Feedwater Heater Design Mode
Development & Applications

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Abstract

Many applications for analyzing various performance aspects of feedwater heaters require that the heater be placed in the design mode. These applications include verifying vendor heater performance curves, analyzing the effects of tube plugging, economic justifications for replacing heaters, and many others. Because this is such a useful tool in feedwater heater analysis, it is important that the heater can be modeled in a reasonable amount of time and can provide reliable results. This paper deals with the procedure used to place a heater in design mode and the various applications for predicting heater performance.

Modeling a feedwater heater requires 40 to 80 pieces of input data depending on the type of heater. The procurement of these data can become time-consuming; and, in many older stations, detailed information on the heater is unavailable. Although having access to all the heater information is desirable, the heater can be modeled effectively knowing only a few important pieces of information, along with using the available correction factors.

With practice, a user can model a heater and can obtain results in several hours. This becomes an essential tool in analyzing feedwater heater and total cycle performance.

Introduction

Feedwater heater studies used to determine the performance characteristics of a heater or its effect on the total cycle require the heater to be placed in design mode. The design mode enables the user to input specific characteristics of the heater such as tube sizes and material, heat transfer coefficients, and hydraulic parameters to simulate the actual performance of the heat exchanger. This paper deals with the methodology used to effectively place a heater in design mode and obtain reliable results.

Depending on the application, the heater can be modeled as a sub-model or it can be integrated into the total cycle. A heater sub-model is effective when verifying a vendor performance curve of the heater. The curve, typically of TTD and DCA vs. feedwater flow, can be duplicated by using the vendor supplied geometric, thermal, and hydraulic characteristics of the heater. After the heater is modeled, feedwater flow and steaming conditions are varied at given increments and the values of TTD and DCA are obtained. The sub-model, which consists of only the heater and its flow sources, is applicable in this situation where heater performance is of concern and not the heater's effects on the total cycle. Figure I illustrates a typical flow diagram for a heater sub-model.

When effects on the cycle are of concern, the heater can be integrated into the turbine cycle. An example of this would be the degredation of heater performance caused by tube plugging. The changes in heat rate and/or generation can be determined by simulating tube plugging in the model. This can be an effective tool for performing economic justifications to determine the optimum replacement time of a feedwater heater.

Plant operations is another area where placing heaters in design mode can be useful. Possibly the costs incurred by removing a heater or heater string from service needs to be determined. The effects on turbine stage loading when removing heaters from service can be another area of interest.

The above examples illustrate ways PEPSE can be used to optimize plant performance along with providing answers to design questions.

Text

Depending on the type of heater being modeled, 40 to 80 pieces of input data are required. For a heater with a condensing section only, 40 inputs are required. A heater with a condensing section and a desuperheating section requires 60 inputs, and a heater consisting of condensing, desuperheating, and drain cooling sections require 80 inputs. Initially this may seem cumbersome, but many inputs are common to each heater section, such as the number of tubes or tube diameter. For parameters that are difficult to obtain, such as baffle plate flow area, reasonable assumptions are made and later refined with the thermal and hydraulic correction factors available to the user. The parameters needed that are essential for modeling the heater correctly include:

a. Tubing I.D. and O.D.
b. Tubing surface area per section
c. Number of tubes
d. Thermal conductivity of tubes
e. Overall section heat transfer coefficients
f. Heater design TTD and DCA at full load (VWO)
g. Pressure drop (or estimated drop) through each section

With these parameters, the heater can usually be modeled to provide confident results. The first step in modeling a heater is to input the data for each applicable section. The following is a description of each input variable required and the acceptable corresponding solution values. The following notation will be used to show which heater section(s) the variable may be applicable.

c - condensing section
ds - desuperheating section
dc - drain cooling section

The input variable descriptions below are in the same order as in the PEPSE user's manual, beginning with word 6-R on page 154-D.

- I.D. of tubing (c, ds, dc) : This value should be accurate.

- O.D. of tubing (c, ds, dc) : Again this value should be accurate.

- Mean free length (c, ds, dc) : This value is defined by the equation

$$L = \frac{A \times 12}{\pi \times \frac{OD}{12} \times T} \text{ ; where}$$

L = mean free length in inches
A = section tubing surface area in ft^2
OD = tubing outside diameter in inches
T = number of tubes

- Number of tubes (c, ds, dc) : This value should be accurate.

- Thermal conductivity of tubes (c, ds, dc) : A reasonable estimate of thermal conductivity should be used; for example carbon steel $\approx$ 28 BTU/ft-hr-°F.

- Elevation of steam entering (c, ds, dc) : If this value is known it can be used although a value of 0. will be acceptable.

- Number of rows for cross-flow (c, ds, dc) : In the condensing section, $R = \sqrt{T}$, where R = number of rows and T = number of tubes. In the desuperheating and drain cooling sections $R = \sqrt{\frac{T}{2}}$.

- Inner tubing wall roughness (c, ds, dc) : An input of 0. will be acceptable for this value.

- Tubing pitch parallel (c, ds, dc) : Typical values include 13/16" and 15/16" which may be used.

- Tubing pitch transverse (c, ds, dc) : The values used for the the parallel pitch can be used if the actual values are not known.

- Flow area around baffle plate (c, ds, dc) : This value is usually difficult to obtain. For the condensing section, a value of 0. should be used. For the desuperheating section, values of approximately 50 to 200 in^2 have been used effectively. Values of 600 to 1200 in^2 have been used in the drain cooling section. These values can be adjusted appropriately according to the size of the heater.

- Number of baffle plates (c, ds, dc) : Estimate the number of baffle plates for each section.

- Water-to-wall fouling factor (c, ds, dc) : A typical value used is .00029 hr-ft^2-°F/BTU.

- Wall-to-shell fouling factor (c, ds, dc) : A value of 0. can be used.

- Overall heat transfer coefficient (c, ds, dc) : This value should be obtained. If the overall U cannot be obtained, enter 0. and PEPSE will calculate a value.

- Lattice flag (c, ds, dc) : Generally the tubes are in a hexagonal array.

- Flow flag (c, ds, dc) : Counterflow heat transfer is generally used.

- Feedwater inlet nozzle size (c) : Estimate a reasonable nozzle diameter if the actual value is not known.

- Feedwater inlet nozzle loss (c) : Enter 0. for this variable.

- Feedwater outlet nozzle size (c) : Input the same value used for the inlet nozzle size if the actual diameter is not known.

- Feedwater outlet nozzle loss (c) : Again input 0.

- Shell inlet equivalent nozzle size (c) : This variable is the equivalent diameter of the steam inlet nozzle and the drains inlet nozzle combined, if applicable.

- Shell inlet nozzle loss (c) : Input 0.

- Shell outlet nozzle size (c) : Input a reasonable diameter for the outlet nozzle.

- Shell outlet nozzle loss (c) : Again 0. can be used.

- Area of drain cooler envelope (c) : This value can also be difficult to obtain. 10 to 40 ft^2 has been used as an estimate.

- Thermal conductivity of drain cooler envelope (c) : This value can usually be estimated as carbon steel.

- Thickness of drain cooler envelope (c) : Values from .5 to 1.0" have been used.

- Condensate level (c) : Estimates from 5 to 20" have been used.

- Flooding factor flag (c) : Flag 1 is usually entered.

- Heat transfer flag (c) : Again Flag 1 is usually entered.

The above data are entered into the PEPSE code. These are used for the initial run. The output tables, detailed feedwater heater performance output (09 and 10), and detailed feedwater heater design output (40), should be flagged in the initial run.

Run number two is used to obtain the thermal and hydraulic bypass factors. These bypass factors are obtained with the use of controls, controlling to the design TTD, DCA and pressure drops in the heater. The hydraulic flow factors will adjust flow bypass around the baffle plate to obtain the design pressure drop. The thermal bypass will adjust the heat transfer necessary to obtain design TTD and DCA.

The bypass factors will compensate for inputs that were estimated earlier, such as baffle plate flow area or number of tubes available for cross-flow. An example of the controls used to obtain bypass factors for a heater with a desuperheating and drain cooling section is shown in Table I. Control limits should be placed on each control to limit the number of iterations required. For this situation, limits between 0.0 and 2.0 are usually sufficient. The thermal and hydraulic bypass factor controls should be entered. Run number two will calculate the appropriate bypass factors. Refer to the heater output tables to insure that the design TTD, DCA and pressure drops appear in the output. The calculated bypass factors can then be entered and the controls can be removed.

Run number three is used to solve for the cleanliness factor on heat transfer. The cleanliness factor is used to simulate heat transfer at varying feedwater flows. This is again accomplished by using controls and the design TTD and DCA. An example of a control used to solve for the cleanliness factor is shown in Table II. Along with entering the cleanliness controls, the overall U for each section must be changed to a negative number. The negative number flags PEPSE to calculate a cleanliness factor. Again control limits should be used. Values of -2.0 to -0.0 are usually sufficient limits. The third run will now calculate the cleanliness factors. Again the heater output should be referenced to insure all design conditions are correct. The cleanliness factors are then substituted for the appropriate overall U. Finally, the controls are removed and the heater is modeled.

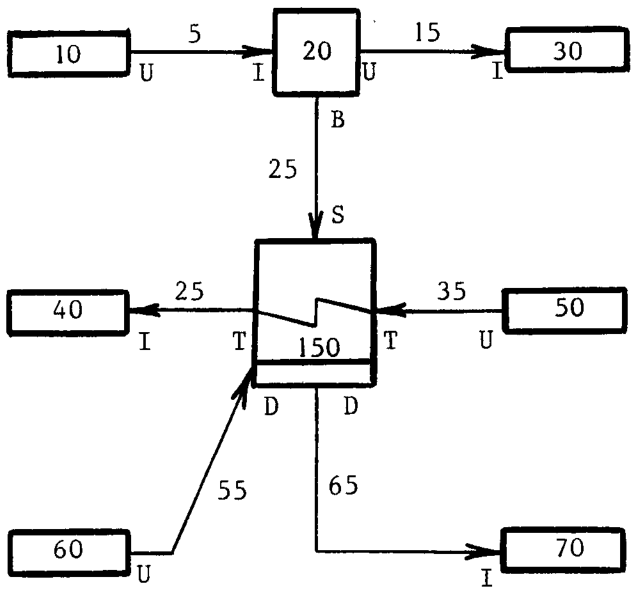
Summary

The method outlined in this paper suggests that certain variables required in the heater input can be estimated and correction factors can be used to obtain good results. This does not imply that these variables are not important and it is not intended to simplify the potential of the design mode. This paper suggests that when time is of concern and a heater must be modeled, very reasonable results can be quickly obtained by estimating certain parameters and then adjusting them to meet design criteria. This proves to be very useful in many situations.

Now that the heater is modeled, it becomes very easy to perform various studies. Tubing material can be changed by altering the thermal conductivity variable. Tube plugging can be simulated by changing the number of tubes. Learning to utilize the feedwater heater design mode effectively enables the utility engineer to make decisions concerning heater replacement, operating procedures, and effects on total cycle performance.

Figure I

Heater Sub-Model Flow Diagram



10) Input
20) Splitter
30) Output
40) Sink
50) Source
60) Source
70) Sink
150) Feedwater Heater

TABLE I

Bypass Flow Factor Controls

Heater No. 150, Design Conditions:

TTD = 5.0°F
DCA = 10.0°F
Inlet Pressure = 253.0 psi
ΔP DS = 1.0 psi
ΔP DC = 2.0 psi

Controls to find flow factors:

840100 BPFDC, 150, 250.0*, 0., 0., PB5*, 150
840200 BPHDC, 150, 10.0, 0., 0., DCAOUT, 150
840300 BPFDS, 150, 252.0*, 0., 0., PB2*, 150
840400 BPHDS, 150, 5.0, 0., 0., TTDOUT, 150

* 250.0 psi = inlet pressure $-\Delta$P DS $-\Delta$P DC

PB5 = pressure exiting drain cooler section

252.0 psi = inlet pressure $-\Delta$P DS

PB2 = pressure exiting desuperheating section

Control limits:

840109 0.0 2.0
840209 0.0 2.0
840309 0.0 2.0
840409 0.0 2.0

TABLE II

<u>Cleanliness Factor Controls</u>

Heater No. 150, Design Conditions:

TTD = 5.0°F
DCA = 10.0°F

Controls to find cleanliness factors:

840100 UALLDS, 150, 5.0, 0., 0., TTDOUT, 150
840200 UALLDC, 150, 10.0, 0., 0., DCAOUT, 150

Control limits:

840109 -2.0 -0.0
840209 -2.0 -0.0

Special Input*:

890011 UALLDC, 150, -1.0, I
890021 UALLDS, 150, -1.0, I

* A negative input for overall U flags PEPSE to calculate a cleanliness factor.