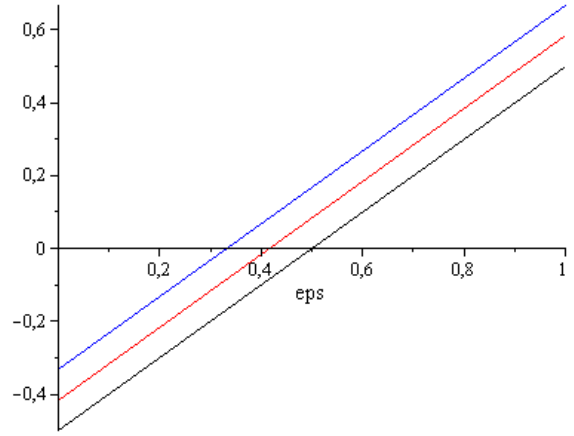
PROGRAM CICLU CARNOT ENDOREVERSIBIL

```
> restart;
> tau:=3;P1:=eps*(1-1/eps/tau);P2:=eps*(1-1.25/eps/tau);P3:=eps*(1-1.5/eps/tau);
```

$$\tau := 3$$

$$P1 := eps\left(1 - \frac{1}{3}\,\frac{1}{eps}\right);\ P2 := eps\left(1 - \frac{0.4166666667}{eps}\right);\ P3 := eps\left(1 - \frac{0.5000000000}{eps}\right)$$

```
> plot([P1(eps),P2(eps),P3(eps)], eps=0..1, color=[blue,red,black], style=[line,line,line]);
```

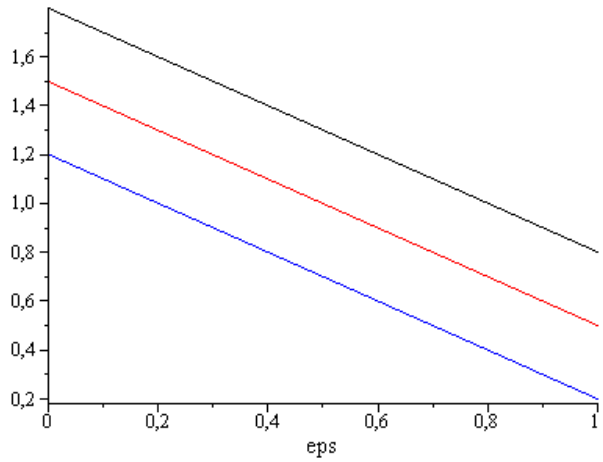



```
> restart;
> tau:=1.2;P1:=eps*(1*tau/eps-1);P2:=eps*(1.25*tau/eps-1);P3:=eps*(1.5*tau/eps-1);
```

$$\tau := 1.2$$

$$P1 := eps\left(\frac{1.2 \cdot 1}{eps} - 1\right);\ P2 := eps\left(\frac{1.500 \cdot 1}{eps} - 1\right);\ P3 := eps\left(\frac{1.80 \cdot 1}{eps} - 1\right)$$

```
> plot([P1(eps),P2(eps),P3(eps)], eps=0..1, color=[blue,red,black], style=[line,line,line]);
```



JOULE – BRAYTON AGENTI DE LUCRU

```
> restart;
> cpaer:=1.01027-1.73736E-4*T+6.08005E-7*T^(2)-3.80644E-10*T^(3)+7.49874E-14*T^(4);
cvaer:=0.72301-1.73889E-4*T+6.09496E-7*T^(2)-3.81877E-10*T^(3)+7.52717E-14*T^(4);
cpO2:=0.82397+3.05587E-4*T+5.32089E-8*T^2-1.30137E-10*T^3+3.58225E-14*T^4;
cvO2:=0.56574+2.96923E-4*T+6.54515E-8*T^2-1.36918E-10*T^3+3.71407E-14*T^4;
cpH2O:=1.84336-2.31223E-4*T+1.1966E-6*T^2-6.15263E-10*T^3+1.0015E-13*T^4;
cvH2O:=1.38161-2.29361E-4*T+1.19327E-6*T^2-6.13657E-10*T^3+9.99765E-14*T^4;
cpN2:=1.07623-3.25964E-4*T+7.92186E-7*T^2-4.66137E-10*T^3+8.87148E-14*T^4;
cvN2:=0.77884-3.22759E-4*T+7.86981E-7*T^2-4.62795E-10*T^3+8.79811E-14*T^4;
cpCO2:=0.46236+0.0016*T-1.2402E-6*T^2+4.78609E-10*T^3-7.32796E-14*T^4;
cvCO2:=0.27337+0.0016*T-1.24189E-6*T^2+4.79536E-10*T^3-7.34111E-14*T^4;
cpHe:=5.19; cvHe:=3.12;
cpH2:=13.63327+0.00349*T-5.57821E-6*T^2+4.56786E-9*T^3-1.12853E-12*T^4;
cvH2:=9.44039+0.00386*T-6.19336E-6*T^2+4.94382E-9*T^3-1.2046E-12*T^4;
Raer:=(.2868355533+0.28726)/2;
RO2:=(.2599467914+0.25823)/2;
RN2:=(.2967773441+0.29739)/2;
RCO2:=(.190161689+0.18899)/2;
RHe:=2.07;
RH2:=(4.14292647+4.19288)/2;
```

$$cpaer := 1.01027 - 0.000173736T + 6.08005\,10^{-7}\,T^2 - 3.80644\,10^{-10}\,T^3 + 7.49874\,10^{-14}\,T^4$$

$$cvaer := 0.72301 - 0.000173889T + 6.09496\,10^{-7}\,T^2 - 3.81877\,10^{-10}\,T^3 + 7.52717\,10^{-14}\,T^4$$

$$cpO2 := 0.82397 + 0.000305587T + 5.32089\,10^{-8}\,T^2 - 1.30137\,10^{-10}\,T^3 + 3.58225\,10^{-14}\,T^4$$

$$cvO2 := 0.56574 + 0.000296923T + 6.5451510^{-8}\,T^2 - 1.3691810^{-10}\,T^3 + 3.7140710^{-14}\,T^4$$

$$cpH2O := 1.84336 - 0.000231223T + 0.00000011966T^2 - 6.1526310^{-10}\,T^3 + 1.001510^{-13}\,T^4$$

$$cvH2O := 1.38161 - 0.000229361T + 0.00000119327T^2 - 6.1365710^{-10}\,T^3 + 9.9976510^{-14}\,T^4$$

$$cpN2 := 1.07623 - 0.000325964T + 7.9218610^{-7}\,T^2 - 4.6613710^{-10}\,T^3 + 8.8714810^{-14}\,T^4$$

$$cvN2 := 0.77884 - 0.000322759T + 7.8698110^{-7}\,T^2 - 4.6279510^{-10}\,T^3 + 8.7981110^{-14}\,T^4$$

$$cpCO2 := 0.46236 + 0.0016\,T - 0.00000124021T^2 + 4.7860910^{-10}\,T^3 - 7.3279610^{-14}\,T^4$$

$$cvCO2 := 0.27337 + 0.0016\,T - 0.000001241891T^2 + 4.7953610^{-10}\,T^3 - 7.3411110^{-14}\,T^4$$

$$cpHe := 5.19$$

$$cvHe := 3.12$$

$$cpH2 := 13.63327 + 0.00349\,T - 0.000005578211T^2 + 4.5678610^{-9}\,T^3 - 1.1285310^{-12}\,T^4$$

$$cvH2 := 9.44039 + 0.00386\,T - 0.000006193361T^2 + 4.9438210^{-9}\,T^3 - 1.204610^{-12}\,T^4$$

$$Raer := 0.287047776$$

$$RO2 := 0.259088395$$

$$RN2 := 0.297083672$$

$$RCO2 := 0.189575844$$

$$RHe := 2.07$$

$$RH2 := 4.16790323$$

```
> T0:=273;etaC:=0.88;etaT:=0.94;etam:=0.99;dpsursa_calda:=0.98;dpsursa_rece:=0.98;
```

$T0 := 273$

$etaC := 0.88$

$etaT := 0.94$

$etam := 0.99$

$dpsursa\_calda := 0.98$

$dpsursa\_rece := 0.98$

```
> DOMENIUpic;piC:=25;DomeniuT3;T3:=1273.15;
```

$DOMENIUpic$

$piC := 25$

$DomeniuT3$

$T3 := 1273.15$

```
> p1:=1;T1:=293.13;p2:=p1*piC;
```

$p1 := 1$

$T1 := 293.13$

$p2 := 25$

```
> COMPRIMARE;
dh12aer:=int(cpaer,T=T1..T2);
dh12O2:=int(cpO2,T=T1..T2);
dh12N2:=int(cpN2,T=T1..T2);
dh12CO2:=int(cpCO2,T=T1..T2);
dh12He:=int(cpHe,T=T1..T2);
dh12H2:=int(cpH2,T=T1..T2);
du12aer:=int(cvaer,T=T1..T2);
du12O2:=int(cvO2,T=T1..T2);
du12N2:=int(cvN2,T=T1..T2);
du12CO2:=int(cvCO2,T=T1..T2);
du12He:=int(cvHe,T=T1..T2);
du12H2:=int(cvH2,T=T1..T2);
k12aer:=dh12aer/du12aer;
k12O2:=dh12O2/du12O2;
```

k12N2:=dh12N2/du12N2;

k12CO2:=dh12CO2/du12CO2;

k12He:=dh12He/du12He;

k12H2:=dh12H2/du12H2;

COMPRIMARE

$$dh12aer := 1.01027000T2 - 293.1108246 - 0.00008686800000T2^2 + 2.02668333310^{-7}\,T2^3 - 9.51610000010^{-11}\,T2^4 + 1.49974800010^{-14}\,T2^5$$

$$dh12O2 := 0.82397000000T2 - 254.8811671 + 0.00015279350000T2^2 + 1.77363000010^{-8}\,T2^3 - 3.25342500010^{-11}\,T2^4 + 7.16450000010^{-15}\,T2^5$$

$$dh12N2 := 1.07623000T2 - 307.3000470 - 0.00016298200000T2^2 + 2.64062000010^{-7}\,T2^3 - 1.16534250010^{-10}\,T2^4 + 1.77429600010^{-14}\,T2^5$$

$$dh12CO2 := 0.46236000000T2 - 194.7110245 + 0.00080000000000T2^2 - 4.13400000010^{-7}\,T2^3 + 1.19652250010^{-10}\,T2^4 - 1.46559200010^{-14}\,T2^5$$

$$dh12He := 5.190000000T2 - 1521.34470($$

$$dh12H2 := 13.633270000T2 - 4107.369452 + 0.00174500000000T2^2 - 0.0000018594033333T2^3 + 1.14196500010^{-9}\,T2^4 - 2.25706000010^{-13}\,T2^5$$

$$du12aer := 0.72301000000T2 - 208.9100927 - 0.00008694450000T2^2 + 2.03165333310^{-7}\,T2^3 - 9.54692500010^{-11}\,T2^4 + 1.50543400010^{-14}\,T2^5$$

$$du12O2 := 0.56574000000T2 - 178.9048192 + 0.00014846150000T2^2 + 2.18171666710^{-8}\,T2^3 - 3.42295000010^{-11}\,T2^4 + 7.42814000010^{-15}\,T2^5$$

$$du12N2 := 0.77884000000\,T2 - 220.2259625 - 0.0001613795000\,T2^2 + 2.62327000010^{-7}\,T2^3 - 1.15698750010^{-10}\,T2^4 + 1.75962200010^{-14}\,T2^5$$

$$du12CO2 := 0.27337000000\,T2 - 139.2998512 + 0.00080000000000\,T2^2 - 4.13963333310^{-7}\,T2^3 + 1.19884000010^{-10}\,T2^4 - 1.46822200010^{-14}\,T2^5$$

$$du12He := 3.120000000\,T2 - 914.565600($$

$$du12H2 := 9.4403900000\,T2 - 2889.703067 + 0.0019300000000\,T2^2 - 0.000002064453333\,T2^3 + 1.23595500010^{-9}\,T2^4 - 2.40920000010^{-13}\,T2^5$$

$$k12aer := \left(1.0102700000\,T2 - 293.1108246 - 0.00008686800000\,T2^2 + 2.02668333310^{-7}\,T2^3 - 9.51610000010^{-11}\,T2^4 + 1.49974800010^{-14}\,T2^5\right) \Big/ \left(0.7230100000\,T2 - 208.9100927 - 0.00008694450000\,T2^2 + 2.03165333310^{-7}\,T2^3 - 9.54692500010^{-11}\,T2^4 + 1.50543400010^{-14}\,T2^5\right)$$

$$k12O2 := \left(0.8239700000\,T2 - 254.8811671 + 0.0001527935000\,T2^2 + 1.77363000010^{-8}\,T2^3 - 3.25342500010^{-11}\,T2^4 + 7.16450000010^{-15}\,T2^5\right) \Big/ \left(0.5657400000\,T2 - 178.9048192 + 0.0001484615000\,T2^2 + 2.18171666710^{-8}\,T2^3 - 3.42295000010^{-11}\,T2^4 + 7.42814000010^{-15}\,T2^5\right)$$

$$k12N2 := \left(1.0762300000\,T2 - 307.3000470 - 0.0001629820000\,T2^2 + 2.64062000010^{-7}\,T2^3 - 1.16534250010^{-10}\,T2^4 + 1.77429600010^{-14}\,T2^5\right) \Big/ \left(0.7788400000\,T2 - 220.2259625 - 0.0001613795000\,T2^2 + 2.62327000010^{-7}\,T2^3 - 1.15698750010^{-10}\,T2^4 + 1.75962200010^{-14}\,T2^5\right)$$

$$k12CO2 := (0.46236000000T2 - 194.7110245 + 0.00080000000000T2^2 - 4.13400000010^{-7}\ T2^3 + 1.19652250010^{-10}\ T2^4 - 1.46559200010^{-14}\ T2^5) / (0.27337000000T2 - 139.2998512 + 0.00080000000000T2^2 - 4.13963333310^{-7}\ T2^3 + 1.19884000010^{-10}\ T2^4 - 1.46822200010^{-14}\ T2^5)$$

$$k12He := \frac{5.19000000000T2 - 1521.344700}{3.12000000000T2 - 914.5656000}$$

$$k12H2 := (13.6332700000T2 - 4107.369452 + 0.00174500000000T2^2 - 0.0000018594033333T2^3 + 1.14196500010^{-9}\ T2^4 - 2.25706000010^{-13}\ T2^5) / (9.4403900000T2 - 2889.703067 + 0.00193000000000T2^2 - 0.0000020644533333T2^3 + 1.23595500010^{-9}\ T2^4 - 2.40920000010^{-13}\ T2^5)$$

```
> eq12taer:=T2-T1*piC^((k12aer-1)/k12aer);
eq12tO2:=T2-T1*piC^((k12O2-1)/k12O2);
eq12tN2:=T2-T1*piC^((k12N2-1)/k12N2);
eq12tCO2:=T2-T1*piC^((k12CO2-1)/k12CO2);
eq12tHe:=T2-T1*piC^((k12He-1)/k12He);
eq12tH2:=T2-T1*piC^((k12H2-1)/k12H2);T2taer:=fsolve(eq12taer,T2);
T2tO2:=fsolve(eq12tO2,T2);
T2tN2:=fsolve(eq12tN2,T2);
T2tCO2:=fsolve(eq12tCO2,T2);
T2tHe:=fsolve(eq12tHe,T2);
T2tH2:=fsolve(eq12tH2,T2);
```

$$eq12tN2 := T2 - 293.13 \left(\left(\left(1.076230000\, T2 - 307.3000470 - 0.0001629820000\, T2^2 + 2.640620000\, 10^{-7}\, T2^3 - 1.165342500\, 10^{-10}\, T2^4 + 1.774296000\, 10^{-14}\, T2^5 \right) \Big/ \left(0.7788400000\, T2 - 220.2259625 - 0.0001613795000\, T2^2 + 2.623270000\, 10^{-7}\, T2^3 - 1.156987500\, 10^{-10}\, T2^4 + 1.759622000\, 10^{-14}\, T2^5 \right) - 1 \right) \left(0.7788400000\, T2 - 220.2259625 - 0.0001613795000\, T2^2 + 2.623270000\, 10^{-7}\, T2^3 - 1.156987500\, 10^{-10}\, T2^4 + 1.759622000\, 10^{-14}\, T2^5 \right) \right) \Big/ \left(1.076230000\, T2 - 307.3000470 - 0.0001629820000\, T2^2 + 2.640620000\, 10^{-7}\, T2^3 - 1.165342500\, 10^{-10}\, T2^4 + 1.774296000\, 10^{-14}\, T2^5 \right) \Big)^{25}$$

$$eq12tCO2 := T2 - 293.13 \left(\left(\left(0.4623600000\, T2 - 194.7110245 + 0.0008000000000\, T2^2 - 4.134000000\, 10^{-7}\, T2^3 + 1.196522500\, 10^{-10}\, T2^4 - 1.465592000\, 10^{-14}\, T2^5 \right) \Big/ \left(0.2733700000\, T2 - 139.2998512 + 0.0008000000000\, T2^2 - 4.139633333\, 10^{-7}\, T2^3 + 1.198840000\, 10^{-10}\, T2^4 - 1.468222000\, 10^{-14}\, T2^5 \right) - 1 \right) \left(0.2733700000\, T2 - 139.2998512 + 0.0008000000000\, T2^2 - 4.139633333\, 10^{-7}\, T2^3 + 1.198840000\, 10^{-10}\, T2^4 - 1.468222000\, 10^{-14}\, T2^5 \right) \right) \Big/ \left(0.4623600000\, T2 - 194.7110245 + 0.0008000000000\, T2^2 - 4.134000000\, 10^{-7}\, T2^3 + 1.196522500\, 10^{-10}\, T2^4 - 1.465592000\, 10^{-14}\, T2^5 \right) \Big)^{25}$$

$$eq12tHe := T2 - 293.13 - \frac{\left(\frac{5.190000000\,T2 - 1521.344700}{3.120000000\,T2 - 914.5656000} - 1\right)(3.120000000\,T2 - 914.5656000)}{5.190000000\,T2 - 1521.344700}\Big/25$$

$$eq12tH2 := T2 - 293.13 - \Big(\big((13.63327000\,T2 - 4107.369452 + 0.001745000000\,T2^2 - 0.000001859403333\,T2^3 + 1.141965000\,10^{-9}\,T2^4 - 2.257060000\,10^{-13}\,T2^5\big)\Big/\big(9.440390000\,T2 - 2889.703067 + 0.001930000000\,T2^2 - 0.000002064453333\,T2^3 + 1.235955000\,10^{-9}\,T2^4 - 2.409200000\,10^{-13}\,T2^5\big) - 1\big)\big(9.440390000\,T2 - 2889.703067 + 0.001930000000\,T2^2 - 0.000002064453333\,T2^3 + 1.235955000\,10^{-9}\,T2^4 - 2.409200000\,10^{-13}\,T2^5\big)\Big/\big(13.63327000\,T2 - 4107.369452 + 0.001745000000\,T2^2 - 0.000001859403333\,T2^3 + 1.141965000\,10^{-9}\,T2^4 - 2.257060000\,10^{-13}\,T2^5\big)\Big)\Big/25$$

$T2taer := 715.540678$

$T2tO2 := 693.282320$

$T2tN2 := 719.926594$

$T2tCO2 := 557.074029$

$T2tHe := 1058.32768$

$T2tH2 := 732.468008$

```
> dh12taer:=int(cpaer,T=T1..T2taer);
dh12tO2:=int(cpO2,T=T1..T2tO2);
dh12tN2:=int(cpN2,T=T1..T2tN2);
dh12tCO2:=int(cpCO2,T=T1..T2tCO2);
dh12tHe:=int(cpHe,T=T1..T2tHe);
dh12tH2:=int(cpH2,T=T1..T2tH2);
```

dh12raer:=dh12taer/etaC;

dh12rO2:=dh12tO2/etaC;

dh12rN2:=dh12tN2/etaC;

dh12rCO2:=dh12tCO2/etaC;

dh12rHe:=dh12tHe/etaC;

dh12rH2:=dh12tH2/etaC;

$dh12taer := 437.418274$

$dh12tO2 := 389.343024$

$dh12tN2 := 453.691271$

$dh12tCO2 := 250.392205$

$dh12tHe := 3971.37597$

$dh12tH2 := 6365.19180$

$dh12raer := 497.066220$

$dh12rO2 := 442.435254$

$dh12rN2 := 515.558262$

$dh12rCO2 := 284.536596$

$dh12rHe := 4512.92723$

$dh12rH2 := 7233.17250$

> eq12raer:=dh12raer-int(cpaer,T=T1..T2riaer);

eq12rO2:=dh12rO2-int(cpO2,T=T1..T2riO2);

eq12rN2:=dh12rN2-int(cpN2,T=T1..T2riN2);

eq12rCO2:=dh12rCO2-int(cpCO2,T=T1..T2riCO2);

eq12rHe:=dh12rHe-int(cpHe,T=T1..T2riHe);

eq12rH2:=dh12rH2-int(cpH2,T=T1..T2riH2);

T2raer:=fsolve(eq12raer,T2riaer);

T2rO2:=fsolve(eq12rO2,T2riO2);

T2rN2:=fsolve(eq12rN2,T2riN2);

T2rCO2:=fsolve(eq12rCO2,T2riCO2);

T2rHe:=fsolve(eq12rHe,T2riHe);

T2rH2:=fsolve(eq12rH2,T2riH2);

$$eq12raer := 790.1770455 - 1.010270000\,T2riaer + 0.000086868000000\,T2riaer^2 - 2.02668333310^{-7}\,T2riaer^3 + 9.51610000010^{-11}\,T2riaer^4 - 1.49974800010^{-14}\,T2riaer^5$$

$$eq12rO2 := 697.3164218 - 0.8239700000\,T2riO2 - 0.0001527935000\,T2riO2^2 - 1.77363000010^{-8}\,T2riO2^3 + 3.25342500010^{-11}\,T2riO2^4 - 7.16450000010^{-15}\,T2riO2^5$$

$$eq12rN2 := 822.8583097 - 1.076230000\,T2riN2 + 0.0001629820000\,T2riN2^2 - 2.64062000010^{-7}\,T2riN2^3 + 1.16534250010^{-10}\,T2riN2^4 - 1.77429600010^{-14}\,T2riN2^5$$

$$eq12rCO2 := 479.2476212 - 0.4623600000\,T2riCO2 - 0.0008000000000\,T2riCO2^2 + 4.13400000010^{-7}\,T2riCO2^3 - 1.19652250010^{-10}\,T2riCO2^4 + 1.46559200010^{-14}\,T2riCO2^5$$

$$eq12rHe := 6034.271939 - 5.190000000\,T2riHe$$

$$eq12rH2 := 11340.54196 - 13.63327000\,T2riH2 - 0.0017450000000\,T2riH2^2 + 0.000001859403333\,T2riH2^3 - 1.14196500010^{-9}\,T2riH2^4 + 2.25706000010^{-13}\,T2riH2^5$$

$$T2raer := 770.588174$$

$$T2rO2 := 744.709858$$

$$T2rN2 := 775.747907$$

$$T2rCO2 := -836.3372280, 589.4623521, 4891.31270$$

$$T2rHe := 1162.67282$$

$$T2rH2 := -1860.068448, 791.5362518, 4191.59390$$

>

```
SURSA_CALDA;T2aer:=770.5881744;T2O2:=744.7098586;T2N2:=775.7479070;T2CO2:=589.4623521;T2He:=1162.672821;T2H2:=791.5362518;dh23aer:=int(cpaer,T=T2aer..T3);dh23O2:=int(cpO2,T=T2O2..T3);dh23N2:=int(cpN2,T=T2N2..T3);dh23CO2:=int(cpCO2,T=T2CO2..T3);dh23He:=int(cpHe,T=T2He..T3);dh23H2:=int(cpH2,T=T2H2..T3);p3:=p2*dpsursa_calda;
```

SURSA_CALDA

$$T2aer := 770.588174$$

$T2O2 := 744.709858$

$T2N2 := 775.747907$

$T2CO2 := 589.462352$

$T2He := 1162.67282$

$T2H2 := 791.536251$

$dh23aer := 573.627311$

$dh23O2 := 574.473793$

$dh23N2 := 581.273441$

$dh23CO2 := 818.360928$

$dh23He := 573.376559$

$dh23H2 := 7253.31858$

$p3 := 24.50$

>

DESTINDERE;p4:=p1/dpsursa_rece;dh34aer:=int(cpaer,T=T3..T4);dh34O2:=int(cpO2,T=T3..T4);dh34N2:=int(cpN2,T=T3..T4);dh34CO2:=int(cpCO2,T=T3..T4);dh34He:=int(cpHe,T=T3..T4);dh34H2:=int(cpH2,T=T3..T4);du34aer:=int(cvaer,T=T3..T4);du34O2:=int(cvO2,T=T3..T4);du34N2:=int(cvN2,T=T3..T4);du34CO2:=int(cvCO2,T=T3..T4);du34He:=int(cvHe,T=T3..T4);du34H2:=int(cvH2,T=T3..T4);k34aer:=dh34aer/du34aer;k34O2:=dh34O2/du34O2;k34N2:=dh34N2/du34N2;k34CO2:=dh34CO2/du34CO2;k34He:=dh34He/du34He;k34H2:=dh34H2/du34H2;

$DESTINDERE$

$p4 := 1.02040816$

$$dh34aer := 1.01027000\,T4 - 1363.804357 - 0.00008686800000\,T4^2 + 2.02668333310^{-7}\,T4^3 - 9.5161000001\,0^{-11}\,T4^4 + 1.49974800010^{-14}\,T4^5$$

$$dh34O2 := 0.82397000\,T4 - 1271.790215 + 0.00015279350\,T4^2 + 1.77363000010^{-8}\,T4^3 - 3.25342500010^{-11}\,T4^4 + 7.16450000010^{-15}\,T4^5$$

$$dh34N2 := 1.07623000\,T4 - 1404.131751 - 0.00016298200\,T4^2 + 2.64062000010^{-7}\,T4^3 - 1.16534250010^{-10}\,T4^4 + 1.77429600010^{-14}\,T4^5$$

$$dh34CO2 := 0.46236000000T4 - 1297.608550 + 0.00080000000000T4^2 - 4.13400000010^{-7}\ T4^3 + 1.19652250010^{-10}\ T4^4 - 1.46559200010^{-14}\ T4^5$$

$$dh34He := 5.190000000T4 - 6607.64850($$

$$dh34H2 := 13.63327000T4 - 18593.86055 + 0.0017450000000T4^2 - 0.000001859403333T4^3 + 1.14196500010^{-9}\ T4^4 - 2.25706000010^{-13}\ T4^5$$

$$du34aer := 0.72301000000T4 - 998.3612444 - 0.00008694450000T4^2 + 2.03165333310^{-7}\ T4^3 - 9.54692500010^{-11}\ T4^4 + 1.50543400010^{-14}\ T4^5$$

$$du34O2 := 0.56574000000T4 - 940.8522976 + 0.0001484615000T4^2 + 2.18171666710^{-8}\ T4^3 - 3.42295000010^{-11}\ T4^4 + 7.42814000010^{-15}\ T4^5$$

$$du34N2 := 0.77884000000T4 - 1026.231034 - 0.0001613795000T4^2 + 2.62327000010^{-7}\ T4^3 - 1.15698750010^{-10}\ T4^4 + 1.75962200010^{-14}\ T4^5$$

$$du34CO2 := 0.27337000000T4 - 1056.354316 + 0.00080000000000T4^2 - 4.13963333310^{-7}\ T4^3 + 1.19884000010^{-10}\ T4^4 - 1.46822200010^{-14}\ T4^5$$

$$du34He := 3.120000000T4 - 3972.22800($$

$$du34H2 := 9.4403900000T4 - 13328.46365 + 0.0019300000000T4^2 - 0.000002064453333T4^3 + 1.23595500010^{-9}\ T4^4 - 2.40920000010^{-13}\ T4^5$$

$$k34aer := (1.0102700000T4 - 1363.804357 - 0.000086868000000T4^2 + 2.02668333310^{-7}\ T4^3 - 9.5161000001 0^{-11}\ T4^4 + 1.49974800010^{-14}\ T4^5) / (0.7230100000T4 - 998.3612444 - 0.00008694450000T4^2 + 2.03165333310^{-7}\ T4^3 - 9.54692500010^{-11}\ T4^4 + 1.50543400010^{-14}\ T4^5)$$

$$k34O2 := (0.8239700000T4 - 1271.790215 + 0.0001527935000T4^2 + 1.77363000010^{-8}\ T4^3 - 3.25342500010^{-11}\ T4^4 + 7.16450000010^{-15}\ T4^5) / (0.5657400000T4 - 940.8522976 + 0.0001484615000T4^2 + 2.18171666710^{-8}\ T4^3 - 3.42295000010^{-11}\ T4^4 + 7.42814000010^{-15}\ T4^5)$$

$$k34N2 := (1.0762300000T4 - 1404.131751 - 0.0001629820000T4^2 + 2.64062000010^{-7}\ T4^3 - 1.16534250010^{-10}\ T4^4 + 1.77429600010^{-14}\ T4^5) / (0.7788400000T4 - 1026.231034 - 0.0001613795000T4^2 + 2.62327000010^{-7}\ T4^3 - 1.15698750010^{-10}\ T4^4 + 1.75962200010^{-14}\ T4^5)$$

$$k34CO2 := (0.4623600000T4 - 1297.608550 + 0.000800000000000T4^2 - 4.13400000010^{-7}\ T4^3 + 1.19652250010^{-10}\ T4^4 - 1.46559200010^{-14}\ T4^5) / (0.2733700000T4 - 1056.354316 + 0.000800000000000T4^2 - 4.13963333310^{-7}\ T4^3 + 1.19884000010^{-10}\ T4^4 - 1.46822200010^{-14}\ T4^5)$$

$$k34He := \frac{5.1900000000T4 - 6607.648500}{3.1200000000T4 - 3972.228000}$$

$$k34H2 := (13.633270000T4 - 18593.86055 + 0.0017450000000T4^2 - 0.0000018594033333T4^3 + 1.14196500010^{-9}\ T4^4 - 2.25706000010^{-13}\ T4^5) / (9.4403900000T4 - 13328.46365 + 0.0019300000000T4^2 - 0.0000020644533333T4^3 + 1.23595500010^{-9}\ T4^4 - 2.40920000010^{-13}\ T4^5)$$

> piT:=p4/p3;eq34taer:=T4-T3*piT^((k34aer-1)/k34aer);eq34tO2:=T4-T3*piT^((k34O2-1)/k34O2);eq34tN2:=T4-T3*piT^((k34N2-1)/k34N2);eq34tCO2:=T4-T3*piT^((k34CO2-1)/k34CO2);eq34tHe:=T4-T3*piT^((k34He-1)/k34He);eq34tH2:=T4-T3*piT^((k34H2-

1)/k34H2);T4taer:=fsolve(eq34taer,T4);T4tO2:=fsolve(eq34tO2,T4);T4tN2:=fsolve(eq34tN2,T4);T4tCO2:=fsolve(eq34tCO2,T4);T4tHe:=fsolve(eq34tHe,T4);T4tH2:=fsolve(eq34tH2,T4);

$$piT := 0.0416493127$$

$$eq34taer := T4 - 1273.15 \left(\left(\left(1.010270000\, T4 - 1363.804357 - 0.04164931278 \left(-0.00008686800000\, T4^2 + 2.026683333\, 10^{-7}\, T4^3 - 9.516100000\, 10^{-11}\, T4^4 + 1.499748000\, 10^{-14}\, T4^5 \right) \right) \Big/ \left(0.7230100000\, T4 - 998.3612444 - 0.04164931278 \left(-0.00008694450000\, T4^2 + 2.031653333\, 10^{-7}\, T4^3 - 9.546925000\, 10^{-11}\, T4^4 + 1.505434000\, 10^{-14}\, T4^5 \right) \right) - 1 \right) \left(0.7230100000\, T4 - 998.3612444 - 0.04164931278 \left(-0.00008694450000\, T4^2 + 2.031653333\, 10^{-7}\, T4^3 - 9.546925000\, 10^{-11}\, T4^4 + 1.505434000\, 10^{-14}\, T4^5 \right) \right) \right) \Big/ \left(1.010270000\, T4 - 1363.804357 - 0.04164931278 \left(-0.00008686800000\, T4^2 + 2.026683333\, 10^{-7}\, T4^3 - 9.516100000\, 10^{-11}\, T4^4 + 1.499748000\, 10^{-14}\, T4^5 \right) \right)$$

$$eq34tO2 := T4 - 1273.15 \left(\left(\left(0.8239700000\, T4 - 1271.790215 \right) 0.04164931278 + 0.0001527935000\, T4^2 + 1.773630000\, 10^{-8}\, T4^3 - 3.253425000\, 10^{-11}\, T4^4 + 7.164500000\, 10^{-15}\, T4^5 \right) \Big/ \left(0.5657400000\, T4 - 940.8522976 + 0.0001484615000\, T4^2 + 2.181716667\, 10^{-8}\, T4^3 - 3.422950000\, 10^{-11}\, T4^4 + 7.428140000\, 10^{-15}\, T4^5 \right) - 1 \right) \left(0.5657400000\, T4 - 940.8522976 + 0.0001484615000\, T4^2 + 2.181716667\, 10^{-8}\, T4^3 - 3.422950000\, 10^{-11}\, T4^4 + 7.428140000\, 10^{-15}\, T4^5 \right) \Big/ \left(0.8239700000\, T4 - 1271.790215 + 0.0001527935000\, T4^2 + 1.773630000\, 10^{-8}\, T4^3 - 3.253425000\, 10^{-11}\, T4^4 + 7.164500000\, 10^{-15}\, T4^5 \right)$$

$$eq34tN2 := T4 - 1273.15 - \frac{0.04164931278 \left(\left(\left(1.076230000\, T4 - 1404.131751 - 0.0001629820000\, T4^2 + 2.640620000\, 10^{-7}\, T4^3 - 1.165342500\, 10^{-10}\, T4^4 + 1.774296000\, 10^{-14}\, T4^5\right) \Big/ \left(0.7788400000\, T4 - 1026.231034 - 0.0001613795000\, T4^2 + 2.623270000\, 10^{-7}\, T4^3 - 1.156987500\, 10^{-10}\, T4^4 + 1.759622000\, 10^{-14}\, T4^5\right) - 1\right) \left(0.7788400000\, T4 - 1026.231034 - 0.0001613795000\, T4^2 + 2.623270000\, 10^{-7}\, T4^3 - 1.156987500\, 10^{-10}\, T4^4 + 1.759622000\, 10^{-14}\, T4^5\right)\right) \Big/ \left(1.076230000\, T4 - 1404.131751 - 0.0001629820000\, T4^2 + 2.640620000\, 10^{-7}\, T4^3 - 1.165342500\, 10^{-10}\, T4^4 + 1.774296000\, 10^{-14}\, T4^5\right)}$$

$$eq34tCO2 := T4 - 1273.15 \left(\left(\left(0.4623600000\ T4 - 1297.608550 \right.\right.\right.$$

$$0.04164931278 + 0.0008000000000\ T4^2 - 4.134000000\ 10^{-7}\ T4^3 + 1.196522500\ 10^{-10}\ T4^4$$

$$\left. - 1.465592000\ 10^{-14}\ T4^5\right) \Big/ \left(0.2733700000\ T4 - 1056.354316 \right.$$

$$+ 0.0008000000000\ T4^2 - 4.139633333\ 10^{-7}\ T4^3 + 1.198840000\ 10^{-10}\ T4^4$$

$$\left. - 1.468222000\ 10^{-14}\ T4^5\right) - 1\Big) \left(0.2733700000\ T4 - 1056.354316 \right.$$

$$+ 0.0008000000000\ T4^2 - 4.139633333\ 10^{-7}\ T4^3 + 1.198840000\ 10^{-10}\ T4^4$$

$$\left. - 1.468222000\ 10^{-14}\ T4^5\right)\Big) \Big/ \left(0.4623600000\ T4 - 1297.608550 \right.$$

$$\left. + 0.0008000000000\ T4^2 - 4.134000000\ 10^{-7}\ T4^3 + 1.196522500\ 10^{-10}\ T4^4 \right.$$

$$\left. - 1.465592000\ 10^{-14}\ T4^5\right)$$

$$eq34tHe := T4 - 1273.15 \left(0.04164931278^{\frac{1}{5.190000000\ T4 - 6607.648500}}\right) \left(\left(1 \Big/ \right.\right.$$

$$\left(3.120000000\ T4 - 3972.228000\right)\left(5.190000000\ T4 - 6607.648500\right) - 1\Big)$$

$$\left.\left(3.120000000\ T4 - 3972.228000\right)\right)$$

$$eq34tH2 := T4 - 1273.15 - \left(\left(\left(13.63327000\,T4 - 18593.86055 + 0.04164931278 + 0.001745000000\,T4^2 - 0.000001859403333\,T4^3 + 1.141965000\,10^{-9}\,T4^4 - 2.257060000\,10^{-13}\,T4^5\right) \Big/ \left(9.440390000\,T4 - 13328.46365 + 0.001930000000\,T4^2 - 0.000002064453333\,T4^3 + 1.235955000\,10^{-9}\,T4^4 - 2.409200000\,10^{-13}\,T4^5\right) - 1\right)\left(9.440390000\,T4 - 13328.46365 + 0.001930000000\,T4^2 - 0.000002064453333\,T4^3 + 1.235955000\,10^{-9}\,T4^4 - 2.409200000\,10^{-13}\,T4^5\right)\right) \Big/ \left(13.63327000\,T4 - 18593.86055 + 0.001745000000\,T4^2 - 0.000001859403333\,T4^3 + 1.141965000\,10^{-9}\,T4^4 - 2.257060000\,10^{-13}\,T4^5\right)$$

$T4taer := 563.858288($

$T4tO2 := 588.5638418$

$T4tN2 := 558.614184'$

$T4tCO2 := 779.220393'$

$T4tHe := 358.359184$

$T4tH2 := 527.229836($

>

```
dh34taer:=int(cpaer,T=T3..T4taer);dh34tO2:=int(cpO2,T=T3..T4tO2);dh34tN2:=int(cpN2,T=T3..T4tN2);dh34tCO2
:=int(cpCO2,T=T3..T4tCO2);dh34tHe:=int(cpHe,T=T3..T4tHe);dh34tH2:=int(cpH2,T=T3..T4tH2);dh34raer:=dh34t
aer*etaT;dh34rO2:=dh34tO2*etaT;dh34rN2:=dh34tN2*etaT;dh34rCO2:=dh34tCO2*etaT;dh34rHe:=dh34tHe*eta
T;dh34rH2:=dh34tH2*etaT;
```

$dh34taer := -794.205571$

$dh34tO2 := -733.684384$

$dh34tN2 := -818.145225($

$dh34tCO2 := -607.270583$

$dh34tHe := -4747.76433$

$dh34tH2 := -11114.3957$

$dh34raer := -746.553236$

$dh34rO2 := -689.663321$

$dh34rN2 := -769.056511$

$dh34rCO2 := -570.834348$

$dh34rHe := -4462.89847$

$dh34rH2 := -10447.5320$

```
> eq34raer:=dh34raer-int(cpaer,T=T3..T4riaer);eq34rO2:=dh34rO2-int(cpO2,T=T3..T4riO2);eq34rN2:=dh34rN2-
int(cpN2,T=T3..T4riN2);eq34rCO2:=dh34rCO2-int(cpCO2,T=T3..T4riCO2);eq34rHe:=dh34rHe-
int(cpHe,T=T3..T4riHe);eq34rH2:=dh34rH2-
int(cpH2,T=T3..T4riH2);T4raer:=fsolve(eq34raer,T4riaer);T4rO2:=fsolve(eq34rO2,T4riO2);T4rN2:=fsolve(eq34r
N2,T4riN2);T4rCO2:=fsolve(eq34rCO2,T4riCO2);T4rHe:=fsolve(eq34rHe,T4riHe);T4rH2:=fsolve(eq34rH2,T4riH2
);
```

$$eq34raer := 617.2511202 - 1.010270000\,T4riaer + 0.00008686800000\,T4riaer^2 - 2.02668333310^{-7}\,T4riaer^3 + 9.51610000010^{-11}\,T4riaer^4 - 1.49974800010^{-14}\,T4riaer^5$$

$$eq34rO2 := 582.1268939 - 0.8239700000\,T4riO2 - 0.0001527935000\,T4riO2^2 - 1.77363000010^{-8}\,T4riO2^3 + 3.25342500010^{-11}\,T4riO2^4 - 7.16450000010^{-15}\,T4riO2^5$$

$$eq34rN2 := 635.0752395 - 1.076230000\,T4riN2 + 0.0001629820000\,T4riN2^2 - 2.64062000010^{-7}\,T4riN2^3 + 1.16534250010^{-10}\,T4riN2^4 - 1.77429600010^{-14}\,T4riN2^5$$

$$eq34rCO2 := 726.7742013 - 0.4623600000\,T4riCO2 - 0.0008000000000\,T4riCO2^2 + 4.13400000010^{-7}\,T4riCO2^3 - 1.19652250010^{-10}\,T4riCO2^4 + 1.46559200010^{-14}\,T4riCO2^5$$

$eq34rHe := 2144.750027 - 5.190000000\,T4riHe$

$$eq34rH2 := 8146.32855 - 13.63327000\,T4riH2 - 0.001745000000\,T4riH2^2 + 0.000001859403333\,T4riH2^3 - 1.141965000\,10^{-9}\,T4riH2^4 + 2.257060000\,10^{-13}\,T4riH2^5$$

$T4raer := 609.257707$

$T4rO2 := 632.335514$

$T4rN2 := 604.360402$

$T4rCO2 := -942.6830890, 810.5859486, 4856.64497$

$T4rHe := 413.246633$

$T4rH2 := -1798.689934, 573.1501398, 4229.48545$

>

SURSA_RECE;T4aer:=609.2577079;T4O2:=632.3355147;T4N2:=604.3604020;T4CO2:=810.5859486;T4He:=413.2466333;T4H2:=573.1501398;dh41aer:=int(cpaer,T=T4aer..T1);dh41O2:=int(cpO2,T=T4O2..T1);dh41N2:=int(cpN2,T=T4N2..T1);dh41CO2:=int(cpCO2,T=T4CO2..T1);dh41He:=int(cpHe,T=T4He..T1);dh41H2:=int(cpH2,T=T4H2..T1);

SURSA_RECE

$T4aer := 609.257707$

$T4O2 := 632.335514$

$T4N2 := 604.360402$

$T4CO2 := 810.585948$

$T4He := 413.246633$

$T4H2 := 573.150139$

$dh41aer := -324.140295$

$dh41O2 := -327.245726$

$dh41N2 := -327.775192$

$dh41CO2 := -532.063176$

$dh41He := -623.405326$

$dh41H2 := -4038.95909$

>

RANDAMENT;Eaer:=1+dh41aer/dh23aer;EO2:=1+dh41O2/dh23O2;EN2:=1+dh41N2/dh23N2;ECO2:=1+dh41CO2/dh23CO2;EHe:=1+dh41He/dh23He;EH2:=1+dh41H2/dh23H2;

RANDAMENT

$Eaer := 0.434928760$

$EO2 := 0.430355691$

$EN2 := 0.436108431$

$ECO2 := 0.349842889$

$EHe := -0.08725290$

$EH2 := 0.443157080$

>

PUTERI;Paer:=dh41aer+dh23aer;PO2:=dh41O2+dh23O2;PN2:=dh41N2+dh23N2;PCO2:=dh41CO2+dh23CO2;PHe:=dh41He+dh23He;PH2:=dh41H2+dh23H2;

PUTERI

$Paer := 249.487015$

$PO2 := 247.228066$

$PN2 := 253.498249$

$PCO2 := 286.297751$

$PHe := -50.028767$

$PH2 := 3214.35948$

> GENERARE_ENTROPIE;ds12aer:=int(cpaer/T,T=T2taer..T2aer);ds23aer:=int(-Raer/p,p=p2..p3);ds34aer:=int(cpaer/T,T=T4taer..T4aer);ds41aer:=int(-Raer/p,p=p4..p1);dsqaer:=int(cpaer/T,T=T2aer..T3);Nirraer_int:=1+(ds12aer+ds23aer+ds34aer+ds41aer)/dsqaer;

GENERARE_ENTROPIE

$ds12aer := 0.0803040545$

$ds23aer := 0.00579914221$

$ds34aer := 0.0812765143$

$ds41aer := 0.00579914214$

$dsqaer := 0.571043608$

$Nirraer\_int := 1.30326730$

> ds12O2:=int(cpO2/T,T=T2tO2..T2O2);ds23O2:=int(-RO2/p,p=p2..p3);ds34O2:=int(cpO2/T,T=T4tO2..T4O2);ds41O2:=int(-RO2/p,p=p4..p1);dsqO2:=int(cpO2/T,T=T2O2..T3);NirrO2_int:=1+(ds12O2+ds23O2+ds34O2+ds41O2)/dsqO2;

$ds12O2 := 0.0738685503$

$ds23O2 := 0.00523428702$

$ds34O2 := 0.0721386018$

$ds41O2 := 0.00523428696$

$dsqO2 := 0.580882494$

$NirrO2\_int := 1.26937586$

> ds12N2:=int(cpN2/T,T=T2tN2..T2N2);ds23N2:=int(-RN2/p,p=p2..p3);ds34N2:=int(cpN2/T,T=T4tN2..T4N2);ds41N2:=int(-RN2/p,p=p4..p1);dsqN2:=int(cpN2/T,T=T2N2..T3);NirrN2_int:=1+(ds12N2+ds23N2+ds34N2+ds41N2)/dsqN2;

$ds12N2 := 0.0827604852$

$ds23N2 := 0.00600189447$

$ds34N2 := 0.0844582794$

$ds41N2 := 0.00600189439$

$dsqN2 := 0.576846956$

$NirrN2\_int := 1.31069341$

> ds12CO2:=int(cpCO2/T,T=T2tCO2..T2CO2);ds23CO2:=int(-RCO2/p,p=p2..p3);ds34CO2:=int(cpCO2/T,T=T4tCO2..T4CO2);ds41CO2:=int(-RCO2/p,p=p4..p1);dsqCO2:=int(cpCO2/T,T=T2CO2..T3);NirrCO2_int:=1+(ds12CO2+ds23CO2+ds34CO2+ds41CO2)/dsqCO2;

$ds12CO2 := 0.0595716623$

$ds23CO2 := 0.00382994530$

$ds34CO2 := 0.0458416931$

$ds41CO2 := 0.00382994525$

$dsqCO2 := 0.910904234$

$NirrCO2\_int := 1.12413296$

> ds12He:=int(cpHe/T,T=T2tHe..T2He);ds23He:=int(-RHe/p,p=p2..p3);ds34He:=int(cpHe/T,T=T4tHe..T4He);ds41He:=int(-RHe/p,p=p4..p1);dsqHe:=int(cpHe/T,T=T2He..T3);NirrHe_int:=1+(ds12He+ds23He+ds34He+ds41He)/dsqHe;

$ds12He := 0.488023520$

$ds23He := 0.0418196041$

$ds34He := 0.739620661$

$ds41He := 0.0418196036$

$dsqHe := 0.471109969$

$NirrHe\_int := 3.78339129$

> ds12H2:=int(cpH2/T,T=T2tH2..T2H2);ds23H2:=int(-RH2/p,p=p2..p3);ds34H2:=int(cpH2/T,T=T4tH2..T4H2);ds41H2:=int(-RH2/p,p=p4..p1);dsqH2:=int(cpH2/T,T=T2H2..T3);NirrH2_int:=1+(ds12H2+ds23H2+ds34H2+ds41H2)/dsqH2;

$ds12H2 := 1.13962191$

$ds23H2 := 0.0842029291$

$ds34H2 := 1.21274522$

$ds41H2 := 0.0842029281$

$dsqH2 := 7.14349516$

$NirrH2\_int := 1.35287669$

> save piC,piT,T1,T3,T2aer,T4aer,T2O2,T4O2,T2N2,T4N2,T2CO2,T4CO2,T2He,T4He,T2H2,T4H2,Paer,PO2,PN2,PCO2,PHe,PH2,Eaer,EO2,EN2,ECO2,EHe,EH2,Nirraer_int,NirrO2_int,NirrN2_int,NirrCO2_int,NirrHe_int,NirrH2_int,"date brayton agenti de lucru";read "date brayton agenti de lucru";

$piC := 25$

$piT := 0.0416493127$

$T1 := 293.13$

$T3 := 1273.15$

$T2aer := 770.588174$

$T4aer := 609.2577075$

$T2O2 := 744.709858$

$T4O2 := 632.335514$

$T2N2 := 775.747907$

$T4N2 := 604.360402$

$T2CO2 := 589.462352$

$T4CO2 := 810.585948$

$T2He := 1162.67282$

$T4He := 413.246633$

$T2H2 := 791.5362518$

$T4H2 := 573.1501398$

$Paer := 249.4870158$

$PO2 := 247.2280665$

$PN2 := 253.4982490$

$PCO2 := 286.2977510$

$PHe := -50.0287678$

$PH2 := 3214.359480$

$Eaer := 0.4349287609$

$EO2 := 0.4303556911$

$EN2 := 0.4361084317$

$ECO2 := 0.3498428897$

$EHe := -0.0872529000$

$EH2 := 0.4431570807$

$Nirraer\_int := 1.3032673000$

$NirrO2\_int := 1.2693758688$

$NirrN2\_int := 1.3106934195$

$NirrCO2\_int := 1.1241329688$

$NirrHe\_int := 3.7833912977$

$NirrH2\_int := 1.3528766995$

>

PROGRAM ARDERE CU RECIRCULARE GAZE DE ARDERE

```
> restart;
> p1:=0.94;T0:=273;T1:=293;T2:=1473;p0:=1;pv0s:=610.8/100000;
```

$p1 := 0.94$

$T0 := 273$

$T1 := 293$

$T2 := 1473$

$p0 := 1$

$pv0s := 0.006108000000$

```
> mair:=4;l0:=2500;u0:=l0-610.8*206.3/1000;
```

$mair := 4$

$l0 := 2500$

u0 := 2373.99196

>

```
Molar_mass_in_kg_per_kmole;MCH4:=16;MC2H6:=30;MC3H8:=44;MC4H10:=58;MCO2
:=44;MN2:=28;MC:=12;MH2:=2;MO2:=32;MH2O:=18;
```

Molar_mass_in_kg_per_kmole

MCH4 := 16

MC2H6 := 30

MC3H8 := 44

MC4H10 := 58

MCO2 := 44

MN2 := 28

MC := 12

MH2 := 2

MO2 := 32

MH2O := 18

```
> Natural_gas_mole_composition_in_kmole_per_kmole_fuel;
rCH4f:=0.865;rC2H6f:=0.079;rC3H8f:=0.022;rC4H10f:=0.003;rCO2f:=0.005;rN
2f:=0.026;sumrif:=rCH4f+rC2H6f+rC3H8f+rC4H10f+rCO2f+rN2f;Mf:=rCH4f*MCH4
+rC2H6f*MC2H6+rC3H8f*MC3H8+rC4H10f*MC4H10+rCO2f*MCO2+rN2f*MN2;
```

Natural_gas_mole_composition_in_kmole_per_kmole_fuel

rCH4f := 0.865

rC2H6f := 0.079

rC3H8f := 0.022

rC4H10f := 0.003

rCO2f := 0.005

rN2f := 0.026

sumrif := 1.000

Mf := 18.300

>

```
Natural_gas_mass_composition_in_kg_per_kg_fuel;gCH4f:=rCH4f*MCH4/Mf;gC2
H6f:=rC2H6f*MC2H6/Mf;gC3H8f:=rC3H8f*MC3H8/Mf;gC4H10f:=rC4H10f*MC4H10/Mf
```

```
;gCO2f:=rCO2f*MCO2/Mf;gN2f:=rN2f*MN2/Mf;sumgif:=gCH4f+gC2H6f+gC3H8f+gC4
H10f+gCO2f+gN2f;gCf:=MC*(rCH4f+2*rC2H6f+3*rC3H8f+4*rC4H10f)/Mf;gH2f:=MH
2*(2*rCH4f+3*rC2H6f+4*rC3H8f+5*rC4H10f)/Mf;sumgif_C_H2:=gCf+gH2f+gCO2f+
gN2f;
```

Natural_gas_mass_composition_in_kg_per_kg_fuel

gCH4f := 0.756284153

gC2H6f := 0.129508196

gC3H8f := 0.0528961748

gC4H10f := 0.00950819672

gCO2f := 0.0120218579

gN2f := 0.0397814207

sumgif := 1.000000000

gCf := 0.721967213

gH2f := 0.226229508

sumgif_C_H2 := 1.000000000

```
>
Dried_Air_Mole_composition_in_kmole_per_kmole_dair;rO2dair:=0.2059;rN2d
air:=0.7809;rCO2dair:=0.0132;Mdair:=rO2dair*MO2+rN2dair*MN2+rCO2dair*MC
O2;
```

Dried_Air_Mole_composition_in_kmole_per_kmole_dair

rO2dair := 0.2059

rN2dair := 0.7809

rCO2dair := 0.0132

Mdair := 29.0348

```
>
Dried_Air_Mass_composition_in_kg_per_kg_dair;gO2dair:=rO2dair*MO2/Mdair
;gN2dair:=rN2dair*MN2/Mdair;gCO2dair:=rCO2dair*MCO2/Mdair;sumgdair:=gO2
dair+gN2dair+gCO2dair;
```

Dried_Air_Mass_composition_in_kg_per_kg_dair

gO2dair := 0.226927686

gN2dair := 0.753068731

gCO2dair := 0.0200035819

sumgdair := 1.000000000

```
> Humid_Air_Mass_composition_in_kg_per_kg_dair;phi1:=0.5;t1:=T1-
273.15;pvsH2O1:=-.4164460979e-18*t1^10+.2004215749e-
15*t1^9+.6588432820e-3*t1-.4117823023e-13*t1^8-.4560213564e-
4*t1^2+.4719547427e-11*t1^7+.6985705427e-5*t1^3-.3308562609e-9*t1^6-
.4022805689e-6*t1^4+.1465463358e-7*t1^5+.6108e-
2;x1:=MH2O*phi1*pvsH2O1/(p1-phi1*pvsH2O1)/Mdair;
```

Humid_Air_Mass_composition_in_kg_per_kg_dair

$\phi 1$:= 0.5

t1 := 19.85

pvsH2O1 := 0.0231529699

x1 := 0.00773008459

```
>
Humid_Air_Mass_composition_in_kg_per_kg_air;R:=8.3145;gO2air:=gO2dair/(
1+x1);gN2air:=gN2dair/(1+x1);gCO2air:=gCO2dair/(1+x1);gH2Oair:=x1/(1+x1
);sumgair:=gO2air+gN2air+gCO2air+gH2Oair;Rair:=R*(gO2air/MO2+gN2air/MN2
+gCO2air/MCO2+gH2Oair/MH2O);
```

Humid_Air_Mass_composition_in_kg_per_kg_air

R := 8.3145

gO2air := 0.225186972

gN2air := 0.747292099

gCO2air := 0.0198501386

gH2Oair := 0.00767078874

sumgair := 0.999999999

Rair := 0.287709893

```
>
Humid_Air_Mass_flow_rates_in_kg_per_sec;mO2air:=mair*gO2air;mN2air:=mai
r*gN2air;mCO2air:=mair*gCO2air;mH2Oair:=mair*gH2Oair;summair:=mO2air+mN
2air+mCO2air+mH2Oair;
```

Humid_Air_Mass_flow_rates_in_kg_per_sec

$mO2air := 0.900747889$

$mN2air := 2.98916839$

$mCO2air := 0.0794005546$

$mH2Oair := 0.0306831549$

$summair := 3.99999999$

```
>
Stoechiometric_relations_in_kg_per_kg_fuel;mO2min:=MO2*(gCf/MC+gH2f/MH2
/2);mairmin:=mO2min/gO2air;
```

Stoechiometric_relations_in_kg_per_kg_fuel

$mO2min := 3.735081968$

$mairmin := 16.58658103$

```
> First_Flue_gases_mass_flow_rates_in_kg_per_sec;mO2fg1:=mair*gO2air-
mf1*mO2min;mN2fg1:=mair*gN2air+mf1*gN2f;mCO2fg1:=mair*gCO2air+mf1*(MCO2
*gCf/MC+gCO2f);mH2Ofg1:=mair*gH2Oair+mf1*(MH2O*gH2f/MH2);mfg1:=mCO2fg1+
mO2fg1+mN2fg1+mH2Ofg1;mfg_verif1:=mair+mf1*(gN2f+MCO2*gCf/MC+gCO2f+MH2O
*gH2f/MH2-mO2min);
```

First_Flue_gases_mass_flow_rates_in_kg_per_sec

$mO2fg1 := 0.9007478896 - 3.735081968\,mf1$

$mN2fg1 := 2.989168399 + 0.03978142077\,mf1$

$mCO2fg1 := 0.07940055460 + 2.659234973\,mf1$

$mH2Ofg1 := 0.03068315497 + 2.036065574\,mf1$

$mfg1 := 3.999999998 + 1.000000000\,mf1$

$mfg\_verif1 := 4 + 1.000000000\,mf1$

```
>
First_Flue_gases_mass_compozition_in_kg_per_kg;gO2fg1:=mO2fg1/mfg1;gN2f
g1:=mN2fg1/mfg1;gCO2fg1:=mCO2fg1/mfg1;gH2Ofg1:=mH2Ofg1/mfg1;
```

First_Flue_gases_mass_compozition_in_kg_per_kg

$$gO2fg1 := \frac{0.9007478896 - 3.735081968\,mf1}{3.999999998 + 1.000000000\,mf1}$$

$$gN2fg1 := \frac{2.989168399 + 0.03978142077\,mf1}{3.999999998 + 1.000000000\,mf1}$$

$$gCO2fg1 := \frac{0.07940055460 + 2.659234973\,mf1}{3.999999998 + 1.000000000\,mf1}$$

$$gH2Ofg1 := \frac{0.03068315497 + 2.036065574\,mf1}{3.999999998 + 1.000000000\,mf1}$$

```
>
First_Dried_flue_gases_mass_composition_in_kg_per_kg;gO2fgd1:=mO2fg1/(mfg1-mH2Ofg1);gN2fgd1:=mN2fg1/(mfg1-mH2Ofg1);gCO2fgd1:=mCO2fg1/(mfg1-mH2Ofg1);
```

First_Dried_flue_gases_mass_composition_in_kg_per_kg

$$gO2fgd1 := \frac{0.9007478896 - 3.735081968\,mf1}{3.969316843 - 1.036065574\,mf1}$$

$$gN2fgd1 := \frac{2.989168399 + 0.03978142077\,mf1}{3.969316843 - 1.036065574\,mf1}$$

$$gCO2fgd1 := \frac{0.07940055460 + 2.659234973\,mf1}{3.969316843 - 1.036065574\,mf1}$$

```
>
Heating_values_of_fuel_in_kJ_per_kg_fuel;HHV_CH4:=evalf(4.185*212790/MCH4);HHV_C2H6:=evalf(4.185*372810/MC2H6);HHV_C3H8:=evalf(4.185*530570/MC3H8);HHV_C4H10:=evalf(4.185*686310/MC4H10);HHV:=gCH4f*HHV_CH4+gC2H6f*HHV_C2H6+gC3H8f*HHV_C3H8+gC4H10f*HHV_C4H10;
```

Heating_values_of_fuel_in_kJ_per_kg_fuel

$$HHV\_CH4 := 55657.8843$$

$$HHV\_C2H6 := 52006.9950$$

$$HHV\_C3H8 := 50464.4420$$

$$HHV\_C4H10 := 49520.8163$$

$$HHV := 51968.7377$$

```
> cpO2:=0.82397+3.05587E-4*T+5.32089E-8*T^2-1.30137E-10*T^3+3.58225E-14*T^4;cvO2:=0.56574+2.96923E-4*T+6.54515E-8*T^2-1.36918E-10*T^3+3.71407E-14*T^4;cpH2O:=1.84336-2.31223E-4*T+1.1966E-6*T^2-6.15263E-10*T^3+1.0015E-13*T^4;cvH2O:=1.38161-2.29361E-4*T+1.19327E-6*T^2-6.13657E-10*T^3+9.99765E-14*T^4;cpN2:=1.07623-3.25964E-4*T+7.92186E-7*T^2-4.66137E-10*T^3+8.87148E-14*T^4;cvN2:=0.77884-3.22759E-4*T+7.86981E-7*T^2-4.62795E-10*T^3+8.79811E-14*T^4;cpCO2:=0.46236+0.0016*T-1.2402E-6*T^2+4.78609E-10*T^3-7.32796E-14*T^4;cvCO2:=0.27337+0.0016*T-1.24189E-6*T^2+4.79536E-10*T^3-7.34111E-
```

```
14*T^4;cpCH4:=0.18537+0.00191*T-3.13681E-6*T^2+2.2951E-
9*T^3;cpair:=gO2air*cpO2+gN2air*cpN2+gCO2air*cpCO2+gH2Oair*cpH2O;cvair:
=gO2air*cvO2+gN2air*cvN2+gCO2air*cvCO2+gH2Oair*cvH2O;cpC2H6:=4.185*(1.6
2+42.1E-3*T-13.9E-6*T^2)/MC2H6;cpC3H8:=4.185*(0.12+64.47E-3*T-22.76E-
6*T^2)/MC3H8;cpC4H10:=1.25*4.185*(0.12+64.47E-3*T-22.76E-6*T^2)/MC4H10;
```

$$cpO2 := 0.82397 + 0.000305587T + 5.3208910^{-8}\,T^2 - 1.3013710^{-10}\,T^3 + 3.5822510^{-14}\,T^4$$

$$cvO2 := 0.56574 + 0.000296923T + 6.5451510^{-8}\,T^2 - 1.3691810^{-10}\,T^3 + 3.7140710^{-14}\,T^4$$

$$cpH2O := 1.84336 - 0.000231223T + 0.00000119667T^2 - 6.1526310^{-10}\,T^3 + 1.001510^{-13}\,T^4$$

$$cvH2O := 1.38161 - 0.000229361T + 0.00000119327T^2 - 6.1365710^{-10}\,T^3 + 9.9976510^{-14}\,T^4$$

$$cpN2 := 1.07623 - 0.000325964T + 7.9218610^{-7}\,T^2 - 4.6613710^{-10}\,T^3 + 8.8714810^{-14}\,T^4$$

$$cvN2 := 0.77884 - 0.000322759T + 7.8698110^{-7}\,T^2 - 4.6279510^{-10}\,T^3 + 8.7981110^{-14}\,T^4$$

$$cpCO2 := 0.46236 + 0.0016\,T - 0.00000124027T^2 + 4.7860910^{-10}\,T^3 - 7.3279610^{-14}\,T^4$$

$$cvCO2 := 0.27337 + 0.0016\,T - 0.00000124189T^2 + 4.7953610^{-10}\,T^3 - 7.3411110^{-14}\,T^4$$

$$cpCH4 := 0.18537 + 0.00191\,T - 0.000003136817^2 + 2.29511\,0^{-9}\,T^3$$

$$cpair := 1.013123421 - 0.0001447895516T + 5.8853701441\,0^{-7}\,T^2 - 3.7286475201\,0^{-10}\,T^3 + 7.3676248771\,0^{-14}\,T^4$$

$$cvair := 0.7254427276 - 0.00014433121737T + 5.87345142510^{-7}\,T^2 - 3.71863574310^{-10}\,T^3 + 7.34208608410^{-14}\,T^4$$

$$cpC2H6 := 0.2259900000 + 0.005872949999T - 0.0000019390500007T^2$$

$$cpC3H8 := 0.01141363636 + 0.006131976138T - 0.0000021647863647T^2$$

$$cpC4H10 := 0.01082327586 + 0.005814804956T - 0.0000020528146557T^2$$

```
>
cplw:=4.185;mlw1:=0;eqca1:=0.95*mf1*HHV+mf1*(gCH4f*int(cpCH4,T=T0..T1)+
gC2H6f*int(cpC2H6,T=T0..T1)+gC3H8f*int(cpC3H8,T=T0..T1)+gC4H10f*int(cpC
4H10,T=T0..T1))+mO2air*int(cpO2,T=T0..T1)+mN2air*int(cpN2,T=T0..T1)+mCO
2air*int(cpCO2,T=T0..T1)+mH2Oair*(int(cpH2O,T=T0..T1)+l0)+mlw1*int(cplw
,T=T0..T1)-mN2fg1*int(cpN2,T=T0..T2)-mCO2fg1*int(cpCO2,T=T0..T2)-
(mH2Ofg1+mlw1)*(int(cpH2O,T=T0..T2)+l0)-
mO2fg1*int(cpO2,T=T0..T2)=0;mfv1:=solve(eqca1,mf1);Qfuel1:=mfv1*HHV;
```

$$cplw := 4.185$$

$$mlw1 := 0$$

$$eqca1 := 39886.26112\,mf1 - 5322.718235 = 0$$

$$mfv1 := 0.133447409$$

$$Qfuel1 := 6935.09343$$

```
>
First_Flue_gases_mass_flow_rates_values_in_kg_per_sec;mO2fgv1:=mair*gO2
air-
mfv1*mO2min;mN2fgv1:=mair*gN2air+mfv1*gN2f;mCO2fgv1:=mair*gCO2air+mfv1*
(MCO2*gCf/MC+gCO2f);mH2Ofgv1:=mair*gH2Oair+mfv1*(MH2O*gH2f/MH2)+mlw1;mf
gv1:=mCO2fgv1+mO2fgv1+mN2fgv1+mH2Ofgv1;mfg_verifv:=mair+mlw1+mfv1*(gN2f
+MCO2*gCf/MC+gCO2f+MH2O*gH2f/MH2-
mO2min);coef_stoechiometric1:=mfgv1/mairmin;
```

First_Flue_gases_mass_flow_rates_values_in_kg_per_sec

mO2fgv1 := 0.402310875

mN2fgv1 := 2.99447712

mCO2fgv1 := 0.434268573

mH2Ofgv1 := 0.302390832

mfgv1 := 4.133447408

mfg_verifv := 4.133447410

coef_stoechiometric1 := 0.249204305

>

```
First_Flue_gases_mass_compozition_values_in_kg_per_kg;gO2fgv1:=mO2fgv1/mfgv1;gN2fgv1:=mN2fgv1/mfgv1;gCO2fgv1:=mCO2fgv1/mfgv1;gH2Ofgv1:=mH2Ofgv1/mfgv1;sumgfgv1:=gO2fgv1+gN2fgv1+gCO2fgv1+gH2Ofgv1;
```

First_Flue_gases_mass_compozition_values_in_kg_per_kg

gO2fgv1 := 0.0973305901

gN2fgv1 := 0.724450278

gCO2fgv1 := 0.105062078

gH2Ofgv1 := 0.0731570532

sumgfgv1 := 1.000000000

>

```
First_Flue_gases_mole_compozition_values_in_kmole_per_kmole;rO2fgv1:=gO2fgv1/MO2/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/MH2O);rN2fgv1:=gN2fgv1/MN2/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/MH2O);rCO2fgv1:=gCO2fgv1/MCO2/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/MH2O);rH2Ofgv1:=gH2Ofgv1/MH2O/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/MH2O);sumrfgv1:=rO2fgv1+rN2fgv1+rCO2fgv1+rH2Ofgv1;
```

First_Flue_gases_mole_compozition_values_in_kmole_per_kmole

rO2fgv1 := 0.0860008750

rN2fgv1 := 0.731566894

rCO2fgv1 := 0.0675144605

rH2Ofgv1 := 0.114917770

sumrfgv1 := 1.000000000

```
>
First_Dried_Flue_gases_mass_compozition_values_in_kg_per_kg;gO2dfgv1:=mO2fgv1/(mO2fgv1+mN2fgv1+mCO2fgv1);gN2dfgv1:=mN2fgv1/(mO2fgv1+mN2fgv1+mCO2fgv1);gCO2dfgv1:=mCO2fgv1/(mO2fgv1+mN2fgv1+mCO2fgv1);sumgdfgv1:=gO2dfgv1+gN2dfgv1+gCO2dfgv1;
```

First_Dried_Flue_gases_mass_compozition_values_in_kg_per_kg

gO2dfgv1 := 0.105013034

gN2dfgv1 := 0.781632186

gCO2dfgv1 := 0.113354779

sumgdfgv1 := 0.999999999

```
> Rair:=int((cpair-cvair),T=T1..T2)/(T2-T1);RO2:=int((cpO2-cvO2),T=T1..T2)/(T2-T1);RN2:=int((cpN2-cvN2),T=T1..T2)/(T2-T1);RCO2:=int((cpCO2-cvCO2),T=T1..T2)/(T2-T1);RH2O:=int((cpH2O-cvH2O),T=T1..T2)/(T2-T1);
```

Rair := 0.287646633

RO2 := 0.260118272

RN2 := 0.296756205

RCO2 := 0.189735137

RH2O := 0.461693151

```
>
Rfgv1:=gO2fgv1*RO2+gN2fgv1*RN2+gCO2fgv1*RCO2+gH2Ofgv1*RH2O;Rdfgv1:=gO2dfgv1*RO2+gN2dfgv1*RN2+gCO2dfgv1*RCO2;
```

Rfgv1 := 0.294012658

Rdfgv1 := 0.280777395

```
> Second_Flue_gases_mass_flow_rates_in_kg_per_sec;mO2fg2:=mO2fgv1-mf2*mO2min;mN2fg2:=mN2fgv1+mf2*gN2f;mCO2fg2:=mCO2fgv1+mf2*(MCO2*gCf/MC+gCO2f);mH2Ofg2:=mH2Ofgv1+mf2*(MH2O*gH2f/MH2);mfg2:=mCO2fg2+mO2fg2+mN2fg2+mH2Ofg2;mfg_verif2:=mfgv1+mf2*(gN2f+MCO2*gCf/MC+gCO2f+MH2O*gH2f/MH2-mO2min);
```

Second_Flue_gases_mass_flow_rates_in_kg_per_sec

mO2fg2 := 1.005721359 − 3.735081968 *mf2*

$mN2fg2 := 3.435336272 + 0.03978142077 mf2$

$mCO2fg2 := 0.1121605930 + 2.659234973 mf2$

$mH2Ofg2 := 0.05464753373 + 2.036065574 mf2$

$mfg2 := 4.607865758 + 1.000000000 mf2$

$mfg\_verif2 := 4.607865758 + 1.000000000 mf2$

>

```
mlw2:=0;eqca2:=0.95*mf2*HHV+mf2*(gCH4f*int(cpCH4,T=T0..T1)+gC2H6f*int(cpC2H6,T=T0..T1)+gC3H8f*int(cpC3H8,T=T0..T1)+gC4H10f*int(cpC4H10,T=T0..T1))+mN2fgv1*int(cpN2,T=T0..T9r)+mCO2fgv1*int(cpCO2,T=T0..T9r)+mlw2*int(cplw,T=T0..T1)+mH2Ofgv1*(int(cpH2O,T=T0..T9r)+l0)+mO2fgv1*int(cpO2,T=T0..T9r)-mN2fg2*int(cpN2,T=T0..T10r)-mCO2fg2*int(cpCO2,T=T0..T10r)-(mH2Ofg2+mlw2)*(int(cpH2O,T=T0..T10r)+l0)-mO2fg2*int(cpO2,T=T0..T10r)=0;mfv2:=solve(eqca2,mf2);Qfuel2:=mfv2*HHV;
```

$mlw2 := 0$

$eqca2 := 41349.22464 mf2 - 354.7447349 = 0$

$mfv2 := 0.00857923547$

$Qfuel2 := 445.852038$

>

```
Second_Flue_gases_mass_flow_rates_values_in_kg_per_sec;mO2fgv2:=mO2fgv1-mfv2*mO2min;mN2fgv2:=mN2fgv1+mfv2*gN2f;mCO2fgv2:=mCO2fgv1+mfv2*(MCO2*gCf/MC+gCO2f);mH2Ofgv2:=mH2Ofgv1+mfv2*(MH2O*gH2f/MH2)+mlw2;mfgv2:=mCO2fgv2+mO2fgv2+mN2fgv2+mH2Ofgv2;mfg_verifv2:=mfgv1+mlw2+mfv2*(gN2f+MCO2*gCf/MC+gCO2f+MH2O*gH2f/MH2-mO2min);coef_stoechiometric1:=mfgv2/mairmin;
```

Second_Flue_gases_mass_flow_rates_values_in_kg_per_sec

$mO2fgv2 := 0.973677211$

$mN2fgv2 := 3.43567756$

$mCO2fgv2 := 0.134974796$

$mH2Ofgv2 := 0.0721154197$

$mfgv2 := 4.61644499$

$mfg\_verifv2 := 4.61644499$

coef_stoechiometric1 := 0.278120026:

>

```
Second_Flue_gases_mass_compozition_values_in_kg_per_kg;gO2fgv2:=mO2fgv2/mfgv2;gN2fgv2:=mN2fgv2/mfgv2;gCO2fgv2:=mCO2fgv2/mfgv2;gH2Ofgv2:=mH2Ofgv2/mfgv2;
```

Second_Flue_gases_mass_compozition_values_in_kg_per_kg

gO2fgv2 := 0.210914938

gN2fgv2 := 0.744225821

gCO2fgv2 := 0.0292378217

gH2Ofgv2 := 0.0156214186

>

```
Second_Flue_gases_mole_compozition_values_in_kmole_per_kmole;rO2fgv2:=gO2fgv2/MO2/(gO2fgv2/MO2+gN2fgv2/MN2+gCO2fgv2/MCO2+gH2Ofgv2/MH2O);rN2fgv2:=gN2fgv2/MN2/(gO2fgv2/MO2+gN2fgv2/MN2+gCO2fgv2/MCO2+gH2Ofgv2/MH2O);rCO2fgv2:=gCO2fgv2/MCO2/(gO2fgv2/MO2+gN2fgv2/MN2+gCO2fgv2/MCO2+gH2Ofgv2/MH2O);rH2Ofgv2:=gH2Ofgv2/MH2O/(gO2fgv2/MO2+gN2fgv2/MN2+gCO2fgv2/MCO2+gH2Ofgv2/MH2O);sumrfgv2:=rO2fgv2+rN2fgv2+rCO2fgv2+rH2Ofgv2;
```

Second_Flue_gases_mole_compozition_values_in_kmole_per_kmole

rO2fgv2 := 0.189928928:

rN2fgv2 := 0.765914794:

rCO2fgv2 := 0.0191481179

rH2Ofgv2 := 0.0250081589

sumrfgv2 := 1.000000000

>

```
Second_Dried_Flue_gases_mass_compozition_values_in_kg_per_kg;gO2dfgv2:=mO2fgv2/(mO2fgv2+mN2fgv2+mCO2fgv2);gN2dfgv2:=mN2fgv2/(mO2fgv2+mN2fgv2+mCO2fgv2);gCO2dfgv2:=mCO2fgv2/(mO2fgv2+mN2fgv2+mCO2fgv2);sumgdfgv2:=gO2dfgv2+gN2dfgv2+gCO2dfgv2;
```

Second_Dried_Flue_gases_mass_compozition_values_in_kg_per_k \
g

gO2dfgv2 := 0.214262015

$gN2dfgv2 := 0.756036178$

$gCO2dfgv2 := 0.0297018061$

$sumgdfgv2 := 1.000000000$

>

```
Rfgv2:=gO2fgv2*RO2+gN2fgv2*RN2+gCO2fgv2*RCO2+gH2Ofgv2*RH2O;Rdfgv2:=gO2d
fgv2*RO2+gN2dfgv2*RN2+gCO2dfgv2*RCO2;
```

$Rfgv2 := 0.288480830$

$Rdfgv2 := 0.285733467$

>

```
dh78t:=mCO2fgv1*int(cpCO2,T=T7r..T8)+mN2fgv1*int(cpN2,T=T7r..T8)+mH2Ofg
v1*(int(cpH2O,T=T7r..T8)+l0)+mO2fgv1*int(cpO2,T=T7r..T8);du78t:=mCO2fgv
1*int(cvCO2,T=T7r..T8)+mN2fgv1*int(cvN2,T=T7r..T8)+mH2Ofgv1*(int(cvH2O,
T=T7r..T8)+u0)+mO2fgv1*int(cpO2,T=T7r..T8);k78t:=dh78t/du78t;eq78t:=T8-
T7r*(p8/p7)^((k78t-1)/k78t)=0;T8t:=fsolve(eq78t,T8);
```

$$dh78t := 4.678489834\,T8 - 5480.984425 - 0.0003228196987\,T8^2 + 9.00409432910^{-7}\,T8^3 - 4.28040110210^{-10}\,T8^4 + 6.76092981610^{-14}\,T8^5$$

$$du78t := 3.610424451\,T8 - 4279.734220 - 0.0003172636955\,T8^2 + 8.94325281910^{-7}\,T8^3 - 4.25121952510^{-10}\,T8^4 + 6.71003508310^{-14}\,T8^5$$

$$k78t := \left(4.678489834\,T8 - 5480.984425 - 0.0003228196987\,T8^2 + 9.00409432910^{-7}\,T8^3 - 4.28040110210^{-10}\,T8^4 + 6.76092981610^{-14}\,T8^5\right) \Big/ \left(3.610424451\,T8 - 4279.734220 - 0.0003172636955\,T8^2 + 8.94325281910^{-7}\,T8^3 - 4.25121952510^{-10}\,T8^4 + 6.71003508310^{-14}\,T8^5\right)$$

$$eq78t := T8 - 1133.15\left(\left(\left(4.678489834\,T8 - 5480.984425\right) 0.3397513034 - 0.0003228196987\,T8^2 + 9.004094329\,10^{-7}\,T8^3 - 4.280401102\,10^{-10}\,T8^4 + 6.760929816\,10^{-14}\,T8^5\right) \Big/ \left(3.610424451\,T8 - 4279.734220 - 0.0003172636955\,T8^2 + 8.943252819\,10^{-7}\,T8^3 - 4.251219525\,10^{-10}\,T8^4 + 6.710035083\,10^{-14}\,T8^5\right) - 1\right)\left(3.610424451\,T8 - 4279.734220 - 0.0003172636955\,T8^2 + 8.943252819\,10^{-7}\,T8^3 - 4.251219525\,10^{-10}\,T8^4 + 6.710035083\,10^{-14}\,T8^5\right)\Big/\left(4.678489834\,T8 - 5480.984425 - 0.0003228196987\,T8^2 + 9.004094329\,10^{-7}\,T8^3 - 4.280401102\,10^{-10}\,T8^4 + 6.760929816\,10^{-14}\,T8^5\right) = 0$$

$$T8t := 897.172380$$

```
>
dh78t:=mCO2fgv1*int(cpCO2,T=T7r..T8t)+mN2fgv1*int(cpN2,T=T7r..T8t)+mH2O
fgv1*(int(cpH2O,T=T7r..T8t)+l0)+mO2fgv1*int(cpO2,T=T7r..T8t);dh78r:=mCO
2fgv1*int(cpCO2,T=T7r..T8)+mN2fgv1*int(cpN2,T=T7r..T8)+mH2Ofgv1*(int(cp
H2O,T=T7r..T8)+l0)+mO2fgv1*int(cpO2,T=T7r..T8);;eq78r:=dh78r/dh78t-
etat1=0;T8r:=fsolve(eq78r,T8);t8r:=T8r-273.15;
```

$$dh78t := -1131.20994$$

$$dh78r := 4.6784898347T8 - 5480.984425 - 0.0003228196987T8^2 + 9.00409432910^{-7}\,T8^3 - 4.28040110210^{-10}\,T8^4 + 6.76092981610^{-14}\,T8^5$$

$$eq78r := -0.00413582807\,3T8 + 3.895240677 + 2.85375584810^{-7}\,T8^2 - 7.95970225810^{-10}\,T8^3 + 3.78391397010^{-13}\,T8^4 - 5.97672418310^{-17}\,T8^5 = 0$$

$$T8r := 907.921882$$

$$t8r := 634.771882$$

```
>
cpfgv1:=gN2fgv1*cpN2+gO2fgv1*cpO2+gCO2fgv1*cpCO2+gH2Ofgv1*cpH2O;Pt1:=-
etam*mfgv1*int(cpfgv1,T=T7r..T8r);Pc12:=-
mair*(int(cpair,T=T1..T2r)+int(cpair,T=T3r..T4r));
```

$$cpfgv1 := 1.015326852 - 0.00014011679\,85T + 5.86221136010^{-7}\,T^2 - 3.71573420510^{-10}\,T^3 + 7.33629208310^{-14}\,T^4$$

$$Pt1 := 1199.15559$$

$$Pc12 := -1199.022230$$

```
>
dh1011t:=mCO2fgv2*int(cpCO2,T=T10r..T11)+mN2fgv2*int(cpN2,T=T10r..T11)+
mH2Ofgv2*(int(cpH2O,T=T10r..T11)+l0)+mO2fgv2*int(cpO2,T=T10r..T11);du10
11t:=mCO2fgv2*int(cvCO2,T=T10r..T11)+mN2fgv2*int(cvN2,T=T10r..T11)+mH2O
fgv2*(int(cvH2O,T=T10r..T11)+u0)+mO2fgv2*int(cpO2,T=T10r..T11);k1011t:=
dh1011t/du1011t;eq1011t:=T11-T10r*(p11/p10)^((k1011t-
1)/k1011t)=0;T11t:=fsolve(eq1011t,T11);
```

$$dh1011t := 4.695201706T11 - 5495.385028 - 0.000311539587\,1T11^2 + 8.97467176910^{-7}\,T11^3 - 4.26994415610^{-10}\,T11^4 + 6.74012920610^{-14}\,T11^5$$

$$du1011t := 3.614657373T11 - 4276.794476 - 0.000305966774\,4T11^2 + 8.91350192510^{-7}\,T11^3 - 4.24063672210^{-10}\,T11^4 + 6.68910884810^{-14}\,T11^5$$

$$k1011t := (4.695201706T11 - 5495.385028 - 0.0003115395871T11^2 + 8.97467176910^{-7}\,T11^3 - 4.2699441561 0^{-10}\,T11^4 + 6.7401292061 0^{-14}\,T11^5) / (3.614657373T11 - 4276.794476 - 0.0003059667744T11^2 + 8.9135019251 0^{-7}\,T11^3 - 4.2406367221 0^{-10}\,T11^4 + 6.6891088481 0^{-14}\,T11^5)$$

$$eq1011t := T11 - 1138.15 \left(\left(\left(4.695201706\,T11 - 5495.385028\right) 0.3522723927 - 0.0003115395871\,T11^2 + 8.974671769\,10^{-7}\,T11^3 - 4.269944156\,10^{-10}\,T11^4 + 6.740129206\,10^{-14}\,T11^5\right) / \left(3.614657373\,T11 - 4276.794476 - 0.0003059667744\,T11^2 + 8.913501925\,10^{-7}\,T11^3 - 4.240636722\,10^{-10}\,T11^4 + 6.689108848\,10^{-14}\,T11^5\right) - 1\right) \left(3.614657373\,T11 - 4276.794476 - 0.0003059667744\,T11^2 + 8.913501925\,10^{-7}\,T11^3 - 4.240636722\,10^{-10}\,T11^4 + 6.689108848\,10^{-14}\,T11^5\right) \Big/ \left(4.695201706\,T11 - 5495.385028 - 0.0003115395871\,T11^2 + 8.974671769\,10^{-7}\,T11^3 - 4.269944156\,10^{-10}\,T11^4 + 6.740129206\,10^{-14}\,T11^5\right) = 0$$

$$T11t := 901.220433$$

```
>
dh1011t:=mCO2fgv2*int(cpCO2,T=T10r..T11t)+mN2fgv2*int(cpN2,T=T10r..T11t
)+mH2Ofgv2*(int(cpH2O,T=T10r..T11t)+l0)+mO2fgv2*int(cpO2,T=T10r..T11t);
dh1011r:=mCO2fgv2*int(cpCO2,T=T10r..T11)+mN2fgv2*int(cpN2,T=T10r..T11)+
mH2Ofgv2*(int(cpH2O,T=T10r..T11)+l0)+mO2fgv2*int(cpO2,T=T10r..T11);eq10
11r:=dh1011r/dh1011t-etat2=0;T11r:=fsolve(eq1011r,T11);t11r:=T11r-
273.15;
```

$$dh1011t := -1101.68980$$

$$dh1011r := 4.695201706\,T11 - 5495.385028 - 0.0003115395871\,T11^2 + 8.97467176910^{-7}\,T11^3 - 4.2699441561\,0^{-10}\,T11^4 + 6.7401292061\,0^{-14}\,T11^5$$

$$eq1011r := -0.004261818225\,T11 + 4.038141837 + 2.8278339741\,0^{-7}\,T11^2 - 8.1462782861\,0^{-10}\,T11^3 + 3.8758134291\,0^{-13}\,T11^4 - 6.1179917901\,0^{-17}\,T11^5 = 0$$

$T11r := 911.617594$

$t11r := 638.467594$

```
> cpfgv2:=gN2fgv2*cpN2+gO2fgv2*cpO2+gCO2fgv2*cpCO2+gH2Ofgv2*cpH2O;Pel:=-
etam*etael*mfgv2*int(cpfgv2,T=T10r..T11r);DP:=100*(Pel-1200)/1200;
```

$$cpfgv2 := 1.017060035 - 0.0001349694787\,T + 5.8321967121\,0^{-7}\,T^2 - 3.6997682511\,0^{-10}\,T^3 + 7.3001294441\,0^{-14}\,T^4$$

$Pel := 1202.47868$

$DP := 0.206557$

```
> eqrec:=mfgv2*int(cpfgv2,T=T12r..T11r)-
mair*int(cpair,T=T4r..T5)=0;T5r:=fsolve(eqrec,T5);t5r:=T5r-273.15;
```

$$eqrec := 4094.222169 - 4.663167775\,T5 + 0.0003331617204\,T5^2 - 9.0310700141\,0^{-7}\,T5^3 + 4.2899884141\,0^{-10}\,T5^4 - 6.7800005821\,0^{-14}\,T5^5 = 0$$

$T5r := 852.022832$

$t5r := 578.872832$

```
> t1:=T1-
273.15;t13:=90;T13:=t13+273.15;T13r:=T13;saturation_pressure_of_water_v
apor;p_in_bar;t_in_degrees_Celsius; pvsH2O1:=-.4164460979e-
18*t1^10+.2004215749e-15*t1^9+.6588432820e-3*t1-.4117823023e-13*t1^8-
.4560213564e-4*t1^2+.4719547427e-11*t1^7+.6985705427e-5*t1^3-
.3308562609e-9*t1^6-.4022805689e-6*t1^4+.1465463358e-7*t1^5+.6108e-
2;xsfgv21:=Rdfgv2*pvsH2O1/(p1-pvsH2O1)/RH2O;pvsH2O13:=-.4164460979e-
```

```
18*t13^10+.2004215749e-15*t13^9+.6588432820e-3*t13-.4117823023e-
13*t13^8-.4560213564e-4*t13^2+.4719547427e-11*t13^7+.6985705427e-
5*t13^3-.3308562609e-9*t13^6-.4022805689e-6*t13^4+.1465463358e-
7*t13^5+.6108e-2;xsfgv213:=Rdfgv2*pvsH2O13/(p12-pvsH2O13)/RH2O;
```

t1 := 25.00

t13 := 90

T13 := 363.15

T13r := 363.15

saturation_pressure_of_water_vapor

p_in_bar

t_in_degrees_Celsius

pvsH2O1 := 0.031672113

xsfgv21 := 0.0215836565

pvsH2O13 := 0.70110010

xsfgv213 := 1.78135895

```
> LHV:=HHV-mH2Ofgv2*l0/(mfv1+mfv2);
```

LHV := 41005.6114

```
> xfgv2:=mH2Ofgv2/(mO2fgv2+mCO2fgv2+mN2fgv2);dxfgv2:=xfgv2-xsfgv21;
```

xfgv2 := 0.0158693199

dxfgv2 := −0.0057143366

```
> mH2Ofgv2_cond:=(mN2fgv2+mCO2fgv2+mO2fgv2)*(xfgv2-xsfgv21);
```

mH2Ofgv2_cond := −0.0259678291

```
>
```

```
Qfuel:=Qfuel1+Qfuel2;Q:=Qfuel+mair*int(cpair,T=T5r..T6r)+mfgv1*int(cpfg
v1,T=T8r..T9r);Q0:=mN2fgv2*int(cpN2,T=T12r..T1)+mO2fgv2*int(cpO2,T=T12r
..T1)+mCO2fgv2*int(cpCO2,T=T12r..T1)+mH2Ofgv2*(int(cpH2O,T=T12r..T1))+m
air*int(cpair,T=T2r..T3r);Q0rec:=mfgv2*int(cpfgv2,T=T12r..T1)+mair*int(
cpair,T=T2r..T3r);P:=mfgv2*int(cpfgv2,T=T11r..T10r);eft:=P/Q;efel:=Pel/
Q;
```

Qfuel := 854.625601

Q := 2908.60214

$Q0 := -1542.24136$

$Q0rec := -1542.24136$

$P := 1226.89387$

$eft := 0.421815638$

$efel := 0.413421507$

```
>
```

```
h1:=int(cpair,T=T0..T1);h2t:=int(cpair,T=T0..T2t);h2r:=int(cpair,T=T0..T2r);h3r:=int(cpair,T=T0..T3r);h4t:=int(cpair,T=T0..T4t);h4r:=int(cpair,T=T0..T4r);h5r:=int(cpair,T=T0..T5r);h6r:=int(cpair,T=T0..T6r);h7r:=int(cpfgv1,T=T0..T7r);h8t:=int(cpfgv1,T=T0..T8t);h8r:=int(cpfgv1,T=T0..T8r);h9r:=int(cpfgv1,T=T0..T9r);h10r:=int(cpfgv2,T=T0..T10r);h11t:=int(cpfgv2,T=T0..T11t);h11r:=int(cpfgv2,T=T0..T11r);h12r:=int(cpfgv2,T=T0..T12r);
```

$h1 := 25.3056305$

$h2t := 139.064322$

$h2r := 159.139385$

$h3r := 26.3192842$

$h4t := 132.850815$

$h4r := 153.142536$

$h5r := 615.046771$

$h6r := 869.402192$

$h7r := 943.536454$

$h8t := 668.391985$

$h8r := 680.666756$

$h9r := 872.499951$

$h10r := 953.202657$

$h11t := 675.504480$

$h11r := 687.436710$

$h12r := 227.177899$

```
>
```

```
Final_1_Flue_gases_mass_compozition_values_in_kg_per_kg;gO2fgv1:=mO2fgv
```

```
/(mfgv-mH2Ofgv+mH2Ofg_rest1);gN2fgv1:=mN2fgv/(mfgv-
mH2Ofgv+mH2Ofg_rest1);gCO2fgv1:=mCO2fgv/(mfgv-
mH2Ofgv+mH2Ofg_rest1);gH2Ofgv1:=mH2Ofg_rest1/(mfgv-
mH2Ofgv+mH2Ofg_rest1);sumfg1:=gO2fgv1+gN2fgv1+gCO2fgv1+gH2Ofgv1;
```

Final_1_Flue_gases_mass_compozition_values_in_kg_per_kg

$$gO2fgv1 := \frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1}$$

$$gN2fgv1 := \frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1}$$

$$gCO2fgv1 := \frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1}$$

$$gH2Ofgv1 := \frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1}$$

$$sumfg1 := \frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1}$$

```
>
Final_1_Flue_gases_mole_compozition_values_in_kmole_per_kmole;rO2fgv1:=
gO2fgv1/MO2/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/MH2O);rN2fg
v1:=gN2fgv1/MN2/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/MH2O);r
CO2fgv1:=gCO2fgv1/MCO2/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH2Ofgv1/
MH2O);rH2Ofgv1:=gH2Ofgv1/MH2O/(gO2fgv1/MO2+gN2fgv1/MN2+gCO2fgv1/MCO2+gH
2Ofgv1/MH2O);sumrfg1:=rO2fgv1+rN2fgv1+rCO2fgv1+rH2Ofgv1;
```

Final_1_Flue_gases_mole_compozition_values_in_kmole_per_kmol

e

$$rO2fgv1 := \frac{1}{32}\, mO2fgv \Big/ \Bigg((mfgv - mH2Ofgv + mH2Ofg\_rest1)\left(\frac{1}{32}\,\frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{28}\,\frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{44}\,\frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{18}\,\frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Bigg)$$

$$rN2fgv1 := \frac{1}{28}\, mN2fgv \Big/ \Bigg((mfgv - mH2Ofgv + mH2Ofg\_rest1)\left(\frac{1}{32}\,\frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{28}\,\frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{44}\,\frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{18}\,\frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Bigg)$$

$$rCO2fgv1 := \frac{1}{44}\, mCO2fgv \Big/ \Bigg((mfgv - mH2Ofgv + mH2Ofg\_rest1)\left(\frac{1}{32}\,\frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{28}\,\frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{44}\,\frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{18}\,\frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Bigg)$$

$$rH2Ofgv1 := \frac{1}{18}\, mH2Ofg\_rest1 \Big/ \Bigg((mfgv - mH2Ofgv + mH2Ofg\_rest1)\left(\frac{1}{32}\,\frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{28}\,\frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{44}\,\frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} + \frac{1}{18}\,\frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Bigg)$$

$$
\begin{aligned}
sumrfg1 := & \frac{1}{32}\, mO2fgv \Big/ \Big((mfgv - mH2Ofgv \\
& + mH2Ofg\_rest1 \,) \left(\frac{1}{32} \frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right. \\
& + \frac{1}{28} \frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& + \frac{1}{44} \frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& \left. + \frac{1}{18} \frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Big) \\
& + \frac{1}{28}\, mN2fgv \Big/ \Big((mfgv - mH2Ofgv \\
& + mH2Ofg\_rest1 \,) \left(\frac{1}{32} \frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right. \\
& + \frac{1}{28} \frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& + \frac{1}{44} \frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& \left. + \frac{1}{18} \frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Big) \\
& + \frac{1}{44}\, mCO2fgv \Big/ \Big((mfgv - mH2Ofgv \\
& + mH2Ofg\_rest1 \,) \left(\frac{1}{32} \frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right. \\
& + \frac{1}{28} \frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& + \frac{1}{44} \frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& \left. + \frac{1}{18} \frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Big) \\
& + \frac{1}{18}\, mH2Ofg\_rest1 \Big/ \Big((mfgv - mH2Ofgv \\
& + mH2Ofg\_rest1 \,) \left(\frac{1}{32} \frac{mO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right. \\
& + \frac{1}{28} \frac{mN2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& + \frac{1}{44} \frac{mCO2fgv}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \\
& \left. + \frac{1}{18} \frac{mH2Ofg\_rest1}{mfgv - mH2Ofgv + mH2Ofg\_rest1} \right) \Big)
\end{aligned}
$$

>

```
p0N2:=rN2air*p0;p0O2:=rO2air*p0;p0CO2:=rCO2air*p0;p0H2O:=pv0;p4tN2:=rN2fgv*p4t;p4tO2:=rO2fgv*p4t;p4tCO2:=rCO2fgv*p4t;p4tH2O:=rH2Ofgv*p4t;sump4t:=p4tN2+p4tO2+p4tCO2+p4tH2O=p3r;p4rN2:=rN2fgv*p4r;p4rO2:=rO2fgv*p4r;p4rCO2:=rCO2fgv*p4r;p4rH2O:=rH2Ofgv*p4r;sump4r:=p4rN2+p4rO2+p4rCO2+p4rH2O=p4r;p5tN2:=rN2fgv*p5t;p5tO2:=rO2fgv*p5t;p5tCO2:=rCO2fgv*p5t;p5tH2O:=rH2Ofgv*p5t;sump5t:=p5tN2+p5tO2+p5tCO2+p5tH2O=p5t;p5rN2:=rN2fgv*p5r;p5rO2:=rO2fgv*p5r;p5rCO2:=rCO2fgv*p5r;p5rH2O:=rH2Ofgv*p5r;sump5r:=p5rN2+p5rO2+p5rCO2+p5rH2O=p5r;p6tN2:=rN2fgv*p6t;p6tO2:=rO2fgv*p6t;p6tCO2:=rCO2fgv*p6t;p6tH2O:=rH2Ofgv*p6t;sump6t:=p6tN2+p6tO2+p6tCO2+p6tH2O=p6t;p6rN2:=rN2fgv*p6r;p6rO2:=rO2fgv*p6r;p6rCO2:=rCO2fgv*p6r;p6rH2O:=rH2Ofgv*p6r;sump6r:=p6rN2+p6rO2+p6rCO2+p6rH2O=p6r;p7tN2:=rN2fgv*p7t;p7tO2:=rO2fgv*p7t;p7tCO2:=rCO2fgv*p7t;p7tH2O:=rH2Ofgv*p7t;sump7t:=p7tN2+p7tO2+p7tCO2+p7tH2O=p7t;p7rN2:=rN2fgv*p7r;p7rO2:=rO2fgv*p7r;p7rCO2:=rCO2fgv*p7r;p7rH2O:=rH2Ofgv*p7r;sump7r:=p7rN2+p7rO2+p7rCO2+p7rH2O=p7r;p1N2:=rN2fgv1*p1;p1O2:=rO2fgv1*p1;p1CO2:=rCO2fgv1*p1;p1H2O:=rH2Ofgv1*p1;sump1fg:=p1N2+p1O2+p1CO2+p1H2O=p1;
```

p0N2 := 0.780

p0O2 := 0.205

p0CO2 := 0.013

p0H2O := 0.00610800000

p4tN2 := 3.39350615

p4tO2 := 0.761208722

p4tCO2 := 0.126268502

p4tH2O := 0.129016617

sump4t := 4.410000000 = 4.410

p4rN2 := 3.35957109

p4rO2 := 0.753596635

p4rCO2 := 0.125005817

p4rH2O := 0.127726451

sump4r := 4.365900000 = 4.3659

$p5tN2 := 0.830682279$

$p5tO2 := 0.186333122$

$p5tCO2 := 0.0309087423$

$p5tH2O := 0.0315814420$

$sump5t := 1.079505586 = 1.07950558$

$p5rN2 := 0.830682279$

$p5rO2 := 0.186333122$

$p5rCO2 := 0.0309087423$

$p5rH2O := 0.0315814420$

$sump5r := 1.079505586 = 1.07950558$

$p6tN2 := 0.830682279$

$p6tO2 := 0.186333122$

$p6tCO2 := 0.0309087423$

$p6tH2O := 0.0315814420$

$sump6t := 1.079505586 = 1.07950558$

$p6rN2 := 0.805761811$

$p6rO2 := 0.180743128$

$p6rCO2 := 0.0299814801$

$p6rH2O := 0.0306339987$

$sump6r := 1.047120419 = 1.047120419$

$p7tN2 := 0.805761811$

$p7tO2 := 0.180743128$

$p7tCO2 := 0.0299814801$

$p7tH2O := 0.0306339987$

$sump7t := 1.047120419 = 1.047120419$

$p7rN2 := 0.769502530$

$p7rO2 := 0.172609687$

$p7rCO2 := 0.0286323135$

$p7rH2O := 0.0292554688$

$sump7r := 0.9999999999 = 1$

$p1N2 := 0.774159948$

$p1O2 := 0.173654408$

$p1CO2 := 0.0288056107$

$p1H2O := 0.0233800317$

$sump1fg := 1.000000000 = 1$

```
> T7t:=T7r;s1:=int(cpair/T,T=T0..T1)-
Rair*int(1/p,p=p0..p1)/1000;s2t:=int(cpair/T,T=T0..T2t)-
Rair*int(1/p,p=p0..p2t)/1000;s2r:=int(cpair/T,T=T0..T2r)-
Rair*int(1/p,p=p0..p2r)/1000;Ds12t_in_proc:=100*(s2t-
s1)/s1;s3t:=int(cpair/T,T=T0..T3t)-
Rair*int(1/p,p=p0..p3t)/1000;s3r:=int(cpair/T,T=T0..T3r)-
Rair*int(1/p,p=p0..p3r)/1000;s4t:=gN2fgv*(int(cpN2/T,T=T0..T4t)-
RN2*int(1/p,p=p0N2..p4tN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T4t)-
RO2*int(1/p,p=p0O2..p4tO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T4t)-
RCO2*int(1/p,p=p0CO2..p4tCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T4
t)-
RH2O*int(1/p,p=p0H2O..p4tH2O)/1000);s4r:=gN2fgv*(int(cpN2/T,T=T0..T4r)-
RN2*int(1/p,p=p0N2..p4rN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T4r)-
RO2*int(1/p,p=p0O2..p4rO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T4r)-
RCO2*int(1/p,p=p0CO2..p4rCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T4
r)-
RH2O*int(1/p,p=p0H2O..p4rH2O)/1000);s5t:=gN2fgv*(int(cpN2/T,T=T0..T5t)-
RN2*int(1/p,p=p0N2..p5tN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T5t)-
RO2*int(1/p,p=p0O2..p5tO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T5t)-
RCO2*int(1/p,p=p0CO2..p5tCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T5
t)-RH2O*int(1/p,p=p0H2O..p5tH2O)/1000);Ds45t_in_proc:=100*(s5t-
s4r)/s5t;s5r:=gN2fgv*(int(cpN2/T,T=T0..T5r)-
RN2*int(1/p,p=p0N2..p5rN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T5r)-
RO2*int(1/p,p=p0O2..p5rO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T5r)-
RCO2*int(1/p,p=p0CO2..p5rCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T5
r)-
RH2O*int(1/p,p=p0H2O..p5rH2O)/1000);s6t:=gN2fgv*(int(cpN2/T,T=T0..T6t)-
RN2*int(1/p,p=p0N2..p6tN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T6t)-
```

```
RO2*int(1/p,p=p0O2..p6tO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T6t)-
RCO2*int(1/p,p=p0CO2..p6tCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T6
t)-
RH2O*int(1/p,p=p0H2O..p6tH2O)/1000);s6r:=gN2fgv*(int(cpN2/T,T=T0..T6r)-
RN2*int(1/p,p=p0N2..p6rN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T6r)-
RO2*int(1/p,p=p0O2..p6rO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T6r)-
RCO2*int(1/p,p=p0CO2..p6rCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T6
r)-
RH2O*int(1/p,p=p0H2O..p6rH2O)/1000);s7t:=gN2fgv*(int(cpN2/T,T=T0..T7t)-
RN2*int(1/p,p=p0N2..p7tN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T7t)-
RO2*int(1/p,p=p0O2..p7tO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T7t)-
RCO2*int(1/p,p=p0CO2..p7tCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T7
t)-
RH2O*int(1/p,p=p0H2O..p7tH2O)/1000);s7r:=gN2fgv*(int(cpN2/T,T=T0..T7r)-
RN2*int(1/p,p=p0N2..p7rN2)/1000)+gO2fgv*(int(cpO2/T,T=T0..T7r)-
RO2*int(1/p,p=p0O2..p7rO2)/1000)+gCO2fgv*(int(cpCO2/T,T=T0..T7r)-
RCO2*int(1/p,p=p0CO2..p7rCO2)/1000)+gH2Ofgv*(10/T0+int(cpH2O/T,T=T0..T7
r)-
RH2O*int(1/p,p=p0H2O..p7rH2O)/1000);s1fg:=gN2fgv1*(int(cpN2/T,T=T0..T1)
-RN2*int(1/p,p=p0N2..p1N2)/1000)+gO2fgv1*(int(cpO2/T,T=T0..T1)-
RO2*int(1/p,p=p0O2..p1O2)/1000)+gCO2fgv1*(int(cpCO2/T,T=T0..T1)-
RCO2*int(1/p,p=p0CO2..p1CO2)/1000)+gH2Ofgv1*(10/T0+int(cpH2O/T,T=T0..T1
)-RH2O*int(1/p,p=p0H2O..p1H2O)/1000);
```

$T7t := 363.15$

$s1 := 0.0709992849$

$s2t := 0.070620625$

$s2r := 0.159945011$

$Ds12t\_in\_proc := -0.533329258$

$s3t := 0.823076726$

$s3r := 0.828860946$

$s4t := 1.36613204$

$s4r := 1.36902736$

s5t := 1.36970293

Ds45t_in_proc := 0.0493223736

s5r := 1.46624681

s6t := 0.856963817

s6r := 0.865738582

s7t := 0.437752773

s7r := 0.451017226

s1fg := 0.199918188

```
> Tmq2r3t:=(T3t-T2r)/ln(T3t/T2r);Tmq2r3ts:=(h3t-h2r)/(s3t-
s2r);Tmq5r6t:=(T5r-T6t)/ln(T5r/T6t);Tmq5r6ts:=(h5r-h6t)/(s5r-
s6t);Tmq6r7r:=(T6r-T7t)/ln(T6r/T7t);Tmq6r7rs:=(h6r-h7r)/(s6r-s7t);
```

Tmq2r3t := 674.812909

Tmq2r3ts := 677.782884

Tmq5r6t := 728.219340

Tmq5r6ts := 731.073804

Tmq6r7r := 448.629194

Tmq6r7rs := 449.158641

```
> DTairmax_fgin:=T5r-T3r;eps_rec:=(T3r-T2r)/(T5r-T2r);
```

DTairmax_fgin := 42.493730

eps_rec := 0.907217659

```
> etaelref:=0.35;etaQref:=0.95;HP:=-Qcog/P;HPel:=-
Qcog/Pel;Exfuel:=Qfuel*0.9875;ExQcog:=-Qcog*(1-
T0/Tmq6r7rs);etaexcog:=(P+ExQcog)/Exfuel;etaexelcog:=(Pel+ExQcog)/Exfue
l;Qfuelref:=Pel/etaelref-Qcog/etaQref;FESR:=1-Qfuel/Qfuelref;
```

etaelref := 0.35

etaQref := 0.95

HP := 1.45406872

HPel := 1.49873090

Exfuel := 371.305203

ExQcog := 60.8083838

etaexcog := 0.451186810

etaexelcog := 0.442621768

Qfuelref := 459.171722

FESR := 0.181122768

```
> save
DTairmax_fgin,p1,p2r,p3r,p4r,p5r,p6r,p7r,T1,T2r,T3r,T4r,T5r,T6r,T7r,eps
_rec,P,Pel,Qfuel,Qcog,HP,HPel,etaHHV,etaelHHV,etacogHHV,etaelcogHHV,eta
excog,etaexelcog,FESR,"date brayton Michel";read "date brayton Michel";
```

DTairmax_fgin := 42.493730

p1 := 1

p2r := 4.5

p3r := 4.410

p4r := 4.3659

p5r := 1.07950558

p6r := 1.04712041

p7r := 1

T1 := 293.15

T2r := 488.248924

T3r := 903.748924

T4r := 1223.15

T5r := 946.242654

T6r := 546.572444

T7r := 363.15

eps_rec := 0.907217659

P := 106.719626

Pel := 103.539382

Qfuel := 376.005269

Qcog := −155.177671

HP := 1.45406872

HPel := 1.49873090

etaHHV := 0.283824817

etaelHHV := 0.275366837

etacogHHV := 0.696525606

etaelcogHHV := 0.688067626

etaexcog := 0.451186810

etaexelcog := 0.442621768

FESR := 0.181122768

TURBOMOTORUL DUBLUFLUX – GAZ PERFECT

cpaer =1.01027-1.73736E-4*T+6.08005E-7*T^2-3.80644E-10*T^3+7.49874E-14*T^4 [kJ/kgK];

cvaer =0.72301-1.73889E-4*T+6.09496E-7*T^2-3.81877E-10*T^3+7.52717E-14*T^4 [kJ/kgK];

cpO2 =0.82397+3.05587E-4*T+5.32089E-8*T^2-1.30137E-10*T^3+3.58225E-14*T^4 [kJ/kgK];

cvO2 =0.56574+2.96923E-4*T+6.54515E-8*T^2-1.36918E-10*T^3+3.71407E-14*T^4 [kJ/kgK];

cpH2O =1.84336-2.31223E-4*T+1.1966E-6*T^2-6.15263E-10*T^3+1.0015E-13*T^4 [kJ/kgK];

cvH2O =1.38161-2.29361E-4*T+1.19327E-6*T^2-6.13657E-10*T^3+9.99765E-14*T^4 [kJ/kgK];

cpN2 =1.07623-3.25964E-4*T+7.92186E-7*T^2-4.66137E-10*T^3+8.87148E-14*T^4 [kJ/kgK];

cvN2 =0.77884-3.22759E-4*T+7.86981E-7*T^2-4.62795E-10*T^3+8.79811E-14*T^4 [kJ/kgK];

cpCO2 =0.46236+0.0016*T-1.2402E-6*T^2+4.78609E-10*T^3-7.32796E-14*T^4 [kJ/kgK];

cvCO2 =0.27337+0.0016*T-1.24189E-6*T^2+4.79536E-10*T^3-7.34111E-14*T^4 [kJ/kgK];

>

>

```
nC:=0.85/12;nH2:=0.15/2;Maer:=0.21*32+0.79*28;Hs:=(nC*94030+nH2*57800)*
4.185;
```

nC := 0.0708333333

nH2 := 0.0750000000

Maer := 28.84

Hs := 46015.9931

>

```
> restart;
> nC:=0.85/12;nH2:=0.15/2;Maer:=0.21*32+0.79*28;Hs:=46000;
```

nC := 0.0708333333

nH2 := 0.0750000000

$Maer := 28.84$

$Hs := 4600$

```
> gO2:=0.21*32/Maer;gN2:=0.79*28/Maer;nO2:=gO2/32;nN2:=gN2/28;
```

$gO2 := 0.233009708$

$gN2 := 0.766990291$

$nO2 := 0.00728155339$

$nN2 := 0.0273925104$

```
> cp:=1.01027-1.73736E-4*T+6.08005E-7*T^(2)-3.80644E-10*T^(3)+7.49874E-
14*T^(4);cv:=0.72301-1.73889E-4*T+6.09496E-7*T^(2)-3.81877E-
10*T^(3)+7.52717E-14*T^(4);cpO2:=0.82397+3.05587E-4*T+5.32089E-8*T^2-
1.30137E-10*T^3+3.58225E-14*T^4;cvO2:=0.56574+2.96923E-4*T+6.54515E-
8*T^2-1.36918E-10*T^3+3.71407E-14*T^4;cpH2O:=1.84336-2.31223E-
4*T+1.1966E-6*T^2-6.15263E-10*T^3+1.0015E-13*T^4;cvH2O:=1.38161-
2.29361E-4*T+1.19327E-6*T^2-6.13657E-10*T^3+9.99765E-
14*T^4;cpN2:=1.07623-3.25964E-4*T+7.92186E-7*T^2-4.66137E-
10*T^3+8.87148E-14*T^4;cvN2:=0.77884-3.22759E-4*T+7.86981E-7*T^2-
4.62795E-10*T^3+8.79811E-14*T^4;cpCO2:=0.46236+0.0016*T-1.2402E-
6*T^2+4.78609E-10*T^3-7.32796E-14*T^4;cvCO2:=0.27337+0.0016*T-1.24189E-
6*T^2+4.79536E-10*T^3-7.34111E-14*T^4;
```

$$cp := 1.01027 - 0.000173736T + 6.08005\,10^{-7}\,T^2 - 3.80644\,10^{-10}\,T^3 + 7.49874\,10^{-14}\,T^4$$

$$cv := 0.72301 - 0.000173889T + 6.09496\,10^{-7}\,T^2 - 3.81877\,10^{-10}\,T^3 + 7.52717\,10^{-14}\,T^4$$

$$cpO2 := 0.82397 + 0.000305587T + 5.32089\,10^{-8}\,T^2 - 1.30137\,10^{-10}\,T^3 + 3.58225\,10^{-14}\,T^4$$

$$cvO2 := 0.56574 + 0.000296923T + 6.54515\,10^{-8}\,T^2 - 1.36918\,10^{-10}\,T^3 + 3.71407\,10^{-14}\,T^4$$

$$cpH2O := 1.84336 - 0.000231223T + 0.00000011966T^2 - 6.15263\,10^{-10}\,T^3 + 1.0015\,10^{-13}\,T^4$$

$$cvH2O := 1.38161 - 0.000229361T + 0.00000011932T^2 - 6.13657\,10^{-10}\,T^3 + 9.99765\,10^{-14}\,T^4$$

$$cpN2 := 1.07623 - 0.000325964T + 7.92186\,10^{-7}\,T^2 - 4.66137\,10^{-10}\,T^3 + 8.87148\,10^{-14}\,T^4$$

$$cvN2 := 0.77884 - 0.000322759T + 7.86981\,10^{-7}\,T^2 - 4.62795\,10^{-10}\,T^3 + 8.79811\,10^{-14}\,T^4$$

$$cpCO2 := 0.46236 + 0.0016\,T - 0.00000124021T^2 + 4.78609\,10^{-10}\,T^3 - 7.32796\,10^{-14}\,T^4$$

$$cvCO2 := 0.27337 + 0.0016\,T - 0.00000124189T^2 + 4.79536\,10^{-10}\,T^3 - 7.34111\,10^{-14}\,T^4$$

>

```
p1:=1;p7:=1;T0:=273;T1:=293;h1:=int(cp,T=T0..T1);T5:=1573;efv1:=0.9;efv
2:=0.9;piv1:=1.1;piv2:=1;pic:=35/piv1/piv2;efc:=0.8;eft:=0.85;dpca:=0.9
8;mv1:=350;mv2:=mv1/2;mc:=evalf(mv1/5);
```

$p1 := 1$

$p7 := 1$

$T0 := 273$

$T1 := 293$

$h1 := 20.0332308$

$T5 := 1573$

$efv1 := 0.9$

$efv2 := 0.9$

$piv1 := 1.1$

$piv2 := 1$

$pic := 31.8181818$

$efc := 0.8$

$eft := 0.85$

$dpca := 0.98$

$mv1 := 350$

$mv2 := 175$

$mc := 70.$

```
> p2:=p1*piv1;T2t:=T1*piv1^((1.401282041-1)/1.401282041);dh12t:=int(
cp, T=T1..T2t);du12t:=int( cv,
T=T1..T2t);km12t:=dh12t/du12t;dh12:=dh12t/efv1;h2t:=int( cp,
T=T0..T2t);
```

$p2 := 1.1$

$T2t := 301.107208$

$dh12t := 8.13088108$

$du12t := 5.80245863$

$km12t := 1.40128204$

$dh12 := 9.03431231$

$h2t := 28.1641119$

```
> eq12:=dh12-int(cp, T=T1..T2)=0;
```

$$eq12 := 302.0148059 - 1.01027000T2 + 0.000086868000T2^2 - 2.02668333310^{-7}\,T2^3 + 9.51610000010^{-11}\,T2^4 - 1.49974800010^{-14}\,T2^5 = 0$$

```
> T2eq:=evalf(solve(eq12,T2));
```

$$T2eq := -685.3537193 - 1788.099286I,\ -685.3537193 + 1788.099286I,\ 302.0076223,\ 3706.916233 - 2107.695718I,\ 3706.916233 + 2107.695718I$$

```
> T2:=302.0076223;ev1:=(T2t-T1)/(T2-T1);h2:=int( cp,T=T0..T2);c12:=(h2-
h1)/(T2-T1);du12:=int(cv,T=T1..T2); km12:=dh12/du12;
```

$T2 := 302.007622$

$ev1 := 0.900038626$

$h2 := 29.0675430$

$c12 := 1.00296304$

$du12 := 6.44728901$

$km12 := 1.40125753$

```
> p3:=p2*piv2;T3t:=T2*piv2^((1.397001058-1)/1.397001058);dh23t:=int(
cp, T=T2..T3t);du23t:=int( cv,
T=T2..T3t);km23t:=dh23t/du23t;dh23:=dh23t/efv2;
```

$p3 := 1.1$

$T3t := 302.007622$

$dh23t := 0.$

$du23t := 0.$

$km23t := Float(undefined)$

$dh23 := 0.$

```
> eq23:=dh23-simplify(int(cp, T=T2..T3))=0;
```

$$eq23 := 302.0148059 - 1.01027000T3 + 0.000086868000T3^2 - 2.02668333310^{-7}\, T3^3 + 9.51610000010^{-11}\, T3^4 - 1.49974800010^{-14}\, T3^5 = 0$$

```
> T3eq:=evalf(solve(eq23,T3));
```

$$T3eq := -685.3537193 - 1788.099286I, -685.3537193 + 1788.099286I, 302.0076223, 3706.916233 - 2107.695718I, 3706.916233 + 2107.695718I$$

```
> T3:=302.0076223;ev2:=(T3t-T2)/(T3-T2);h3:=int( cp,T=T0..T3);c23:=(h3-
h2)/(T3-T2);du23:=int(cv,T=T2..T3); km23:=dh23/du23;
```

$T3 := 302.007622$

$ev2 := Float(undefined)$

$h3 := 29.0675430$

$c23 := Float(undefined)$

$du23 := 0.$

$km23 := Float(undefined)$

```
> p4:=p3*pic;T4t:=T3*pic^((1.379753301-1)/1.379753301);dh34t:=int( cp,
T=T3..T4t);du34t:=int( cv,
T=T3..T4t);km34t:=dh34t/du34t;dh34:=dh34t/efc;h4t:=int( cp, T=T0..T4t);
```

$p4 := 35.0000000$

$T4t := 782.714504$

$dh34t := 501.392583$

$du34t := 363.392897$

$km34t := 1.37975339$

$dh34 := 626.740729$

$h4t := 530.460126$

```
> eq34:=dh34-simplify(int(cp, T=T3..T4))=0;
```

$$eq34 := 928.7555350 - 1.01027000\,T4 + 0.000086868000\,T4^2 - 2.02668333\,10^{-7}\,T4^3 + 9.51610000\,10^{-11}\,T4^4 - 1.49974800\,10^{-14}\,T4^5 = 0$$

```
> T4eq:=evalf(solve(eq34,T4));
```

$$T4eq := -881.7301576 - 1789.018572I,\ -881.7301576 + 1789.018572I,\ 896.1614303,\ 3606.215767 - 2089.579802I,\ 3606.215767 + 2089.579802I$$

```
> T4:=896.1614303;ec:=(T4t-T3)/(T4-T3);h4:=int( cp, T=T0..T4);c34:=(h4-h3)/(T4-T3);du34:=int(cv,T=T3..T4); km34:=dh34/du34;
```

$T4 := 896.161430$

$ec := 0.809061350$

$h4 := 655.808272$

$c34 := 1.05484593$

$du34 := 456.190125$

$km34 := 1.37385860$

```
>
> eqca:=mcb*Hs+mc*int(cp,T=T0..T4)-mc*nN2*28*int(cpN2,T=T0..T5)-mcb*nC*44*int(cpCO2,T=T0..T5)-mcb*nH2*18*int(cpH2O,T=T0..T5)-(mc*nO2-mcb*nC-mcb*nH2/2)*32*int(cpO2,T=T0..T5)=0;
```

$$eqca := 42126.69337\,mcb - 56455.88487 = 0$$

```
> mcb:=solve(eqca,mcb);
```

$mcb := 1.340145177$

```
> mga:=mc+mcb;mga:=mc*nN2*28+mcb*nC*44+mcb*nH2*18+(mc*nO2-mcb*nC-mcb*nH2/2)*32;
```

$mga := 71.34014518$

$mga := 71.3401451'$

```
>
h5:=(mc*nN2*28*int(cpN2,T=T0..T5)+mcb*nC*44*int(cpCO2,T=T0..T5)+mcb*nH2
*18*int(cpH2O,T=T0..T5)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T0..T5))/mga;
```

$h5 := 1507.61197$

```
>
> p5:=p4*dpca;c45:=(h5-h4)/(T5-T4);
```

$p5 := 34.3000000$

$c45 := 1.25850348$

```
>
dh56ti:=(mc*nN2*28*int(cpN2,T=T5..T6t)+mcb*nC*44*int(cpCO2,T=T5..T6t)+m
cb*nH2*18*int(cpH2O,T=T5..T6t)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T5..T6t))/mga;dh56i:=dh56ti*eft;
```

$$dh56ti := 1.01849689\,2T6t - 1784.992168 - 0.00005376798496T6t^2 + 1.87540201410^{-7}\,T6t^3 - 8.99167307110^{-11}\,T6t^4 + 1.41744005110^{-14}\,T6t^5$$

$$dh56i := 0.8657223582T6t - 1517.243343 - 0.00004570278722T6t^2 + 1.59409171210^{-7}\,T6t^3 - 7.64292211010^{-11}\,T6t^4 + 1.20482404310^{-14}\,T6t^5$$

```
> eqI:=mv1*dh12+mv2*dh23+mc*dh34+mga*dh56i=0;
```

$$eqI := -61206.49995 + 61.76075871T6t - 0.003260443475T6t^2 + 0.0000113722734\,1T6t^3 - 5.45247172910^{-9}\,T6t^4 + 8.59523221310^{-13}\,T6t^5 = 0$$

```
> T6teqI:=evalf(solve(eqI,T6t));
```

$$T6teqI := -960.3467968 - 1808.727417I,\ -960.3467968 + 1808.727417I,\ 942.9968412,\ 3660.648506 - 2146.163286I,\ 3660.648506 + 2146.163286I$$

```
>
T6t:=942.9968412;dh56t:=(mc*nN2*28*int(cpN2,T=T5..T6t)+mcb*nC*44*int(cp
```

```
CO2,T=T5..T6t)+mcb*nH2*18*int(cpH2O,T=T5..T6t)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T5..T6t))/mga;dh56:=dh56t*eft;du56t:=(mc*nN2*2
8*int(cvN2,T=T5..T6t)+mcb*nC*44*int(cvCO2,T=T5..T6t)+mcb*nH2*18*int(cvH
2O,T=T5..T6t)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cvO2,T=T5..T6t))/mga;h6t:=(mc*nN2*28*int(cpN2,T=T0..T
6t)+mcb*nC*44*int(cpCO2,T=T0..T6t)+mcb*nH2*18*int(cpH2O,T=T0..T6t)+(mc*
nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T0..T6t))/mga;dh56:=dh56t*eft;km56t:=dh56t/du5
6t;
```

$T6t := 942.996841$

$dh56t := -775.635559$

$dh56 := -659.290225$

$du56t := -593.756753$

$h6t := 731.976415$

$dh56 := -659.290225$

$km56t := 1.30631871$

```
> eqIverificare:=mv1*dh12+mv2*dh23+mc*dh34+mga*dh56=0;
```

$eqIverificare := -0.00002 = 0$

```
> eq56:=dh56-
simplify((mc*nN2*28*int(cpN2,T=T5..T6)+mcb*nC*44*int(cpCO2,T=T5..T6)+mc
b*nH2*18*int(cpH2O,T=T5..T6)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T5..T6))/mga)=0;
```

$$eq56 := 1125.701943 - 1.01849689\,2T6 + 0.000053767984\,96T6^2 - 1.875402014\,10^{-7}\,T6^3 + 8.991673071\,10^{-11}\,T6^4 - 1.417440051\,10^{-14}\,T6^5 = 0$$

```
> T6eq:=evalf(solve(eq56,T6));
```

$$T6eq := -989.8076466 - 1814.419979I,\ -989.8076466 + 1814.419979I,\ 1041.347056,\ 3640.934247 - 2143.940324I,\ 3640.934247 + 2143.940324I$$

```
> T6:=1041.347056;p6:=p5*(T6t/T5)^((dh56t/du56t)/((dh56t/du56t)-
1));et:=(T5-T6)/(T5-
```

```
T6t);h6:=(mc*nN2*28*int(cpN2,T=T0..T6)+mcb*nC*44*int(cpCO2,T=T0..T6)+mc
b*nH2*18*int(cpH2O,T=T0..T6)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T0..T6))/(mc*nN2*28+mcb*nC*44+mcb*nH2*18+(mc*n
O2-mcb*nC-mcb*nH2/2)*32);c56:=(h6-h5)/(T6-
T5);du56:=(mc*nN2*28*int(cvN2,T=T5..T6)+mcb*nC*44*int(cvCO2,T=T5..T6)+m
cb*nH2*18*int(cvH2O,T=T5..T6)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cvO2,T=T5..T6))/(mc*nN2*28+mcb*nC*44+mcb*nH2*18+(mc*n
O2-mcb*nC-mcb*nH2/2)*32);km56:=dh56/du56;
```

$T6 := 1041.34705$

$p6 := 3.86925212$

$et := 0.843889330$

$h6 := 848.321749$

$c56 := 1.24007631$

$du56 := -505.806259$

$km56 := 1.30344418$

```
> T7t:=T6*(p7/p6)^((1.331543213-
1)/1.331543213);dh67t:=(mc*nN2*28*int(cpN2,T=T6..T7t)+mcb*nC*44*int(cpC
O2,T=T6..T7t)+mcb*nH2*18*int(cpH2O,T=T6..T7t)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T6..T7t))/mga;du67t:=(mc*nN2*28*int(cvN2,T=T6.
.T7t)+mcb*nC*44*int(cvCO2,T=T6..T7t)+mcb*nH2*18*int(cvH2O,T=T6..T7t)+(m
c*nO2-mcb*nC-
mcb*nH2/2)*32*int(cvO2,T=T6..T7t))/mga;km67t:=dh67t/du67t;h7t:=(mc*nN2*
28*int(cpN2,T=T0..T7t)+mcb*nC*44*int(cpCO2,T=T0..T7t)+mcb*nH2*18*int(cp
H2O,T=T0..T7t)+(mc*nO2-mcb*nC-mcb*nH2/2)*32*int(cpO2,T=T0..T7t))/mga;
```

$T7t := 743.500454$

$dh67t := -345.348592$

$du67t := -259.359703$

$km67t := 1.33154298$

$h7t := 502.973157$

```
> dh67:=dh67t*0.98;
```

$dh67 := -338.441620$

```
> eq67:=dh67-
```

```
simplify((mc*nN2*28*int(cpN2,T=T6..T7)+mcb*nC*44*int(cpCO2,T=T6..T7)+mc
b*nH2*18*int(cpH2O,T=T6..T7)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T6..T7))/mga)=0;
```

$$eq67 := 787.2603228 - 1.018496892\,T7 + 0.00005376798488\,T7^{2} - 1.87540201610^{-7}\,T7^{3} + 8.99167307010^{-11}\,T7^{4} - 1.41744004910^{-14}\,T7^{5} = 0$$

```
> T7eq:=evalf(solve(eq67,T7));
```

$$T7eq := -899.8723869 - 1800.029561I,\ -899.8723869 + 1800.029561I,\ 749.6445992,\ 3696.850220 - 2151.191691I,\ 3696.850220 + 2151.191691I$$

```
> T7:=749.6445992;eaj:=(T7-T6)/(T7t-
T6);h7:=(mc*nN2*28*int(cpN2,T=T0..T7)+mcb*nC*44*int(cpCO2,T=T0..T7)+mcb
*nH2*18*int(cpH2O,T=T0..T7)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cpO2,T=T0..T7))/mga;c67:=(h7-h6)/(T7-
T6);du67:=(mc*nN2*28*int(cvN2,T=T6..T7)+mcb*nC*44*int(cvCO2,T=T6..T7)+m
cb*nH2*18*int(cvH2O,T=T6..T7)+(mc*nO2-mcb*nC-
mcb*nH2/2)*32*int(cvO2,T=T6..T7))/mga;km67:=dh67/du67;
```

$$T7 := 749.644599$$

$$eaj := 0.979371446$$

$$h7 := 509.880129$$

$$c67 := 1.16022889$$

$$du67 := -254.226445$$

$$km67 := 1.33126048$$

```
>
> w7:=sqrt(-2000*dh67);Ft7:=mga*w7/1000/9.81;
```

$$w7 := 804.121376$$

$$Ft7 := 5.84771993$$

```
> w7v2:=sqrt(2000*0.98*(dh12+dh23));Ft7v2:=(mv2-mc)*w7v2/1000/9.81;
```

$$w7v2 := 133.068599$$

$$Ft7v2 := 1.42428164$$

```
> w7v1:=sqrt(2000*0.98*dh12);Ft7v1:=(mv1-mv2-mc)*w7v1/1000/9.81;
```

$w7v1 := 133.068599$

$Ft7v1 := 1.42428164$

```
> Ft:=Ft7+Ft7v2+Ft7v1;
```

$Ft := 8.69628322$

```
> > restart;
> cpN2:=evalf(1.742661-22878.11/T^(3/2)+478584.8/T^2-
3.660212*10^7/T^3);cpO2:=evalf(1.670028+8.968502*T^(3/2)/10^7-
7966.8957/T^(3/2)+105683.9/T^2);cpH2O:=evalf(6.382172-
2.5894729*T^0.25+0.3691933*T^0.5-1.6502632*T/10^3);cpCO2:=evalf(-
0.1666681+0.136205*T^0.5-1.8307308*T/10^3+1.079593*T^2/10^7);
```

$$cpN2 := 1.742661 - \frac{22878.11}{T^{3/2}} + \frac{4.78584810^5}{T^2} - \frac{3.6602120001 0^7}{T^3}$$

$$cpO2 := 1.670028 + 8.9685020001 0^{-7}\, T^{3/2} - \frac{7966.8957}{T^{3/2}} + \frac{1.0568391 0^5}{T^2}$$

$$cpH2O := 6.382172 - 2.5894729 T^{0.25} + 0.3691933 T^{0.5} - 0.0016502632 00 T$$

$$cpCO2 := -0.1666681 + 0.136205 T^{0.5} - 0.0018307308 00 T + 1.0795930001 0^{-7}\, T^2$$

```
> cpaer:=0.21*cpO2+0.79*cpN2;
```

$$cpaer := 1.72740807 + 1.8833854201 0^{-7}\, T^{3/2} - \frac{19746.75500}{T^{3/2}} + \frac{4.0027561110^5}{T^2} - \frac{2.8915674801 0^7}{T^3}$$

```
> haer:=cpaer*(T-T0);evalf(int( haer, T = T0..T1 ));
```

$$haer := \left(1.72740807 + 1.8833854201 0^{-7}\, T^{3/2} - \frac{19746.75500}{T^{3/2}} + \frac{4.0027561110^5}{T^2} - \frac{2.8915674801 0^7}{T^3}\right)(T - 273)$$

$$\frac{1}{TI^{5/2}}\left(2.93040293010^{-18}\left(1.83630078410^{10}\,TI^{6}\right.\right.$$
$$-\,7.01834159810^{12}\,TI^{5}-1.34771602910^{22}\,TI^{3}$$
$$-\,3.67926475810^{24}\,TI^{2}+2.94739001910^{17}\,TI^{9/2}$$
$$-\,1.60927495110^{20}\,TI^{7/2}-1.34691020410^{27}\sqrt{TI}$$
$$+\,4.71576502910^{25}\,TI^{3/2}+1.36594052310^{23}\ln(TI)\,TI^{5/2}$$
$$\left.\left.-\,4.53559294210^{23}\,TI^{5/2}\right)\right)$$

```
> DUBLUFLUX OPTIMIZARE;
```

DUBLUFLUX

```
>
> restart;
>
m:=355;mga:=1.02*m/rm;k12:=1.4;k23:=1.37;k45:=1.305;c12:=1.005;c23:=1.0
55;c45:=1.24;efv:=0.9;efc:=0.8;eft:=0.85;T1:=293;T4:=1573;;pic:=35/piv;
```

$m := 355$

$mga := \frac{362.10 \cdot 1}{rm}$

$k12 := 1.4$

$k23 := 1.37$

$k45 := 1.305$

$c12 := 1.005$

$c23 := 1.055$

$c45 := 1.24$

$efv := 0.9$

$efc := 0.8$

$eft := 0.85$

$T1 := 293$

$T4 := 1573$

$pic := \frac{35 \cdot 1}{piv}$

```
> T2t:=T1*(piv)^((k12-1)/k12);T2:=T1+(T2t-T1)/efv;
```

$$T2t := 293\, piv^{0.2857142857}$$

$$T2 := -32.5555555 + 325.5555555\, piv^{0.2857142857}$$

```
> T3t:=T2*(pic)^((k23-1)/k23);
```

$$T3t := 2.612227984\left(-32.5555555 + 325.5555555\, piv^{0.2857142857}\right)\left(\frac{1}{piv}\right)^{0.2700729927}$$

```
> T3:=T2+(T3t-T2)/efc;
```

$$T3 := 8.13888888 - 81.3888889\, piv^{0.2857142857} + 3.265284980\left(-32.5555555 + 325.5555555\, piv^{0.2857142857}\right)\left(\frac{1}{piv}\right)^{0.2700729927}$$

```
> p4:=p3*dpca;
```

$$p4 := p3\ dpca$$

```
> p5:=p4*pit;T5t:=T4*pit^((k45-1)/k45);
```

$$p5 := p3\ dpca\ pit$$

$$T5t := 1573\, pit^{0.2337164751}$$

```
>
> T5:=T4-(T4-T5t)*eft;
```

$$T5 := 235.95 + 1337.05\, pit^{0.2337164751}$$

```
> p6:=1;
```

$$p6 := 1$$

```
>
> T6t:=T5*(p6/p5)^((k56-1)/k56);
```

$$T6t := \left(235.95 + 1337.05\, pit^{0.2337164751}\right)\left(\frac{1}{p3\ dpca\ pit}\right)^{\frac{k56-1}{k56}}$$

```
>
> T6:=T5-(T5-T6t)*efaj;
```

$$T6 := 235.95 + 1337.05\,pit^{0.2337164751} - \Bigg(235.95 + 1337.05\,pit^{0.2337164751} - \left(235.95 + 1337.05\,pit^{0.2337164751}\right)\left(\frac{1}{p3\ dpca\ pit}\right)^{\frac{k56-1}{k56}} \Bigg) efaj$$

```
>
> eqI:=evalf((mga*c45*(T4-T5)-m*c12*(T2-T1)+m*c23*(T3-T4)/rm))=0;
```

$$eqI := \frac{449.0040\left(1337.05 - 1337.05\,pit^{0.2337164751}\right)}{rm} - 1.16150083310^{5}\,piv^{0.2857142857} + 1.16150083310^{5} + \frac{1}{rm}\Bigg(374.525\Bigg(-1564.861111 - 81.3888889\,piv^{0.2857142857} + 3.265284980\left(-32.5555555 + 325.5555555\,piv^{0.2857142857}\right)\left(\frac{1}{piv}\right)^{0.2700729927}\Bigg)\Bigg) = 0$$

```
>
>
>
> 449.0040*(1337.05-
1337.05*pit^.2337164751)/rm=116150.0833*piv^.2857142857-116150.0833-
374.525*(-1564.861111-81.3888889*piv^.2857142857+3.265284980*(-
32.5555555+325.5555555*piv^.2857142857)*(1/piv)^.2700729927)/rm;
```

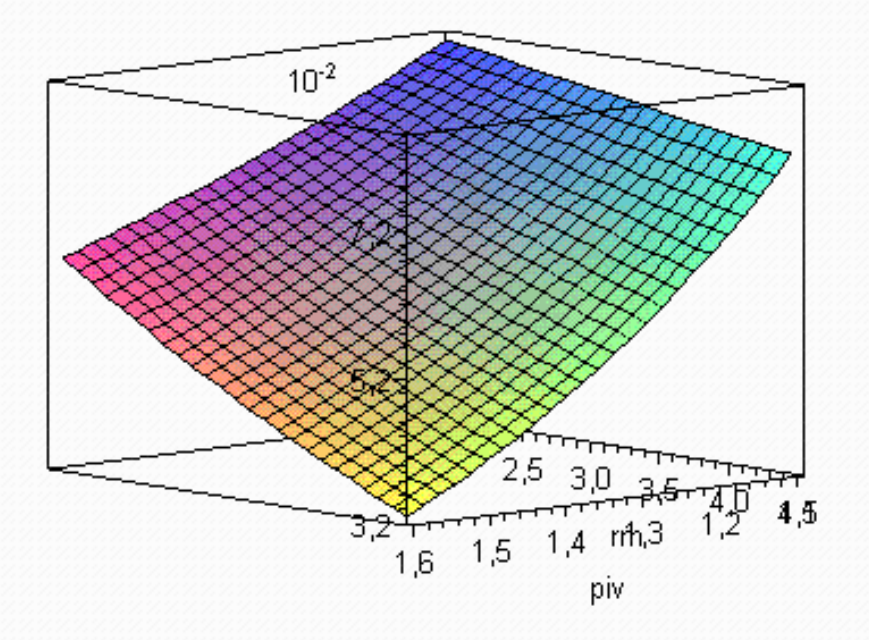
$$\frac{449.0040\left(1337.05 - 1337.05\,pit^{0.2337164751}\right)}{rm} = 1.16150083310^{5}\,piv^{0.2857142857} - 1.16150083310^{5} - \frac{1}{rm}\Bigg(374.525\Bigg(-1564.861111 - 81.3888889\,piv^{0.2857142857} + 3.265284980\left(-32.5555555 + 325.5555555\,piv^{0.2857142857}\right)\left(\frac{1}{piv}\right)^{0.2700729927}\Bigg)\Bigg)$$

```
>
> pit:=(-(rm*(116150.0833*piv^.2857142857-116150.0833-374.525*(-
1564.861111-81.3888889*piv^.2857142857+3.265284980*(-
32.5555555+325.5555555*piv^.2857142857)*(1/piv)^.2700729927)/rm)/449.00
40/1337.05-1))^(1/.2337164751);
```

$$pit := \left(-0.000001665720542\,rm \left(1.16150083310^{5}\, piv^{0.2857142857} - 1.16150083310^{5} - \frac{1}{rm}\left(374.525\left(-1564.861111 - 81.3888889 piv^{0.2857142857} + 3.265284980\left(-32.5555555 + 325.5555555 piv^{0.2857142857} \right) \left(\frac{1}{piv} \right)^{0.2700729927} \right) \right) \right) + 1 \right)$$

4.278688525

```
> plot3d( pit,piv=1.1..1.6,rm=2..4.5);
```




```
>
>
>
```

```
> restart;
> dh12:=wv^2/2;dh56:=wt^2/2;
```

$$dh12 := \frac{1}{2}\, wv^2$$

$$dh56 := \frac{1}{2}\, wt^2$$

```
> m:=1;mga:=1.02*m/rm;
```

$$m := 1$$

$$mga := \frac{1.02 \cdot 1}{rm}$$

```
>
> eqI:=m*dh12+m*dh23/rm-mga*dh45=0;
```

$$eqI := \frac{1}{2}\, wv^2 + \frac{dh23}{rm} - \frac{1.02\, dh45}{rm} = 0$$

```
> eqT:=fT-mga*wt-m*wv/rm=0;
```

$$eqT := fT - \frac{1.02\, wt}{rm} - \frac{wv}{rm} = 0$$

POMPA DE CALDURA CU APORT SOLAR

```
A:=aperture;Asc:=absorber_area;Is:=solar_insolation;FO:=optical_efficie
ncy;etasc:=solar_colector_efficiency;epssc:=solar_colector_effectivenes
s;UL:=solar_colector_heat_loss_coefficient;Tsai:=-
.6666666666*Ta+491.9166666;Tsao:=-
.9047619047*Ta+562.1904761;Ca:=1000;Csc:=1000;
```

$$A := aperture$$

$$Asc := absorber\_area$$

$$Is := solar\_insolation$$

$$FO := optical\_efficiency$$

$$etasc := solar\_colector\_efficiency$$

$$epssc := solar\_colector\_effectiveness$$

$$UL := solar\_colector\_heat\_loss\_coefficient$$

$$Tsai := -0.6666666666 Ta + 491.916666$$

$Tsao := -0.9047619047Ta + 562.190476$

$Ca := 1000$

$Csc := 1000$

```
> Ntsai_50_30;DNtsai_tsao_10;with(CurveFitting):
Tsai:=PolynomialInterpolation([[253.15,323.15],[288.15,303.15]], Ta);
```

Ntsai_50_30

DNtsai_tsao_10

$Tsai := -0.5714285714Ta + 467.807142$

```
> with(CurveFitting):
Tsao:=PolynomialInterpolation([[253.15,333.15],[288.15,304.4]], Ta);
```

$Tsao := -0.8214285714Ta + 541.094642$

```
> restart;
>
Refrigerent_R134a;Ta:=253.15;Is:=50;FO:=0.95;UL:=2;Ca:=1000;Csc:=1000;e
tasc:=0.75;epssc:=0.75;
```

Refrigerent_R134a

$Ta := 253.15$

$Is := 50$

$FO := 0.95$

$UL := 2$

$Ca := 1000$

$Csc := 1000$

$etasc := 0.75$

$epssc := 0.75$

```
> Tsai:=-.5714285714*Ta+467.8071428;Tsao:=-.8214285714*Ta+541.0946428;
```

$Tsai := 323.150000$

$Tsao := 333.150000$

```
> Condenser;Tc:=Tsai+Qc/Ca/epsc;
```

Condenser

$$Tc := 323.1500000 + \frac{1}{1000}\,\frac{Qc}{epsc}$$

```
> Solar_colector;Asc:=100;A:=Asc;Tsc:=Ta+Is*(FO-
```

```
etasc)/UL;Ts:=Ta+Is*FO/UL;Tsco:=Ta+Is*(FO-etasc)/UL-
etasc*Is*Asc/epssc/Csc;Tsci := Ta+etasc*Is*Asc*(1-1/epssc)/Csc+Is*(FO-
etasc)/UL;
```

Solar_colector

$Asc := 100$

$A := 100$

$Tsc := 258.150000($

$Ts := 276.900000($

$Tsco := 253.150000($

$Tsci := 256.900000($

```
> Evaporator;Te:=Ta+etasc*Is*Asc*(1-1/epssc)/Csc+Is*(FO-etasc)/UL-
etasc*Is*Asc/epse/Csc;Qe:=epse*Csc*(Tsci-Te);
```

Evaporator

$$Te := 256.9000000 - \frac{3.750000000}{epse}$$

$Qe := 3750.00000($

```
> Irreversibility;RT:=Tc/Te;COP_r:=-
.9796943861+1.910346905196670 39*RT;;Irr:=COP_r/RT;
```

Irreversibility

$$RT := \frac{323.1500000 + \frac{1}{1000}\,\frac{Qc}{epsc}}{256.9000000 - \frac{3.750000000}{epse}}$$

$$COP\_r := -0.9796943861 + \frac{1.910346905196670 39\left(323.1500000 + \frac{1}{1000}\,\frac{Qc}{epsc}\right)}{256.9000000 - \frac{3.750000000}{epse}}$$

$$Irr := \frac{1}{323.1500000 + \frac{1}{1000}\,\frac{Qc}{epsc}}\left(\left(-0.9796943861 + \frac{1.91034690519667039\left(323.1500000 + \frac{1}{1000}\,\frac{Qc}{epsc}\right)}{256.9000000 - \frac{3.750000000}{epse}}\right)\left(256.9000000 - \frac{3.750000000}{epse}\right)\right)$$

```
> Qc:=solve((Qc-Qe*RT*Irr),Qc);Tsao:=Tsai+Qc/Ca;
```

$$Qc := \left(150.\,epsc\,\left(4.57056393210^{12}\,epse + 4.59231743510^{10}\right)\right) / \left(1.28450000010^{11}\,epsc\,epse - 1.87500000010^{9}\,epsc - 3.58190044710^{9}\,epse\right)$$

$$Tsao := 323.1500000 + \left(0.1500000000\,epsc\,\left(4.57056393210^{12}\,epse + 4.59231743510^{10}\right)\right) / \left(1.28450000010^{11}\,epsc\,epse - 1.87500000010^{9}\,epsc - 3.58190044710^{9}\,epse\right)$$

```
> W:=Qe-Qc;COP:=-Qc/W;
```

$$W := 3750.000000 - \left(150.\,epsc\,\left(4.57056393210^{12}\,epse + 4.59231743510^{10}\right)\right) / \left(1.28450000010^{11}\,epsc\,epse - 1.87500000010^{9}\,epsc - 3.58190044710^{9}\,epse\right)$$

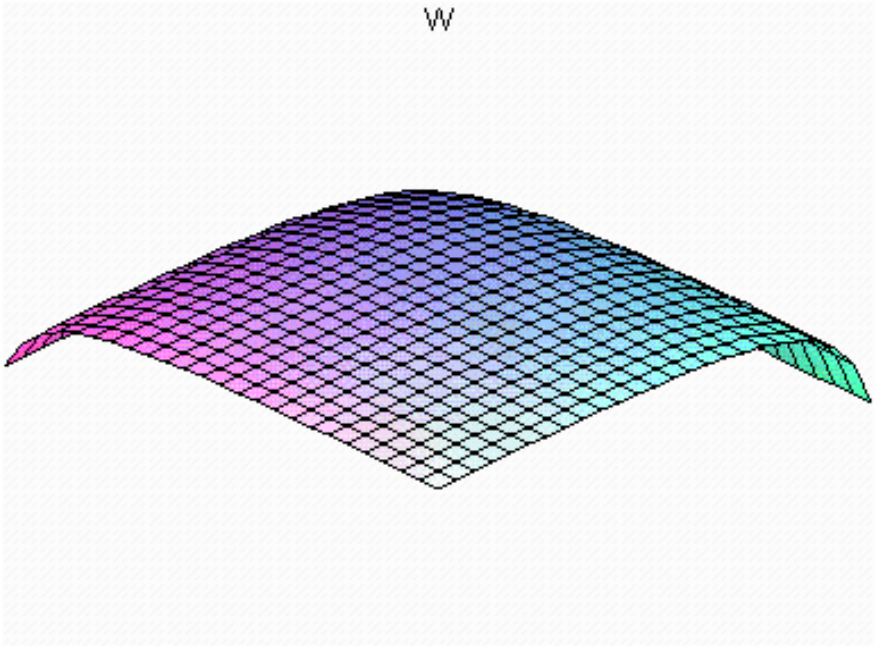
$$COP := -\left(150.\,epsc\,\left(4.57056393210^{12}\,epse + 4.59231743510^{10}\right)\right) \Big/ \left(\left(1.28450000010^{11}\,epsc\,epse - 1.87500000010^{9}\,epsc - 3.58190044710^{9}\,epse\right)\left(3750.000000 - \left(150.\,epsc\,\left(4.57056393210^{12}\,epse + 4.59231743510^{10}\right)\right) / \left(1.28450000010^{11}\,epsc\,epse - 1.87500000010^{9}\,epsc - 3.58190044710^{9}\,epse\right)\right)\right)$$

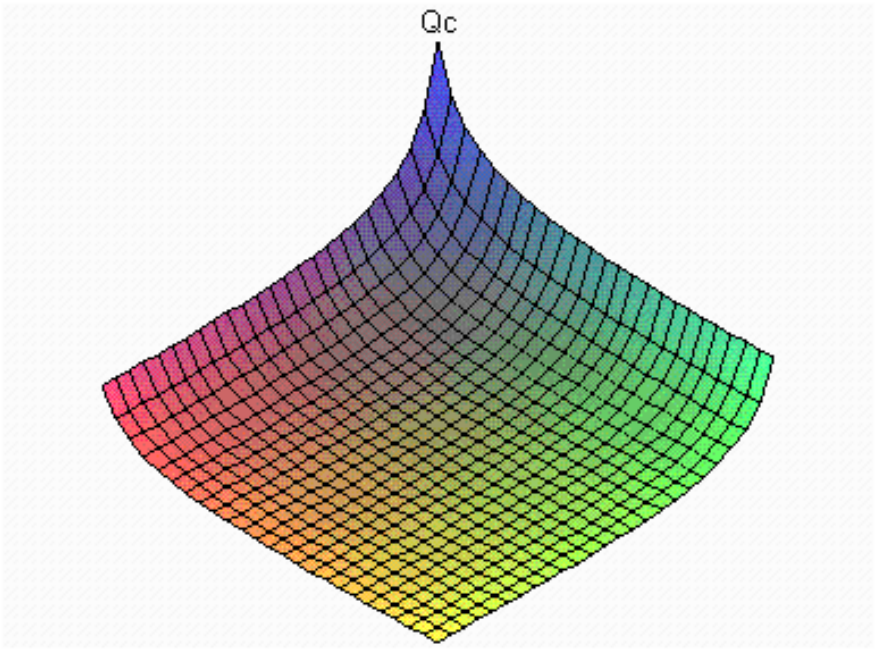
```
> COP_Carnot:=Tc/(Tc-Te);R_COP:=COP/COP_Carnot;
```

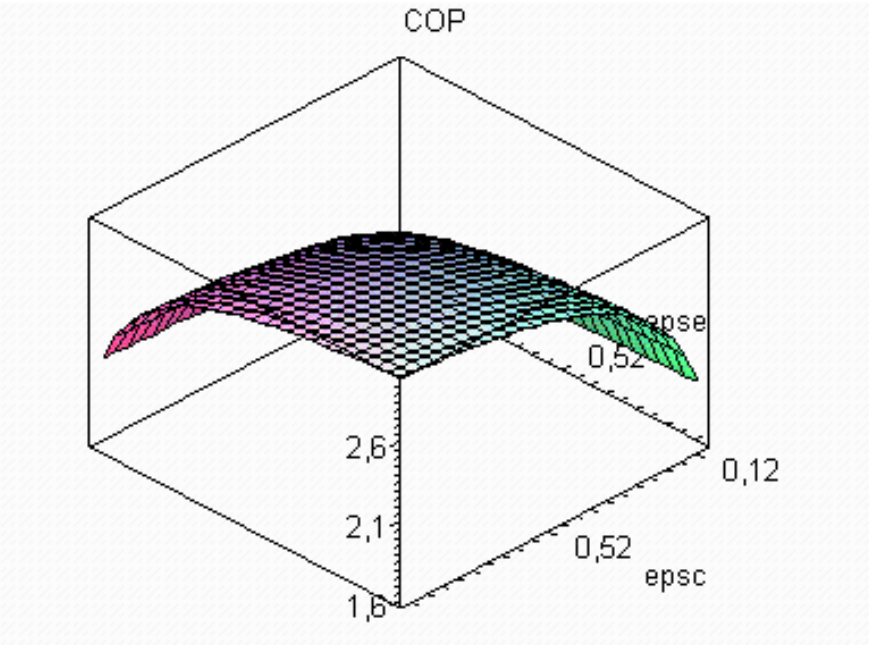
$$COP\_Carnot := \left(323.1500000 + \left(0.1500000000\left(4.57056393210^{12}\ epse + 4.59231743510^{10}\right)\right)\Big/\left(1.28450000010^{11}\ epsc\ epse - 1.87500000010^{9}\ epsc - 3.58190044710^{9}\ epse\right)\right)\Big/\left(66.2500000 + \left(0.1500000000\left(4.57056393210^{12}\ epse + 4.59231743510^{10}\right)\right)\Big/\left(1.28450000010^{11}\ epsc\ epse - 1.87500000010^{9}\ epsc - 3.58190044710^{9}\ epse\right) + \frac{3.750000000}{epse}\right)$$

$$R\_COP := -\left(150.\ epsc\ \left(4.57056393210^{12}\ epse + 4.59231743510^{10}\right)\left(66.2500000 + \left(0.1500000000\left(4.57056393210^{12}\ epse + 4.59231743510^{10}\right)\right)\Big/\left(1.28450000010^{11}\ epsc\ epse - 1.87500000010^{9}\ epsc - 3.58190044710^{9}\ epse\right) + \frac{3.750000000}{epse}\right)\right)\Big/\left(\left(1.28450000010^{11}\ epsc\ epse - 1.87500000010^{9}\ epsc - 3.58190044710^{9}\ epse\right)\left(3750.000000 - \left(150.\ epsc\ \left(4.57056393210^{12}\ epse + 4.59231743510^{10}\right)\right)\Big/\left(1.28450000010^{11}\ epsc\ epse - 1.87500000010^{9}\ epsc - 3.58190044710^{9}\ epse\right)\right)\left(323.1500000 + \left(0.1500000000\left(4.57056393210^{12}\ epse + 4.59231743510^{10}\right)\right)\Big/\left(1.28450000010^{11}\ epsc\ epse - 1.87500000010^{9}\ epsc - 3.58190044710^{9}\ epse\right)\right)\right)$$

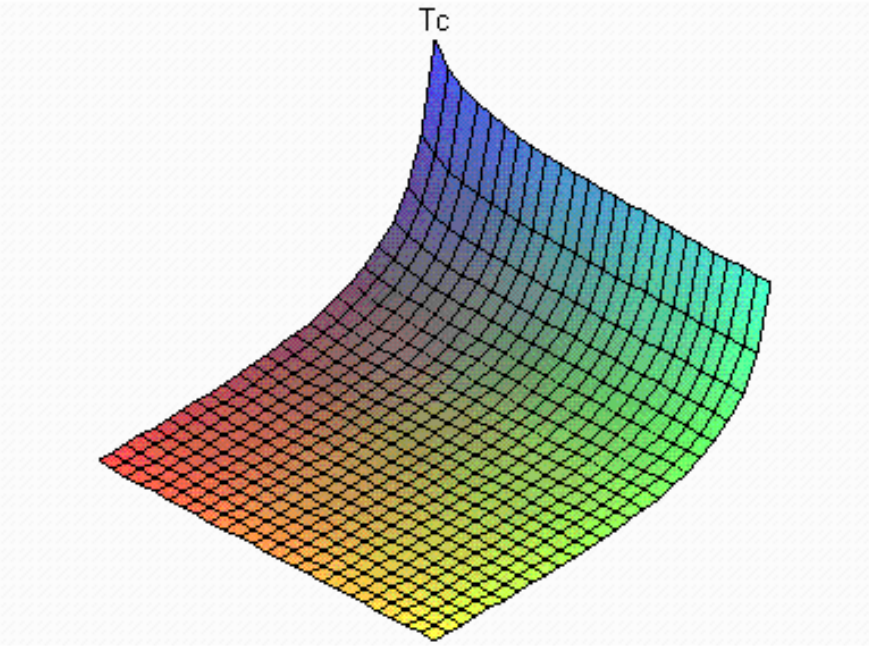
```
>
plot3d(W,epsc=0.1..0.9,epse=0.1..0.9,title="W");plot3d(Qc,epsc=0.1..0.9
,epse=0.1..0.9,title="Qc");plot3d(COP,epsc=0.1..0.9,epse=0.1..0.9,title
="COP");
```

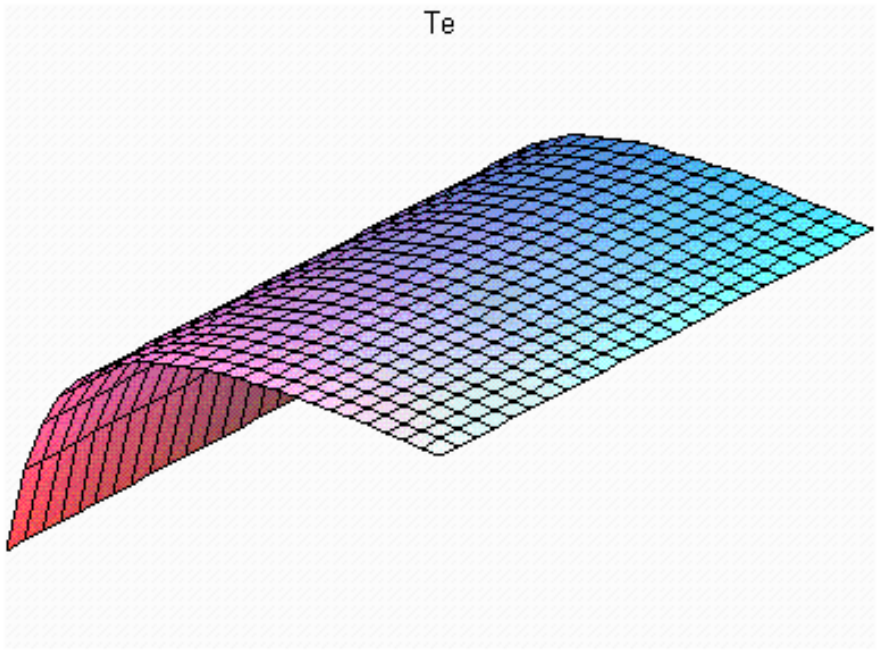




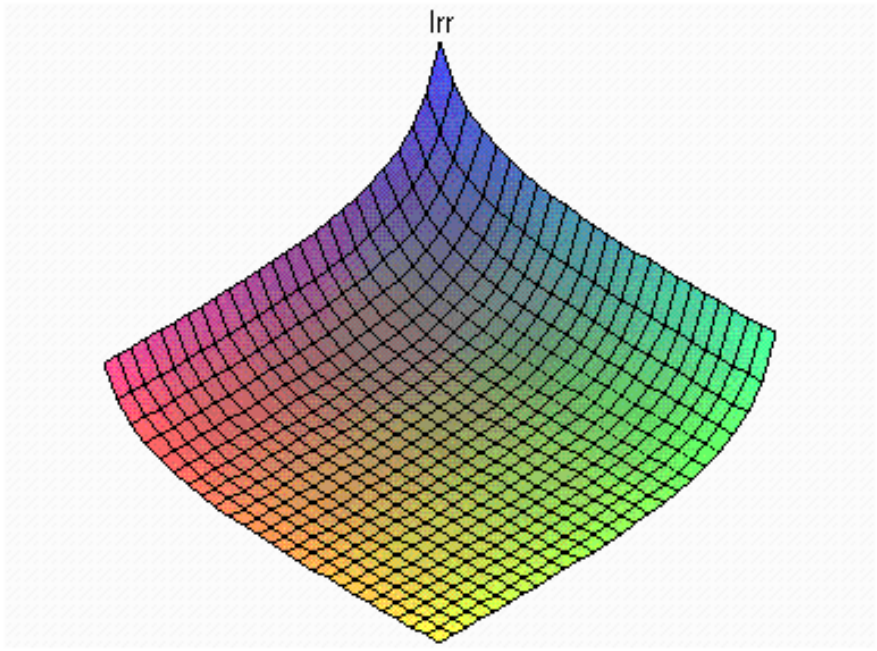


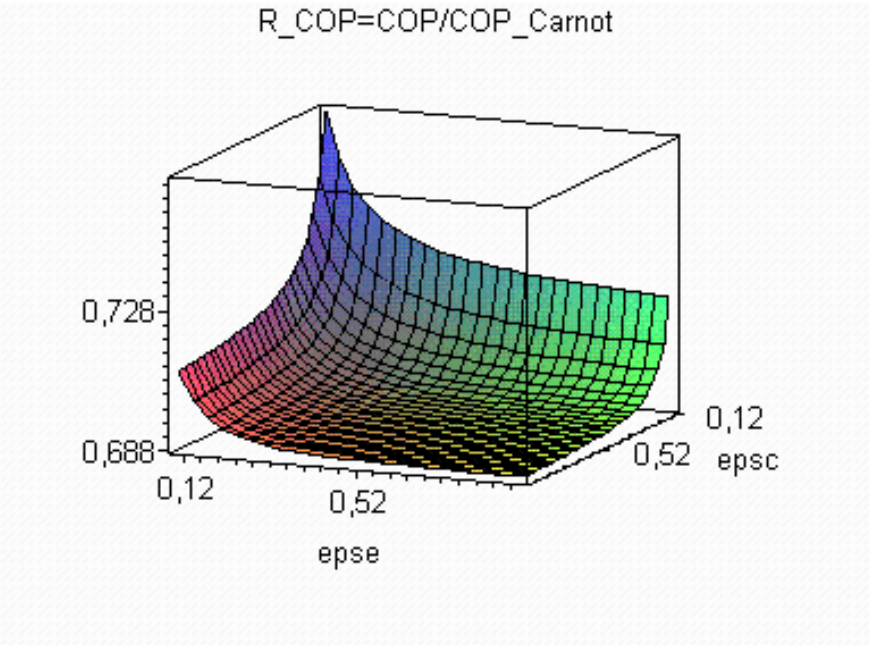

```
>
plot3d(Tc,epsc=0.1..0.9,epse=0.1..0.9,title="Tc");plot3d(Te,epsc=0.1..0
.9,epse=0.1..0.9,title="Te");
```

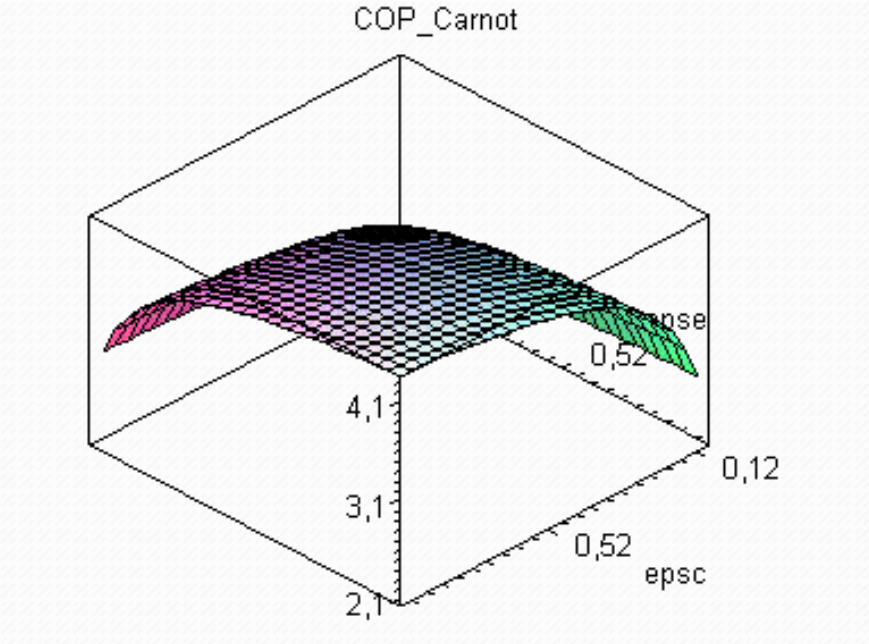





```
>
plot3d(Irr,epsc=0.1..0.9,epse=0.1..0.9,title="Irr");plot3d(R_COP,epsc=0
.1..0.9,epse=0.1..0.9,title="R_COP=COP/COP_Carnot");plot3d(COP_Carnot,e
psc=0.1..0.9,epse=0.1..0.9,title="COP_Carnot");
```








```
>
```

COMPRESOR CENTRIFUGAL

```
> restart;
```

1-Debitul masic: m [kg/s]

```
> m:=1.2;
```

$m := 1.2$

2-Umiditatea relativa a aerului aspirat de compresor: fiN

```
> fiN:=0.7;
```

$fiN := 0.7$

3-Presiunea totala a aerului aspirat de compresor: p_tot_N, [n/m2]

```
> p_tot_N:=101325;
```

$p\_tot\_N := 101325$

4-Temperatura aerului aspirat de compresor: T_tot_N, [K]

```
> T_tot_N:=288;
```

$T\_tot\_N := 288$

5-Constanetele de gaz perfect pentru aerul aspirat de compresor si vaporii de apa: R_a_us si R_v, [J/kg K]

```
> R_a_us:=287;R_v:=462;
```

$R\_a\_us := 287$

$R\_v := 462$

6-Exponentul adiabatic al aerului: k

```
> k:=1.395;
```

$k := 1.395$

7-Presiunea de saturatie a vaporilor din aerul umed: p_sat, [N/m2]

```
> p_sat:=1704.1;
```

$p\_sat := 1704.1$

8-Presiunea partiala a vaporilor din aerul umed aspirat: p_v, [N/m2]

```
> p_v:=fiN*p_sat;
```

$p\_v := 1192.87$

9-Continutul de umiditate al aerului umed aspirat de compresor: x, [kg/kg]

```
> x:=0.622*p_v/(p_tot_N-p_v);
```

$x := 0.00740986075$

10-Constanta de gaz perfect a aerului umed, R_a_um, [J/kg K]

```
> R_a_um:=(R_a_us+x*R_v)/(1+x);
```

$R\_a\_um := 288.287187$

11-Caldura specifica izobara a aerului umed aspirat de compresor: cp, [J/kg K]

```
> cp:=k*R_a_um/(k-1);
```

$cp := 1018.12816$

12-Viteza absoluta a aerului aspirat de compresor: c1, [m/s]

```
> cN:=30;
```

$cN := 30$

Viteza absoluta a aerului la intrarea in rotor: c1, [m/s]

```
> c1:=60;
```

$c1 := 60$

13-Unghiul vitezei absolute la intrarea in rotor, pozitiv in sensul de rotatie al rotorului, considerat constant pe raza (se alege intre 0 si 30 grade): psi, [rad]

```
> psi:=(30*evalf(Pi)/180);psi_gr:=psi*180/evalf(Pi);
```

$\psi := 0.523598775$

$psi\_gr := 30.0000000$

Temperatura statica a aerului aspirat de compresor: TN, [K]

```
> TN:=T_tot_N-cN^2*(k-1)/2/k/R_a_um;
```

$TN := 287.558012$

14-Presiunea statica a aerului aspirat de compresor: pN, [N/m2]

```
> pN:=p_tot_N*(TN/T_tot_N)^(k/(k-1));
```

$pN := 1.00776890310^{5}$

15-Raportul vitezelor in racordul de aspiratie, c1_cN

```
> c1_cN:=c1/cN;
```

$c1\_cN := 2$

16-Temperatura teoretica statica a aerului la intrarea in rotor, T1s, [K]

```
> T1s:=T_tot_N-c1^2*(k-1)/2/k/R_a_um;
```

$T1s := 286.232049$

17-Coeficientul de pierderi in racordul de aspiratie, (se alege in domeniul 0,5....1,5): zRI

```
> zRI:=1;
```

$zRI := 1$

18-Pierderi in racordul de aspiratie: l_N_1, [J/kg]; L_N_1, [W]

```
> l_N_1:=zRI*c1^2/2;L_N_1:=l_N_1*m;
```

$l\_N\_1 := 1800$

$L\_N\_1 := 2160.0$

19-Cifra politropica in racordul de aspiratie, (este de fapt n/(n-1)): sRI

```
> sRI:=k*(1-l_N_1*(k-1)/k/R_a_um/(T1s-TN))/(k-1);
```

$sRI := 8.24050641$

20-Exponentul politropic in racordul de aspiratie: n

```
> n:=sRI/(sRI-1);
```

$n := 1.13811188$

21-Temperatura statica a aerului la intrarea in rotor, T1, [K]

```
> T1:=T_tot_N-(c1^2-cN^2)/2/cp-l_N_1/cp;
```

$T1 := 284.906087$

22-Presiunea statica la intrarea in rotor: p1, [N/m2]

```
> p1:=pN*(T1/TN)^(n/(n-1));
```

$p1 := 93369.1178$

23-Presiunea totala la intrarea in rotor: p1_tot, [N/m2]

```
> p1_tot:=p1*(T_tot_N/T1)^(k/(k-1));
```

$p1\_tot := 96999.4687$

Coeficientul de restabilire a presiunii totale: DRI

```
> DRI:=p1_tot/p_tot_N;
```

$DRI := 0.957310325$

24-Presiunea totala a aerului comprimat: p_tot_K, [N/m2]

```
> p_tot_K:= 920000;
```

$p\_tot\_K := 920000$

25-Raportul de comprimare al compresorului, in parametri de franare: piC

```
> piC_tot:=evalf(p_tot_K/p_tot_N);
```

$piC\_tot := 9.07969405$

26-Randamentul izentropic global, se impune initial in domeniul 0,75....0,85 si se verifica ulterior: etas

```
> etas_tot:=.7166739258;
```

$etas\_tot := 0.716673925$

27-Consumurile energetice teoretice globale: ladC_tot, [J/kg] si LadC_tot, [W]

```
> ladC_tot:=k*R_a_um*T_tot_N*(piC_tot^((k-1)/k)-1)/(k-
1);LadC_tot:=m*ladC_tot;
```

$ladC\_tot := 2.543958767 10^{5}$

$LadC\_tot := 3.05275052010^{5}$

28-Consumuri energetice reale globale: l_real_C, [J/kg] si L_real_C, [W]

```
> l_real_C_tot:=ladC_tot/etas_tot;L_real_C_tot:=m*l_real_C_tot;
```

$l\_real\_C\_tot := 3.54967395310^{5}$

$L\_real\_C\_tot := 4.25960874410^{5}$

29-Cifra de debit (aleasa intre 0,25....0,35, probabil este raportul c2r/u2): fi2

```
> fi2:=0.25;
```

$fi2 := 0.25$

30-Numarul de palete pe rotor (intre 15 ....35): z2

```
> z2:=18;
```

$z2 := 18$

31-Unghiul geometric de iesire din paletele mobile: beta2 [rad]

```
> beta2:=evalf(Pi/2);
```

$\beta 2 := 1.57079632$

32-Raportul dintre diametrul minim al paletei la intrare (curgerea axiala) si diametrul maxim al rotorului (uzual intre 0,15 ....0,35): db_rap

```
> db_rap:=0.015;
```

$db\_rap := 0.015$

33-Raportul dintre diametrul maxim al paletei la intrare (curgerea axiala) si diametrul maxim al rotorului (intre 0,45 ....0,65): db_rap

```
> dext_rap:=0.545;
```

$dext\_rap := 0.545$

34-Raportul dintre diametrul mediu al paletei la intrare (curgerea axiala) si diametrul maxim al rotorului: d1_pe_d2

```
> d1_pe_d2:=sqrt((dext_rap^2+db_rap^2)/2);
```

$d1\_pe\_d2 := 0.385519130$

35-Coeficientul de circulatie: miu

```
> miu:=1/(1+2*evalf(Pi)/3/z2/(1-d1_pe_d2^2));
```

$miu := 0.879764759$

36-Coeficientul cinematic de sarcina (probabil c2u/u2): fiu2

```
> fiu2:=miu*(1-fi2*cot(beta2));
```

fiu2 := 0.879764759

37-Coeficient de pierderi prin frecare (intre 0,03....0,1): alfa

```
> alfa:=0.075;
```

alfa := 0.075

38-Unghiul vitezei absolute la intrarea in rotor: alfa1 [rad], alfa1_gr [grade]

```
> alfa1:=evalf(Pi/2)-psi;alfa1_gr:=alfa1*180/evalf(Pi);
```

alfa1 := 1.04719755

alfa1_gr := 59.9999999

39-Viteza tangentiala la intrarea in rotor (considerata constanta pe raza, zona de curgere axiala): c1u [m/s]

```
> c1u:=c1*cos(alfa1);
```

c1u := 30.0000000

Viteza axiala la intrarea in rotor (considerata constanta pe raza, zona de curgere axiala): c1a [m/s]

```
> c1a:=c1*sin(alfa1);
```

c1a := 51.9615242

40-Viteza tangentiala la iesirea din rotor: u2 [m/s]

```
>
u2:=c1u*d1_pe_d2/2/(fiu2+alfa)+sqrt((c1u*d1_pe_d2/2/(fiu2+alfa))^2+l_re
al_C_tot/(fiu2+alfa));
```

u2 := 615.828749

41-Densitatea aerului la intrarea in rotor: ro1 [kg/m3]

```
> ro1:=p1/R_a_um/T1;
```

ro1 := 1.13677937

42-Pierderi raportate prin scapari, intre roata si carcasa (intre 0,02....0,04): betapr

```
> betapr:=0.03;
```

betapr := 0.03

43-Diametrul exterior al rotorului: d2 [m]

```
> d2:=sqrt(4*m*(1+betapr)/evalf(Pi)/ro1/c1a/(dext_rap^2-db_rap^2));
```

d2 := 0.299607935

44-Diametrul butucului la intrare (la baza paletei, curgere axiala): d1b [m]

```
> d1b:=d2*db_rap;
```

d1b := 0.00449411903

45-Diametrul maxim al rotorului la intrare (la varful paletei, curgere axiala): d1ext [m]

```
> d1ext:=d2*dext_rap;
```

$d1ext := 0.163286325$

46-Diametrul mediu al rotorului la intrare (curgere axiala): d1 [m]

```
> d1:=d2*d1_pe_d2;
```

$d1 := 0.115504590$

47-Turatia rotorului: turatia [rot/min]

```
> turatia:=60*u2/evalf(Pi)/d2;
```

$turatia := 39256.1790$

Viteza unghiulara a rotorului: omega [rad/s]

```
> omega:=evalf(Pi)*turatia/30;
```

$\omega := 4110.89745$

48-Viteza tangentiala intrarea in rotor, la diametrul mediu: u1 [m/s]

```
> u1:=u2*d1_pe_d2;
```

$u1 := 237.413764$

49-Viteza tangentiala la varful paletei, la intrarea in rotor: u1ext [m/s]

```
> u1ext:=u2*dext_rap;
```

$u1ext := 335.626668$

50-Viteza tangentiala la baza paletei, la intrarea in rotor: u1b [m/s]

```
> u1b:=u2*db_rap;
```

$u1b := 9.237431248$

51-Componenta tangentiala a vitezei relative a aerului la d1ext (negativa pentru ca este in sens contrar lui u): w1ext [m/s]

```
> w1uext:=c1u-u1ext;
```

$w1uext := -305.626668$

52-Componenta tangentiala a vitezei relative aerului la d1b (negativa pentru ca este in sens contrar lui u): w1b [m/s]

```
> w1ub:=c1u-u1b;
```

$w1ub := 20.76256876$

53-Unghiul vitezei relative la d1ext (masurat de la axa +u): beta1ext [rad], beta1ext_gr [grade]

```
> beta1ext:=evalf(Pi)-arctan(c1a/(u1ext-
```

```
c1u));beta1ext_gr:=beta1ext*180/evalf(Pi);
```

beta1ext := 2.97318662

beta1ext_gr := 170.351045

54-Unghiul vitezei relative la d1b (masurat de la axa +u): beta1b [rad], beta1b_gr [grade]

```
> beta1b:=evalf(Pi)-arctan(c1a/(u1b-
c1u));beta1b_gr:=beta1b*180/evalf(Pi);
```

beta1b := 4.33224832

beta1b_gr := 248.219545

55-Unghiul vitezei relative la d1 (masurat de la axa +u): beta1 [rad], beta1_gr [grade]

```
> beta1:=evalf(Pi)-arctan(c1a/(u1-c1u));beta1_gr:=beta1*180/evalf(Pi);
```

β1 := 2.89612360

beta1_gr := 165.935659

56-Viteza relativa la d1ext: w1ext [m/s]

```
> w1ext:=sqrt(c1a^2+w1uext^2);
```

w1ext := 310.012355

57-Viteza sunetului la intrarea in rotor: a1 [m/s]

```
> a1:=sqrt(k*T1*R_a_um);
```

a1 := 338.493737

58-Numarul Mach la d1ext: Mw1ext [m/s]

```
> Mw1ext:=w1ext/a1;
```

Mw1ext := 0.915858466

59-Viteza relativa la intrarea in rotor, la diametrul mediu: w1 [m/s]

```
> w1:=c1a/sin(beta1);
```

w1 := 213.823454

60-Unghiul vitezei absolute la iesirea din rotor: alfa2 [rad], alfa2_gr [grade]

```
> alfa2:=arctan(fi2/fiu2);alfa2_gr:=alfa2*180/evalf(Pi);
```

alfa2 := 0.276868447

alfa2_gr := 15.8633935

61-Viteza absoluta la iesirea din rotor: c2 [m/s]

```
> c2:=u2*sqrt(fi2^2+fiu2^2);
```

c2 := 563.234574

Temperatura franata a aerului la iesirea din rotor: T2_tot [K]

```
> T2_tot:=TN+l_real_C_tot*(k-1)/k/R_a_um;
```

$T2\_tot := 636.205074$

62-Temperatura franata a aerului la iesirea din rotor: T2_tot [K]

```
> T2:=T2_tot-c2^2*(k-1)/2/k/R_a_um;
```

$T2 := 480.412711$

63-Coeficientii de rezistenta ai rotii de lucru, la intrare csi1 (intre 0,1...0,3) si la rasucirea curentului in roata de lucru csi2 (intre 0,1...0,2)

```
> csi1:=0.15;csi2:=0.15;
```

$csi1 := 0.15$

$csi2 := 0.15$

64-Pierderi in rotor: suma_lr [J/kg], suma_Lr [W]

```
> suma_lr:=csi1*w1^2/2+csi2*fi2^2*u2^2/2;suma_Lr:=m*suma_lr;
```

$suma\_lr := 5206.74640$

$suma\_Lr := 6248.09569$

65-Pierderi prin frecare i rotor: lf [J/kg], Lf [W]

```
> lf:=alfa*u2^2;Lf:=m*lf;
```

$lf := 28443.3786$

$Lf := 34132.0544$

66-Cifra politropica in roata de lucru: sr1

```
> sr1:=k*(1-(k-1)*(lf+suma_lr)/k/R_a_um/(T2-T1))/(k-1);
```

$sr1 := 2.93461047$

67-Exponentul politropic in roata de lucru: n_r1

```
> n_r1:=sr1/(sr1-1);
```

$n\_r1 := 1.51689992$

68-Presiunea statica la iesirea din rotor: p2 [N/m2]

```
> p2:=p1*(T2/T1)^sr1;
```

$p2 := 4.32617242010^{5}$

69-Densitatea aerului la iesirea din rotor: ro2 [kg/m3]

```
> ro2:=p2/T2/R_a_um;
```

$ro2 := 3.12366169$

70-Latimea raportata a rotii de lucru la iesire:b2_pe_d2 (uzual intre 0,03....0,08)

```
> b2_pe_d2:=m/evalf(Pi)/d2^2/fi2/ro2/u2;
```

$b2\_pe\_d2 := 0.00884831933$

71-Latimea rotii de lucru la iesire:b2 [m]

```
> b2:=d2*b2_pe_d2;
```

$b2 := 0.00265102668$

72-Viteza sunetului la iesirea din rotor: a2 [m/s]

```
> a2:=sqrt(k*R_a_um*T2);
```

$a2 := 439.548720$

73-Numarul Mach la iesirea din rotor, pentru viteza absoluta: Mc2

```
> Mc2:=c2/a2;
```

$Mc2 := 1.28139282$

74-Consumuri energetice politropice in roata de lucru: lpol12 [J/kg], Lpol12 [W]

```
> lpol12:=n_r1*R_a_um*T1*((p2/p1)^((n_r1-1)/n_r1)-1)/(n_r1-
1);Lpol12:=m*lpol12;
```

$lpol12 := 1.65400677010^5$

$Lpol12 := 1.98480812410^5$

75-Randamentul interior al rotii de lucru: etai12

```
> etai12:=(lpol12+0.5*(c2^2-c1^2))/l_real_C_tot;
```

$etai12 := 0.907737652$

76-Dimensiunea radiala raportata a difuzorului nepaletat (intre 1,03....1,15): d3_pe_d2

```
> d3_pe_d2:=1.2;
```

$d3\_pe\_d2 := 1.2$

77-Latimea difuzorului nepaletat la iesire (normal = b2+(0,0005....0,001): b3 [m]

```
> b3:=b2+0.001;
```

$b3 := 0.00365102668$

78-Raportul intre densitatea ro2 si ro3, (se alege prealabil 0,75...0,98 si se verifica ulterior): ro3 [kg/m3]

```
> ro2_pe_ro3:=.9100861254;
```

$ro2\_pe\_ro3 := 0.910086125$

79-Unghiul de orientare a gazului la iesirea din difuzorul nepaletat: alfa3 [rad], alfa_gr [grade]

```
>
```

```
alfa3:=arctan(b2*ro2_pe_ro3*tan(alfa2)/b3);alfa3_gr:=180*alfa3/evalf(Pi
);
```

alfa3 := 0.185620806

alfa3_gr := 10.6352888

80-Diametrul la iesire din difuzorul nepaletat: d3 [m]

```
> d3:=d2*d3_pe_d2;
```

d3 := 0.359529522

81-Viteza gazului la iesirea din difuzorul nepaletat: c3 [m/s]

```
> c3:=m*ro2_pe_ro3/evalf(Pi)/ro2/d3/b3/sin(alfa3);
```

c3 := 459.378288

81-Temperatura statica la iesirea din difuzorul nepaletat: T3 [K]

```
> T3:=T2_tot-(k-1)*c3^2/2/k/R_a_um;
```

T3 := 532.569590

82-Coeficientul de rezistenta al difuzorului nepaletat (intre 0,03...0,25; valori mai mici pentru d3/d2 mai mici): csidn

```
> csidn:=0.15;
```

csidn := 0.15

83-Pierderi pe difuzorul nepaletat: lp_dn [J/kg], Lp_dn [W]

```
> lp_dn:=csidn*c2^2/2;Lp_dn:=m*lp_dn;
```

lp_dn := 23792.4889

Lp_dn := 28550.9867

84-Cifra politropica pentru comprimarea din difuzorul nepaletat: sdn

```
> sdn:=k*(1-lp_dn*(k-1)/k/R_a_um/(T3-T2))/(k-1);
```

sdn := 1.94929414

85-Exponentul politropic pentru comprimarea din difuzorul nepaletat: n_dn

```
> n_dn:=sdn/(sdn-1);
```

n_dn := 2.05341427

86-Recalcularea raportului ro2_pe_ro3

```
> ro2_pe_ro3_f:=(T2/T3)^(1/(n_dn-1));errro:=ro2_pe_ro3/ro2_pe_ro3_f;
```

ro2_pe_ro3_f := 0.906792282

errro := 1.00363241

87-Presiunea statica la iesirea din difuzorul nepaletat: p3 [N/m2]

```
> p3:=p2*(T3/T2)^(sdn);
```

$p3 := 5.28880900210^{5}$

88-Viteza sunetului la iesirea din difuzorul nepaletat: a3 [m/s]

```
> a3:=sqrt(k*R_a_um*T3);
```

$a3 := 462.794252$

89-Numarul Mach la iesirea din difuzorul nepaletat: Mc3

```
> Mc3:=c3/a3;
```

$Mc3 := 0.992618827$

90-Viteza gazului la iesirea din difuzorul paletat (intre 60...120): c4 [m/s]

```
> c4:=70;
```

$c4 := 70$

91-Latimea difuzorului paletat la iesire - nu are indicatie de alegere: b4 [m]

```
> b4:=b3;
```

$b4 := 0.00365102668$

92-Unghiul geometric al paletelor la intrarea in difuzorul paletat (alfa3 + pana la 2 grade): alfa3p [rad] alfa3p_gr [grade]

```
> alfa3p:=alfa3+1.42*evalf(Pi)/180; alfa3p_gr:=alfa3_gr+1.42;
```

$alfa3p := 0.210404482$

$alfa3p\_gr := 12.0552888$

93-Unghiul geometric al paletelor la iesirea din difuzorul paletat (alfa3p + (10..15) grade): alfa4p [rad] alfa4p_gr [grade]

```
> alfa4p:=alfa3p+14*evalf(Pi)/180;alfa4p_gr:=alfa3p_gr+14;
```

$alfa4p := 0.454750577$

$alfa4p\_gr := 26.0552888$

94-Unghiul de ramanere in urma a curentului la iesirea din difuzorul paletat (1..3 grade): dalfa4 [rad] dalfa4_gr [grade]

```
> dalfa4:=2*evalf(Pi)/180;dalfa4_gr:=dalfa4*180/evalf(Pi);
```

$dalfa4 := 0.0349065850$

$dalfa4\_gr := 2.00000000$

95-Unghiul vitezei absolute la iesirea din difuzorul paletat: alfa4 [rad], alfa_gr [grade]

```
> alfa4:=alfa4p-dalfa4;alfa4_gr:=alfa4p_gr-dalfa4_gr;
```

alfa4 := 0.419843992

alfa4_gr := 24.0552888

96-Coefientul de rezistenta al difuzorului paletat (intre 0,1....0,25): csidp

```
> csidp:=0.12;
```

csidp := 0.12

97-Pierderi in difuzorul paletat: lp_dp [J/kg], Lp_dp [W]

```
> lp_dp:=csidp*c3^2/2;Lp_dp:=m*lp_dp;
```

lp_dp := 12661.7047

Lp_dp := 15194.0456

98-Temperatura statica la iesirea din difuzorul paletat: T4 [K]

```
> T4:=T2_tot-c4^2*(k-1)/2/k/R_a_um;
```

T4 := 633.798697

99-Cifra politropica in difuzorul paletat: sdp

```
> sdp:=k*(1-lp_dp*(k-1)/k/R_a_um/(T4-T3))/(k-1);
```

sdp := 3.09777376

100-Exponentul politropic in difuzorul paletat: n_dp

```
> n_dp:=sdp/(sdp-1);
```

n_dp := 1.47669582

101-Presiunea statica la iesirea din difuzorul paletat: p4 [N/m2]

```
> p4:=p3*(T4/T3)^sdp;
```

$p4 := 9.06717644810^{5}$

102-Raportul dimetrelor in difuzorul paletat (recomandabil intre 1,25...1,35): d4_pe_d3 [m]

```
> d4_pe_d3:=c3*(T3/T4)^(1/(n_dp-1))*b3*sin(alfa3)/c4/b4/sin(alfa4);
```

d4_pe_d3 := 2.06257481

103-Diametrul de iesire din difuzorul paletat: d4 [m]

```
> d4:=d3*d4_pe_d3;
```

d4 := 0.741556537

104-Unghiul mediu de deschidere echivalent al unui difuzor plan (se alege intre 6....8 grade): tetam [rad], tetam_gr [grade]

```
> tetam_gr:=7;tetam:=tetam_gr*evalf(Pi)/180;
```

tetam_gr := 7

tetam := 0.122173047

105-Numarul de palete din difuzor (se rotunjeste, e de dorit ca z2 si z3 sa fie numere prime intre ele): z3

```
>
z3:=round(2*evalf(Pi)*sin((alfa3p)^2)*((d4*sin(alfa4p)/d3/sin(alfa3p))^
2-1)/((d4/d3)^2-1)/tetam);
```

z3 := 12

106-Sectiunile de curgere normale la vitezele de intrare si iesire din difuzorul paletat: S3, S4 [m2]

```
> S3:=evalf(Pi)*d3*b3*sin(alfa3);S4:=evalf(Pi)*d4*b4*sin(alfa4);
```

S3 := 0.000761078199

S4 := 0.00346706913

107-Raportul ariiloe S4/S3, mai mic de 4: S4_pe_S3

```
> S4_pe_S3:=S4/S3;
```

S4_pe_S3 := 4.55547029

108-Viteza la iesirea din camera spirala, (intre 40...80, dar mai mica decat c4): c5 [m/s]

```
> c5:=50;
```

c5 := 50

109-Coeficient de rezistenta in camera spirala (intre 0,15...0,3): csics

```
> csics:=0.258;
```

csics := 0.258

110-Pierderi in camera spirala: lp_cs [J/kg], Lp_cs [W]

```
> lp_cs:=csics*c4^2/2;Lp_cs:=m*lp_cs;
```

lp_cs := 632.100000

Lp_cs := 758.520000

111-Temperatura statica la iesirea din camera spirala: T5 [K]

```
> T5:=T2_tot-c5^2*(k-1)/2/k/R_a_um;
```

T5 := 634.977331

112-Cifra politropica din camera spirala: scs

```
> scs:=k*(1-(k-1)*lp_cs/k/R_a_um/(T5-T4))/(k-1);
```

scs := 1.67135121

113-Exponentul politropic in camera spirala: n_cs

```
> n_cs:=scs/(scs-1);
```

$n\_cs := 2.48953331$

114-Presiunea statica la iesirea din camera spirala: p5 [N/m2]

```
> p5:=p4*(T5/T4)^scs;
```

$p5 := 9.09537573910^{5}$

115-Presiunea totala la iesirea din camera spirala: p5_tot [N/m2]

```
> p5_tot:=p5*(T2_tot/T5)^(k/(k-1));
```

$p5\_tot := 9.15763583210^{5}$

116-Raportul de crestere a presiunii totale: piC_tot_f

```
> piC_tot_f:=p5_tot/p_tot_N;errpiC:=piC_tot/piC_tot_f;
```

$piC\_tot\_f := 9.03788387$

$errpiC := 1.00462610$

117-Randamentul izentropic calculat in parametrii de franare: etas_tot_f

```
> etas_tot_f:=T_tot_N*(piC_tot_f^((k-1)/k)-1)/(T2_tot-
T_tot_N);erretas:=etas_tot/etas_tot_f;
```

$etas\_tot\_f := 0.715566227$

$erretas := 1.00154800$

118-Randamentul mecanic al compresorului (intre 0,95...0,99): etamec

```
> etamec:=0.975;
```

$etamec := 0.975$

119-Puterea totala reala a compresorului: Pm [J/kg], P [W]

```
> Pm:=l_real_C_tot/etamec;P:=m*Pm;
```

$Pm := 3.64069123410^{5}$

$P := 4.36882948110^{5}$

```
>
>
>
>
> save
m,psi_gr,piC_tot_f,P,turatia,etas_tot_f,etai12,TN,T1,T2,T3,T4,T5,pN,p1,
p2,p3,p4,p5,p5_tot,d1b,d1ext,d1,d2,d3,d4,b2,b3,b4,beta1b_gr,beta1ext_gr
```

```
,beta1_gr,Mw1ext,alfa2_gr,c2,Mc2,c3,Mc3,c4,c5,alfa3p_gr,alfa4p_gr,alfa4
_gr,z2,z3, "date COMCIP";
> read "date COMCIP";
```

$m := 1.2$

$psi\_gr := 30.0000000$

$piC\_tot\_f := 9.03788387$

$P := 4.36882948110^{5}$

$turatia := 39256.1790$

$etas\_tot\_f := 0.715566227$

$etai12 := 0.907737652$

$TN := 287.558012$

$T1 := 284.906087$

$T2 := 480.412711$

$T3 := 532.569590$

$T4 := 633.798697$

$T5 := 634.977331$

$pN := 1.00776890310^{5}$

$p1 := 93369.1178$

$p2 := 4.32617242010^{5}$

$p3 := 5.28880900210^{5}$

$p4 := 9.06717644810^{5}$

$p5 := 9.09537573910^{5}$

$p5\_tot := 9.15763583210^{5}$

$d1b := 0.00449411903$

$d1ext := 0.163286325$

$d1 := 0.115504590$

$d2 := 0.299607935$

$d3 := 0.359529522$

$d4 := 0.741556537$

$b2 := 0.00265102668$

$b3 := 0.00365102668$

$b4 := 0.00365102668$

$beta1b\_gr := 248.219545$

$beta1ext\_gr := 170.351045$

$beta1\_gr := 165.935659$

$Mw1ext := 0.915858466$

$alfa2\_gr := 15.8633935$

$c2 := 563.234574$

$Mc2 := 1.28139282$

$c3 := 459.378288$

$Mc3 := 0.992618827$

$c4 := 70$

$c5 := 50$

$alfa3p\_gr := 12.0552888$

$alfa4p\_gr := 26.0552888$

$alfa4\_gr := 24.0552888$

$z2 := 18$

$z3 := 12$

>

IREVERSIBILITATE - VARIATII CONSTANTE DE ENTROPIE

> $restart;$

> $eqdT := U \cdot A \cdot \Delta T - (T - \Delta T) \cdot \Delta S = 0; \Delta T := solve(eqdT, \Delta T);$

$eqdT := U\,A\,\Delta T - (T - \Delta T)\,\Delta S = 0$

$$\Delta T := \frac{T\,\Delta S}{U\,A + \Delta S}$$

> $eqdT0 := U0 \cdot A0 \cdot \Delta T0 - (T0 + \Delta T0) \cdot \Delta S; \Delta T0 := solve(eqdT0, \Delta T0);$

$eqdT0 := U0\ A0\ \Delta T0 - (T0 + \Delta T0)\ \Delta S$

$$\Delta T0 := \frac{T0\ \Delta S}{U0\ A0 - \Delta S}$$

> $Q := U \cdot A \cdot \Delta T;$

$$Q := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S}$$

> $Q0 := U0 \cdot A0 \cdot \Delta T0;$

$$Q0 := \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}$$

> $P := Q - Q0;$

$$P := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S} - \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}$$

> $\eta := 1 - \frac{Q0}{Q};$

$$\eta := 1 - \frac{U0\,A0\,T0\,(U\,A + \Delta S)}{(U0\,A0 - \Delta S)\,U\,A\,T}$$

>

> $restart;$

> $\Delta S := 25; A := 1; A0 := 1; T := 900; T0 := 450;$

$$\Delta S := 25$$

$$A := 1$$

$$A0 := 1$$

$$T := 900$$

$$T0 := 450$$

> $\Delta T := \frac{T\,\Delta S}{U\,A + \Delta S}; \Delta T0 := \frac{T0\,\Delta S}{U0\,A0 - \Delta S};$

$$\Delta T := \frac{22500}{U + 25}$$

$$\Delta T0 := \frac{11250}{U0 - 25}$$

> $Q := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S}; Q0 := \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}; P := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S} - \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}; \eta := 1 - \frac{U0\,A0\,T0\,(U\,A + \Delta S)}{(U0\,A0 - \Delta S)\,U\,A\,T};$

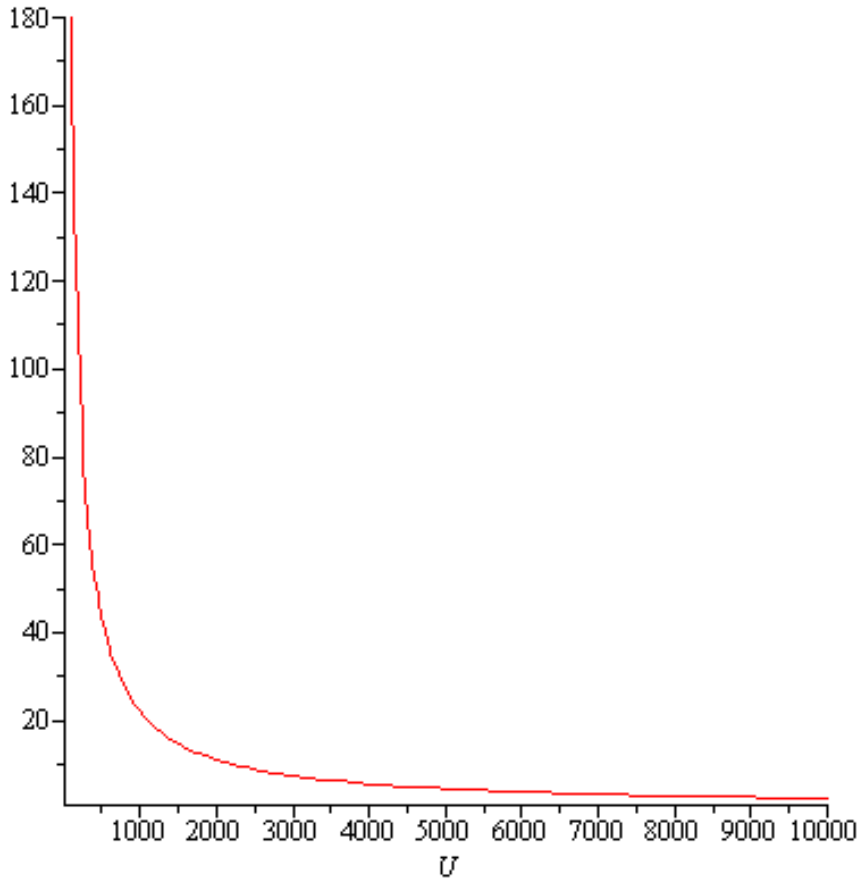
$$Q := \frac{22500\,U}{U + 25}$$

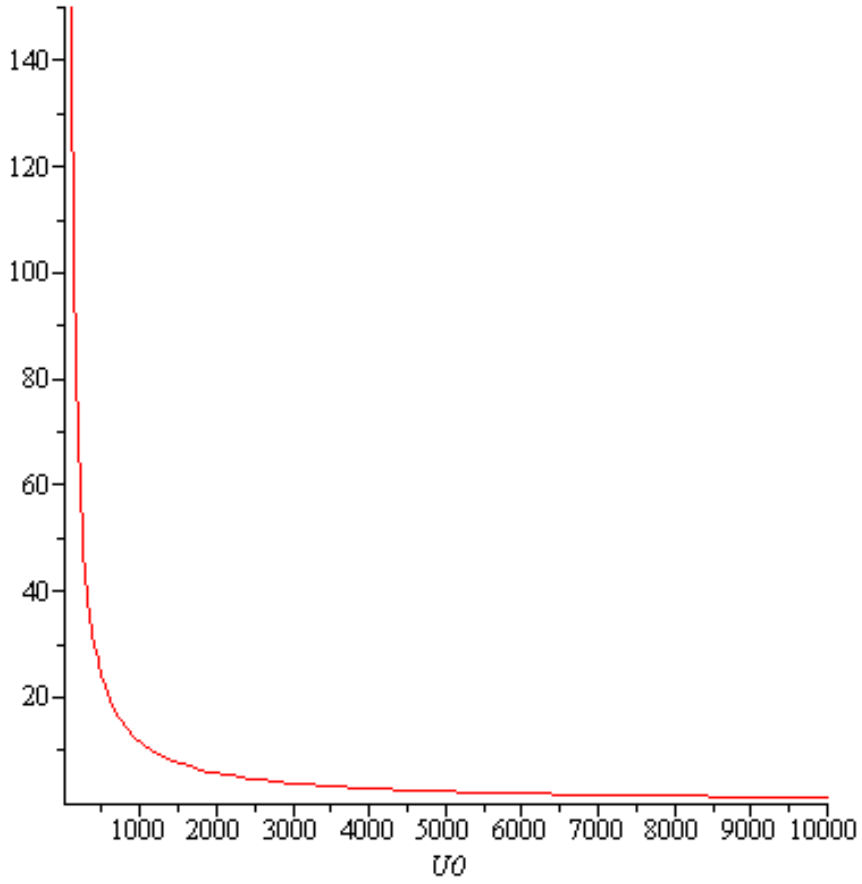
$$Q0 := \frac{11250\,U0}{U0 - 25}$$

$$P := \frac{22500\,U}{U + 25} - \frac{11250\,U0}{U0 - 25}$$

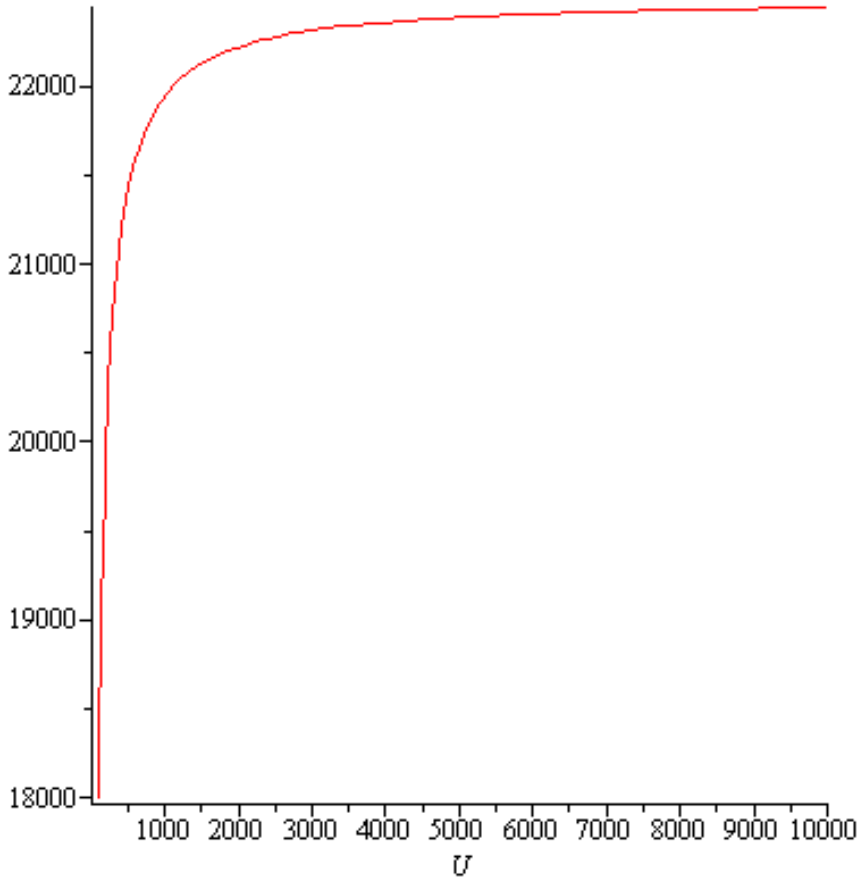
$$\eta := 1 - \frac{1}{2}\,\frac{U0\,(U+25)}{(U0-25)\,U}$$

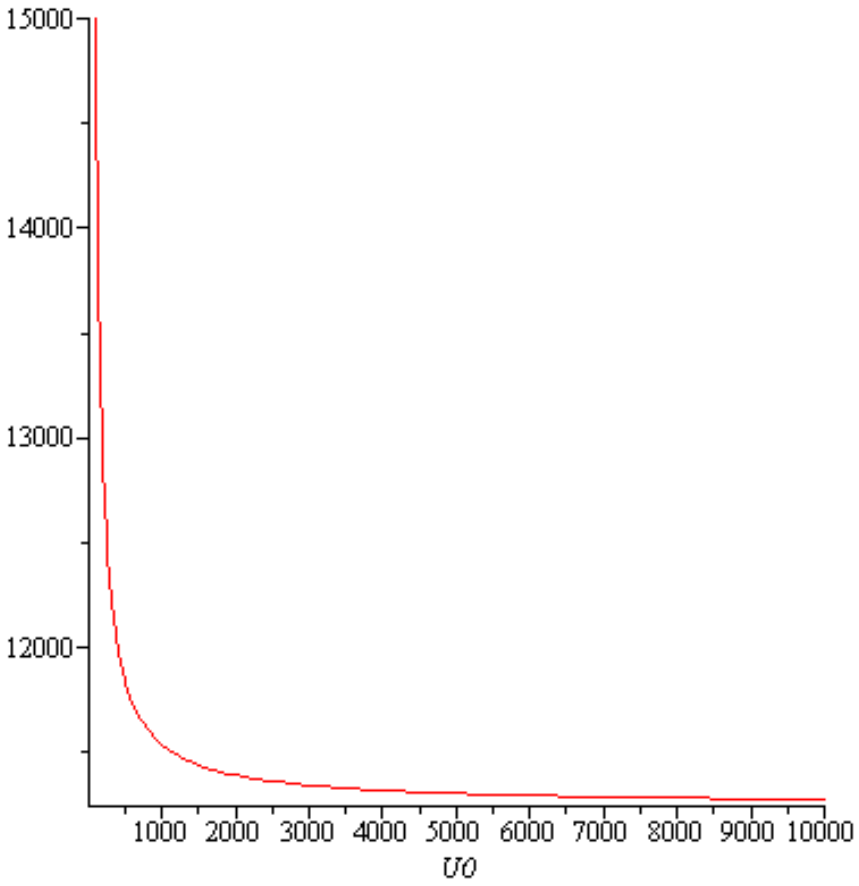
> $plot(\Delta T, U = 100..10000); plot(\Delta T0, U0 = 100..10000);$



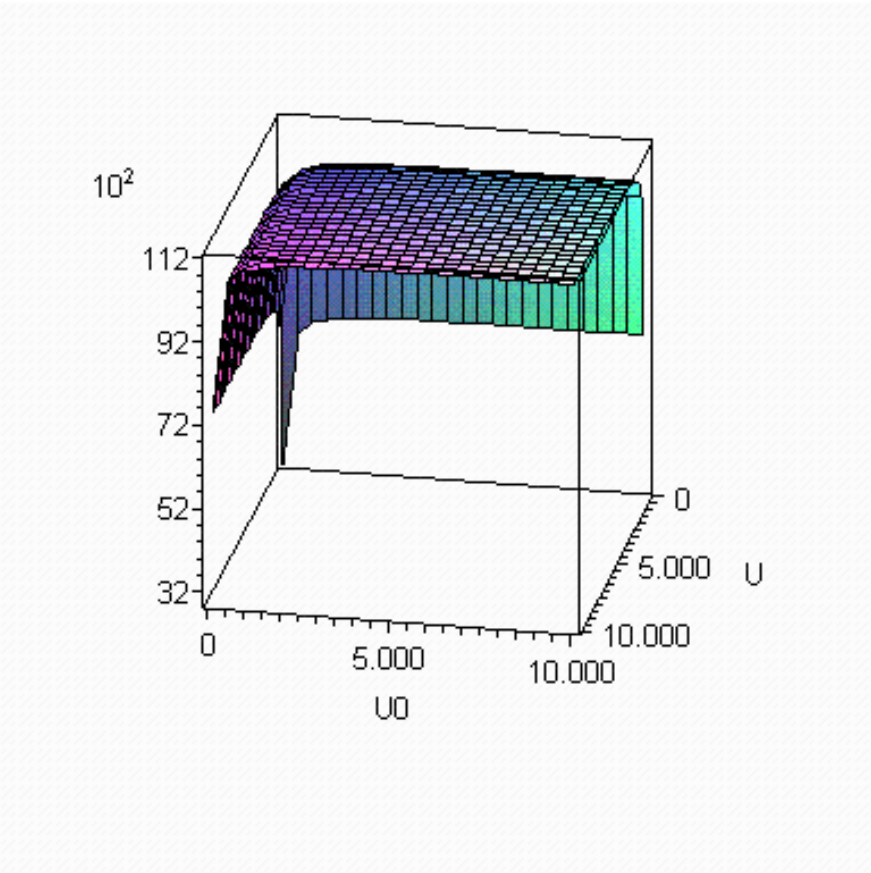


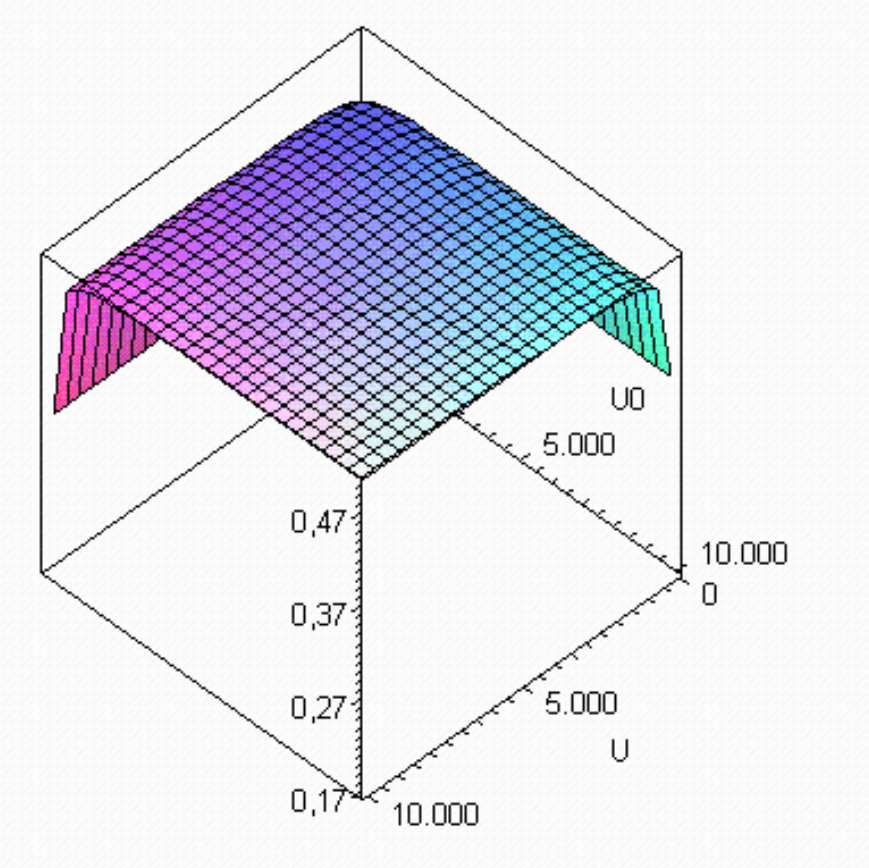
> $plot(Q, U = 100..10000); plot(Q0, U0 = 100..10000);$


22000
21000
20000
19000
18000
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
U



> *plot3d*(P, U = 100..10000, U0 = 100..10000); *plot3d*(η, U = 100..10000, U0 = 100..10000);


10^2
112
92
72
52
32
0
5.000
10.000
U0
0
5.000
10.000
U



>

>

IREVERSIBILITATE - VARIATII CONSTANTE DE ENTROPIE

> $restart;$

> $eqdT := U \cdot A \cdot \Delta T - (T - \Delta T) \cdot \Delta S = 0; \Delta T := solve(eqdT, \Delta T);$

$$eqdT := U\,A\,\Delta T - (T - \Delta T)\,\Delta S = 0$$

$$\Delta T := \frac{T\,\Delta S}{U\,A + \Delta S}$$

> $eqdT0 := U0 \cdot A0 \cdot \Delta T0 - (T0 + \Delta T0) \cdot \Delta S; \Delta T0 := solve(eqdT0, \Delta T0);$

$$eqdT0 := U0\,A0\,\Delta T0 - (T0 + \Delta T0)\,\Delta S$$

$$\Delta T0 := \frac{T0\,\Delta S}{U0\,A0 - \Delta S}$$

> $Q := U \cdot A \cdot \Delta T;$

$$Q := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S}$$

> $Q0 := U0 \cdot A0 \cdot \Delta T0;$

$$Q0 := \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}$$

> $P := Q - Q0;$

$$P := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S} - \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}$$

> $\eta := 1 - \frac{Q0}{Q};$

$$\eta := 1 - \frac{U0\,A0\,T0\,(U\,A + \Delta S)}{(U0\,A0 - \Delta S)\,U\,A\,T}$$

>

> $restart;$

> $\Delta S := 25; A := 1; A0 := 1; T := 900; T0 := 450;$

$$\Delta S := 25$$

$$A := 1$$

$$A0 := 1$$

$$T := 900$$

$$T0 := 450$$

> $\Delta T := \frac{T\,\Delta S}{U\,A + \Delta S}; \Delta T0 := \frac{T0\,\Delta S}{U0\,A0 - \Delta S};$

$$\Delta T := \frac{22500}{U + 25}$$

$$\Delta T0 := \frac{11250}{U0 - 25}$$

> $Q := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S}; Q0 := \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}; P := \frac{U\,A\,T\,\Delta S}{U\,A + \Delta S} - \frac{U0\,A0\,T0\,\Delta S}{U0\,A0 - \Delta S}; \eta := 1 - \frac{U0\,A0\,T0\,(U\,A + \Delta S)}{(U0\,A0 - \Delta S)\,U\,A\,T};$

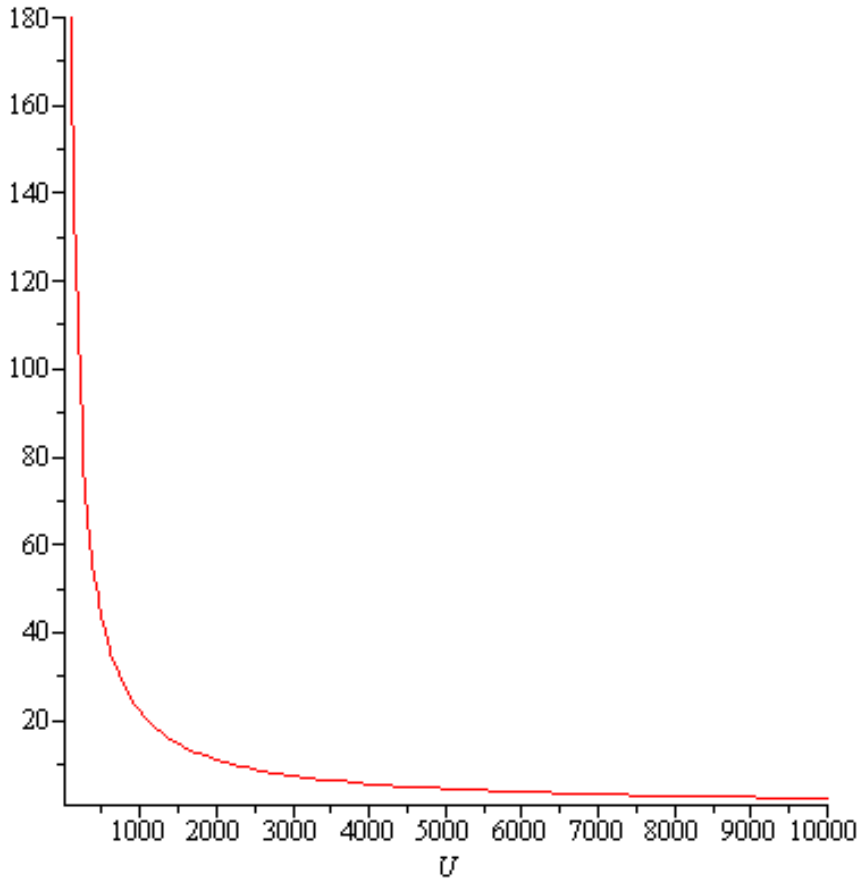
$$Q := \frac{22500\,U}{U + 25}$$

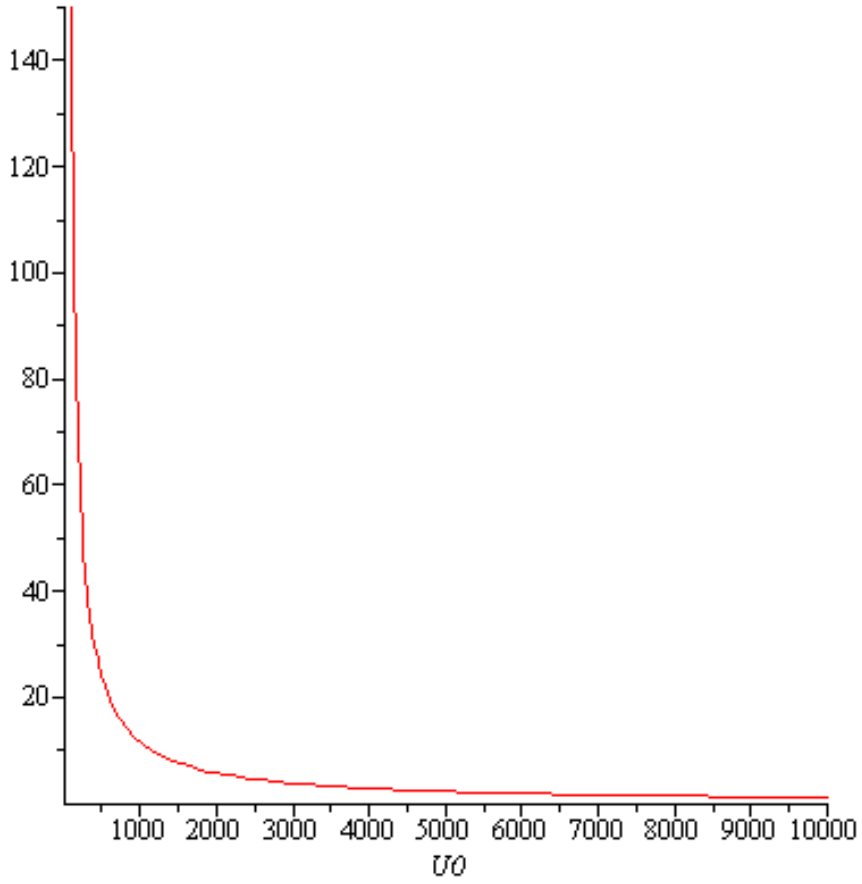
$$Q0 := \frac{11250\,U0}{U0 - 25}$$

$$P := \frac{22500\,U}{U + 25} - \frac{11250\,U0}{U0 - 25}$$

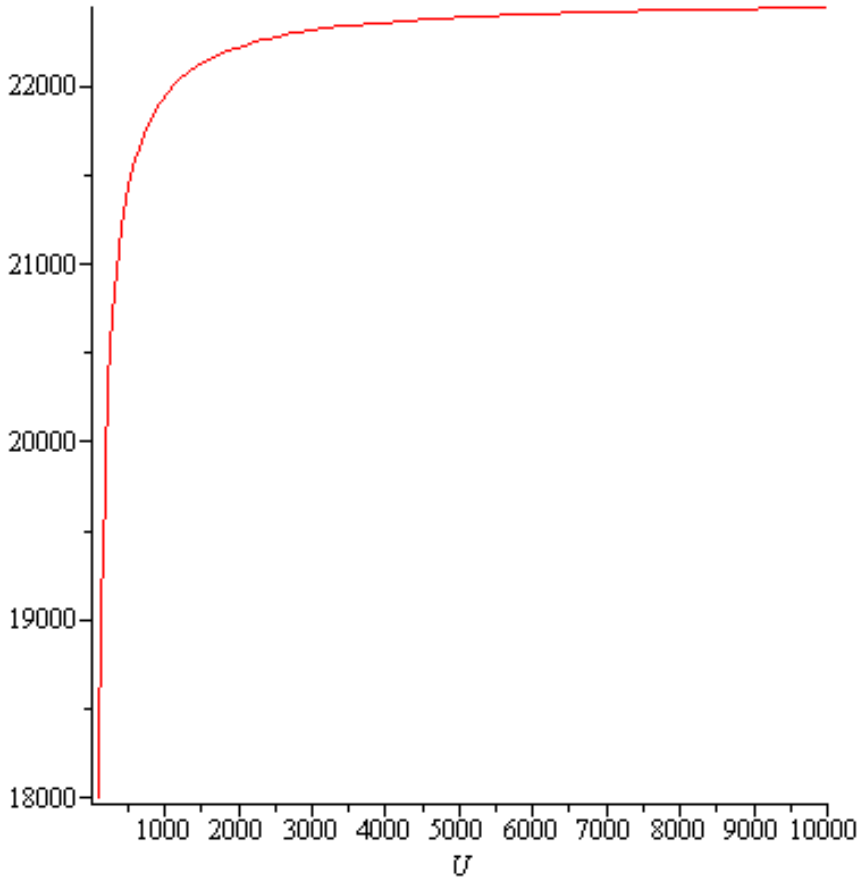
$$\eta := 1 - \frac{1}{2}\,\frac{U0\,(U+25)}{(U0-25)\,U}$$

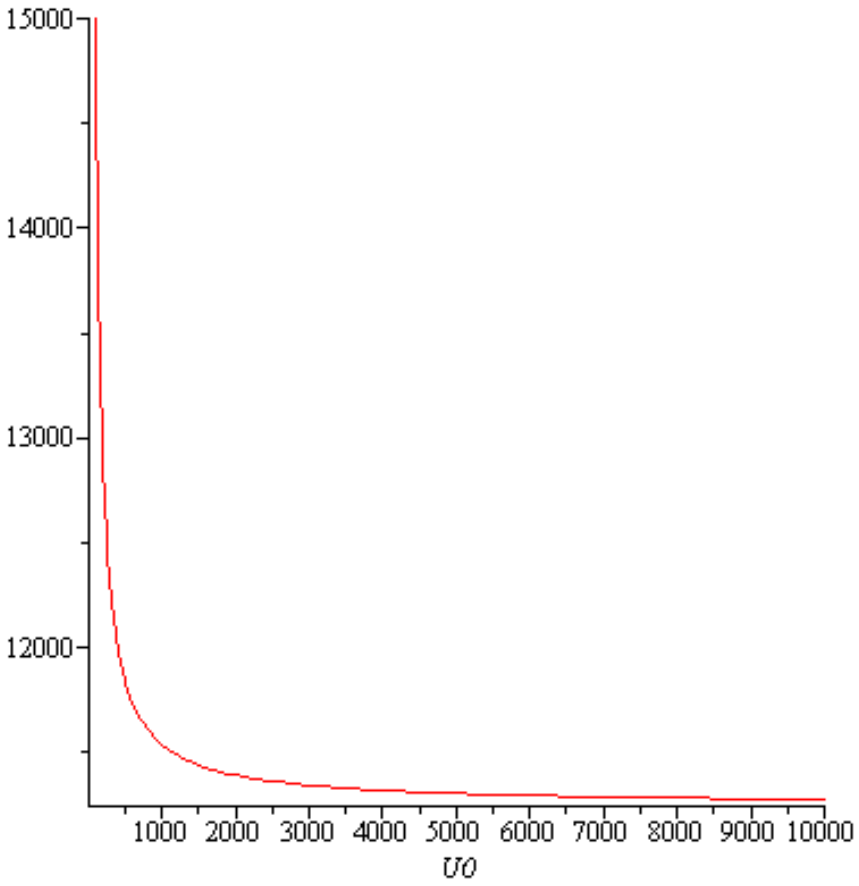
> $plot(\Delta T, U = 100..10000); plot(\Delta T0, U0 = 100..10000);$



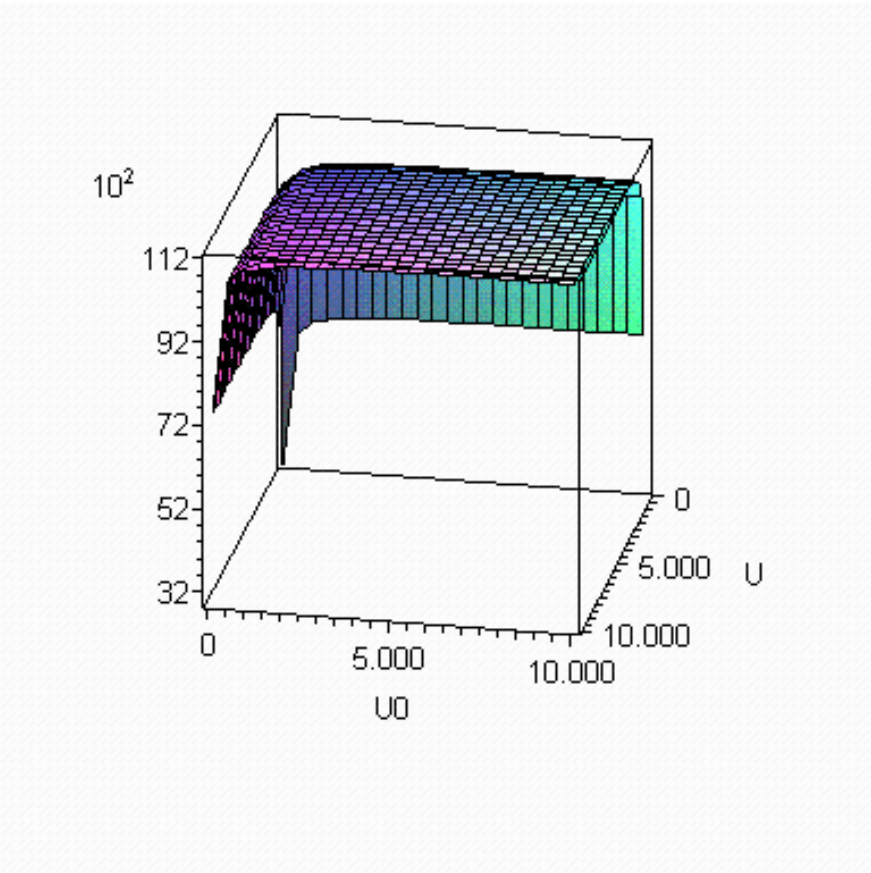


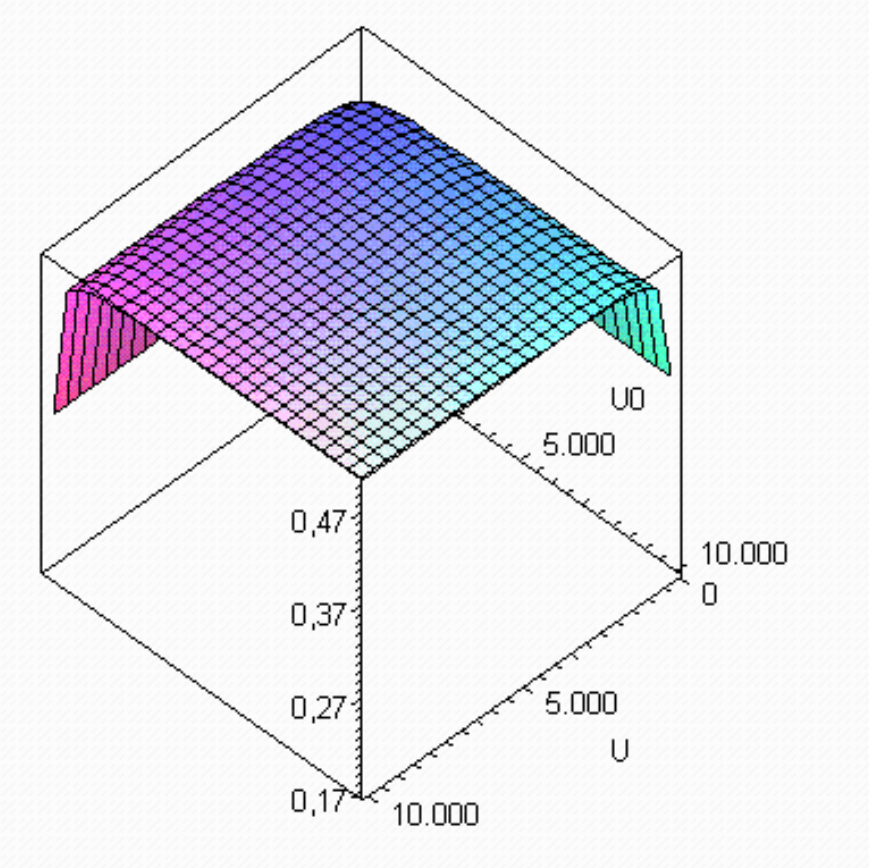
> $plot(Q, U = 100..10000); plot(Q0, U0 = 100..10000);$


22000
21000
20000
19000
18000
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
U



> *plot3d*(P, U = 100..10000, U0 = 100..10000); *plot3d*(η, U = 100..10000, U0 = 100..10000);


10^2
112
92
72
52
32
0
5.000
10.000
U0
0
5.000
10.000
U



>

> **IREVERSIBILITATE - Q CONSTANT**

> *restart*;

> $T := 900;\ T0 := 300;\ UA0perdS := \frac{(T0 + dT0)}{dT0};\ UAperdS := \frac{(T - dT)}{dT};$

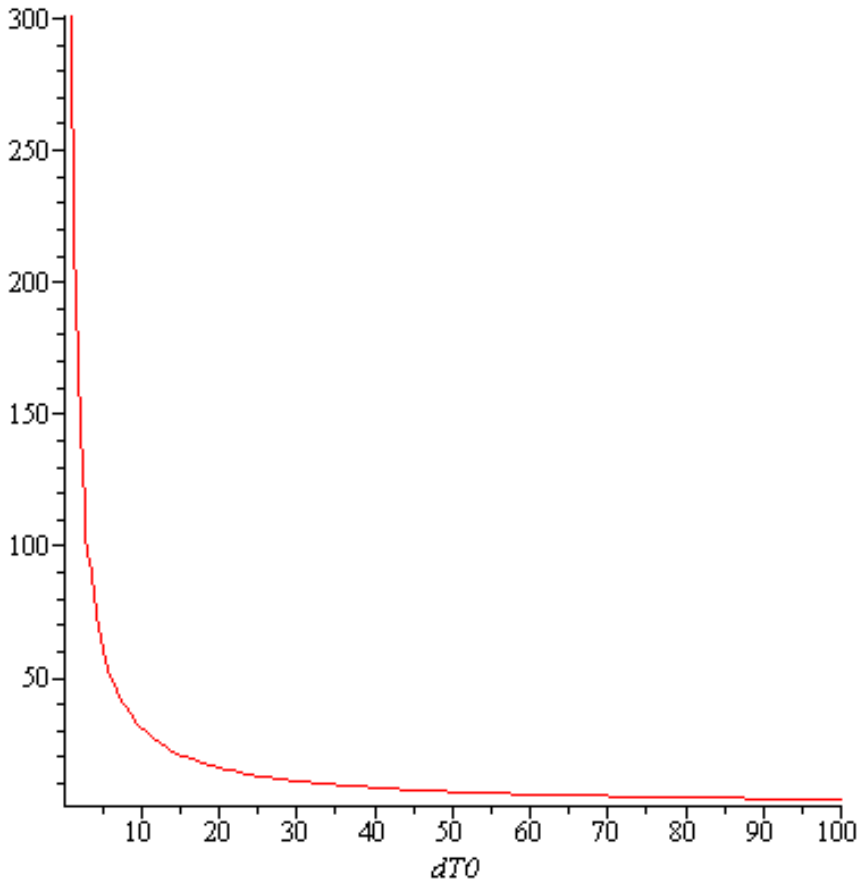
$T := 900$

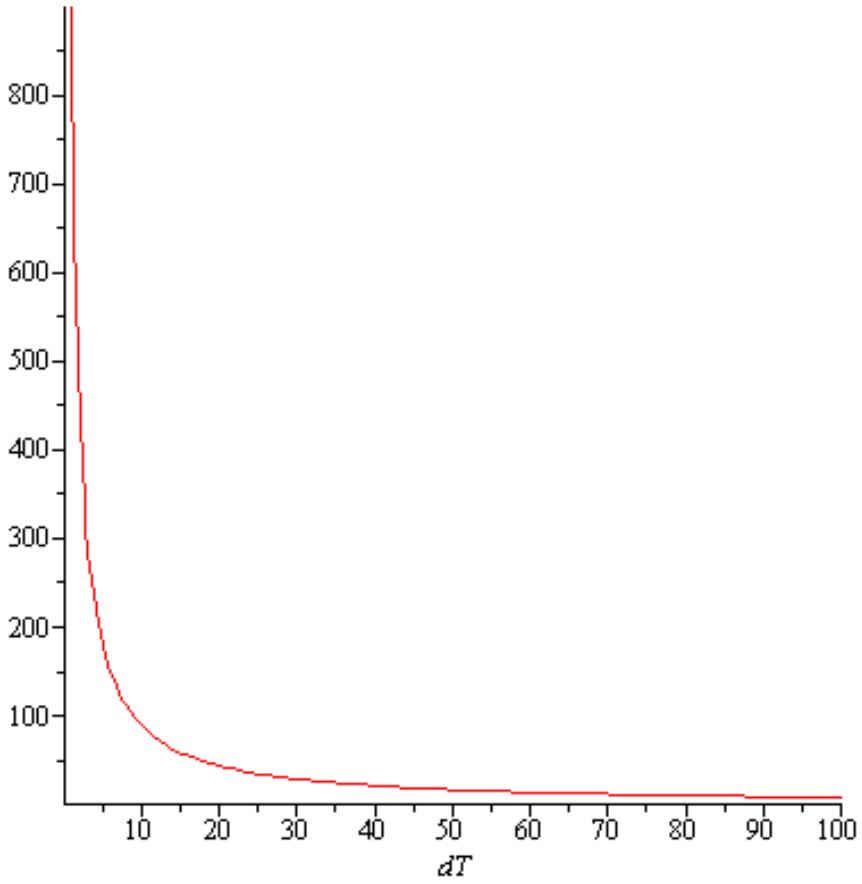
$T0 := 300$

$UA0perdS := \frac{300 + dT0}{dT0}$

$UAperdS := \frac{900 - dT}{dT}$

> $plot(UA0perdS, dT0 = 1..100);\ plot(UAperdS, dT = 1..100);$


300
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100
dT0



> *restart*;

> $dSlim := \frac{Q}{T}$;

$$dSlim := \frac{Q}{T}$$

> $dT := \frac{Q}{U \cdot A}$; $dS := \frac{Q}{T - \frac{Q}{U \cdot A}}$;

$$dT := \frac{10000}{U}$$

$$dS := \frac{10000}{900 - \frac{10000}{U}}$$

> $Q0 := (T0 + dT0) \cdot dS$; $P := Q - Q0$;

$$Q0 := \frac{(T0 + dT0)\, Q}{T - \frac{Q}{U\, A}}$$

$$P := Q - \frac{(T0 + dT0)\, Q}{T - \frac{Q}{U\, A}}$$

> $eqdT0 := Q0 - U0 \cdot A0 \cdot dT0 = 0;\ dT0 := solve(eqdT0, dT0);$

$$eqdT0 := \frac{(T0 + dT0)\, Q}{T - \frac{Q}{U\, A}} - U0\ A0\ dT0 = 0$$

$$dT0 := \frac{T0\ Q\ U\ A}{-Q\ U\ A + U0\ A0\ T\ U\ A - U0\ A0\ Q}$$

> $restart;$

> $\%Q := 10000;\ \%A := 1;\ \%A0 := 1;\ \%T := 900;\ \%T0 := 400;$

$$\%Q := 10000$$

$$\%A := 1$$

$$\%A0 := 1$$

$$\%T := 900$$

$$\%T0 := 400$$

> $dT := \frac{Q}{U \cdot A};\ dT0 := \frac{T0}{\frac{U0\ A0}{Q}\ T - \frac{U0\ A0}{U \cdot A} - 1};\ dS := \frac{Q}{T - \frac{Q}{U \cdot A}};$

$$dT := \frac{Q}{U\, A}$$

$$dT0 := \frac{T0}{\frac{U0\ A0\ T}{Q} - \frac{U0\ A0}{U\, A} - 1}$$

$$dS := \frac{Q}{T - \frac{Q}{U\, A}}$$

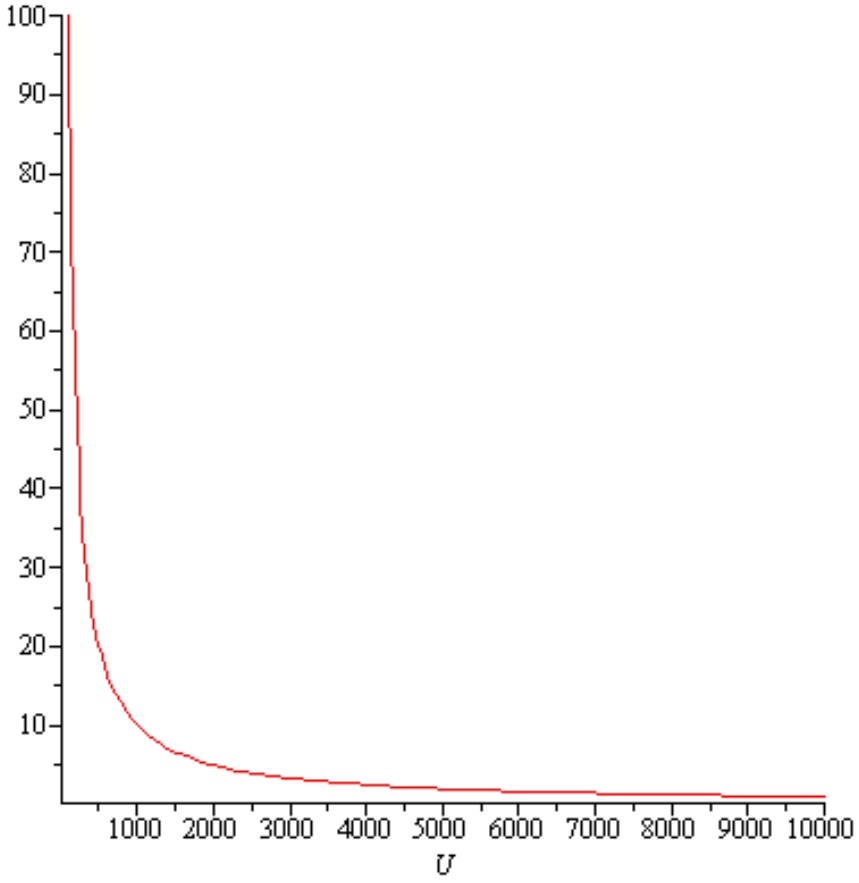
> $Q0 := (T0 + dT0) \cdot dS;\ P := Q - Q0;\ \eta := \frac{P}{Q};$

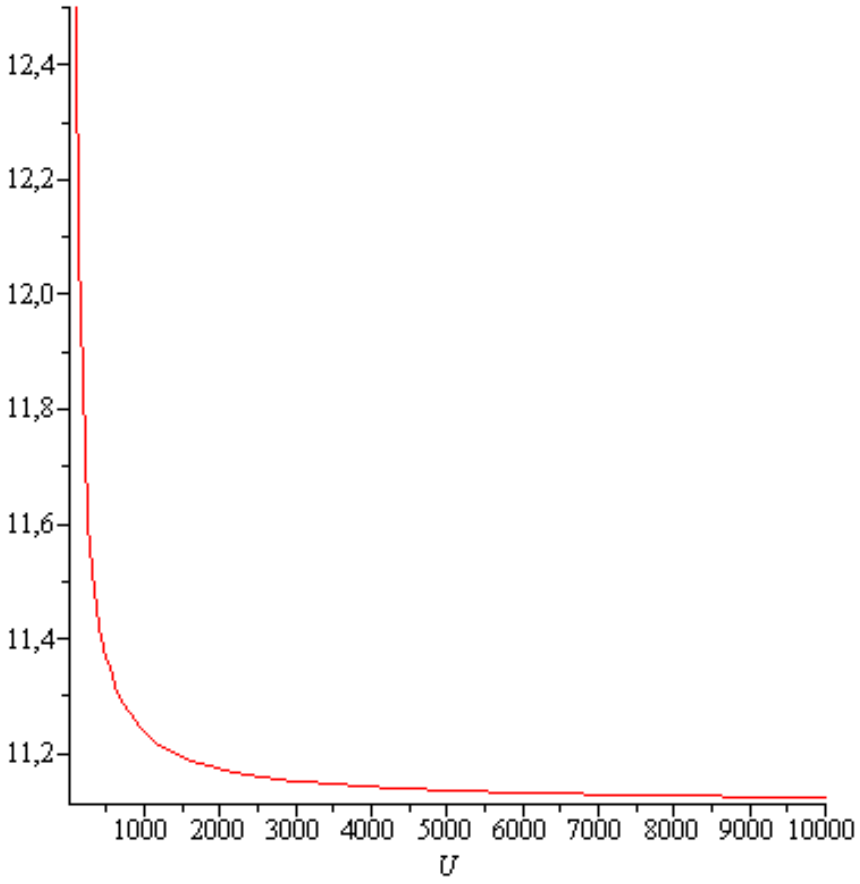
$$Q0 := \frac{\left(T0 + \frac{T0}{\frac{U0\ A0\ T}{Q} - \frac{U0\ A0}{U\, A} - 1}\right) Q}{T - \frac{Q}{U\, A}}$$

$$P := Q - \frac{\left(T0 + \frac{T0}{\frac{U0\ A0\ T}{Q} - \frac{U0\ A0}{U\, A} - 1}\right) Q}{T - \frac{Q}{U\, A}}$$

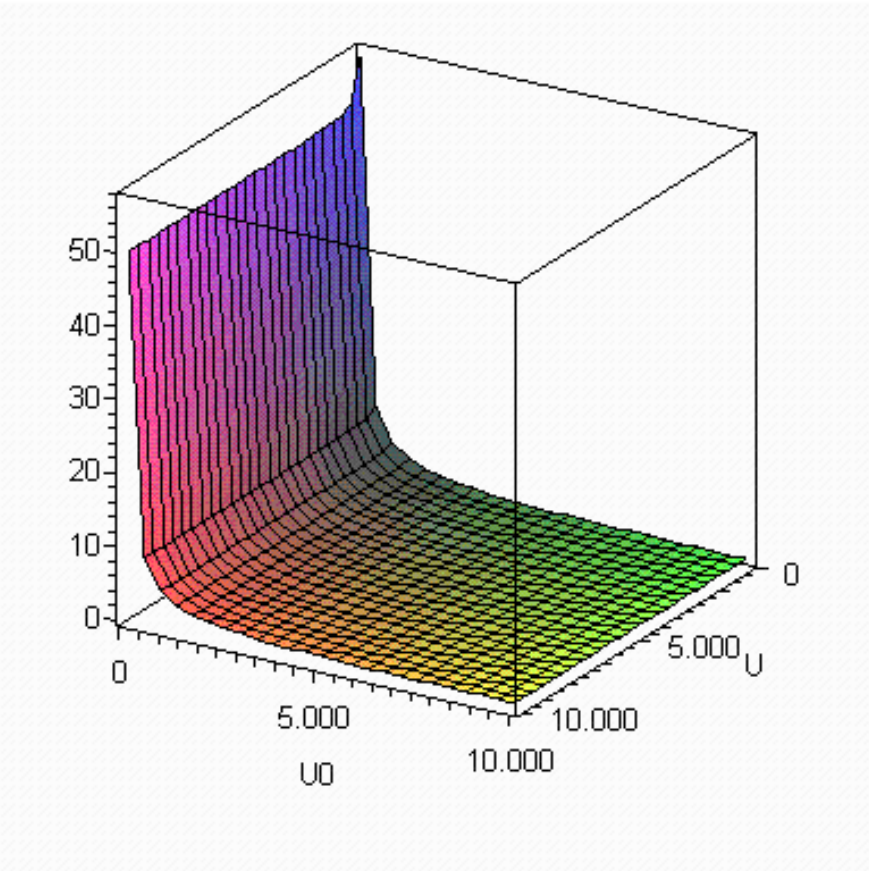
$$\eta := \frac{Q - \frac{\left(T0 + \frac{T0}{\frac{U0\ A0\ T}{Q} - \frac{U0\ A0}{U\ A} - 1}\right) Q}{T - \frac{Q}{U\ A}}}{Q}$$

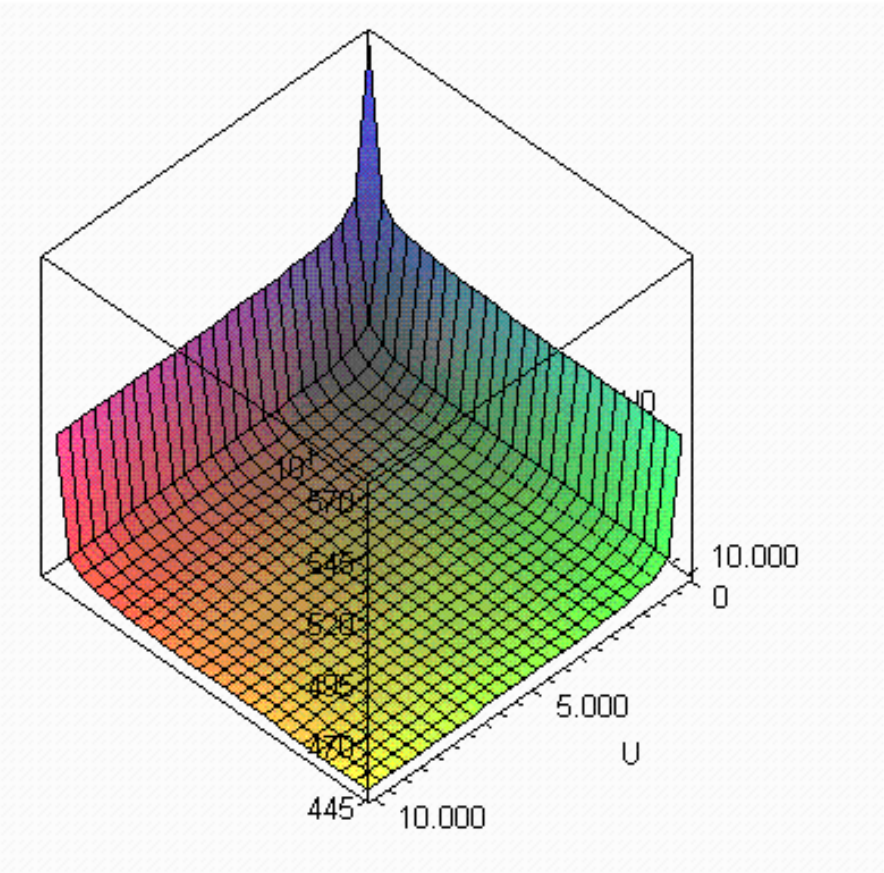
```
> plot(dT, U = 100..10000); plot(dS, U = 100..10000);
```

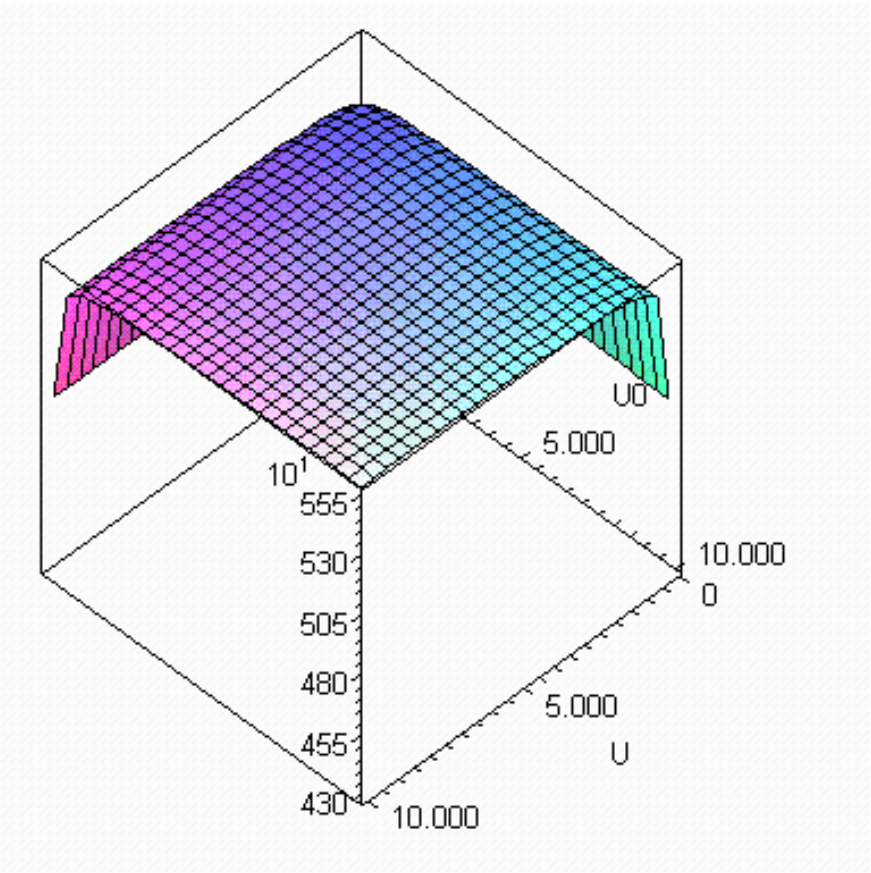


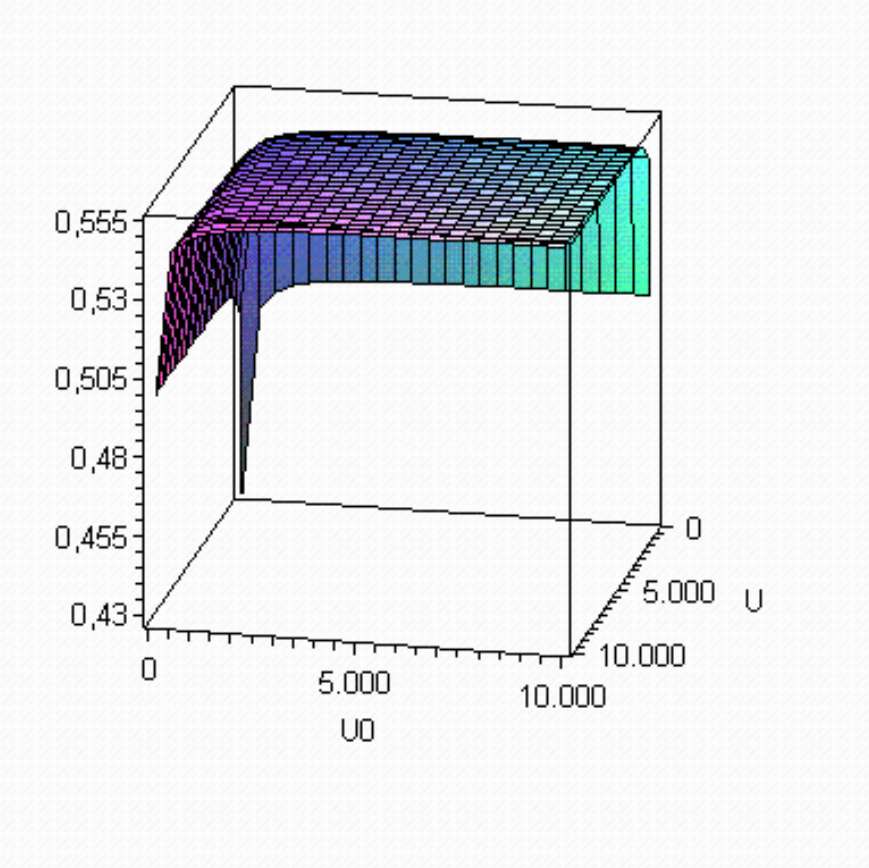


> *plot3d*(dT0, U = 100..10000, U0 = 100..10000); *plot3d*(Q0, U = 100..10000, U0 = 100..10000); *plot3d*(P, U = 100..10000, U0 = 100..10000); *plot3d*(η, U = 100..10000, U0 = 100..10000);


50
40
30
20
10
0
0
5.000
10.000
U0
0
5.000
10.000
U


570
545
520
495
470
445
10.000
5.000
U
0
10.000


U0
5.000
10.000
0
10^1
555
530
505
480
455
430
5.000
U
10.000



> TURBOMOTORUL TRIPLUFLUX

```
> restart;
> G2:=solve((RF-G1/G2),G2);G1:=solve((R-((G1+G2)/(G-G1-G2))),G1);
```

$$G2 := \frac{G1}{RF}$$

$$G1 := \frac{R\,G\,RF}{R\,RF + R + RF + 1}$$

```
> restart;
>
G:=359;R:=10.869;RF:=3;G1:=evalf(G*R*RF/(R+RF+1+R*RF));G2:=evalf(G1/RF)
;G3:=G-G1-G2;sumG:=G1+G2+G3;
```

$G := 359$

$R := 10.869$

$RF := 3$

$G1 := 246.564853$

$G2 := 82.1882846$

$G3 := 30.2468616$

$sumG := 359.0000000$

```
> piF:=1.745;piF1:=1.288;piF2:=piF/piF1;piC:=32.7/piF;es12:=0.92;es23:=0.92;es34:=0.88;es56:=0.94;em:=0.99;fi2a:=0.99;fi3b:=0.99;fi6c:=0.99;
```

$piF := 1.745$

$piF1 := 1.288$

$piF2 := 1.35481366$

$piC := 18.7392550$

$es12 := 0.92$

$es23 := 0.92$

$es34 := 0.88$

$es56 := 0.94$

$em := 0.99$

$fi2a := 0.99$

$fi3b := 0.99$

$fi6c := 0.99$

```
> Ta:=273.15;p0:=1.01325;T0:=288;
```

$Ta := 273.15$

$p0 := 1.01325$

$T0 := 288$

```
> aer_uscat;rausO2:=0.2059;rausN2:=0.7809;rausCO2:=0.0132;MO2:=32;MN2:=28.016;MCO2:=44.01;MH2O:=18.0156;Maus:=rausO2*MO2+rausN2*MN2+rausCO2*MCO2;gausO2:=rausO2*MO2/Maus;gausN2:=rausN2*MN2/Maus;gausCO2:=rausCO2*MCO2/Maus;sumgaus:=gausO2+gausN2+gausCO2;
```

aer_uscat

$rausO2 := 0.2059$

$rausN2 := 0.7809$

$rausCO2 := 0.0132$

$MO2 := 32$

$MN2 := 28.016$

$MCO2 := 44.01$

$MH2O := 18.015$

$Maus := 29.047426$

$gausO2 := 0.226829045$

$gausN2 := 0.753171523$

$gausCO2 := 0.0199994310$

$sumgaus := 1.000000000$

```
> aer_umed;l0:=2500;u0:=l0-610.8*206.3/1000;phi0:=0.4;t0:=T0-
273.15;pvsH2O0:=-.4164460979e-18*t0^10+.2004215749e-
15*t0^9+.6588432820e-3*t0-.4117823023e-13*t0^8-.4560213564e-
4*t0^2+.4719547427e-11*t0^7+.6985705427e-5*t0^3-.3308562609e-9*t0^6-
.4022805689e-6*t0^4+.1465463358e-7*t0^5+.6108e-
2;x0:=MH2O*phi0*pvsH2O0/(p0-
phi0*pvsH2O0)/Maus;gaumO2:=gausO2/(1+x0);gaumN2:=gausN2/(1+x0);gaumCO2:
=gausCO2/(1+x0);gaumH2O:=x0/(1+x0);sumgaum:=gaumO2+gaumN2+gaumCO2+gaumH
2O;
```

aer_umed

$l0 := 250$

$u0 := 2373.99196$

$\phi 0 := 0.4$

$t0 := 14.85$

$pvsH2O0 := 0.0168449354$

$x0 := 0.00415194359$

$gaumO2 := 0.225891157$

$gaumN2 := 0.750057327$

$gaumCO2 := 0.0199167378$

$gaumH2O := 0.00413477624$

$sumgaum := 0.999999999$

```
> cpO2:=0.82397+3.05587E-4*T+5.32089E-8*T^2-1.30137E-10*T^3+3.58225E-
```

```
14*T^4;cvO2:=0.56574+2.96923E-4*T+6.54515E-8*T^2-1.36918E-
10*T^3+3.71407E-14*T^4;cpH2O:=1.84336-2.31223E-4*T+1.1966E-6*T^2-
6.15263E-10*T^3+1.0015E-13*T^4;cvH2O:=1.38161-2.29361E-4*T+1.19327E-
6*T^2-6.13657E-10*T^3+9.99765E-14*T^4;cpN2:=1.07623-3.25964E-
4*T+7.92186E-7*T^2-4.66137E-10*T^3+8.87148E-14*T^4;cvN2:=0.77884-
3.22759E-4*T+7.86981E-7*T^2-4.62795E-10*T^3+8.79811E-
14*T^4;cpCO2:=0.47158+0.00155*T-1.15247E-6*T^2+4.2015E-10*T^3-6.01131E-
14*T^4;cvCO2:=0.28209+0.00156*T-1.15879E-6*T^2+4.24136E-10*T^3-
6.09268E-
14*T^4;cpaum:=gaumO2*cpO2+gaumN2*cpN2+gaumCO2*cpCO2+gaumH2O*cpH2O;cvaum
:=gaumO2*cvO2+gaumN2*cvN2+gaumCO2*cvCO2+gaumH2O*cvH2O;Raum:=cpaum-
cvaum;RO2:=cpO2-cvO2;RH2O:=cpH2O-cvH2O;RN2:=cpN2-cvN2;RCO2:=cpCO2-
cvCO2;
```

$$cpO2 := 0.82397 + 0.000305587T + 5.3208910^{-8}\,T^2 - 1.3013710^{-10}\,T^3 + 3.5822510^{-14}\,T^4$$

$$cvO2 := 0.56574 + 0.000296923T + 6.5451510^{-8}\,T^2 - 1.3691810^{-10}\,T^3 + 3.7140710^{-14}\,T^4$$

$$cpH2O := 1.84336 - 0.000231223T + 0.00000119667T^2 - 6.1526310^{-10}\,T^3 + 1.001510^{-13}\,T^4$$

$$cvH2O := 1.38161 - 0.000229361T + 0.00000119327T^2 - 6.1365710^{-10}\,T^3 + 9.9976510^{-14}\,T^4$$

$$cpN2 := 1.07623 - 0.000325964T + 7.9218610^{-7}\,T^2 - 4.6613710^{-10}\,T^3 + 8.8714810^{-14}\,T^4$$

$$cvN2 := 0.77884 - 0.000322759T + 7.8698110^{-7}\,T^2 - 4.6279510^{-10}\,T^3 + 8.7981110^{-14}\,T^4$$

$$cpCO2 := 0.47158 + 0.00155\,T - 0.00000115247T^2 + 4.201510^{-10}\,T^3 - 6.0113110^{-14}\,T^4$$

$$cvCO2 := 0.28209 + 0.00156\,T - 0.000001158\,79\,T^2 + 4.241\,36\,10^{-10}\,T^3 - 6.092\,68\,10^{-14}\,T^4$$

$$cpaum := 1.010\,375\,951 - 0.000\,145\,547\,397\,3\,T + 5.881\,985\,646\,10^{-7}\,T^2 - 3.732\,022\,277\,10^{-10}\,T^3 + 7.385\,001\,281\,10^{-14}\,T^4$$

$$cvaum := 0.723\,301\,273\,6 - 0.000\,144\,893\,718\,1\,T + 5.869\,203\,687\,10^{-7}\,T^2 - 3.721\,412\,754\,10^{-10}\,T^3 + 7.358\,054\,183\,10^{-14}\,T^4$$

$$Raum := 0.287\,074\,677\,4 - 6.536\,792\,10^{-7}\,T + 1.278\,195\,910^{-9}\,T^2 - 1.060\,952\,310^{-12}\,T^3 + 2.694\,709\,810^{-16}\,T^4$$

$$RO2 := 0.25823 + 0.000\,008\,664\,T - 1.224\,26\,10^{-8}\,T^2 + 6.781\,10^{-12}\,T^3 - 1.318\,2\,10^{-15}\,T^4$$

$$RH2O := 0.46175 - 0.000\,001\,862\,T + 3.33\,10^{-9}\,T^2 - 1.606\,10^{-12}\,T^3 + 1.735\,10^{-16}\,T^4$$

$$RN2 := 0.29739 - 0.000\,003\,205\,T + 5.205\,10^{-9}\,T^2 - 3.342\,10^{-12}\,T^3 + 7.337\,10^{-16}\,T^4$$

$$RCO2 := 0.18949 - 0.00001\,T + 6.32\,10^{-9}\,T^2 - 3.986\,10^{-12}\,T^3 + 8.137\,10^{-16}\,T^4$$

```
> w1r:=160;w1t:=w1r/0.99;h0:=int(cpaum,T=Ta..T0);h1r:=h0-
w1r^2/2/1000;h1t:=h0-w1t^2/2/1000;es01:=(h0-h1r)/(h0-h1t);
```

$$w1r := 160$$

$$w1t := 161.616161$$

$$h0 := 14.9697442$$

$$h1r := 2.1697442$$

$$h1t := 1.9098523$$

$$es01 := 0.980100000$$

```
> eq01t:=h1t-
int(cpaum,T=Ta..T1ti)=0;T1t:=fsolve(eq01t,T1ti);eq01r:=h1r-
```

```
int(cpaum,T=Ta..T1ri)=0;T1r:=fsolve(eq01r,T1ri);k01:=int(cpaum,T=T0..T1
t)/int(cvaum,T=T0..T1t);
```

$$eq01t := 275.9632285 - 1.010375951\,T1ti + 0.00007277369865\,T1ti^2 - 1.960661882\,10^{-7}\,T1ti^3 + 9.330055692\,10^{-11}\,T1ti^4 - 1.477000256\,10^{-14}\,T1ti^5 = 0$$

$$T1t := 275.0458148$$

$$eq01r := 276.2231203 - 1.010375951\,T1ri + 0.00007277369865\,T1ri^2 - 1.960661882\,10^{-7}\,T1ri^3 + 9.330055692\,10^{-11}\,T1ri^4 - 1.477000256\,10^{-14}\,T1ri^5 = 0$$

$$T1r := 275.3037690$$

$$k01 := 1.397911730$$

```
> combustibil;gC:=0.85;gH2:=0.15;Hs:=46000;
```

$$combustibil$$

$$gC := 0.85$$

$$gH2 := 0.15$$

$$Hs := 46000$$

```
> p1:=(T1t/T0)^(k01/(k01-1));
```

$$p1 := 0.8507103122$$

```
>
compression_F1;h1f:=h1r+w1r^2/2/1000;T1f:=fsolve((int(cpaum,T=Ta..T1fi)
-
h1f),T1fi);k11f:=int(cpaum,T=T1r..T1f)/int(cvaum,T=T1r..T1f);p1f:=p1*(T
1f/T1r)^(k11f/(k11f-
1));k1f2:=int(cpaum,T=T1f..T2ti)/int(cvaum,T=T1f..T2ti);eq12:=T1f*piF1^
((k1f2-1)/k1f2)-
T2ti=0;T2t:=fsolve(eq12,T2ti);h2t:=int(cpaum,T=Ta..T2t);h2r:=h1f+(h2t-
h1f)/es12;T2r:=fsolve((int(cpaum,T=Ta..T2ri)-h2r),T2ri);es02:=(h2t-
h0)/(h2r-h0);PF1:=G*(h2r-h1f);
```

$$compression\_F1$$

$$h1f := 14.96974420$$

$$T1f := 287.999999$$

$$k11f := 1.39790441$$

$$p1f := 0.996714225$$

$$k1f2 := \left(1.01037595\,1T2ti - 289.0231202 - 0.00007277369865\,T2ti^2 + 1.96066188\,210^{-7}\,T2ti^3 - 9.33005569\,210^{-11}\,T2ti^4 + 1.47700025\,610^{-14}\,T2ti^5\right) \Big/ \left(0.7233012736\,T2ti - 206.3642627 - 0.00007244685905\,T2ti^2 + 1.95640122\,910^{-7}\,T2ti^3 - 9.30353188\,510^{-11}\,T2ti^4 + 1.47161083\,710^{-14}\,T2ti^5\right)$$

$$eq12 := 287.9999999 \left(\left(\left(1.010375951\,T2ti - 289.0231202 \right.\right.\right.$$

$$1.288 - 0.00007277369865\,T2ti^2 + 1.960661882\,10^{-7}\,T2ti^3$$

$$\left. - 9.330055692\,10^{-11}\,T2ti^4 + 1.477000256\,10^{-14}\,T2ti^5\right) \Big/ \left(0.7233012736\,T2ti\right.$$

$$\left. - 206.3642627 - 0.00007244685905\,T2ti^2 + 1.956401229\,10^{-7}\,T2ti^3\right.$$

$$\left. - 9.303531885\,10^{-11}\,T2ti^4 + 1.471610837\,10^{-14}\,T2ti^5\right) - 1\Big)$$

$$\left(0.7233012736\,T2ti - 206.3642627 - 0.00007244685905\,T2ti^2\right.$$

$$\left. + 1.956401229\,10^{-7}\,T2ti^3 - 9.303531885\,10^{-11}\,T2ti^4\right.$$

$$\left. + 1.471610837\,10^{-14}\,T2ti^5\right)\Big) \Big/ \left(1.010375951\,T2ti - 289.0231202\right.$$

$$\left. - 0.00007277369865\,T2ti^2 + 1.960661882\,10^{-7}\,T2ti^3\right.$$

$$\left. - 9.330055692\,10^{-11}\,T2ti^4 + 1.477000256\,10^{-14}\,T2ti^5\right) - T2ti = 0$$

$$T2t := 309.471934$$

$$h2t := 36.6572189$$

$$h2r := 38.5430863$$

$$T2r := 311.336554$$

$es02 := 0.919999999$

$PF1 := 8462.82981$

```
>
speed_of_first_jet;p2:=p1f*piF1;k2a:=int(cpaum,T=T2r..Ttai)/int(cvaum,T
=T2r..Ttai);Tta:=fsolve((T2r*(p0/p2)^((k2a-1)/k2a)-
Ttai),Ttai);wat:=sqrt(2000*int(cpaum,T=Tta..T2r));war:=wat*fi2a;Th1:=G1
*war;Tra:=T2r-(T2r-Tta)*fi2a^2;Rgpa:=int(Raum,T=Tta..Tra)/(Tra-
Tta);ka:=int(cpaum,T=Tra..Tta)/int(cvaum,T=Tra..Tta);Machar:=war/sqrt(1
000*Rgpa*ka*Tra);
```

speed_of_first_jet

$p2 := 1.28376792$

$$k2a := \left(1.010375951 Ttai - 312.5964624 - 0.00007277369865 Ttai^2 + 1.96066188210^{-7}\, Ttai^3 - 9.33005569210^{-11}\, Ttai^4 + 1.47700025610^{-14}\, Ttai^5\right) \Big/ \left(0.7233012736 Ttai - 223.2407787 - 0.00007244685905 Ttai^2 + 1.95640122910^{-7}\, Ttai^3 - 9.30353188510^{-11}\, Ttai^4 + 1.47161083710^{-14}\, Ttai^5\right)$$

$Tta := 291.098403$

$wat := 202.222815$

$war := 200.200587$

$Th1 := 49362.4284$

$Tra := 291.501142$

$Rgpa := 0.286968438$

$ka := 1.39733757$

$Machar := 0.585568196$

```
>
compression_F2;k23:=int(cpaum,T=T2r..T3ti)/int(cvaum,T=T2r..T3ti);eq23:
=T2r*piF2^((k23-1)/k23)-
T3ti=0;T3t:=fsolve(eq23,T3ti);h3t:=int(cpaum,T=Ta..T3t);h3r:=h2r+(h3t-
h2r)/es23;T3r:=fsolve((int(cpaum,T=Ta..T3ri)-
h3r),T3ri);p3:=p2*piF2;PF2:=(G-G1)*(h3r-h2r);
```

compression_F2

$$k23 := \left(1.010375951\,T3ti - 312.5964624 - 0.00007277369865\,T3ti^2 + 1.96066188210^{-7}\,T3ti^3 - 9.33005569210^{-11}\,T3ti^4 + 1.47700025610^{-14}\,T3ti^5\right) \Big/ \left(0.7233012736\,T3ti - 223.2407787 - 0.00007244685905\,T3ti^2 + 1.95640122910^{-7}\,T3ti^3 - 9.30353188510^{-11}\,T3ti^4 + 1.47161083710^{-14}\,T3ti^5\right)$$

$$eq23 := 311.3365548 \left(\left(\left(1.010375951\,T3ti - 312.5964624\right) 1.354813665 - 0.00007277369865\,T3ti^2 + 1.960661882\,10^{-7}\,T3ti^3 - 9.330055692\,10^{-11}\,T3ti^4 + 1.477000256\,10^{-14}\,T3ti^5\right) \Big/ \left(0.7233012736\,T3ti - 223.2407787 - 0.00007244685905\,T3ti^2 + 1.956401229\,10^{-7}\,T3ti^3 - 9.303531885\,10^{-11}\,T3ti^4 + 1.471610837\,10^{-14}\,T3ti^5\right) - 1\right) \left(0.7233012736\,T3ti - 223.2407787 - 0.00007244685905\,T3ti^2 + 1.956401229\,10^{-7}\,T3ti^3 - 9.303531885\,10^{-11}\,T3ti^4 + 1.471610837\,10^{-14}\,T3ti^5\right) \Big/ \left(1.010375951\,T3ti - 312.5964624 - 0.00007277369865\,T3ti^2 + 1.960661882\,10^{-7}\,T3ti^3 - 9.330055692\,10^{-11}\,T3ti^4 + 1.477000256\,10^{-14}\,T3ti^5\right) - T3ti = 0$$

$T3t := 339.296254$

$h3t := 66.8738811$

$h3r := 69.3374285$

$T3r := 341.722740$

$p3 := 1.73926632$

$PF2 := 3462.36636$

>

```
speed_of_second_jet;p3:=p2*piF2;k3b:=int(cpaum,T=T3r..Ttbi)/int(cvaum,T
=T3r..Ttbi);Ttb:=fsolve((T3r*(p0/p3)^((k3b-1)/k3b)-
Ttbi),Ttbi);wbt:=sqrt(2000*int(cpaum,T=Ttb..T3r));wbr:=wbt*fi3b;Th2:=G2
*wbr;Trb:=T3r-(T3r-Ttb)*fi3b^2;Rgpb:=int(Raum,T=Ttb..Trb)/(Trb-
Ttb);kb:=int(cpaum,T=Trb..Ttb)/int(cvaum,T=Trb..Ttb);Machbr:=wbr/sqrt(1
000*Rgpb*kb*Trb);
```

speed_of_second_jet

$p3 := 1.73926632$

$$k3b := \left(1.010375951\,Ttbi - 343.3908045 - 0.00007277369865\,Ttbi^{2} + 1.96066188210^{-7}\,Ttbi^{3} - 9.33005569210^{-11}\,Ttbi^{4} + 1.47700025610^{-14}\,Ttbi^{5}\right) \Big/ \left(0.7233012736\,Ttbi - 245.3153895 - 0.00007244685905\,Ttbi^{2} + 1.95640122910^{-7}\,Ttbi^{3} - 9.30353188510^{-11}\,Ttbi^{4} + 1.47161083710^{-14}\,Ttbi^{5}\right)$$

$Ttb := 293.195167$

$wbt := 313.448985$

$wbr := 310.314495$

$Th2 := 25504.2160$

$Trb := 294.160866$

$Rgpb := 0.286968078$

$kb := 1.39719280$

$Machbr := 0.903575924$

```
>
compression_34;k34:=int(cpaum,T=T3r..T4ti)/int(cvaum,T=T3r..T4ti);eq34:
=T4ti-T3r*piC^((k34-
1)/k34);T4t:=fsolve(eq34,T4ti);h4t:=int(cpaum,T=Ta..T4t);h4r:=h3r+(h4t-
h3r)/es34;T4r:=fsolve((int(cpaum,T=Ta..T4ri)-
h4r),T4ri);p4:=p3*piC;PC:=G3*(h4r-h3r);
```

compression_34

$$k34 := \left(1.010375951 T4ti - 343.3908045 - 0.00007277369865 T4ti^2 + 1.96066188210^{-7}\ T4ti^3 - 9.33005569210^{-11}\ T4ti^4 + 1.47700025610^{-14}\ T4ti^5\right) \Big/ \left(0.7233012736 T4ti - 245.3153895 - 0.00007244685905 T4ti^2 + 1.95640122910^{-7}\ T4ti^3 - 9.30353188510^{-11}\ T4ti^4 + 1.47161083710^{-14}\ T4ti^5\right)$$

$$eq34 := T4ti - 341.7227402 \left(\left(\left(1.010375951\ T4ti - 343.3908045\right) \Big/ 18.73925502 - 0.00007277369865\ T4ti^2 + 1.960661882\ 10^{-7}\ T4ti^3 - 9.330055692\ 10^{-11}\ T4ti^4 + 1.477000256\ 10^{-14}\ T4ti^5\right) \Big/ \left(0.7233012736\ T4ti - 245.3153895 - 0.00007244685905\ T4ti^2 + 1.956401229\ 10^{-7}\ T4ti^3 - 9.303531885\ 10^{-11}\ T4ti^4 + 1.471610837\ 10^{-14}\ T4ti^5\right) - 1\right) \left(0.7233012736\ T4ti - 245.3153895 - 0.00007244685905\ T4ti^2 + 1.956401229\ 10^{-7}\ T4ti^3 - 9.303531885\ 10^{-11}\ T4ti^4 + 1.471610837\ 10^{-14}\ T4ti^5\right) \Big/ \left(1.010375951\ T4ti - 343.3908045 - 0.00007277369865\ T4ti^2 + 1.960661882\ 10^{-7}\ T4ti^3 - 9.330055692\ 10^{-11}\ T4ti^4 + 1.477000256\ 10^{-14}\ T4ti^5\right)$$

$T4t := 758.590791$

$h4t := 508.934142$

$h4r := 568.879148$

$T4r := 812.778401$

$p4 := 32.5925551$

$PC := 15109.5692$

>

```
combustion;T5:=1540;p5:=p4*0.97;eca:=0.98;GO2:=gaumO2*G3;GN2:=gaumN2*G3
;GCO2:=gaumCO2*G3;GH2O:=gaumH2O*G3;h5N2:=int(cpN2,T=T0..T5);h5CO2:=int(
cpCO2,T=T0..T5);h5O2:=int(cpO2,T=T0..T5);h5H2O:=10+int(cpH2O,T=T0..T5);
u5N2:=int(cvN2,T=T0..T5);u5CO2:=int(cvCO2,T=T0..T5);u5O2:=int(cvO2,T=T0
..T5);u5H2O:=u0+int(cvH2O,T=T0..T5);
```

combustion

$T5 := 154($

$p5 := 31.6147785$

$eca := 0.98$

$GO2 := 6.83249859($

$GN2 := 22.6868801$

$GCO2 := 0.602418812$

$GH2O := 0.125064004$

$h5N2 := 1431.55209($

$h5CO2 := 1456.20844$

$h5O2 := 1324.93416$

$h5H2O := 5299.90799$

$u5N2 := 1060.01493$

$u5CO2 := 1226.95512$

$u5O2 := 999.282467$

$u5H2O := 4595.84717($

```
> eq45:=eca*mcb*Hs+G3*(h4r+gaumH2O*10)-GN2*h5N2-
(GCO2+44*mcb*gC/12)*h5CO2-(GH2O+18*mcb*gH2/2)*h5H2O-(GO2-
32*mcb*(gC/12+gH2/4))*h5O2=0;mcb:=fsolve(eq45,mcb);
```

$eq45 := 37979.71298mcb - 25550.66774 = 0$

$mcb := 0.672745150$

```
>
GO2consumat:=32*mcb*(gC/12+gH2/4);alfaO2:=GO2/GO2consumat;Gga:=G3+mcb;
```

$GO2consumat := 2.33218318$

$alfaO2 := 2.92965776$

$Gga := 30.9196067$

```
>
h5:=(GN2*h5N2+(GCO2+44*mcb*gC/12)*h5CO2+(GH2O+18*mcb*gH2/2)*h5H2O+(GO2-
32*mcb*(gC/12+gH2/4))*h5O2)/Gga;u5:=(GN2*u5N2+(GCO2+44*mcb*gC/12)*u5CO2
+(GH2O+18*mcb*gH2/2)*u5H2O+(GO2-32*mcb*(gC/12+gH2/4))*u5O2)/Gga;
```

$h5 := 1547.45888$

$u5 := 1183.90878$

```
> eqpr1:=Gga*(h5-h6)-(PF1+PF2+PC)/em=0;
```

$eqpr1 := 20538.97638 - 30.91960675\,h6 = 0$

```
> h6r:=fsolve(eqpr1,h6);h6t:=h5-(h5-h6r)/es56;
```

$h6r := 664.270297$

$h6t := 607.896557$

```
>
h6N2:=int(cpN2,T=T0..T6);h6CO2:=int(cpCO2,T=T0..T6);h6O2:=int(cpO2,T=T0
..T6);h6H2O:=10+int(cpH2O,T=T0..T6);
```

$$h6N2 := 1.07623000000\,T6 - 301.9771738 - 0.000162982000000\,T6^2 + 2.64062000010^{-7}\,T6^3 - 1.16534250010^{-10}\,T6^4 + 1.77429600010^{-14}\,T6^5$$

$$h6CO2 := 0.471580000000\,T6 - 191.6187609 + 0.000775000000000\,T6^2 - 3.84156666710^{-7}\,T6^3 + 1.05037500010^{-10}\,T6^4 - 1.20226200010^{-14}\,T6^5$$

$$h6O2 := 0.823970000000\,T6 - 250.1907158 + 0.000152793500000\,T6^2 + 1.77363000010^{-8}\,T6^3 - 3.25342500010^{-11}\,T6^4 + 7.16450000010^{-15}\,T6^5$$

$$h6H2O := 1970.192045 + 1.84336000000\,T6 - 0.000115611500000\,T6^2 + 3.98866666710^{-7}\,T6^3 - 1.53815750010^{-10}\,T6^4 + 2.00300000010^{-14}\,T6^5$$

```
> eq6r:=h6r-
(GN2*h6N2+(GCO2+44*mcb*gC/12)*h6CO2+(GH2O+18*mcb*gH2/2)*h6H2O+(GO2-
32*mcb*(gC/12+gH2/4))*h6O2)/Gga=0;eq6t:=h6t-
```

```
(GN2*h6N2+(GCO2+44*mcb*gC/12)*h6CO2+(GH2O+18*mcb*gH2/2)*h6H2O+(GO2-
32*mcb*(gC/12+gH2/4))*h6O2)/Gga=0;
```

$$eq6r := 873.1449765 - 1.01236654\,5T6 + 0.000033556624\,2T6^2 - 1.76127911310^{-7}\,T6^3 + 8.62118048010^{-11}\,T6^4 - 1.36813048410^{-14}\,T6^5 = 0$$

$$eq6t := 816.7712367 - 1.01236654\,5T6 + 0.000033556624\,2T6^2 - 1.76127911310^{-7}\,T6^3 + 8.62118048010^{-11}\,T6^4 - 1.36813048410^{-14}\,T6^5 = 0$$

```
> T6r:=fsolve(eq6r,T6);T6t:=fsolve(eq6t,T6);
```

$T6r := 822.047914($

$T6t := 772.926796($

```
>
u6N2t:=int(cvN2,T=T0..T6t);u6CO2t:=int(cvCO2,T=T0..T6t);u6O2t:=int(cvO2
,T=T0..T6t);u6H2Ot:=u0+int(cvH2O,T=T0..T6t);u6N2r:=int(cvN2,T=T0..T6r);
u6CO2r:=int(cvCO2,T=T0..T6r);u6O2r:=int(cvO2,T=T0..T6r);u6H2Or:=u0+int(
cvH2O,T=T0..T6r);u6t:=(GN2*u6N2t+(GCO2+44*mcb*gC/12)*u6CO2t+(GH2O+18*mc
b*gH2/2)*u6H2Ot+(GO2-
32*mcb*(gC/12+gH2/4))*u6O2t)/Gga;u6r:=(GN2*u6N2r+(GCO2+44*mcb*gC/12)*u6
CO2r+(GH2O+18*mcb*gH2/2)*u6H2Or+(GO2-
32*mcb*(gC/12+gH2/4))*u6O2r)/Gga;PT:=Gga*(h5-h6r);DP:=PT-
(PC+PF2+PF1)/em;
```

$u6N2t := 373.842217$

$u6CO2t := 402.724901$

$u6O2t := 350.328056($

$u6H2Ot := 3110.91518($

$u6N2r := 414.259904$

$u6CO2r := 450.843682($

$u6O2r := 389.119662$

$u6H2Or := 3193.77362$

$u6t := 464.408458($

$u6r := 506.680025($

$PT := 27307.8439($

$DP := 0.$

```
> k56:=(h5-h6t)/(u5-u6t);p6:=p5*(T6t/T5)^(k56/(k56-1));
```

$k56 := 1.30585393'$

$p6 := 1.66596871$

```
>
p7:=p0;h7N2:=int(cpN2,T=T0..T7);h7CO2:=int(cpCO2,T=T0..T7);h7O2:=int(cp
O2,T=T0..T7);h7H2O:=10+int(cpH2O,T=T0..T7);u7N2:=int(cvN2,T=T0..T7);u7C
O2:=int(cvCO2,T=T0..T7);u7O2:=int(cvO2,T=T0..T7);u7H2O:=u0+int(cvH2O,T=
T0..T7);h7t:=(GN2*h7N2+(GCO2+44*mcb*gC/12)*h7CO2+(GH2O+18*mcb*gH2/2)*h7
H2O+(GO2-
32*mcb*(gC/12+gH2/4))*h7O2)/Gga;u7t:=(GN2*u7N2+(GCO2+44*mcb*gC/12)*u7CO
2+(GH2O+18*mcb*gH2/2)*u7H2O+(GO2-
32*mcb*(gC/12+gH2/4))*u7O2)/Gga;k67:=(h6r-h7t)/(u6r-u7t);
```

$p7 := 1.01325$

$$h7N2 := 1.07623000T7 - 301.9771738 - 0.0001629820000T7^2 + 2.64062000010^{-7}\ T7^3 - 1.16534250010^{-10}\ T7^4 + 1.77429600010^{-14}\ T7^5$$

$$h7CO2 := 0.4715800000T7 - 191.6187609 + 0.0007750000000T7^2 - 3.84156666710^{-7}\ T7^3 + 1.05037500010^{-10}\ T7^4 - 1.20226200010^{-14}\ T7^5$$

$$h7O2 := 0.8239700000T7 - 250.1907158 + 0.0001527935000T7^2 + 1.77363000010^{-8}\ T7^3 - 3.25342500010^{-11}\ T7^4 + 7.16450000010^{-15}\ T7^5$$

$$h7H2O := 1970.192045 + 1.843360000T7 - 0.0001156115000T7^2 + 3.98866666710^{-7}\ T7^3 - 1.53815750010^{-10}\ T7^4 + 2.00300000010^{-14}\ T7^5$$

$$u7N2 := 0.77884000000T7 - 216.4257834 - 0.0001613795000T7^2 + 2.62327000010^{-7}\ T7^3 - 1.15698750010^{-10}\ T7^4 + 1.75962200010^{-14}\ T7^5$$

$$u7CO2 := 0.28209000000T7 - 137.4165703 + 0.00078000000000T7^2 - 3.86263333310^{-7}\ T7^3 + 1.06034000010^{-10}\ T7^4 - 1.21853600010^{-14}\ T7^5$$

$$u7O2 := 0.56574000000T7 - 175.5475052 + 0.0001484615000T7^2 + 2.18171666710^{-8}\ T7^3 - 3.42295000010^{-11}\ T7^4 + 7.42814000010^{-15}\ T7^5$$

$$u7H2O := 1977.114606 + 1.381610000T7 - 0.0001146805000T7^2 + 3.97756666710^{-7}\ T7^3 - 1.53414250010^{-10}\ T7^4 + 1.99953000010^{-14}\ T7^5$$

$$h7t := 1.012366545T7 - 208.8746788 - 0.0000335566242T7^2 + 1.76127911310^{-7}\ T7^3 - 8.62118048010^{-11}\ T7^4 + 1.36813048410^{-14}\ T7^5$$

$$u7t := 0.724602846T7 - 130.2752195 - 0.0000325437381T7^2 + 1.75227845810^{-7}\ T7^3 - 8.57451015810^{-11}\ T7^4 + 1.35966426310^{-14}\ T7^5$$

$$k67 := (873.1449765 - 1.012366545T7 + 0.0000335566242T7^2 - 1.76127911310^{-7}\ T7^3 + 8.62118048010^{-11}\ T7^4 - 1.36813048410^{-14}\ T7^5) / (636.9552445 - 0.724602846T7 + 0.0000325437381T7^2 - 1.75227845810^{-7}\ T7^3 + 8.57451015810^{-11}\ T7^4 - 1.35966426310^{-14}\ T7^5)$$

```
> eq67:=T7-T6r*(p7/p6)^((k67-1)/k67)=0;
```

$$eq67 := T7 - 822.0479146 \left(\left(\left(873.1449765 - 1.012366545\, T7 + 0.00003355662422\, T7^2 - 1.761279113\, 10^{-7}\, T7^3 + 8.621180480\, 10^{-11}\, T7^4 - 1.368130484\, 10^{-14}\, T7^5 \right) \Big/ \left(636.9552445 - 0.7246028460\, T7 + 0.00003254373812\, T7^2 - 1.752278458\, 10^{-7}\, T7^3 + 8.574510158\, 10^{-11}\, T7^4 - 1.359664263\, 10^{-14}\, T7^5 \right) - 1 \right) \left(636.9552445 - 0.7246028460\, T7 + 0.00003254373812\, T7^2 - 1.752278458\, 10^{-7}\, T7^3 + 8.574510158\, 10^{-11}\, T7^4 - 1.359664263\, 10^{-14}\, T7^5 \right) \Big/ \left(873.1449765 - 1.012366545\, T7 + 0.00003355662422\, T7^2 - 1.761279113\, 10^{-7}\, T7^3 + 8.621180480\, 10^{-11}\, T7^4 - 1.368130484\, 10^{-14}\, T7^5 \right) \right) 0.6082047000 = 0$$

```
> T7t:=fsolve(eq67,T7);
```

$T7t := 725.411406$

```
>
h7N2t:=int(cpN2,T=T0..T7t);h7CO2t:=int(cpCO2,T=T0..T7t);h7O2t:=int(cpO2
,T=T0..T7t);h7H2Ot:=l0+int(cpH2O,T=T0..T7t);u7N2t:=int(cvN2,T=T0..T7t);
u7CO2t:=int(cvCO2,T=T0..T7t);u7O2t:=int(cvO2,T=T0..T7t);u7H2Ot:=u0+int(
cvH2O,T=T0..T7t);h7t:=(GN2*h7N2t+(GCO2+44*mcb*gC/12)*h7CO2t+(GH2O+18*mc
b*gH2/2)*h7H2Ot+(GO2-
32*mcb*(gC/12+gH2/4))*h7O2t)/Gga;u7t:=(GN2*u7N2t+(GCO2+44*mcb*gC/12)*u7
CO2t+(GH2O+18*mcb*gH2/2)*u7H2Ot+(GO2-
32*mcb*(gC/12+gH2/4))*u7O2t)/Gga;k67:=(h6r-h7t)/(u6r-u7t);
```

$h7N2t := 465.062001$

$h7CO2t := 438.320351$

$h7O2t := 427.130325$

$h7H2Ot := 3360.23788$

$u7N2t := 335.266149$

$u7CO2t := 357.134521$

$u7O2t := 313.312262$

$u7H2Ot := 3032.37213$

$h7t := 553.957513$

$u7t := 424.111554$

$k67 := 1.33601584$

```
> speed_of_third_jet;wcr:=fi6c*sqrt(2000*(h6r-
h7t));Rfg:=(GN2*RN2+(GCO2+44*mcb*gC/12)*RCO2+(GH2O+18*mcb*gH2/2)*RH2O+(
GO2-32*mcb*(gC/12+gH2/4))*RH2O)/Gga;h7r:=h6r-fi6c^2*(h6r-h7t);
```

$speed\_of\_third\_jet$

$wcr := 465.010881$

$$Rfg := 0.3173858154 - 0.000003557820116\,T + 4.96677154510^{-9}\,T^2 - 3.08753177910^{-12}\,T^3 + 6.40426393410^{-16}\,T^4$$

$h7r := 556.152737$

```
>
h7N2r:=int(cpN2,T=T0..T7ri);h7CO2r:=int(cpCO2,T=T0..T7ri);h7O2r:=int(cp
O2,T=T0..T7ri);h7H2Or:=l0+int(cpH2O,T=T0..T7ri);T7r:=fsolve(h7r-
(GN2*h7N2r+(GCO2+44*mcb*gC/12)*h7CO2r+(GH2O+18*mcb*gH2/2)*h7H2Or+(GO2-
32*mcb*(gC/12+gH2/4))*h7O2r)/Gga,T7ri);u7N2r:=int(cvN2,T=T0..T7r);u7CO2
r:=int(cvCO2,T=T0..T7r);u7O2r:=int(cvO2,T=T0..T7r);u7H2Or:=u0+int(cvH2O
,T=T0..T7r);u7r:=(GN2*u7N2r+(GCO2+44*mcb*gC/12)*u7CO2r+(GH2O+18*mcb*gH2
/2)*u7H2Or+(GO2-32*mcb*(gC/12+gH2/4))*u7O2r)/Gga;k7:=(h7r-h7t)/(u7r-
u7t);Rfgc:=int(Rfg,T=T7t..T7r)/(T7r-
T7t);Machc:=wcr/sqrt(1000*Rfgc*k7*T7r);
```

$$h7N2r := 1.076230000\,T7ri - 301.9771738 - 0.0001629820000\,T7ri^2 + 2.64062000010^{-7}\,T7ri^3 - 1.16534250010^{-10}\,T7ri^4 + 1.77429600010^{-14}\,T7ri^5$$

$$h7CO2r := 0.4715800000T7ri - 191.6187609 + 0.0007750000000T7ri^2 - 3.84156666710^{-7}\ T7ri^3 + 1.05037500010^{-10}\ T7ri^4 - 1.20226200010^{-14}\ T7ri^5$$

$$h7O2r := 0.8239700000T7ri - 250.1907158 + 0.0001527935000T7ri^2 + 1.77363000010^{-8}\ T7ri^3 - 3.25342500010^{-11}\ T7ri^4 + 7.16450000010^{-15}\ T7ri^5$$

$$h7H2Or := 1970.192045 + 1.843360000T7ri - 0.0001156115000T7ri^2 + 3.98866666710^{-7}\ T7ri^3 - 1.53815750010^{-10}\ T7ri^4 + 2.00300000010^{-14}\ T7ri^5$$

$T7r := 727.3553110$

$u7N2r := 336.834396$

$u7CO2r := 358.980115$

$u7O2r := 314.816491$

$u7H2Or := 3035.554798$

$u7r := 425.748645$

$k7 := 1.34092973$

$Rfgc := 0.316417059$

$Machc := 0.837060509$

```
>
Thfg:=Gga*wcr;Th:=Th1+Th2+Thfg;mcbspecific:=36000*mcb/Th;difmcbspecific
:=100*(0.383-mcbspecific)/0.383;
```

$Thfg := 14377.95360$

$Th := 89244.59815$

$mcbspecific := 0.271375813$

$difmcbspecific := 29.14469618$

```
> X:=(PF1+PF2+PC)/(PT+Gga*(h6r-
h7r));XT:=(es12*PF1+es23*PF2+es34*PC)/(PT/es56+Gga*(h6t-h7t));
```

$X := 0.882024896$

$XT := 0.789995140$

```
> save R,RF, X,piF1, piF2, piF,piC,war, wbr, wcr, Th1, Th2, Thfg, Th,
```

```
mcb,mcbspecific,difmcbspecific, G1,G2,G3,Gga, "date tripluflux";
> read "date tripluflux";
R := 10.869
RF := 3
X := 0.882024896
piF1 := 1.288
piF2 := 1.35481366
piF := 1.745
piC := 18.7392550
war := 200.200587
wbr := 310.314495
wcr := 465.010881
Th1 := 49362.4284
Th2 := 25504.2160
Thfg := 14377.9536
Th := 89244.5981
mcb := 0.672745150
mcbspecific := 0.271375813
difmcbspecific := 29.1446961
G1 := 246.564853
G2 := 82.1882846
G3 := 30.2468616
Gga := 30.9196067
>
>
>
```