

1. Find out the optimum reheat pressure of simple ideal Rankine cycle working between boiler pressure of 180 bar and condenser pressure of 0.05 bar if the maximum temperature is 500 degrees and keeping the operation of the turbine safe.

Using EES

The Problem is Solved as the following

```

EES Equations Window
"Q1"
P_b=180
T_3=500
T_R=500
P_c=0.05
"P_R=?"
|
H1=ENTHALPY(STEAM,P=P_c,X=0)
H2=H1+0.1*(P_b-P_c)

H3=ENTHALPY(STEAM,P=P_b,T=T_3)
S3=ENTROPY(STEAM,P=P_b,T=T_3)
H4=ENTHALPY(STEAM,P=P_R,S=S3)

H5=ENTHALPY(STEAM,P=P_R,T=T_R)
S5=ENTROPY(STEAM,P=P_R,T=T_R)
H6=ENTHALPY(STEAM,S=S5,P=P_c)
X6=Quality(Steam,P=P_c,H=H6)

W_T=H3-H4+H5-H6
W_P=H2-H1
W_DOT_NET=W_T-W_P
Q_ADD=H3-H2+H5-H4

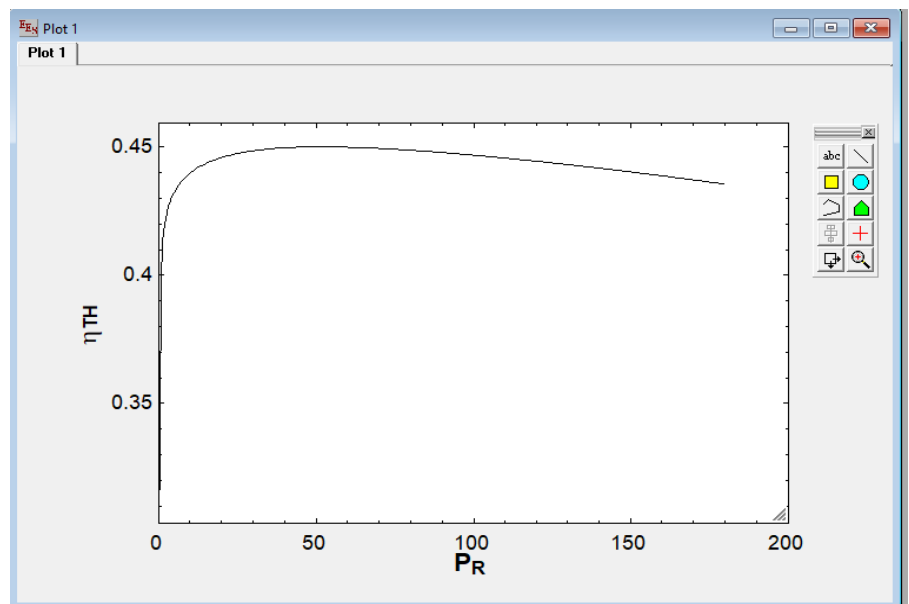
ETA_TH=(W_DOT_NET)/(Q_ADD)

X Line: 1 Char: 5 Wrap: On Insert Caps Lock: Off SI C bar kJ mass deg Warnings: On Unit Chk: Auto Complex: Off

```

Using table method in EES to vary the value of Reheat Pressure we found that best reheat pressure to get best efficiency

As chart shows



And using tables to check the safety also

| 1..300 | 1 η_{TH} | 2 P_R | 3 X6 |
|---------------|---------------|---------|--------|
| Run 74 | 0.4497 | 43.96 | 0.8294 |
| Run 75 | 0.4497 | 44.56 | 0.8285 |
| Run 76 | 0.4497 | 45.16 | 0.8276 |
| Run 77 | 0.4497 | 45.77 | 0.8268 |
| Run 78 | 0.4497 | 46.37 | 0.8259 |
| Run 79 | 0.4498 | 46.97 | 0.8251 |
| Run 80 | 0.4498 | 47.57 | 0.8243 |
| Run 81 | 0.4498 | 48.17 | 0.8234 |
| Run 82 | 0.4498 | 48.77 | 0.8226 |
| Run 83 | 0.4498 | 49.37 | 0.8218 |
| Run 84 | 0.4498 | 49.98 | 0.821 |
| Run 85 | 0.4498 | 50.58 | 0.8203 |
| Run 86 | 0.4498 | 51.18 | 0.8195 |
| Run 87 | 0.4498 | 51.78 | 0.8187 |
| Run 88 | 0.4498 | 52.38 | 0.818 |
| Run 89 | 0.4498 | 52.98 | 0.8172 |
| Run 90 | 0.4498 | 53.58 | 0.8165 |
| Run 91 | 0.4498 | 54.19 | 0.8157 |
| Run 92 | 0.4498 | 54.79 | 0.815 |
| Run 93 | 0.4498 | 55.39 | 0.8143 |
| Run 94 | 0.4498 | 55.99 | 0.8136 |
| Run 95 | 0.4498 | 56.59 | 0.8129 |
| Run 96 | 0.4497 | 57.19 | 0.8122 |
| Run 97 | 0.4497 | 57.8 | 0.8115 |
| Run 98 | 0.4497 | 58.4 | 0.8108 |
| Run 99 | 0.4497 | 59 | 0.8101 |

We found best efficiency will be within range of **Pressure of reheat** is **46.97** to **56.59 bar** so the **efficiency** is max with value of **0.4498=44.98%** but on the other hand that not safe as in the best case when **P=46.97 bar** and **efficiency=0.4498** the **dryness fraction X=82.51%** and that is **unsafe** for turbine blades

So we put the quality of output steam in considers and get it value ≥ 0.95

Which in it's best cases we will have the **pressure** at **6.053 bar** and then the **efficiency** will be **43.45%** and steam **quality** here **X=95.01%** which is **safe**

| | | | |
|--------|--------|-------|--------|
| Run 28 | 0.4333 | 5.452 | 0.9563 |
| Run 29 | 0.4337 | 5.653 | 0.9542 |
| Run 30 | 0.4341 | 5.853 | 0.9521 |
| Run 31 | 0.4345 | 6.053 | 0.9501 |
| Run 32 | 0.4348 | 6.253 | 0.9482 |
| Run 33 | 0.4352 | 6.453 | 0.9463 |
| Run 34 | 0.4355 | 6.653 | 0.9445 |

It also can be solved with EES to get the best safe value directly using if condition

Equations Window

```

"Q1"
function funE(X6,W_DOT_NET,Q_ADD)
if (X6>=0.95) then
ETA_TH=(W_DOT_NET)/(Q_ADD)
else
ETA_TH=0
endif
funE=ETA_TH
end

P_b=180
T_3=500
T_R=500
P_c=0.05
"P_R=??"

H1=ENTHALPY(STEAM,P=P_c,X=0)
H2=H1+0.1*(P_b-P_c)

H3=ENTHALPY(STEAM,P=P_b,T=T_3)
S3=ENTROPY(STEAM,P=P_b,T=T_3)
H4=ENTHALPY(STEAM,P=P_R,S=S3)

H5=ENTHALPY(STEAM,P=P_R,T=T_R)
S5=ENTROPY(STEAM,P=P_R,T=T_R)
H6=ENTHALPY(STEAM,S=S5,P=P_c)
X6=Quality(Steam,P=P_c,H=H6)

W_T=H3-H4+H5-H6
W_P=H2-H1
W_DOT_NET=W_T-W_P
Q_ADD=H3-H2+H5-H4

ETA_TH=funE(X6,W_DOT_NET,Q_ADD)

```

Parametric Table

| | 1 | 2 | 3 |
|--------|-------------|-------|--------|
| | η_{TH} | P_R | X6 |
| Run 50 | 0.4258 | 2.878 | 0.9939 |
| Run 51 | 0.4269 | 3.127 | 0.989 |
| Run 52 | 0.4279 | 3.396 | 0.9841 |
| Run 53 | 0.4288 | 3.689 | 0.9793 |
| Run 54 | 0.4298 | 4.007 | 0.9744 |
| Run 55 | 0.4308 | 4.353 | 0.9696 |
| Run 56 | 0.4317 | 4.728 | 0.9647 |
| Run 57 | 0.4327 | 5.136 | 0.9598 |
| Run 58 | 0.4336 | 5.579 | 0.9549 |
| Run 59 | 0.4345 | 6.06 | 0.95 |
| Run 60 | 0 | 6.582 | 0.9452 |
| Run 61 | 0 | 7.15 | 0.9403 |
| Run 62 | 0 | 7.767 | 0.9354 |
| Run 63 | 0 | 8.436 | 0.9304 |
| Run 64 | 0 | 9.164 | 0.9255 |
| Run 65 | 0 | 9.954 | 0.9206 |
| Run 66 | 0 | 10.81 | 0.9157 |
| Run 67 | 0 | 11.74 | 0.9107 |

X Line: 1 Char: 5 Wrap: On Insert Caps Lock: Off SI C bar kJ mass deg Warnings: On Unit Chk: Auto Complex: Off

as we used if condition we got the most accurate and **ignore** any **unsafe** results by make their efficiency is Zero so the **Optimum** and **safe** value of **pressure** is **6.06 Bar** and having **efficiency** of **43.45%**