Evaluation of Feedwater Heater Design Proposals Using PEPSE

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ABSTRACT

PEPSE can be a very useful tool for evaluating feedwater heater design proposals in design mode. The effect of the feedwater heater design on the entire turbine-generator cycle can also be analyzed using PEPSE. This can be very helpful when trying to compare dissimilar designs and determine which one is the best alternative taking into consideration the initial bid price, efficiency, pumping costs, etc.

In order to model a feedwater heater in design mode, several pieces of input data are required. Most of this information can be obtained from the manufacturer's design specification sheet. Additional information may be obtained by contacting the manufacturer and requesting additional information. Some of the inputs do not have a significant impact on the final results. Therefore, PEPSE's default values may be used for these inputs. An educated guess must be used for the remaining inputs, if they are unattainable. If a number of proposals are being compared, the defaulted and assumed values should be consistent for each proposal.

Once a feedwater heater submodel has been erected it can be inserted into a larger model such as a turbine generator cycle, if so desired. Then the overall effects of the various design proposals can be measured and compared against each other.

INTRODUCTION

Omaha Public Power District (OPPD) has experienced an increasing problem with "tube denting" and corrosion of the steam generators at Fort Calhoun Nuclear Station. A contributing factor to this problem is believed to be copper transport, which is being carried over from the low pressure feedwater heater train. The first three heaters in the feedwater heater train have arsenic copper tubing. The remainder of the heaters have stainless steel tubing.

In order to try and alleviate this problem, OPPD decided to replace the tubing in the low pressure heaters with stainless steel tubing. One disadvantage with stainless steel tubing, however, is that it has a much lower thermal conductivity than copper. Consequently, the overall heat transfer coefficient (U) will decrease for these heaters and so will the heat transfer rate if the tubes are replaced tube for tube. As a result, the thermal efficiency of the heaters and also of the entire unit will decrease unless the heat transfer surface area is increased to counteract the effects of the change in tube material.

One way to increase the heat transfer surface area is to increase the size of the heater shells. Since the heaters involved are all located in the neck of the condenser it would be an extremely difficult task to enlarge the diameter of the shells. Another possibility is to add a flanged spool piece to one end of the heaters to make the shells longer. However, space limitations on either side of the heaters prevent this since there would not be enough room to slide the tube bundles into place. Therefore, the only alternative left is to optimize the heat transfer surface area within the existing shell constraints. This is the alternative that OPPD decided to implement.

This can be done by decreasing the tube diameter and increasing the number of tubes in each heater. This will increase the head loss through the heater train, however. The tube length might also be increased slightly if space permits. This will also increase the head loss slightly.

Contract specifications were prepared requesting the Vendors bidding on this job to optimize the thermal performance of the heaters within the existing shell configuration. They were supplied with the dimensions of the existing heaters, the inlet conditions of the feedwater or condensate into heater no. 1 and the extraction steam conditions being supplied to each heater.

Meanwhile, feedwater heater sub-models were being constructed in design mode on PEPSE to duplicate the specifications of the existing feedwater heaters. Design input data was obtained from the original feedwater heater specification sheet. A couple of controls were necessary in order to match the performance data on the specification sheets closely. Once these sub-models were fine tuned, they were incorporated into the entire Fort Calhoun turbine generator cycle model which was constructed earlier.

After the design proposals were received from the Vendors, the bids were reviewed for satisfactory compliance with contract requirements and the list was narrowed down to four manufacturers and five design proposals (one manufacturer submitted two proposals). The design data from each proposal were input into the feedwater heater design models which were then incorporated into the base model. Separate cases were run for each proposal to determine the effect of each design on overall cycle performance. The results were compiled and the vendors were evaluated primarily on turbine heat rate, gross generation and tubeside pressure drop across the feedwater heater train. Tubeside pressure drop was a concern because, based upon the condensate pump curves, too large of an increase in the system head requirements would cause a restriction in pump output and, as a result, a restriction in load capability.

Dollar values were placed upon these performance results. These figures along with the contract prices were used to help determine who was awarded the contract.

TEXT

I. CONSTRUCTING FEEDWATER HEATER SUB-MODELS

In order to compare and evaluate the feedwater heater designs, the first step was to set up an individual feedwater heater model for each heater to be replaced using design mode on PEPSE (see figure I). The heaters to be replaced at Fort Calhoun are low pressure heaters 1, 2 and 3 along with the external drain coolers. Although there is a dual feedwater heater train at Fort Calhoun, only one of each heater was modeled since these trains are identical by design. Also, since a drain cooler cannot be modeled in design mode the external drain cooler was incorporated into heater #1, for the purposes of this analysis, changing it from a component type 14 (standard feedwater heater) to a type 16 (feedwater heater with internal drain cooler). This superficial change in the design model will have no effect on the analysis of the performance of the heater (i.e. - the performance output will be the same, whether this is modeled as an internal or external drain cooler, provided that the proper input data is used). The remaining two heaters (#2 and #3) are also feedwater heaters with internal drain coolers (CTYPE 16).

A feedwater heater with internal drain cooler requires 60 pieces of input data in design mode on PEPSE (1). The first 40 inputs are specifically for the condensing section and the remaining inputs are for the drain cooling section. Most of these inputs were obtained from the feedwater heater specification sheets. More inputs were obtained from the manufacturer by requesting additional information. Some of the inputs were defaulted to allow PEPSE to calculate a value using internal algorithms and certain values to use as benchmarks for later comparisons. An "educated guess" had to be used on a few of the inputs since the information was not available. A listing of the input data for a typical feedwater heater is shown in Table I.

For the first run, the design specifications for the existing feedwater heaters, with arsenic copper tubing, were input to try and match the performance output specified by the manufacturers (TTD, DCA, etc). The results were not quite the same as those specified by the manufacturer on the initial run. Therefore, another run was performed using controls to establish the proper values as specified by the manufacturer. The heat transfer bypass factor for the drain cooling section (word 62-R) was used to control the Drain Cooler Approach. The hydraulic bypass flow factor for the drain cooling section (word 61-R) was used to control the shell side pressure drop of the heaters. The feedwater inlet nozzle form loss coefficient was used to control the tube side pressure drop. The values calculated by these controls were treated as fixed values and were input directly into the design for each Vendor proposal later on.

Several difficulties were encountered while trying to model the existing feedwater heaters. One of the major problems was trying to match the overall heat transfer coefficient, U_o (word 23-R). Originally, the value listed on the heater specification sheet was taken for granted and input directly into the design model. Another run was made defaulting this value so that PEPSE would calculate an overall heat transfer coefficient. The value calculated by PEPSE was much higher than the value given on the specification sheet. As a result, the performance outputs such as TTD and DCA were quite a bit different also.

Because of this discrepancy, an independent evaluation of U_o was performed to compare with the results given by the manufacturer and PEPSE. The formula given in figure II, which is fairly standard, was used to calculate U_o(2). In order to calculate U_o, however, it is necessary to evaluate the inside and outside convective film coefficients, h_i and h_o. There are several different empirical relationships that have been developed to calculate these values. Most of them are similar, however. The formulas shown in figures III and IV were used to calculate these values. These values were then substituted into the equation for U_o. The HEI Standards were used for the inside and outside fouling factors, R_{fi} and R_{fo}(3). The resultant value was very close to that calculated by PEPSE.

After experimenting around with different fouling factors for a while, it was discovered that using the values recommended by TEMA for fouling resistance achieved approximately the same value for U_o as that shown on the specification sheet(4). The difference between the HEI Standards and TEMA Standards for fouling factors alters the value of U_o dramatically. Therefore, it was suspected that the manufacturer had used the TEMA Standards instead of HEI. When approached about this, however, the manufacturer insisted that they had used the minimum recommended HEI fouling factors.

Upon researching this discrepancy further, with the aid of a consultant, it was concluded that the original specification sheet was incorrect for the heaters that were installed at Fort Calhoun. When Fort Calhoun was originally being designed, all of the feedwater heaters were to have stainless steel tubes. The contract was awarded on this basis and, later, the design was changed from stainless steel to arsenic copper tubes. The tube material on the specification sheets was changed but the performance values were not updated along with the change in tube material, for some reason. As a result, the values given were for stainless steel tubes instead of arsenic copper tubes and, therefore, were incorrect. This was verified by inputting the thermal conductivity for stainless steel into the equation for U_o, along with the HEI fouling factors. The result was very close to the value given on the specification sheet.

Once this problem was resolved, the values for the arsenic copper tubing were input back into the model to serve as the basis for comparison. The increase in U_o also had an effect on the other performance parameters. The heat transfer rate went up which caused the temperature gradient, ΔT_m, to decrease. This partially offset the increase in U_o. The extraction steam flow also increased due to the increased heat transfer rate.

Once the feedwater heater submodels were satisfactorily completed, these submodels were incorporated into the overall turbine-generator cycle schematic to replace the performance mode of the feedwater heaters (see figure V). This is done by simply substituting the design data shown in Table I for the performance data normally used on these feedwater heaters. In the PEPSE diagram (figure V), the feedwater heaters being replaced are components 470, 480 and 490. As stated earlier, only one half of the feedwater heater train was being modeled on the individual feedwater heater models. Therefore, the number of tubes for each heater model was doubled to account for the fact that there are actually two feedwater heaters apiece. This was done for both the condensing section and drain cooling section.

II. PREPARING CONTRACT SPECIFICATIONS

While this was going on, contract specifications were being prepared by design engineers to be sent to prospective Vendors so that they could bid on this project. We knew that with the change in tube material from arsenic copper to stainless steel tubing that the overall heat transfer coefficient for these heaters would decrease because of the difference in the thermal conductivity of these materials. As a result, the heat transfer rate for the same effective heat transfer surface area would also decrease. This would cause an increase in the Terminal Temperature Difference (Sat temp of heater - feedwater outlet temp) and the Drain Cooler Approach (heater drain outlet temp - feedwater inlet temp). As an end result, the thermal efficiency of the entire unit will be adversely affected.

This can be avoided by increasing the effective surface area to offset the decrease in the overall heat transfer coefficient (see Table II). In order to completely offset the change in tube material, the shells of these heaters would have to be enlarged. Except for the external drain coolers, the heaters to be replaced are all located in the neck of the condenser. Therefore, increasing the diameter of the shells would be an extremely costly and time consuming modification. Extending the length of the heaters by adding a spool piece to one end would be much easier. After studying this option, however, it was determined that the length of the heaters could only be increased by about one foot and still allow enough room to be able to slide the new tube bundles in place, based upon the space limitations.

As a result, a decision was finally reached to keep the existing shell without modifying it and to replace the tube bundles only. In order to try and minimize the loss in efficiency, it was decided to try and optimize the design of the heaters within the boundaries of the existing heater shells.

The contract specifications were therefore prepared requesting the Bidders to provide the most efficient design possible within the given shell constraints. The only operating conditions specified were the inlet conditions to the external drain coolers, including the maximum condensate flow, and the extraction steam conditions (pressure, temperature and enthalpy) entering each heater shell. The Vendor was requested to supply the remaining data for these heaters, based upon their design. PEPSE requires some inputs, in design mode, that are not normally included on a design proposal. Therefore, these items were included on a list of information to be provided by the Vendor.

III. INPUTTING SPECIFICATIONS FROM VENDORS' DESIGN PROPOSALS INTO FEEDWATER HEATER MODELS

After the design proposals were received from the Vendors, they were reviewed for technical and legal compliance with the contract requirements. Preliminary economic considerations were also taken into account. After the preliminary review, the list of prospective Vendors was narrowed down to four. One Vendor submitted two different proposals so the final list included five different proposals.

The design data from the remaining proposals were collected and input into a separate feedwater heater design model for each proposal. Some of the input data requested were not supplied by the Vendors. Therefore, assumptions had to be made for these inputs. All of the assumptions made were consistent for each proposal. Also, the values arrived at using the controls on the base model were also applied to the input data for each design proposal. This was done to provide a fair comparison of the new design proposals with the present design. The feedwater heater design data were then input into the PEPSE model and a separate case was run for each proposal. The output data from these runs were compared with the base case (present feedwater heater design) as well as with each other.

IV. DISCUSSION OF RESULTS

Some of the key parameters being evaluated were TTD, DCA, tubeside pressure drop, heat transfer rate, mass flow to heater shell, overall heat transfer coefficient and shell side pressure drop. Most of this information is located on PEPSE's Detailed Feedwater Heater Design Output" page shown on figure.VI. There are also several other useful pieces of information on this page, such as the film coefficients calculated by PEPSE and the thermal and hydraulic bypass flow factors, if utilized.

The primary output parameters being evaluated, however, were the overall cycle parameters - gross generation and heat rate. Since Fort Calhoun is a nuclear plant and, therefore, the heat input is basically fixed at full load, the main focus was on gross generation. If the cycle efficiency decreases, the heat input cannot be increased (as at a fossil unit) in order to maintain the same load requirements. Consequently, gross generation will decrease as the cycle efficiency decreases.

Makeup generation costs were computed by multiplying the difference in generation capacity between the present design and each feedwater heater proposal by an average production cost for producing this electricity with one of our other generating units. Table III shows the makeup generation cost comparisons, relative to the present design, of the various design proposals. These figures are on an annualized basis.

The tubeside (feedwater) pressure drop across the feedwater heater train was also evaluated closely for each proposal and compared to the original design. As mentioned earlier, the tubeside pressure drop was a concern because of possible limitations on condensate pump capacity due to increased head requirements and, thus, possible restrictions in generation output resulting from a reduction in steam flow capacity. Part of the reason why this is a problem results from an upgrade in power level (called "Stretch Power") at Fort Calhoun a few years ago. Fort Calhoun's operating license was increased from 1420 MWTH to 1500 MWTH, thus requiring an increase in flow throughout the system, among other things. As a result, the condensate pumps are already operating above the original design operating conditions and the margin of safety has been reduced.

Of the proposals considered, none of the pressure drops were large enough to create a restriction in flow capacity (unless a future increase in power level occurs). However, the variation in pressure drops was enough to have a slight effect on the power input to the condensate pumps and, therefore, on the pumping costs associated with these pumps. Although this is a minor factor, it is not totally insignificant and was included in the cost considerations for these heaters.

After these costs were established, an economic evaluation was performed to determine the most cost effective proposal overall. The initial bid price was treated as a capital cost and the makeup generation costs from Table III along with the pumping costs were treated as an annuity since they are recurring every year. The final ranking of the proposals, based upon the economic evaluation, is shown in Table IV. The results of this analysis were then reported to Management to aid in selecting the best proposal for this contract.

SUMMARY

Corrosion of the steam generators at Fort Calhoun Station, attributed at least partially to exfoliation of copper tubing in the low pressure feedwater heaters, has prompted Omaha Public Power District (OPPD) to replace all of the copper tubing in the feedwater heater train with stainless steel tubing. Stainless steel has a much lower thermal conductivity than copper so the heat transfer rate will decrease unless the heat transfer surface area is increased to make up for this. Since all of the heaters with copper tubing are located in the neck of the condenser, it would be extremely difficult to enlarge the shells of the heaters. Therefore, contract specifications were prepared requesting the Vendors bidding on the project to submit the most efficient design permissible within the existing shell constraints.

PEPSE was used in design mode on the feedwater heaters to compare the design proposals received on an equivalent basis. The first step involved setting up individual feedwater heater submodels in design mode on PEPSE. Design specifications from the existing feedwater heaters were input so that the performance data given by the original manufacturer could be duplicated. Once these models were fine tuned, they were incorporated into the entire Fort Calhoun turbine generator cycle model which was constructed earlier. Then, the design data supplied by each vendor were input into the feedwater heater models and several cases were run to determine the effect of each design on the entire cycle performance. The results were then compiled and the Vendors were ranked based upon overall cycle performance.

In conclusion, PEPSE can be extremely helpful for evaluation and comparison of feedwater heater design proposals. In addition, PEPSE can be used in design mode for several other applications such as verifying design specifications, calculating cleanliness factors and simulating plugged tubes. If utilized properly, PEPSE's Design Mode can be a very powerful tool.

REFERENCES

1. Kettenacker, Minner, Hansen, Klink, PEPSE Manual Vol. I: User Input Description, Energy Incorporated, January 1979.

2. Lindeburg, Mechanical Engineering Review Manual, Sixth edition, Professional Engineering Registration Program, 1980, pp. 3-12, 18, 19, 20, 21.

3. Standard For Closed Feedwater Heaters, Heat Exchange Institute, 1974, p. 2.

4. Standards Of Tubular Exchanger Manufacturer's Association, Tubular Exchanger Manufacturer's Association, 1968, pp. 124, 125.

FIGURE I: O. P. P. D.
FORT CALHOUN STATION
FEEDWATER HEATER NO. 1 SUBMODEL

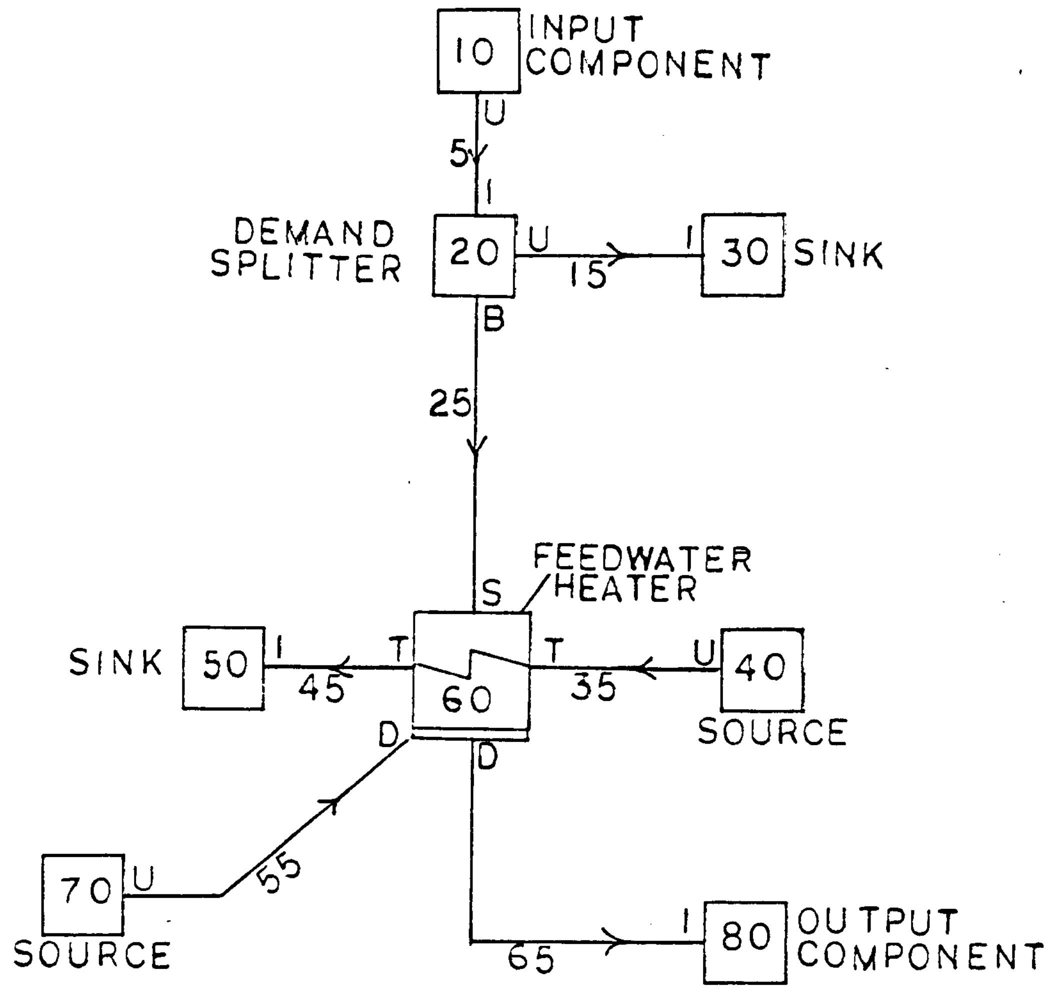

Table I: Typical Design Input Data For A Feedwater Heater

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700600 16, 0, -20, 1, 0., 0.652, 0.75, 857.7, 659., 221., 0., 0., 1.0E-99
700601 0.0, 0.9375, 0.9375, 0., 0., .0002, 0., 0., 0., 0., 1, 2, 13.25, 1.54
700602 13.25, 0., 23.25, 1.0E-99, 7.981, 1.0, 25., 26.2, 0.25, 0., 1, 0, 1
700603 0.652, 0.75, 93.1, 659., 221., 0., 0., 13.0, 0., 0.9375, 0.9375, 600.
700604 5., .0003, 0., 0., 0., 0., 1, 2
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Figure II: <u>Formula For Calculating U_o</u>

$$1/U_o = 1/h_o + (r_o/k)\ln(r_o/r_i) + R_{fo} + (R_{fi}+1/h_i)(r_o/r_i)$$

where, U_o = Overall heat transfer coefficient, btu/hr ft^2 F
h_o = outside convective film coefficient, btu/hr ft^2 F
h_i = inside convective film coefficient, btu/hr ft^2 F
r_o = outside radius of tube, ft
r_i = inside radius of tube, ft
k = thermal coductivity of tube material, btu/hr ft^2 F
R_{fo} = fouling resistance on outside of tube, hr ft^2 F/btu
R_{fi} = fouling resistance on inside of tube, hr ft^2 F/btu

Figure III: <u>Calculating Inside Convective Film Coefficient</u>

For turbulent flow in pipes:

$h_i x D_i / k = .0225(N_{re})^{0.8}(N_{pr})^n$

h_i = inside convective film coefficient, btu/hr ft^2 F

D_i = inside diameter of tube, ft

k = thermal coductivity of water @ T_{bulk}, btu/hr ft F

$N_{re} = v x D_i / \nu$

v = velocity of water flowing through tubes, ft/sec

ν = kinematic viscosity @ T_{bulk}, ft^2/sec

$N_{pr} = c_p x u / k$

c_p = specific heat of water @ T_{bulk}, btu/lbmF

u = absolute viscosity @ T_{bulk}, lbm/ft-sec

n = 0.3 for heat flow out of tube
0.4 for heat flow into tube

Restrictions:

$N_{re} > 10,000$

$0.7 < N_{pr} < 100$

$L/D > 60$

Figure IV: Calculating Outside Convective Film Coefficient

Film Coefficient With Condensing Vapor:

$$h_o = 0.725 \left[\frac{\rho_l(\rho_l - \rho_v) g h_{fg} (k)^3}{D_o u_l (T_{sv} - T_s)} \right]^{0.25}$$

h_o = outside convective film coefficient, btu/hr-ft^2-F

ρ_l = liquid density, lbm/ft^3

ρ_v = vapor density, lbm/ft^3

g = acceleration due to gravity = 4.17×10^8 ft/hr^2

h_{fg} = latent heat of condensation

$h_{fg}' = h_{fg} + (3/8) c_p (T_{sv} - T_s)$

(include the second term for subcooling only)

c_p = specific heat of liquid, btu/lbm-F

T_s = surface temp of tube, F

T_{sv} = saturated vapor temp, F

k = thermal conductivity of liquid, btu/hr-ft-F

u_l = liquid viscosity, lbm/hr-ft

Notes:

1. Assume $T_{sv} - T_s$ is between 5 and 40 F.
2. Evaluate the fluid properties @ $(T_s + T_{sv})/2$.
3. Approximate range of h_o is 2000 to 4000.

Figure 5: PEPSE

Turbine-Generator Cycle Schematic

Fort Calhoun Unit #1

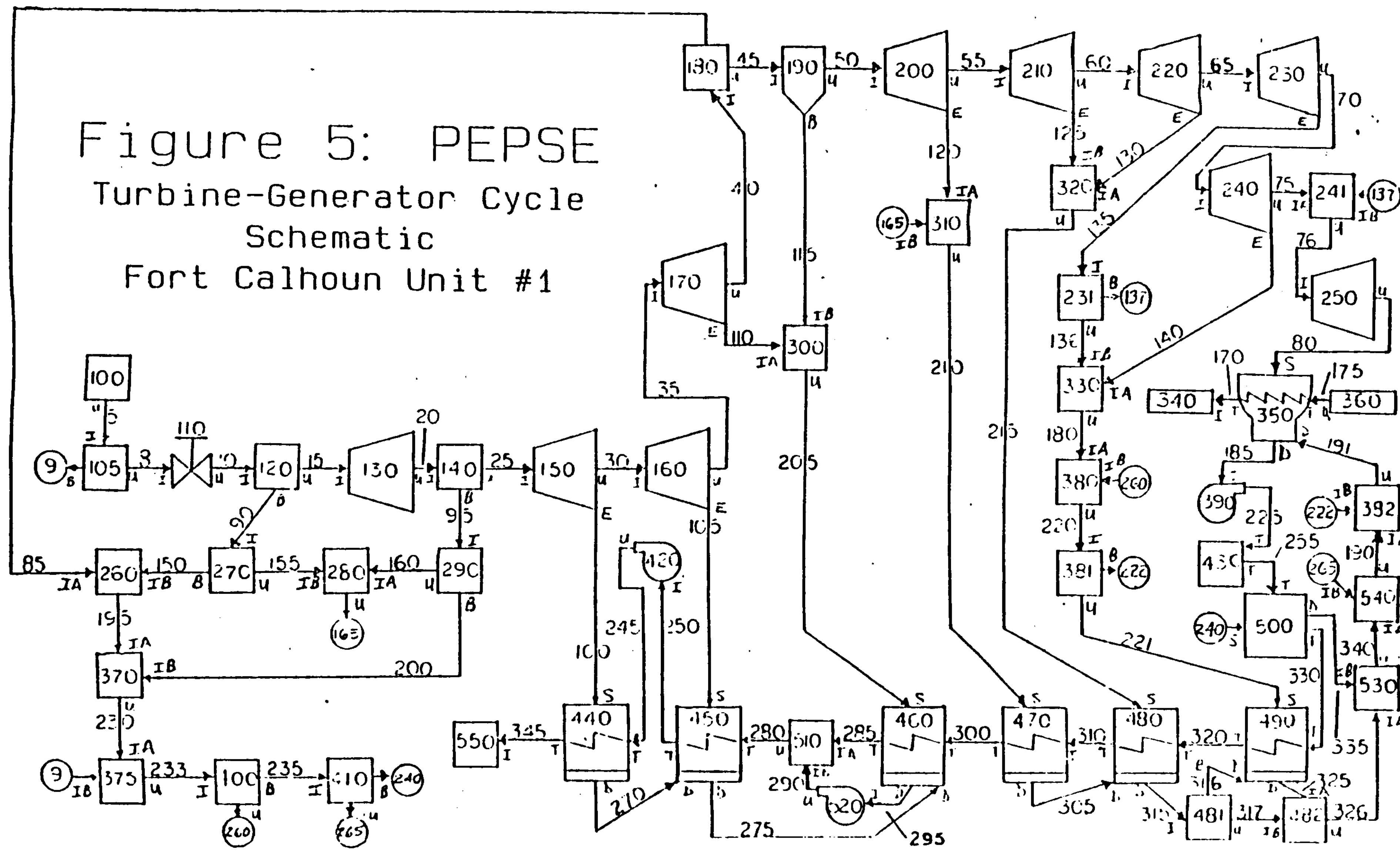

TABLE II. Comparison of Heat Transfer Surface Areas Required for Copper Versus Stainless Steel Tubes

Heater	Condition No. 1* Surface Area (ft^2)	Condition No. 2** Surface Area (ft^2)	
1. Drain Cooler	4,702	6,734	(43.2%)
2. Heaters 1A & 1B	18,920	22,161	(17.1%)
3. Heaters 2A & 2B			
a. Condensing Section	20,395	23,655	(16.0%)
b. Drain Cooler Section	4,269	3,972	(-7.0%)
c. Total	24,664	27,627	(12.0%)
4. Heaters 3A & 3B			
a. Condensing Section	18,496	21,382	(15.6%)
b. Drain Cooler Section	1,746	1,724	(-1.3%)
c. Total	20,243	23,106	(14.1%)

*Condition 1: Present Configuration - Copper arsenic tubes with a 10° DCA for the Drain Cooler and 5° TTDs for Heaters 1-3.

**Condition 2: Stainless Steel Tubes with same design conditions - 10° DCA and 5° TTDs.

NOTE: Numbers in parentheses are percentage increase over present condition.

FIGURE VI: DETAILED FEEDWATER HEATER DESIGN OUTPUT

COMPONENT NUMBER 60

PARAMETER		SHELL-SIDE SUMMARY DESUPERHEATER	CONDENSER	DRAIN COOLER	TUBE-SIDE SUMMARY DESUPERHEATER	CONDENSER	DRAIN COOLER
TEMPERATURE IN	(F) =	N.A.	275.937	275.938	N.A.	204.358	199.103
TEMPERATURE OUT	(F) =	N.A.	275.938	209.102	N.A.	270.935	204.358
PRESSURE IN	(PSIA) =	N.A.	46.100	46.099	N.A.	98.087	98.770
PRESSURE OUT	(PSIA) =	N.A.	46.099	45.227	N.A.	90.612	98.087
ENTHALPY IN	(BTU/LBM) =	N.A.	1108.417	245.018	N.A.	172.664	167.384
ENTHALPY OUT	(BTU/LBM) =	N.A.	245.018	177.319	N.A.	240.003	172.664

HEAT TRANSFER COEFFICIENTS

FEEDWATER HEATER ZONES	FILM INSIDE TUBE PEPSE USED (BTU/HR-FT2-F)	FILM INSIDE TUBE PEPSE CALC (BTU/HR-FT2-F)	FILM OUTSIDE TUBE PEPSE USED (BTU/HR-FT2-F)	FILM OUTSIDE TUBE PEPSE CALC (BTU/HR-FT2-F)	OVERALL PEPSE USED (BTU/HR-FT2-F)	OVERALL PEPSE CALC (BTU/HR-FT2-F)
CONDENSER	2.5724E+03	2.5724E+03	2.7809E+03	2.7809E+03	6.6536F+02	6.6536E+02
DRAIN COOLER	2.3510E+03	2.3510E+03	1.7210E+03	1.7210E+03	4.5027E+02	4.5027E+02

SHELL-SIDE PRESSURE DROPS

FEEDWATER HEATER ZONES	ENTRANCE NOZZLE (PSI)	ZONE P DROP (PSI)	TUBE BANK CROSS FLOW (PSI)	ACCELERATION (PSI)	ELEVATION (PSI)	BAFFLE (PSI)	EXIT NOZZLE (PSI)	BYPASS FLOW FACTORS THERMAL (-)	BYPASS FLOW FACTORS HYDRAULIC (-)
CONDENSER	2.6366-100	6.3990E-04	6.3993E-04	-3.7317E-08	0.	0.	N.A.	N.A.	N.A.
DRAIN COOLER	N.A.	8.7277E-01	8.6896E-01	6.9856E-04	0.	3.1097E-03	3.5266E+00	1.0000E+00	1.0000E+00

HOTWELL CONDENSATE ELEVATION PRESSURE DROP (PSI)= 0.

TABLE III. Ranking of Proposals Based Upon Makeup Generation Costs

Proposal	Gross Turbine Heat Rate	Gross Gen. Output	Increase From Base	KW Output From Base	Makeup Gen. Cost
Base - Present Design Configuration	10,019 btu/Kwh	513,192 Kw	-	-	-
1. Proposal No. 5	10,023 btu/Kwh	512,962 Kw	3.4 psi	230 Kw	$28,140/yr.
2. Proposal No. 4	10,026 btu/Kwh	512,836 Kw	11.0 psi	356 Kw	$43,560/yr.
3. Proposal No. 1	10,031 btu/Kwh	512,599 Kw	2.3 psi	539 Kw	$72,500/yr.
4. Proposal No. 3	10,031 btu/Kwh	512,578 Kw	1.1 psi	614 Kw	$75,130/yr.
5. Proposal No. 2	10,032 btu/Kwh	512,521 Kw	-7.3 psi	671 Kw	$82,106/yr.

TABLE IV: Overall Ranking of Proposals Based Upon Economic Analysis

Proposal	Present Equivalent Cost * (1985 Dollars)	Annual Equivalent Cost*
Proposal No. 5	$1,310,960	$ 71,670
Proposal No. 4	$1,561,160	$ 85,350
Proposal No. 1	$1,898,450	$103,790
Proposal No. 3	$1,973,600	$107,900
Proposal No. 2	$1,990,460	$108,800

*These costs include contract price, makeup generation costs and increased pumping costs.

Assumptions:

Remaining life expectancy of Fort Calhoun Station = 23 years
Anticipated interest rate for next 23 yrs. = 8%
Anticipated inflation rate for next 23 yrs.= 6%