q_{do} - |q_{cal}| = 3385,15 - 1973,46 = 1411,69 \ KJ/kg$

$\eta_t = \frac{l_{neto}}{q_{do}} = 0,417$

$N = \dot{m}(h_1 - h_2)$

$\dot{m} = \frac{N}{h_1 - h_2} = \frac{110\,000}{1420,04} = 77,46 \ kg/s$

Zadatak 8-2-25.







$N_t = 110 \ MW$

$\eta_{at} = 0,85$

$\eta_{ap} = 0,75$

Stanje (1)

$s_1 = 6,906 \ KJ/kgK$

$h_1 = 3545 \ KJ/kg$

Stanje (2.)

$s_{2s} = s_1 = 6,906 \ KJ/kg$

$x_{2s} = \frac{s_2 - s_{t2}}{s_{p2} - s_{t2}} = \frac{6,906 - 0,5207}{8,1328 - 0,5207} = \frac{6,385}{7,807} = 0,817$

$h_{2s} = h_t + x(h_p - h_t) = 2124,96 \ KJ/kg$

Stanje (3)

$s_3 = s_{3t} = 0,5207 \ KJ/kgK$

$h_3 = h_{3t} = 151,5 \ KJ/kg$

Stanje (4.)

$s_3 = s_4 = 0,5207 \ KJ/kgK$

$T_4 = T_m + \frac{s_4 - s_a}{s_3 - s_a}(T_m - T_4) = 35,49 \ K$

$h_{4s} = h_a + \frac{T_4 - T_m}{T_m - T_1}(h_b - h_a) = 91,3 + \frac{35,49 - 20}{40 - 20}(176,5 - 91,3)$

$h_{4s} = 155,73 \ KJ/kg$

$q_{do} = q_{ur} + q_{s1} = h_1 - h_{4r} = 3545 - 155,73 = 3389,27 \ KJ/kg$

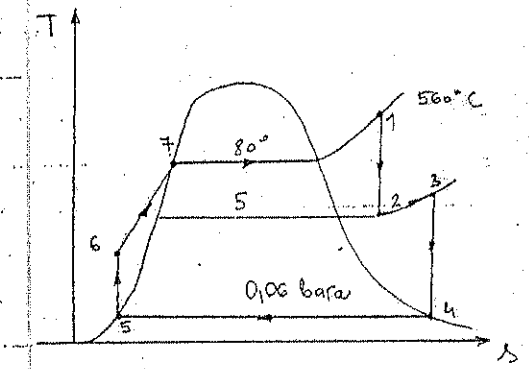
$\eta_{tk} = \frac{l_{neto}}{q_{do}} = \frac{l_{turbine} + l_{pumpe}}{q_{do}} = \frac{\eta_{at}(h_1 - h_{2s})(h_{4s} - h_3)\cdot\eta_{ap}}{q_{do}}$

$\eta_{tk} = \frac{1207,03 + 3,172}{3389,27} = \frac{1210,20}{3389,27} = 0,357$

$N = \dot{m} \cdot l_{turbine}$

$\dot{m} = \frac{N}{l_{turbine}} = \frac{N}{h_1 - h_2} = \frac{110\,000}{1420,04} = 77,46 \ \frac{kg}{s}$

8-2-25.




$N_t = 110$ MW

Stanje ①

$s_1 = 6,906$ kJ/kgK

$h_1 = 3545$ kJ/kg

Stanje ③

$s_3 = 8,0877$ kJ/kgK

$h_3 = 3483,7$ kJ/kg

Stanje ②

$s_1 = s_2 = 6,906$ kJ/kgK

$T_2 = T_m + \frac{s_2 - s_a}{s_b - s_a}(T_n - T_m) = 160 + \frac{6,906 - 6,8654}{6,9665 - 6,8654}(180 - 160)$

$T_2 = 168,03$ K

$h_2 = h_a + \frac{T_2 - T_m}{T_n - T_m}(h_b - h_a) = 2769,3 + \frac{168,03 - 160}{180 - 160}(2812 - 2707,3)$

$h_2 = 2785,28$ kJ/kg

Stanje ④

$s_3 = s_4 = 8,0879$ kJ/kgK

$x_4 = \frac{s_4 - s_t}{s_p - s_t} = \frac{8,0877 - 0,5207}{8,1328 - 0,5207} = 0,969$

$h_4 = h_t + x(h_p - h_t) = 151,5 + 0,969(2567 - 151,5) = 2492,119$ kJ/kg

Stanje ⑤

$s_5 = s_t = 0,5207$ kJ/kgK

$h_5 = h_t = 151,5$ kJ/kg

Stanje ⑥

$s_6 = s_5 = 0,5207$ kJ/kgK

$T_6 = T_m + \frac{s_6 - s_a}{s_b - s_a}(T_n - T_m) = 20 + \frac{0,5207 - 0,294}{0,569 - 0,294}(40 - 20)$

$T_6 = 36,48$ K

$h_6 = h_a + \frac{T_6 - T_m}{T_n - T_m}(h_b - h_a) = 91,3 + \frac{36,48 - 20}{40 - 20}(174,5 - 91,3)$

$h_6 = 159,85$ kJ/kg

$q_{do} = q_{16} + q_{23} = h_1 - h_6 + (h_3 - h_2) = 4083,57$ kJ/kg

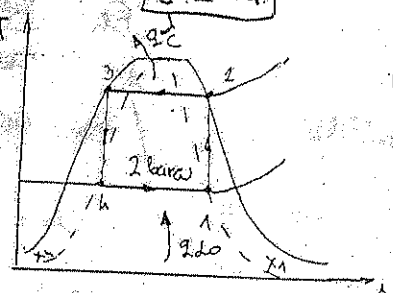
$|q_{od}| = q_{45} = h_5 - h_4 = -2340,619$ kJ/kg

$l_{neto} = q_{do} - |q_{od}| = 1742,95$ kJ/kg

$\eta_{tc} = \frac{l_{neto}}{q_{do}} = 0,4268$

$\dot{N} = \dot{m} \cdot L_{turbine} \Rightarrow \dot{m} = \frac{N}{L_{turbine}} = \frac{110000}{1751,3} = 62,81$ kg/s

## Zadatak 9-2-1




Rashladni medij je R-1340

$\dot{Q}_i = 0{,}1$ MJ/min $= 1{,}8333$ KJ/s

$P_i = P_u = 2$ bara

$P_u = 7$ bara

$t_h = -10{,}07$ °C

$t_k = 26{,}72$

Stanje ②

$S_2 = S_{2p} = 0{,}919$ KJ/kgK

$h_2 = h_{2p} = 264{,}73$ KJ/kg

Stanje ①

$S_1 = S_2 = 0{,}919$ KJ/kgK

$x_1 = \frac{S_2 - S_{2t}}{S_p - S_{2t}} = \frac{0{,}919 - 0{,}1533}{0{,}1936 - 0{,}1533} = 0{,}9782$

$h_1 = h_{2t} + x(h_{2p} - h_{2t}) = 239{,}65$ KJ/kg

Stanje ③

$S_3 = 0{,}13304$ KJ/kgK

$h_3 = 88{,}354$ KJ/kg

Stanje ④

$S_4 = S_3 = 0{,}13304$ KJ/kgK

$x_4 = \frac{S_3 - S_{3t}}{S_{3p} - S_{3t}} = \frac{0{,}13304 - 0{,}1533}{0{,}1936 - 0{,}1533} = 0{,}2261$

$h_4 = h_{4t} + x(h_{4p} - h_{4t}) = 84{,}719$ KJ/kg

$l_{kompresa} = l_{12} = h_2 - h_1 = 264{,}73 - 239{,}65 = 25{,}108$ KJ/kg

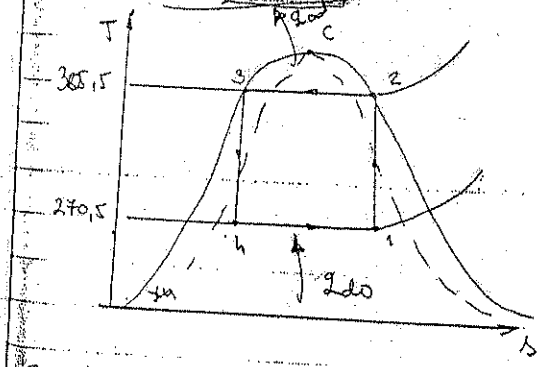
$\varepsilon_h = \frac{q_h}{l_{kompresa}} = \frac{h_1 - h_4}{l_{kompr.}} = \frac{239{,}65 - 84{,}719}{25108} = 6{,}18$

$\varepsilon_h = \frac{T_1}{T_K - T_4} = \frac{262{,}93}{299{,}7 - 262{,}93} = 7{,}146$

$q_{do} = q_h = h_1 - h_4 = 154{,}93$ KJ/kg

$\dot{m} = \frac{\dot{Q}_{do}}{q_{do}} = 0{,}01183$ kg/s

## Zadatak 9-2-2




R-1340 medij

Stanje ②

$S_2 = S_{2p} = S_m + \frac{T - T_1}{T_2 - T_1}(S_n - S_m) = 0{,}9175 + \frac{325 - 30}{35 - 30}(0{,}9158 - 0{,}9175)$

$S_2 = 0{,}9155$ KJ/kgK

$h_2 = h_{2p} = h_m + \frac{T - T_1}{T_2 - T_1}(h_n - h_m) = 266{,}30 + \frac{325 - 30}{35 - 30}(268{,}75 - 266{,}3)$

$h_2 = 267{,}155$ KJ/kg

Stanje ①

$S_1 = S_{2p} = 0,91665 \ KJ/kgK$

$h_p = h_{2p} = h_m + \frac{T-T_1}{T_2-T_1}(h_n - h_m) = 266,36 + \frac{32,5-30}{35-30}(268,75 - 266,36)$

$h_p = 239,07 \ KJ/kg$

$h_t = 38,202 + \frac{-2,5+10}{0+10}(51,427 - 38,202) = 48,120 \ KJ/kg$

$S_p = 0,936 + \frac{(-2,5)+10}{0+10}(0,9301 - 0,936) = 0,9315 \ KJ/kgK$

$S_t = 0,1536 + \frac{(-2,5)+10}{0+10}(0,2026 - 0,1536) = 0,19035 \ KJ/kg$

$x_1 = \frac{0,91665 - 0,1903}{0,19315 - 0,1903} = \frac{0,7263}{0,7412} = 0,9798$

$h_1 = h_t + x(h_p - h_t) = 234,86 \ KJ/kg$

Stanje ③

$S_{3t} = S_m + \frac{T-T_1}{T_2-T_1}(S_n - S_m) = 0,346 + \frac{32,5-30}{35-30}(0,369 - 0,346)$

$S_{3t} = 0,3515 \ KJ/kgK$

$h_{3t} = h_m + \frac{T-T_1}{T_2-T_1}(h_n - h_m) = 93,076 + \frac{32,5-30}{35-30}(100,37 - 93,076)$

$h_{3t} = 96,723 \ KJ/kg$

Stanje ④

$S_{3t} = S_4 = 0,3517$

$x_4 = \frac{0,3517 - 0,1903}{0,19315 - 0,1903} = \frac{0,1614}{0,7412} = 0,2177$

$h_4 = h_t + x(h_p - h_t) = 89,689 \ KJ/kg$

$q_h = q_{do} = q_{14} = h_1 - h_4 = 145,170 \ KJ/kg$

$l_{12} = q_{do} = q_{14} = h_1 - h_4 = 145,170 \ KJ/kg$

$q_{od} = q_{23} = h_3 - h_2 = -170,82 \ KJ/kg$

$\dot{m} = \frac{N}{l_{kompr}} = \frac{2,5}{32,69} = 0,076 \ \frac{kg}{s}$

$\varepsilon_h = \frac{q_{do}}{l_{komp}}$

$\varepsilon_h = \frac{145,170}{32,69}$

$\varepsilon_h = 4,44$

Stanje ②

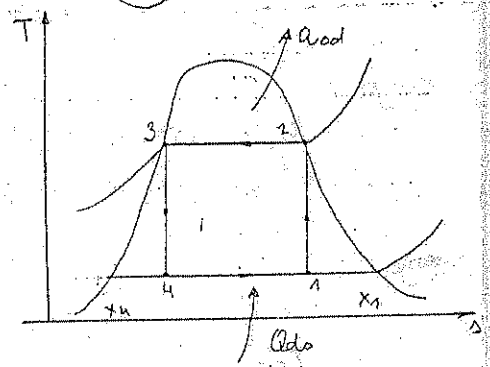
$t_1 = 0°F$

$t_2 = 95°F$

$Q_{do} = 145 \ Btu/min$

$t_1 = \frac{5}{9}(0-32) = -17,78 °C$

$t_2 = \frac{5}{9}(95-32) = 35°C$




$Q_{do} = 145 \ Btu/min = \left| \begin{array}{l} 42,41 \ Btu/min = 0,74570 \ KW \\ 1 \ Btu/min = X \ KW \end{array} \right|$

$Q_{do} = 145 \ \frac{0,74570}{42,41} = 2,5496 \ KW$

$\dot{Q}_{do} = \dot{m}(h_1 - h_4)$

$\dot{m} = \frac{\dot{Q}_{do}}{h_1 - h_4}$

Stanje ②

$t_2 = 35°C \quad S_2 = 0,9158 \ KJ/kgK$

Stanje ③

$t_3 = 35°C \quad S_3 = 0,365 \ KJ/kgK$

Stanje ①

$S_1 = S_2 = 0,9158 \ KJ/kgK$

$t_1 = -17,78°C$

| $t_1$ (°C) | $S_t$ | $S_p$ |
|---|---|---|
| -10 | 0,1536 | 0,936 |
| -20 | 0,1036 | 0,9443 |

$$S_t = S_{ta} + \frac{S_{tb} - S_{ta}}{t_b - t_a}(t - t_a) = 0,1036 + \frac{0,1536 - 1,036}{10 - (-20)}(-17,78 - (-2$$

$S_t = 0,115$ KJ/kgK

$S_p = 0,9425$ KJ/kgK

$$x_1 = \frac{S_1 - S_t}{S_p - S_t} = \frac{0,9158 - 0,1151}{0,942 - 0,11151} = 0,968$$

$x_4 = 0,307$

| t[C] | $h_t$ | $h_p$ |
|---|---|---|
| -10 | 38,202 | 205,98 |
| -20 | 25,245 | 212,84 |

$$h_t = h_{ta} + \frac{h_{tb} - h_{ta}}{t_b - t_a}(t - t_a) = 25,245 + \frac{38,202 - 2,245}{-10 - (-20)}(-17,78 - (-20)$$

$h_t = 28,1225$ KJ/kg

$h_p = 211,317$ KJ/kg

$h_1 = h_t + x_1 \cdot (h_p - h_t) = 205,455$ KJ/kg

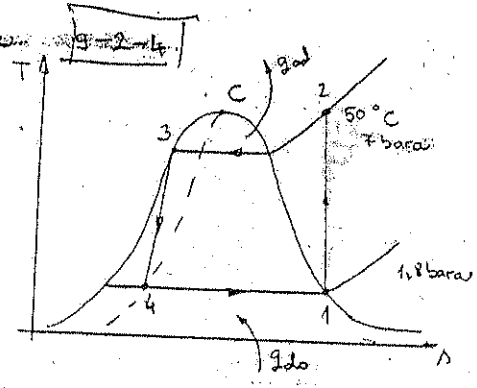
$h_4 = h_t + x_4 \cdot (h_p - h_t) = 84,363$ KJ/kg

$$\dot{m} = \frac{Q}{h_1 - h_4} = \frac{2,5496}{205,449 - 84,363} = 0,0211 \frac{kg}{s}$$

$$m = 0,0211 \frac{kg}{s} = \left| 1\,kg = 2,2046\ lbm \right| = 0,0211 \cdot 2,2046 \frac{lbm}{s}$$

$$= 0,0465 \frac{lbm}{s}$$

Zadatak 9-2-4




$\dot{m} = 0,07$ kg/s

$S_2 = 0,994$ KJ/kgK

$h_2 = 288,11$ KJ/kg

$v_2 = 0,0333$ m³/kg

Stanje ①

$S_2 = S_1 = 0,994$ KJ/kg

$$h_1 = h_m + \frac{P - P_1}{P_2 - P_1}(h_m - h_n) = 239,85 + \frac{1,8 - 1,5}{2 - 1,5}(244,14 - 239,85)$$

$h_1 = 242,42$ KJ/kg

$$h_{1t} = h_m + \frac{P - P_1}{P_2 - P_1}(h_m - h_n) = 28,95 + \frac{1,8 - 1,5}{2 - 1,5}(38,117 - 28)$$

$h_{1t} = 34,45$ KJ/kg

Stanje ③

$S_3 = S_{3t} = 0,3304$ KJ/kgK

$h_3 = h_{3t} = 88,354$ KJ/kg

Stanje ④

$h_3 = h_4 = 88,354$

$$x_4 = \frac{h_4 - h_{t4}}{h_{p4} - h_{t4}} = \frac{88,354 - 34,45}{242,42 - 34,45} = 0,259$$

$h_4 = h_t + x \cdot (h_p - h_t) = 88,314$ KJ/kg

$l_{kompresc} = l_{12} = h_2 - h_1 = 45,69$ KJ/kg

$q_{do} = q_{14} = h_1 - h_4 = 154,106 \ \frac{kJ}{kg}$

$Q_{do} = 10,78 \ kJ/s$

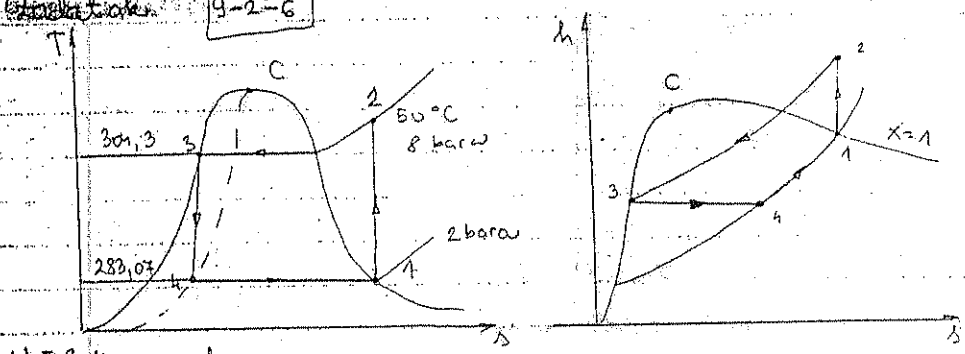
$q_{od} = q_{23} = h_3 - h_2 = -199,76 \ \frac{kJ}{kg}$

$Q_{od} = -13,98 \ kJ/s$

$N = \dot{m} \cdot l_{kompresu} = 0,07 \cdot 45,69 = 3,198 \ kW$

$\varepsilon_h = \frac{q_h}{l_{kompresu}} = \frac{154,106}{45,69} = 3,372$

Schemat teoretyczny 9-2-6




$N = 3 \ kW$ 4 kompresory

$R = 134a$ - radni medij

Stanje ② $s_2 = 0,978 \ kJ/kgK$

$h_2 = 286,28 \ kJ/kg$

$v_2 = 0,1285 \ m^3/kg$

Stanje ① $s_1 = s_{1p} = s_2 = 0,978 \ kJ/kgK$

$h_1 = h_{1p} = 244,14 \ kJ/kg$

Stanje ③ $s_3 = s_{3t} = 0,3522 \ kJ/kgK$

$h_3 = h_{3t} = 95,009 \ kJ/kg$

Stanje ④

$h_3 = h_4 = 95,009 \ kJ/kg$

$x_4 = 0,23761$

$l_{kompresa} = l_{12} = h_2 - h_1 = 42,14 \ kJ/kg$

$q_{do} = q_h = q_{14} = h_1 - h_4 = 149,131 \ kJ/kg$

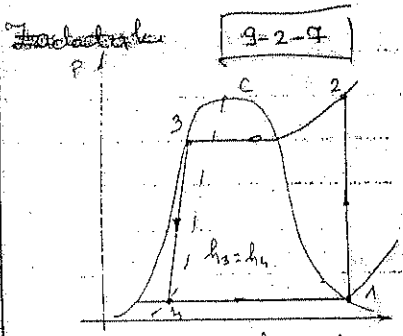
$q_{od} = q_K = q_{23} = h_3 - h_2 = -191,24 \ kJ/kg$

$\varepsilon_h = \frac{q_h}{l_{kompresa}} = \frac{149,131}{42,14} = 3,538$

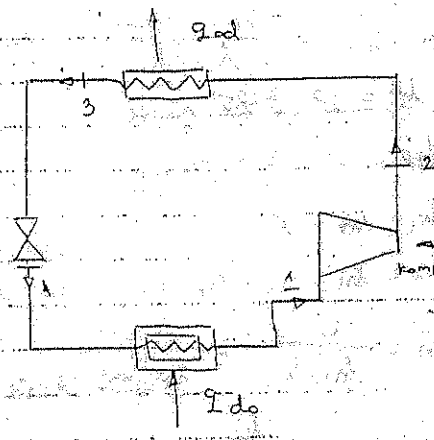
$\dot{N} = \dot{m} \cdot l_{kompres} = \dot{m} \cdot (|q_{od}| - q_{do})$

$\dot{m} = \frac{N}{l_{kompres}} = \frac{3}{42,14} = 0,07119 \ \frac{kg}{s}$

Schemat teoretyczny 9-2-7




$s_3 < s_4 \quad h_3 = h_4$




$R = 134a$

$N = 16 \ KW$ kondenzator

Stanje ② $s_2 = 0,964 \ kJ/kgK$

$h_2 = 284,36 \ kJ/kg$

$V_2 = 0,10248 \ m^3/kg$

Stanje ① $S_1 = S_2 = 0{,}964$ kJ/kgK

$h_{1p} = h_m + \frac{T - T_1}{T_2 - T_1}(h_n - h_m) = 239{,}85 + \frac{16 - 15}{20 - 15}(244{,}14 - 239{,}8)$

$h_{1p} = 240{,}708$ kJ/kg

Stanje ③

$S_{3t} = 0{,}372$ kJ/kgK

$h_{3t} = 101{,}15$ kJ/kg

Stanje ④

$h_3 = h_4 = 101{,}15$ kJ/kg

$S_3 < S_4$

$l_{12} = h_2 - h_1 = 43{,}652$ kJ/kg

$L = m \cdot l_{12} = 5$ KW

$L = \dot{m}(|q_{od}| - q_{do}| = 5$ KW

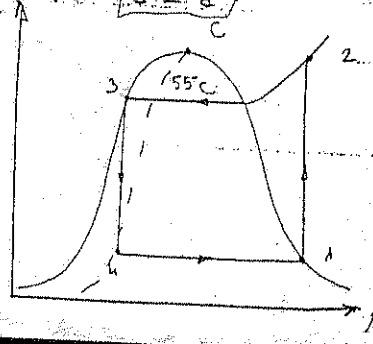
$\dot{m} = \frac{1C}{139{,}558} = 0{,}114$ kg/s

$q_{do} = q_{41} = h_1 - h_4 = 139{,}558$ kJ/kg

$q_{od} = q_{23} = h_3 - h_2 = -183{,}21$

$\varepsilon_h = \frac{q_h}{l_{komp}} = \frac{139{,}558}{43{,}652} = 3{,}197$

Zadatak: 9-2-8




$\dot{m} = 0{,}185$ kg/s

R = 134a radni medij

Stanje ① $S_1 = 0{,}9274$ KJ/kgK

$h_1 = h_p = 253{,}0$ KJ/kg

Stanje ② ($t_k = 55°C$ , $P = 14{,}90$ bara)

$S_1 = S_2 = 0{,}9274$ KJ/kgK

* za pritisak P = 14 bara biramo vrijednosti entalpije

$h_a = h_{a_2} + \frac{h_{a_1} - h_{a_2}}{S_{a_1} - S_{a_2}}(S_2 - S_{a_2}) = 285{,}12 + \frac{275{,}93 - 285{,}12}{0{,}909 - 0{,}937}(0{,}9274 - 0{,}$

$h_a = 281{,}96$ KJ/kg

* za pritisak P = 16 bara i poznatu entalpiju biramo vrijednosti

$h_b = h_{b_2} + \frac{h_{b_1} - h_{b_2}}{S_{b_1} - S_{b_2}}(S_2 - S_{b_2}) = 292{,}89 + \frac{280{,}42 - 292{,}89}{0{,}915 - 0{,}951}(0{,}9274 - 0$

$h_b = 284{,}715$ KJ/kg

$h_2 = h_a + \frac{h_b - h_a}{P_b - P_a}(P - P_a) = 281{,}96 + \frac{284{,}71 - 281{,}96}{16 - 14}(14{,}9 - 14) = 283{,}19$ KJ/kg

Stanje ③ $S_3 = S_{3t} = 0{,}4636$ KJ/kgK

$h_3 = h_{3t} = 130{,}87$ KJ/kg

Stanje ④ $x_4 = \frac{h_4 - h_t}{h_p - h_t} = \frac{130{,}87 - 58{,}151}{255{,}0 - 58{,}151} = \frac{72{,}719}{134{,}84} = 0{,}5392$

$h_3 = h_4 = 130{,}87$ KJ/kg

$\dot{Q}_{do} = \dot{Q}_{41} = \dot{m}(h_1 - h_4) = 0{,}185 \cdot (253 - 130{,}8) = 103{,}87$ KJ/s

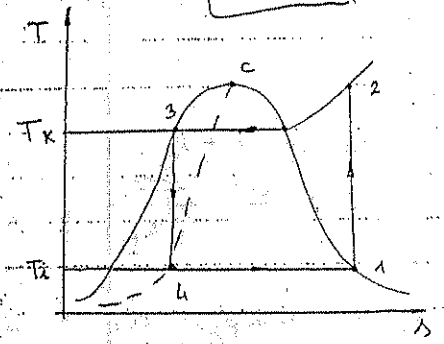
$\dot{Q}_{od} = \dot{Q}_{23} = \dot{m}(h_3 - h_2) = 0{,}185 \cdot (130{,}8 - 283{,}19) = -129{,}53$ KJ/s

$q_h = q_{do} = q_{41} = h_1 - h_4 = 122{,}2$ KJ/kg

$L_{kompresa} = l_{12} = h_2 - h_1 = 30{,}19$ KJ/kg

$\varepsilon_h = \frac{q_h}{l_{kompresa}} = \frac{122{,}2}{30{,}19} = 4{,}04$

Zadatak 9.2-10




R – 134a radni medij

$T_0 = 238\,K \rightarrow t_0 = -35°C$

$T_K = 303\,K \rightarrow t_K = 30°C$

Stanje ① $s_1 = s_{p1} + \frac{T - T_1}{T_2 - T_1}(s_{p2} - s_{p1})$

$s_1 = 0{,}9675 + \frac{238 - 233}{243 - 233}(0{,}955 - 0{,}9675) = 0{,}9612\ kJ/kgK$

$h_1 = h_{1p} + \frac{T - T_1}{T_2 - T_1}(h_{2p} - h_{1p}) = 255{,}59 + \frac{238 - 233}{243 - 233}(231{,}38 - 225{,}59)$

$h_1 = 228{,}73\ kJ/kg$

$h_t = 6{,}26\ kJ/kg$

Stanje ③ $s_3 = s_{3t} = 0{,}346\ kJ/kgK$

$h_3 = h_{3t} = 93{,}076\ kJ/kg$

Stanje ④ $h_3 = h_4 = 93{,}076\ kJ/kg$

$x_4 = \frac{h_4 - h_t}{h_p - h_t} = \frac{93{,}076 - 6{,}26}{228{,}75 - 6{,}26} = 0{,}3902$

Stanje ② ($T_K = 303\,K$ , $p = 7{,}705\,bara$)

$s_1 = s_2 = 0{,}9274\ kJ/kgK$

x za pritisak $p = 7$ bara i poznatom entalpijom kiranja vrijednosti

$h_a = h_{a2} + \frac{h_{a1} - h_{a2}}{s_{a1} - s_{a2}}(s_2 - s_{a2}) = 268{,}08 + \frac{264{,}73 - 268{,}08}{0{,}9186 - 0{,}9297}(0{,}9274 - 0{,}9297)$

$h_a = 267{,}37\ kJ/kg$

x za pritisak $p = 8$ bara i poznatu entalpiju prolaznavat ćemo

$h_b = h_{b2} + \frac{h_{b1} - h_{b2}}{s_{a1} - s_{b2}}(s_2 - s_{b2}) = 276{,}04 + \frac{267{,}04 - 276{,}04}{0{,}9186 - 0{,}9297}(0{,}9274 - 0{,}9297)$

$h_b = 270{,}24\ kJ/kg$

$h_2 = h_a + \frac{p - p_1}{p_2 - p_1}(h_b - h_a) = 267{,}37 + \frac{7{,}70 - 7}{8 - 7}(270{,}24 - 267{,}3)$

$h_2 = 269{,}42\ kJ/kg$

$q_h = q_{do} = q_{41} = h_1 - h_4 = 135{,}65\ kJ/kg$

$l_{12} = l_{komp} = h_2 - h_1 = 40{,}69\ kJ/kg$

$\varepsilon_h = \frac{q_h}{l_{kompr}} = \frac{135{,}65}{40{,}69} = 3{,}33$

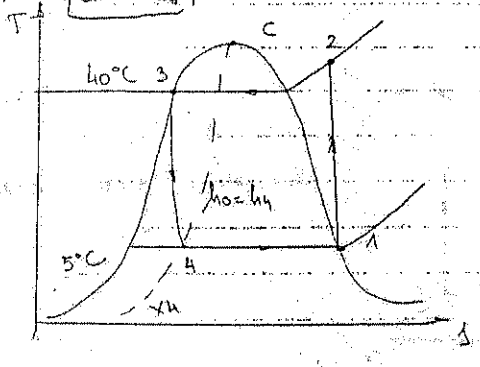
$s_4 = s_{t4} + x_4(s_{p4} - s_{t4}) = 0{,}02625 + 0{,}39(0{,}9612 - 0{,}02625)$

$s_4 = 0{,}3908\ kJ/kgK$

$s_t = s_{t1} + \frac{T - T_1}{T_2 - T_1}(s_{t2} - s_{t1}) = 0{,}0 + \frac{-35 + 40}{-30 + 40}(0{,}0525 - 0)$

$s_t = 0{,}02625\ kJ/kgK$

Zadatak 9.2-11




R – 134a radni medij

$\eta_t = 0{,}7$

Stanje ① ($t_1 = 5°C$, $P = 3,495$ bara)

$s_1 = s_{1p} = 0,9274$ kJ/kgK

$h_1 = h_{1p} = 253$ kJ/kg

$h_t = 58,151$ kJ/kg

Stanje ③ ($t_k = 40°C$, $P = 10,16$ bar)

$t_3 = s_3 = 0,393$ kJ/kgK

$h_3 = 107,178$ kJ/kg

Stanje ④

$h_3 = h_4 = 107,178$ kJ/kg

$$x_4 = \frac{h_4 - h_t}{h_p - h_t} = \frac{107,78 - 58,15}{253 - 58,15} = 0,254$$

$s_4 = s_t + x_4 \cdot (s_p - s_t) = 0,2269 + 0,254\,(0,9274 - 0,2269) = 0,424$ kJ/kgK

Stanje ②

$s_1 = s_2 = 0,9274$ kJ/kgK, $P = 10,16$ bar

Za tlak $P = 10$ bara i entalpiju čitamo vrijednosti

$$h_a = h_{a_2} + \frac{h_{a_1} - h_{a_2}}{s_{a_1} - s_{a_2}} (s_1 - s_{a_2}) = 282,34 + \frac{270,74 - 282,34}{0,914 - 0,951} (0,9274 - 0,951)$$

$h_a = 274,94$ kJ/kg

Za tlak $P = 12$ bara i entalpiju

$$h_b = h_{b_2} + \frac{h_{b_1} - h_{b_2}}{s_{b_1} - s_{b_2}} (s_2 - s_{b_2})$$

$$h_b = 289,26 + \frac{274,94 - 289,26}{0,925 - 0,959} (0,927 - 0,959)$$

$h_b = 278,60$ kJ/kg

$$h_2 = h_a + \frac{P - P_1}{P_2 - P_1} (h_b - h_a) = 275,23 \text{ kJ/kg}$$

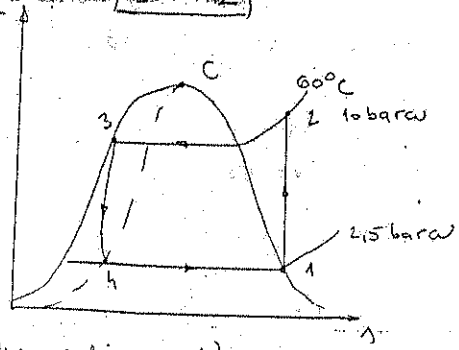
$q_{do} = q_i = q_{41} = h_1 - h_4 = 145,22$ kJ/kg

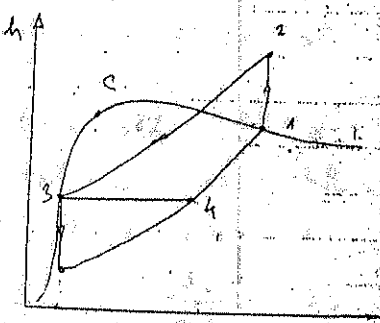
$q_{od} = q_k = q_{23} = h_3 - h_2 = -167,45$ kJ/kg

$l_{kompresa} = l_{12} = h_2 - h_1 = 22,23$ kJ/kg

$$\varepsilon = \frac{q_{do}}{l_{komp}} = 6,532$$

~~Izobarno~~ $q = 2 - 12$




R-134a radni medij

$N = 26,7$ kJ/s $= 26,7$ kW

Stanje ② ($t = 60°C$, $P = 10$ bara)

$s_2 = 0,983$ kJ/kgK

$h_2 = 292,95$ kJ/kgK

Stanje ① (2,5 bara)

$s_{1p} = s_2 = 0,983$ kJ/kgK

$$h_{1p} = h_{p_1} + \frac{P - P_1}{P_2 - P_1} (h_{p_2} - h_{p_1}) = 244,14 + \frac{2,5 - 2}{3 - 2} (250,51 - 244,14)$$

$h_{1p} = 247,32$ kJ/kg

Stanje ③ (10 bara)

$s_3 = s_{3t} = 0,390$ kJ/kgK

$h_3 = h_{3t} = 106,87$ kJ/kg

Stanje ④

$h_3 = h_4 = 106,87$ kJ/kg

$$h_t = h_m + \frac{P - P_1}{P_2 - P_1} (h_n - h_m) = 38,117 + \frac{2,5 - 2}{3 - 2} (52,34 - 38,117) = 45,22$$

$$x_4 = \frac{h_4 - h_t}{h_p - h_t} = \frac{106,87 - 45,228}{247,32 - 45,228} = 0,305$$

$$S_t = 0,1533 + \frac{2,5-2}{3-2}(0,206 - 0,1533) = 0,1796 \ kJ/kgK$$

$$S_p = 0,1936 + \frac{2,5-2}{3-2}(0,1929 - 0,1936) = 0,1925 \ kJ/kgK$$

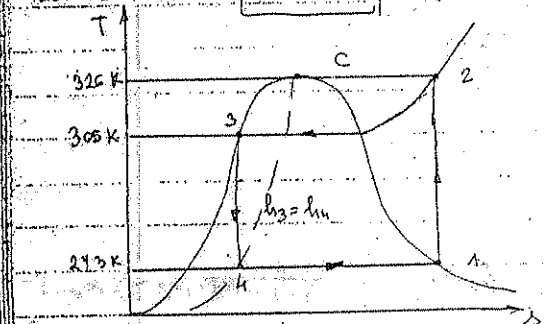
$$S_4 = S_t + x \cdot (S_p - S_t) = 0,409 \ kJ/kgK$$

$$q_{do} = q_k = q_{41} = h_1 - h_4 = 140,45 \ kJ/kg$$

$$l_{komp} = l_{12} = h_2 - h_1 = 45,67 \ kJ/kg$$

$$\varepsilon_h = \frac{q_k}{l_{komp}} = \frac{140,45}{45,67} = 3,075$$

Zadatak 10-2-10




R - 134a radni medij

$T_i = 0°C$

$t_K = 32°C$

$t_2 = 53°C$

$Q_{do} = 80 \ kJ/h = 22,2 \ kJ/s$

Stanje ② ($t = 53°C$, $p = 9$ bara)

$$S_2 = S_m + \frac{T - T_1}{T_2 - T_1}(S_n - S_m) = 0,1978 + \frac{52-50}{60-50}(1,005 - 0,1978)$$

$$S_2 = 0,9842 \ kJ/kgK$$

$$h_2 = h_m + \frac{T - T_1}{T_2 - T_1}(h_n - h_m) = 286,28 + \frac{52-50}{60-50}(296,14 - 286,18)$$

$$h_2 = 288,25 \ kJ/kg$$

Stanje ③ ($t_K = 32°C$, $p = 9$ bara)

$S_3 = S_{3t} = 0,372 \ kJ/kgK$

$h_3 = h_{3t} = 101,15 \ kJ/kg$

Stanje ④

$h_3 = h_4 = 101,15 \ kJ/kg$

$q_{od} = h_3 - h_2 = 101,15 - 288,25 = -187,1 \ kJ/kg$

Zadatak 10-2-11

$t_1 = 38°C$

$t_2 = 20°C$

$\varphi_1 = 0,3$

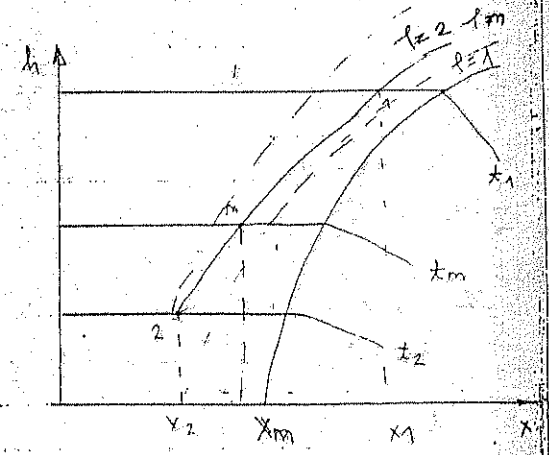
$\varphi_2 = 0,4$

$\dot{V}_1 = 22 \ m^3/min$

$\dot{V}_2 = 16 \ m^3/min$

$p = 1 \ atm = 1,013 \ bar$

$t_m = ?$ $\varphi_m = ?$




$P_{z2} = P_{z,20°C} = 0,0233 \ bar$

$P_{z1} = P_{z,38°C} = 0,0667 \ bar$

$P_1 = \varphi_1 \cdot P_{z1} = 0,3 \cdot 0,0667 = 0,02 \ bar$

$P_2 = \varphi_2 \cdot P_{z2} = 0,4 \cdot 0,0233 = 0,0093 \ bar$

$P_{zr1} = p - P_{p1} = 1,013 - 0,02 = 0,993 \ bar$

$P_{zr2} = p - P_{p2} = 1,013 - 0,0093 = 1,0037 \ bar$

$P_{zr} \cdot V = m_{zr} \cdot R_{zr} \cdot T$

$$\dot{m}_{zr1} = \frac{p_{zr1} \cdot \dot{V}_1}{R_{zr} \cdot T_1} = \frac{0,9930 \cdot 10^5 \cdot 22}{287 \cdot (38+273,15)} = 24,46 \text{ kg/min}$$

$$\dot{m}_{zr2} = \frac{p_{zr2} \cdot \dot{V}_2}{R_{zr} \cdot T_2} = 19,088 \text{ kg/min}$$

$$x_1 = 0,622 \cdot \frac{\varphi_1 \cdot p_{z1}}{p - \varphi_1 \cdot p_{z1}} = 0,622 \cdot \frac{0,02}{0,993} = 0,0125$$

$$x_2 = 0,622 \cdot \frac{\varphi_2 \cdot p_{z2}}{p - \varphi_2 \cdot p_{z2}} = 0,00058$$

$$\dot{m}_{zr1} + \dot{m}_{zr2} = \dot{m}_{zr}$$

$$\dot{m}_{zrm} = 24,46 + 19,088 = 43,548 \text{ kg/min}$$

$$\dot{m}_{zr1} \cdot x_1 + \dot{m}_{zr2} \cdot x_2 = \dot{m}_{zrm} \cdot x_m$$

$$x_m = \frac{\dot{m}_{zr1} \cdot x_1 + \dot{m}_{zr2} x_2}{\dot{m}_{zrm}} = 0,0096$$

$$\dot{m}_{zr1} (h_1 + x)_1 + \dot{m}_{zr2} (h_1 + x)_2 = \dot{m}_{zrm} (h_1 + x)_m$$

$$(h_1+x)_m = \frac{\dot{m}_{zr1} (h_1+x)_1 + \dot{m}_{zr2} (h_1+x)_2}{\dot{m}_{zrm}}$$

$$(h_1+x)_1 = c_{pzr} \cdot t_1 + x_1 (r_0 + c_p \cdot t_1) = 1,005 \cdot 38 + 0,0125 (2500 - 1,93 \cdot 38)$$

$$(h_1+x)_1 = 70,354 \text{ kJ/kg}$$

$$(h_1+x)_2 = 34,824 \text{ kJ/kg}$$

$$(h_1+x)_m = 54,782 \text{ kJ/kg}$$

$$(h_1+x)_m = c_{pzr} \cdot t_m + x_m (r_0 + c_p t_m)$$

$$t_m = \frac{(h_1+x)_m - x_m \cdot r_0}{c_{p\,zr} + x_m \cdot c_p} = \frac{54,782 - 0,0096 \cdot 2500}{1,005 + 0,0096 \cdot 1,93} \doteq 30,074 °C$$

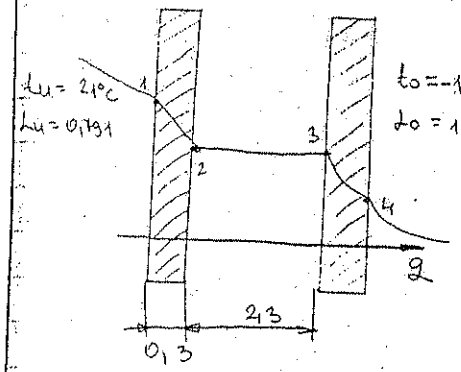
$$\approx 30°C$$

$$p_{zrm} = p_{zrm\,30°} = 0,0424 \text{ bar}$$

$$x_m = 0,622 \frac{p_m \cdot p_{em}}{p - p_m p_{em}} \Rightarrow p_m = \frac{\frac{x_m \cdot p}{0,622}}{p_{zr}\left(1 + \frac{x_m}{0,622}\right)} = 0,301$$

$$p_m = 30,31 \text{ \%}$$

Zadatak 13-2-6




$\lambda_u = 0,791$ Btu/h·ft²·F = x

0,1761 Btu/h·ft²·F = 1 W/m²·°C

$$x = \frac{0,791}{0,1761} = 4,491 \text{ W/m}^2\text{°C} \Rightarrow \lambda_u = 0,01644 \frac{W}{m^2K}$$

$\lambda_o = 12,79$ Btu/h·ft²F = x

0,1761 Btu/h·ft²·F = 1 W/m²·°C

$$x = \frac{12,79}{0,1761} = 72,629 \text{ W/m}^2\text{°C} \Rightarrow \lambda_o = 0,013783 \frac{W}{m^2K}$$

$$k = \frac{1}{\frac{1}{\lambda_o} + \frac{\delta}{\lambda_1} + \frac{\delta}{\lambda_2} + \frac{\delta}{\lambda_3} + \frac{1}{\lambda_u}} = \frac{1}{0,013783 + 0,00766 + 0,12266 + 0,2180}$$

$k = 0,9411 \text{ W/m}^2\text{K}$

°C ⇒ $\lambda_2 = 0,243$ W/mK

100°C ⇒ $\lambda_{21} = 0,0319$ W/mK

$$\lambda_z = \frac{0,0243 + 0,0319}{2} = 0,0281 \text{ W/mK}$$

$$q = k(t_u - t_o) = 0,941 (21 + 1,057) = 21,3159 \text{ W/m}^2 = \frac{J}{sm^2}$$

$$q = 76737,294 \frac{J}{hm^2} = 76,73729 \frac{kJ}{hm^2}$$

Zadatak 13-2-57

$p = 24$ bara

$T = 1100$ K

18 mm

45 $W/m^2K$

30,25 $W/m^2K$

8,025 $W/m^2K$

$d = 1,5$ cm

0,45 $W/m^2K$

$$k_1 = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta_1}{\lambda_1} + \frac{1}{\alpha_2}} = \frac{1}{\frac{1}{30,25} + \frac{0,018}{45} + \frac{1}{8,025}} = 29,7774 \frac{W}{m^2K}$$

$$q_1 = k_1 (t_{ps} - t_{zp}) = 29,7774 \, (1100 - 494,92) = 18,0177 \cdot 10^3 \frac{W}{m^2K}$$

$t_{zp} = 221,77$ °C

$T_{zp} = 273,15 + 221,77 = 494,92$ pri $p = 24$ bara

Kad se nataloži kamenac koeficijent prolaza topline

$$k_2 = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{1}{\alpha_2}} = \frac{1}{\frac{1}{30,25} + \frac{0,018}{45} + \frac{0,015}{0,45} + \frac{1}{8,025}}$$

$k_2 = 14,9448$ $W/m^2K$

Toplotni tok kroz grejne površine poslije taloženja

$\dot{q}_2 = k_2 (t_{ps} - t_{zp}) = 14,9448 \, (1100 - 494,92) = 9042,799 =$

$\dot{q}_2 = 9,042799$ $W/m^2$

Promjena specifičnog toka

$\Delta \dot{q} = \dot{q}_1 - \dot{q}_2 = 18,0177 \cdot 10^3 - 9,042799 \cdot 10^3 = 8,9749 \cdot 10^3 \frac{W}{m^2}$

Temperatura spoljne površine u slučaju da nema naslaga kamenca

$$T_1 = T_{ps} - \frac{\dot{q}_1}{\alpha_1} = 1100 - \frac{18,0177 \cdot 10^3}{30,25} = 504,373 \text{ K}$$

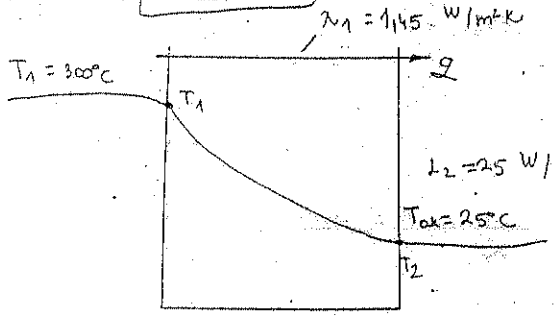
$T_1 = 231,22$ °C

U slučaju kada imamo naslage kamenca

$$T_2 = T_{ps} - \frac{\dot{q}_2}{\alpha_1} = 1100 - \frac{9,042799 \cdot 10^3}{30,25} = 801,05 \text{ K}$$

$T_2 = 527,914$ °C

Zadatak 13-2-58



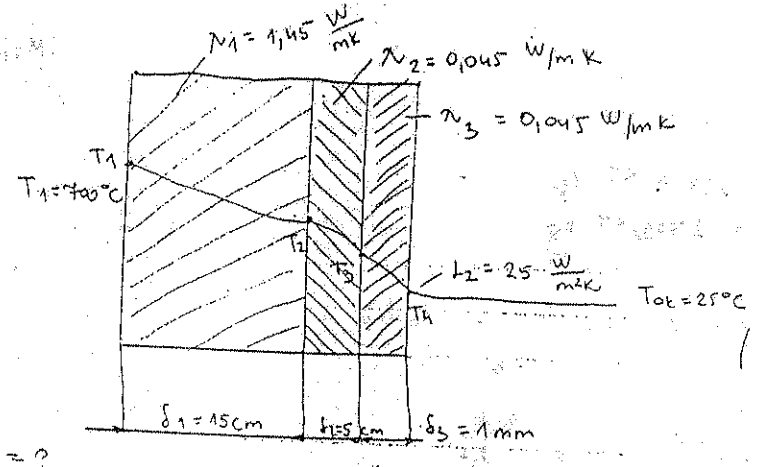

$q = k (T_1 - T_{ok})$

$$k = \frac{1}{\frac{\delta_1}{\lambda_1} + \frac{1}{\alpha_2}} = \frac{1}{\frac{0,15}{1,45} + \frac{1}{25}} = 6,9712 \frac{W}{m^2K}$$

$q = 6,9712 \, (700 - 25) = 4705,53 \frac{W}{m^2}$

$q = \alpha_2 (T_2 - T_{ok})$

$$T_2 = T_{ok} + \frac{q}{\alpha_2} = 25 + \frac{4705,53}{25} = 213,22 \text{°C}$$




$\Delta q = ?$

$\Delta T_m = ?$

$q' = k'(T_1 - T_{ok})$

$$k' = \frac{\lambda}{\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3} + \frac{1}{\alpha_2}} = 0,7970$$

$q' = 0,7972\,(700 - 25) = 537,99 \ W/m^2$

$\Delta q = q - q'$

$\Delta q = 4705 - 537,99 = 4167,54 \ W/m^2$

$q' = \alpha_2 (T_4 - T_{ok})$

$$T_4 = T_{ok} + \frac{q'}{\alpha_2} = 25 + \frac{537,99}{25} = 46,52\,°C$$

$\Delta T = T_2 - T_4 = 213,22 - 46,52 = 166,7\,°C$

## Zadatak 5-2-4

$V = 25\ m^3$

$p_1 = 1\ bar$

$T_1 = 260\ K$

$A = 3\ m^2$

$T_2 = 29°C + 273 = 302\ K$

$p \cdot V = mRT$

$$m = \frac{p \cdot V}{R \cdot T} = \frac{10^5 \cdot 25}{287 \cdot 260\,K} = \frac{25}{74620} = 33,5\ kg$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$p_2 = p_1 \cdot \frac{T_2}{T_1}$$

$p_2 = 1,16153\ bar$

$\Delta p = p_2 - p_1 = 0,1162\ bar$

$F = A \cdot (p_2 - p_1) = A \cdot \Delta p = 4860\ N$

## Zadatak 4-2-6

$p = 2\ bar$

$t = 72°C$

| | | $v$ | $h$ | $s$ |
|---|---|---|---|---|
| $t_a$ = | 70° C | 0,0010228 | 293,10 | 0,9548 |
| $t_b$ = | 80° C | 0,0010292 | 335,0 | 1,0752 |

$$v = v_a + \frac{v_b - v_a}{t_b - t_a}(t - t_a)$$

$$v = 0{,}0010228 + \frac{0{,}0010292 - 0{,}0010228}{80 - 70}(72 - 70)$$

$$v = 0{,}0010240\,6 \ m^3/kg$$

$$h = h_a + \frac{h_b - h_a}{t_b - t_a}(t - t_a)$$

$$h = 293{,}0 + \frac{335{,}0 - 293{,}0}{80 - 70}(72 - 70)$$

$$h = 301{,}48 \ kJ/kg$$

$$s = s_a + \frac{s_b - s_a}{t_b - t_a}(t - t_a)$$

$$s = 0{,}9548 + \frac{1{,}0752 - 0{,}9548}{80 - 70}(72 - 70)$$

$$s = 0{,}9788 \ kJ/kgK$$

**Zadatak 4-2-7**

$t = 50°C$

$h = 2{,}450 \ MJ/kg = 2450 \ kJ/kg$

$x = ?$

$s_x = ?$

$v_x = ?$

Za $t = 50°C$ $\quad v' = 0{,}0010\,1210 \ m^3/kg$

$v_t = 1{,}0121 \ dm^3/kg \quad v_p = 12{,}04 \ m^3/kg$

$s_t = 0{,}7038 \ kJ/kgK \quad s_p = 8{,}0753 \ kJ/kgK$

$h_t = 209{,}3 \ kJ/kg$

$h_p = 2592 \ kJ/kg$

$$h = h_x = (1 - x) \cdot h_t + x \cdot h_p$$

$$h - h_t = x \cdot (h_p - h_t)$$

$$x = \frac{h - h_t}{h_p - h_t}$$

$$x = \frac{2450 - 209{,}3}{2592 - 209{,}3} = \frac{2240{,}7}{2382{,}7}$$

$$\boxed{x = 0{,}94}$$

$$v_x = (1 - x) \cdot v_t + x \cdot v_p$$

$$v_x = (1 - 0{,}94) \cdot 0{,}0010\,1210 + 0{,}94 \cdot 12{,}04$$

$$v_x = 0{,}0600\,60726 + 11{,}3176$$

$$\boxed{v_x = 11{,}31766 \ m^3/kg}$$

$$s_x = (1 - x) \cdot s_t + x \cdot s_p$$

$$s_x = (1 - 0{,}94) \cdot 0{,}7038 + 0{,}94 \cdot 8{,}0753$$

$$s_x = 0{,}7038 - 0{,}6615\,72 + 7{,}590\,782$$

$$\boxed{s_x = 7{,}633\,01 \ kJ/kgK}$$

**Zadatak 4-2-8**

$x = 95\% = 0{,}95$ $\quad v_x = ?$

$t = 95°C$ $\quad s_x = ?$

$h_x = ?$

Za $t = 95°C$

$v_t = 1,0396 = 0,0010396$ $\quad h_t = 398$ $\quad s_t = 1,2502$

$v_p = 1,982\ m^3/kg$ $\quad h_p = 2668$ $\quad s_p = 7,4155$

$v_x = (1-x)\,v_t + x \cdot v_p$

$v_x = (1-0,95) \cdot 0,0010396 + 0,95 \cdot 1,982$

$v_x = 0,0010396 - 0,000098762 + 1,8829$

$\boxed{v_x = 1,88295\ m^3/kg}$

$h_x = (1-x) \cdot h_t + x \cdot h_p$

$h_x = (1-0,95) \cdot 398 + 0,95 \cdot 2668$

$h_x = 398 - 378,1 + 2534,6$

$\boxed{h_x = 2554,5\ kJ/kg}$

$s_x = (1-x) \cdot s_t + x \cdot s_p$

$s_x = (1-0,95) \cdot 1,2502 + 0,95 \cdot 7,4155$

$s_x = 1,2502 - 1,18769 + 7,044725$

$\boxed{s_x = 7,1072\ kJ/kgK}$

Zadatak 4-2-1

$t = 122°C$

| | $v_t \cdot 0,0010603$ | $h_t$ | $s_t$ |
|---|---|---|---|
| $t_a = 120°$ | 1,0603 // | 503,7 | 1,5277 |
| $t_b = 125°$ | 1,065 | 525 | 1,58 |

$v = v_a + \frac{v_b - v_a}{t_b - t_a} \cdot (t - t_a)$

$v = 0,0010603 + \frac{1,065 - 0,0010603}{125 - 120} \cdot (122 - 120)$

$v = 0,0010603 + 0,000094 \cdot 2$

$\boxed{v = 0,1206\ m^3/kg}$

$h = h_a + \frac{h_b - h_a}{t_b - t_a} (t - t_a)$

$h = 503,7 + \frac{525 - 503,7}{125 - 120} (122 - 120)$

$\boxed{h = 512,22\ kJ/kg}$

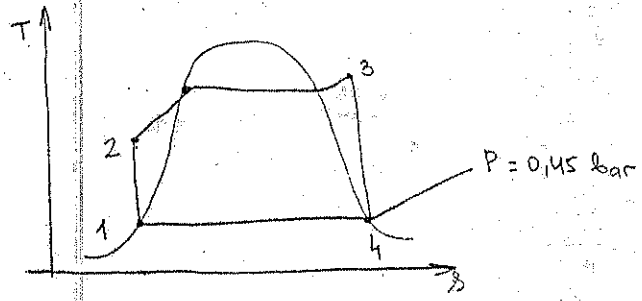
$s = s_a + \frac{s_b - s_a}{t_b - t_a} (t - t_a)$

$s = 1,5277 + \frac{1,58 - 1,5277}{125 - 120} (122 - 120)$

$\boxed{s = 1,54862\ kJ/kgK}$

## Zadatak 8-2-6

$P_1 = 45\,kPa = 0{,}45$ bara
$P_2 = 32$ bara
$t = 640°C$




Stanje (1)
$P_1 = 0{,}45$ bara

| P[bar] | $h_t$ | $h_p$ | $S_t$ | $S_p$ |
|---|---|---|---|---|
| $P_a = 0{,}4$ | 317,7 | 2636 | 1,0261 | 7,167 |
| $P_b = 0{,}5$ | 340,6 | 2645 | 1,091 | 7,593 |

$v_{ta} = 1{,}0264 \cdot 10^{-3}\ m^3/kg$
$v_{tb} = 1{,}0299 \cdot 10^{-3}\ m^3/kg$

$$v_1 = v_{ta} + \frac{v_{tB} - v_{ta}}{P_b - P_a}(P_1 - P_a) \quad m^3/kg$$

$$h_1 = h_{ta} + \frac{h_{tb} - h_{ta}}{P_b - P_a}(P_1 - P_a) \quad kJ/kg$$

$$s_1 = s_{ta} + \frac{s_{tb} - s_{ta}}{\ldots}(P_1 - P_a)$$

Stanje (2)
$S_1 = S_2 =$ (iz stanja 1)

$$L_p = v_1 \cdot (P_2 - P_1) =$$

$$h_2 = h_1 + L_p$$

Stanje (3)
$P_3 = 32$ bara
$t_3 = 640°C$
Dvostruka interpolacija za
a) $t_{a_1} = 600°C$ $P = 30$ bara $\Rightarrow h_{a_1} = 3685{,}5$ kJ/kg
$t_{a_2} = 650°C$ $P = 50$ bara $\Rightarrow h_{a_2} = 3798{,}6$ kJ/kg

$$h_a = h_{a_1} + \frac{h_{a_2} - h_{a_1}}{t_{a_2} - t_{a_1}}(t_3 - t_{a_1})$$

b) $t_{b_1} = 600°C$ $P = 30$ bara $\Rightarrow h_{b_1} = 3665{,}4$
$t_{b_2} = 650°C$ $P = 50$ bara $\Rightarrow h_{b_2} = 3781{,}1$

$$h_b = h_{b_1} + \frac{h_{b_2} - h_{b_1}}{t_{b_2} - t_{b_1}}(t_3 - t_{a_1})$$

$$h_3 = h_a + \frac{h_b - h_a}{P_b - P_a}\underset{32}{(P} - \underset{30}{P_a})$$

Stanje (4.)
$P_4 = 0{,}45$ bara

$s_4 = s_3$

$x_4 = \frac{s_4 - s_t}{s_p - s_t}$

$s_t$ i $s_p$ tražimo interpolacijom

$h_4 = h_t + x_4 \cdot (h_p - h_t)$

$L_{neto} = q_{do} - q_{od} = h_3 - h_2 - (h_4 - h_1)$

$\eta_{te} = \frac{L_{neto}}{q_{do}}$

$\eta_{te} = \frac{h_3 - h_4}{h_3 - h_1}$ (ako se zanemari rad pumpe)

**Zadatak 8-2-8**

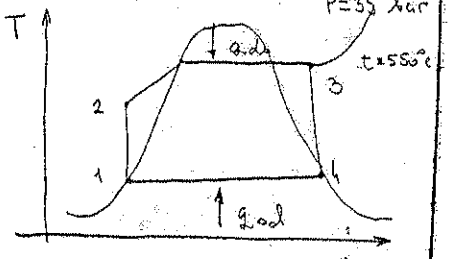
$N_{turbine} = 5\ MW = 50\ bara$

$t_3 = 550\ °C$

$p_3 = 35\ bara$

$\dot{m} = ?$

$\eta_{te} = ?$




Stanje ③

$p_3 = 35\ bara$

$t_3 = 550\ °C$

$h =$

$s =$

Stanje ④

$s_3 = s_4$

$h_4 = h_p$

$s_4 = s_p$

} iz tablice pothlađenog

Stanje ①

$h_1 = h_t$

$s_1 = s_t$

Stanje ②

$p = 35\ bara$

$s_1 = s_2$

$h =$

$N_{turbine} = q_{34} \cdot \dot{m} \Rightarrow \dot{m} = \frac{N_{turb}}{q_{34}} = \frac{N_{turbine}}{h_4 - h_3}$

$q_{kotla} = h_2' - h_2$

**Zadatak 10-2-1**

$V = 5 \times 5 \times 5 = 125\ m^3$

$t = 25°C$

$p = 100\ kPa$

$\varphi = 75\ \%$

$p_z = ?$

$m_{zr} = ?$

$m_p = ?$

$\varphi = \frac{p_p}{p_z} \Rightarrow p_p = \varphi \cdot p_z$

$p_z = 0{,}0316\ [bar]$ za $t = 25°C$

$X = \frac{m_p}{m_{zr}} = 0{,}622 \cdot \frac{p_p}{p_{zr}} = 0{,}622 \cdot \frac{\varphi \cdot p_z}{p - \varphi p_z}$

$$X = 0{,}622 \cdot \frac{0{,}75 \cdot 0{,}0316}{1 - 0{,}95 \cdot 0{,}0316} = 0{,}015$$

$$p_{zr} = p - \varphi p_z = 1 - 0{,}75 \cdot 0{,}0316 = 0{,}9763 \text{ bar}$$

$$h_1 + X = c_{pzr} + X \cdot (r_0 + c_{pp} \cdot t) = 1{,}005 \cdot 25 + 0{,}015\,(2500 + 1{,}93 \cdot 25)$$

$$h_1 + X = 63{,}349 \text{ [kJ/kg] zraka}$$

$$m_p = \frac{p_{zr} \cdot V}{R_{zr} \cdot T} = \frac{\varphi \cdot p_z \cdot V}{R_p \cdot T} = \frac{0{,}75 \cdot 0{,}0316 \cdot 10^5 \cdot 125}{4614 \cdot 298} = 1{,}29 \text{ kg}$$

$$m_{zr} = \frac{p_{zr} \cdot V}{R_{zr} \cdot T} = \frac{0{,}9763 \cdot 10^5 \cdot 125}{287 \cdot 298} = 85{,}61 \text{ kg}$$

$$X = \frac{m_p}{m_{zr}} = \frac{1{,}29}{85{,}61} = 0{,}015$$

**Zadatak 10-2-2**

$t = 25°C$

$\varphi_1 = 80\,\% = 0{,}8$

$P = 99{,}325$ Pa

$t_2 = 45°C$

$X_1 = ?$

$$X_1 = 0{,}622 \cdot \frac{\varphi_1 \cdot p_{z1}}{P - \varphi_1 \cdot p_{z1}} = 0{,}622 \cdot \frac{0{,}8 \cdot 0{,}0316 \cdot 10^5}{99325 - 0{,}8 \cdot 0{,}0316 \cdot 10^5}$$

$X_1 = 0{,}01624$ za $t = 25°C$ i $p_{z1} = 0{,}0316$ bar

$$h_1 = 1{,}0048 \cdot t_1 + X_1 \cdot (1{,}926 \cdot t_1 + 2500)$$

$$h_1 = 1{,}0048 \cdot 25 + 0{,}01624\,(1{,}926 \cdot 25 + 2500) = 66{,}5 \text{ kJ/kg}$$

Uzimajući da je $h_1 = h_2$

$$X_2 = \frac{h_2 - 1{,}0048\, t_2}{1{,}926 \cdot t_2 + 2500} = \frac{66{,}5 - 1{,}0048 \cdot 45}{1{,}926 \cdot 45 + 2500} = 0{,}00822$$

$$\varphi_2 = \frac{X_2}{0{,}622 + X_2} \cdot \frac{P}{p_{z2}} = \frac{0{,}00822}{0{,}622 + 0{,}00822} \cdot \frac{99325}{0{,}0958 \cdot 10^5} = 0{,}135$$

za $t_2 = 45°C$ $p_{z2} = 0{,}0958$ bar

Promjena apsolutne vlažnosti

$$\Delta X = X_1 - X_2 = 0{,}01624 - 0{,}00822 = 0{,}00802$$

Promjena relativne vlažnosti je

$$\Delta\varphi = \varphi_1 - \varphi_2 = 0{,}8 - 0{,}135 = 0{,}665$$

$$\Delta\varphi = 66{,}5\,\%$$

**Zadatak 10-2-3**

$P = 101\,325$ Pa

$t_1 = 5°C$

$X = 0{,}01$

$\varphi = 68\,\%$

Za $t_1 = 5°C$

$c_w = 4{,}2$ kJ/kg K

$p_z = 0{,}00871\,9$ bar

$$X_{z1} = 0{,}622 \cdot \frac{p_z}{P - p_z} = 0{,}622 \cdot \frac{0{,}00871\,9}{1{,}01325 - 0{,}00871\,9} = 0{,}0054$$

$$h_1 = 1{,}0048\, t_1 + X_{z,1}\,(1{,}926\, t_1 + 2500) + (X_1 - X_{z1}) \cdot c_w \cdot t_1$$

$$h_1 = 1{,}0048 \cdot 5 + 0{,}0054 \cdot (1{,}926 \cdot 5 + 2500) + (0{,}01 - 0{,}0054) \cdot 4{,}2 \cdot 5$$

$$h_1 = 18{,}67 \text{ kJ/kg}$$

$$X_2 = 0{,}622 \cdot \frac{\varphi_2 \cdot p_{z,2}}{P - \varphi_2 \cdot p_{z,2}}$$

$X_1 = X_2$

$$p_{z,2} = \frac{X_2 \cdot p}{l_2 (0{,}622 + X_2)} = \frac{0{,}01 \cdot 1{,}01325}{0{,}685 \cdot (0{,}622 + 0{,}01)} = 0{,}0234 \text{ bar}$$

za $p_{z,2} = 0{,}0234$ bar

$t_2 \approx 20\,^\circ C$

$$h_2 = 1{,}0048 \cdot t_2 + X_2 (1{,}925 \cdot t_2 + 2500)$$

$$h_2 = 1{,}0048 \cdot 20 + 0{,}01 (1{,}926 \cdot 20 + 2500) = 45{,}48 \text{ kJ/kg}$$

$$q_{12} = h_2 - h_1 = 45{,}48 - 18{,}67 = 26{,}81 \text{ kJ/kg}$$

**Zadatak (10-2-4)**

$t = 30\,^\circ C$

$\varphi = 60\,\% = 0{,}6$

$p_M = 100$ kPa

$p_p = ?$ $\quad x = ?$

$$X = 0{,}622 \cdot \frac{\varphi \cdot p_z}{p - \varphi \cdot p_z} = 0{,}622 \cdot \frac{0{,}60 \cdot 0{,}424 \cdot 10^5}{100 \cdot 10^3 - 0{,}6 \cdot 0{,}424 \cdot 10^5} = 0{,}2122$$

gdje je za $t = 30\,^\circ C$ $\quad p_z = 0{,}424$ bara

Obzirom da je

$$X = \frac{m_p}{m_{zr}} = 0{,}622 \cdot \frac{p_p}{p_{zr}} = 0{,}622 \cdot \frac{\varphi \cdot p_z}{p - \varphi p_z}$$

slijedi da je : $p_p = \varphi \cdot p_z = 0{,}6 \cdot 0{,}424 \cdot 10^5 = 25440$ Pa

$p_p$ – parcijalni pritisak

Declaration

Kuga je fizička bolest zarazna