1 Logistics

We will meet at the UCI Central Plant for the laboratory periods again this week. Bring your lab handout, a calculator and properties sheet (see below) with you. Bring a sheet of values of required properties (densities of water and air, specific heats, hfg, etc.) and conversion factors with you for sample calculations to be done at the plant during the lab period. Note the variables to be measured as on the attached data sheet and the calculations to be done in the Questions section below. Plan your calculations accordingly before coming to lab. Pre-lab quiz may cover those contents.

Bring a thermo book with steam tables if possible.

2 Introduction

The purpose of the second lab at Central Plant is to design lab procedures and take appropriate measurements to determine (1) the efficiencies of the boilers-economizer, HTW heat exchangers, STG (steam turbine generator) and the combination of boilers, HX, and STG (steam turbine generator), (2) heating load of the campus, and (3) Co-generation efficiency. Data will be obtained from the computer displays in the CP Control Room. (Caution: please don’t click the schematics on the screen; always use “cancel” if accidently entering another window; if you are not sure, please ask first. Improper action may lead to CP shutdown…) If needed, additional or back-up measurements can be obtained from gauges on equipment in the plant itself.

If the boilers are operating to produce steam solely for the hot water heat exchangers, no work (power) is being produced and a simple ratio of the product, energy of the steam, to supply (natural gas) is the boiler efficiency. If steam turbine power is being produced as well via the Rankine cycle from a portion of the steam, then the cycle efficiency applies for that portion. The heat exchangers are treated as open systems and again a simple ratio of product (hot water) to supply (steam) is the efficiency. For only hot water production, the overall open system efficiency is the ratio of the HTW product to the supply (natural gas).

We will treat the boilers (including the economizer) as simple combustion systems under the cold-air standard assumptions. The (lower) heating value of natural gas is 1050 BTU/scf. The heat exchangers are treated as open systems. We assume the volume ratio of O2 to N2 is ¼ and use the exhaust oxygen content to calculate the air injection rate.

3 Measurements
Make a table similar to Fig. 2 and list what need to be measured in order to finish the lab report (please take a look at Figs. 3-5 which show the screens and information you can get access in the CP control room). FYI, the following is for calculating efficiency of the old boiler+HX system in 2006:

The boiler measurements to be logged at approximately 10-minute intervals for two hours are:
1. Time [hh:mm]
2. Total Boiler Feed Water (BFW) flow rate [gpm]
3. Boiler gas flow rate [scfh]
4. Boiler air flow rate [cfm]
5. Boiler steam flow rate [lb/hr]
6. Boiler steam pressure [psig]
7. Boiler steam temperature [F]
8. Boiler exhaust stack temperature [F]

The heat exchanger (HX) measurements are to be logged simultaneously with the boiler measurements as follows:
1. Hot Water Return Temperature (HTWR) [F]
2. Hot Water Supply Temperature (HTWS) [F]
3. Condensate pressure [psig]
4. High temperature water (HTW) flow rate [gpm]

There will be one set of data for all. In your lab group, organize yourselves into sub-groups to take the readings, log the data, start the calculations, etc. Everyone should have a part. You will be required to do calculations for Questions 4, 5, 6, and 8 for one 10-minute set of data during the lab period and show the results to the TA.

For this year measurement, we might need the following information (using Figs. 3-5 as references):
1. Time [hh:mm]
2. Fuel injection rate [pph]
3. Electrical power generated [MW]
4. Oxygen content at the exhaust gas [%]
5. Stream temperature [F]
6. Steam flow rates [pph]
7. Boiler Feed Water (BFW) pressure [psi]
8. ………………

4 Analysis

Make appropriate analyses of the boiler(s) (Co-gen) and heat exchanger(s) to determine their efficiencies. The boiler(s), heat exchanger(s), and the combination of boilers and heat exchangers can be treated as open systems.

5 Questions
1. Draw the (1) boiler(s)-economizer (as one system), (2) heat exchanger(s), (3) STG, and (4) boilers (including economizer)-heat exchanger-STG open system block diagrams showing
main inputs, outputs and other relevant information (main control valves, etc.). Clearly label all flow streams. [10 points]

2. Show the open system balance equations for each of the above and define the efficiencies. [10 points]

3. From the tabulated data, plot the relevant observed data versus time. Group similar data onto the same plot. [5 points]

4. Calculate the heating load to the campus from the data in a spreadsheet and plot. Watch the significant figures. Use units that make sense, e.g., MMBTU/hr. [5 points]

5. Estimate the CO2 production and air injection rate in the co-generation and plot. Use units that make sense, e.g., pounds mass/hour. Since CO2 is one of the greenhouse gases, comment on the impact of the Central Plant on the global warming based on the estimate (Assume CH4 is the only component in the natural gas). [7 points]

6. For the boiler(s) (including the economizer), calculate and plot the components of the open system balance versus time, i.e., “input” from natural gas, output of the steam and stack loss in consistent units. [10 points]

7. Calculate and plot the efficiencies of the boilers (including the economizer), heat exchanger, STG, and gas turbine generator versus time. [10 points]

8. For the boiler-HX system (assuming no STG), use the pressure data of the high pressure S from boiler, SC after the HX and BFW pressure to sketch the P-v diagram for steam and show the path of the water/steam through the boiler. [8 points]

9. What is the percentage of enthalpy change of the water in the boiler system (two boilers+economizer) due to sensible heating relative to the total change? [5 points]

10. Use an expanded section of the attached steam P − h diagram to show the thermodynamic path of the steam from the boiler through the control valve into the shell side of the heat exchanger(s). Clearly describe the change in the state of the steam in this process. [10 points]

11. If the price for natural gas is $0.80 per "therm". A "therm" is 100,000 Btu. Electricity from the outside grid is $0.11 per kWh. Can you estimate how much we can save per kWh by using Co-gen (STG+gas turbine generator) (if neglecting the HTW production)? [10 points]

12. Write a one-page Summary. (Place it at the beginning of the report.) The summary should include, in a concise form, the purpose of the experiment, the procedure, the main results, the conclusions, and comments on Co-gen. [10 points]
Figure 1: P-h Diagram for Steam [Note pressure scale is psia].

Figure 2: CP Data Sheet (This is a sample. Make a similar one for your own calculation)
Fig. 3