GROUP MEMBERS:

Name	Roll Number
Atharva Bodhale	22110043
Pavani Khale	22110191
Shivrajsinh Bhosale	22110048
Sridhar Singh	22110257
Vedant Chichmalkar	22110282

Improving the Performance of a Power Plant Operating on a Basic Rankine Cycle

Problem Statement

The project involves enhancing the performance of a power plant utilizing an ideal Rankine cycle, which currently operates with a 41% thermal efficiency and a steam quality of 76%. The objective is to elevate the thermal efficiency beyond 46% and increase the steam quality at the condenser inlet to over 85%. Essential constraints include maintaining the boiler and condenser pressures at 15 MPa and 10 kPa, respectively, and ensuring the turbine temperature does not surpass 500 °C. The Rankine cycle components, including the pump, boiler, turbine, and condenser, must be strategically modified or optimized to achieve the efficiency and steam quality targets within these operational limits.

Overview of Rankine Cycle

The Rankine cycle is an essential thermodynamic concept used in designing and analyzing vapor power plants, serving as the ideal model for such systems. This cycle comprises four distinct processes that are crucial for power generation. The ideal Rankine cycle does not involve any internal irreversibilities and consists of the following four processes:

- Isentropic Compression in a pump (1-2)
- Constant heat addition in a boiler (2-3)
- Isentropic expansion in a turbine (3-4)
- Constant Pressure heat rejection in a condenser (4-1)

The first process involves the compression of water in a pump from state 1 to state 2, resulting in a slightly increased temperature due to the isentropic compression process. The second process is constant pressure heat addition in a boiler, where water enters as a compressed liquid at state 2 and leaves as superheated vapour at state 3. This phase represents the transformation of heat originating from combustion gases, nuclear reactors, or other sources into mechanical work. The third process entails an isentropic expansion in a turbine, where the superheated vapour at state 3 undergoes expansion, producing work by rotating a shaft connected to an electric generator. Finally, the fourth process is constant pressure heat rejection in a condenser, where steam is condensed at state 4, releasing heat to a cooling medium such as water, air, or the atmosphere. The condensed steam then enters the pump, completing the cycle. The Rankine cycle forms the basis for understanding and optimizing the performance of vapour power plants, playing a crucial role in the field of thermodynamics and energy analysis.

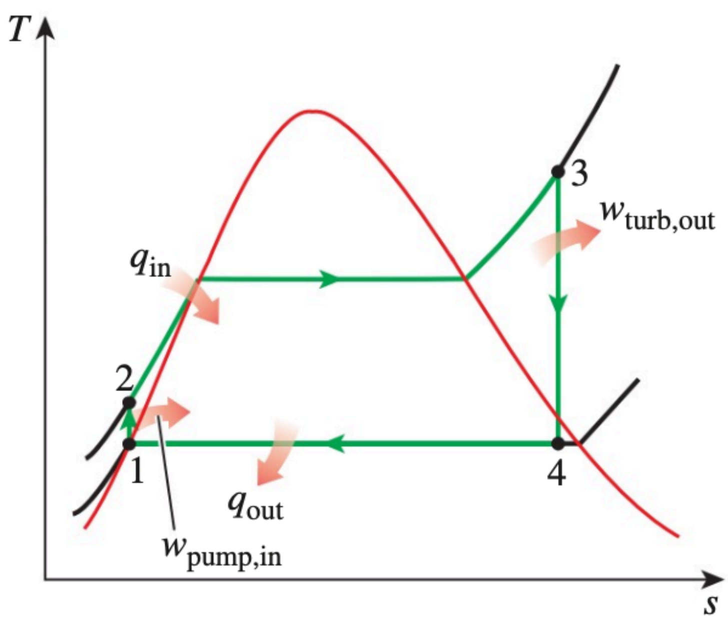


Fig: The Simple Ideal Rankine Cycle

General ways to increase the efficiency of the Rankine Cycle

The fundamental concept underlying all adjustments aimed at boosting the thermal efficiency of a power cycle remains consistent: either elevate the average temperature during heat transfer to the working fluid in the boiler or diminish the average temperature during the heat rejection phase from the working fluid in the condenser. The goal is to maximize the average fluid temperature during heat addition and minimize it during heat rejection. In the subsequent discussion, three methods for achieving this objective in the context of the simple ideal Rankine cycle are explored.

- **Lowering the Condenser Pressure (Lowers $T_{low,avg}$)**

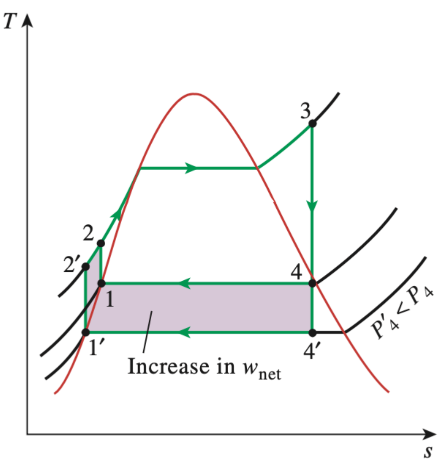


FIGURE 10–6
The effect of lowering the condenser pressure on the ideal Rankine cycle.

The presence of steam in a condenser as a saturated mixture, determined by the condenser's internal pressure, means that reducing the condenser pressure automatically lowers the steam temperature, affecting the heat rejection temperature. This impact on the Rankine cycle efficiency is depicted in Figure 10–6 on a T-s diagram, with a maintained turbine inlet state for comparison. Lowering the condenser pressure from P4 to P49 increases the network output, though heat input requirements also slightly rise (shown by the area under curve 29-2). Steam power plant condensers often operate below atmospheric pressure to capitalize on improved efficiencies. However, a minimum condenser pressure is dictated by the saturation pressure corresponding to the cooling medium temperature; for instance, a condenser cooled by a river at 15°C requires a pressure above 3.2 kPa. Lowering condenser pressure has drawbacks, including the risk of air leakage and increased steam moisture in the turbine's final stages, negatively impacting turbine efficiency and blade erosion. Solutions to mitigate these issues are discussed subsequently.

- **Superheating the Steam to High Temperatures (Increases $T_{high,avg}$)**

Another effective method to enhance thermal efficiency without raising boiler pressure is superheating steam to high temperatures. This process is depicted on a T-s diagram (Fig. 10–7), where the colored area signifies increased net work. The total area under the process curve 3-39 indicates heightened heat input, resulting in elevated net work and heat input due to steam superheating. This, in turn, boosts overall thermal efficiency by increasing the average temperature during heat addition. Superheating steam to higher temperatures also brings the added benefit of reducing moisture content at the turbine exit, evident in the T-s diagram where the quality at state 49 surpasses that at state 4. However, there are limitations to the temperature to which steam can be superheated, constrained by metallurgical factors. Currently capped at around 620°C (1150°F) at the turbine inlet, any future increase hinges on advancements in materials or the discovery of new ones capable of withstanding higher temperatures, with ceramics showing promise in this context.

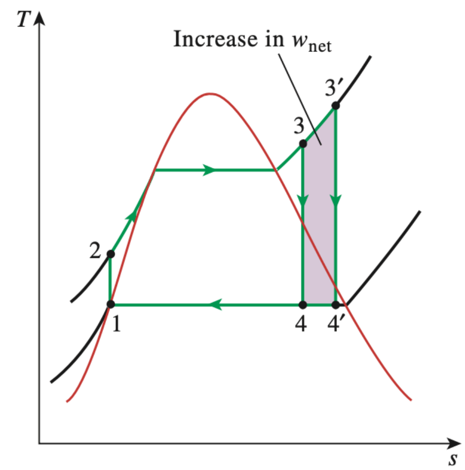


FIGURE 10–7
The effect of superheating the steam to higher temperatures on the ideal Rankine cycle.

- **Increasing the Boiler Pressure (Increases $T_{high,avg}$)**

Increasing the boiler pressure is an additional method to elevate the average temperature in the heat-addition process, automatically raising the boiling temperature and, consequently, the average temperature for heat transfer to steam. This enhances the thermal efficiency of the cycle. The impact of heightened boiler pressure on vapour power cycles is depicted in Figure 10–8 on a T-s diagram. It is observed that, with a constant turbine inlet temperature, the cycle shifts leftward, leading to increased moisture content in the steam at the turbine exit—an undesirable outcome. However, this issue can be rectified through steam reheating, as elaborated in the following section. Over the years, boiler operating pressures have steadily risen, from approximately 2.7 MPa (400 psia) in 1922 to over 30 MPa (4500 psia) today. Modern steam power plants often operate at supercritical pressures exceeding 22.06 MPa, achieving thermal efficiencies of around 40 percent for fossil-fuel plants and 34 percent for nuclear plants.

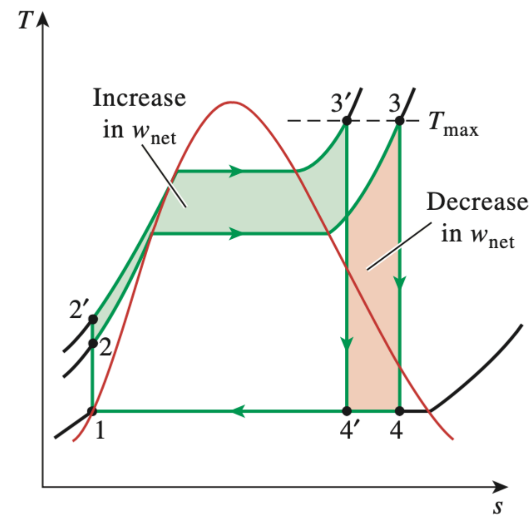


FIGURE 10–8
The effect of increasing the boiler pressure on the ideal Rankine cycle.

Reheat Rankine Cycle

The ideal Rankine cycle, a thermodynamic process used in steam power plants, faces challenges such as increased moisture content at higher boiler pressures. To address this issue, two solutions are considered: superheating steam to high temperatures or incorporating a reheat process. The latter involves expanding steam in two turbine stages and reheating it in between. This modification, known as the ideal reheat Rankine cycle, is depicted in a T-s diagram.

The reheat process improves cycle efficiency by 4 to 5 percent by increasing the average temperature of heat transfer to the steam. While additional reheat stages could further enhance efficiency, practical constraints limit the benefits. Double reheat is used in supercritical-pressure power plants, and a third reheat stage provides minimal gains, making it economically impractical.

The reheat cycle, initially introduced in the 1920s and temporarily abandoned in the 1930s, was reinstated in the late 1940s and early 1950s due to increasing boiler pressures. Reheat temperatures closely match turbine inlet temperatures, and the optimum reheat pressure is approximately one-fourth of the maximum cycle pressure.

The primary purpose of the reheat cycle is to mitigate moisture content in the steam during the expansion process's final stages. This is necessary due to the limitations of materials in withstanding extremely high temperatures; otherwise, a reheat cycle would be unnecessary.

Regenerative Rankine Cycle

The ideal regenerative Rankine cycle addresses the inefficiency of heat transfer at low temperatures during the Rankine cycle's process. To enhance efficiency, regeneration involves heating the feedwater (liquid leaving the pump) before it enters the boiler. One method is to use a regenerator or feedwater heater, where steam extracted from the turbine heats the feedwater.

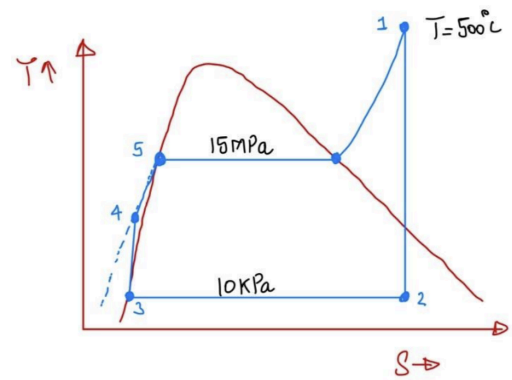
Practical regeneration involves extracting steam from the turbine at various points to heat the feedwater in a regenerator. This process not only improves cycle efficiency but also deaerates the feedwater, preventing corrosion, and helps control steam flow rates. Feedwater heaters can be open or closed systems.

In open feedwater heaters, steam mixes directly with feedwater in a chamber, and the ideal regenerative Rankine cycle involves steam expansion, extraction, feedwater heating, and mixing. The thermal efficiency increases with regeneration, especially when using multiple feedwater heaters.

Closed feedwater heaters transfer heat without direct mixing. In the ideal closed feedwater heater scenario, the feedwater reaches the exit temperature of the extracted steam. However, practical considerations lead to the feedwater leaving slightly below the steam exit temperature. Closed heaters are more complex and expensive but don't require separate pumps for each heater.

Most steam power plants use a combination of open and closed feedwater heaters to balance simplicity, cost, and efficiency.

Our Approach to Increase the Efficiency



Initially, we considered the given problem as the reference model with an efficiency of 41.43% and a quality of 0.7592.

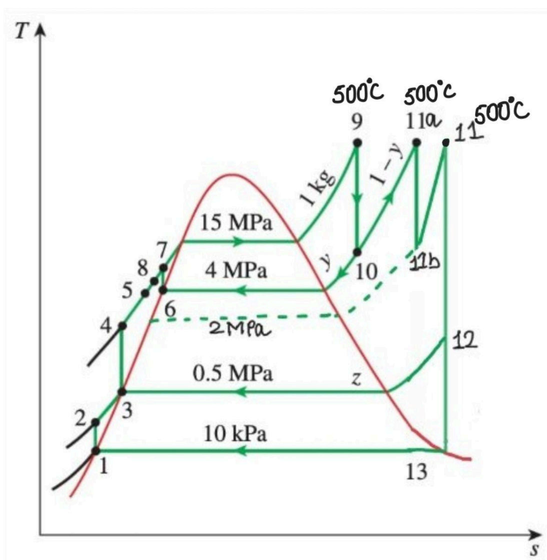
In the first approach, we employed the ideal Rankine cycle. At stage 1, a turbine was introduced to lower the temperature, reducing the pressure. Subsequently, a heater was added to reheat the fluid to 500 degrees Celsius. The fluid then was made to pass through a turbine, decreasing both temperature and pressure, ultimately entering the condenser inlet. Despite these modifications, the efficiency and vapour fraction remained unchanged.

Next, we implemented the ideal regenerative Rankine cycle. A portion of the steam from the turbine was extracted at a certain pressure and reintroduced into the original stream at an elevated pressure. This process resulted in an efficiency increase of 44.7% while the vapor fraction remained constant.

Following that, we adopted the ideal reheat regenerative Rankine cycle. The fluid, post-turbine passage, had a portion extracted for reheating before passing through the turbine again. Prior to entering the condenser, another portion of the remaining heat was extracted. This cycle involved one reheating and two regeneration stages, yielding an efficiency of 45.33% and a quality of 0.8586.

To further enhance efficiency before the initial reheating, a portion of the fluid was extracted, and the remaining portion was directed to the heater. After passing through the turbine and experiencing a temperature decrease, the fluid was reheated to 500 degrees Celsius before passing through the turbine once more. Some of the extracted heat was returned, while the rest proceeded through the condenser. This final modification resulted in an efficiency of 49.54%, and the quality of the condenser inlet changed to 0.9042.

T-s DIAGRAM FOR MODIFIED RANKINE CYCLE



Description of Step-by-Step Processes

State 1 to State 2: Incompressible liquid pumping.

State 2 to State 3: Sensible heating.

State 3 to State 4: Incompressible liquid pumping.

State 4 to State 5: Sensible heating.

State 6 to State 7: Incompressible liquid pumping.

State 7 to State 8: Mixing takes place in the mixing chamber.

State 8 to State 9: Boiler.

State 9 to State 10: High-pressure turbine.

State 10 to State 11a: Reheating 1.

State 11a to State 11b: Turbine.

State 11b to State 11: Reheating 2.

State 11 to State 13: Low-pressure turbine.

State 12: Heat extracted for regeneration.

State 13 to State 1: Condenser.

Formulas and Calculations involved

Efficiency = 1 - (q_{out}/q_{in})   OR w_{NET}/q_{in}

x13 - quality at condenser inlet calculated from cantera using function vaporFraction

Control Volume And Energy Balances

Assumptions to be made:

1. Steady flow.
2. Neglecting change in kinetic energy and potential energy.
3. Boiler and Condenser do not involve any work.
4. The pump and Turbine are isentropic.

General Energy Balance Equation:

dE/dT = Qdot- W_{cv}dot + E_{in}dot - E_{out}dot

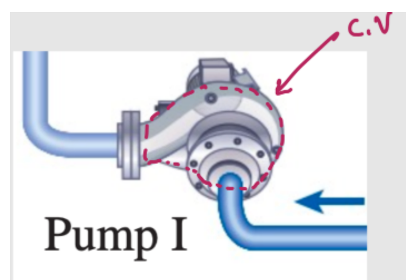
Energy Balance Equation used here:

Q_dot - W_{cv}dot + E_{in}dot - E_{out}dot = 0

$(q_{in}-q_{out}) - (w_{in} - w_{out}) = h_{out} - h_{in}$

Energy balances on each system:

PUMP: Q_dot= 0



w_{in}(pump1) = (1-y-z)*(h2-h1)

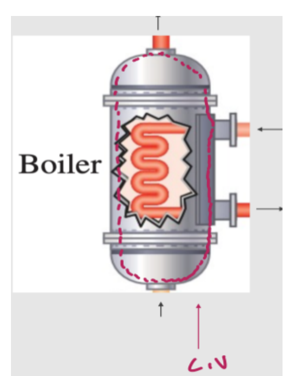
w(pump2) = (1-y)*(h4-h3)

w_{in}(pump3) =y* (h7-h6)

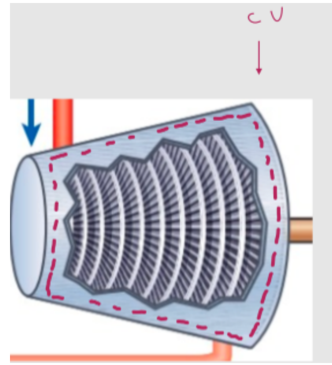
w_{in}(pump) = w_{in}(pump1) + w_{in}(pump2) + w_{in}(pump3)

w_{in}(pump) = (1-y-z)*h2-h1) +(1-y)* (h4-h3) + y*(h7-h6)

BOILER : W_{cv}dot = 0



q_{in} = h9 - h8



TURBINE: Qdot= 0

$w_{\_out}(t1) = (h9 - h10)$

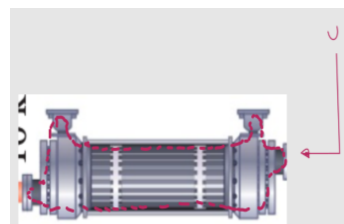
$w_{out}(t2) = (1\text{-}y)*(11a\text{-}11b)$

$w_{out}(t3) = (1\text{-}y)*(h11\text{-}h12)$

$w_{out}(t4) = (1\text{-}y\text{-}z)*(h12\text{-}h13)$

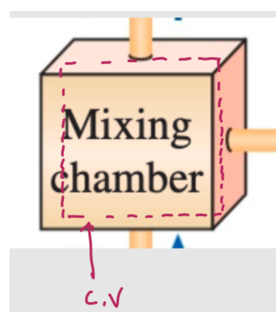
$w_{out}(t) = w_{out}(t1) + w_{out}(t2) + w_{out}(t3) + w_{out}(t4)$

$w_{out}(t) = (h9\text{-}h10) + (1\text{-}y)*(11a\text{-}11b) + (1\text{-}y)*(h11\text{-}h12) + (1\text{-}y\text{-}z)*(h12\text{-}h13)$



CONDENSER : Wcv_dot = 0

$$q_{out} = (1\text{-}y\text{-}z)*(h13\text{-}h1)$$



Mixing Chamber : Q_dot = 0, Wcv_dot = 0

$E_{in}dot - E_{out}dot = 0$

$E_{in}dot = E_{out}dot$

$(1)h8 = (1\text{-}y)*h5 + y*h7$

Open Feedwater Heater :

$$E_{in}dot - E_{out}dot = 0$$

$$z*h12 + (1\text{-}y\text{-}z)*h2 = (1\text{-}y)*h3$$

<u>**Closed Feedwater Heater**</u> :

$$E_{in\_}dot - E_{out}dot = 0$$

$$y*h10 + (1-y)*h4 = (1-y)*h5 + y*h6$$

<u>**Heaters**</u> :

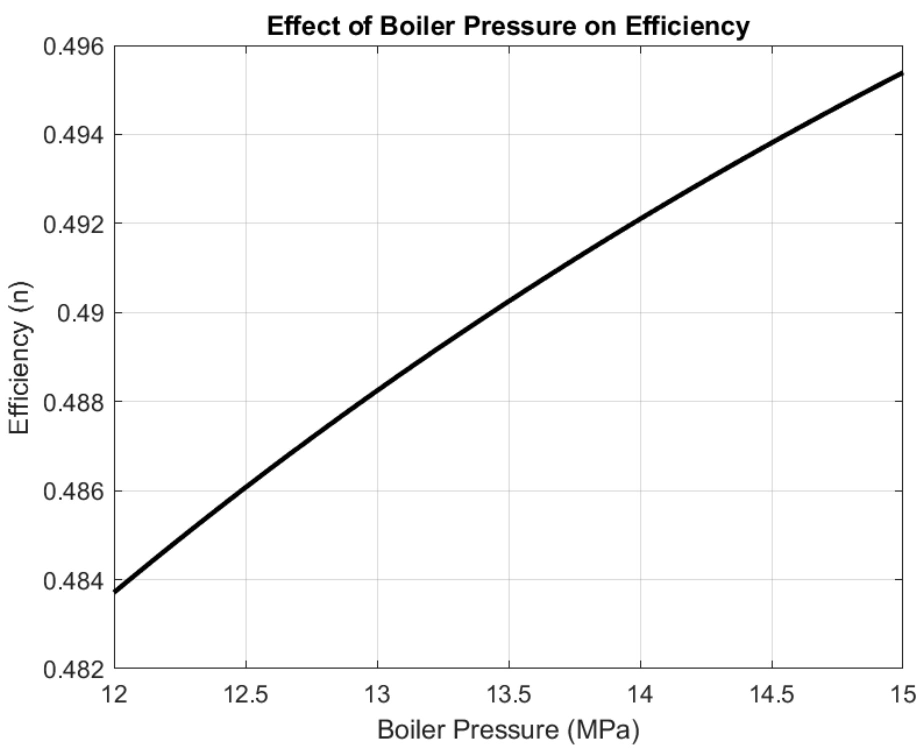
$$q_{in}(reheat\ 1) = (1-y)*(h11a - h10)$$

$$q_{in}(reheat\ 2) = (1-y)*(h11 - h11b)$$

Variation Of Efficiency And Work Done With Boiler Pressure And Condenser Pressure

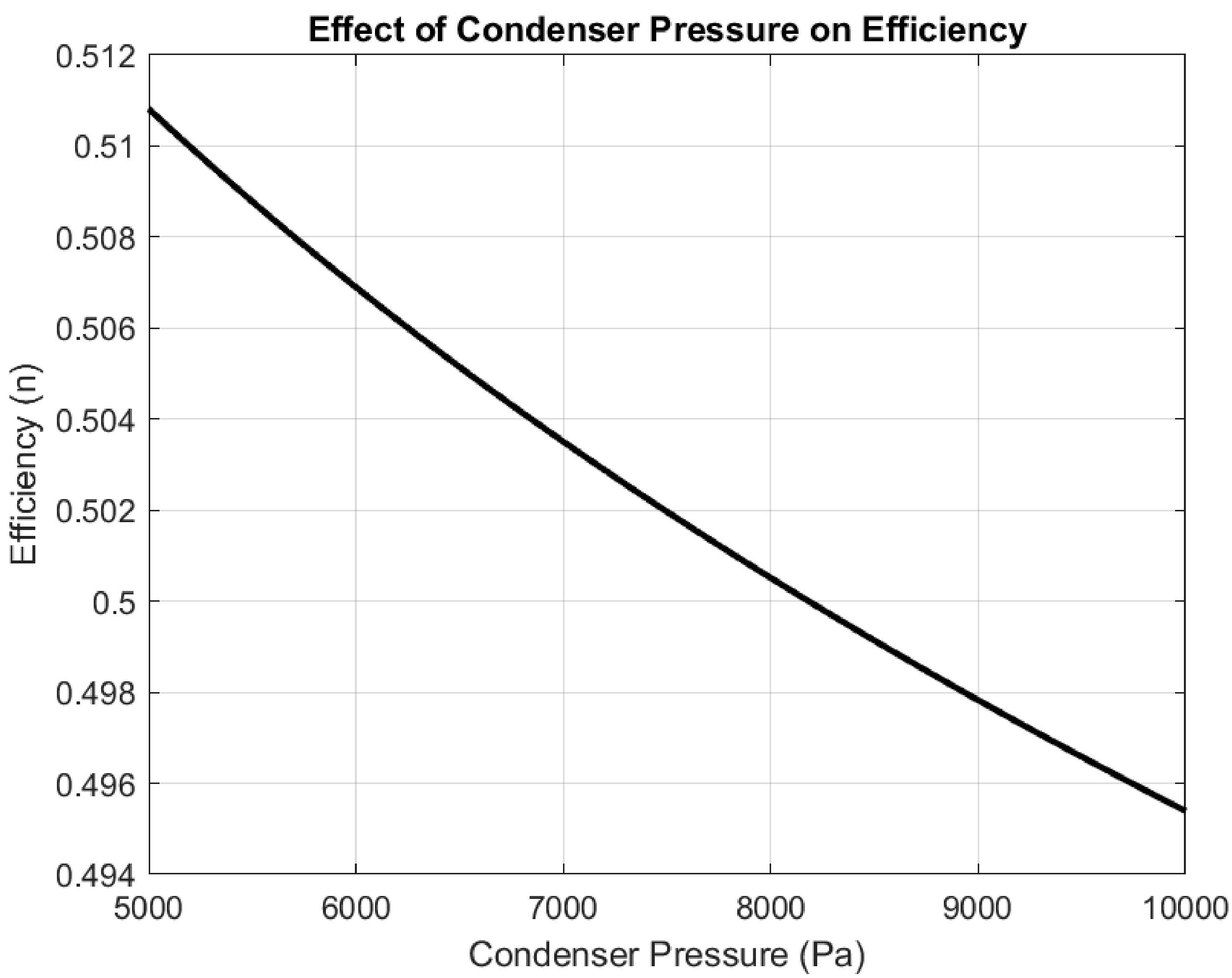
I. Variation of thermal efficiency

Efficiency VS Boiler Pressure



- *As we can see, as the boiler pressure increases, the efficiency increases.*

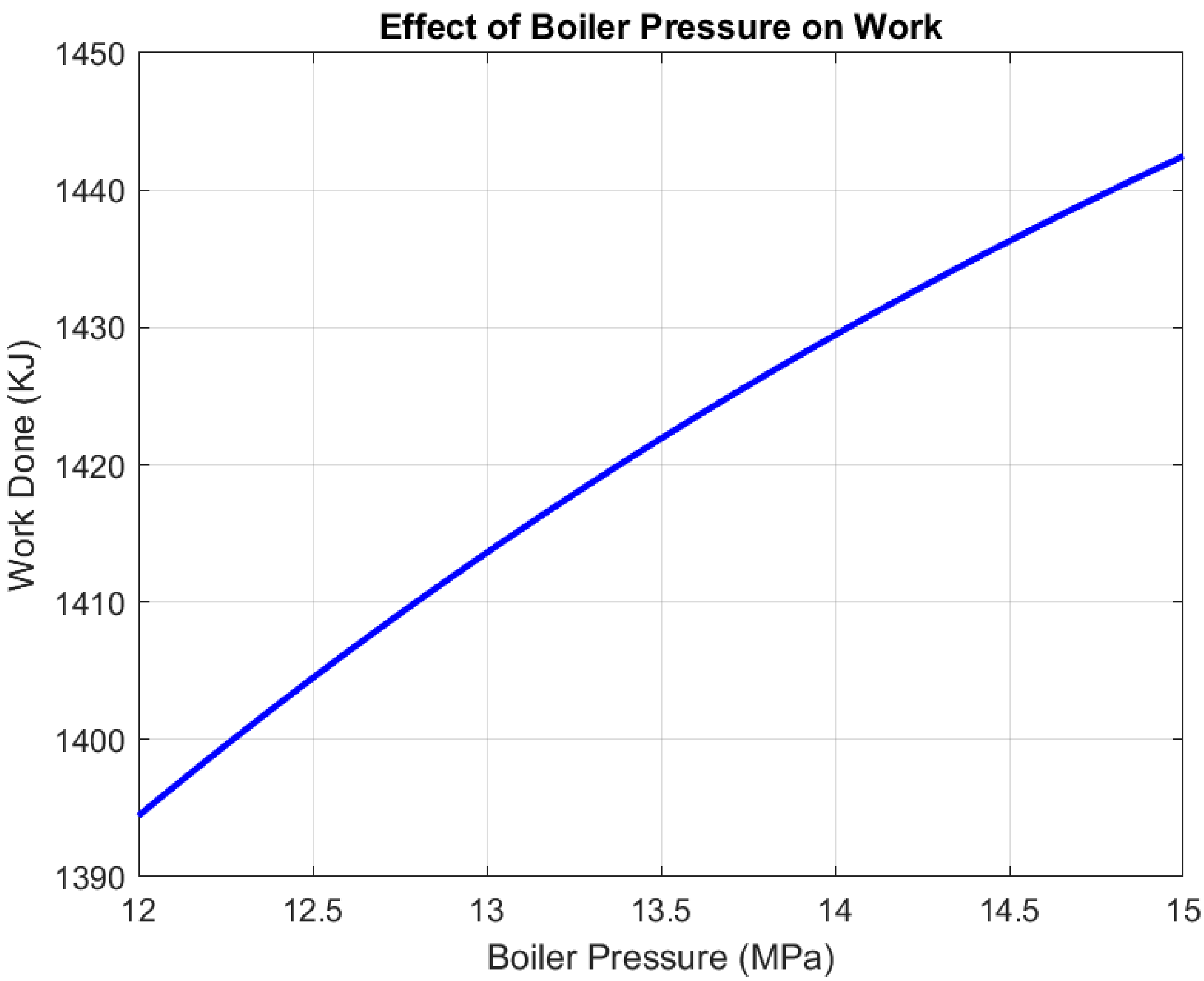
Efficiency VS Condenser Pressure



- *As we can see, as the condenser pressure increases, the efficiency decreases.*

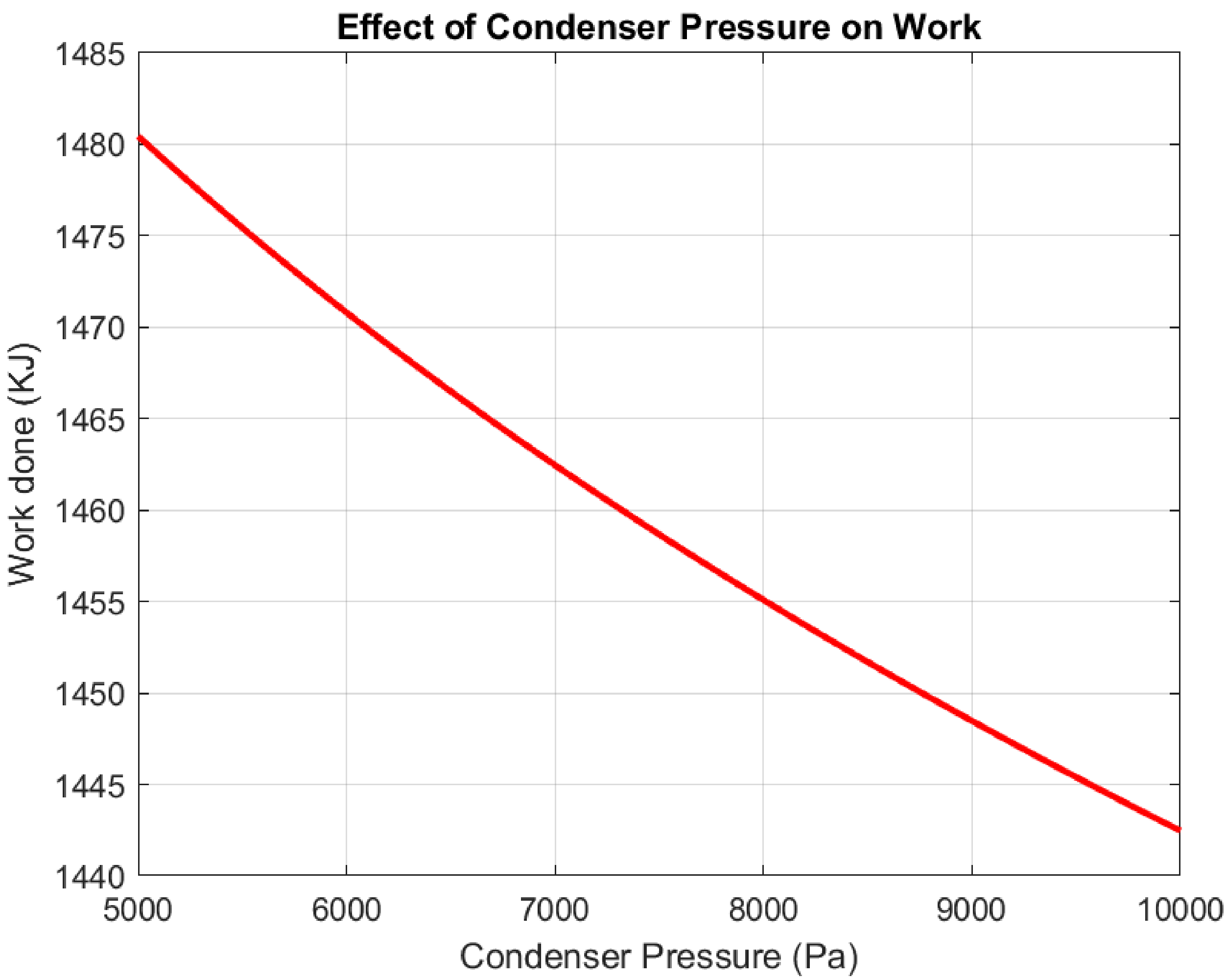
II. Variation of net work output

Net Work Output VS Boiler Pressure



- *As we can see, as the boiler pressure increases, the Work output increases.*

Net Work Output VS Condenser Pressure



- *As we can see, as the condenser pressure increases, the Work output decreases.*

Code and Algorithm

Initial Rankine Cycle :

```
clc;
clear all;

w = Solution('liquidvapor.cti','water');

%IDEAL RANKINE CYCLE
P1=10000;
P2=15000000;
T=500+273.15;

%STATE 3
set(w,'P',P1,'Vapor',0);
h3=enthalpy_mass(w)/1000;
s3=entropy_mass(w)/1000;

%STATE 4
setState_SP(w,[s3*1000,P2])
h4=enthalpy_mass(w)/1000;
s4=entropy_mass(w)/1000;

%STATE 5
set(w,'P',P2,'Vapor',0);
h5=enthalpy_mass(w)/1000;
s5=entropy_mass(w)/1000;
```

```
%STATE 1
set(w,'P',P2,'T',T);
h1=enthalpy_mass(w)/1000;
s1=entropy_mass(w)/1000;

%STATE 2
setState_SP(w,[s1*1000,P1])
h2=enthalpy_mass(w)/1000;
s2=entropy_mass(w)/1000;
%Quality at condenser inlet
x2=vaporFraction(w);

%efficiency
neta=1-((h2-h3)/(h1-h4));
```

```
neta =

    0.4143

>> x2

x2 =

    0.7592
```

Approach 1 :

```
clc;
clear all;

w = Solution('liquidvapor.cti','water');

%IDEAL REHEAT RANKINE CYCLE

P1=10000;
P2=15000000;
T1=500+273.15;

%STATE 3
set(w,'P',P1,'Vapor',0);
h3=enthalpy_mass(w)/1000;
s3=entropy_mass(w)/1000;

%STATE 4
setState_SP(w,[s3*1000,P2])
h4=enthalpy_mass(w)/1000;
s4=entropy_mass(w)/1000;
P4=pressure(w);

%STATE 6
set(w,'P',P2,'T',T1);
h6=enthalpy_mass(w)/1000;
s6=entropy_mass(w)/1000;
```

```
%STATE 7
setState_SP(w,[s6*1000,P4])
h7=enthalpy_mass(w)/1000;
s7=entropy_mass(w)/1000;

%STATE 5
set(w,'P',P2,'Vapor',0);
h5=enthalpy_mass(w)/1000;
s5=entropy_mass(w)/1000;

%STATE 1
set(w,'P',P2,'T',T1);
h1=enthalpy_mass(w)/1000;
s1=entropy_mass(w)/1000;

%STATE 2
setState_SP(w,[s1*1000,P1])
h2=enthalpy_mass(w)/1000;
s2=entropy_mass(w)/1000;
x2=vaporFraction(w);

ql=h2-h3;
qs=(h6-h4)+(h1-h7);
neta=1-(ql/qs);
```

```
>> neta

neta =

    0.4143

>> x2

x2 =

    0.7592
```

Approach 2:

```
clc;
clear all;

w = Solution('liquidvapor.cti','water');

%IDEAL REGERATIVE RANKINE CYCLE
P1=10000;
P2=15000000;
P3=1500000;
T1=500+273.15;

%STATE 3
set(w,'P',P1,'Vapor',0);
h3=enthalpy_mass(w)/1000;
s3=entropy_mass(w)/1000;

%STATE 4
setState_SP(w,[s3*1000,P3])
h4=enthalpy_mass(w)/1000;
s4=entropy_mass(w)/1000;
```

```
%STATE 5
set(w,'P',P3,'Vapor',0);
h5=enthalpy_mass(w)/1000;
s5=entropy_mass(w)/1000;

%STATE 6
setState_SP(w,[s5*1000,P2])
h6=enthalpy_mass(w)/1000;
s6=entropy_mass(w)/1000;

%STATE 7
set(w,'P',P2,'Vapor',0);
h7=enthalpy_mass(w)/1000;
s7=entropy_mass(w)/1000;

%STATE 1
set(w,'P',P2,'T',T1);
h1=enthalpy_mass(w)/1000;
s1=entropy_mass(w)/1000;

%STATE 8
setState_SP(w,[s1*1000,P3])
h8=enthalpy_mass(w)/1000;
```

```
%STATE 2
setState_SP(w,[s1*1000,P1])
h2=enthalpy_mass(w)/1000;
s2=entropy_mass(w)/1000;
x2=vaporFraction(w);

y=(h5-h4)/(h8-h4);

ql=(1-y)*(h2-h3);
qs=(h1-h6);
neta=1-(ql/qs);
```

```
>> neta

neta =

    0.4475

>> x2

x2 =

    0.7592
```

Approach 3 :

```
clc;
clear all;

w = Solution('liquidvapor.cti','water');

%IDEAL REHEAT - REGERATIVE RANKINE CYCLE

%STATE 1

P1=10000;
set(w,'P',P1,'Vapor',0);
h1=enthalpy_mass(w)/1000;
s1=entropy_mass(w)/1000;

%STATE 2
P2=500000;
s2=s1;
setState_SP(w,[s2*1000,P2]);
h2=enthalpy_mass(w)/1000;
```

```
%STATE 3
P3=P2;
set(w,'P',P1,'Vapor',0);
h3=enthalpy_mass(w)/1000;
s3=entropy_mass(w)/1000;

%STATE 4
P4=15000000;
s4=s3;
setState_SP(w,[s4*1000,P4]);
h4=enthalpy_mass(w)/1000;

%STATE 6
P6=4000000;
set(w,'P',P6,'Vapor',0)
h6=enthalpy_mass(w)/1000;
s6=entropy_mass(w)/1000;
```

```
%STATE 5
T5=satTemperature(w,P6);
P5=P4;
set(w,'P',P5,'T',T5)
h5=enthalpy_mass(w)/1000;
s5=entropy_mass(w)/1000 ;

%STATE 7
P7=P4;
s7=s6;
setState_SP(w,[s7*1000,P7]);
h7=enthalpy_mass(w)/1000;

%STATE 9
P9=P4;
T9=500+273.15;

set(w,'P',P9,'T',T9);
h9=enthalpy_mass(w)/1000;
s9=entropy_mass(w)/1000;
```

```
%STATE 10

P10=P6;
s10=s9;
setState_SP(w,[s10*1000,P10]);
h10=enthalpy_mass(w)/1000;

%STATE 11
P11=P6;
T11=500+273.15;

set(w,'P',P11,'T',T11);
h11=enthalpy_mass(w)/1000;
s11=entropy_mass(w)/1000;

%STATE 12

P12=P2;
s12=s11;
setState_SP(w,[s12*1000,P12]);
h12=enthalpy_mass(w)/1000;
```

```
%STATE 13
P13=P1;
s13=s11;
setState_SP(w,[s13*1000,P13]);
h13=enthalpy_mass(w)/1000;
%quality at condenser inlet
x13=vaporFraction(w);
%1st regernation
y=(h5-h4)/((h10-h6)+(h5-h4));
%2nd regeration
z= ((1-y)*(h3-h2))/(h12-h2);

%STATE 8
h8=((1-y)*h5) + (y*h7);


q_in= (h9-h8) + ((1-y)*(h11-h10));
q_loss=(1-y-z)*(h13-h1);
m=q_loss/q_in;
%efficiency
n=1-m;
```

```
>> n

n =

    0.4533

>> x13

x13 =

    0.8586
```

Final Approach :

```
clc;
clear all;

w = Solution('liquidvapor.cti','water');

%IDEAL REHEAT - REGERATIVE RANKINE CYCLE

%STATE 1  (CONDENSER)
P1=10000;
set(w,'P',P1,'Vapor',0);
h1=enthalpy_mass(w)/1000;
s1=entropy_mass(w)/1000;

%STATE 2
P2=500000;
s2=s1;
setState_SP(w,[s2*1000,P2]);
h2=enthalpy_mass(w)/1000;

%STATE 3
P3=P2;
set(w,'P',P1,'Vapor',0);
h3=enthalpy_mass(w)/1000;
s3=entropy_mass(w)/1000;
```

```
%STATE 4   (BOILER)
P4=15000000;
s4=s3;
setState_SP(w,[s4*1000,P4]);
h4=enthalpy_mass(w)/1000;

%STATE 6
P6=4000000;
set(w,'P',P6,'Vapor',0)
h6=enthalpy_mass(w)/1000;
s6=entropy_mass(w)/1000;

%STATE 5
T5=satTemperature(w,P6);
P5=P4;
set(w,'P',P5,'T',T5)
h5=enthalpy_mass(w)/1000;
s5=entropy_mass(w)/1000 ;

%STATE 7
P7=P4;
s7=s6;
setState_SP(w,[s7*1000,P7]);
h7=enthalpy_mass(w)/1000;
```

```
%STATE 9
P9=P4;
T9=500+273.15;
set(w,'P',P9,'T',T9);
h9=enthalpy_mass(w)/1000;
s9=entropy_mass(w)/1000;

%STATE 10 (Reheat)
P10=P6;
s10=s9;
setState_SP(w,[s10*1000,P10]);
h10=enthalpy_mass(w)/1000;

%state 11a
P11a=P4;
T11a=500+273.15;

set(w,'P',P11a,'T',T11a);
h11a=enthalpy_mass(w)/1000;
s11a=entropy_mass(w)/1000;
```

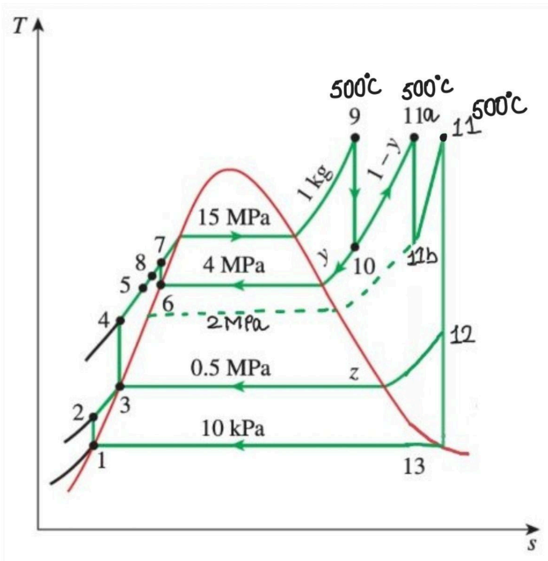
```
%state 11b (Reheat)
P11b=2000000;
s11b=s11a;
setState_SP(w,[s11b*1000,P11b]);
h11b=enthalpy_mass(w)/1000;

%STATE 11
P11=P11b;
T11=500+273.15;
set(w,'P',P11,'T',T11);
h11=enthalpy_mass(w)/1000;
s11=entropy_mass(w)/1000;

%STATE 12
P12=P2;
s12=s11;
setState_SP(w,[s12*1000,P12]);
h12=enthalpy_mass(w)/1000;

%STATE 13
P13=P1;
s13=s11;
setState_SP(w,[s13*1000,P13]);
h13=enthalpy_mass(w)/1000;
```

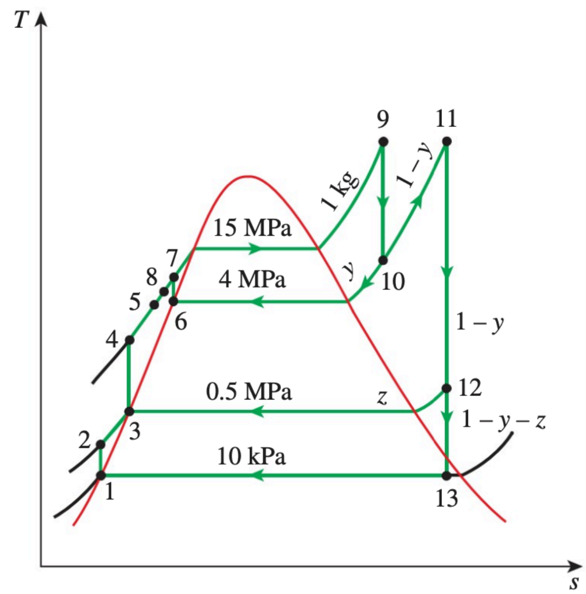
```
%quality at condenser inlet
x13=vaporFraction(w);

%energy balance on closed feedwater heater
y=(h5-h4)/((h10-h6)+(h5-h4));

%energy balance on open feedwater heater
z= ((1-y)*(h3-h2))/(h12-h2);

%STATE 8
%mass and energy balance on mixing chamber
h8=((1-y)*h5) + (y*h7);

q_in= (h9-h8) + ((1-y)*(h11a-h10))+ ((1-y)*(h11-h11b));
q_loss=(1-y-z)*(h13-h1);
%net work done
Wnet=q_in-q_loss;

m=q_loss/q_in;
%efficiency
n=1-m;
```

```
>> n

n =

    0.4954

>> x13

x13 =

    0.9042
```

```
%STATE 5
T5=satTemperature(w,P6);
P5=P4;
set(w,'P',P5,'T',T5)
h5=enthalpy_mass(w)/1000;
s5=entropy_mass(w)/1000 ;

%STATE 7
P7=P4;
s7=s6;
setState_SP(w,[s7*1000,P7]);
h7=enthalpy_mass(w)/1000;

%STATE 9
P9=P4;
T9=500+273.15;

set(w,'P',P9,'T',T9);
h9=enthalpy_mass(w)/1000;
s9=entropy_mass(w)/1000;
```

RESULTS





T-s diagram of our work

Efficiency: 49.54%

Quality: 0.9042

The Ideal Case

Efficiency: 41.43

Quality: 0.7592

Pros and Cons of adding an extra reheater

Plus Point:

Increased Efficiency: One of the primary advantages is an increase in the overall efficiency of the Rankine cycle. Reheating the steam between turbine stages allows for additional expansion, extracting more work from the steam and improving the cycle efficiency.

Negative Point:

Increased Stress: The addition of extra components, such as reheaters and turbines, can subject materials to higher stresses and temperatures. This heightened stress may lead to material fatigue over time, impacting the structural integrity of the components. Also, the maintenance cost rises.

CHALLENGES FACED

Discovering methods to enhance efficiency proved challenging. Identifying strategies to increase the system's effectiveness and optimize performance required considerable effort and exploration.

CONCLUSION

Observing the existing scenario, it becomes evident that there is a substantial gap that warrants improvement in efficiency. Even a marginal enhancement in efficiency can translate into significant fuel savings. However, the adoption of the extra reheating technique comes with the drawback of potential material damage. Despite this challenge, progress in material science and engineering holds the promise of mitigating such concerns. Advances in materials can play a pivotal role in ensuring the feasibility and success of implementing extra reheating, ultimately contributing to more efficient and sustainable energy utilization.

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