100

Design Project

Thermodynamics II

Dr. Crown

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We modeled a steam powered power plant at 520°C and 10 MPa. Such power plant has an efficiency of 44.842%. After viewing which parameters could be changed, we decided to create 2 new models, one with optimized parameters and another with an additional reheat. Both are covered in the sections below.

Model 1: Original Power Plant

The original power plant is represented by the first model. It works at a high efficiency, 44.8%, and it produces a good amount of profit, approximately $22 million. Regardless of this, the parameters are not optimized thus the plant is not producing as much profit as it could. This can be fixed by changing the initial temperature and pressure and by changing the percentage of feed water. In the next two models, two options are explored: higher initial temperature and pressure for greater work output, and an additional reheat before turbine 3 to increase the amount of work produced by that turbine.

Model 2: Optimized Parameters

In this model we decided to increase the temperature from 520°C to 600°C. The pressure was also increased from 10 MPa to 12 MPa. These values increased the efficiency from 44% to 47%. Considering coal costs the profits increased from $22.3 million to $27.5 million. This model does not provide as much profit as the third model but it does meet regulatory standards set by the government. CO_2 production is at a minimum which means less expense in filtering the pollutant out and no risk of fines.

↳ why do you say this? What is the reason? Refer reader to explanation on ~~second~~ third model description

Model 3: Additional Reheat

In this model we added a reheat after turbine 2 before turbine 3 as shown in the figure below. This reheat increases the initial heat of the fluid before entering turbine 3 thus more work can be produced than if the temperature remained at the same temperature of turbine 2 exit. The additional reheat both positive and negative consequences. The efficiency is reduced drastically, from 44% to about 28.94%. On the other hand the power output increases by a huge factor, from 85.515 MW to 141.145 MW. This in turn increases the profit from $22 million to $36 million including cost for coal used as fuel. This model is not intended as the main proposal; it only serves as an alternative to maximize profit regardless of efficiency. Although this model maximizes the profit it may have legal implications i.e. the low efficiency may produce more CO_2 gas pollutant which may exceed regulatory standards. The profit would still far exceed the profit of the original model even taking into account the expenses for filtering CO_2 but the government standards have to be taken into account.

Conclusion

Overall, model 3 provides the most profit with a low efficiency but environmental concerns have to be taken to account in addition to possible federal regulations. The most viable and safe option is model 2 which simply optimizes the parameters to produce the most work. This model has minimal environmental concerns and does not have any likelihood of violating any regulations. Depending on the area the plant is located and the regulations in that area, either of both models can be picked but the best choice overall would be model 2.

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Exam Problem

Exam Example Problem with isentropic efficiencies (eff_pump=90%, eff_turbine=85%)

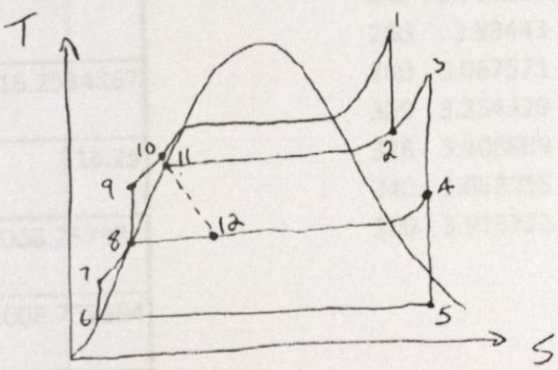
State	Given		Find	
#1	T=	520	H=	3424.484426
	P=	10000	S=	6.66125196
#2s				
#2	P=	4000	H=	3142.679281
	S2=	6.661252	S=	6.66125196
#3	T=	520	H=	3490.560945
	P=	4000	S=	7.147701673
#4s				
#4	P=	500	H=	2898.041925
	S=	7.147702	S=	7.1477
#5s				
#5	P=	8	H=	2236.616118
	S=	7.1477	S=	7.1477
#6	P=	8	H=	173.6315799
	X= 0			----
#7s				
#7	P=	500	H=	174.1277875
	v= 0.001009			
#8	P=	500	H=	639.7324329
	X= 0			
#9s				
#9	P=	10000	H=	653.53508
	v= 0.001453			
#10	P=	10000	H=	838.4843579
	HX Bal.			
#11	P=	4000	H=	1087.687306
	X=	0		
#12	P=	500	H=	1087.687306
	H12= H11			

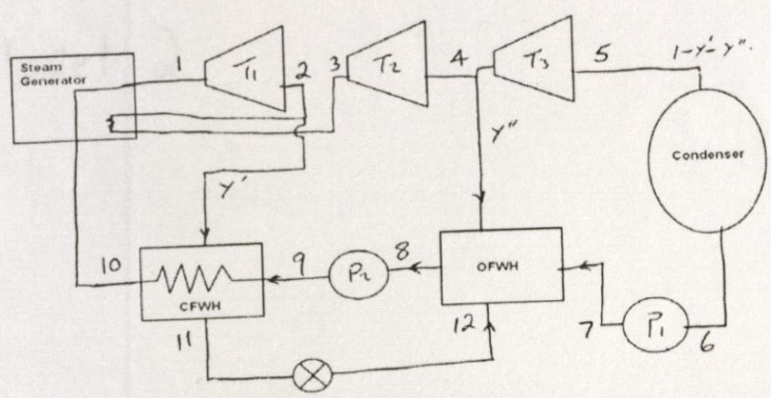
m_dot=	65 kg/s
y'=	9.00%
y''=	14.07%

Wt1=	18317.33442 kW
Wt2=	35047.50003 kW
Wt3=	33072.22171 kW
Wp1=	-24.8110803 kW
Wp2=	-897.1720647 kW
Qin1=	168090.0045 kW
Qin2=	22612.30812 kW
Eff=	44.84217934 % ✓

Wtotal	85515.07301
Rate	$0.10
Profit per Day	$68,412.06
Profit per Year	$23,944,220.44
Coal	2460 kWh/ton
$Coal	$16.67
Total Coal	97334.22944 ton
Total $ Coal	$1,622,561.60
Actual Profit	$22,321,658.84

where did you get this price?





Model 1

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Exam More Efficient

State	Given		Find	
#1	T=	600	H=	3607.819932
	P=	12000	S=	6.80275942
#2s				
#2	P=	3000	H=	3153.157407
	T=	366.4154	S=	6.80275942
#3	T=	600	H=	3681.874836
	P=	3000	S=	7.507660861
#4s				
#4	P=	709	H=	3189.25341
	T=	362.5085	S=	7.5077
#5s				
#5	P=	8	H=	2349.881337
	T=	41.51129	S=	7.5077
#6	P=	8	H=	173.6315799
	T=	41.51129	S=	7.5077
#7s				
#7	P=	709	H=	174.3385749
	v=	0.001009		
#8	P=	709	H=	699.0144041
	X=	0		
#9s				
#9	P=	12000	H=	716.2534867
	v=	0.001527		
#10	P=	12000	H=	716.25
	HX Bal.			
#11	P=	3000	H=	1008.757984
	X=	0		
#12	P=	500	H=	1008.757984
	H12= H11			

Wtotal=	105479.3863
Rate	$0.10
Profit per Day	$84,383.51
Profit per Year	$29,534,228.17
Coal	2460
$Coal	$16.67 kWh/ton
Total Coal	$120,057.84
Total $ Coal	$2,001,364.16 ton
Actual Profit	$27,532,864.01

Model 2

m_dot=	65
y'=	0.00%
y''=	17.40%

Wt1=	29553.06	kW
Wt2=	32020.39	kW
Wt3=	45064.43	kW
Wp1=	-37.9573	kW
Wp2=	-1120.54	kW
Qin1=	187951.8	kW
Qin2=	34366.63	kW
Eff=	47.44518	%

✓

Temp	s_f	s_g
20	0.292811	8.666387
40	0.571146	8.256159
60	0.832346	7.908735
80	1.077178	7.611366
100	1.307965	7.354042
120	1.527455	7.128783
140	1.738025	6.929064
160	1.941414	6.749365
180	2.138731	6.584897
200	2.330691	6.43144
220	2.518075	6.285232
240	2.702054	6.142853
260	2.88443	6.000998
280	3.067571	5.856055
300	3.254329	5.703215
316	3.408809	5.570101
340	3.658015	5.333203
360	3.913722	5.04852

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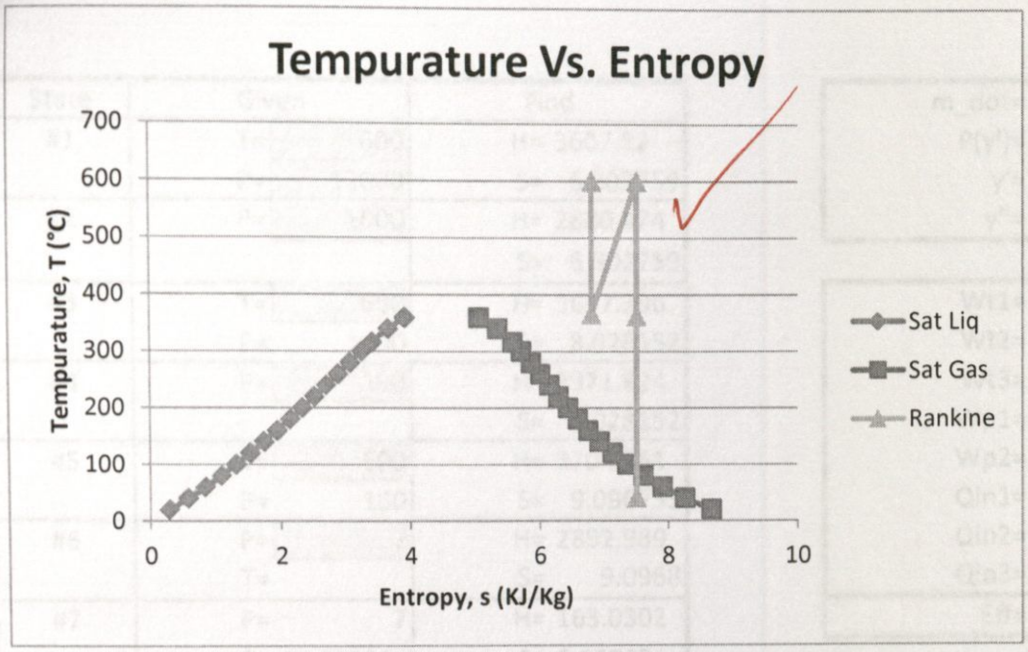
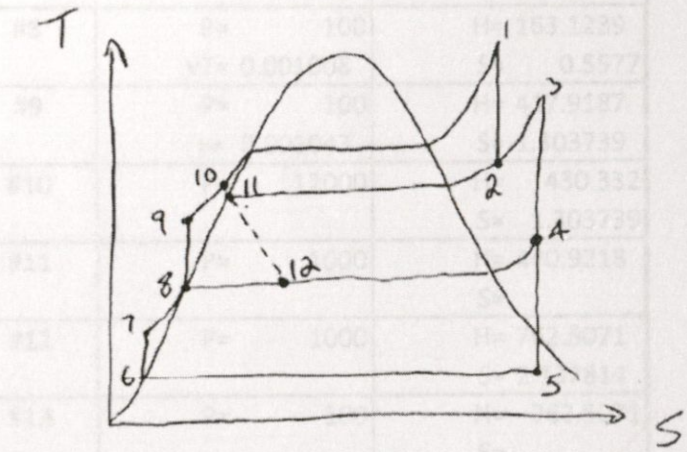
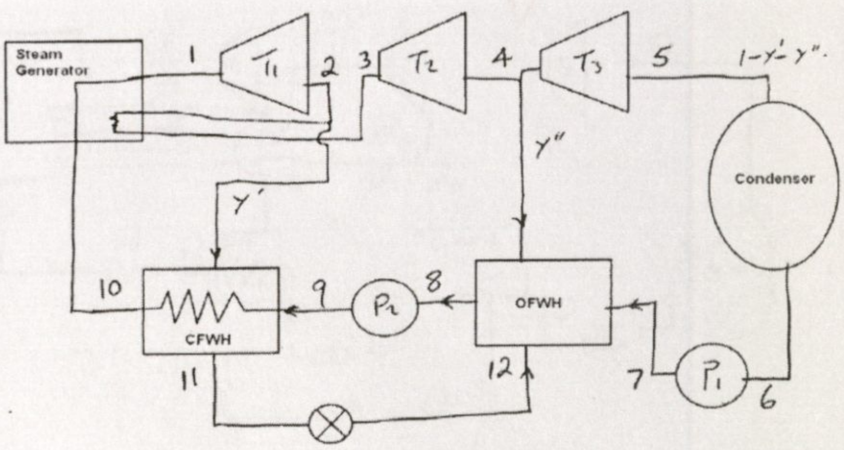
Exam More Efficient



Stage	Temp	S
1	600	6.802759
2	366.4154	6.802759
3	600	7.507661
4	362.5085	7.5077
5	41.51129	7.5077





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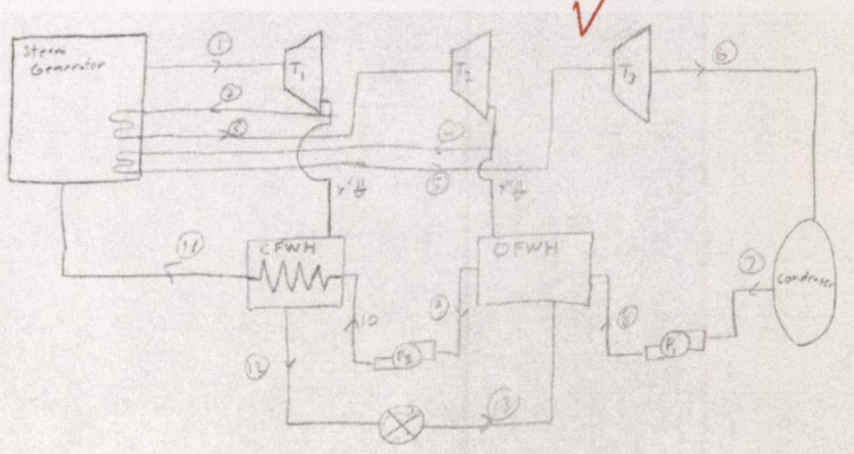
Extra Reheat

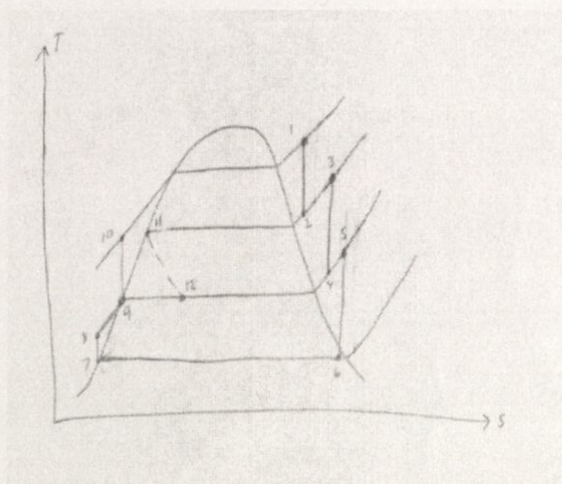
State	Given		Find	
#1	T=	600	H=	3607.82
	P=	12000	S=	6.802759
#2	P=	1000	H=	2880.474
			S=	6.802759
#3	T=	600	H=	3697.396
	P=	1000	S=	8.028152
#4	P=	100	H=	2971.624
			S=	8.028152
#5	T=	600	H=	3704.261
	P=	100	S=	9.096753
#6	P=	7	H=	2892.989
	T=		S=	9.0968
#7	P=	7	H=	163.0302
	T=	39.00202	S=	0.557671
#8	P=	100	H=	163.1239
	v7=	0.001008	S=	0.5577
#9	P=	100	H=	417.9187
	v=	0.001043	S=	1.303739
#10	P=	12000	H=	430.332
			S=	1.303739
#11	P=	1000	H=	440.9218
			S=	
#12	P=	1000	H=	762.5071
			S=	2.137814
#13	P=	100	H=	762.5071
			S=	

m_dot=	65	kg/s
P(y')=	1000	
y'=	0.50%	
y''=	8.97%	

Wt1=	47277.50428	kW
Wt2=	46939.31199	kW
Wt3=	47741.24965	kW
Wp1=	-5.514393038	kW
Wp2=	-806.8640252	kW
Qin1=	238689.1373	kW
Qin2=	43113.78102	kW
Qin3=	205848.3767	kW
Eff=	28.94397881	%

Carnot %	64.26%	
Wtotal =	141145.6875	
Rate	$0.10	
Profit per Day	$112,916.55	
Profit per Year	$39,520,792.50	
Coal	2460	kWh/ton
$Coal	$16.67	
Total Coal	160653.6281	ton
Total $ Coal	$2,678,095.98	
Actual Profit	$36,842,696.52	





Model 3

$$\eta = \frac{\Sigma W}{\Sigma Q_{in}}$$

$$\eta = \frac{h_1 - h_2 + (1-y')(h_3 - h_4) + (1-y'-y'')(h_5 - h_6) + (1-y'-y'')(h_7 - h_8) + h_9 - h_{10}}{(1-y')(h_3 - h_2) + (1-y'-y'')(h_5 - h_4) + h_1 - h_{11}}$$

$$\eta = \frac{h_1 - h_2 + (1-y')(h_3 - h_4) + (1-y'-y'')(h_5 - h_6 + h_7 - h_8) + h_9 - h_{10}}{(1-y')(h_3 - h_2 + h_5 - h_4) + y''(h_5 - h_4) + h_1 - h_{11}}$$

$$\eta = \frac{h_1 - h_2 + (1-y')(h_3 - h_4) + (1-y'-y'')(h_5 - h_6 + h_7 - h_8) + h_9 - h_{10}}{(1-y')(h_3 - h_4) + (1-y')(h_5 - h_2) + y''(h_5 - h_4) + h_1 - h_{11}}$$

↑ Factors to increase	No Effect	↓ Factors to decrease
h_4 h_7 h_9 h_{11}	h_1 h_3	h_2 h_5 h_6 h_8 h_{10}