

The University Power Plant: A Readily Accessible Remote Learning Platform

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Introduction

Combined heat and power (CHP) or cogeneration is critical to the economic viability of many industries, including fuels, chemicals, plastics, paper, and ferrous and nonferrous metals. U.S. investment in new CHP is expected to remain >\$10 billion/year, and there are many ongoing projects in existing CHP systems resulting in substantial dollar savings through optimal energy management schemes.

CHP systems provide an excellent platform for students to study thermodynamics, certain unit operations and process design principles, optimization, data reconciliation, and emissions control. Even better, many Universities have ready (albeit remote) access to such a system on their own campus. At LSU, we are opening our newer (commissioned 2005, 20 MW, \$20 MM) cogeneration system to the world of engineering education through real-time data delivery using formats which can communicate with virtually any control/data acquisition system and then broadcast compressed data via the net. Easy to use (from Excel) educational modules have been developed which make use of these data to teach the above-mentioned topics in classes ranging from introductory Sophomore-level to capstone design.

This remote educational platform also offers students the opportunity to make real-dollar energy management decisions on a complex yet easily visualized system, where students must consider tradeoffs in cost minimization and operability. It can therefore become a unique tool for engineering economics education.

Experimental

We purchased OSIsoft PI[®] software to interface to and collect data from various control systems (JCI Metasys, ABB Symphony) of the LSU Cogeneration Facility. The interfaces make use of both OPC and ODBC data transfer protocols. Data are then archived using a PI Server (version 3.4) installed in a commercial PC, transferred to Excel via PI Excel Datalink. Data are now being linked to the web using a web server running PI's RTWebparts (version 2.0) software, which is deployed with MS SharePoint. User-friendly displays were created using Visio and PI Process Book.

Results

A Visio-created schematic of the entire system showing real-time data is given in Figure 1 below.

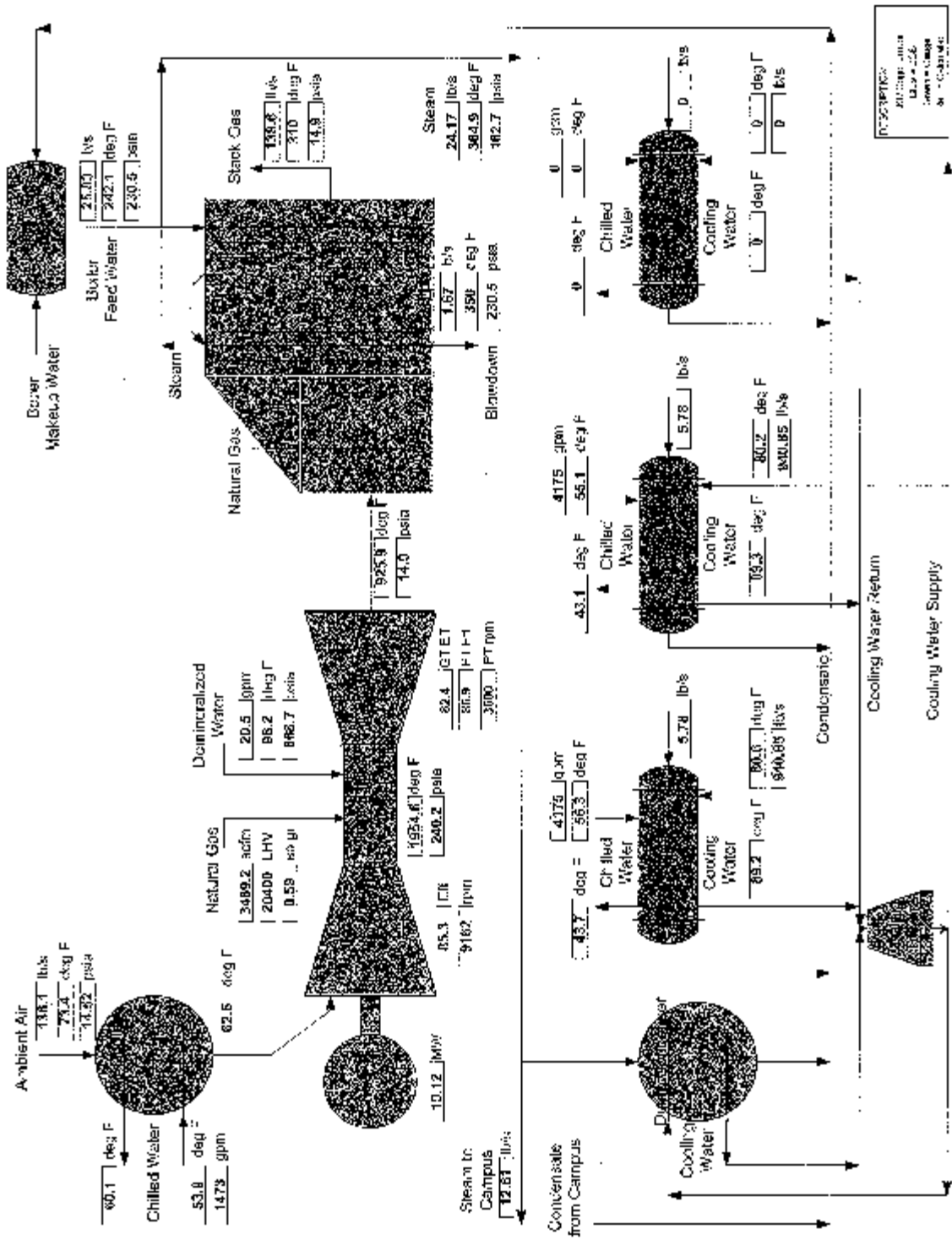


Figure 1. Schematic of LSU Cogeneration System

Educational modules completed so far include Excel-callable rigorous thermodynamics functions for all fluids (steam, water, air, methane, refrigerants, etc.) in the cogeneration system. This provides great flexibility for the students to solve cogen problems. These functions are based on the same open-source functions as used in the commercial GE code Gatecycle for cogen calculations.

1. Data Reconciliation / Gross Error Detection – these use real data from the cogen system to illustrate these concepts, and can be used in a numerical methods, lab or design course.

2. Design of Cogen System - here the non-detailed design of a complete cogeneration system is accomplished, at first using ideal gas and other standard assumptions, and then using rigorous thermodynamics. All is done using Excel so optimization and system improvement and alternatives can be quickly accomplished.

3.) Energy Dispatching / On-line Optimization - here a simplified version of the cogeneration system with data from all units for one-year are provided - students must fit data and then develop a plan to reduce energy costs. How utilities charge for electricity is explained, and then students must predict utility costs (easy to do once they understand how utilities calculate rates) and understand varying loads.

4.) Heat Recovery / Steam Generator (HRSG) – This key component of a cogen system is used to develop concepts in boiling heat transfer, unsteady-state heat transfer, and numerical solutions of ordinary and partial differential equations by finite differences. This module can be used in either Numerical Methods, Heat Transfer or Unit Operations classes.

For example, a typical problem might be **Determination of the HRSG Physical Design**. For the HRSG shown below assume the evaporator is 30 tubes wide and the economizer is 20 tubes wide. The tubes are: O.D. = 2 in.; wall thickness = 0.095 in.; length = 15ft.; tube spacing 4 in. square. Using a typical value for overall heat transfer coefficient based on the tube outside area of $12.3 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$, determine the equivalent number of rows needed in the evaporator and economizer sections.

The equations are solved numerically by a simple finite difference method implemented in Excel. The grid design and resulting temperature profiles are shown below in Figure 2. The solution strategy and computation of the heat transfer coefficients are discussed by Knopf (“Energy Design and Optimization”, manuscript in preparation, 2008). An Excel module showing the calculated temperature distribution for a few nodes of the economizer section is shown as Figure 3.

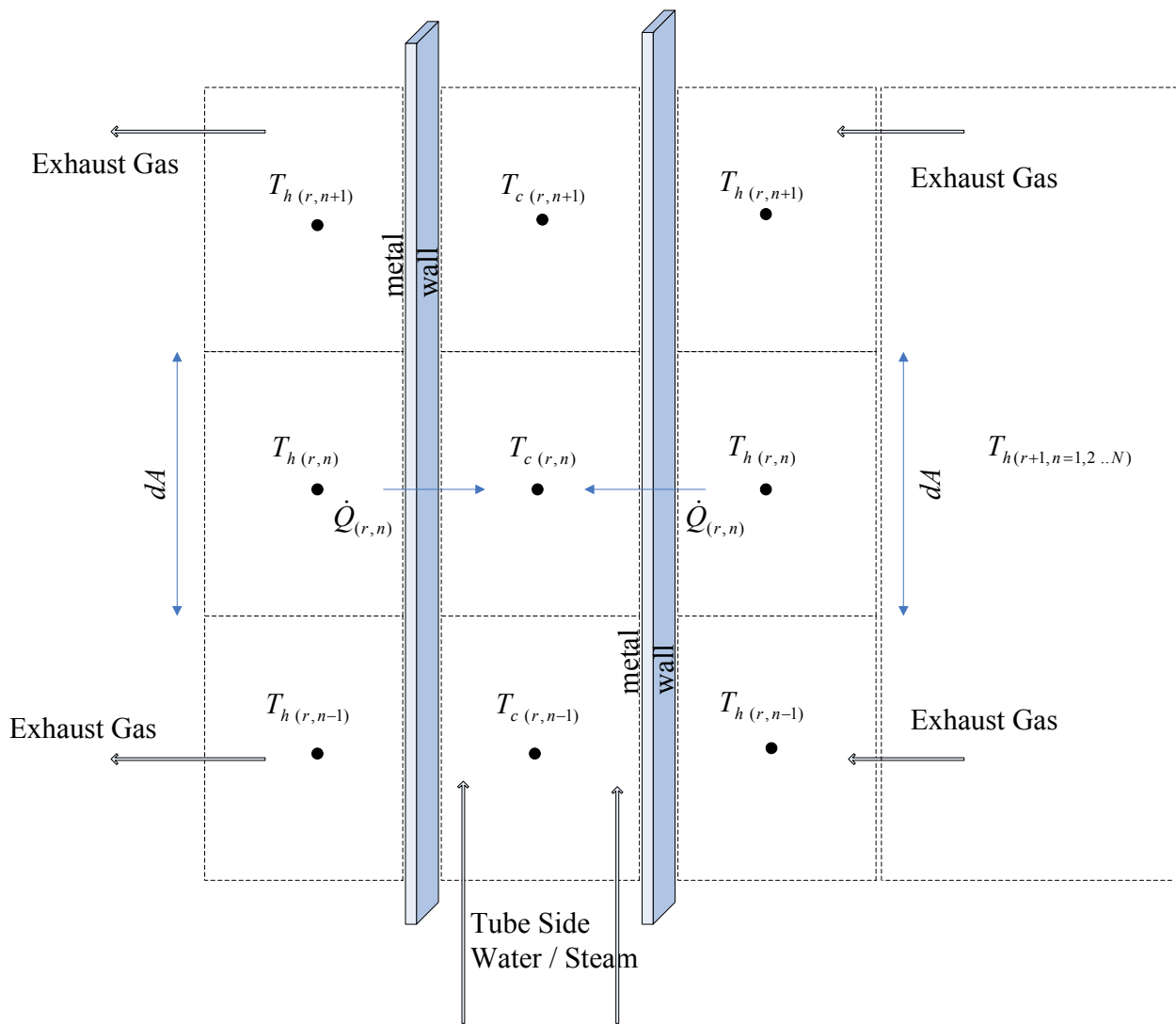
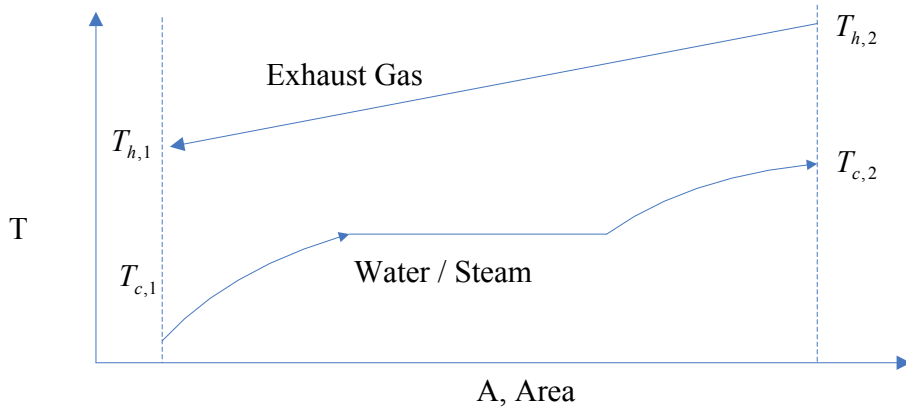


Figure 2. a.) temperature profile in the HRSG evaporator section b.) nomenclature for numerical analysis of a single tube in the HRSG (evaporator or economizer section).

Numerical Solution Economizer Tubes Temperature Profile

			To Stack ←				← Exhaust Gas			
Tube Data			Tube Pass = 1				Tube Pass = 2			
data input in green cells										
			Position	$U_{(r=1, n=1..N)}$	$T_{h(r=1, n=1..N)}$	$T_{c(r=1, n=1..N)}$	Position	$U_{(r=2, n=1..N)}$	$T_{h(r=2, n=1..N)}$	$T_{c(r=2, n=1..N)}$
Outside Diameter	2	in	1	20.21	251.52	77.00	1	20.24	254.09	81.96
Inside Diameter	1.81	in	2	20.21	251.52	77.33	2	20.24	254.09	82.29
Number of Tubes Wide	20		3	20.22	251.52	77.67	3	20.25	254.09	82.62
Tube Spacing	4	in	4	20.22	251.52	78.00	4	20.25	254.09	82.95
Tube Length	15	ft	5	20.23	251.52	78.33	5	20.25	254.09	83.28
Number Tube Passes	200		6	20.23	251.52	78.67	6	20.26	254.09	83.60
k_{wall}	25	btu/hr-ft-°F	7	20.23	251.52	79.00	7	20.26	254.09	83.93
Water Flow Data			8	20.24	251.52	79.33	8	20.27	254.09	84.26
$F_c = F_{water}$	111096	lb/hr	9	20.24	251.52	79.66	9	20.27	254.09	84.58
$T_{c(r=R, n=1)}$	77	°F	10	20.25	251.52	79.99	10	20.27	254.09	84.91
P_{water}	290.08	psia	11	20.25	251.52	80.32	11	20.28	254.09	85.23
Exhaust Flow Data			12	20.25	251.52	80.65	12	20.28	254.09	85.56
	840327.		13	20.26	251.52	80.98	13	20.29	254.09	85.88
$F_h = F_{exhaust}$	8	lb/hr	14	20.26	251.52	81.30	14	20.29	254.09	86.21
$G_h = G_{exhaust}$	16806.5	lb/ft ² -hr	15	20.27	251.52	81.63	15	20.29	254.09	86.53
$T_{h(r=R, n=1)} \dots T_{h(r=R, n=N)}$	251.524	°F								
Finite Difference Data										
dL	1	ft								
number nodes / tube	15									

Figure 3: Numerical Solution of Temperature Distribution for Economizer, Heat Recovery Steam Generator