ME343 - Thermal Fluid Systems
Spring 2011, Semester Project Phase 2
Analysis of Westinghouse Model 251B Combustion Turbine
Final Report is Due May 6, 2011

Overview

The University of Texas cogeneration power plant houses a Westinghouse Model 251B combustion turbine-generator system for electric power generation and a Henry Vogt waste-heat recovery boiler for cogeneration of steam. In your term project, you will develop a computer model to predict and confirm performance of the combustion turbine unit under various operating conditions including the performance effects of evaporative cooling of inlet air and backpressure effects of the waste-heat recovery unit. Your model must be flexible enough to incorporate changes in design parameters (e.g., turbine inlet temperature and inlet airflow) and will be used to perform base case analyses of the W251B system. Figure 1 shows the overall system components and the thermodynamic station numbers for the W251B.

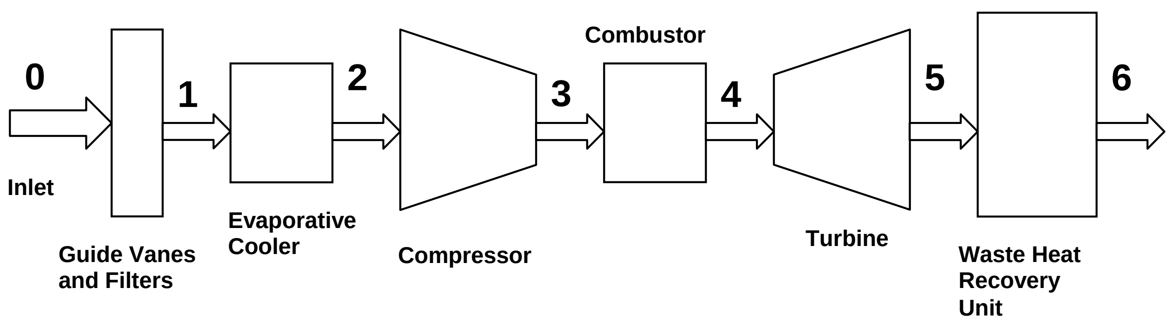

Figure 1: Westinghouse W251B thermodynamic station designations

Phase 2: Complete System Model, Case Studies and Exergy Analysis

In this last phase of the project you will extend the system model to include (i) use moist air coming into the system, (ii) pressure drop across specified components, (iii) evaporative cooler, (iv) combustion modeling and analysis, and (v) assessment of waste heat recovery unit installation. Once you verify the accuracy of your model with respect to the manufacturer's specifications, you will perform a number of case studies to investigate how the performance of the system varies according to changes in operational conditions. Finally, you will perform an exergy analysis to identify the key components contributing to the system inefficiency and comment on the improvements that can be performed to enhance the efficiency of W251B. Finally, you will prepare a professional quality technical report documenting your work

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Spring 2011, Team Project Phase #2
Specifications for Phase 2 Model of Westinghouse 251B Gas Turbine

Input operating parameters

- Base air inlet conditions: P_0, T_0, RH_0, **sea level, 59ºF, 60%**
- Inlet flow rate: $\dot{V}_{IN}$ **290,000 scfm (dry air, 68ºF, 1 std atm ref.)**
- Base inlet pressure loss (across 0 to 2): ΔP_{IN} **4 in H_2O**
- Base exhaust pressure loss (across 5 to 6): ΔP_{EX} **4 in H_2O**
- For exergy analysis, assume that the atmospheric reservoir is at 298K and 1 atm.
- Fuel type and lower heating value: Natural gas (composition by volume): 96.1% CH_4, 2.5% C_2H_6, 0.2% C_3H_8, 0.8% CO_2, 0.4% N_2. LHV = 20,960 Btu/lbm
- Vary fuel mass flow rate $\dot{m}_F$ (lb_m/hr) to achieve loads from 20% to 100% of the full load of 48 MWe (Mega Watt electric)

Input design parameters

- Compressor pressure ratio: r_P **15:1**
- Compressor efficiency: **86.6%**
- Turbine efficiency: **88.5%**
- Generator (Dynamo) efficiency: η_{GEN} **98.5%**

Output performance parameters (to be plotted versus percent of full load)

- Thermal efficiency: η_{TH}
- Exergy accounting and exergetic efficiency of each component
- Fuel mass flow rate $\dot{m}_F$ (lb_m/hr)
- Specifc fuel consumption: SFC (lb_m/kW-hr)
- Heat rate: HR, (BTU/kW-hr)
- Firing (turbine inlet) temperature: T_4 (K and ºF)

Output engine operating conditions

- Temperature and pressure at each major thermodynamic station (create table vs. % load)

Case Studies of Westinghouse Model 251B

Carry out the following case study analyses using the computer model you have developed for the gas turbine power plant. For each analysis, plot or tabulate your results and provide an in depth discussion.

1. **Base case analysis of W251B for ISO standard conditions:**
   Run your model using the standard ISO base case conditions for the W251B. Compare computed performance (net power, heat rate, exhaust flow, fuel flow, and exhaust temperature) with the manufacturer's quoted performance using natural gas as the fuel. Discuss any discrepancies between your results and the quoted performance.

2. **Effect of inlet and exhaust pressure losses:**
   Run the base case conditions with inlet Δp of 0.0, 3.0, and 6.0 inches of H_2O and exhaust Δp of 0.0, 8.0, and 16.0 inches of H_2O. Discuss your results and compare with the Westinghouse correction factor curves for power, heat rate, and exhaust flow.

3. **Part load and hot day performance:**
   Part load operation for these constant speed machines is achieved primarily by varying firing temperature (i.e., fuel flow) which in turn influences the exhaust temperature. Run the base case with varying firing temperatures and plot net power output (expressed as percent of full load) vs. firing temperature and exhaust temperature. Run similar cases for an ambient temperature of 100°F. Compare your calculated results for exhaust temperature, exhaust flow, and fuel flow against the part load/ambient temperature correction factors provided by Westinghouse. Calculate and plot the heat rate as a function of load. Discuss your results.

4. **Effect of evaporative cooler:**
   Compare the full load power output and heat rate (at 95°F ambient temperature and relative humidity ranging from 25 to 100%) with and without the evaporative cooler in operation. Also show the evaporative water loss (lbm/hr) for the cooler-on cases. Discuss your results in terms of the effects on system operation in hot, humid weather conditions.

5. **Cogeneration option:**
   Using the UT libraries and online citation indexes investigate the general subject of cogeneration with a focus on gas/steam turbine cogeneration systems. Write an introductory chapter on the order of 3-4 pages discussing the rationale for cogeneration and the current state-of-the-art. Also employing your exergy analysis you will assess the energy efficiency and economic value of installing a waste heat recovery system for cogeneration for the W251B. The technical and economic details of the waste heat recovery system will be provided as a separate document.

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Project Phase #2 (Final Report) Grading Guideline

Phase 2 requires you to write a full length technical report. There is no page limit however, your report should be concise and to the point.

Names:____Total:_______/100___

_______(10) Introduction: a chapter on the order of 3-4 pages discussing the rationale for cogeneration and the current state-of-the-art. Use credible sources and cite them properly. For how to cite your references, please look at: http://www.asme.org/Publications/ConfProceedings/Author/References_2.cfm

________(5) Project Description: State what you are modeling, why you are modeling and how you are modeling. Be specific and state the major inputs and outputs of the model.

_______(10) Modeling and Analysis: Describe your model. How does it work, what is your algorithm? Use flow charts and refer to them for clarity and keeping the report concise.

_______(55) Results and Discussion:

(i) Present the results of the ISO base case at full load and compare it to your hand calculations and to the manufacturer's data.

(ii) Present all the results for the case studies outlined in your assignment namely (1) effect of inlet and exhaust pressure losses, (2) part load and hot day performance, (3) effect of evaporative cooler. You should clearly present your results summarizing your findings in tables and/or figures as required.

(iii) Exergy accounting and Co-generation design analysis. Present and discuss your findings.

________(5) References: List your references according to ASME standard (http://www.asme.org/Publications/ConfProceedings/Author/References_2.cfm)

________(5) The property calculator assignment grade will make up 5% of the final report grade.

________(5) Appendix:

(i) Presentation of hand calculations
(ii) Copy of Matlab script including the property calculator
(iii) Extra material you may want to include

________(5) Overall appearance and organization.