KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
MECHANICAL ENGINEERING DEPARTMENT
SEMESTER (012)

ME-204

(THERMODYNAMICS)

DESIGN PROBLEM

Prepared For

Dr. Habib

By

Ayman Abdallah

973610

Sec # 03

TABLE OF CONTENTS

STATEMENT OF THE PROBLEM

We have a Rankine cycle used in a plant and should produce 400 MW of power output. We are going to add one, two and then three Feedwater to the cycle to study the performance of the cycle.

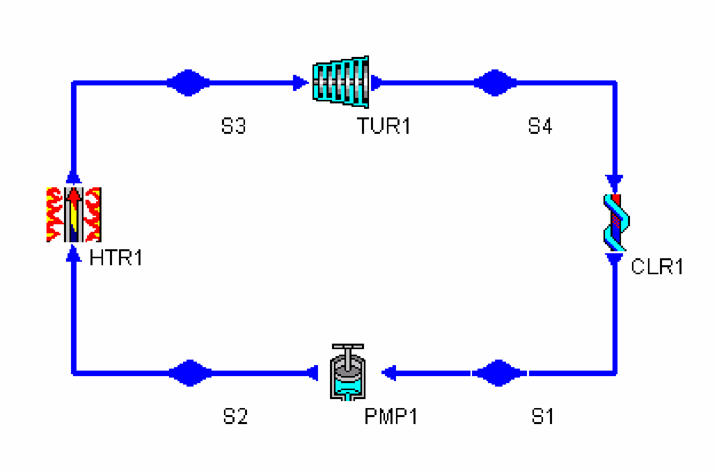
OBJECTIVE

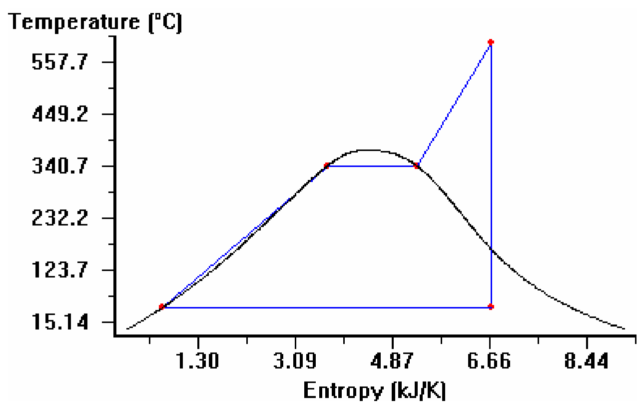
- Determine the thermal efficiency for each of the following cycle:
  - No Feedwater.
  - One Feedwater.
  - Two Feedwater.
  - Three Feedwater.
- Investigate the intermediate pressure at which the system gives the optimum performance for each one, two and three Feedwater.
- Discussing the economics of adding Feedwater.

CYCLE DESCRIPTION

Our main cycle is the Rankine Cycle. The cycle consists of (1) pump, (2) steam generator or (boiler), (3) turbine and finally (4) condenser. Steam leaves the boiler at 15 MPa, 600^{o}C, and the cycle has a condenser pressure of 10 kPa.

No Feedwater





Cycle Performance

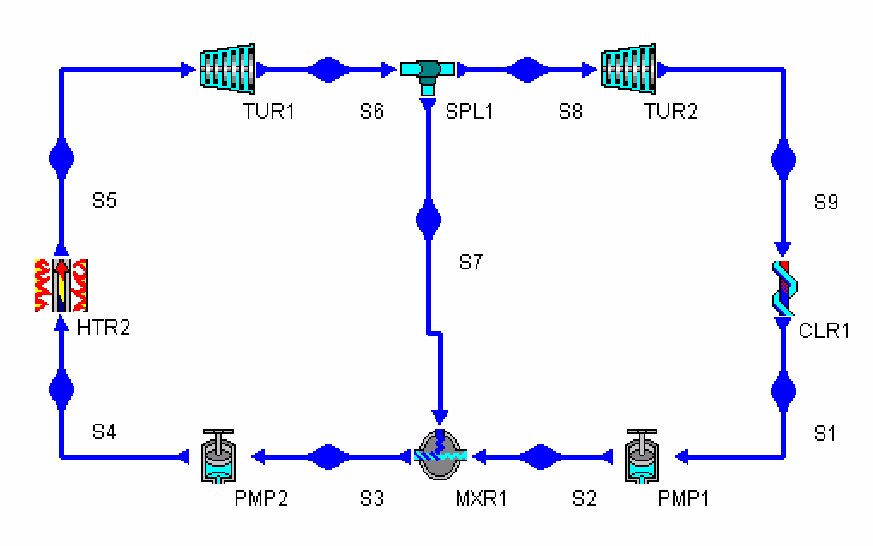
$\eta_{th} = 43.03\%$

$\dot{Q}_H = 939.7MW$

Cost of Energy $= 0.01MJ$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(939.7MW) = 9.397\,\$/s$

One Feedwater (5 MPa)



Cycle Performance

$\eta_{th} = 45.26\%$

Optimizing FW

For optimizing I will use two methods to find the optimum Feedwater pressure to make sure of the results, also the two methods should give the same results:

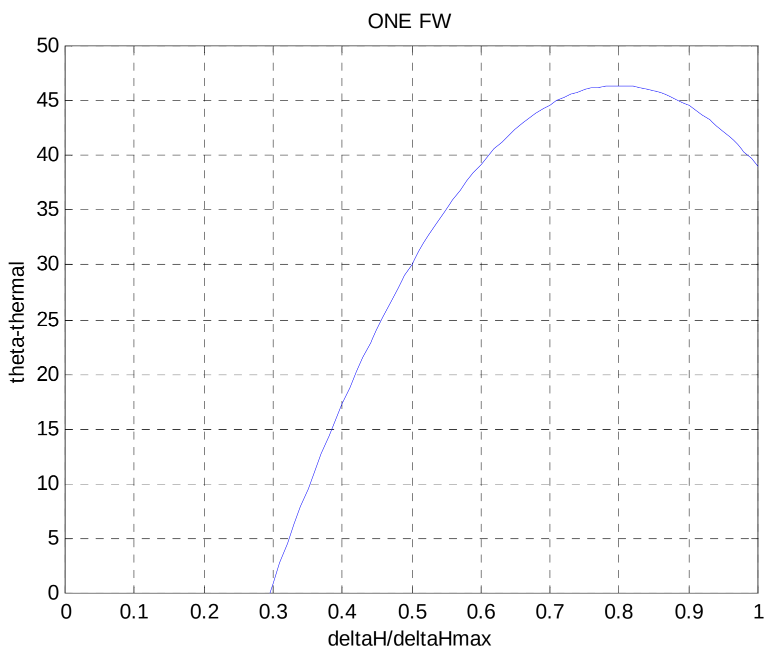
1. Drawing $\frac{\Delta H}{\Delta H_{\max}}$ vs η_{th}
2. Drawing P of Feedwater vs η_{th}

P(FW)	h	m_{tot}	m_{con}	$\Delta H/\Delta H_{max}$	η
1.8	2940	321.9	140.9	0.816469	46.34
1.6	2908	318.5	240.4	0.803912	46.39
1.4	2877	315.1	240.3	0.794803	46.4
1.2	2848	311.8	240.6	0.786255	46.37

$h_{\max} = 3582$

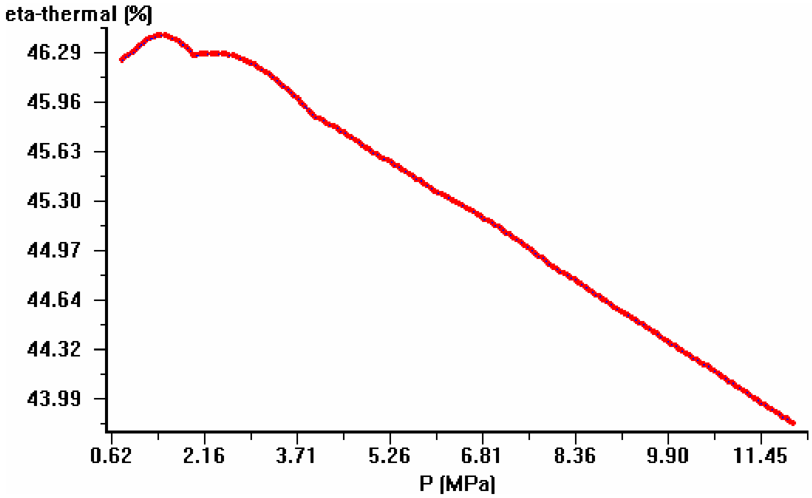
$h_{con} = 191.8$

$$\frac{\Delta H}{\Delta H_{\max}} = \frac{\dot{m}_{tot} h \quad \dot{m} h_{con}}{\dot{m} h_{\max} \quad \dot{m} h_{con}}$$



Maximum $\frac{\Delta H}{\Delta H_{\max}} = 0.8$ which gives $\eta_{th} = 46.4\%$

This corresponds to Feedwater Pressure of 1.45 MPa



Best Pressure for Feedwater is 1.45 MPa which gives $\eta_{th} = 46.4\%$

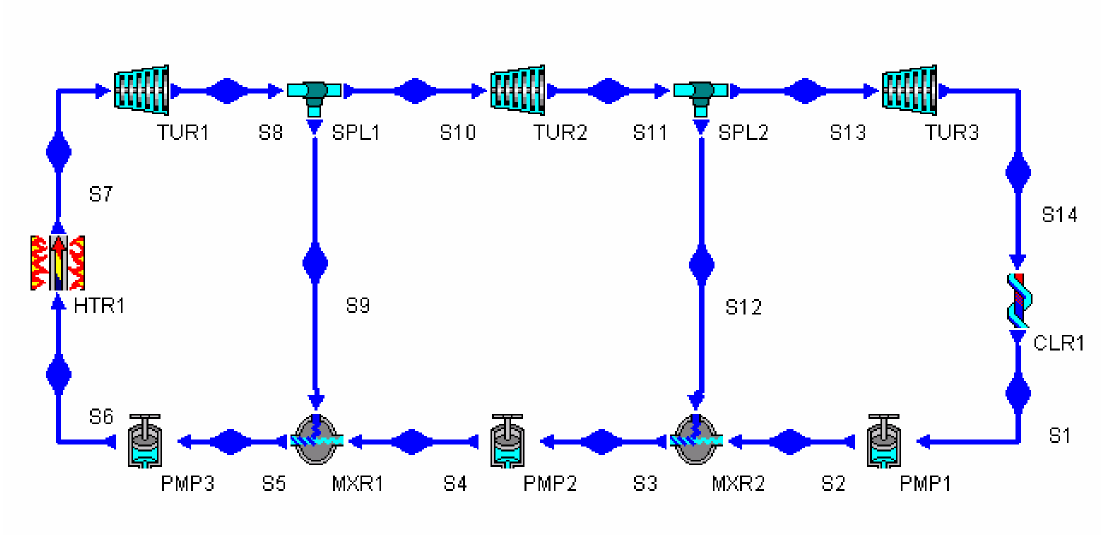
Cycle Performance

$\eta_{th} = 46.4\%$

$\dot{Q}_H = 861.9 MW$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(861.9 MW) = 8.619\$/s$

Two Feedwater (5 MPa), (1.5 MPa)



Cycle Performance

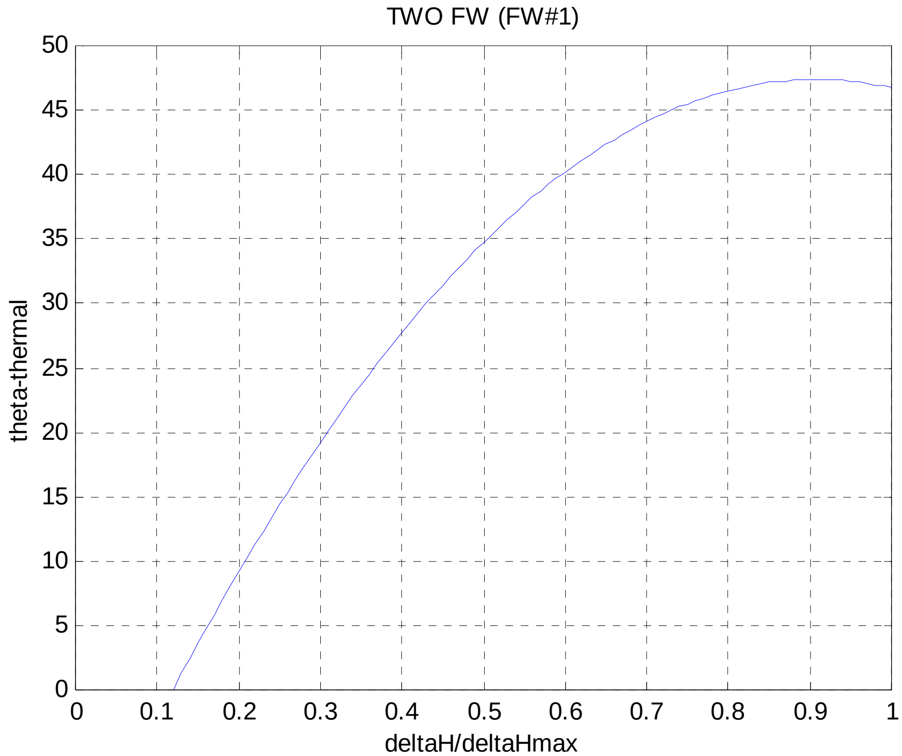
$\eta_{th} = 47.38\%$

<u>Optimizing FW-1</u>

P(FW1)	h	m_{tot}	m_{con}	$\Delta H/\Delta H_{max}$	η
7	3316	366.5	231	0.923146	47.37
6	3271	358.2	231	0.910072	47.39
5	3217	349.6	213	0.894665	47.38

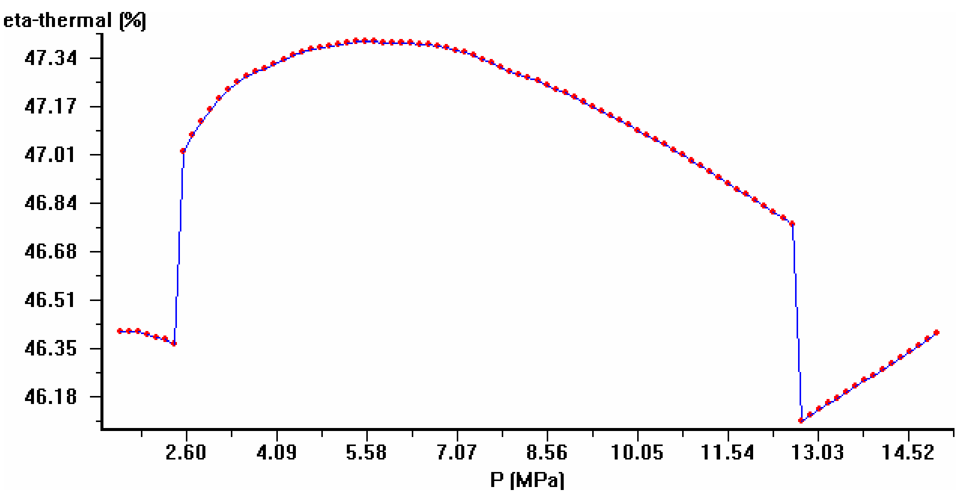
$h_{\max} = 3582$

$h_{con} = 191.8$



Maximum $\dfrac{\Delta H}{\Delta H_{\max}} = 0.907$ which gives $\eta_{th} = 47.4\%$

Which corresponds to Feedwater Pressure of 5.8 MPa



Best Pressure for Feedwater is 5.8 MPa gives $\eta_{th} = 47.4\%$

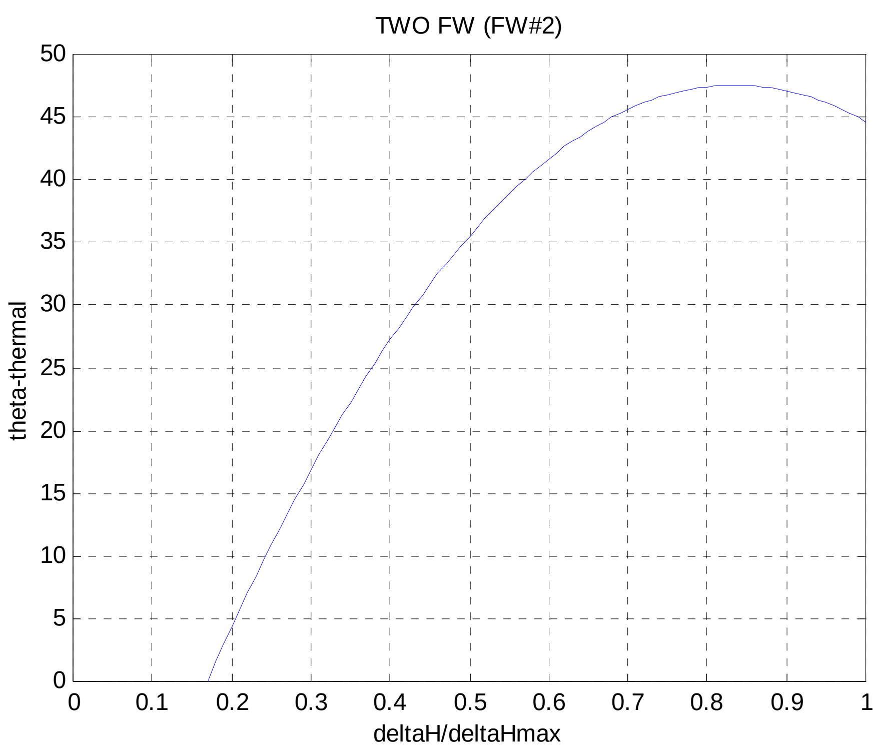
Now,
Assigning this optimized value for FW-1, and finding optimized value for FW-2

Optimizing FW-2

P(FW2)	h	m_{tot}	m_{pump2}	$\Delta H/\Delta H_{max}$	η
1.5	2892	356.5	304.4	0.881146	47.4
1	2820	355.9	293.9	0.858138	47.48
0.9	2798	355.6	291.4	0.851104	47.51
0.8	2775	355.5	288.8	0.843759	47.53

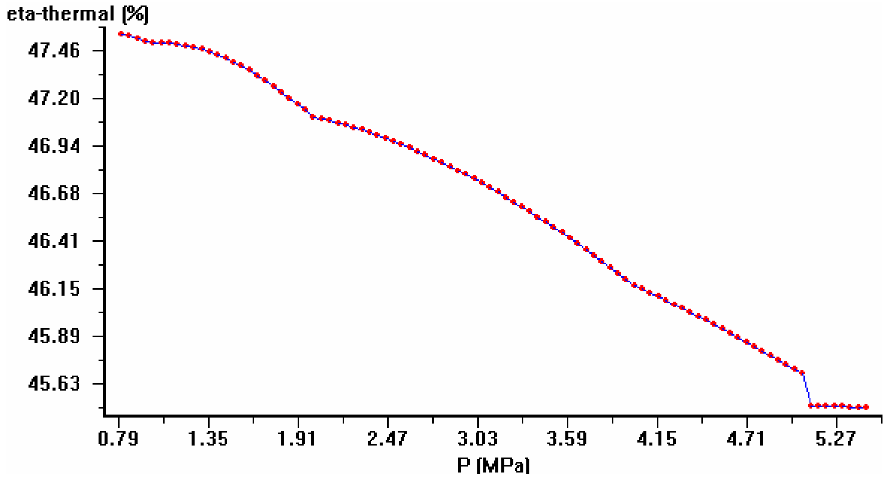
$h_{\max} = 3260$

$h_{con} = 191.8$



Maximum $\dfrac{\Delta H}{\Delta H_{\max}} = 0.83$ which gives $\eta_{th} = 47.53\%$

This corresponds to Feedwater Pressure of 0.8 MPa



Best Pressure for Feedwater is 0.8 MPa gives $\eta_{th} = 47.53\%$

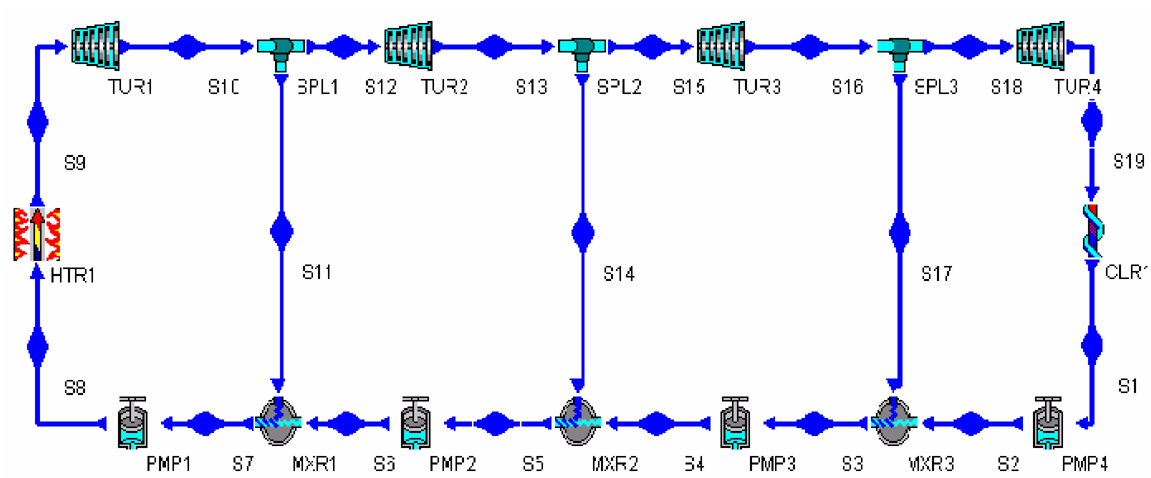
Cycle Performance

$\eta_{th} = 47.53\%$

$\dot{Q}_H = 841.6 MW$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(841.6MW) = 8.416\$/s$

Three Feedwater (10 MPa), (5 MPa), (1 MPa)



Cycle Performance

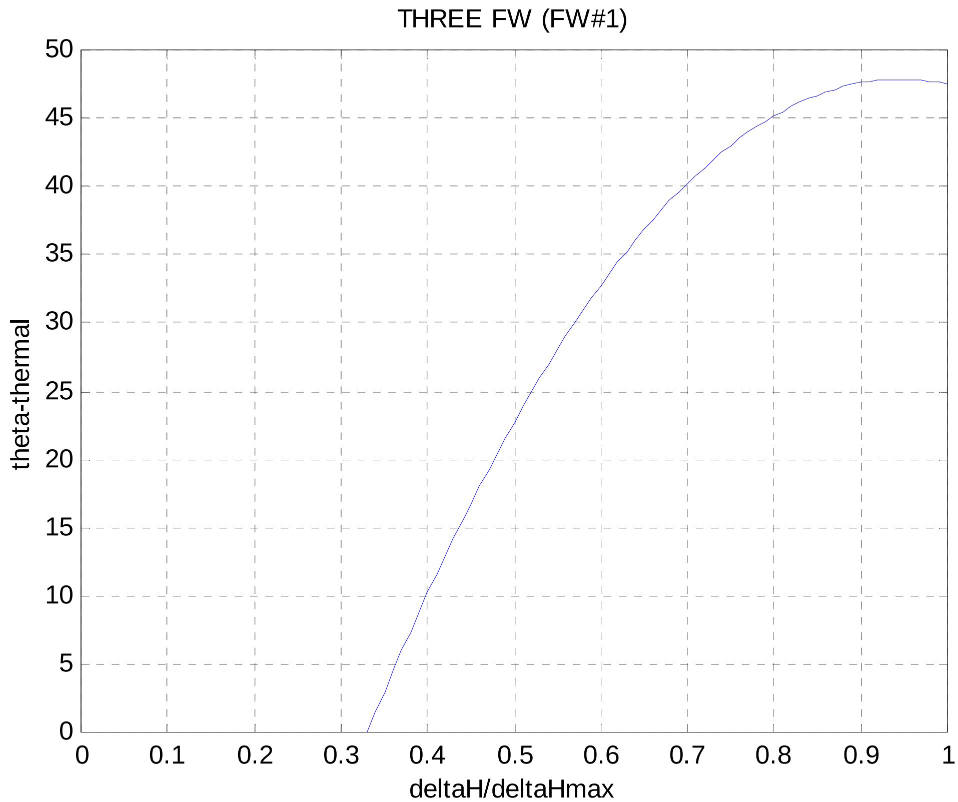
$\eta_{th} = 47.84\%$

Optimizing FW-1

P(FW1)	h	m_{tot}	m_{con}	$\Delta H/\Delta H_{max}$	η
9	3401	378.2	226.7	0.947794	47.85
8.5	3381	374.5	226.8	0.942005	47.85
8	3362	370.8	226.9	0.936501	47.84
7.5	3339	367.1	227	0.929838	47.82

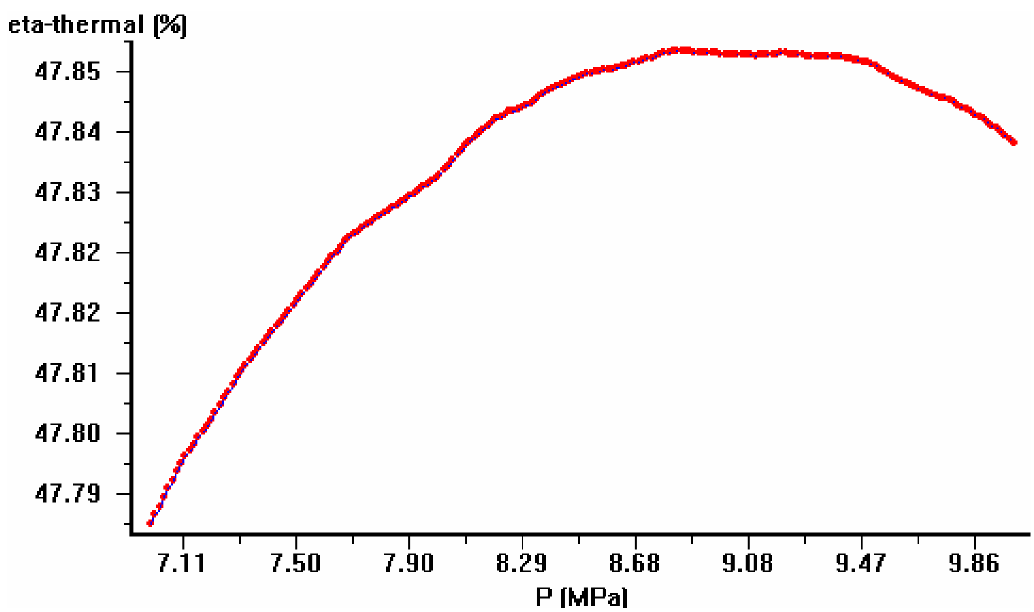
$h_{\max} = 3582$

$h_{con} = 191.8$



Maximum $\frac{\Delta H}{\Delta H_{\max}} = 0.95$ which gives $\eta_{th} = 47.85\%$

This corresponds to Feedwater Pressure of 8.85 MPa



Best Pressure for Feedwater is 8.85 MPa gives $\eta_{th} = 47.85\%$

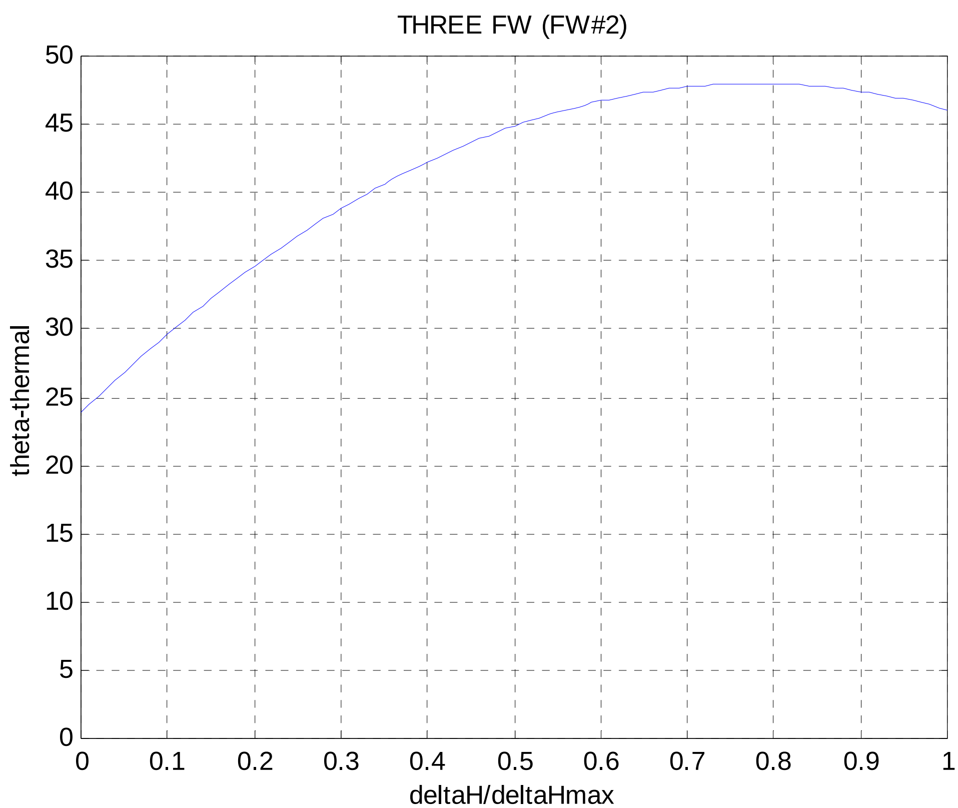
Now,
Assigning this optimized value for FW-1, and finding optimized value for FW-2

<u>Optimizing FW-2</u>

P(FW2)	h	m_{tot}	m_{pump2}	m_{con}	$\Delta H/\Delta H_{max}$	η
4	3153	376.4	333.4	225.9	0.816396	47.94
3.5	3104	376.1	327.8	225.5	0.789748	47.99
3	3058	376.1	322.2	225.5	0.763643	47.98
2.5	3014	376.6	316.6	226.1	0.73743	47.92

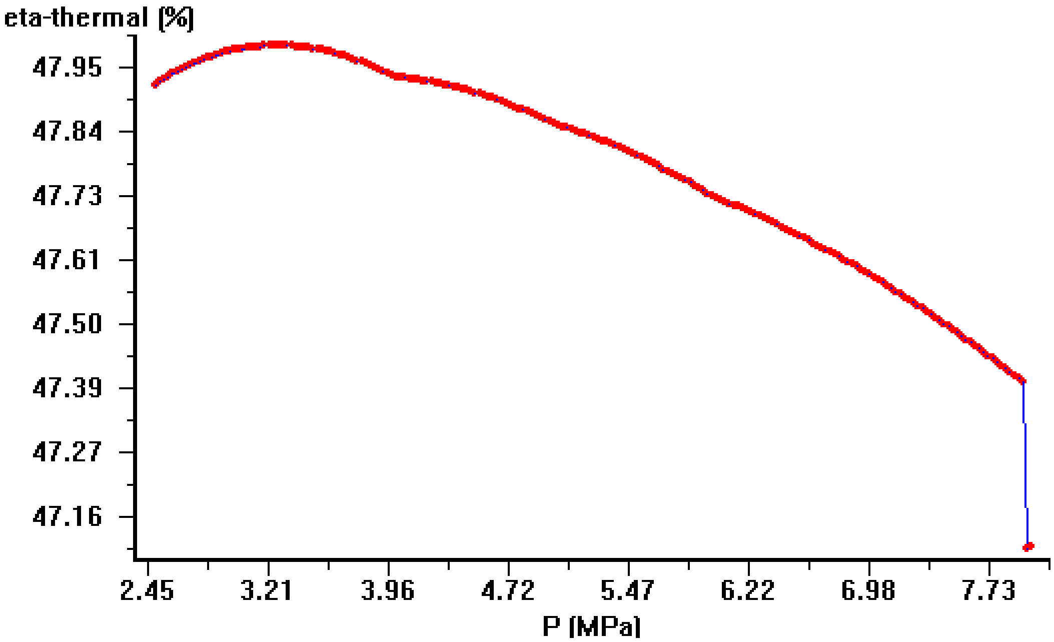
$h_{\max} = 3395$

$h_{con} = 191.8$



Maximum $\dfrac{\Delta H}{\Delta H_{\max}} = 0.91$ which gives $\eta_{th} = 47.99\%$

This corresponds to Feedwater Pressure of 3.3 MPa



Best Pressure for Feedwater is 3.3 MPa gives $\eta_{th} = 47.99\%$

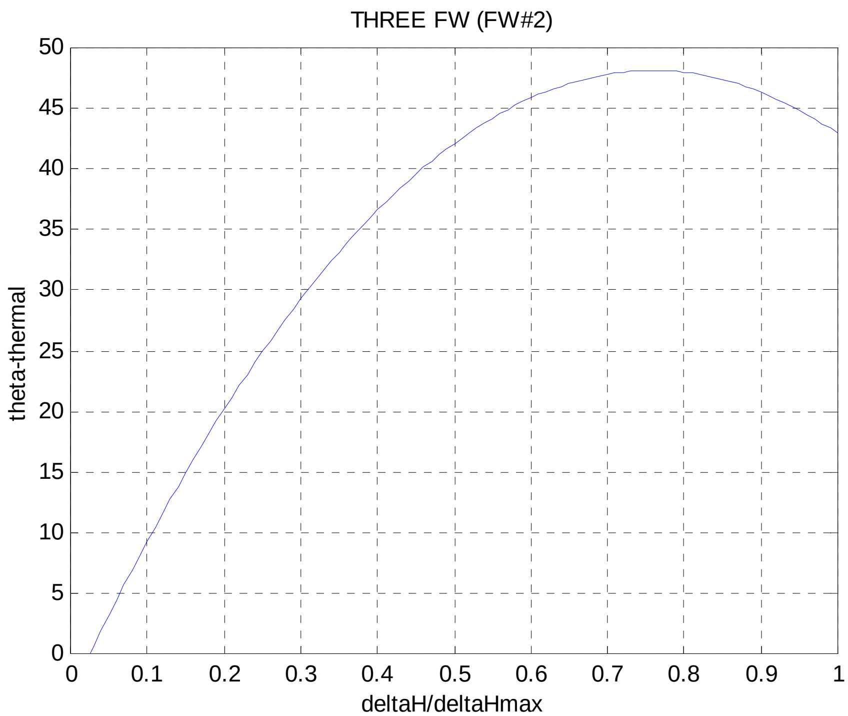
Now,
Assigning this optimized value for FW-2, and finding optimized value for FW-3

<u>Optimizing FW-3</u>

P(FW3)	h	m_{pump2}	m_{pump3}	m_{con}	$\Delta H/\Delta H_{max}$	η
0.9	2798	325.2	285.2	225	0.785949	48.05
0.85	2787	325	283.8	224.7	0.779133	48.08
0.8	2775	324.9	282.3	224.5	0.771506	48.1
0.77	2768	324.8	281.4	224.5	0.767097	48.11
0.768	2767	324.8	281.3	224.4	0.76652	48.12

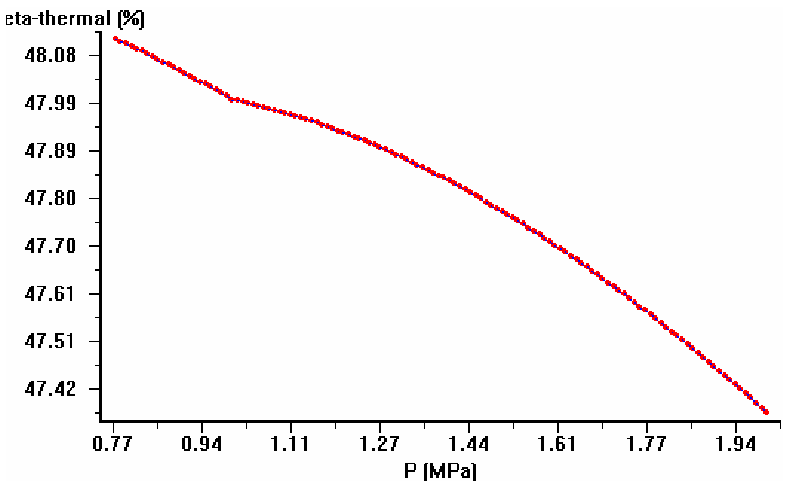
$h_{\max} = 3086$

$h_{con} = 191.8$



Maximum $\dfrac{\Delta H}{\Delta H_{\max}} = 0.76$ which gives $\eta_{th} = 48.12\%$

This corresponds to Feedwater Pressure of 0.739 MPa



Best Pressure for Feedwater is 0.769 MPa gives $\eta_{th} = 48.12\%$

Cycle Performance

$\eta_{th} = 48.12\%$

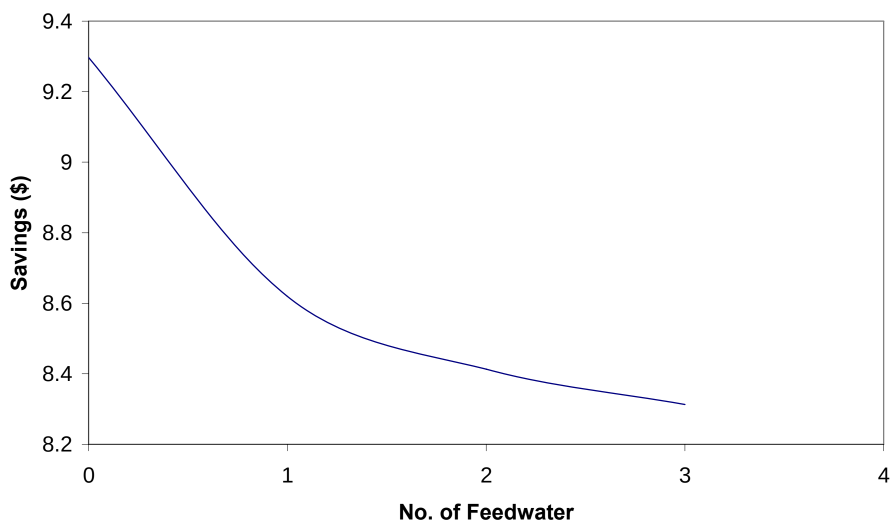
$\dot{Q}_H = 831.4 MW$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(831.4MW) = 8.314\$/s$

THE EFFECT OF ADDING FEEDWATER

No. of Feedwater	Savings ($)
0	9.397
1	8.619
2	8.416
3	8.314

THE EFFECT OF NUMBER OF FEEDWATER



ECONOMIC STUDY

Cost of Simple Power Plant ($COSPP$) $= 1\times10^{6}\ \$/MW$
For a Power Plant Produces 400 MW

$$COSPP = (400)(1\times10^{6}) = 400\times10^{6}\$$$

<u>FOR ADDING ONE FEEDWATER</u>

Cost of Two Feedwater $(CO1FW) = 1(0.05)(400\times10^{6}\$) = 20\times10^{6}\$$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(8.619MW) = 8.619\,\$/s$

The Number of Years to Cover the Cost of the Two Feedwater

$$= \frac{CO1PP}{Savings} = \frac{20\times10^{6}\$}{8.619\,\$/s} = 27days$$

So that adding two Feedwater is acceptable and economic.

<u>FOR ADDING TWO FEEDWATER</u>

Cost of Two Feedwater $(CO2FW) = 2(0.05)(400\times10^{6}\$) = 40\times10^{6}\$$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(841.6MW) = 8.416\,\$/s$

The Number of Years to Cover the Cost of the Two Feedwater

$$= \frac{CO2FP}{Savings} = \frac{40\times10^{6}\$}{8.416\,\$/s} = 55days$$

So that adding two Feedwater is acceptable and economic.

<u>FOR ADDING THREE FEEDWATER</u>

Cost of Two Feedwater $(CO3FW) = 3(0.05)(400\times10^{6}\$) = 60\times10^{6}\$$

Savings $= (0.01\$/MJ)\Delta\dot{Q}_H = (0.01\$/MJ)(831.4MW) = 8.314\,\$/s$

The Number of Years to Cover the Cost of the Two Feedwater

$$= \frac{CO3FP}{Savings} = \frac{60\times10^{6}\$}{8.314\,\$/s} = 83.5day$$

So that adding two Feedwater is acceptable and economic.

ENVIRONMENTAL IMPACT OF ADDING FEEDWATER

- The need for bigger place for a plant.
- For each Feedwater added we need to install a pump before it.
- The installed pump will
  - Make noise
  - Pollutes the air
  - Consume fuel
  - Needs maintenance