Honeywell

Modular Integrated Energy Systems

Task 6 Field Monitoring
Interim Report
Period Covered:
May 2005–August 2005

April 28, 2006

Prepared for:

Oak Ridge National Laboratory
P.O. Box 2008
Building 3147
Oak Ridge, TN 37831

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Section 1. Introduction

This document presents an updated set of results from Honeywell's data collection activity for the integrated energy system (or CHP -- Cooling, Heat and Power) system at Ft. Bragg. Much of this work is funded by the U.S. Department of Energy, thru Oak Ridge National Laboratory (ORNL). Honeywell is providing significant cost sharing in this development. A brief description of the overall project is presented in the following paragraphs.

The objective of the ORNL project is to develop packaging technologies for large (2 to 5 MW) integrated energy systems (IES) and field-test a prototype design. The major equipment at the Ft. Bragg site consists of a gas turbine-generator, a heat recovery steam generator, and a waste heat fired absorption chiller. The key goals of the project are:

- Develop a set of "reference" CAD-based IES modular system designs,
- Develop a supervisory control system having on-line optimization,
- Develop a 1000 Ton exhaust-driven absorption chiller,
- Install and monitor the performance of a prototype IES modular system employing the above technologies

The installation site for the packaged IES system is the 82nd Heating Plant at Ft. Bragg, NC. The 82nd plant serves a large number of barracks and other buildings with steam for heating and domestic hot water, and chilled water for cooling. This project is allied with on-going work by the Honeywell's Energy Services Team, serving as a provider of Energy Savings Performance Contract (ESPC) services to the U.S. Army at Ft. Bragg. In a related activity, the Honeywell Energy Services Team at Ft. Bragg is also collaborating with the U.S. DOE's Federal Energy Management (FEMP) Program (thru Oak Ridge National Laboratory) to enable the 82nd Central Plant at Ft. Bragg to serve as a showcase IES site for the FEMP program.

1.1 Data Acquisition Overview

This DOE/ORNL funded project includes a period of field performance monitoring for the IES System at the Ft. Bragg 82nd Central Heating Plant. During this period, certain performance data will be collected and analyzed to produce summary reports describing the measured performance of the system. The following sections describe the details of the data collection activity.

1.1.1 Objective

Performance data have been collected by the project team, and made available to a number of interested parties. The data will be used for the following purposes:

- Field monitoring of absorption chiller performance. BroadUSA will monitor the chiller's operation and performance during the field monitoring period of the project.
- Field monitoring of the system control and optimization performance. Honeywell will monitor the performance of the CHP Manager optimization software during the field monitoring period. (Note: Results of this work will be reported separately.)

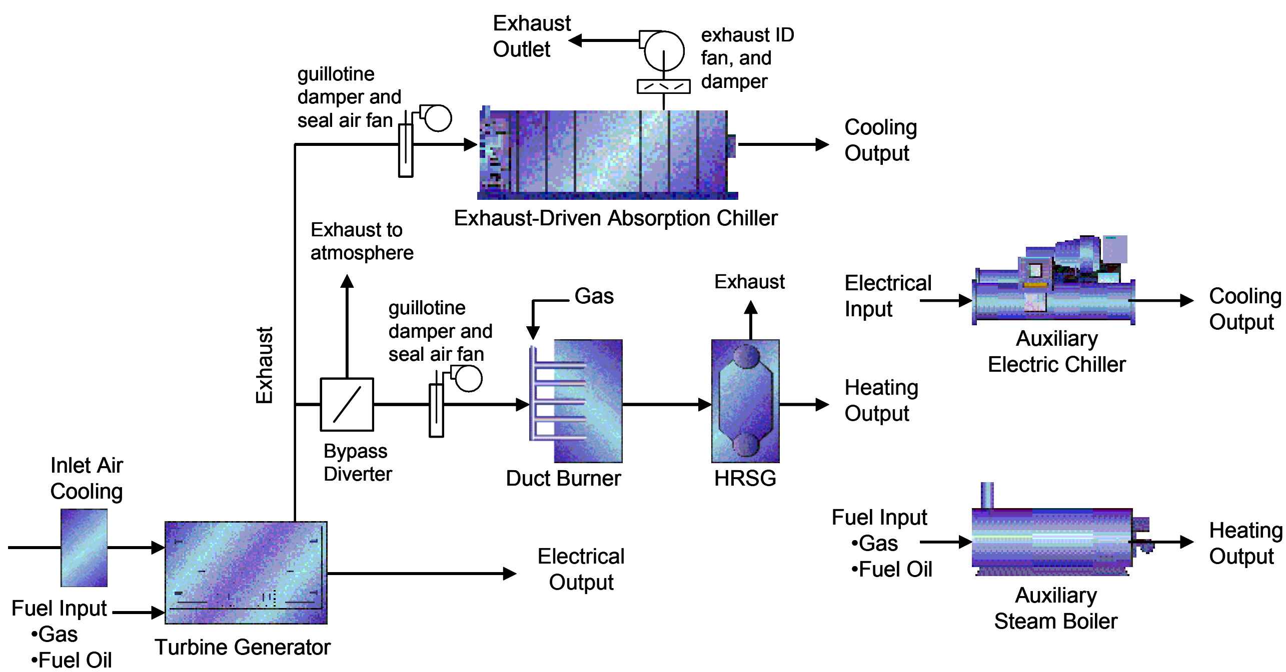
- Sharing of equipment operating data with researchers at Oak Ridge National Lab. These groups are using the data to construct advanced models of IES equipment, as part of other technical work that is not directly associated with this project.
- Sharing of system operational data with researchers at the DOE FEMP Program Office. This activity is in accordance with the memorandum of understanding between DOE, Honeywell, and the U.S. Army, and is related to Honeywell's Energy Savings Performance Contract (ESPC) services to the Army at Ft. Bragg.

1.1.2 Other Related Work

As part of the Honeywell's ESPC contract with the Army at Ft. Bragg, there will be a separate activity for Measurement and Verification (M&V) of energy use and cost savings. The M&V activity addresses only the heating portion of the system (installed under the ESPC), and will be accomplished separately (and is not related to this data collection and analysis activity).

1.2 System Overview

A block diagram of the Ft. Bragg 82nd Central Heating Plant IES system is shown in the figure below.



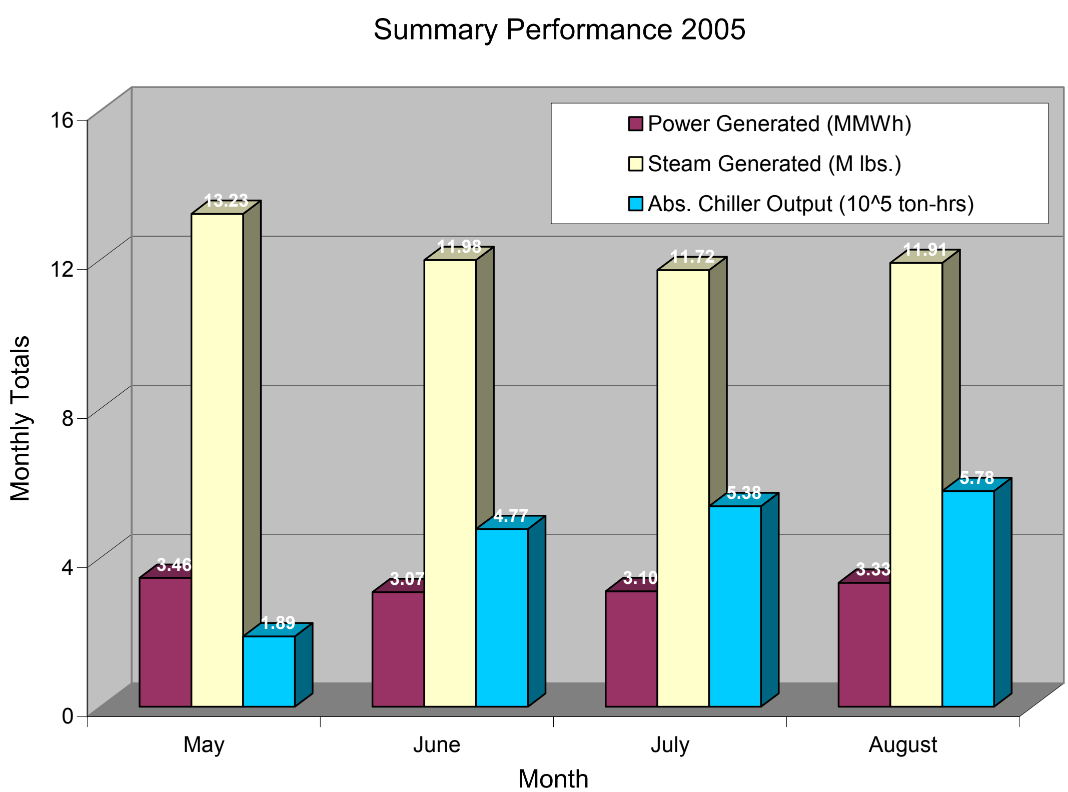
The major equipment in the system consists of a 5MW gas turbine generator, a 1000 ton exhaust-driven absorption chiller, a heat recovery steam generator (HRSG), and a duct burner. Additional technical information is included in a later section of this report.

Section 2. Summary Performance Results

Earlier reports covered the period of June 2004 thru April 2005. This document presents the performance results for the period of May thru August 2005. Summary performance results for the period are presented in the following sections.

2.1 Summary Energy Performance Results: Summer 2005

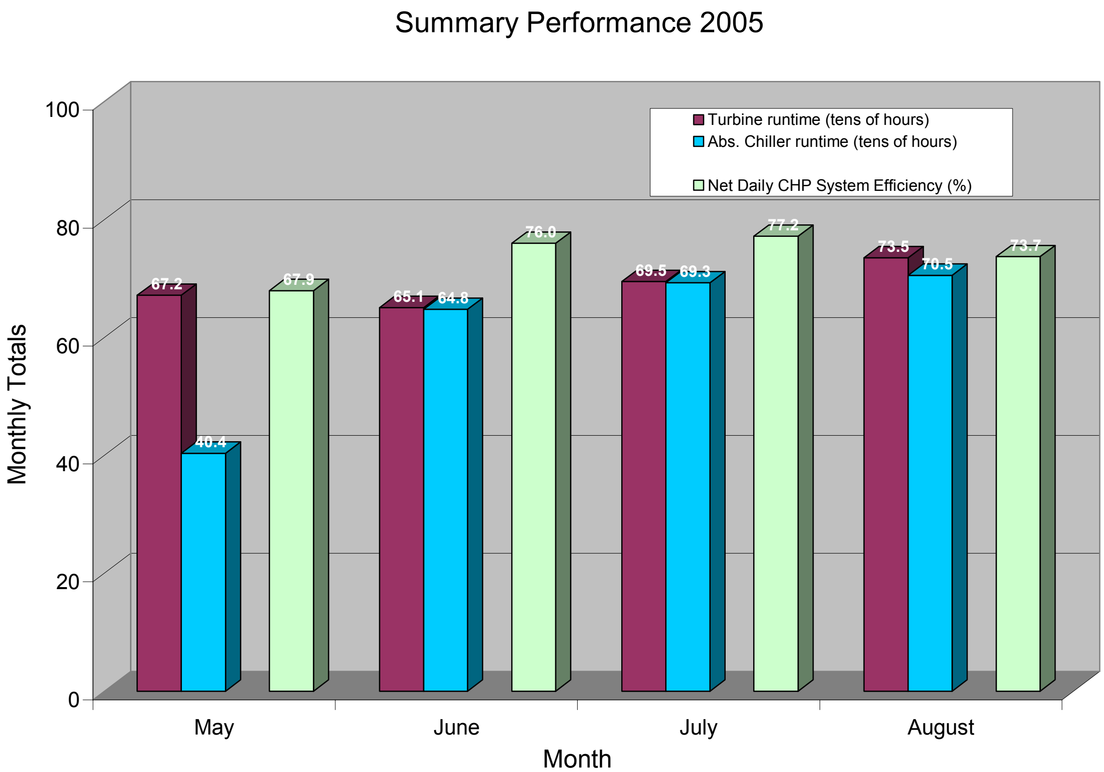
A high level summary of energy delivery results for the summer months of 2005 is shown in the following figure and table.



	Summary Performance Data		
Month	Power Generated (kWh)	Steam Generated (lbs.)	Absorption Chiller Output (ton-hours)
May	3,456,023	13,226,844	188,622
June	3,074,551	11,983,409	476,606
July	3,098,944	11,716,781	538,104
August	3,327,250	11,906,622	578,439

2.2 Summary Operating Performance Results: Summer 2005

A high level summary of operational results for the summer months of 2005 is shown in the following figure and table. The CHP system energy efficiency is based on the lower heating value (LHV) of the fuel input.



	Summary Performance Data		
Month	Turbine run hours	Absorption Chiller run hours	Net Daily CHP System Efficiency (%)
May	672	404	67.9
June	651	648	76.0
July	695	693	77.2
August	735	705	73.7

Section 3. Detailed Performance Results: Summer 2005

Detailed performance results for the summer period (May thru August) are presented in the following sections. The data for each month is presented in a set of key tables and figures, as follows:

Table or Figure	Data Presented
Summary Data Table	Measured and calculated daily performance indices
Monthly Overview	High level summary of system performance for the month. The parasitic power includes the gas compressor, condensate pump, boiler/HRSG feedwater pump, and the absorption chiller's exhaust induced draft (ID) fan.
Daily Performance	Daily totals for key performance indices
Turbine Generator Performance	Hourly data for the turbine generator heat rate and power output, plotted as a function of outdoor ambient temperature. Error bars showing the degree of uncertainty in the data, are shown in the figures. Note: Some outliers are seen in the plotted data, due to startup periods (or due to bad data and the limited amount of data cleaning and filling that was done).
Absorption Chiller Performance	Hourly data for the absorption chiller heat rate, plotted to show the relationship between heat input to the chiller and its cooling output. Error bars showing the degree of uncertainty in the data, are shown in the figure. Note: Some outliers are seen in the plotted data, due to startup periods (or due to bad data and the limited amount of data cleaning and filling that was done).
Hourly Performance Overview	High level system data, plotted for each hour in the month.
Energy Input Data	Energy input to the system, plotted for each hour in the month.
Energy Output Data	Energy output from the system, plotted for each hour in the month.
Cooling Output Data	Cooling energy produced by the system, and its utilization. (Note: Cooling energy used for reducing the turbine inlet air temperature is shown in this figure.)

3.1 Detailed Performance Results: May 2005

Detailed performance results for the month of May 2005, are shown in the table and figures on the following pages.

Field observations noted during the month are:

- The IES system was off-line on May 4, to enable improvements to the control software and hardware interfaces.
- The absorption chiller was activated on May 14.
- Cooling loads remained relatively low during the last half of the month.

Data analysis comments for the month are:

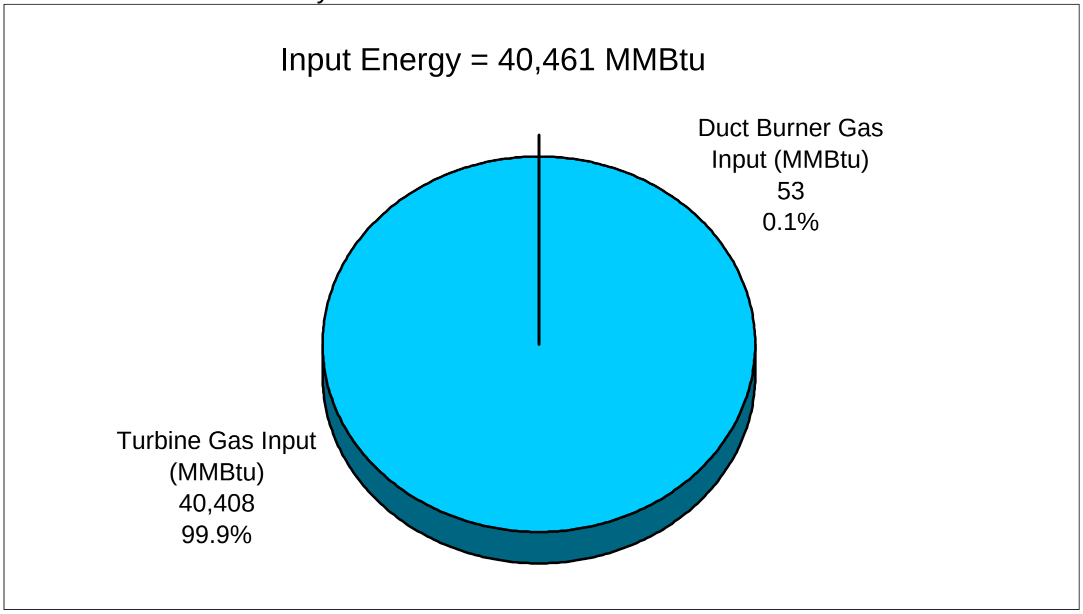
Table or Figure	Analysis Comments
Summary Data Table	The system's operational performance was good during the month. Not all of the recoverable energy was usable during the month, due to low heating and cooling loads.
Monthly Overview	The system's energy performance was good, given the smaller magnitude of the thermal loads during the month.
Daily Performance	See comments above.
Turbine Generator Performance	Very good performance, the measured data matches pretty well with the design data (given the expected uncertainty). (Note: The last thorough cleaning of the turbine blades was done in March 2005.)
Absorption Chiller Performance	Very good performance, the measured data matches pretty well with the design data (within the expected uncertainty). Some divergence of the data at low loads is not significant.
Hourly Performance Data	Daily cycles are evident. System efficiency tends to be higher with increased thermal load (as expected).
Energy Input Data	All turbine fuel used was natural gas.
Energy Output Data	Relatively low cooling loads during the month.
Cooling Output Data	Turbine inlet air cooling was used continuously during the month.

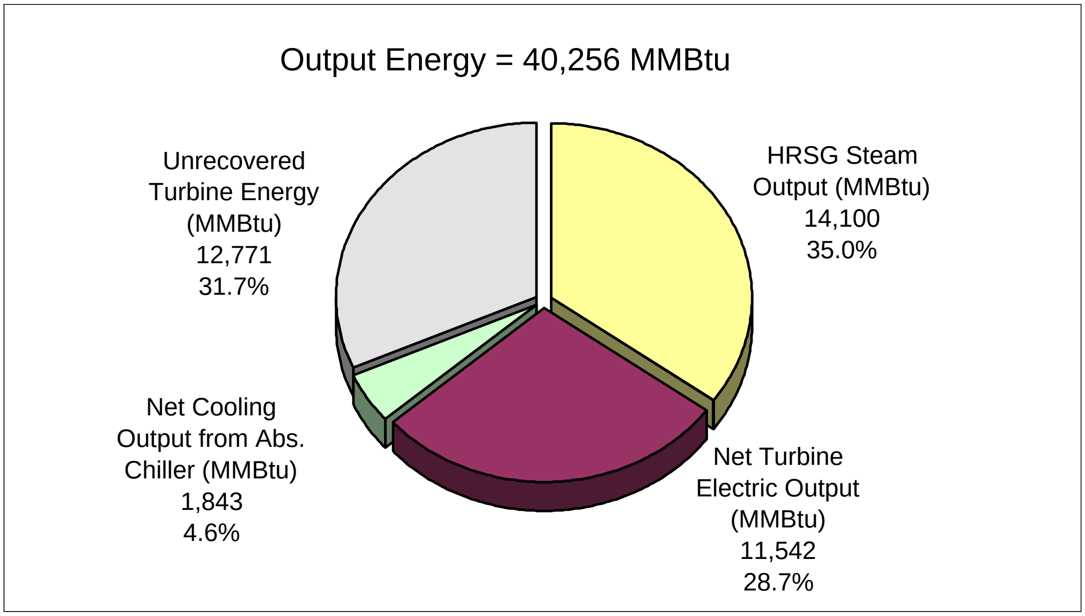
Additional plots of more detailed operating data are presented in Appendix A.

	Measured Data										Calculated Results							
Date	Electric Power Gen. (MWh)	HRSG Steam Gen. (lbs.)	Abs. Chiller Output (ton-hours)	Turbine Nat. Gas Cons. (MCF)	Turbine Fuel Oil Cons. (gal.)	Duct Burner Nat. Gas Cons. (MCF)	Turbine Runtime (hours)	Abs. Chiller Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Aux. Electric Chiller Runtime (hours)	Turbine Total Energy Input (MMBtu)	Duct Burner Natural Gas Input (MMBtu)	HRSG Steam Output (MMBtu)	Net Turbine Electric Output (MMBtu)	Net Cooling Output from Abs. Chiller (MMBtu)	Total CHP Output (MMBtu)	Net Daily CHP System Efficiency (%)	Parasitic Energy (MWh)
1-May-05	120	522,871	0	1,356	0	0	24	0	1	0	1,406	0	557	400	0	957	68.1	2.5
2-May-05	121	544,195	0	1,365	0	5	24	0	1	0	1,415	6	580	404	0	984	69.2	2.5
3-May-05	38	155,315	0	426	0	0	7	0	17	0	442	0	166	127	0	292	66.1	0.7
4-May-05	0	0	0	4	0	0	0	0	24	0	5	0	0	0	0	0	0.0	0.0
5-May-05	27	15,107	0	317	0	0	6	0	24	0	329	0	16	91	0	107	32.6	0.6
6-May-05	55	222,290	0	623	0	15	11	0	14	0	646	15	237	184	0	421	63.6	1.2
7-May-05	125	502,720	0	1,404	0	24	24	0	1	0	1,456	25	536	419	0	955	64.5	2.5
8-May-05	127	480,652	0	1,416	0	0	24	0	0	0	1,468	0	512	423	0	935	63.7	2.5
9-May-05	127	503,375	0	1,419	0	0	24	0	0	0	1,472	0	537	423	0	960	65.2	2.5
10-May-05	125	484,799	0	1,409	0	4	24	0	1	0	1,461	4	517	419	0	936	63.9	2.5
11-May-05	124	477,343	0	1,402	0	0	24	0	0	0	1,454	0	509	416	0	925	63.6	2.5
12-May-05	124	464,661	0	1,399	0	0	24	0	0	0	1,451	0	495	414	0	909	62.6	2.5
13-May-05	126	486,789	0	1,413	0	0	24	0	1	0	1,466	0	519	420	0	939	64.1	2.5
14-May-05	125	451,024	10,960	1,400	0	0	24	23	1	10	1,452	0	481	416	101	998	68.7	2.7
15-May-05	123	459,136	11,836	1,392	0	0	24	24	1	1	1,444	0	489	412	109	1,010	70.0	2.7
16-May-05	124	472,596	10,062	1,392	0	0	24	22	0	0	1,443	0	504	414	97	1,014	70.3	2.7
17-May-05	125	479,443	11,120	1,405	0	0	24	24	1	0	1,457	0	511	416	107	1,035	71.0	2.7
18-May-05	124	480,486	10,204	1,406	0	0	24	23	1	0	1,458	0	512	416	100	1,028	70.5	2.7
19-May-05	124	477,854	11,533	1,398	0	0	24	23	0	0	1,450	0	509	413	113	1,035	71.4	2.7
20-May-05	123	464,154	12,741	1,386	0	0	24	23	1	0	1,437	0	495	409	125	1,028	71.5	2.7
21-May-05	125	462,703	5,952	1,401	0	0	24	18	1	0	1,453	0	493	417	62	972	66.9	2.6
22-May-05	124	462,806	8,871	1,393	0	0	24	20	1	0	1,445	0	493	414	87	994	68.8	2.7
23-May-05	117	464,948	12,485	1,315	0	3	24	23	1	0	1,364	3	496	390	120	1,006	73.6	2.7
24-May-05	123	486,719	9,172	1,383	0	0	24	22	1	0	1,435	0	519	410	92	1,021	71.2	2.6
25-May-05	124	480,401	5,681	1,391	0	0	24	17	1	0	1,443	0	512	413	58	983	68.2	2.6
26-May-05	124	478,239	8,951	1,393	0	0	24	21	0	0	1,444	0	510	412	90	1,012	70.1	2.7
27-May-05	123	477,602	11,599	1,390	0	0	24	23	1	0	1,442	0	509	410	115	1,034	71.7	2.7
28-May-05	122	437,504	12,808	1,387	0	0	24	24	1	0	1,438	0	466	408	126	1,000	69.6	2.7
29-May-05	123	447,651	11,170	1,395	0	0	24	24	1	0	1,447	0	477	411	112	1,000	69.2	2.7
30-May-05	123	444,528	11,247	1,394	0	0	24	24	1	0	1,446	0	474	411	110	994	68.8	2.7
31-May-05	123	438,932	12,231	1,388	0	0	24	24	1	0	1,440	0	468	411	119	998	69.3	2.7
totals	3,456	13,226,844	188,622	38,966	0	51	672	404	94	11	40,408	53	14,100	11,542	1,843	27,485	67.9	73.5

Month Overview

May 2005 Performance Data



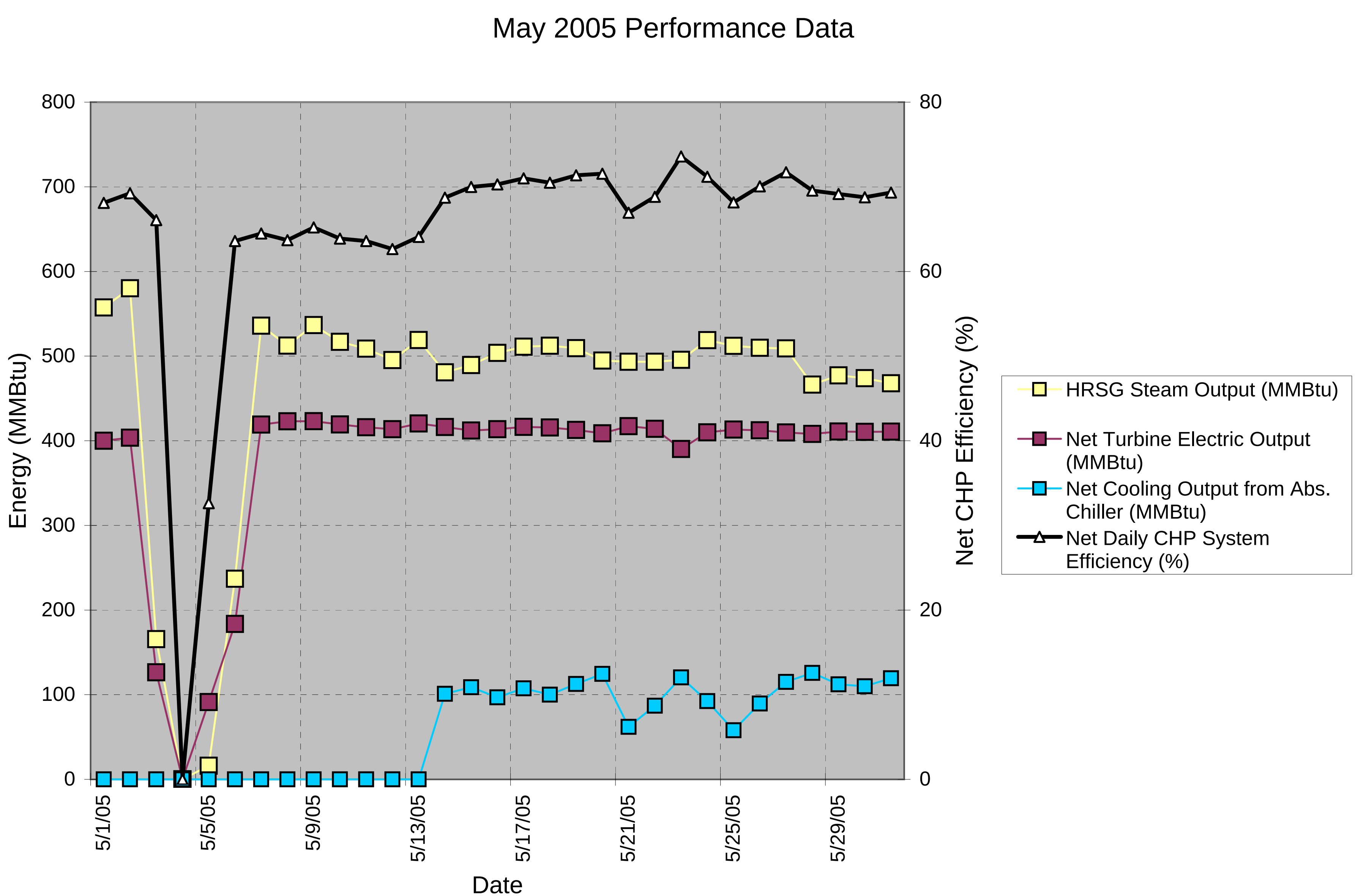


Net CHP Efficiency *

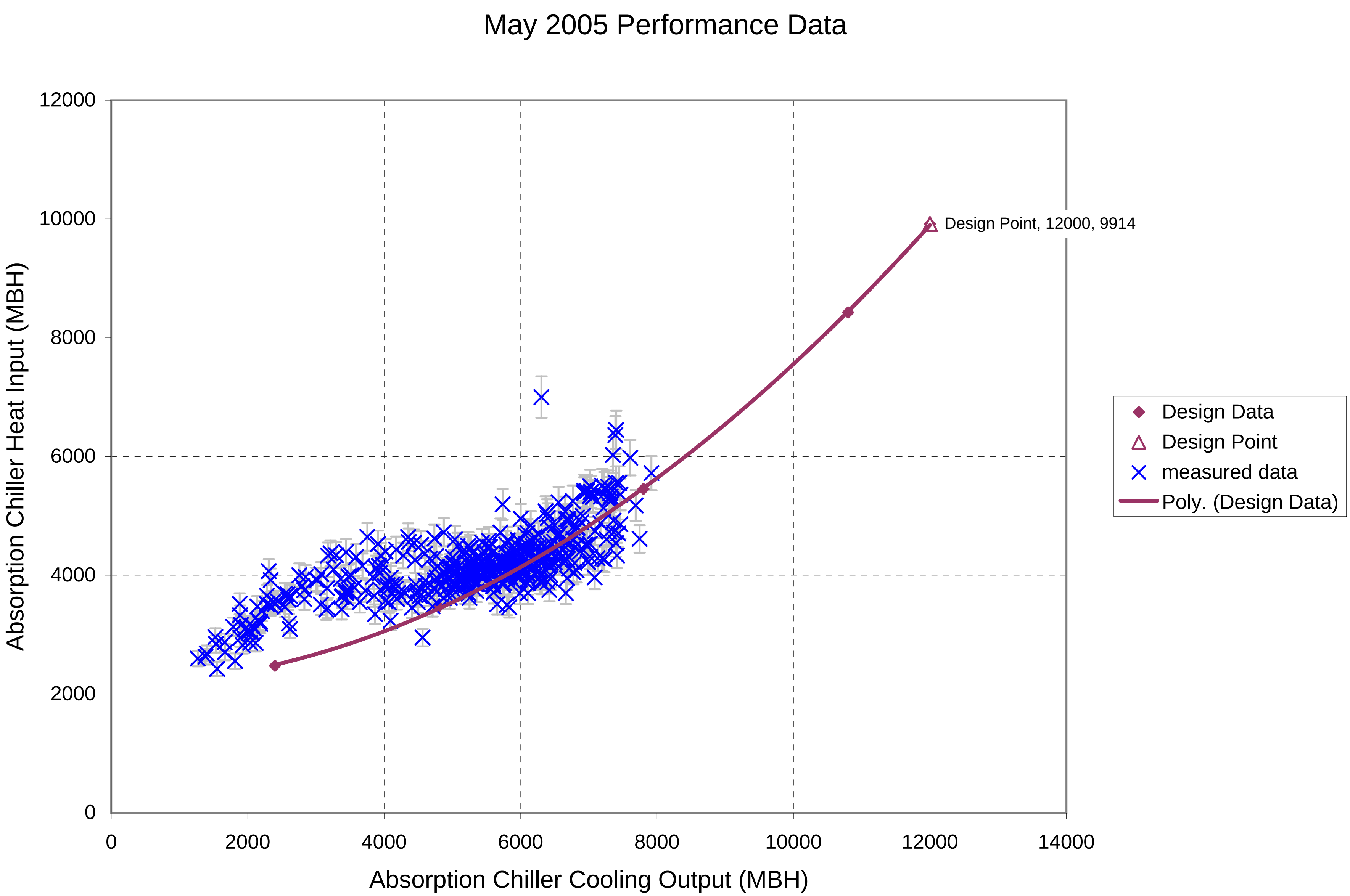
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

= **67.9%**

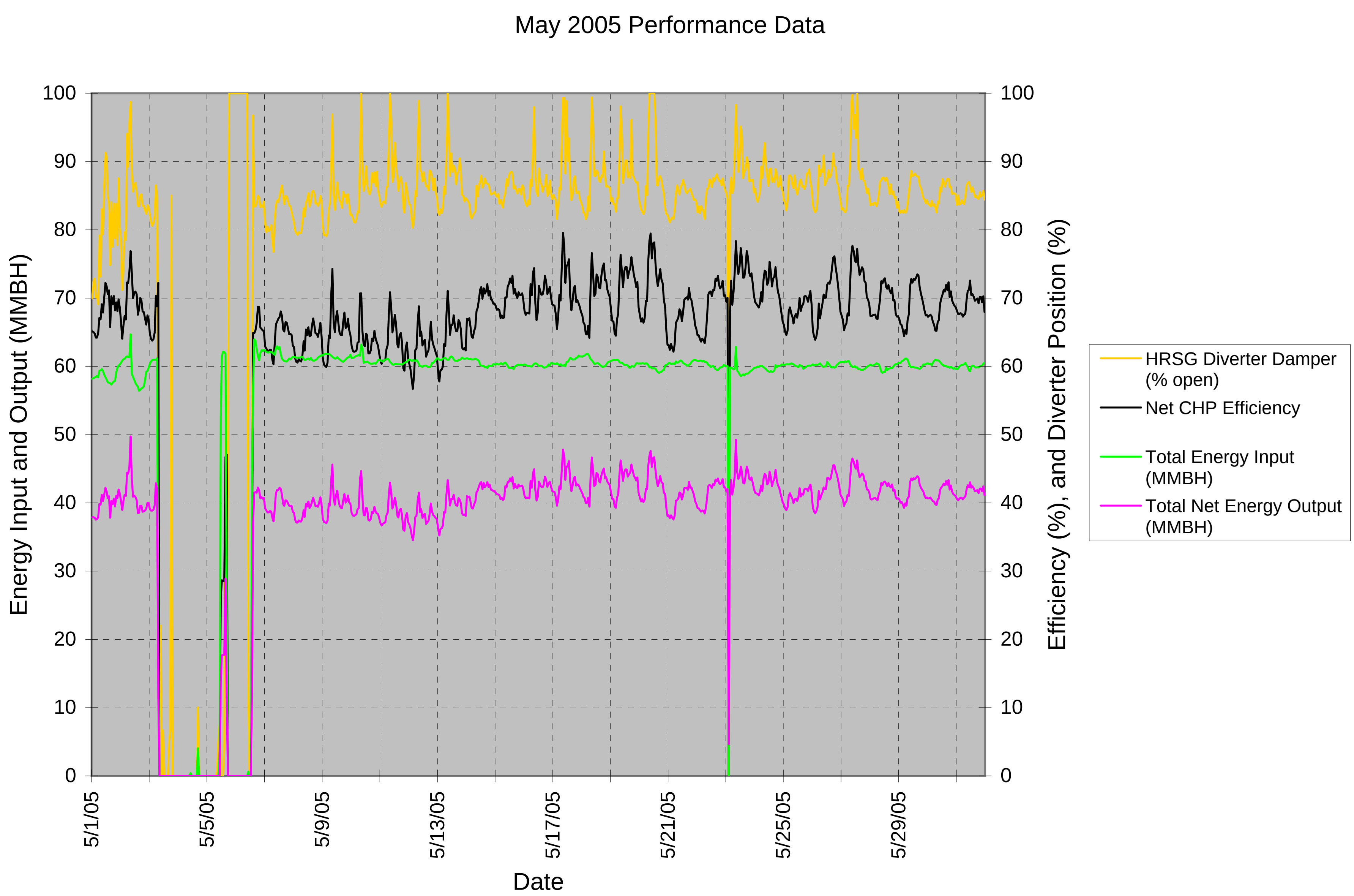
* as defined on page 27 of: "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org


May 2005 Performance Data
800
700
600
500
400
300
200
100
0
Energy (MMBtu)
80
60
40
20
0
Net CHP Efficiency (%)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
Date
HRSG Steam Output (MMBtu)
Net Turbine Electric Output (MMBtu)
Net Cooling Output from Abs. Chiller (MMBtu)
Net Daily CHP System Efficiency (%)

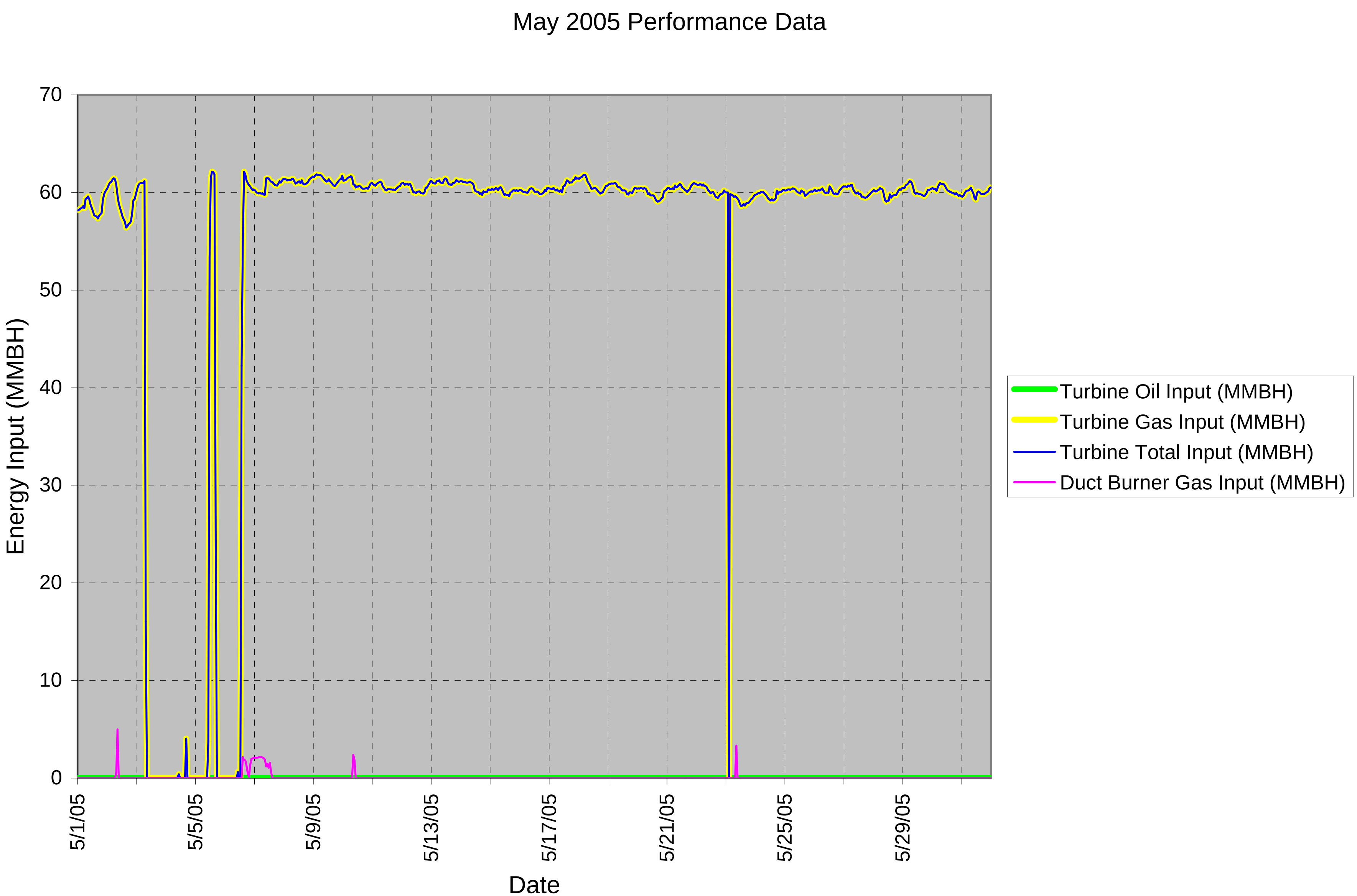

May 2005 Performance Data
Turbine Power Output (kW) and Turbine Heat Rate (Btu/kWh)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Turbine Heat Rate (Btu/kWh)
Design Turbine Heat Rate (Btu/kWh)
System Design Point (no Duct Burner oper.)
Turbine Electric Output (kW)
Design Power Output (kW)
System Design Point


May 2005 Performance Data
Absorption Chiller Heat Input (MBH)
Absorption Chiller Cooling Output (MBH)
0
2000
4000
6000
8000
10000
12000
14000
Design Point, 12000, 9914
Design Data
Design Point
measured data
Poly. (Design Data)

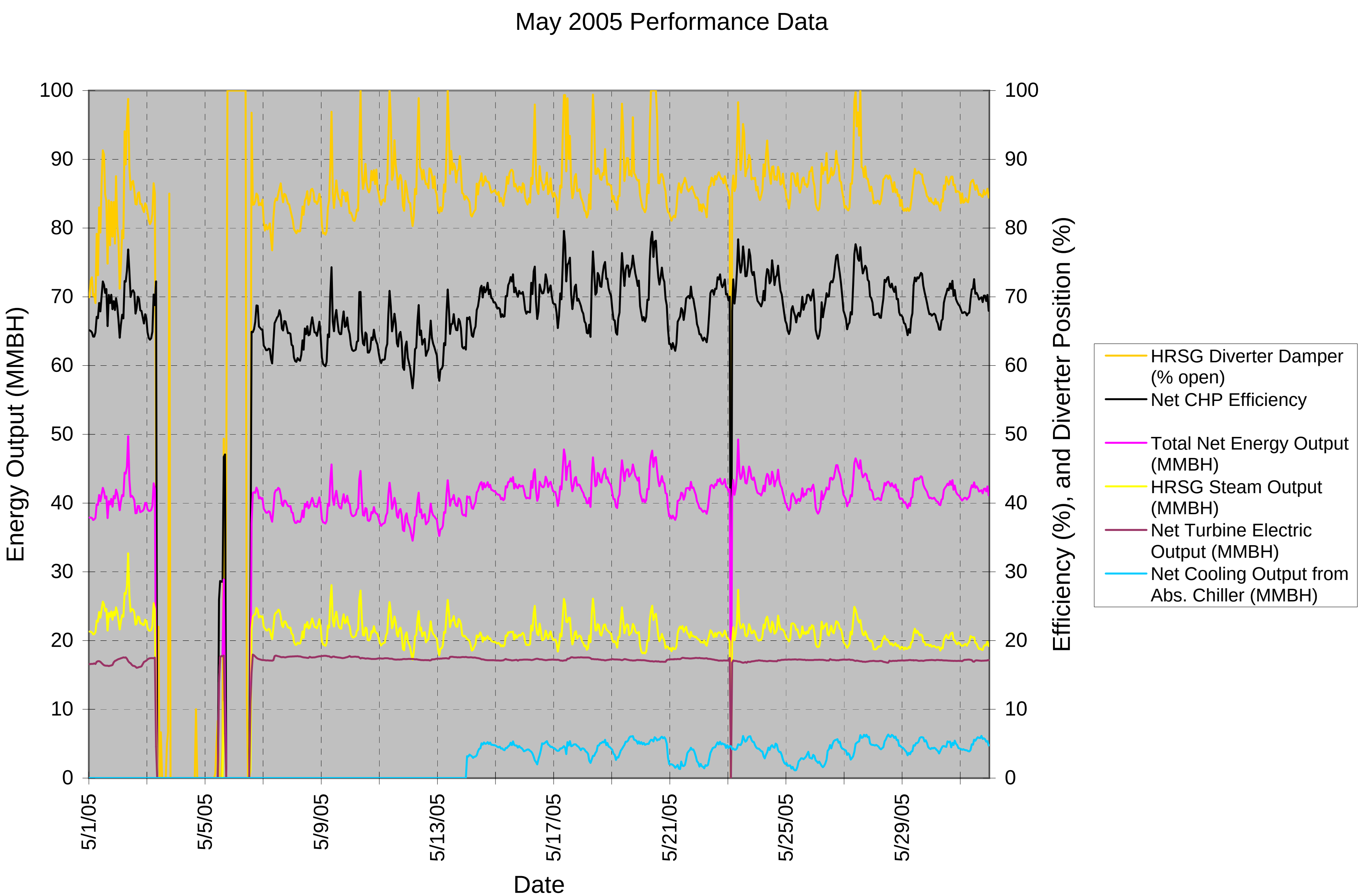
Hourly Overview



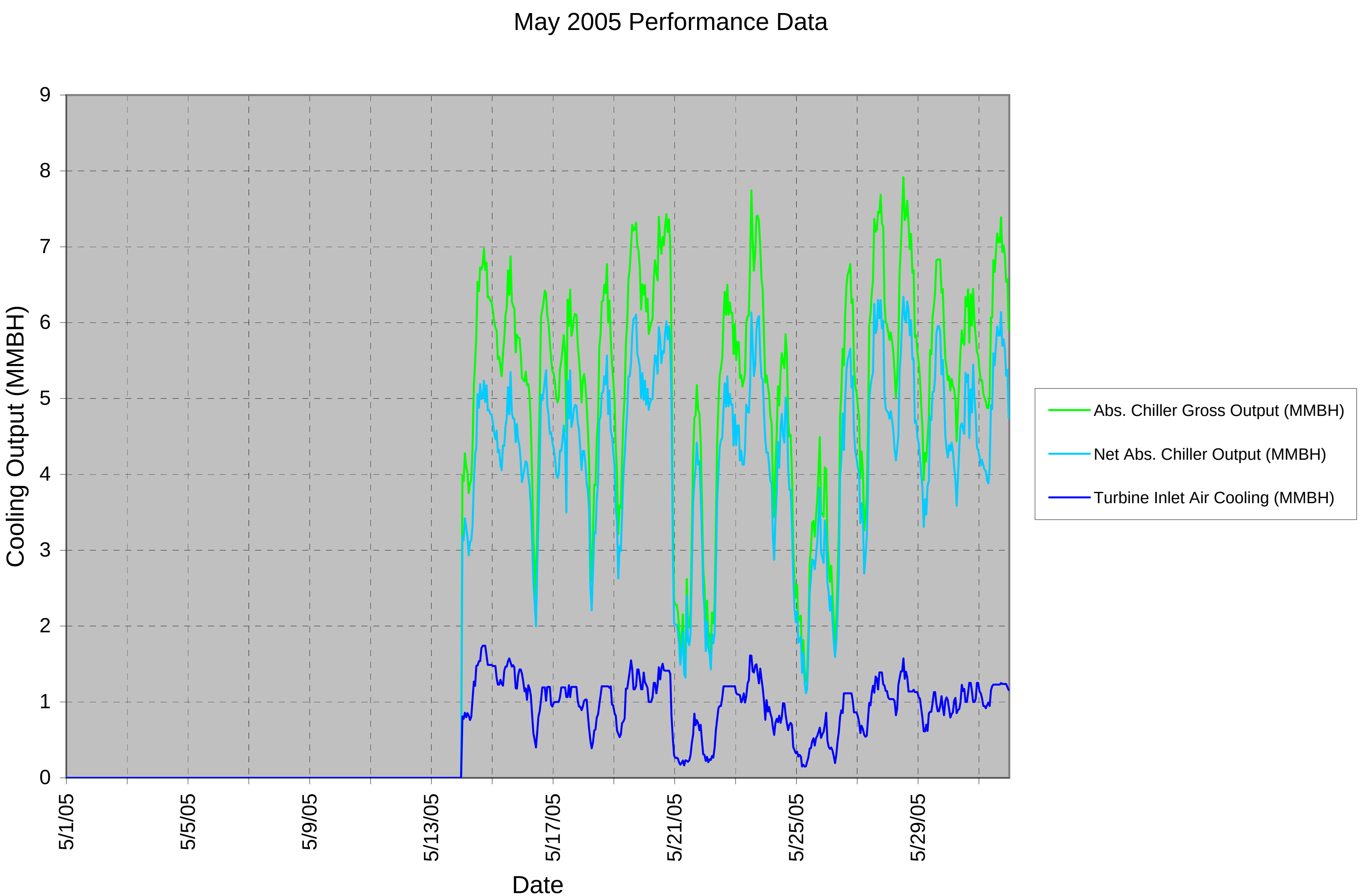
Energy Input



Energy Output



Cooling Output



3.2 Detailed Performance Results: June 2005

Detailed performance results for the month of June 2005, are shown in the table and figures on the following pages.

Field observations noted during the month are:

- The IES system was off-line on June 4, to enable replacement of the inlet air filters for the turbine generator.
- The absorption chiller operated simultaneously with the turbine generator during the month.
- Cooling loads increased as expected toward the end of the month.

Data analysis comments for the month are:

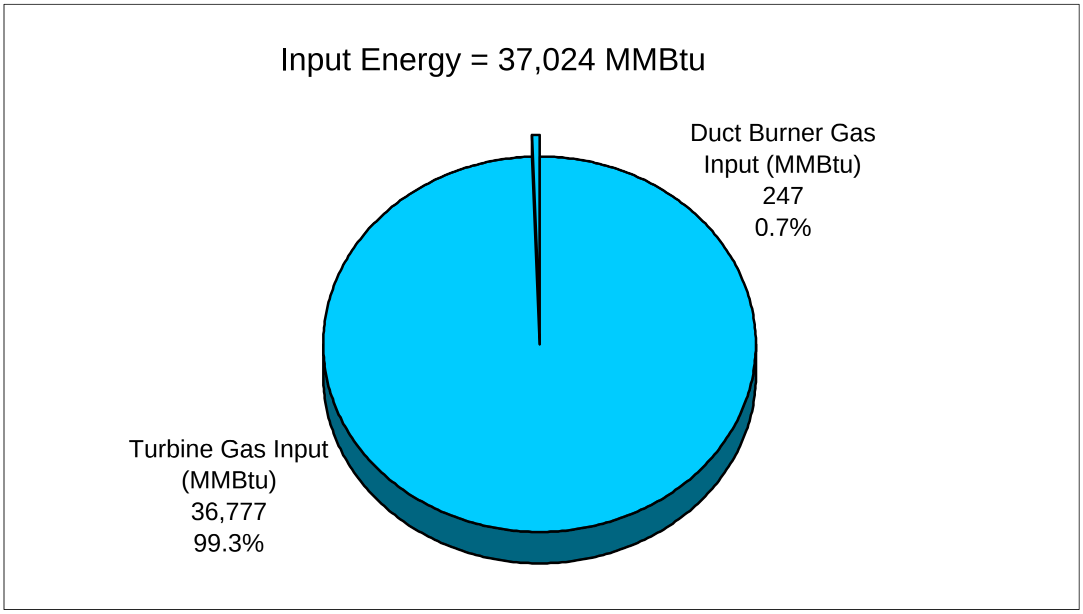
Table or Figure	Analysis Comments
Summary Data Table	The system's operational performance and system efficiency were very good during the month. A greater amount of energy was recovered from the turbine exhaust this month, due to increased cooling loads.
Monthly Overview	The system's energy performance was very good, due to increased thermal loads during the month.
Daily Performance	See comments above.
Turbine Generator Performance	Good performance, the measured data matches pretty well with the design data (within the expected uncertainty). (Note: The last thorough cleaning of the turbine blades was done in March 2005.)
Absorption Chiller Performance	Very good performance, the measured data matches pretty well with the design data (given the expected uncertainty).
Hourly Performance Data	Daily cycles are evident. System efficiency tends to be higher with increased thermal load (as expected).
Energy Input Data	All turbine fuel used was natural gas.
Energy Output Data	Much higher cooling loads during the month, as compared with May.
Cooling Output Data	Turbine inlet air cooling was used during much of the month.

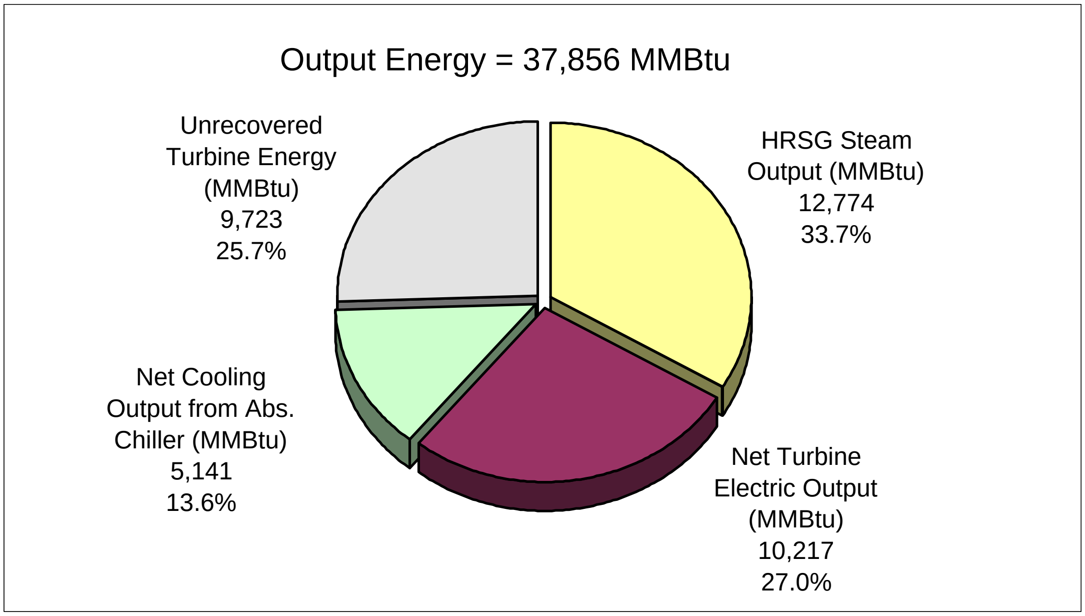
Additional plots of more detailed operating data are presented in Appendix B.

	Measured Data										Calculated Results							
Date	Electric Power Gen. (MWh)	HRSG Steam Gen. (lbs.)	Abs. Chiller Output (ton-hours)	Turbine Nat. Gas Cons. (MCF)	Turbine Fuel Oil Cons. (gal.)	Duct Burner Nat. Gas Cons. (MCF)	Turbine Runtime (hours)	Abs. Chiller Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Aux. Electric Chiller Runtime (hours)	Turbine Total Energy Input (MMBtu)	Duct Burner Natural Gas Input (MMBtu)	HRSG Steam Output (MMBtu)	Net Turbine Electric Output (MMBtu)	Net Cooling Output from Abs. Chiller (MMBtu)	Total CHP Output (MMBtu)	Net Daily CHP System Efficiency (%)	Parasitic Energy (MWh)
1-Jun-05	123	465,609	10,751	1,398	0	0	24	24	0	0	1,450	0	496	411	106	1,013	69.9	2.7
2-Jun-05	113	456,360	11,567	1,298	0	0	22	24	1	0	1,346	0	486	377	113	976	72.5	2.5
3-Jun-05	2	170	88	33	0	0	1	0	24	24	34	0	0	7	1	8	24.0	0.1
4-Jun-05	0	0	0	0	0	0	0	0	24	24	0	0	0	0	0	0	N/A	0.0
5-Jun-05	27	84,864	3,823	302	0	0	6	5	20	19	313	0	90	88	39	217	69.5	0.7
6-Jun-05	108	466,708	18,984	1,242	0	49	24	24	1	0	1,288	51	498	358	183	1,038	77.6	3.2
7-Jun-05	98	472,337	18,698	1,145	0	82	24	24	1	0	1,188	85	504	322	183	1,009	79.2	3.2
8-Jun-05	107	471,651	18,045	1,230	0	42	24	24	1	0	1,275	44	503	355	177	1,035	78.5	3.2
9-Jun-05	108	421,269	19,302	1,219	0	22	22	22	3	2	1,265	23	449	357	193	998	77.5	3.0
10-Jun-05	124	446,913	21,632	1,391	0	0	24	24	1	0	1,442	0	476	412	215	1,103	76.4	3.2
11-Jun-05	124	438,301	19,048	1,390	0	0	24	24	0	0	1,441	0	467	412	188	1,067	74.0	3.0
12-Jun-05	123	437,771	20,109	1,384	0	0	24	24	1	0	1,435	0	467	408	194	1,069	74.5	3.1
13-Jun-05	118	446,818	19,702	1,346	0	3	24	24	0	0	1,395	4	476	393	199	1,069	76.4	3.1
14-Jun-05	113	449,639	19,259	1,303	0	9	24	24	1	0	1,352	9	479	374	210	1,064	78.2	3.1
15-Jun-05	106	442,929	17,705	1,243	0	0	24	24	1	0	1,289	0	472	351	212	1,035	80.3	2.8
16-Jun-05	106	440,075	16,055	1,248	0	0	24	24	1	0	1,295	0	469	353	193	1,015	78.4	2.7
17-Jun-05	110	439,717	13,873	1,281	0	0	24	24	1	0	1,329	0	469	366	166	1,001	75.3	2.7
18-Jun-05	111	424,073	12,915	1,295	0	0	24	23	0	0	1,343	0	452	371	155	978	72.8	2.7
19-Jun-05	113	415,845	14,406	1,309	0	0	24	24	1	0	1,358	0	443	377	169	990	72.9	2.7
20-Jun-05	120	435,927	15,115	1,374	0	0	24	24	1	0	1,425	0	465	401	166	1,032	72.4	2.7
21-Jun-05	121	435,068	15,127	1,382	0	0	24	23	1	0	1,433	0	464	404	158	1,026	71.6	2.8
22-Jun-05	112	444,064	16,598	1,301	0	4	24	24	0	0	1,349	4	473	373	188	1,034	76.4	2.7
23-Jun-05	109	429,902	17,194	1,288	0	3	24	24	1	0	1,335	3	458	364	195	1,017	76.0	2.8
24-Jun-05	110	435,753	17,146	1,291	0	7	24	24	1	0	1,339	7	465	367	197	1,029	76.4	2.8
25-Jun-05	118	408,330	19,869	1,359	0	0	24	24	1	0	1,409	0	435	391	202	1,029	73.0	3.1
26-Jun-05	116	417,280	22,399	1,337	0	2	24	24	1	0	1,386	2	445	385	225	1,054	75.9	3.3
27-Jun-05	108	434,659	20,233	1,269	0	13	24	24	1	0	1,316	14	463	359	232	1,054	79.3	3.0
28-Jun-05	110	440,161	18,748	1,286	0	0	24	24	1	0	1,333	0	469	366	225	1,060	79.5	2.9
29-Jun-05	109	445,507	18,712	1,271	0	0	24	24	1	0	1,318	0	475	362	225	1,061	80.5	2.9
30-Jun-05	106	435,709	19,500	1,251	0	0	24	24	1	0	1,297	0	464	353	234	1,051	81.1	3.1
totals	3,075	11,983,409	476,606	35,465	0	238	651	648	90	69	36,777	247	12,774	10,217	5,141	28,133	76.0	80.0

Month Overview

June 2005 Performance Data



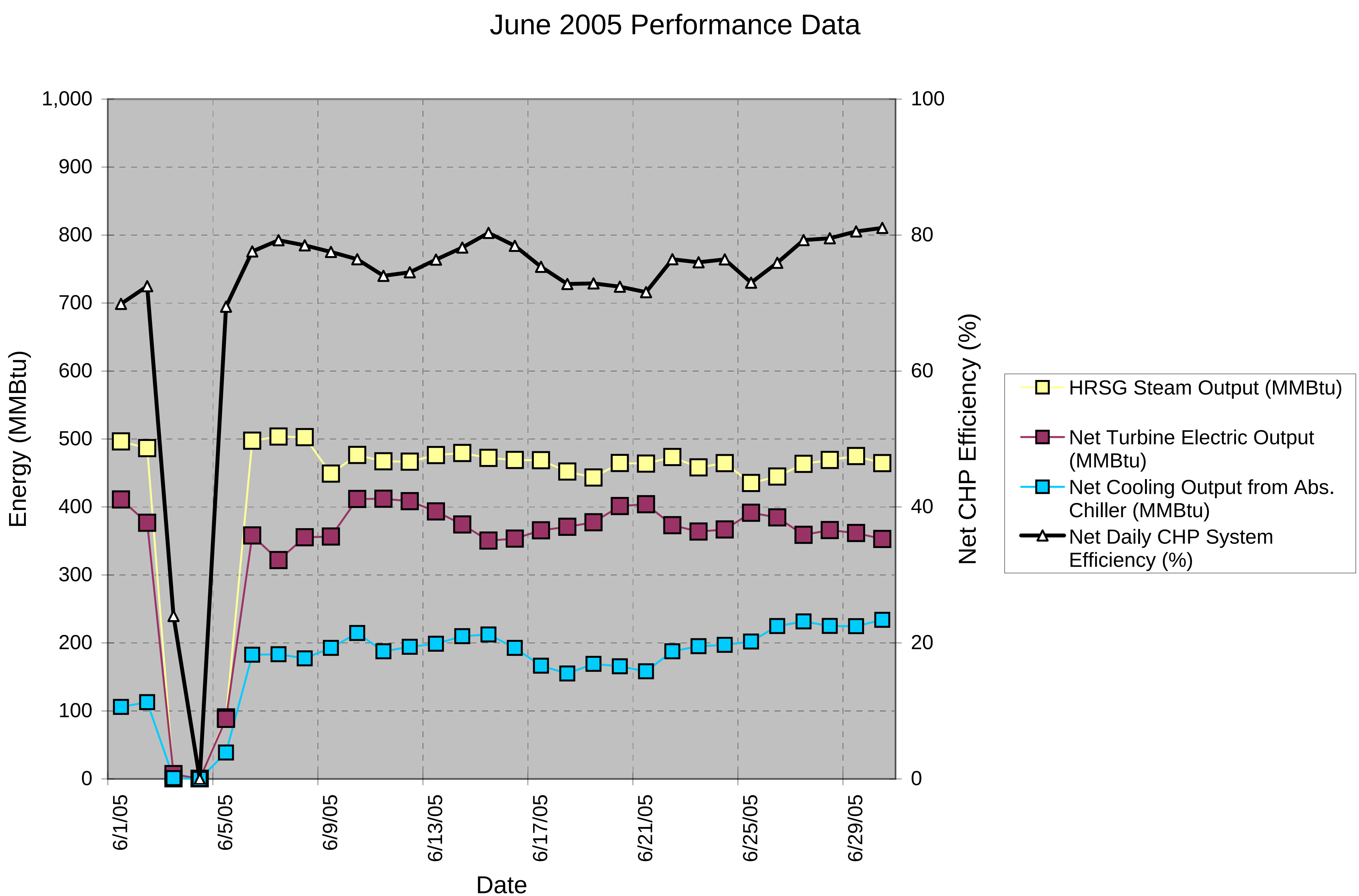


Net CHP Efficiency *

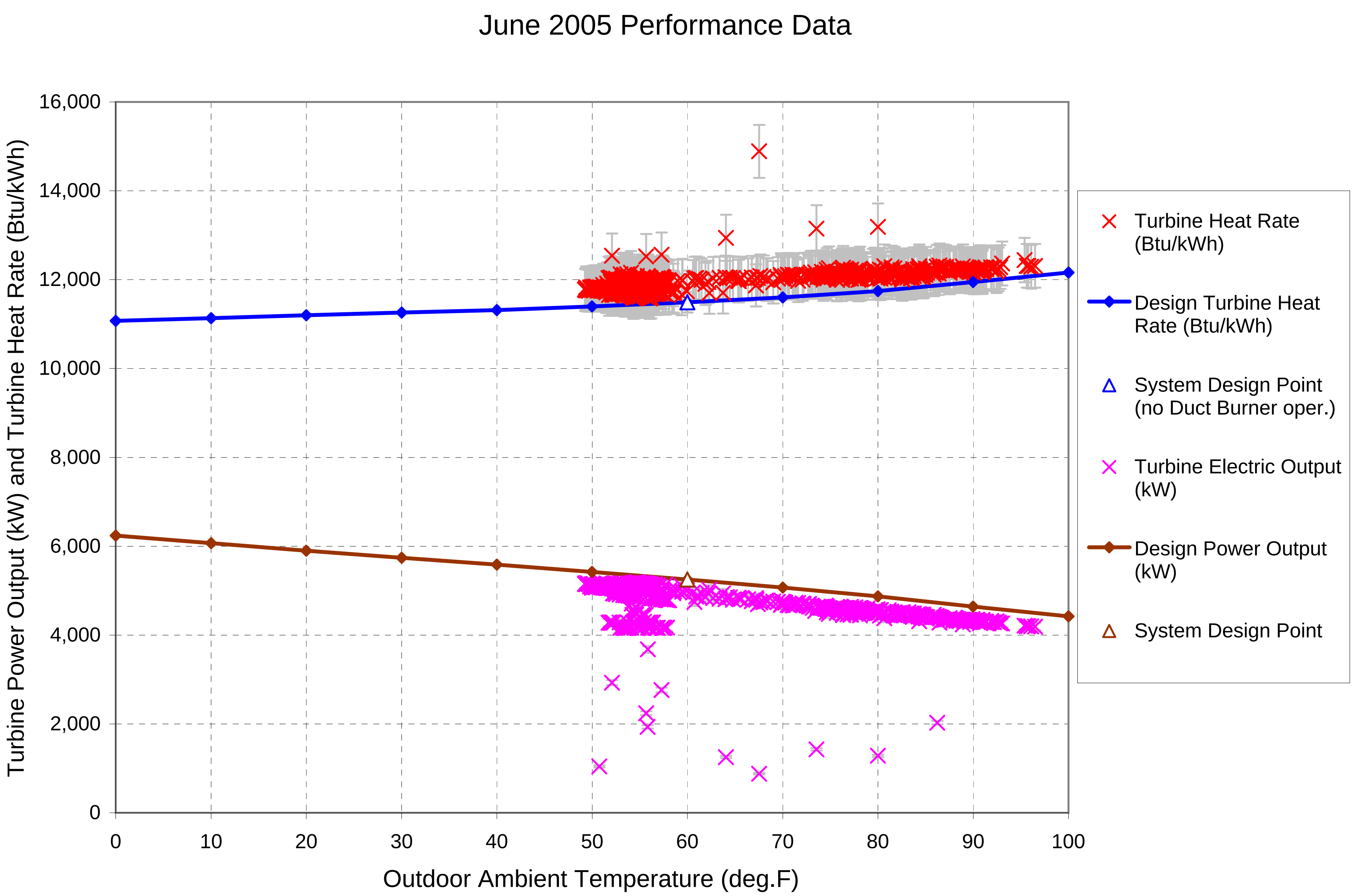
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

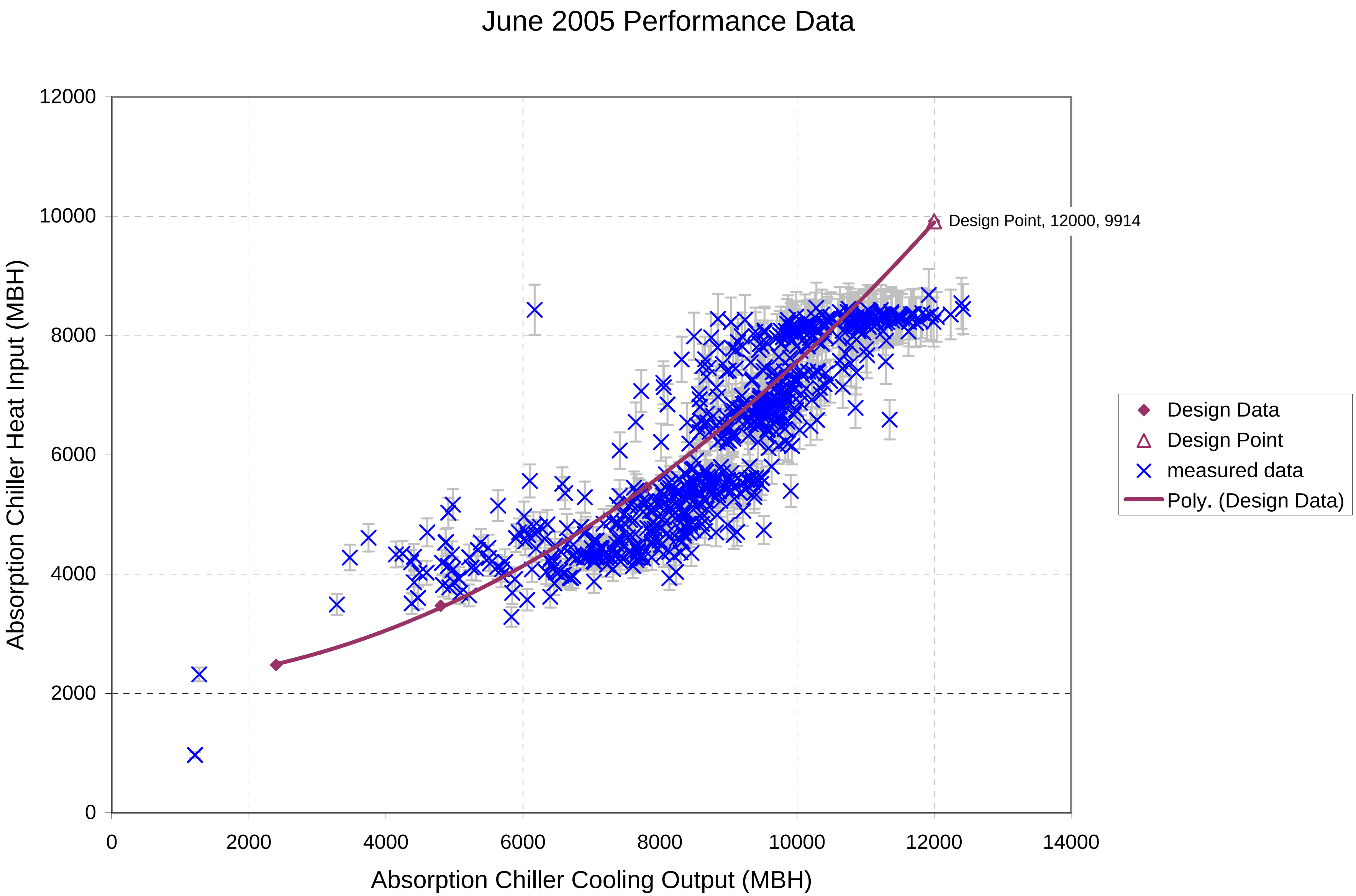
= **76.0%**

* as defined on page 27 of: “Distributed Generation Combined Heat and Power Long Term Monitoring Protocols” Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

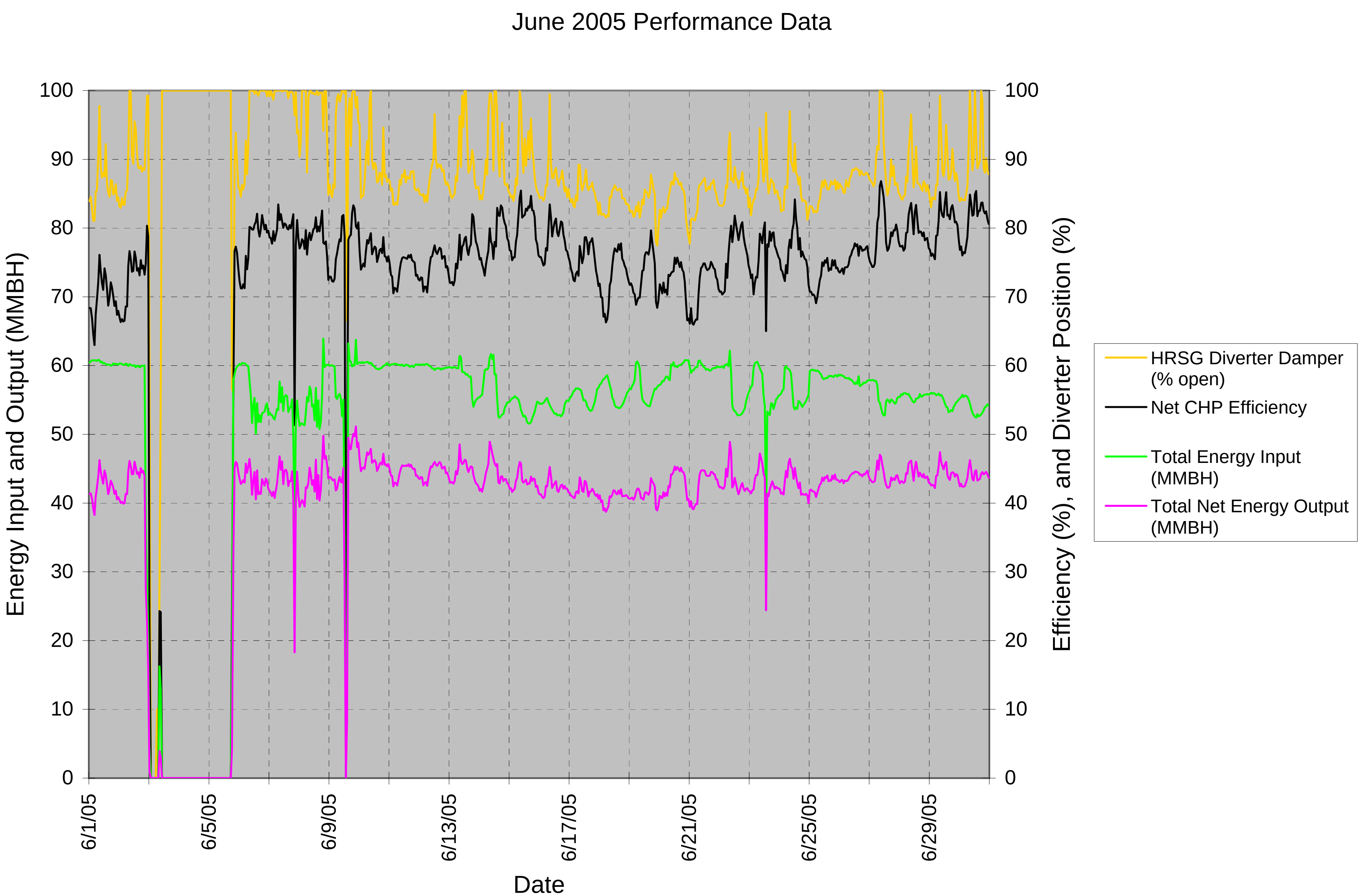


June 2005 Performance Data
Energy (MMBtu)
1,000
900
800
700
600
500
400
300
200
100
0
Net CHP Efficiency (%)
100
80
60
40
20
0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
Date
HRSG Steam Output (MMBtu)
Net Turbine Electric Output (MMBtu)
Net Cooling Output from Abs. Chiller (MMBtu)
Net Daily CHP System Efficiency (%)

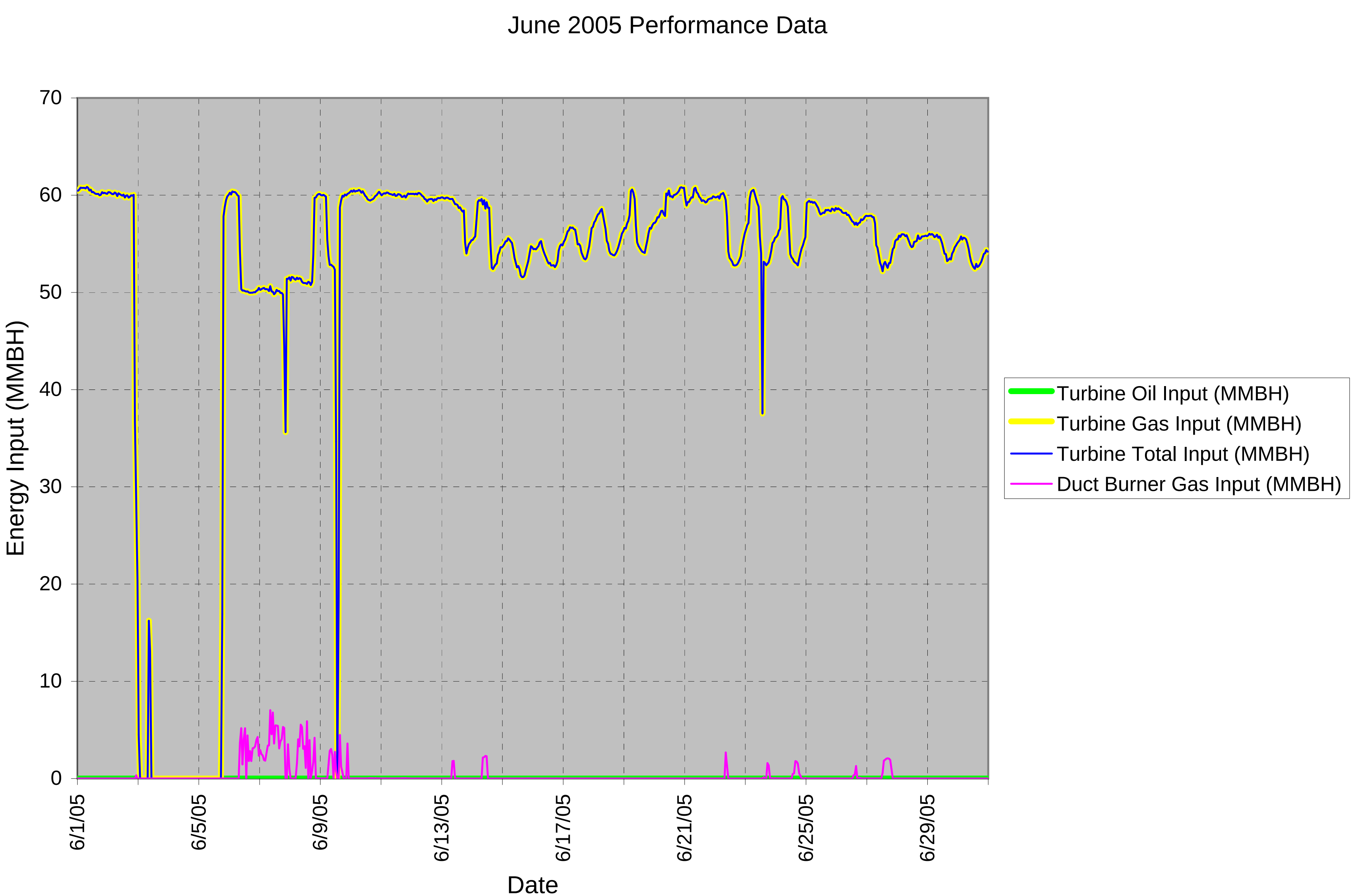

June 2005 Performance Data
Turbine Power Output (kW) and Turbine Heat Rate (Btu/kWh)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Turbine Heat Rate (Btu/kWh)
Design Turbine Heat Rate (Btu/kWh)
System Design Point (no Duct Burner oper.)
Turbine Electric Output (kW)
Design Power Output (kW)
System Design Point


June 2005 Performance Data
Absorption Chiller Heat Input (MBH)
Absorption Chiller Cooling Output (MBH)
0
2000
4000
6000
8000
10000
12000
14000
Design Point, 12000, 9914
Design Data
Design Point
measured data
Poly. (Design Data)

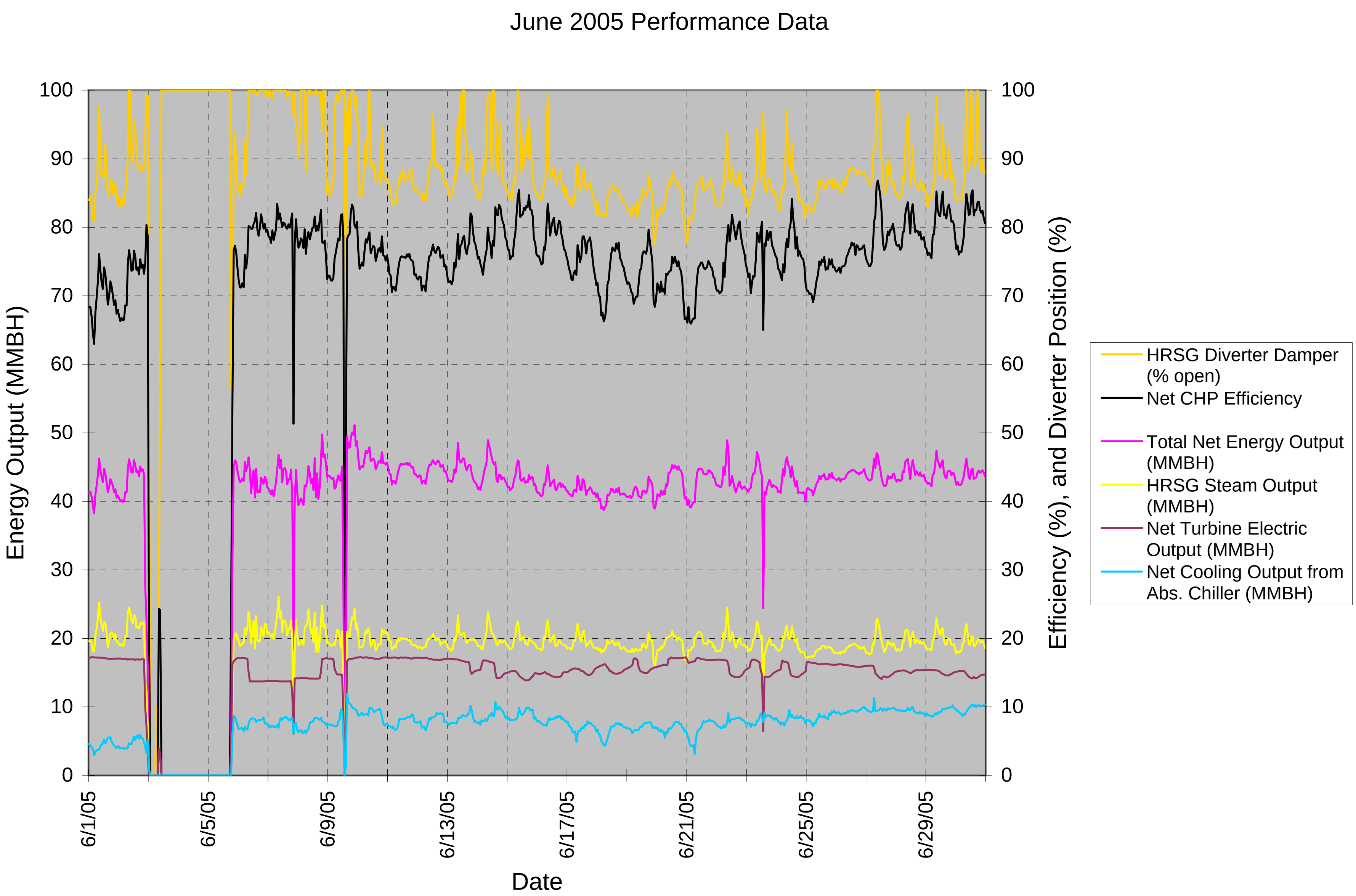
Hourly Overview



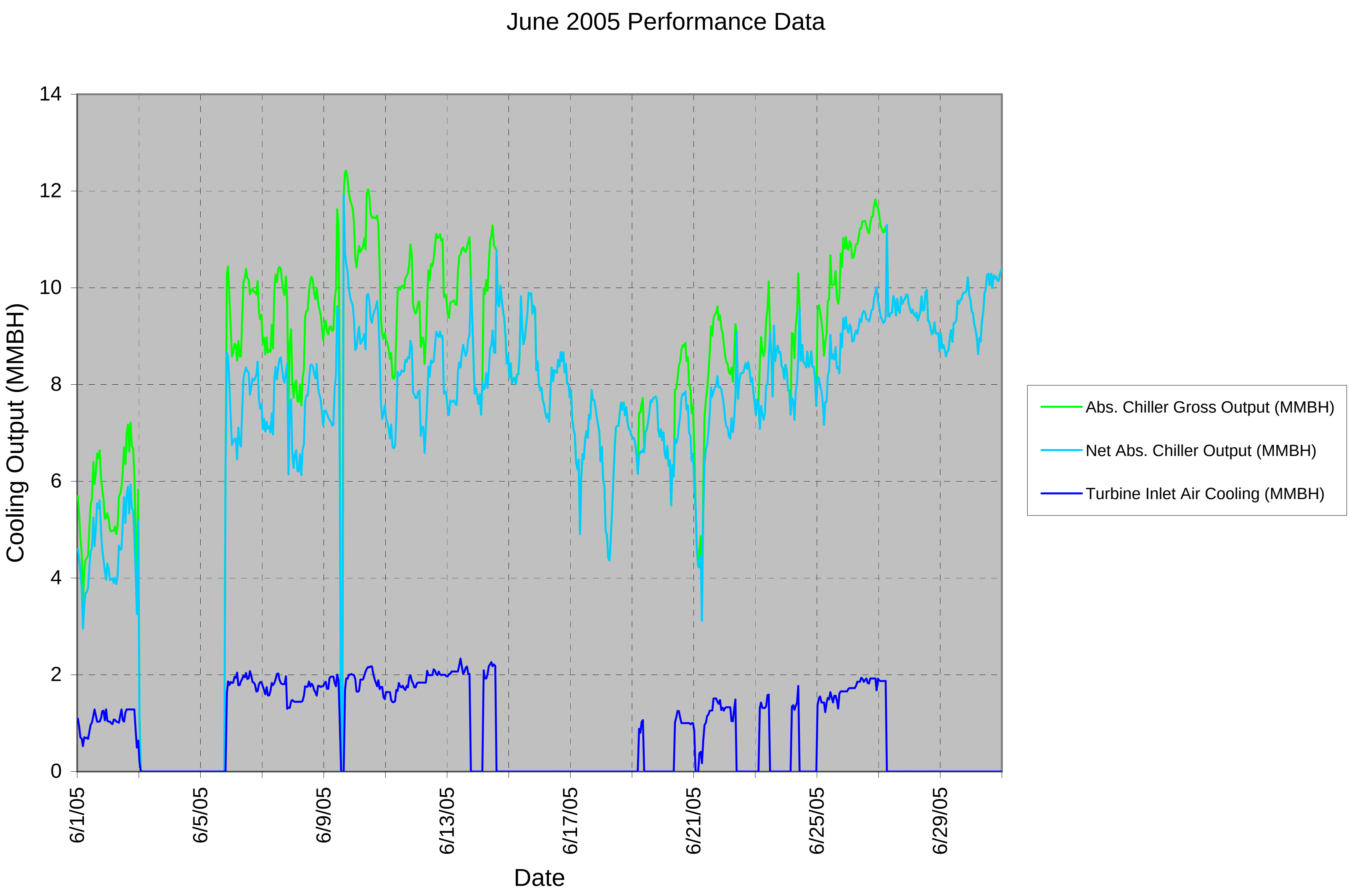
Energy Input



Energy Output



Cooling Output



3.3 Detailed Performance Results: July 2005

Detailed performance results for the month of July 2005, are shown in the table and figures on the following pages.

Field observations noted during the month are:

- The IES system was off-line on July 14, to enable system maintenance and improvements to the control software.
- The absorption chiller operated simultaneously with the turbine generator during the month.
- Cooling loads were consistently high during the month (daily cycles were evident).

Data analysis comments for the month are:

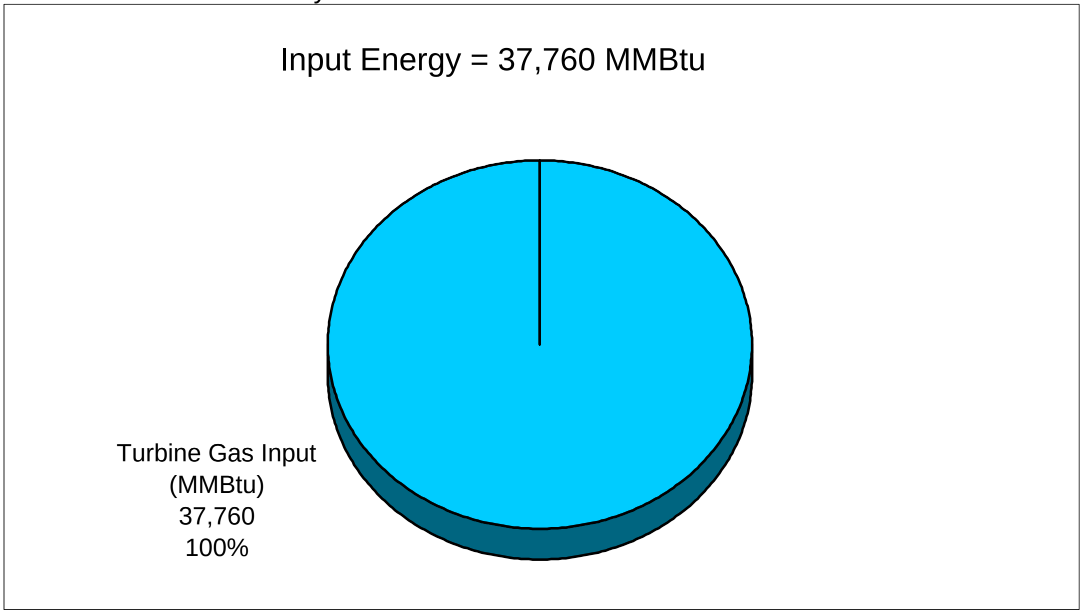
Table or Figure	Analysis Comments
Summary Data Table	The system efficiency was very good, due to significant use of recovered energy from the turbine exhaust delivered to the absorption chiller to satisfy high cooling loads.
Monthly Overview	The system's energy performance was very good, due to high cooling loads during the month.
Daily Performance	See comments above.
Turbine Generator Performance	Good performance, however the measured data indicates that the turbine blades were beginning to collect dirt thereby slightly reducing performance. (Note: The last thorough cleaning of the turbine blades was done in March 2005.)
Absorption Chiller Performance	Very good performance, the measured data matches pretty well with the design data (given the expected uncertainty).
Hourly Performance Data	Daily cycles are evident. System efficiency was very good throughout the month.
Energy Input Data	All turbine fuel used was natural gas.
Energy Output Data	Relatively high cooling loads throughout the month, as expected.
Cooling Output Data	Turbine inlet air cooling was not used during much of the month, in order to maximize the cooling delivered to the building loads.

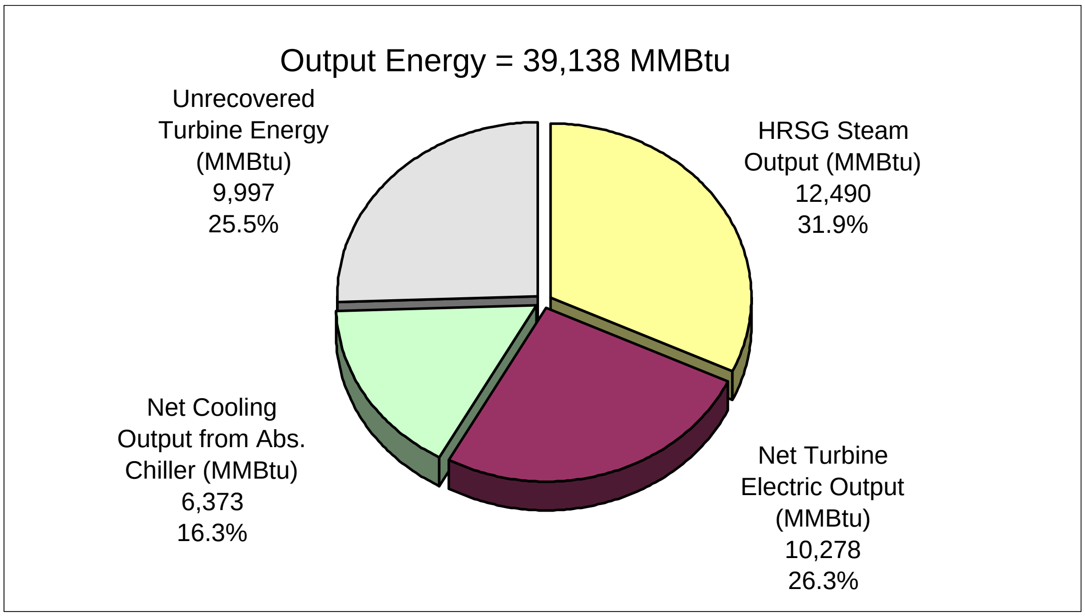
Additional plots of more detailed operating data are presented in Appendix C.

	Measured Data										Calculated Results							
Date	Electric Power Gen. (MWh)	HRSG Steam Gen. (lbs.)	Abs. Chiller Output (ton-hours)	Turbine Nat. Gas Cons. (MCF)	Turbine Fuel Oil Cons. (gal.)	Duct Burner Nat. Gas Cons. (MCF)	Turbine Runtime (hours)	Abs. Chiller Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Aux. Electric Chiller Runtime (hours)	Turbine Total Energy Input (MMBtu)	Duct Burner Natural Gas Input (MMBtu)	HRSG Steam Output (MMBtu)	Net Turbine Electric Output (MMBtu)	Net Cooling Output from Abs. Chiller (MMBtu)	Total CHP Output (MMBtu)	Net Daily CHP System Efficiency (%)	Parasitic Energy (MWh)
1-Jul-05	105	425,705	19,188	1,243	0	0	24	24	1	0	1,289	0	454	349	230	1,033	80.2	3.0
2-Jul-05	114	413,004	19,786	1,313	0	0	24	24	1	0	1,362	0	440	378	209	1,028	75.5	3.2
3-Jul-05	109	438,520	17,300	1,269	0	0	24	24	1	0	1,316	0	467	361	208	1,036	78.7	2.8
4-Jul-05	108	431,007	17,929	1,264	0	0	24	24	1	0	1,311	0	459	357	215	1,032	78.7	3.0
5-Jul-05	106	451,770	19,191	1,251	0	0	24	24	1	0	1,298	0	482	353	230	1,064	82.0	3.0
6-Jul-05	105	429,346	18,688	1,238	0	0	24	24	1	0	1,284	0	458	348	224	1,030	80.2	2.9
7-Jul-05	105	419,019	18,595	1,243	0	0	24	24	1	0	1,289	0	447	350	223	1,020	79.1	2.9
8-Jul-05	109	415,329	17,214	1,264	0	0	24	24	1	0	1,311	0	443	361	207	1,010	77.1	2.8
9-Jul-05	108	407,175	17,602	1,262	0	0	24	24	1	0	1,309	0	434	359	211	1,004	76.7	2.8
10-Jul-05	108	412,511	18,481	1,264	0	0	24	24	1	0	1,311	0	440	358	222	1,019	77.7	2.9
11-Jul-05	39	136,136	7,161	457	0	0	8	8	17	16	474	0	145	128	86	359	75.9	1.0
12-Jul-05	0	0	89	0	0	0	0	0	24	24	0	0	0	0	0	0	N/A	0.0
13-Jul-05	62	235,943	9,369	739	0	0	15	14	11	12	766	0	252	206	111	569	74.2	1.8
14-Jul-05	108	422,779	17,137	1,266	0	0	24	24	1	0	1,313	0	451	359	206	1,016	77.4	2.8
15-Jul-05	109	417,885	18,423	1,279	0	0	24	24	1	0	1,326	0	445	362	221	1,028	77.6	2.9
16-Jul-05	107	398,497	19,315	1,262	0	0	24	24	1	0	1,309	0	425	355	232	1,012	77.3	3.1
17-Jul-05	107	388,571	19,399	1,261	0	0	24	24	1	0	1,308	0	414	354	233	1,001	76.5	3.1
18-Jul-05	107	401,800	19,184	1,262	0	0	24	24	1	0	1,308	0	428	354	230	1,013	77.4	3.1
19-Jul-05	107	396,140	19,297	1,254	0	0	24	24	0	0	1,300	0	422	353	232	1,007	77.5	3.1
20-Jul-05	106	398,250	19,305	1,248	0	0	24	24	0	0	1,294	0	425	352	232	1,008	77.9	3.1
21-Jul-05	106	396,134	19,736	1,249	0	0	24	23	1	0	1,295	0	422	351	237	1,010	77.9	3.1
22-Jul-05	105	388,501	19,553	1,244	0	0	24	24	1	0	1,290	0	414	348	235	997	77.3	3.1
23-Jul-05	106	380,209	18,933	1,242	0	0	24	24	0	0	1,288	0	405	350	227	983	76.3	3.0
24-Jul-05	106	391,554	17,575	1,246	0	0	24	24	1	0	1,293	0	417	351	211	979	75.8	2.9
25-Jul-05	103	401,296	18,466	1,229	0	0	24	24	1	0	1,274	0	428	343	222	992	77.8	3.0
26-Jul-05	100	384,399	19,081	1,197	0	0	24	24	1	0	1,241	0	410	331	229	970	78.2	3.1
27-Jul-05	101	383,493	18,703	1,208	0	0	24	24	1	0	1,252	0	409	336	224	969	77.4	3.1
28-Jul-05	111	373,658	19,344	1,290	0	0	24	24	1	0	1,337	0	398	369	213	980	73.3	3.1
29-Jul-05	116	396,709	20,783	1,332	0	0	24	24	1	0	1,382	0	423	385	215	1,023	74.1	3.2
30-Jul-05	107	386,289	16,740	1,262	0	0	24	24	1	0	1,309	0	412	356	201	969	74.0	2.9
31-Jul-05	108	395,152	16,536	1,273	0	0	24	24	1	0	1,320	0	421	360	198	980	74.2	2.8
totals	3,099	11,716,781	538,104	36,413	0	0	695	693	72	51	37,760	0	12,490	10,278	6,373	29,141	77.2	86.7

Month Overview

July 2005 Performance Data



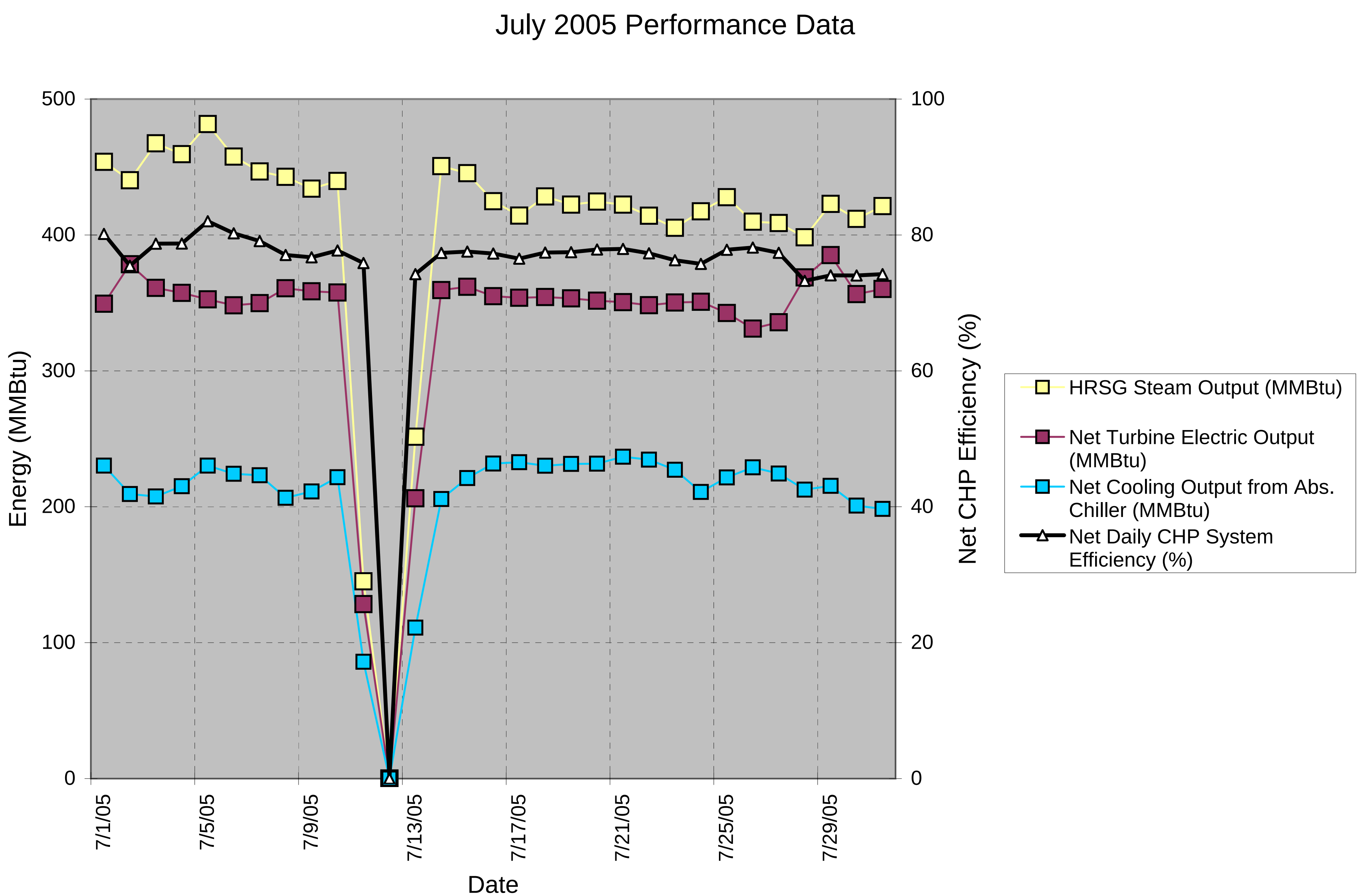


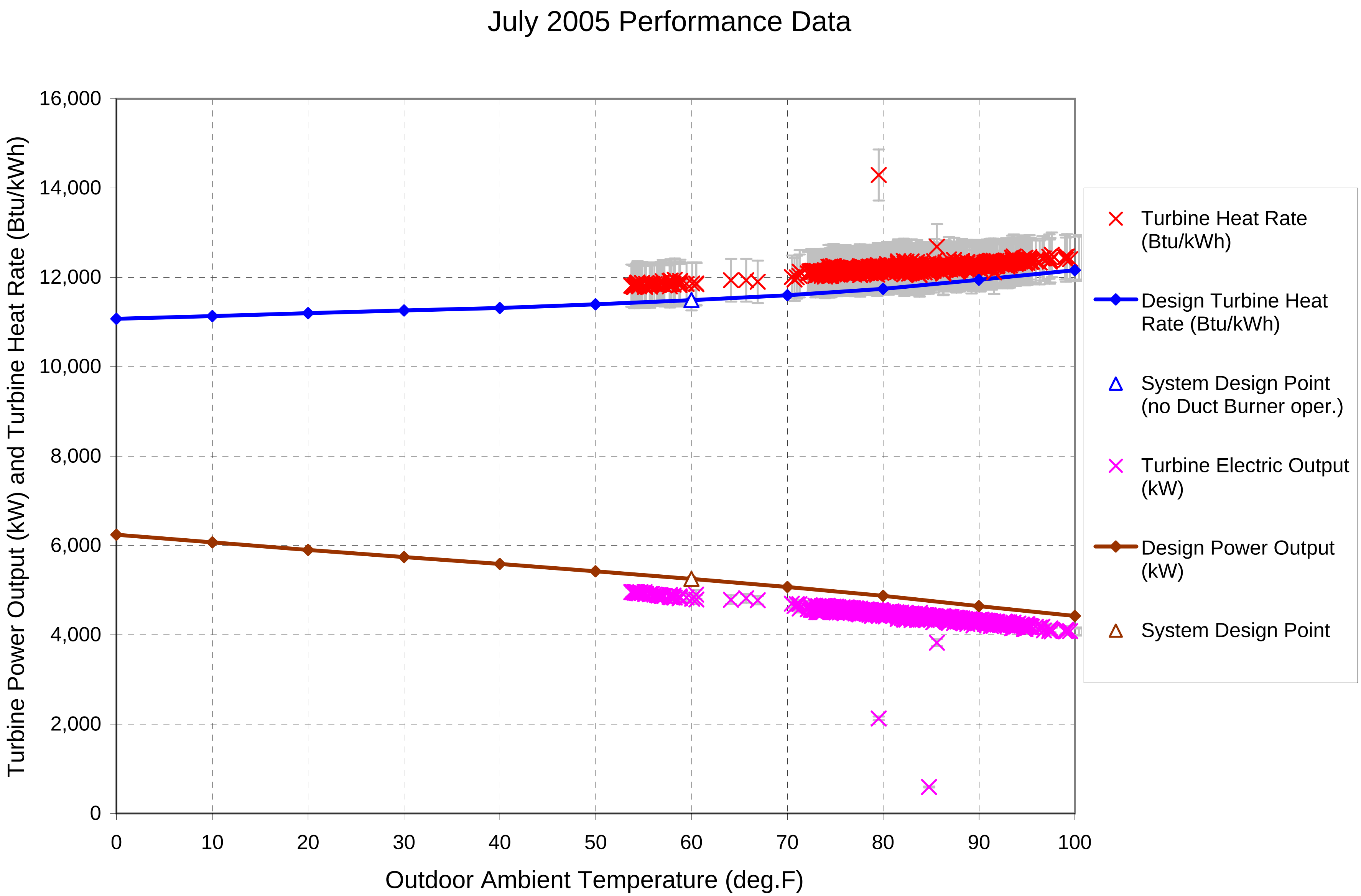
Net CHP Efficiency *

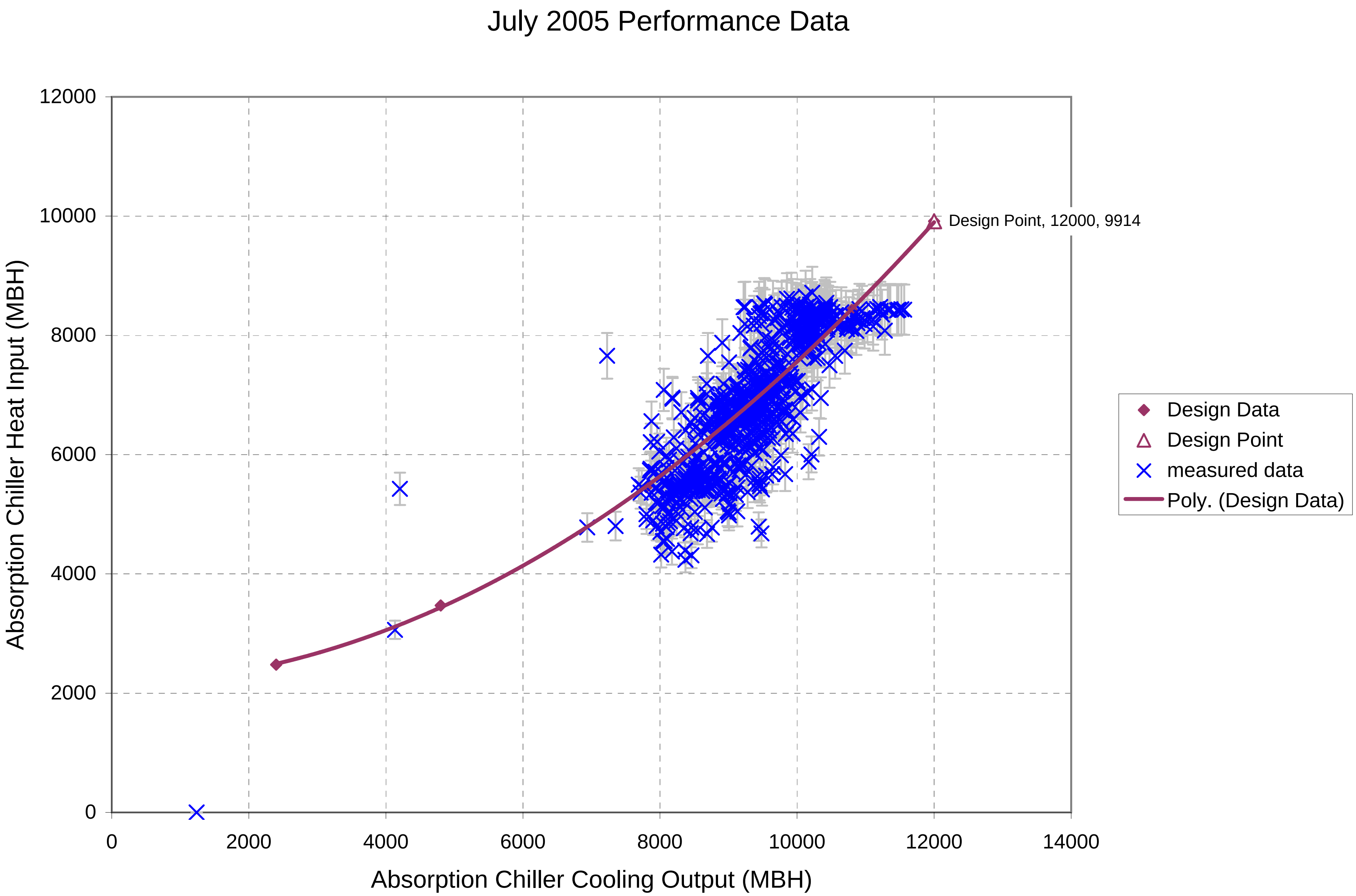
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

= **77.2%**

* as defined on page 27 of: "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

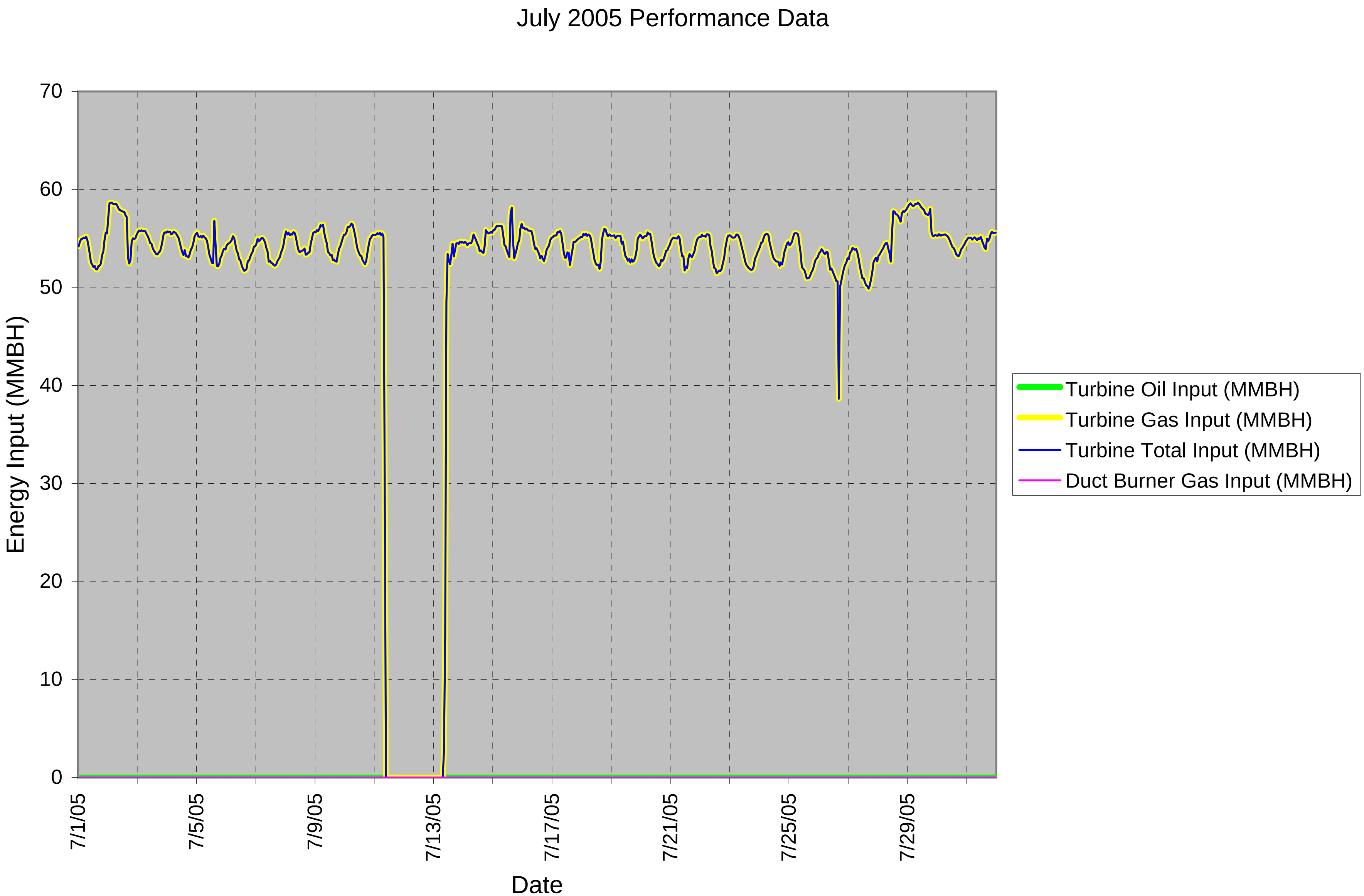

July 2005 Performance Data
Energy (MMBtu)
500
400
300
200
100
0
Net CHP Efficiency (%)
100
80
60
40
20
0
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
Date
HRSG Steam Output (MMBtu)
Net Turbine Electric Output (MMBtu)
Net Cooling Output from Abs. Chiller (MMBtu)
Net Daily CHP System Efficiency (%)


July 2005 Performance Data
Turbine Power Output (kW) and Turbine Heat Rate (Btu/kWh)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Turbine Heat Rate (Btu/kWh)
Design Turbine Heat Rate (Btu/kWh)
System Design Point (no Duct Burner oper.)
Turbine Electric Output (kW)
Design Power Output (kW)
System Design Point

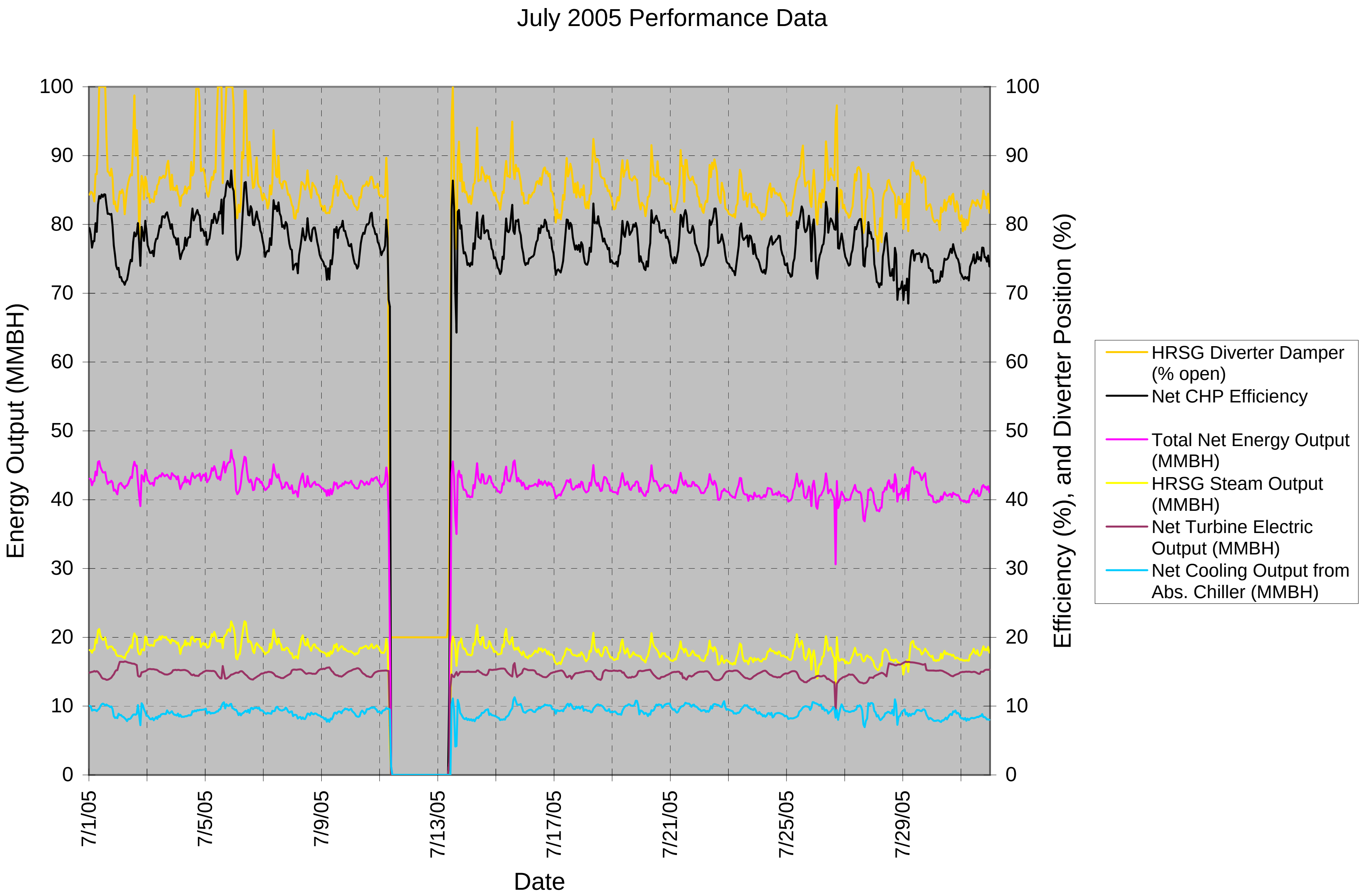

July 2005 Performance Data
Absorption Chiller Heat Input (MBH)
Absorption Chiller Cooling Output (MBH)
0
2000
4000
6000
8000
10000
12000
14000
Design Point, 12000, 9914
Design Data
Design Point
measured data
Poly. (Design Data)


July 2005 Performance Data
Energy Input and Output (MMBH)
Efficiency (%), and Diverter Position (%)
100
90
80
70
60
50
40
30
20
10
0
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
Date
HRSG Diverter Damper (% open)
Net CHP Efficiency
Total Energy Input (MMBH)
Total Net Energy Output (MMBH)

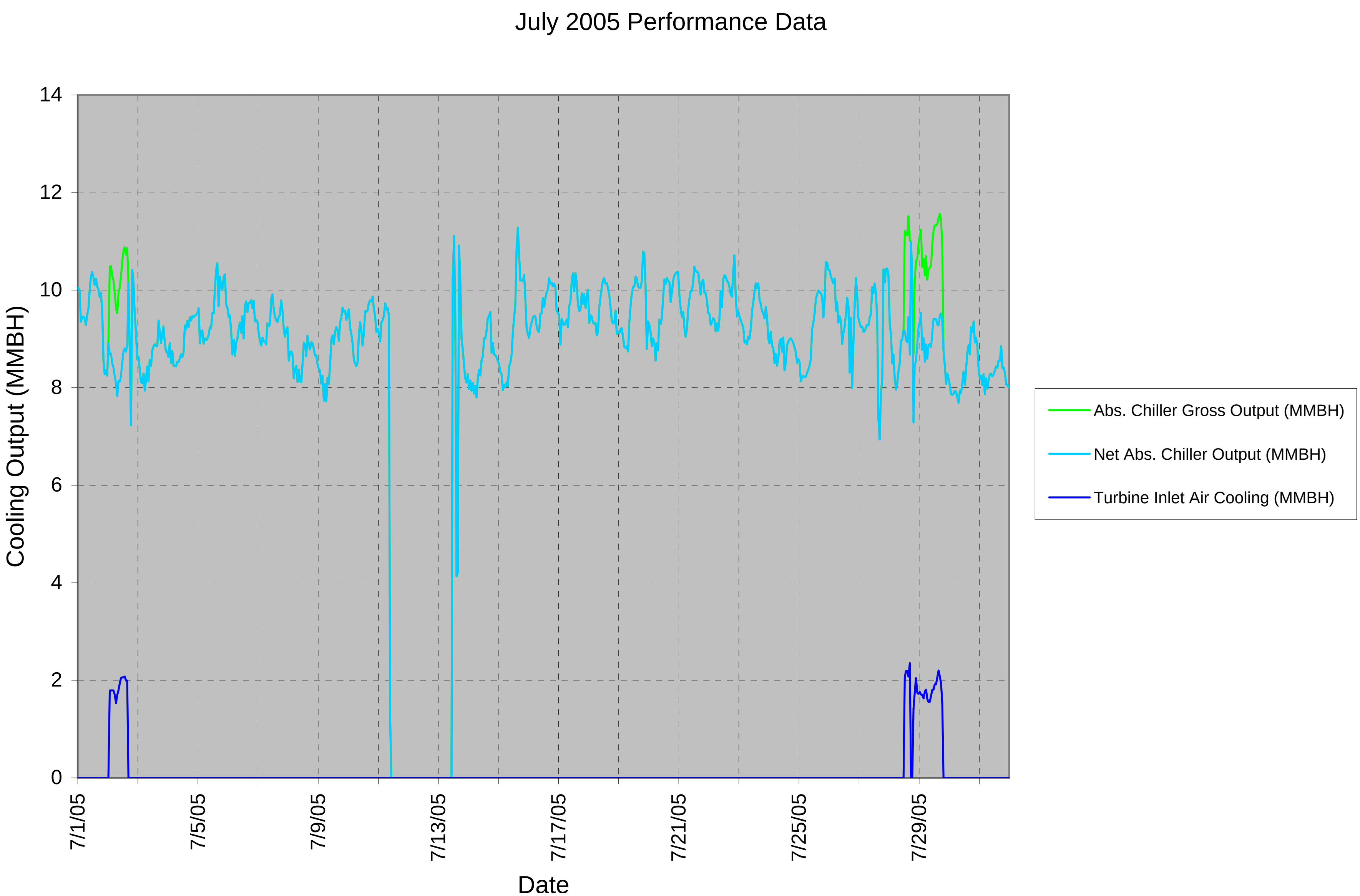
Energy Input



Energy Output



Cooling Output



3.4 Detailed Performance Results: August 2005

Detailed performance results for the month of August 2005, are shown in the table and figures on the following pages.

Field observations noted during the month are:

- The IES system was off-line briefly on August 4, to correct maintenance problems with some of the control wiring.
- The absorption chiller operated simultaneously with the turbine generator during the month.
- Cooling loads were consistently high during the month (daily cycles were evident).
- Flow rates in the chilled water and condenser water loops for the absorption chiller were found to be slightly above design values. These flow rates will be adjusted downward upon system startup in the spring of 2006. Lower flow rates may enable the system to produce a slightly higher maximum cooling output.

Data analysis comments for the month are:

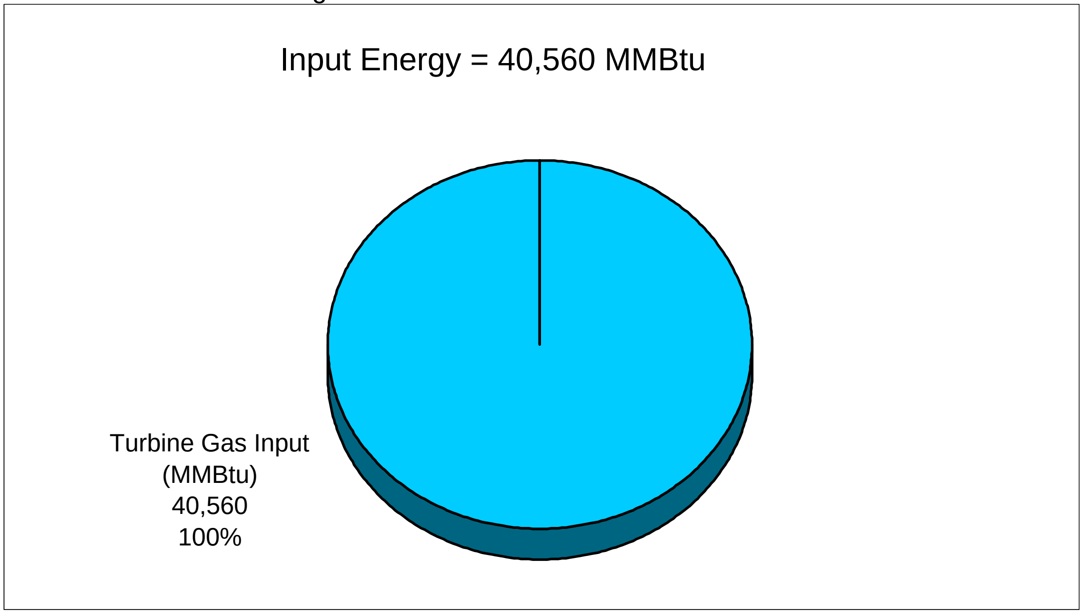
Table or Figure	Analysis Comments
Summary Data Table	The system efficiency was very good again this month, with significant use of recovered energy from the turbine exhaust delivered to the absorption chiller to satisfy high cooling loads.
Monthly Overview	The system's energy performance was very good, due to high cooling loads.
Daily Performance	See comments above.
Turbine Generator Performance	Acceptable performance, however the measured data indicates that the turbine blades had continued to collect dirt thereby reducing performance. As a result, plant operators scheduled a thorough cleaning of the turbine blades that was performed in September. (Note: After the blade cleaning, turbine performance returned to levels equal to the manufacturer's specifications.)
Absorption Chiller Performance	Very good performance, the measured data matches pretty well with the design data (given the expected uncertainty). Some dispersion is seen in the data (due perhaps to greater measurement uncertainty than we had predicted).
Hourly Performance Data	Daily cycles are evident. System efficiency was very good throughout the month.
Energy Input Data	All turbine fuel used was natural gas.
Energy Output Data	Relatively high cooling loads throughout the month, as expected.
Cooling Output Data	Turbine inlet air cooling was used during much of the month.

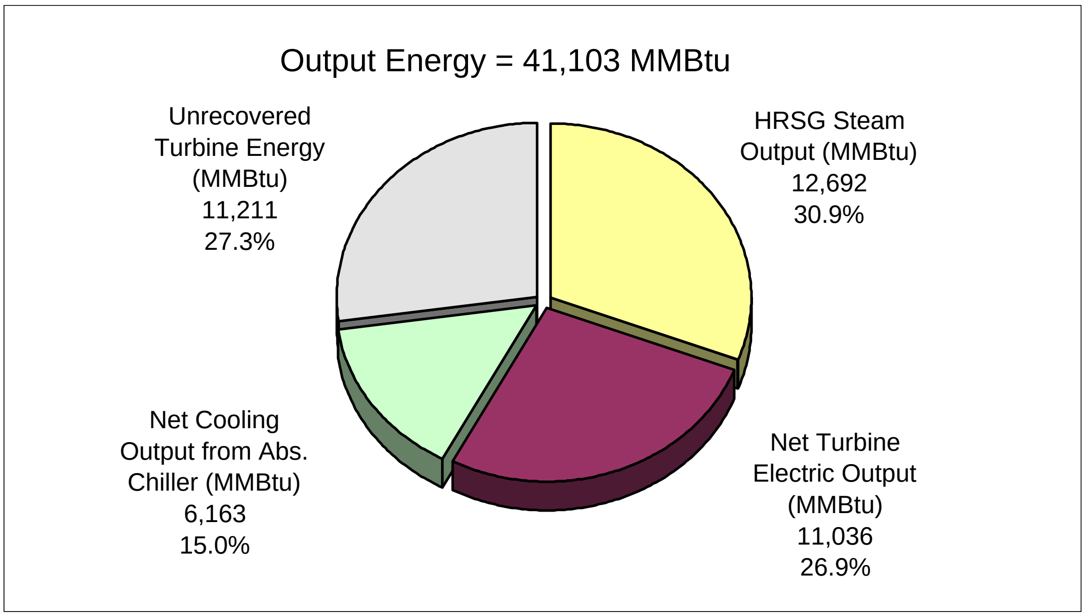
Additional plots of more detailed operating data are presented in Appendix D.

Date	Measured Data										Calculated Results							
Date	Electric Power Gen. (MWh)	HRSG Steam Gen. (lbs.)	Abs. Chiller Output (ton-hours)	Turbine Nat. Gas Cons. (MCF)	Turbine Fuel Oil Cons. (gal.)	Duct Burner Nat. Gas Cons. (MCF)	Turbine Runtime (hours)	Abs. Chiller Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Aux. Electric Chiller Runtime (hours)	Turbine Total Energy Input (MMBtu)	Duct Burner Natural Gas Input (MMBtu)	HRSG Steam Output (MMBtu)	Net Turbine Electric Output (MMBtu)	Net Cooling Output from Abs. Chiller (MMBtu)	Total CHP Output (MMBtu)	Net Daily CHP System Efficiency (%)	Parasitic Energy (MWh)
1-Aug-05	108	398,797	16,096	1,263	0	0	24	24	0	0	1,310	0	425	360	193	978	74.7	2.8
2-Aug-05	107	397,532	17,072	1,252	0	0	24	24	1	0	1,299	0	424	354	205	983	75.6	2.8
3-Aug-05	105	395,190	3,784	1,240	0	0	24	6	0	19	1,286	0	421	349	45	815	63.4	2.6
4-Aug-05	71	221,916	7,901	833	0	0	16	9	11	14	863	0	237	235	81	553	64.0	1.9
5-Aug-05	117	400,169	20,502	1,346	0	0	24	24	0	0	1,395	0	427	390	198	1,015	72.7	3.0
6-Aug-05	116	374,956	19,758	1,337	0	0	24	24	1	0	1,387	0	400	385	192	976	70.4	3.0
7-Aug-05	115	378,873	19,229	1,331	0	0	24	24	0	0	1,380	0	404	382	187	973	70.5	3.0
8-Aug-05	115	387,932	19,183	1,328	0	0	24	24	1	0	1,377	0	414	380	186	980	71.2	3.1
9-Aug-05	116	388,197	19,965	1,339	0	0	24	24	1	0	1,389	0	414	384	193	991	71.4	3.1
10-Aug-05	116	395,189	19,912	1,335	0	0	24	23	1	2	1,385	0	421	384	200	1,006	72.7	3.1
11-Aug-05	112	399,220	21,460	1,307	0	0	24	24	1	0	1,355	0	426	372	222	1,020	75.3	3.2
12-Aug-05	108	391,115	20,538	1,270	0	0	24	24	1	0	1,317	0	417	357	231	1,005	76.3	3.2
13-Aug-05	106	363,381	19,636	1,256	0	0	24	24	0	0	1,302	0	387	352	228	967	74.3	3.0
14-Aug-05	107	384,094	20,616	1,266	0	0	24	24	0	0	1,313	0	409	356	227	992	75.6	3.2
15-Aug-05	104	383,064	19,615	1,244	0	0	24	24	0	0	1,290	0	408	346	224	978	75.8	3.1
16-Aug-05	101	378,063	19,296	1,216	0	0	24	24	0	0	1,261	0	403	334	232	969	76.8	3.1
17-Aug-05	107	382,519	18,887	1,263	0	0	24	24	1	0	1,310	0	408	356	215	979	74.7	2.9
18-Aug-05	115	389,299	20,311	1,324	0	0	24	22	1	0	1,373	0	415	380	202	997	72.6	3.1
19-Aug-05	105	430,013	20,645	1,247	0	0	24	24	0	0	1,293	0	458	347	231	1,036	80.1	3.2
20-Aug-05	98	383,931	19,649	1,192	0	0	24	24	0	0	1,236	0	409	325	236	970	78.5	3.0
21-Aug-05	98	389,223	18,710	1,192	0	0	24	24	0	0	1,237	0	415	325	225	965	78.0	3.0
22-Aug-05	103	395,966	18,015	1,231	0	0	24	24	0	0	1,276	0	422	341	206	970	76.0	2.8
23-Aug-05	110	387,091	20,224	1,287	0	0	24	24	1	0	1,335	0	413	363	211	987	73.9	3.1
24-Aug-05	112	386,253	21,566	1,308	0	0	24	24	0	0	1,356	0	412	372	212	996	73.5	3.2
25-Aug-05	113	393,537	18,384	1,314	0	0	24	24	0	0	1,362	0	420	375	183	978	71.8	2.8
26-Aug-05	112	389,134	17,590	1,312	0	0	24	24	1	0	1,361	0	415	374	169	958	70.4	2.7
27-Aug-05	111	387,050	20,246	1,299	0	0	24	24	0	0	1,347	0	413	369	197	979	72.7	3.1
28-Aug-05	111	385,503	20,897	1,293	0	0	24	24	1	0	1,341	0	411	367	195	973	72.6	3.2
29-Aug-05	107	392,971	19,593	1,262	0	0	24	22	0	0	1,309	0	419	353	193	965	73.7	3.2
30-Aug-05	99	390,087	19,469	1,200	0	0	24	24	1	0	1,245	0	416	328	228	971	78.1	3.1
31-Aug-05	102	386,360	19,689	1,227	0	0	24	24	1	0	1,272	0	412	338	214	964	75.8	3.0
totals	3,327	11,906,622	578,439	39,113	0	0	735	705	26	34	40,560	0	12,692	11,036	6,163	29,891	73.7	92.8

Month Overview

August 2005 Performance Data



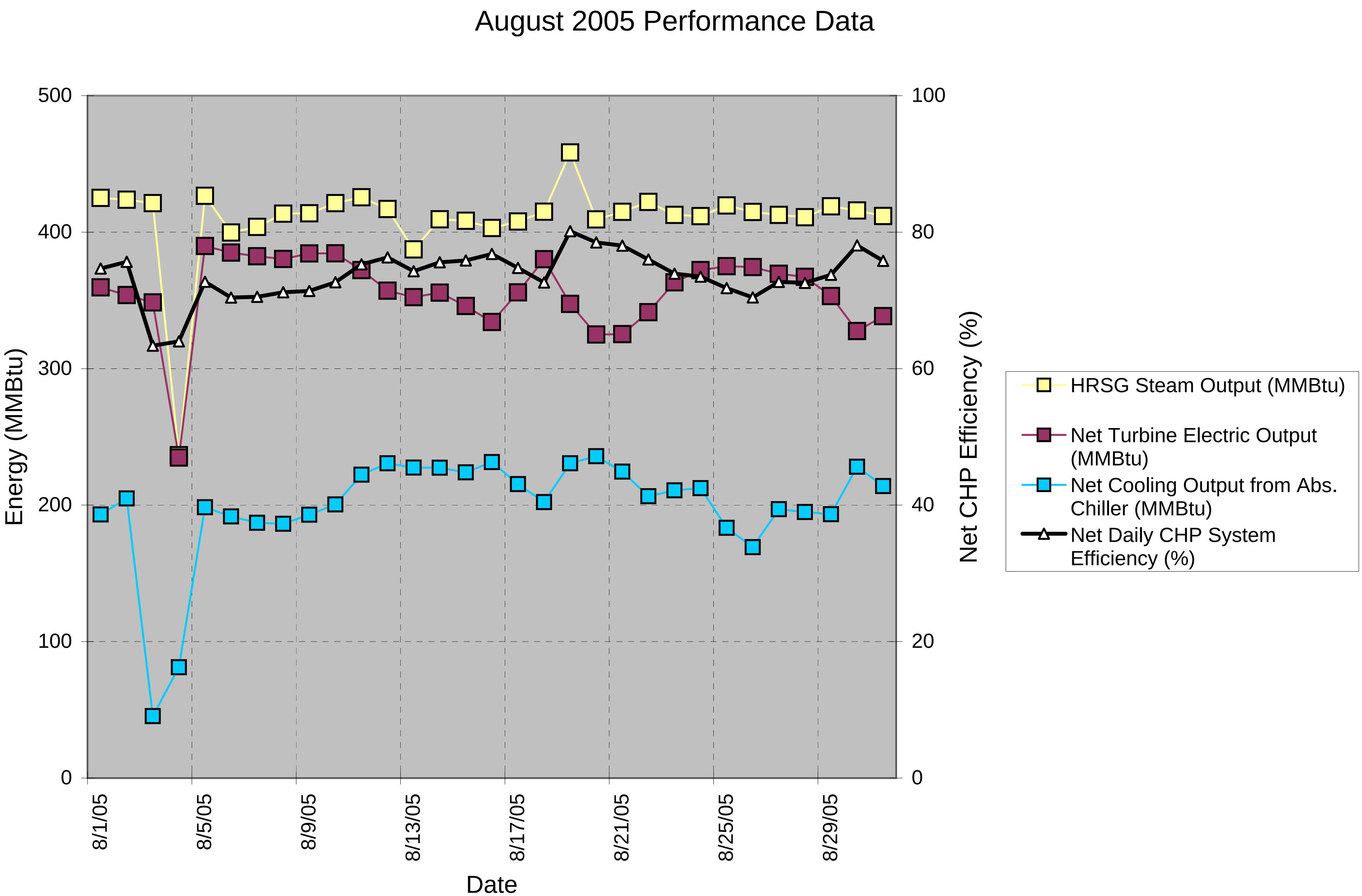


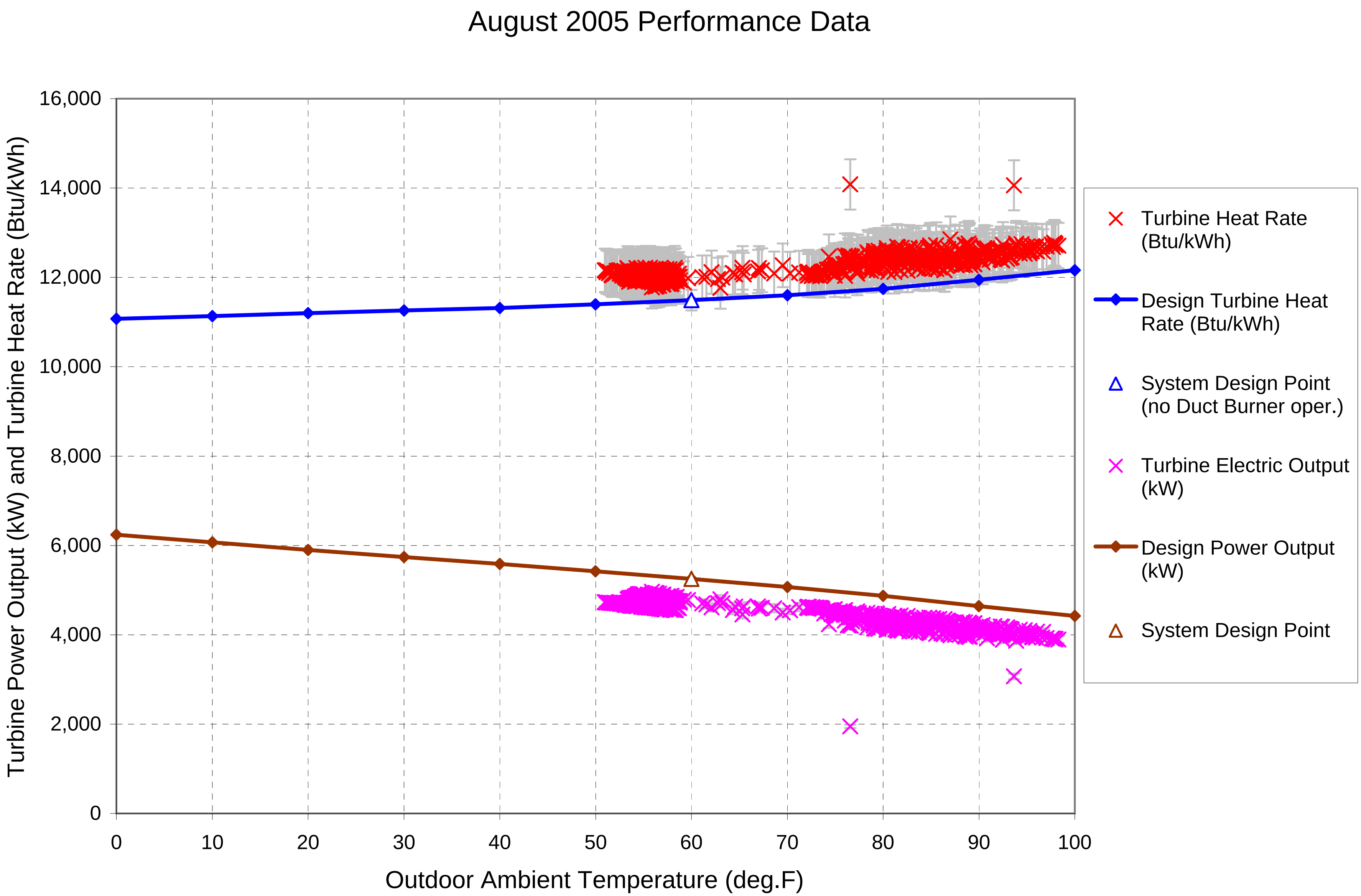
Net CHP Efficiency *

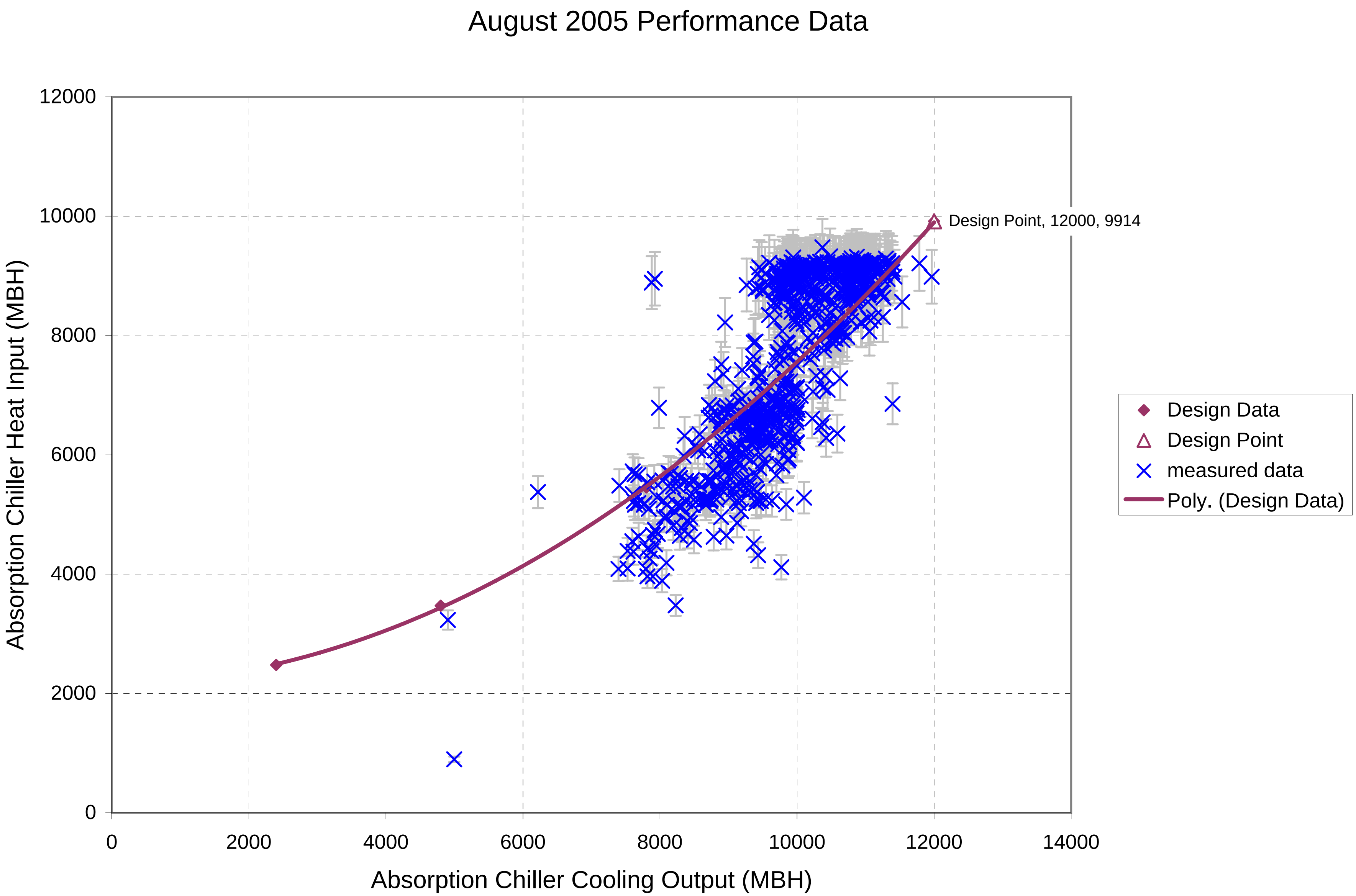
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

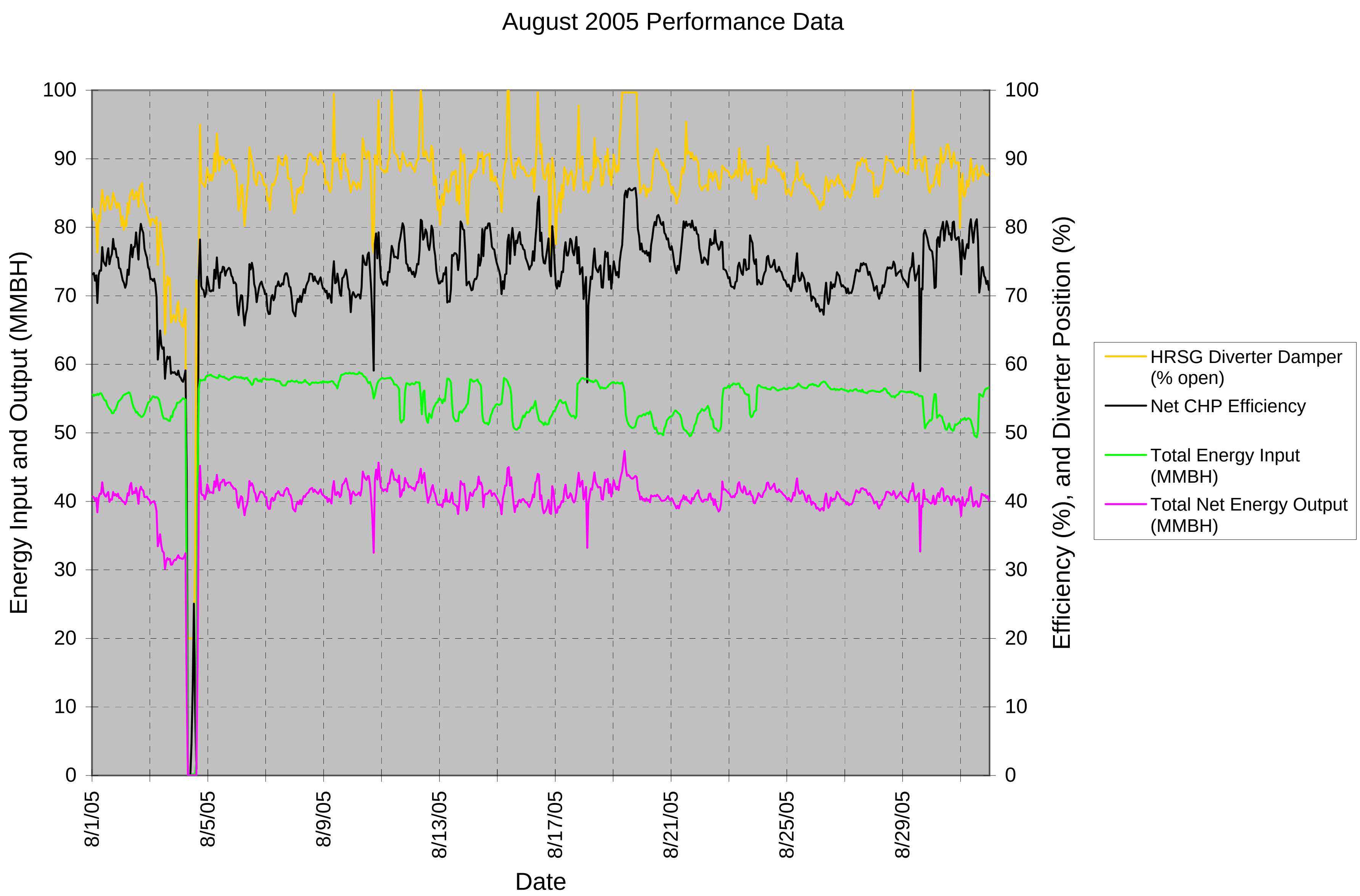
= **73.7%**

* as defined on page 27 of: "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

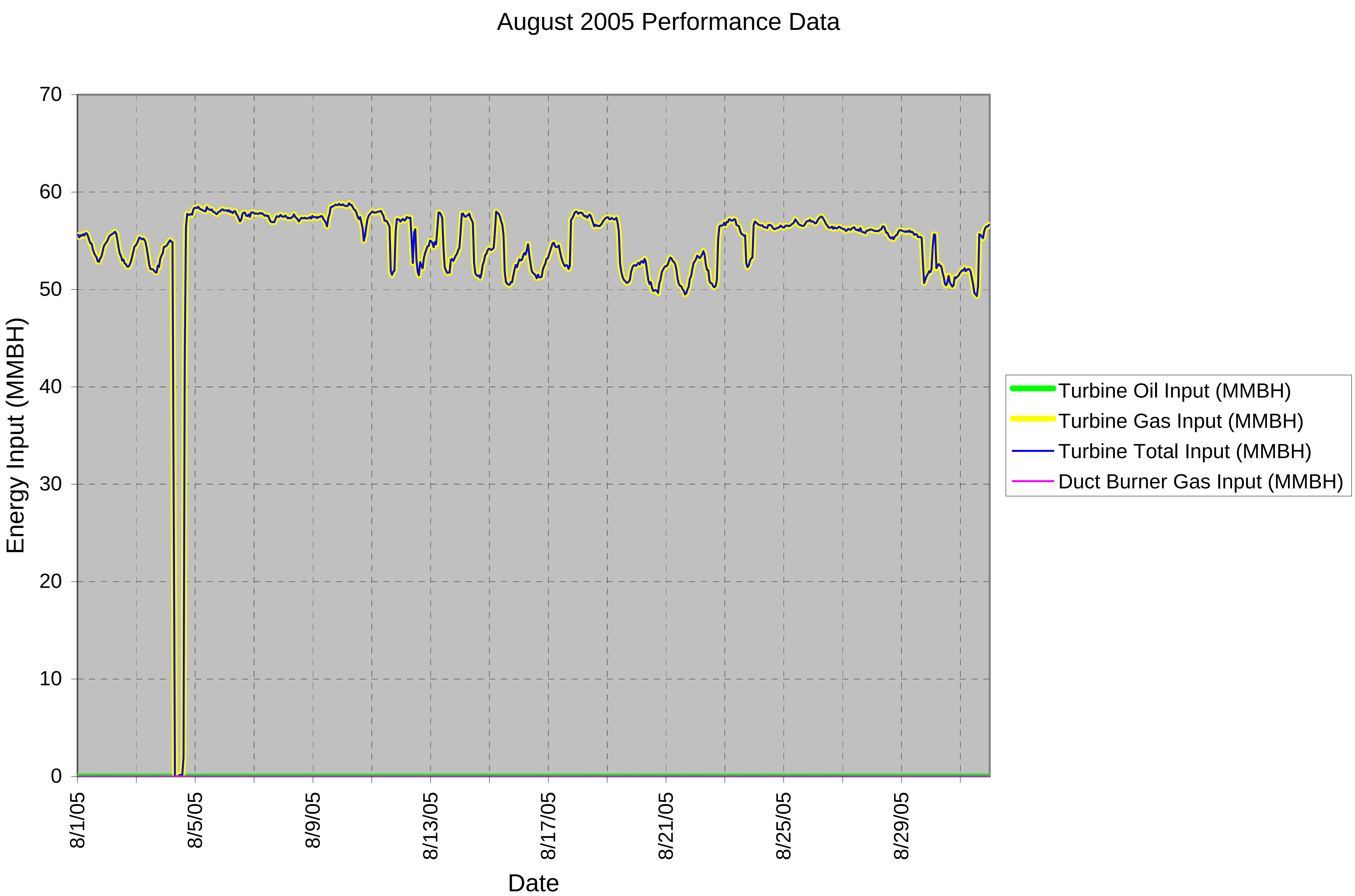

August 2005 Performance Data
500
400
300
200
100
0
100
80
60
40
20
0
Energy (MMBtu)
Net CHP Efficiency (%)
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
Date
HRSG Steam Output (MMBtu)
Net Turbine Electric Output (MMBtu)
Net Cooling Output from Abs. Chiller (MMBtu)
Net Daily CHP System Efficiency (%)


August 2005 Performance Data
Turbine Power Output (kW) and Turbine Heat Rate (Btu/kWh)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Turbine Heat Rate (Btu/kWh)
Design Turbine Heat Rate (Btu/kWh)
System Design Point (no Duct Burner oper.)
Turbine Electric Output (kW)
Design Power Output (kW)
System Design Point

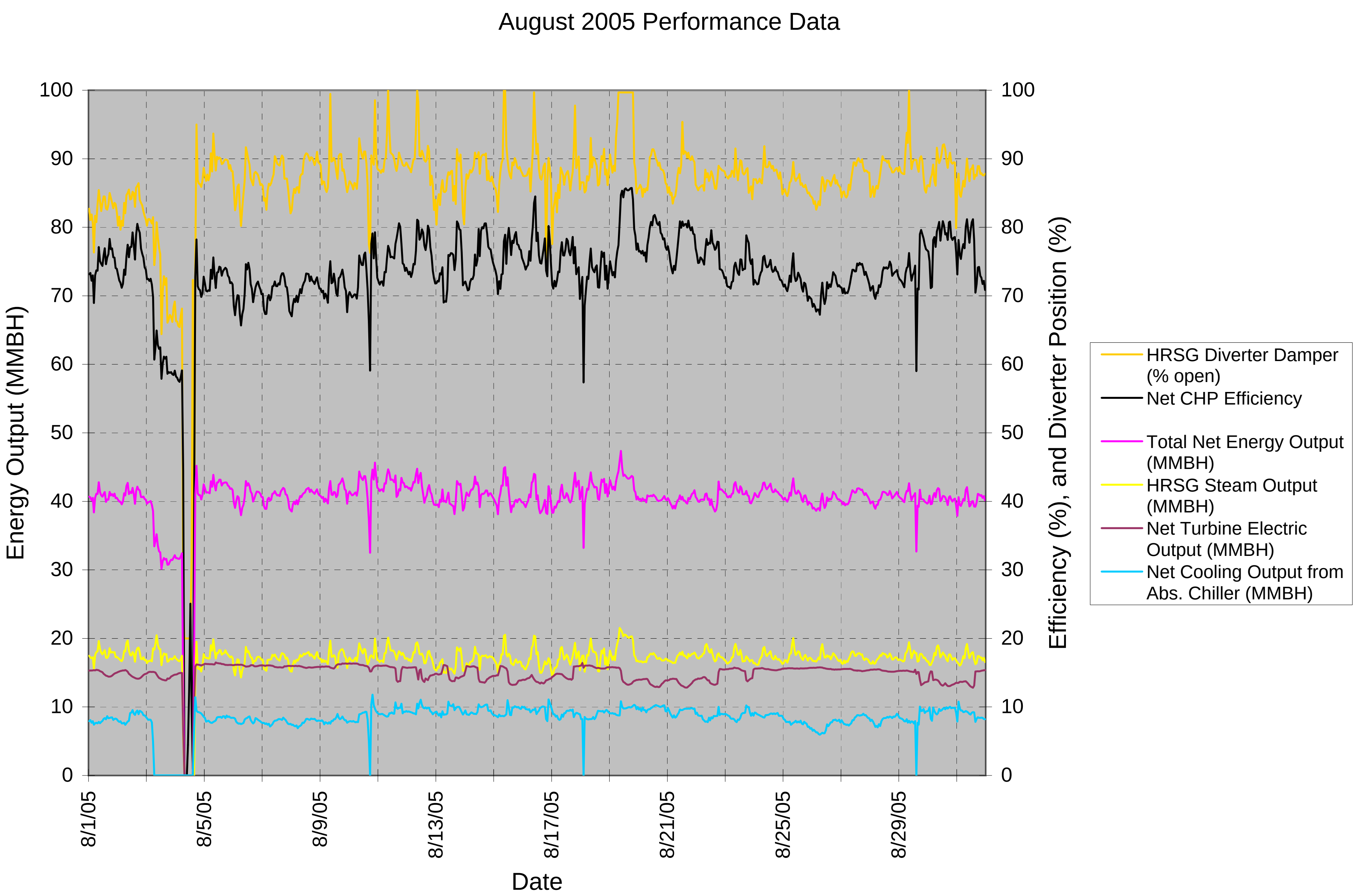

August 2005 Performance Data
Absorption Chiller Heat Input (MBH)
Absorption Chiller Cooling Output (MBH)
12000
10000
8000
6000
4000
2000
0
0
2000
4000
6000
8000
10000
12000
14000
Design Point, 12000, 9914
Design Data
Design Point
measured data
Poly. (Design Data)


August 2005 Performance Data
Energy Input and Output (MMBH)
Efficiency (%), and Diverter Position (%)
Date
100
90
80
70
60
50
40
30
20
10
0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
HRSG Diverter Damper (% open)
Net CHP Efficiency
Total Energy Input (MMBH)
Total Net Energy Output (MMBH)

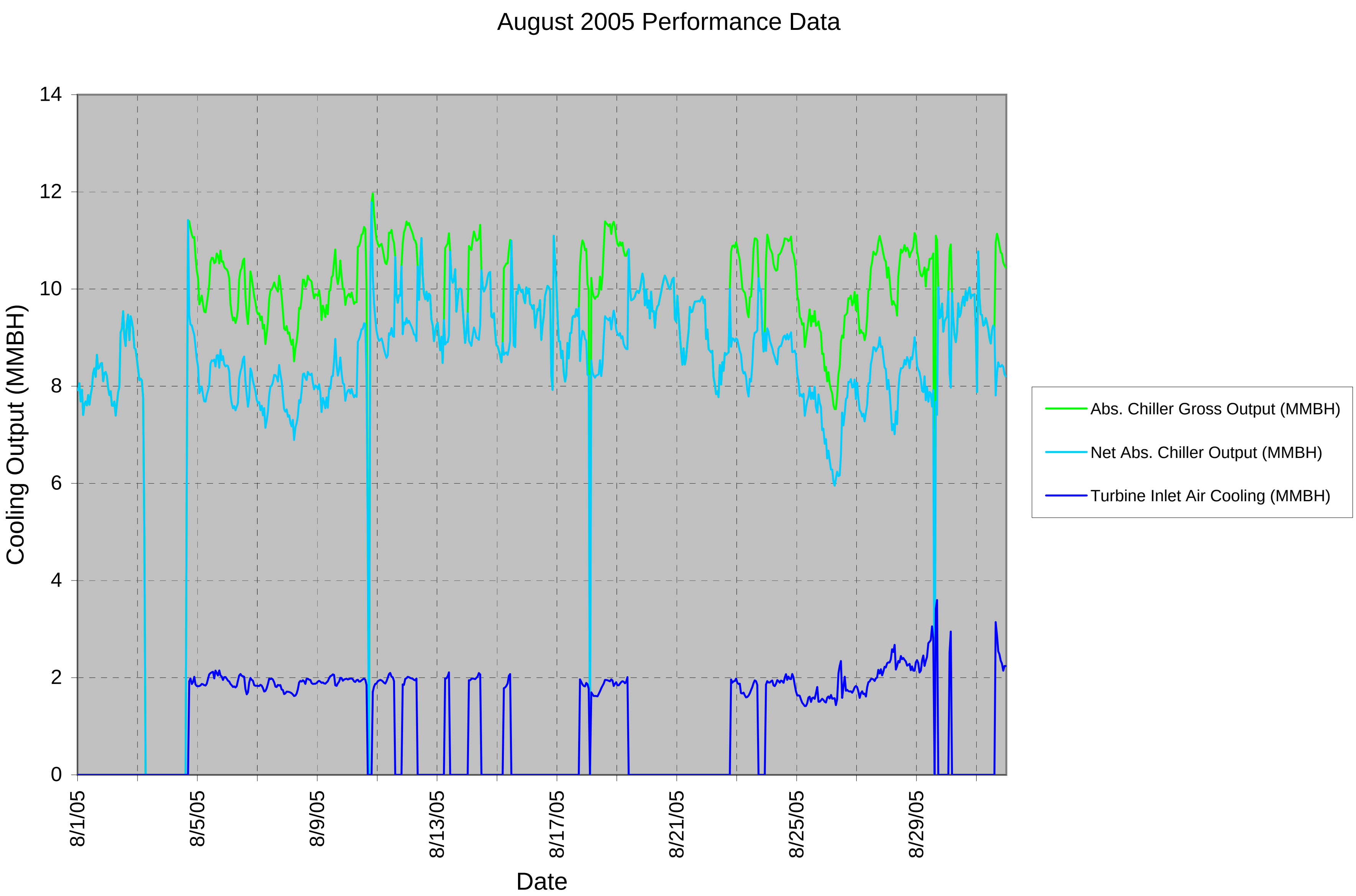
Energy Input



Energy Output



Cooling Output



Section 4. Background Data

The following sections present background information describing the IES system and the data collection and data analysis activity.

4.1 Data Collection and Analysis Approach

Operation of the IES system at the 82nd Central Heating Plant is governed by a conventional SCADA control system implemented using the Honeywell Enterprise Building Integrator (EBI) product. This plant control system is used by operators on a daily basis to control the operation of all plant equipment.

4.1.1 Approach

The technical approach for this data collection and data analysis activity is guided by the process described in the "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org. Our work utilizes this protocol and the field instrumentation that was available at the site when system operations began in mid-2004.

4.1.2 Data Collection

Collection of performance data for this project is accomplished by the Honeywell EBI system, using the same instrumentation that is used to control the plant's operation. This project data is stored in EBI, along with all other plant information (i.e. that is used by the plant operators, and facility managers).

The project team has archived the raw data for use on this project. This archive will be made available to all parties working with, or for, Oak Ridge National Lab and DOE.

4.1.3 Data Format

The performance data is collected and presented as follows:

- This activity addresses hourly data only. The raw field data is in the form of hourly averaged values.
- Use the EBI data in raw form only -- with minimal manual cleaning and filling of the data. This is most representative of how plant operators will use the ASERTTI protocol.
- Hourly data for natural gas consumption is adjusted by applying a correction factor. This adjustment is based on daily logs of manual readings taken from a utility grade gas meter by the plant operators. The correction factor is calculated for the entire month and is then applied to all of the gas consumption data for the month. A new correction factor is computed for the next month.
- The plots generally include all of the measured and calculated data. However, zero values in the calculated data are excluded in most cases (for clarity). The HRSG performance

data is selected for periods when the diverter damper is nearly full open (nearly all exhaust flow thru the HRSG).

- System efficiency calculations are based on lower heating values (LHV) for the fuels used.
- The system net energy efficiency calculations were computed as defined on page 27 of the ASERTTI "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols".

4.2 Instrumentation

A set of instrument points in the EBI system was selected for use in data collection. The list of instrumentation is shown in the following table.

Point Name	Description	Units	Typical Value
AN_Engine_Fired_Hours	Cumulative Operating Hours for Turbine	hours	- - -
AN_Total_Kw	Turbine Generator kW Output	kW	up to 5000
Boiler_5_Status	Aux. Boiler#5 On/Off Status	binary	- - -
HPNG_Flow_A	Natural Gas Flowrate to Turbine	lb per hr.	up to 3000
HRSG_Div_Dmpr	HRSG Diverter Damper Position	% open	- - -
HRSG_Steam_Flow_A	Steam Flowrate from HRSG	lb per hr.	up to 28,000 (unfired), up to 80,000 (fired)
AN_T1_Temperature	Outdoor Ambient Temperature	deg. F	- - -
TurbFOflow_A	Turbine Fuel Oil Consumption Rate	lb per min.	up to 50
AN_Exhaust_Gas_Flow	Turbine Exhaust Flow Rate	lb per hr.	up to 190,000
HRSG_InltDct_Tmp_A	HRSG Exhaust Inlet Temperature	deg. F	up to 990
Deaerator_Temp	Deaerator Temperature	deg. F	up to 190F
Boiler_Outlet_PSI	Steam Header Pressure	psig	120 to 130
C_Chill_Water_Outlet_Temp	Abs. Chiller, chilled water outlet temperature	deg. F	45 to 50
C_Chill_Wtr_Inlet_Temp	Abs. Chiller, Chilled Water Inlet Temperature	deg. F	50 to 55
C_Cool_Wtr_Outlet_Temp	Abs. Chiller, Condenser Water Outlet Temperature	deg. F	85 to 90
C_Cool_Wtr_Inlet_Temp	Abs. Chiller, Condenser Water Inlet Temperature	deg. F	approx. 82
C_Exhaust_Inlet	Abs. Chiller, Exhaust Inlet Temperature	deg. F	45 to 50
C_Exhaust_Outlet	Abs. Chiller, Exhaust Outlet Temperature	deg. F	250 to 300
CH_Guillotine_Open	Abs. Chiller, Exhaust Damper Position	open / close	- - -
CTF-2A_Speed	Cooling Tower Fan Motor Speed	%	up to 100
CTF-2B_Speed	Cooling Tower Fan Motor Speed	%	up to 100

4.3 ASERTTI Background

An overview of the ASERTTI "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" is shown on the following pages.

ASERTTi

ASSOCIATION OF STATE ENERGY RESEARCH AND TECHNOLOGY TRANSFER INSTITUTIONS

Distributed Generation Testing Protocols and Performance Database With an Emphasis on Combined Heat and Power Applications

Distributed Generation Testing Protocols

Distributed generation (DG) systems offer significant benefits such as reduced line losses and improved combined heat and power (CHP) capability. However, the lack of accurate, unbiased performance data impedes their implementation. To address this need, protocols are being developed for laboratory testing, field testing, long-term monitoring, and case studies of microturbines, reciprocating engines, and small turbines up to 3 MW.

The laboratory test, field test, and long-term monitoring protocols establish procedures for assessing the electrical, thermal, and environmental performance of DG-CHP systems. In addition to this, field test protocols and long-term monitoring protocols specify procedures to evaluate the operational performance (reliability, availability, maintainability, and durability) of the DG-CHP systems. Case study protocols investigate financial as well as certain qualitative aspects of DG-CHP systems.

Interim protocols have been developed and are available for downloading as PDF files. Download Acrobat Reader.

- Laboratory Testing Protocol (PDF 1.2 MB)
- Field Testing Protocol (PDF 1.2 MB)
- Long-term Monitoring Protocol (PDF 286 KB)
- Case Study Protocol (PDF 392 KB)

The timeline for developing the final version of the protocols and first-stage lab and field data collection is from early 2003 through early 2005. Protocol development is funded by the U.S. Department of Energy, the California Energy Commission, the Energy Center of Wisconsin, the New York State Research and Development Authority, and the Illinois Department of Commerce and Economic Opportunity. State organizations are working through the Association of State Energy Research and Technology Transfer Institutions. The U.S. Environmental Protection Agency is also providing support through a separate working relationship.

Distributed Generation Performance Database

A Distributed Generation performance database is being developed to store DG performance test reports for you to review and download. The database will also store sets of high-level data that you can query to view a snapshot of the results of each test, making it easy to select test reports of interest to you. No final reports will be available for long-term monitoring sites because they do not have an end date. High-level data for these sites will be available and will be updated monthly to reflect the latest site operation. For more detailed data about long-term monitoring sites, users will be provided a link to a Web site run by the company in charge of continuously collecting and storing data from these sites.

Additional Information

Related Websites

Expanded Protocol Descriptions

Laboratory and Field Test Protocols

Laboratory test protocols cover microturbines from 10 to 250kW capacity, and reciprocating engines and small turbines up to 3 MW. The laboratory performance testing is done for a specific set of limited conditions, and allows more efficient fine-tuning and evaluation than is possible in the field. Laboratory data will have inherently greater accuracy than field data, and as a result, and provides the basis against

which field protocols can be checked.

Field Testing Protocol

The field test protocol was designed for microturbines as well as reciprocating engines up to 7MW capacity. Field test protocols for small turbines up to 7MW capacity as well as fuel cell laboratory and field protocols will be developed in a future effort, as funds are identified. The field performance testing is for a wider set of equipment configurations and operating conditions than laboratory testing, some of which cannot be controlled to the same degree of accuracy as they are in the laboratory.

Long-term Monitoring Protocol

Like field testing, long-term monitoring (LTM) of DG/CHP unit performance is done at real-world applications; unlike field testing, LTM is expected to be in effect continuously without an explicit completion date. The instrumentation stipulated by the protocol is intended to be a permanent part of the system; and so the cost to support LTM is a more important consideration.

Case Study Protocol

Selected LTM sites will be assessed in project case studies. Case studies are unique because their goal is to assess financial measures (e.g. energy cost, equipment cost) and certain qualitative aspects (e.g. major reasons to install DG/CHP, lessons learned from the installation) of DG/CHP performance.

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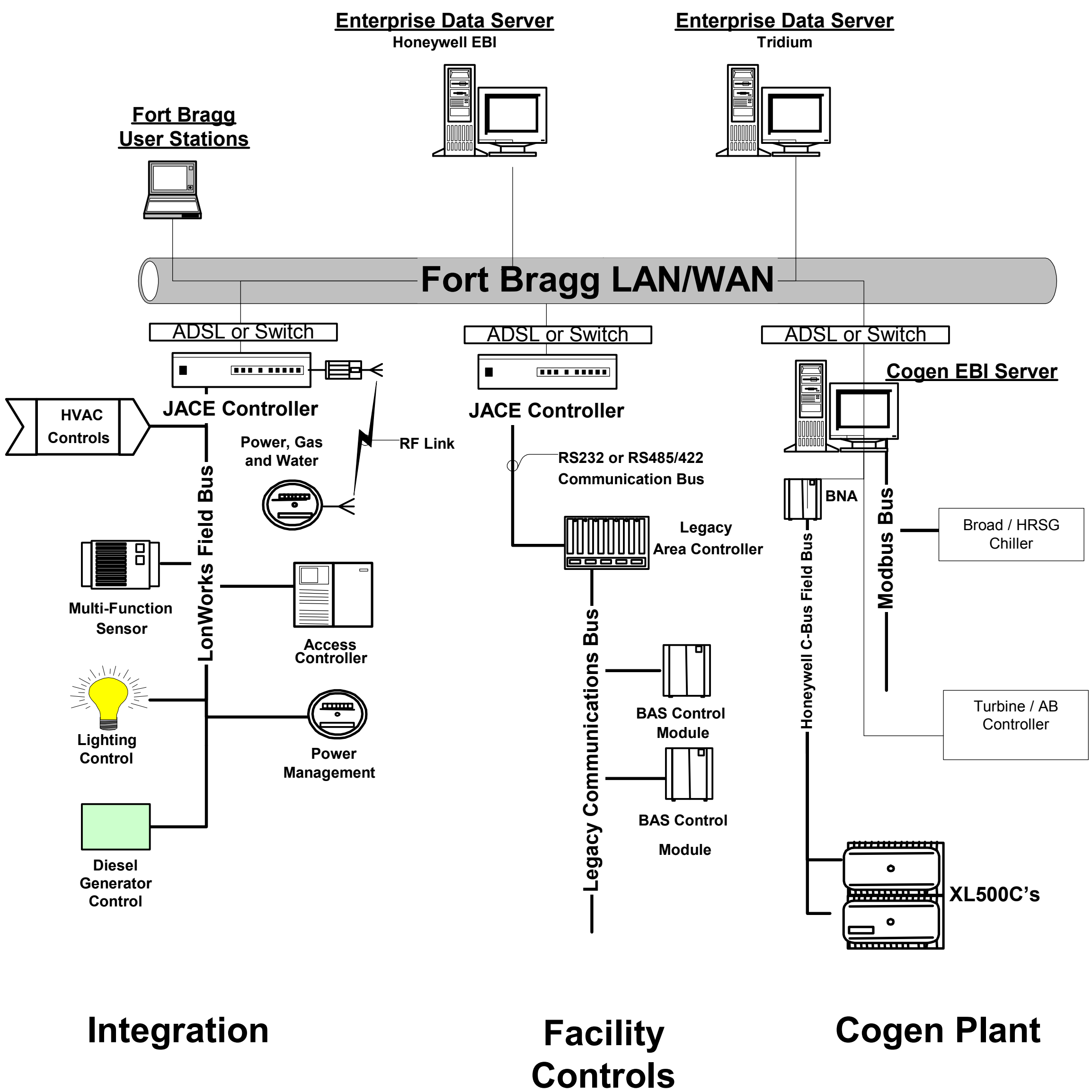
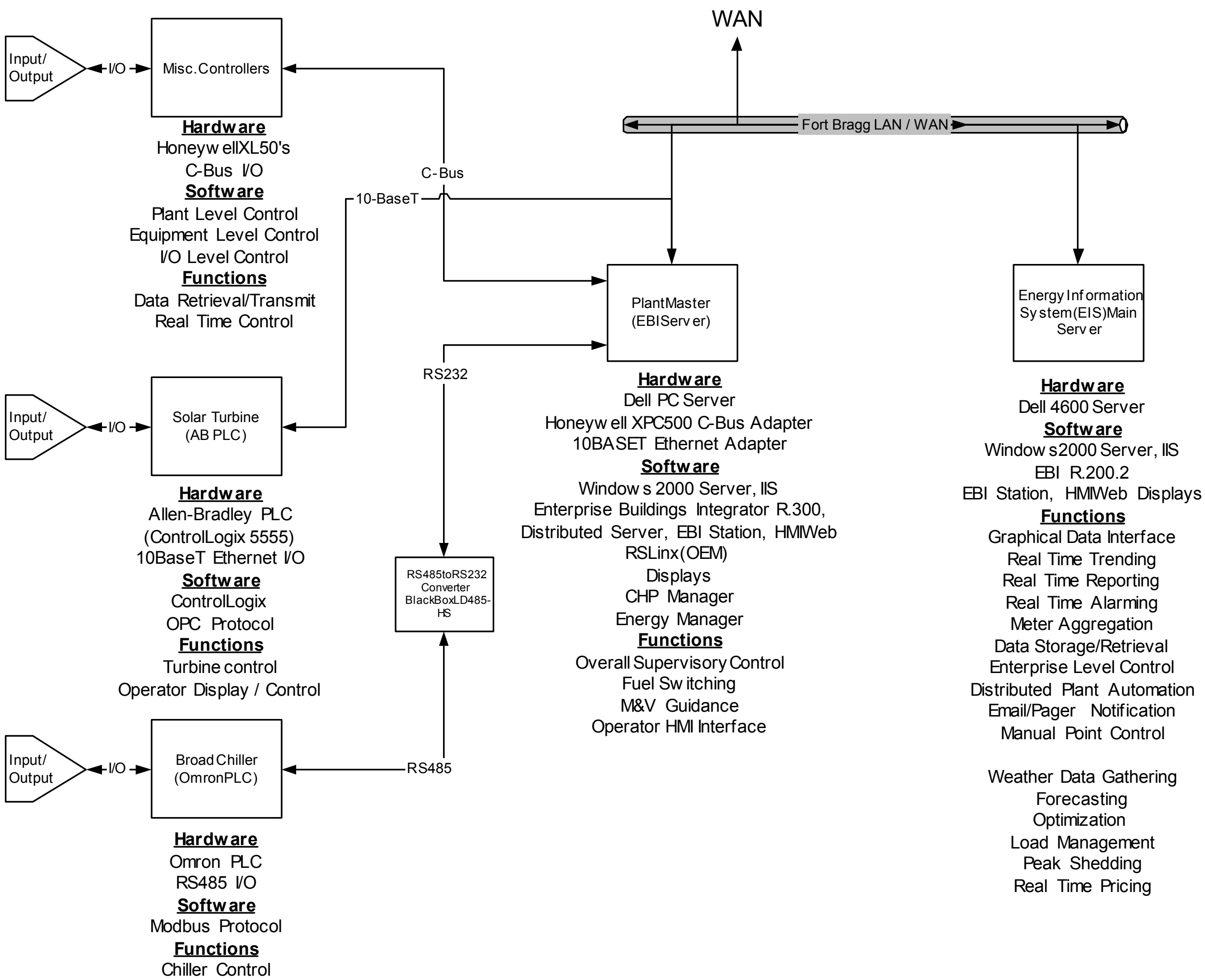
Content Last Updated: 03/01/2005

4.4 Plant Control System Overview

A top level overview of the Ft. Bragg energy information system (including the 82nd Heating Plant CHP system "CoGen Plant" controls) is shown in the following figure.



A top level overview of the 82nd Heating Plant CHP control system is shown in the following figure.



4.5 Measurement Uncertainty

The measured data and calculated data have been evaluated for measurement uncertainty according to the guidelines offered in the ASERTTI protocols. The approach taken is as follows:

- Measured data is taken from the Plant Control System as hourly average readings (computed from sensor data sampled at six minute intervals).
- Measured data errors are estimated as a composite of error sources (sensor, transmitter, analog input electronics, sensor calibration, etc.).
- All errors are defined as relative error, in % of reading.

Estimates of the measured and calculated data uncertainties are presented in the following tables.

Given Data	Estimated Error	Source
HPNG_Correction	0.5%	comparison with manual readings of utility-grade gas meter
Gas_Density	1.0%	data from gas supplier
Gas_LHV	2.0%	data from gas supplier
Oil_LHV	1.5%	data from fuel oil supplier
Oil_Density	1.0%	data from fuel oil supplier
Thermal_Content	2.0%	manual off-line calculation based on monthly averages of measured steam pressure and temperature of feedwater
Chilled_Water_Flow	3.0%	manual differential pressure measurements at the pump and Abs. Chiller heat exchanger, with comparisons to mfr. specifications

Measured Data	Estimated Error	Source
HPNG_Flow	3.0%	field instrumentation
TurbFO_Flow	3.0%	field instrumentation
HRSGSteam_Flow	3.0%	field instrumentation
TurbineGenerator_kW	2.0%	internal turbine generator instrumentation, (uncertainty also accounts for outdoor ambient temperature effects, as applied to turbine output plots)
Chiller_Exhaust_Flow	5.0%	field instrumentation, uses ID fan power measurement with correlation to measured exhaust flows on-site

Calculated Data	Estimated Error	Source
GasFuel_Input	3.8%	(HPNG_Flow)*(HPNG_Correction)*(Gas_Density)*(Gas_LHV)
OilFuel_Input	3.5%	(TurbFO_Flow)*(Oil_LHV)/(Oil_Density)
HRSGSteam_Output	3.6%	(HRSGSteam_Flow)*(Thermal_Content)
Chilled_Water_Temp_Difference	1.4%	(CHWR_Temp – CHWS_Temp)
Chiller_Exhaust_Temp_Difference	1.4%	(Exh_Inlet_Temp - Exh_Outlet_Temp)

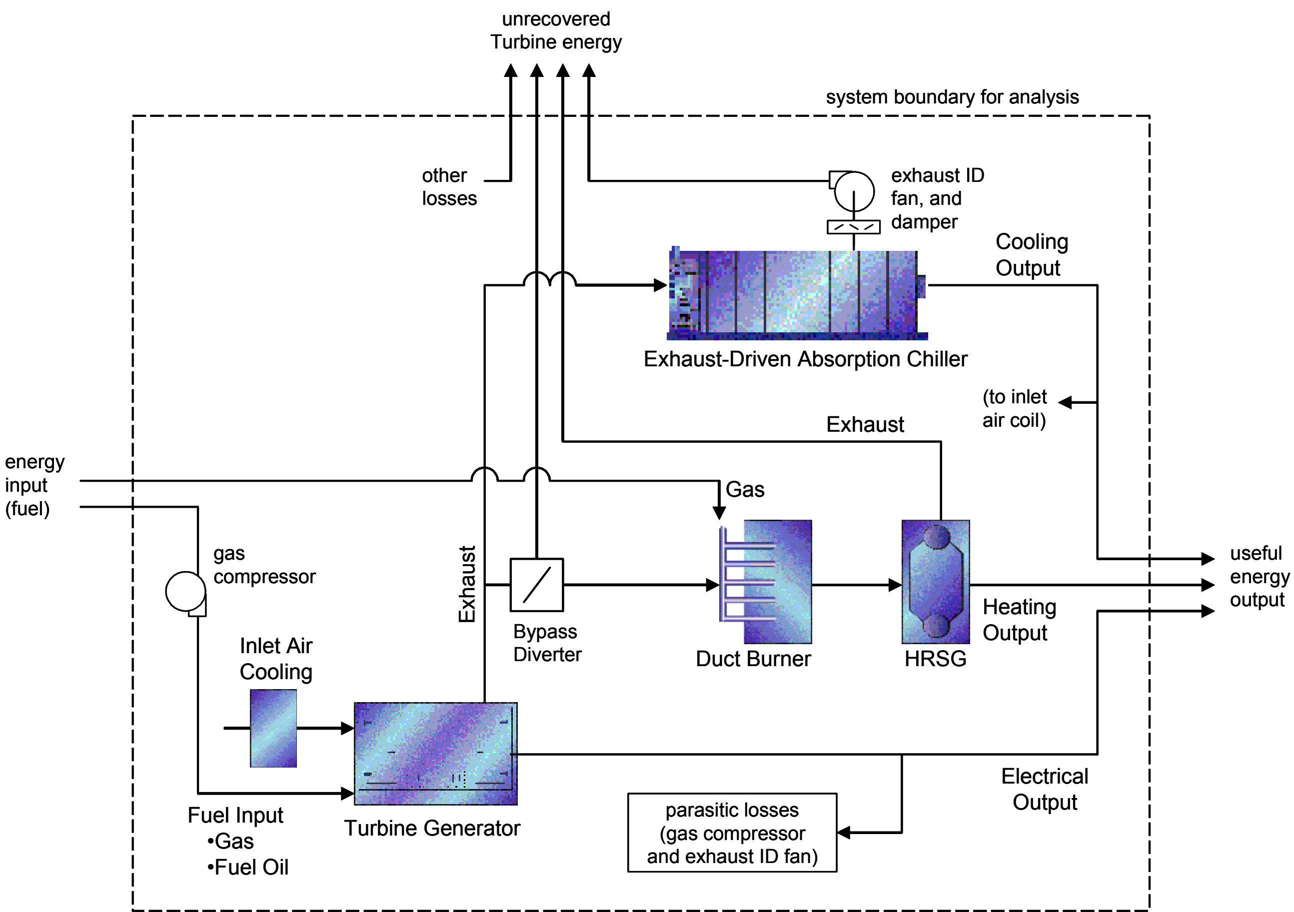
Calculated Results	Estimated Error	Source
Cooling_Output	3.3%	(Chilled_Water_Temp_Difference)*(Chilled_Water_Flow)
Chiller_Heat_Input	5.2%	(Chiller_Exhaust_Temp_Difference)*(Chiller_Exhaust_Flow)
Turbine_Heat_Rate	4.3%	(GasFuel_Input)/(TurbineGenerator_kW), or (OilFuel_Input)/(TurbineGenerator_kW)
MeasuredSystem_Energy_Effectiveness	5.2%	(Energy_Output)/(GasFuel_Input), or (Energy_Output)/(OilFuel_Input)

4.6 Data Analysis

Elements of the data analysis approach are described in the following paragraphs.

4.6.1 Analysis Block Diagram

A system block diagram showing the system data analysis boundaries is shown in the figure below. The definition of system efficiency is shown in the figure.



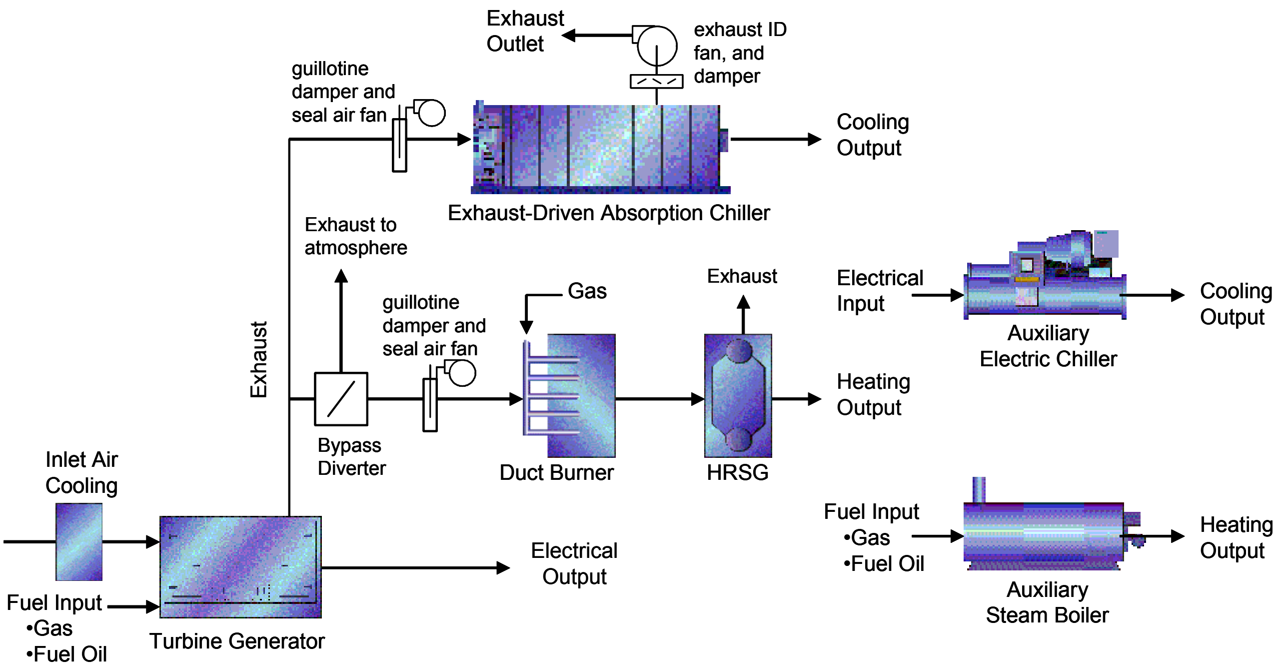
4.6.2 System Energy Efficiency

The definition of system efficiency is shown below.

$$\textit{System Efficiency} = \frac{\textit{useful energy output}}{\textit{energy input (fuel)}}$$

4.7 System Description

A block diagram of the Ft. Bragg 82nd Central Heating Plant IES system is shown in the figure below.



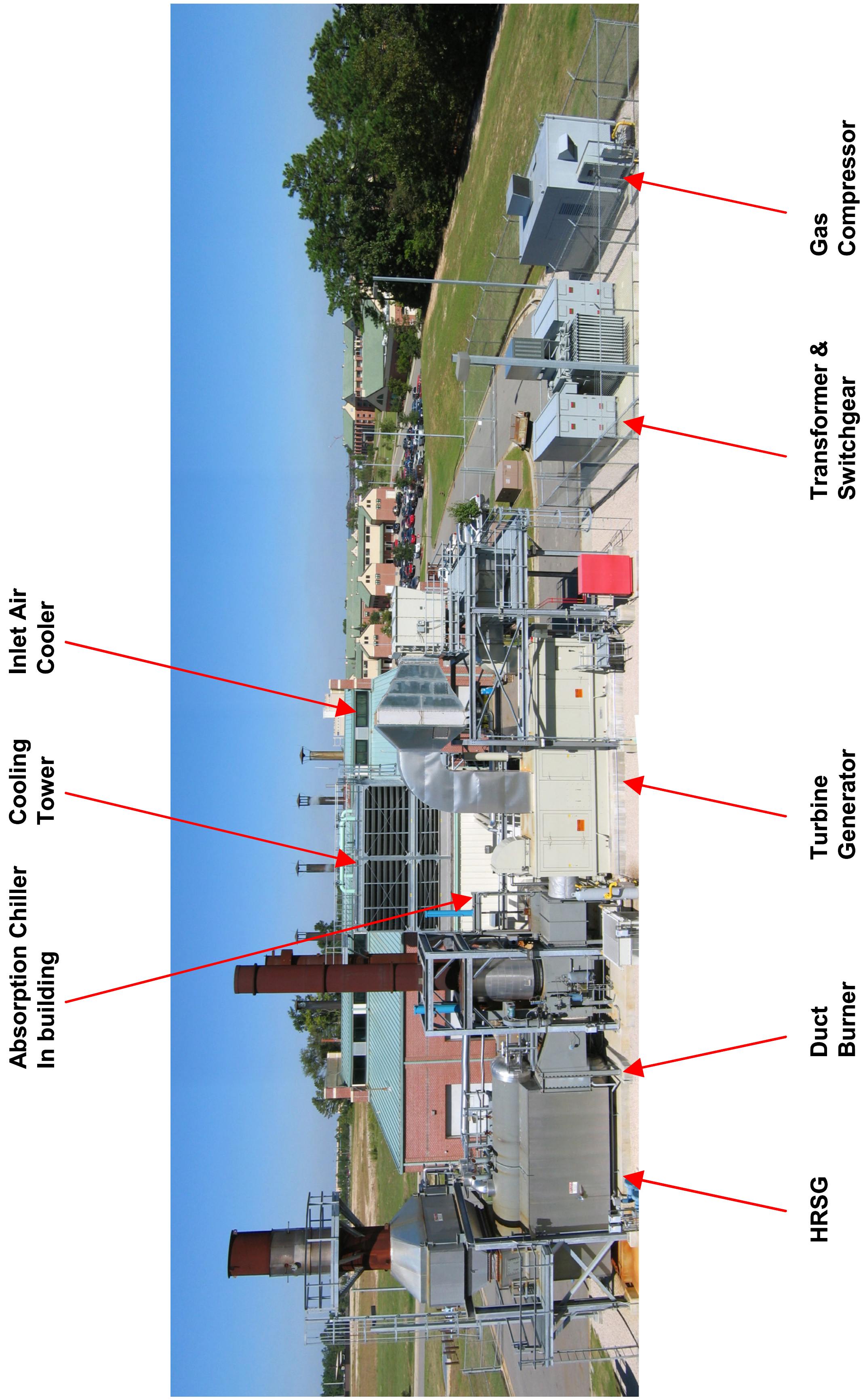
The major IES equipment in the system is described in the following table.

Equipment	Description
Gas Turbine	one Solar Turbines, Taurus 60 dual-fuel gas turbine (4160 volt, 3 phase, nominal 5MW electrical output), with SoLoNox burner technology www.solarturbines.com
Absorption Chiller	one Broad Air Conditioning, 1000 tons capacity, exhaust-driven, 44F/54F CHW design, 85F/95.2F CDW design www.broadusa.com
Heat Recovery Steam Generator (HRSG)	one Rentech Boiler Systems, type "O" shop-assembled, 28,700 pph at 125psig (unfired), 81,200 pph (fired) www.rentechboilers.com
Duct Burner	Coen, rated at 55.2 MMBH on natural gas www.coen.com

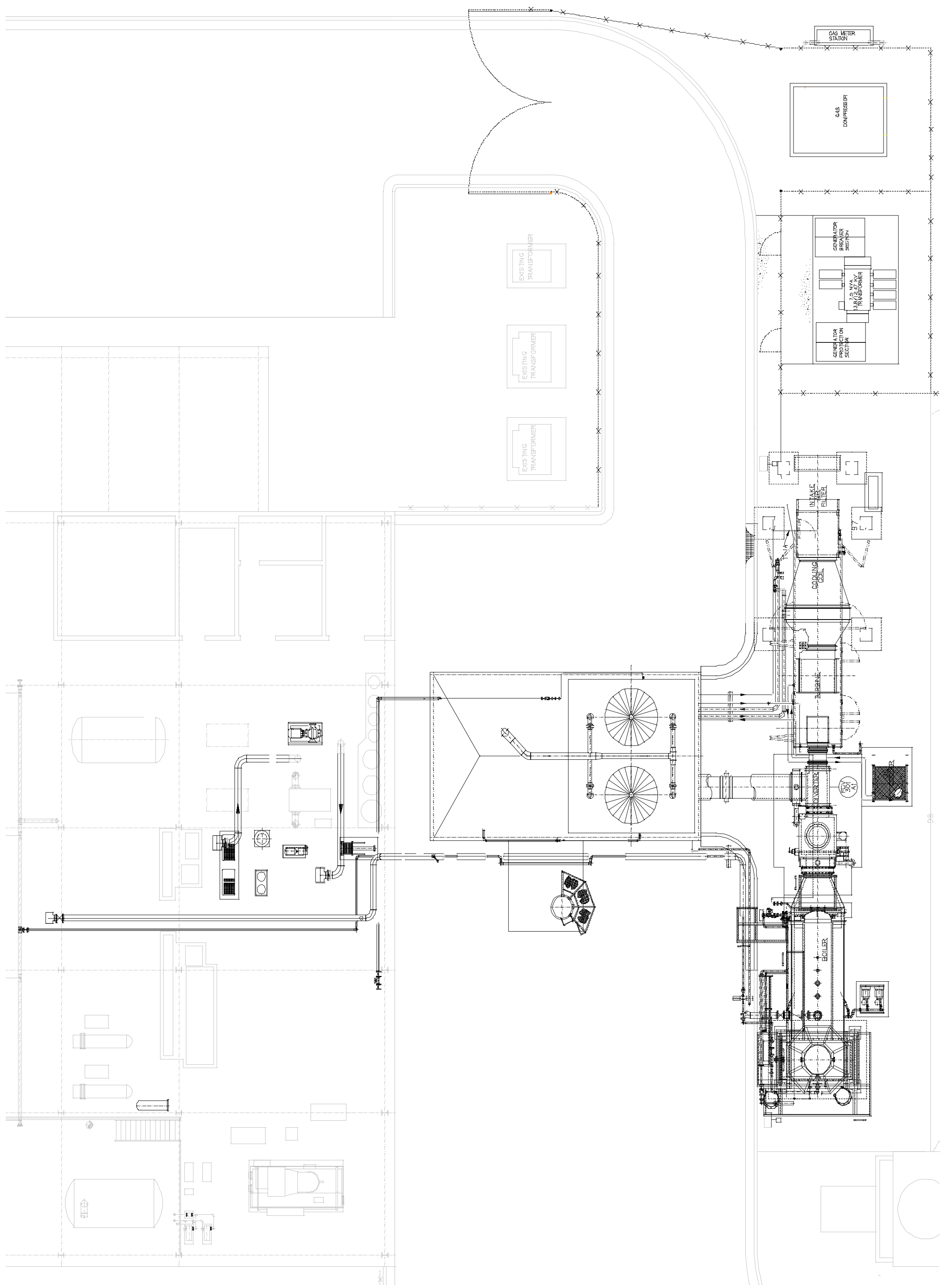
The major auxiliary equipment in the system is described in the following table.

Equipment	Description
Boiler	English, rated at 60,000 pounds of steam per hour, 125 psig
Electric Chiller	Trane, 800 tons nominal capacity

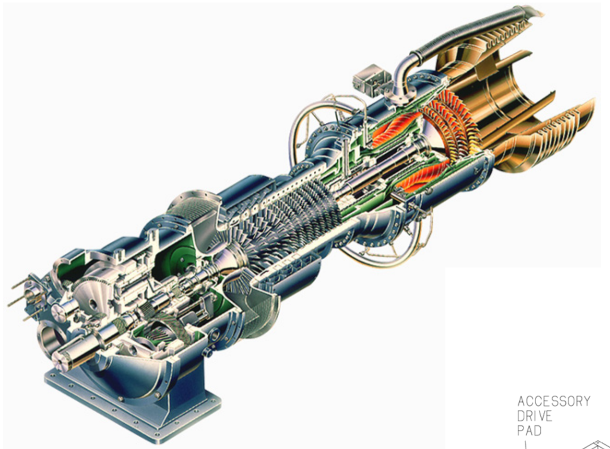
The equipment installation is shown in the photo below.

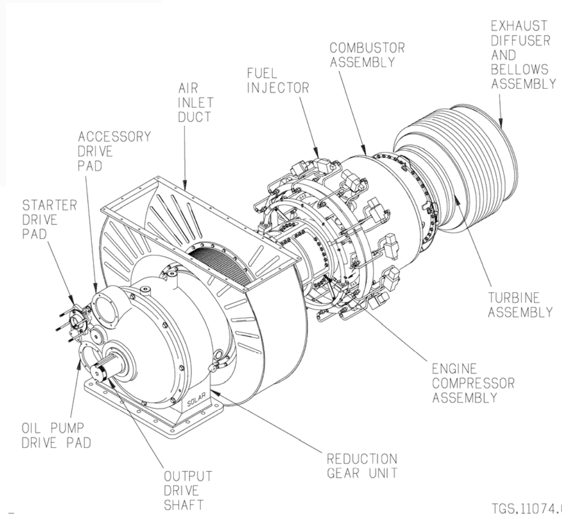


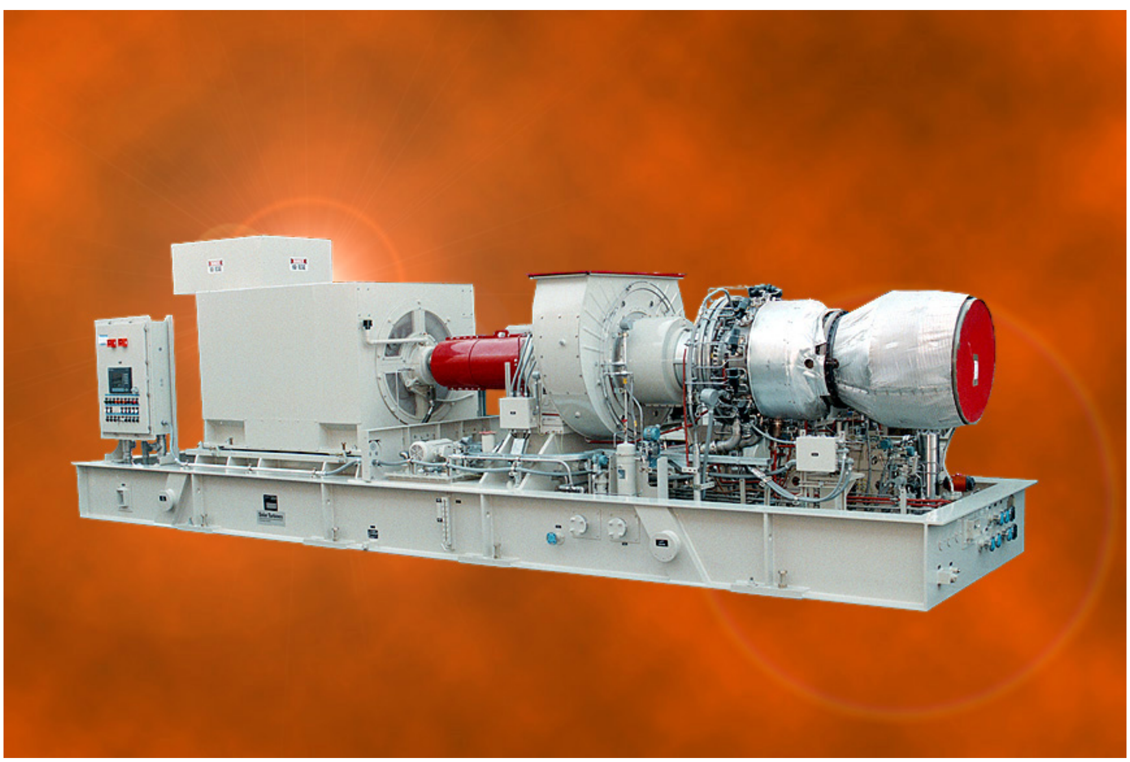
The physical arrangement of the equipment is shown in the figure below.



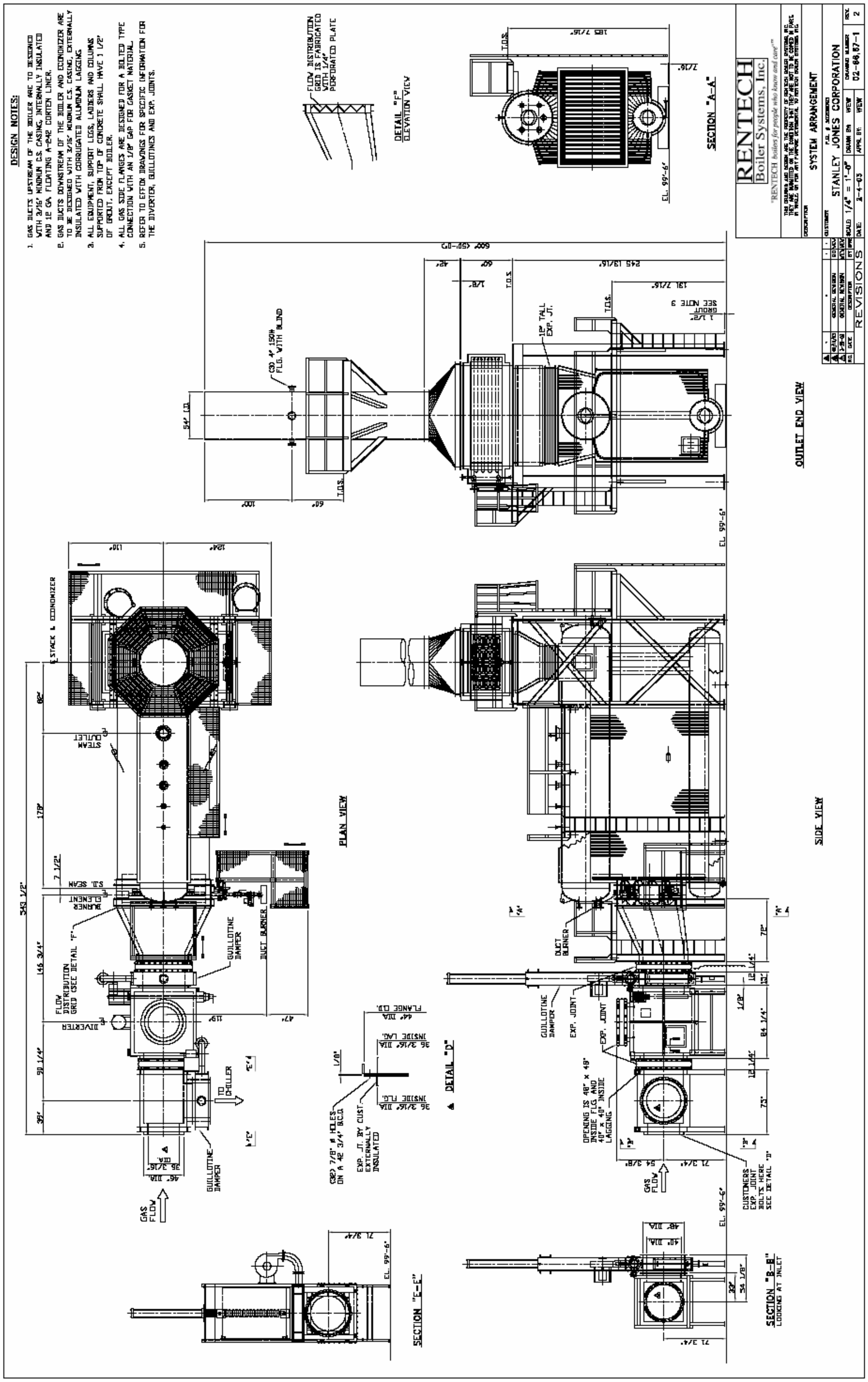
The details of the turbine generator are shown in the figures below.





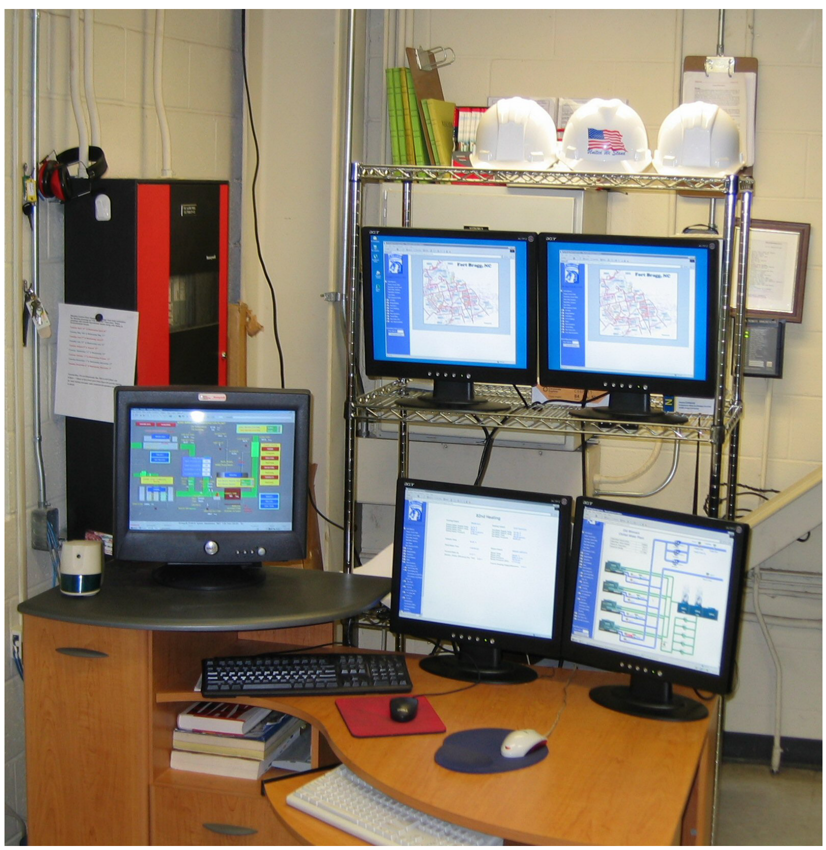


The details of the heat recovery generator are shown in the figure below.



The absorption chiller is shown in the figure below.

A photo of the EBI control system at the 82nd Heating Plant is shown below.



The EBI plant control system is tied into the Honeywell Energy Information Center at Ft. Bragg. A photo of this operations center is shown below.

4.8 Site Description

The following sections present a background description of the IES project at Ft. Bragg.

4.8.1 Technical Description

The site for this system is the 82nd Central Heating Plant at Ft. Bragg, NC, which is the largest of 14 central plants on the post. This IES system is an important element of the Army's strategy to improve energy efficiency and reduce operating cost at Ft. Bragg. The project was a combination of an Energy Savings Performance Contract (ESPC) between the Army and Honeywell (providing the turbine generator, HRSG, and other components), and the IES R&D project funded by the DOE's Office of Distributed Energy Resources and administered by Oak Ridge National Laboratory (providing the absorption chiller and advanced controls). Data gathering and technical support was provided by Federal Energy Management Program (FEMP).

The 82nd plant provides district heating and cooling to serve a large number of barracks and other buildings with 125psig steam for heating, 170 deg. F. hot water (converted from steam), and 44 deg. F. chilled water for cooling. The plant originally contained five large water tube steam boilers. Four of these boilers were poorly performing, unreliable and in need of replacement. This condition provided an excellent application for installing an integrated energy system (or cooling, heating, and power system).

The IES system's major equipment consists of a 5MW gas turbine generator, a heat recovery steam generator (HRSG), and a 1000 ton exhaust-driven absorption chiller. The IES equipment is fired with natural gas, and can also be fired with fuel oil as a backup fuel source. The plant also includes an auxiliary steam boiler and an auxiliary electric centrifugal chiller, for backup or to provide additional capacity when required. The IES system has an electrical generating capacity of 5250 kW, and a heating capacity of 28,700 lbs. per hour of steam at nominal ambient conditions (60 deg. F.). The plant serves a year-around heating load for domestic hot water and food service needs. Space heating loads are served during the fall and winter months. Cooling is provided during the spring, summer, and early fall.

The IES system operates in a base load condition, essentially offsetting some of the electric demand on the post. The balance of the electric load is purchased from the local electric utility. During periods of low heating load, the heating demand is less than the maximum thermal output of the IES system. During periods of high heating load, the auxiliary duct burner is employed to increase the output of the HRSG. At present, all of the cooling load for the building served can be satisfied by the 1000 ton absorption chiller.

The IES system is operated in a number of different load-following strategies, based on achieving the best economic performance. The appropriate operating strategy is determined by an on-line optimization function that is resident in the plant's supervisory control system. The optimizer guides the plant operator by recommending the optimal setpoints for electric power generation, heating, and cooling equipment.

This project is a key contributor to the post's Force Protection and energy security initiative. The on-site generation capacity of this IES system is a valuable asset that can be used to mitigate the effects of utility plant outages and other disruptions on the electrical grid.

4.8.2 Relevance to Federal Energy Policy

This project helps the post meet the requirements of Executive Order 13123 "Greening the Government Through Efficient Energy Management", dated June 1999. The project satisfies the objectives of the following sections of the Executive Order:

Section	Order Instructions	Project Relevance
Sec. 206 Source Energy	"The Federal Government shall strive to reduce total energy use and associated greenhouse gas and other air emissions, as measured at the source. To that end, agencies shall undertake life-cycle cost-effective projects in which source energy decreases, even if site energy use increases. In such cases, agencies will receive credit toward energy reduction goals through guidelines developed by DOE.."	The project's advanced natural gas fired gas turbine produces electric power with lower emissions than many existing coal-fired central power plants.
Sec. 403 (a) Financing Mechanisms	"Agencies shall maximize their use of available alternative financing contracting mechanisms, including Energy-Savings Performance Contracts and utility energy-efficiency service contracts, when life-cycle cost-effective, to reduce energy use and cost in their facilities and operations."	The project was financed thru an Energy Savings Performance Contract (ESPC).
Sec. 403 (g) Highly Efficient Systems	"Agencies shall implement district energy systems, and other highly efficient systems, in new construction or retrofit projects when life-cycle cost-effective. Agencies shall consider combined cooling, heat, and power when upgrading and assessing facility power needs and shall use combined cooling, heat, and power systems when life-cycle cost-effective."	The project employs a combined cooling, heat, and power design to provide highly efficient operation.

4.8.3 Environmental and/or Non-Energy Benefits

By converting fuel into both electrical and thermal energy, this system improves the overall energy efficiency of the 82nd plant. The electricity produced displaces some of the power that was previously purchased from the local electric utility, generated in part at coal-fired power plants. The related transmission and distribution losses are avoided thru the use of on-site generation. Emissions are effectively decreased by reducing the need for utility-provided power from coal-fired central plants. In addition, this IES system reduces emissions by replacing the poorly performing steam boilers at the 82nd Plant. The turbine generator employs state-of-the-art low NOx burners that offer excellent emissions performance, with NOx emissions measured at less than 25ppmv under steady-state operating conditions. This emissions performance provides a significant reduction over the approximate 290 ppm NOx emissions produced by the existing steam boilers.

The poor condition of the existing steam boilers had resulted in significant water make-up and chemical treatment costs. Frequent cycling of these boilers also resulted in significant blowdown effluent, contributing to water treatment loads on the post. The IES system eliminates these problems and associated impacts on the post's sanitary sewer and wastewater treatment systems. These changes will benefit the post's efforts to improve the performance of its wastewater treatment plant and its effluent water quality.

4.8.4 Honeywell Energy Services at Ft. Bragg

Background description of Honeywell's energy services activity at Ft. Bragg is shown on the following pages.

4.8.5 Project History

The key dates in the history of the project are:

- Design Phase & Approvals: 2002 and early 2003
- Construction: 3Q2003 and 1Q2004
- Startup and Commissioning: 2Q2004
- Commercial Operation: June 1, 2004

Honeywell Helps Fort Bragg Save $31 Million in Energy Costs

Energy Savings Performance Contract cuts total energy costs by 25%, Improves Quality of Life for 44,000 Soldiers and their Families.

Fort Bragg, an 84-year-old U.S. Army post in Fayetteville, N.C., has plenty to brag about. It's one of the largest Army installations in the world and has been designated as an Army Community of Excellence. It's also home to the 18th Airborne Corps, the 82nd Airborne Division, Special Forces Command, and numerous other commands, as well as 44,000 soldiers and their families.

Fort Bragg's approach to energy management also is a point of pride. In 2003, the post's comprehensive Energy Management Modernization Program delivered $8.131 million in savings; more-efficient energy management, using 162,993 fewer million British thermal units (MMBTU); and improved comfort for soldiers and their families.

Led by the Fort Bragg Directorate of Public Works (DPW), the program is providing a business model for other organizations seeking to maximize implementation of Department of Defense energy and privatization policies. It employs a unique public-private energy services team structure, aggressive supply-side energy management, and upgrade projects to maximize efficiency, reliability and customer service.

Bringing Together Public and Private Resources

Three powerful elements created the program's foundation for success: an integrated public-private structure, staff member understanding and support, and measurement of results for continuous improvement. The DPW staff consists of 315 employees and provides public works functions at the post. Over the past two years, DPW put key contractors in place to help manage Fort Bragg's operations, including Honeywell for energy services.

ESPC as a Tool for Modernization

Fort Bragg's Energy Savings Performance Contract (ESPC) with Honeywell is an example of the public-private partnerships that have made the Energy Modernization Management Program succeed at Fort Bragg. "Fort Bragg and Honeywell developed a key partnership that has resulted in energy savings and quality of life improvements to our installation," said Gregory Bean, DPW director.

Fort Bragg has cut total energy costs by more than 25 percent. The ESPC program has netted more than $31 million in energy costs savings enabling over $66 million in capital investments for Fort Bragg at no additional operating cost to the government. No small feat for an Army post with almost 30 million square feet of facilities.

Since the partnership began in the late 90s, Honeywell has undertaken more than 23 major projects to reduce energy consumption and costs at Fort Bragg. These include:

- Expanding the post's limited underground natural gas distribution system with a new system that provides extended natural gas use at the post.
- Installing new, high-efficiency, natural gas-fired steam and hot-water boilers to replace one of the post's outdated central steam plants.
- Improving working conditions by converting warehouses, vehicle maintenance facilities and hangers from forced induction heating to radiant heating.

- Upgrading the central plants with new chillers, cooling towers, variable frequency drive motors and new controls, and providing full-service maintenance.
- Extending existing post-wide HVAC automation to DDC controls to provide 24- hour control and monitoring of mechanical systems.
- Replacing aging and oversized centrifugal chillers with ones that use a third of the energy.
- Installing high-efficiency lighting, including lamps and ballasts, throughout the post.

The ESPC team also tackled costs on the energy supply side. Honeywell assisted Fort Bragg in obtaining new rate structures with local gas and electric utilities, earning substantial savings for the post. Since 2001, for example, Fort Bragg has been able to claim more than $5.4 million per year in savings through supply-side management.

Capturing Supply-Side Savings

Capturing supply-side savings is a crucial part of the ESPC equation.

"We provide the means to capture supply-side savings, so Fort Bragg can re-invest excess savings into its infrastructure and improve quality of life for soldiers," says Steve Craig, the lead energy services liaison with federal customers at Honeywell.

The most unique project funded through supply-side savings to date is the installation of an energy information system (EIS) or energy control "cockpit." EIS is a centralized computer terminal center that monitors utility consumption at Fort Bragg from more than 256 meters, remotely controls central plant and facilities equipment, automatically operates peak shaving generators, and provides reporting and data collection for billing of Fort Bragg's reimbursable customers.

More Improvements to Come

Significant savings have been achieved at Fort Bragg and more are anticipated in the future. PWBC will continue to pursue projects that support and improve the program, including:

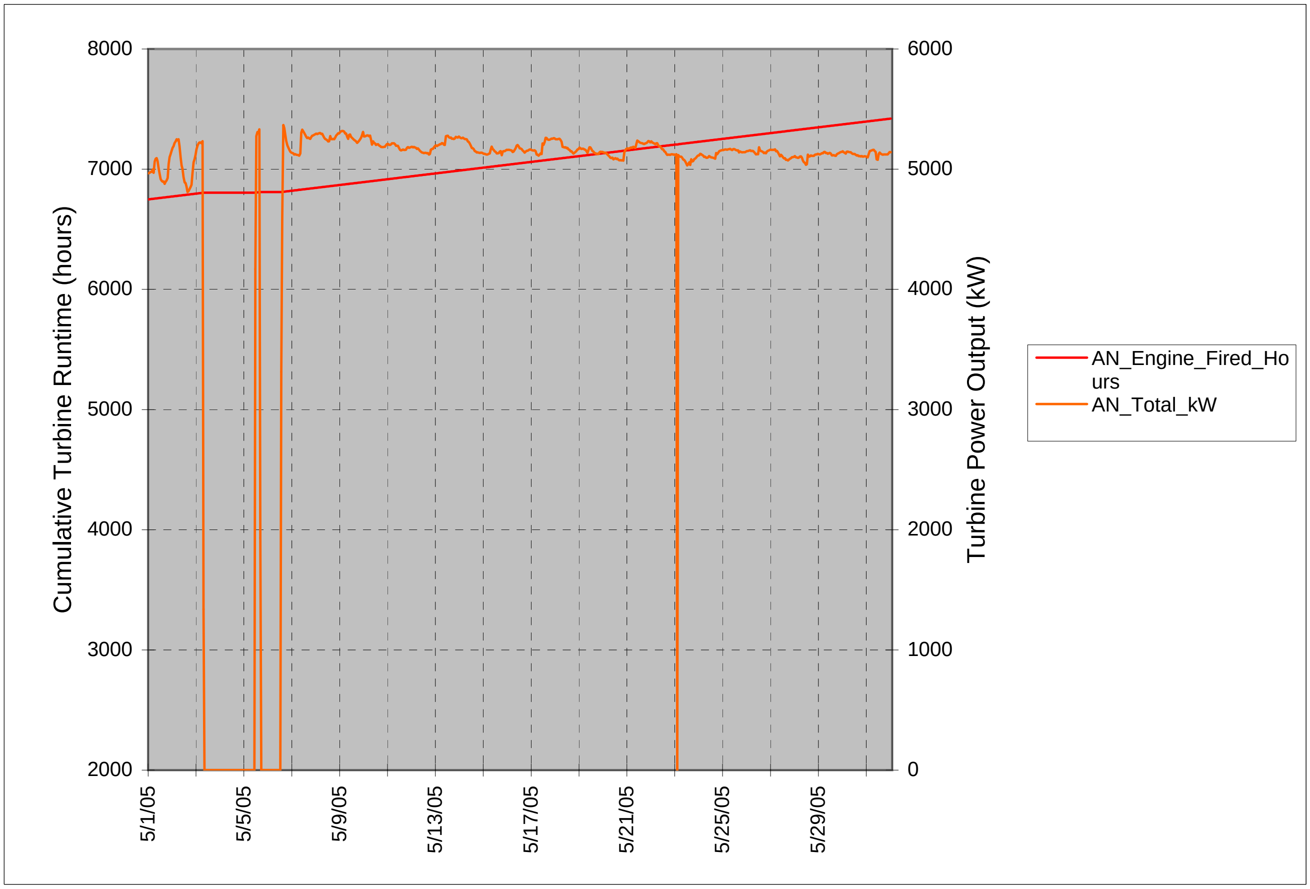
- An $11 million, five megawatt (MW) co-generation cooling, heating and power plant was installed to reduce Fort Bragg's energy costs by an additional $1.5 million annually and provide on-site generation to support the hospital or other critical loads. Honeywell and several technology partners won a Department of Energy grant to support this demonstration project.
- With the aid of Sandhills Utility Services and Honeywell, PWBC is actively working to upgrade the high voltage delivery system and add onsite generation to ensure power reliability and quality.
- PWBC also has begun enacting enhanced maintenance and operations activities at its largest plant that will cut fuel consumption by $350,000 annually.
- PWBC is in the early phases on integrating the numerous utility management (SCADA) systems into a comprehensive facility management system.

For more information on Honeywell's Energy Services, visit
http://www.honeywell.com/sites/acs/buildingsolutions.htm
http://www.honeywell.com/sites/honeywell/casestudy3_cat181ec08-fbaa1ed448-3e3e4447ab3472a0c2a5e5fdc1e6517d_H47CFA9EB-85A0-6872-89A0-EAE6F3FBF15C.htm

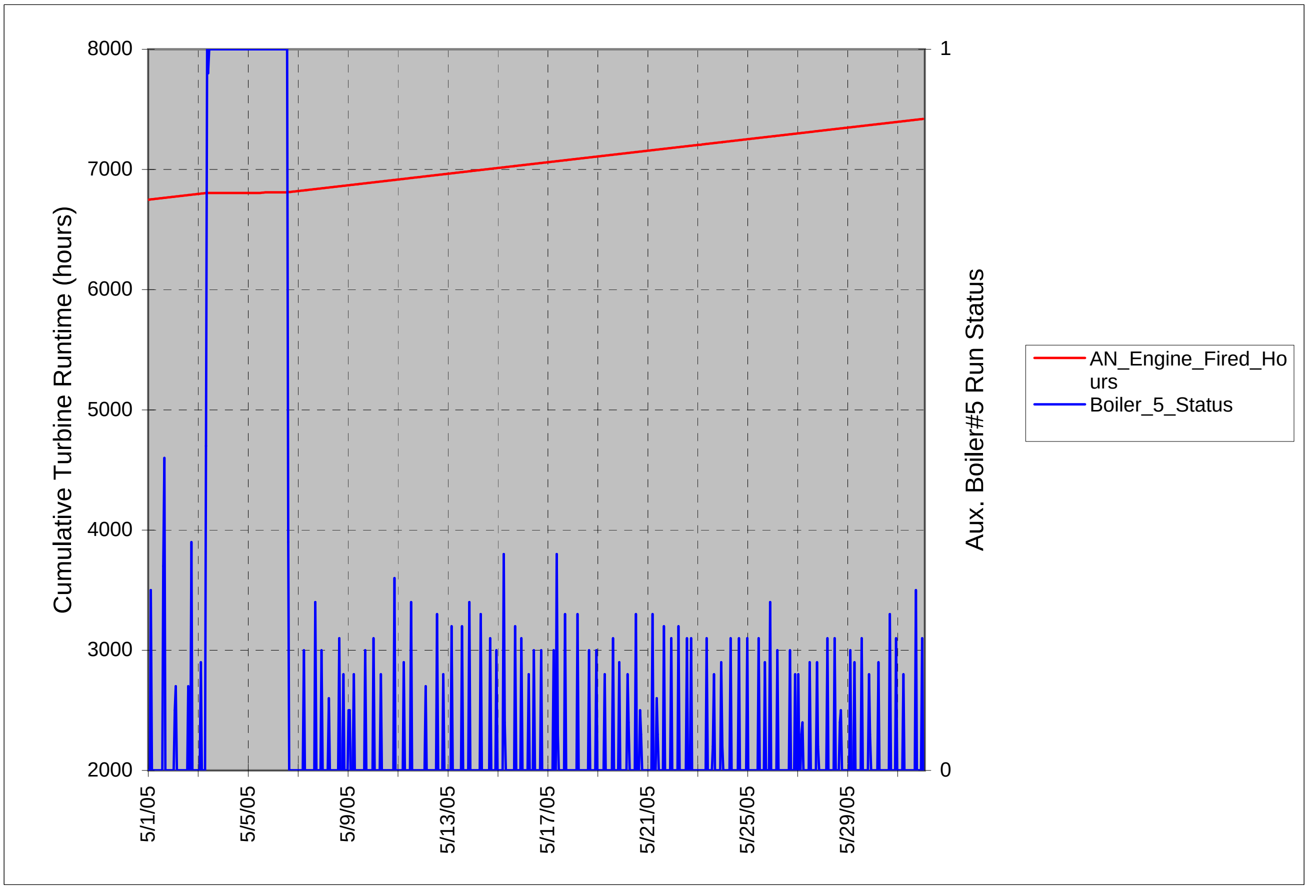
Appendix A

Detailed Operational Data: May 2005

Misc. Plots



8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
AN_Engine_Fired_Hours
AN_Total_kW



8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
1
0
Aux. Boiler#5 Run Status
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
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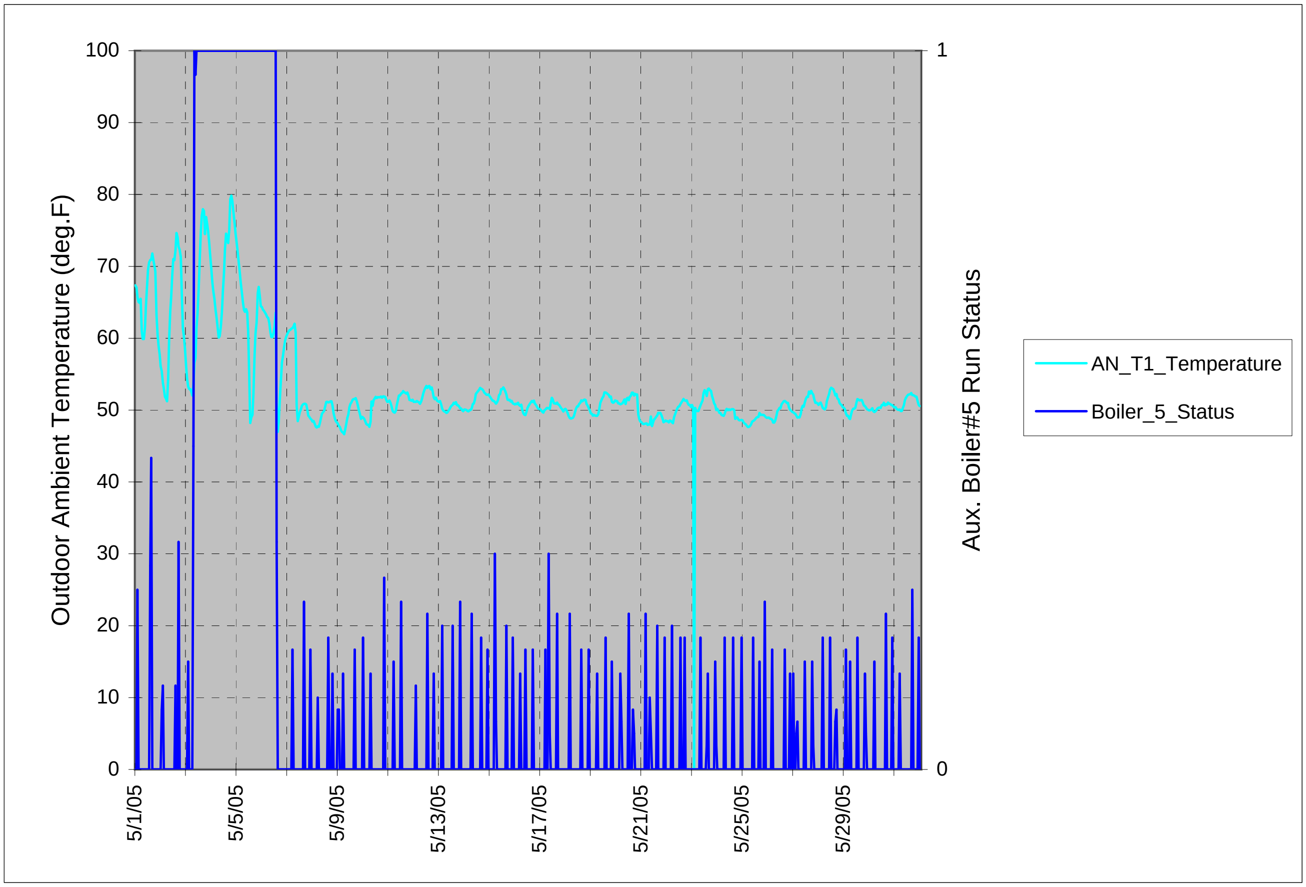
Boiler_5_Status


Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
AN_T1_Temperature
Boiler_5_Status
0
10
20
30
40
50
60
70
80
90
100
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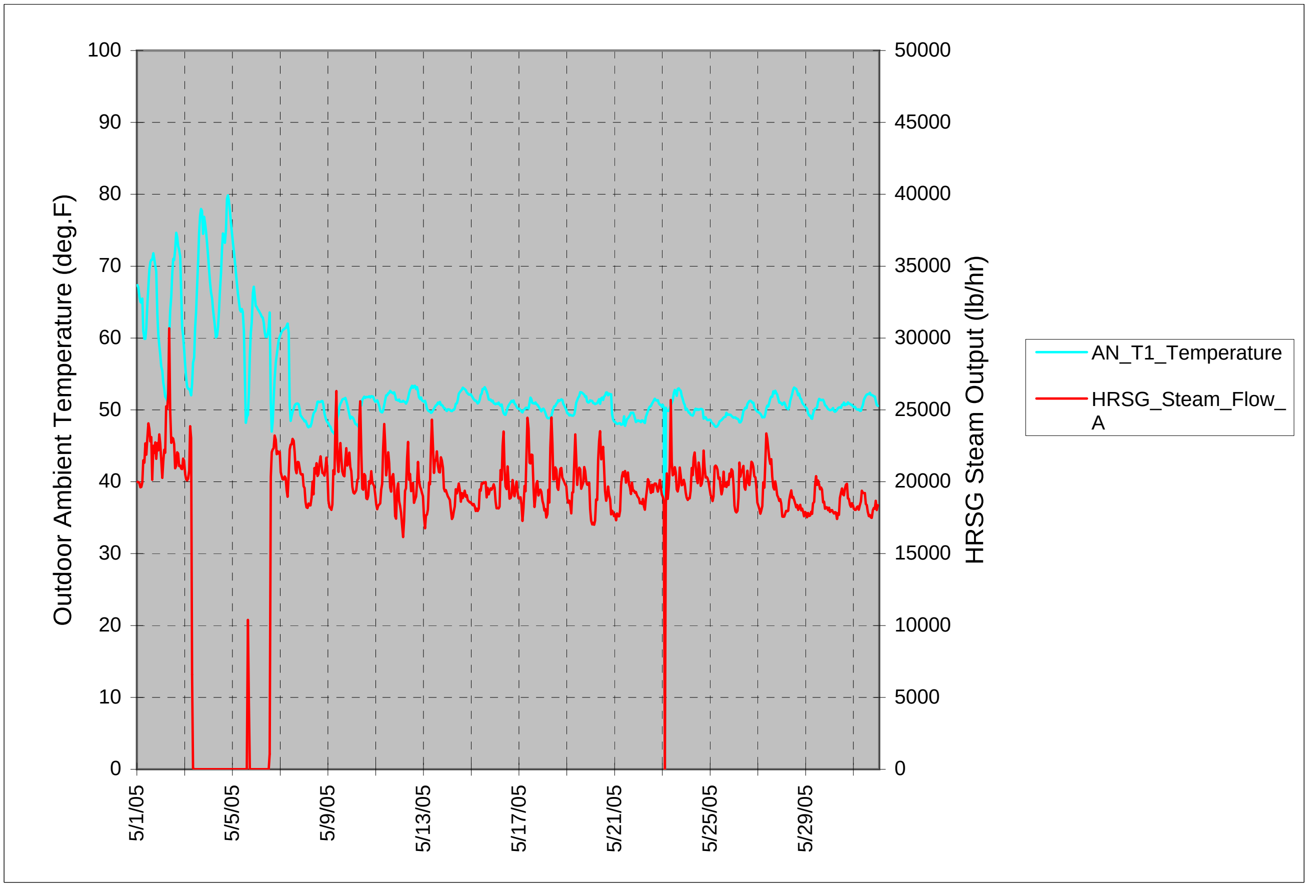
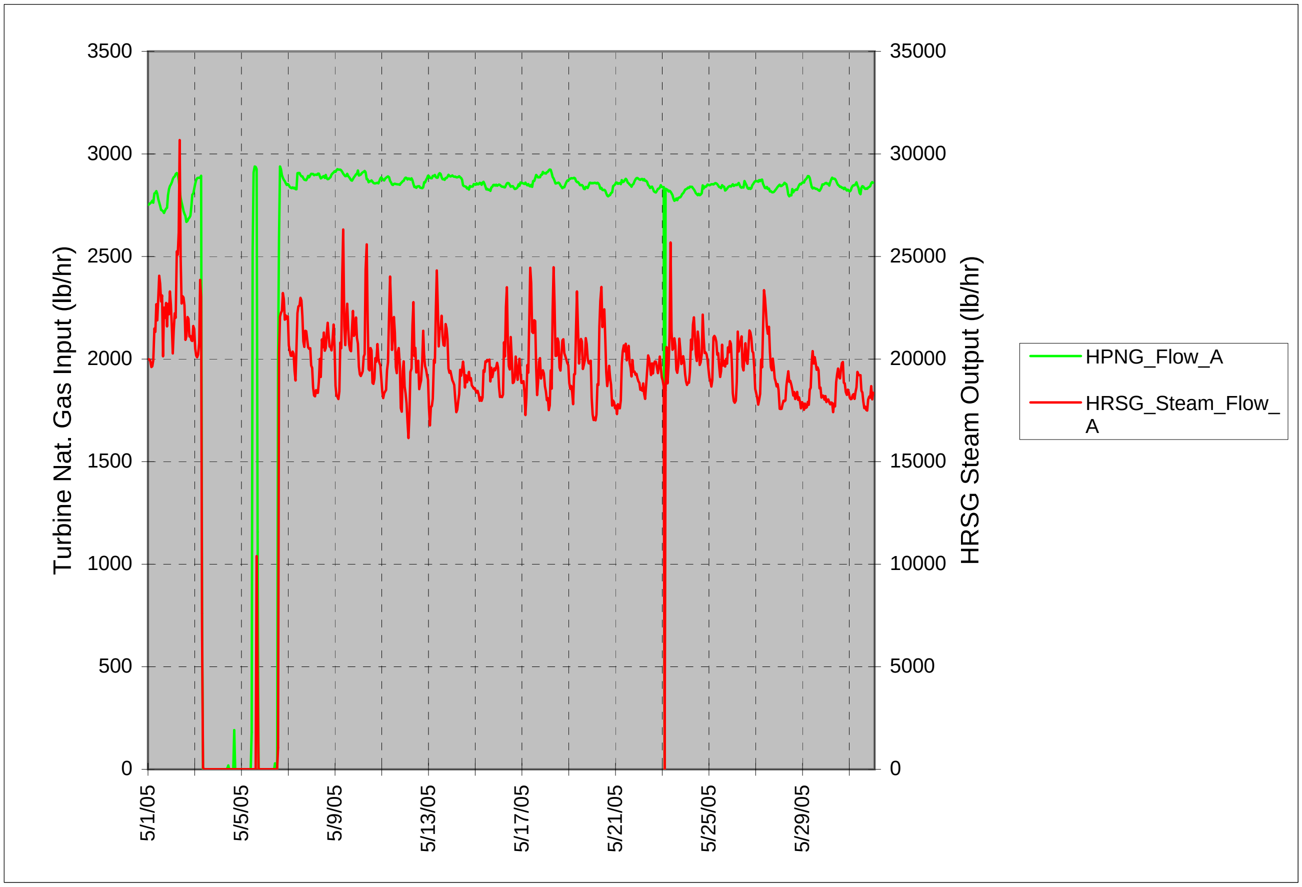
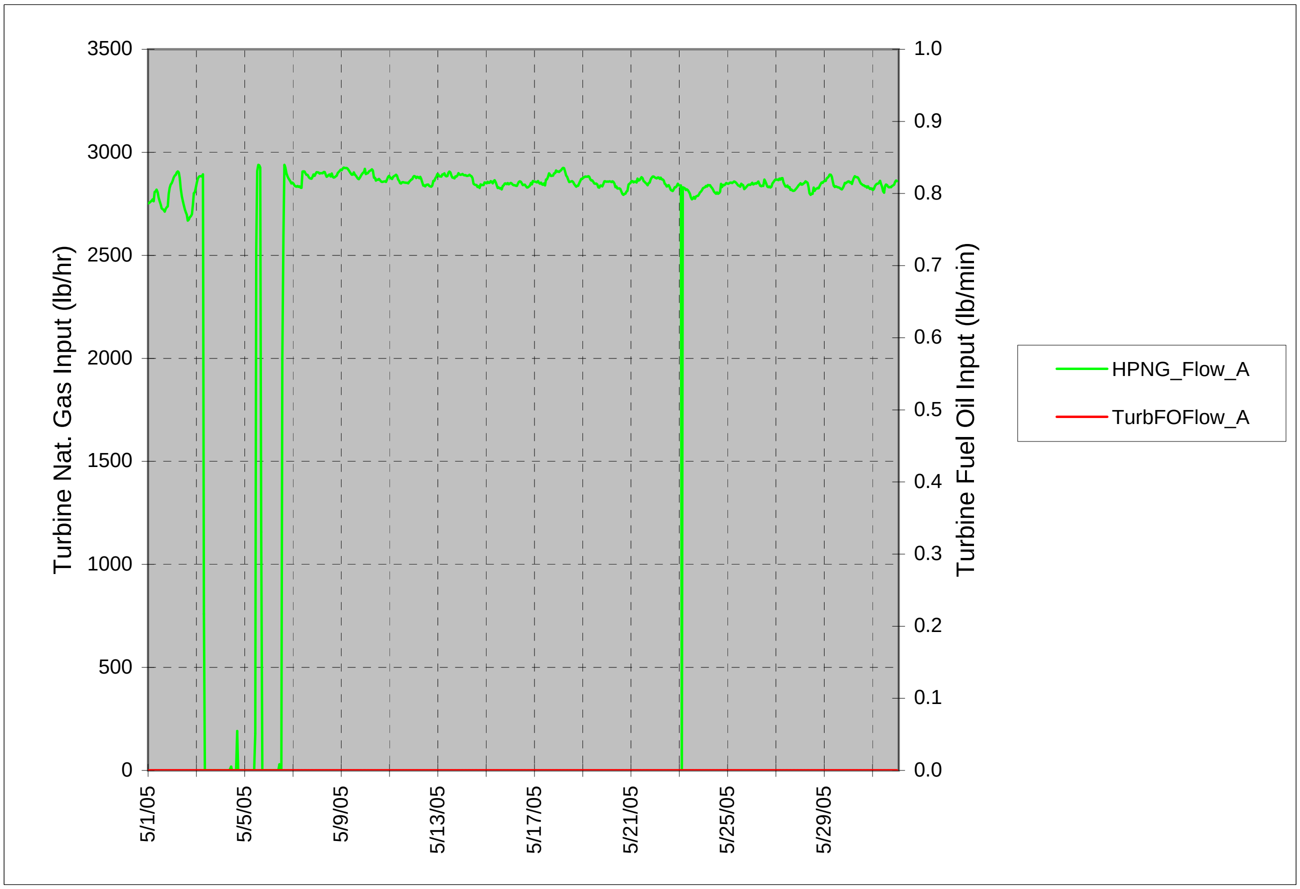
5/25/05
5/29/05


Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
AN_T1_Temperature
HRSG_Steam_Flow_A
0
10
20
30
40
50
60
70
80
90
100
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05

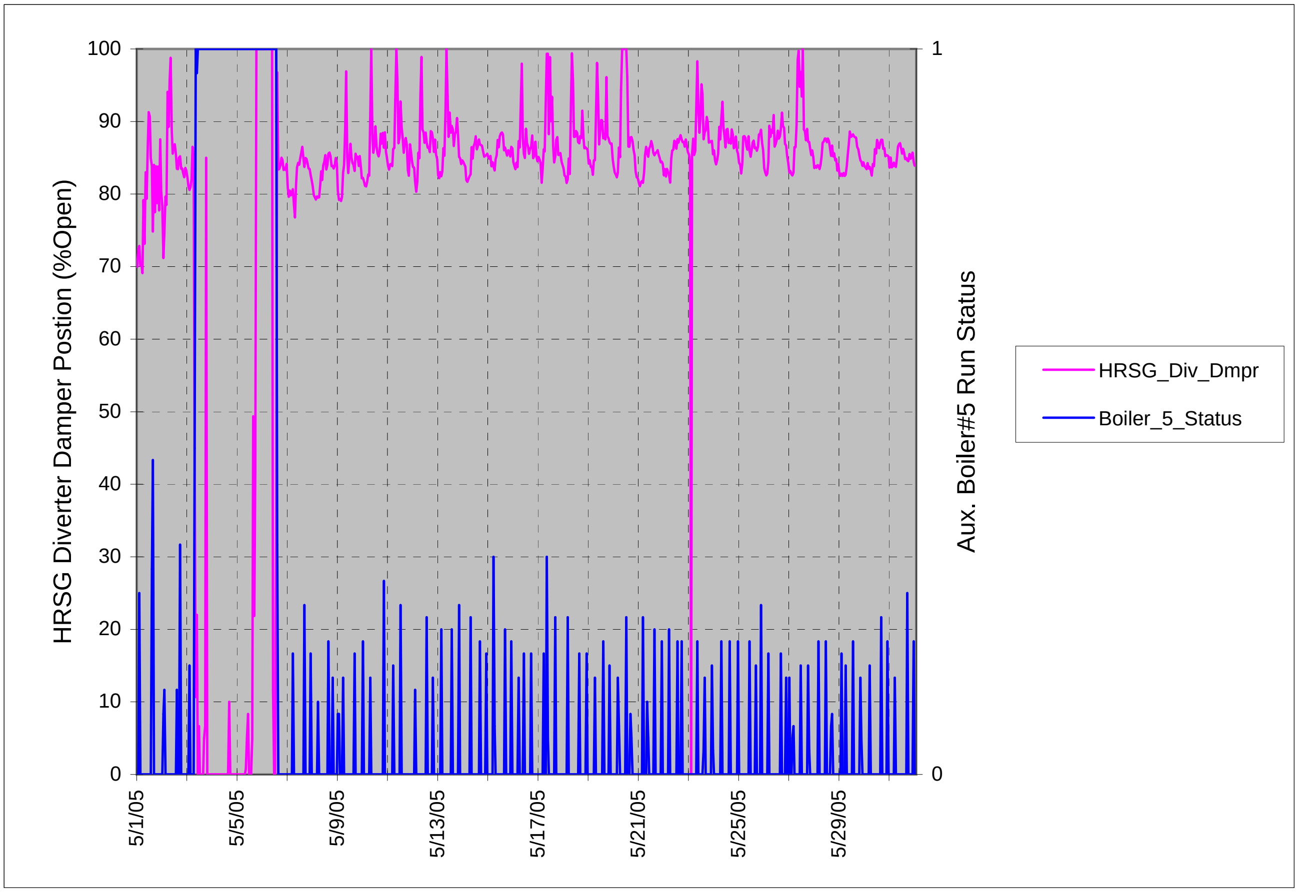
Misc. Plots

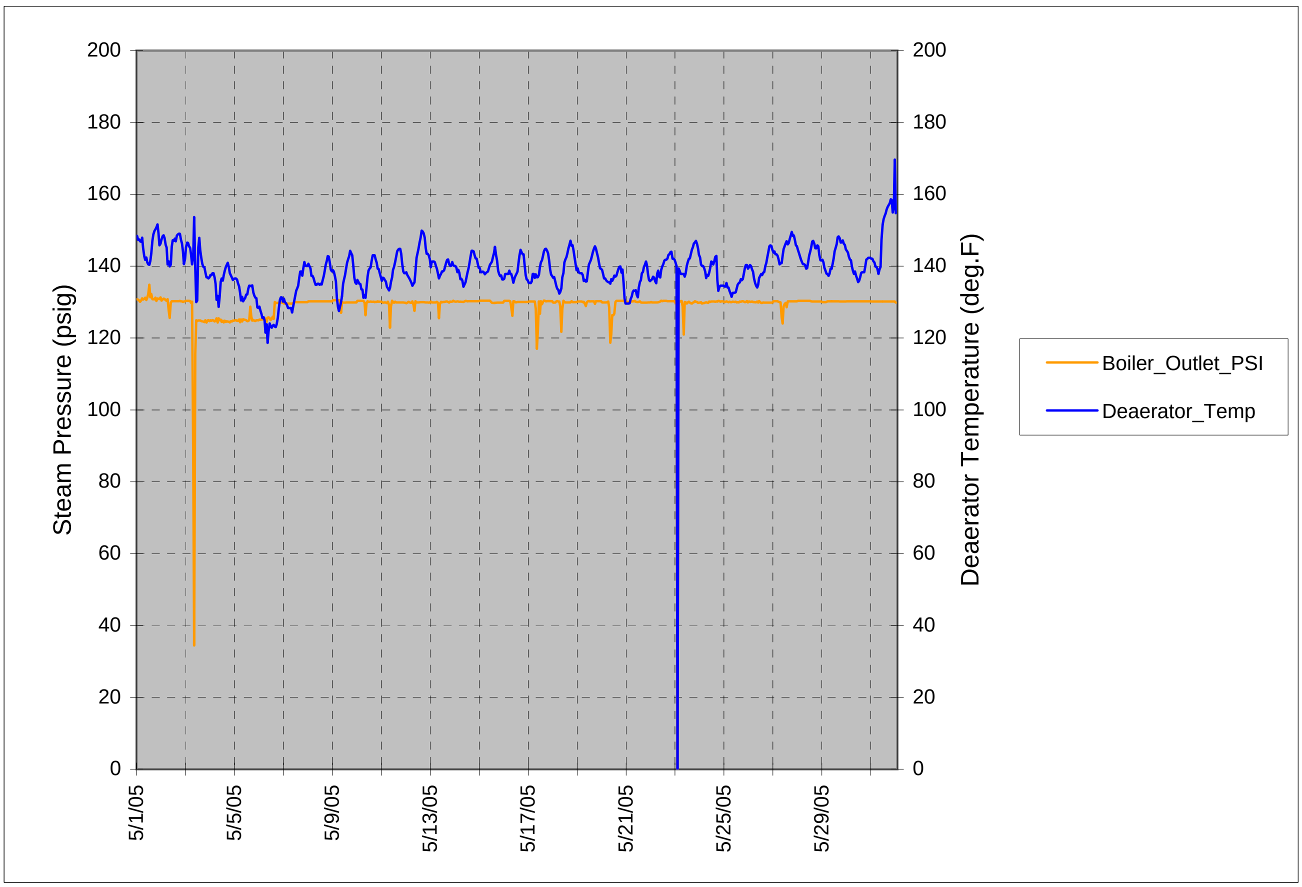


3500
3000
2500
2000
1500
1000
500
0
35000
30000
25000
20000
15000
10000
5000
0
Turbine Nat. Gas Input (lb/hr)
HRSG Steam Output (lb/hr)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A

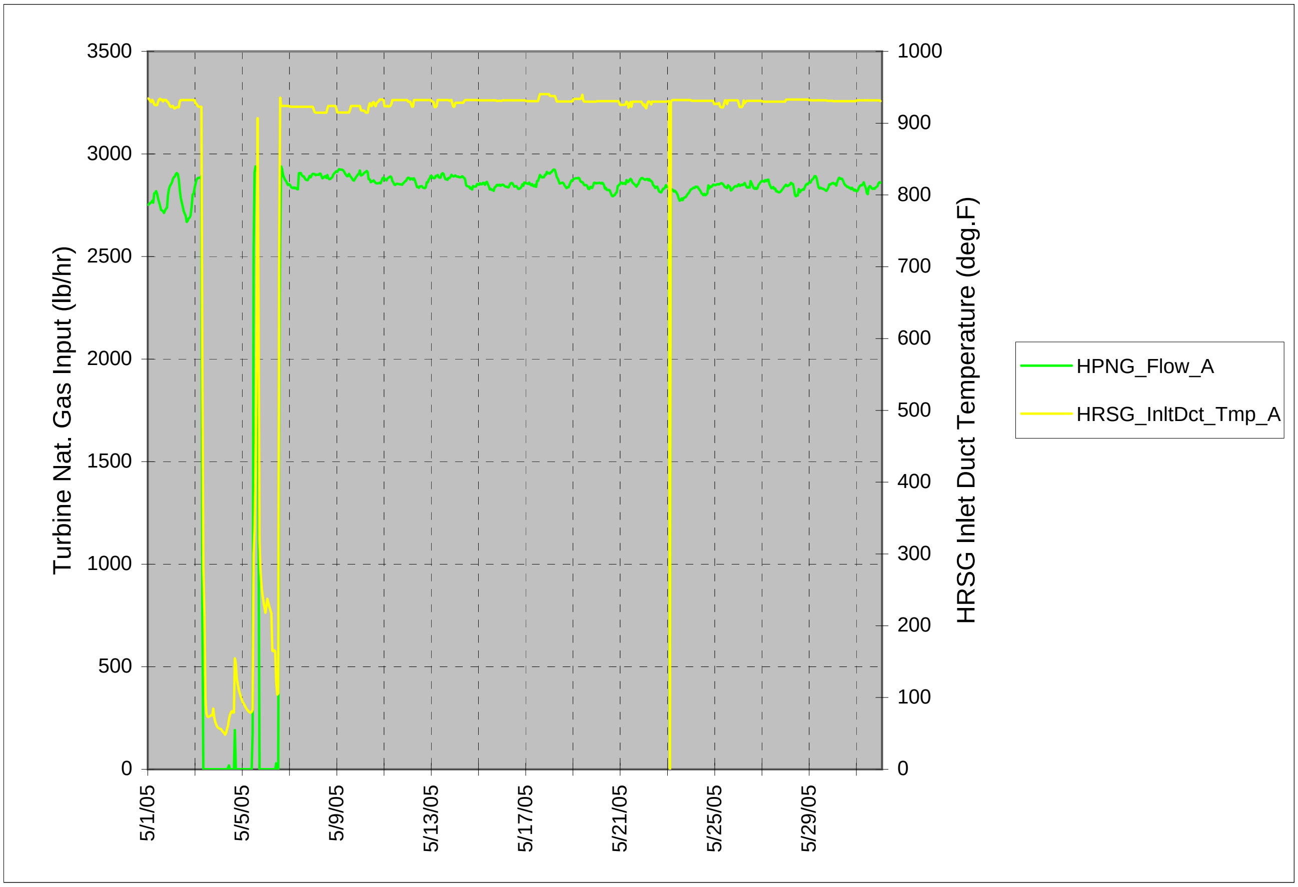


3500
3000
2500
2000
1500
1000
500
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Turbine Nat. Gas Input (lb/hr)
Turbine Fuel Oil Input (lb/min)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
HPNG_Flow_A
TurbFOFlow_A

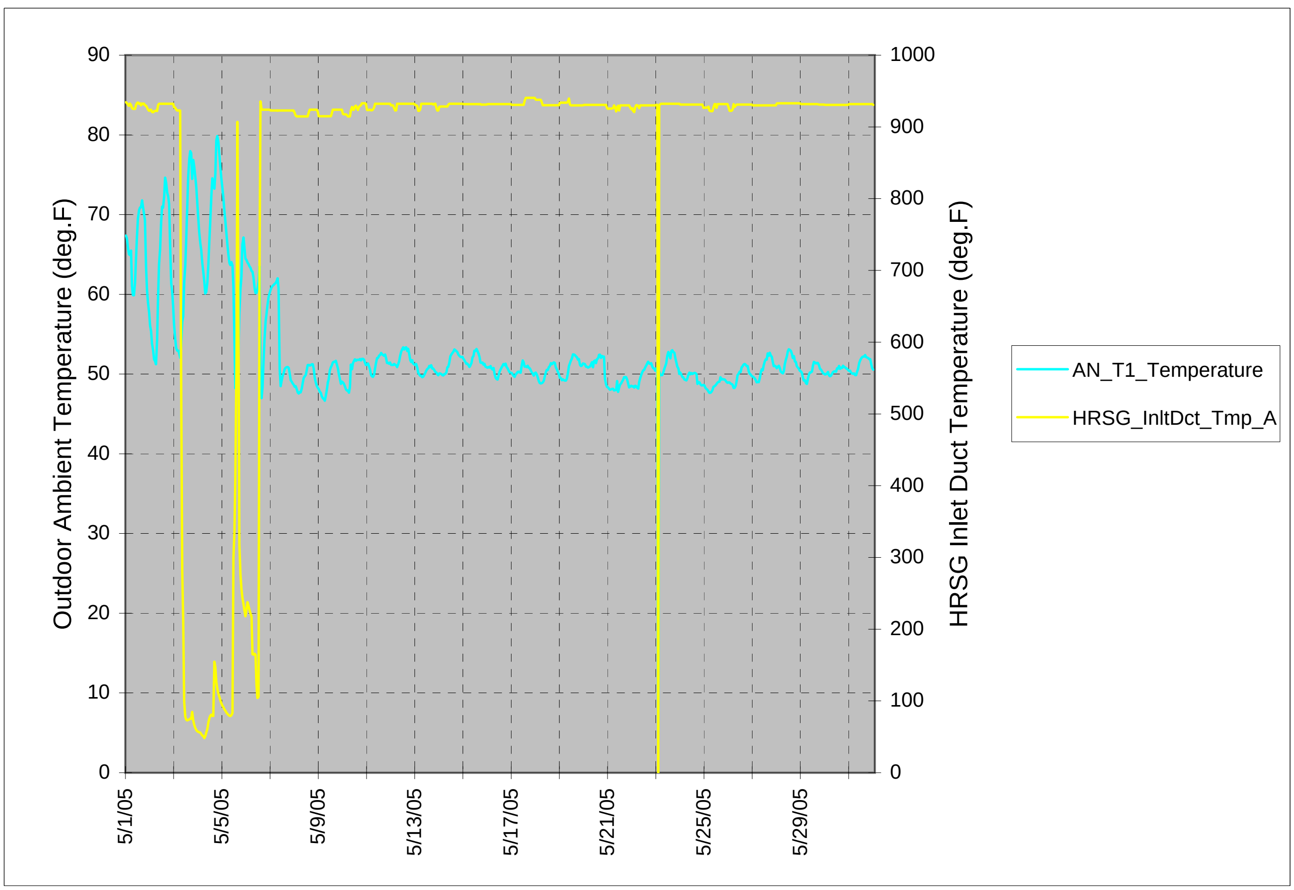

HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
HRSG_Div_Dmpr
Boiler_5_Status
100
90
80
70
60
50
40
30
20
10
0
1
0
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05


Steam Pressure (psig)
Deaerator Temperature (deg.F)
Boiler_Outlet_PSI
Deaerator_Temp
200
180
160
140
120
100
80
60
40
20
0
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05

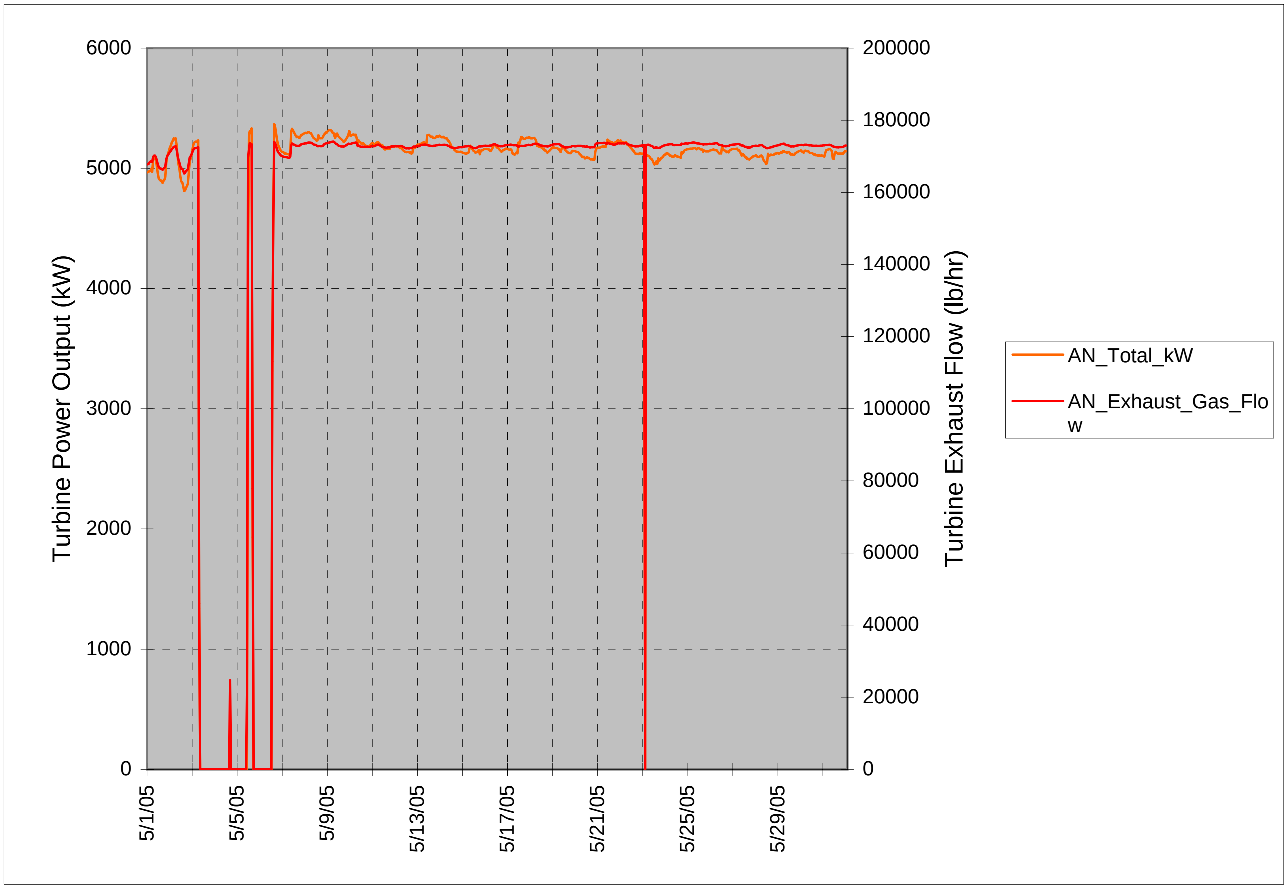
Misc. Plots



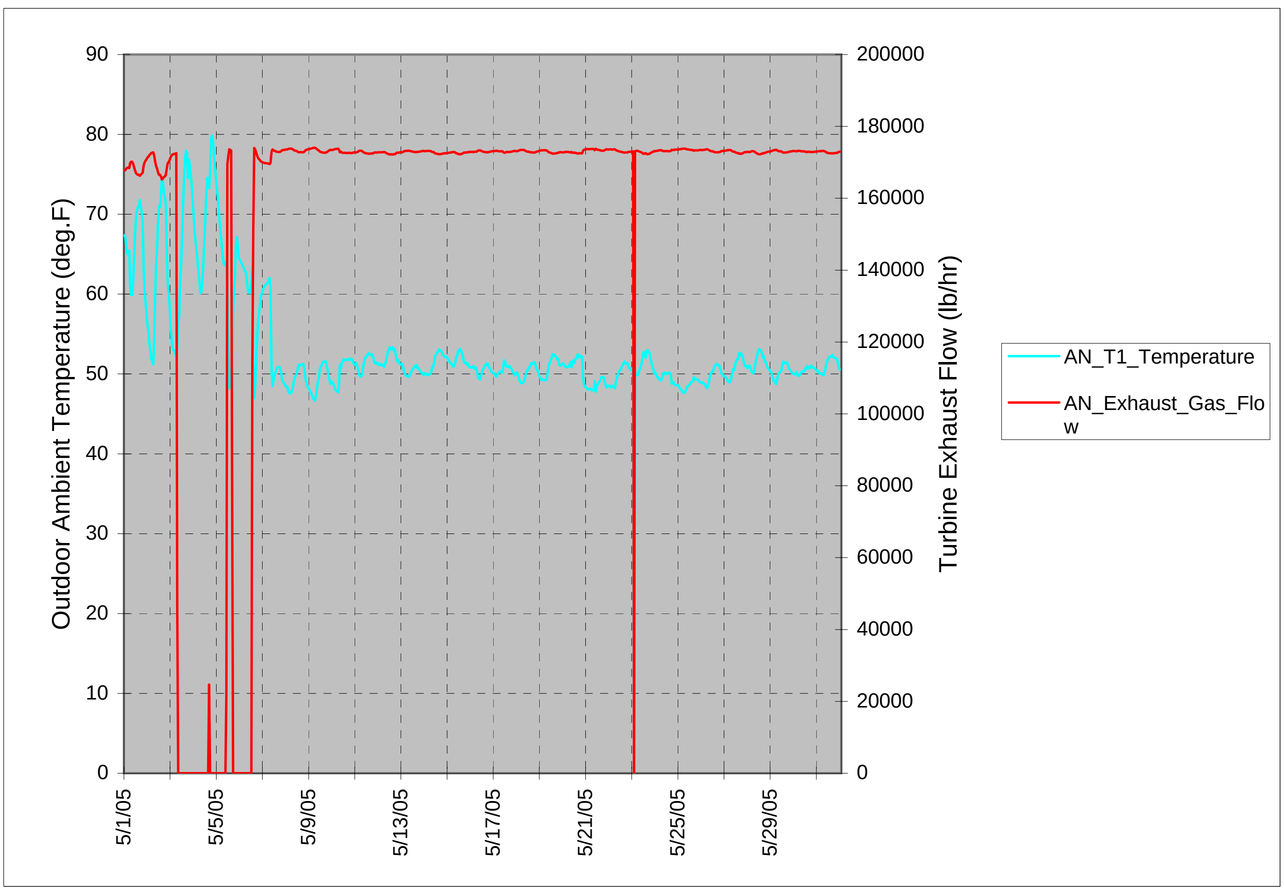
3500
3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
1000
900
800
700
600
500
400
300
200
100
0
HRSG Inlet Duct Temperature (deg.F)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A



90
80
70
60
50
40
30
20
10
0
Outdoor Ambient Temperature (deg.F)
1000
900
800
700
600
500
400
300
200
100
0
HRSG Inlet Duct Temperature (deg.F)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A

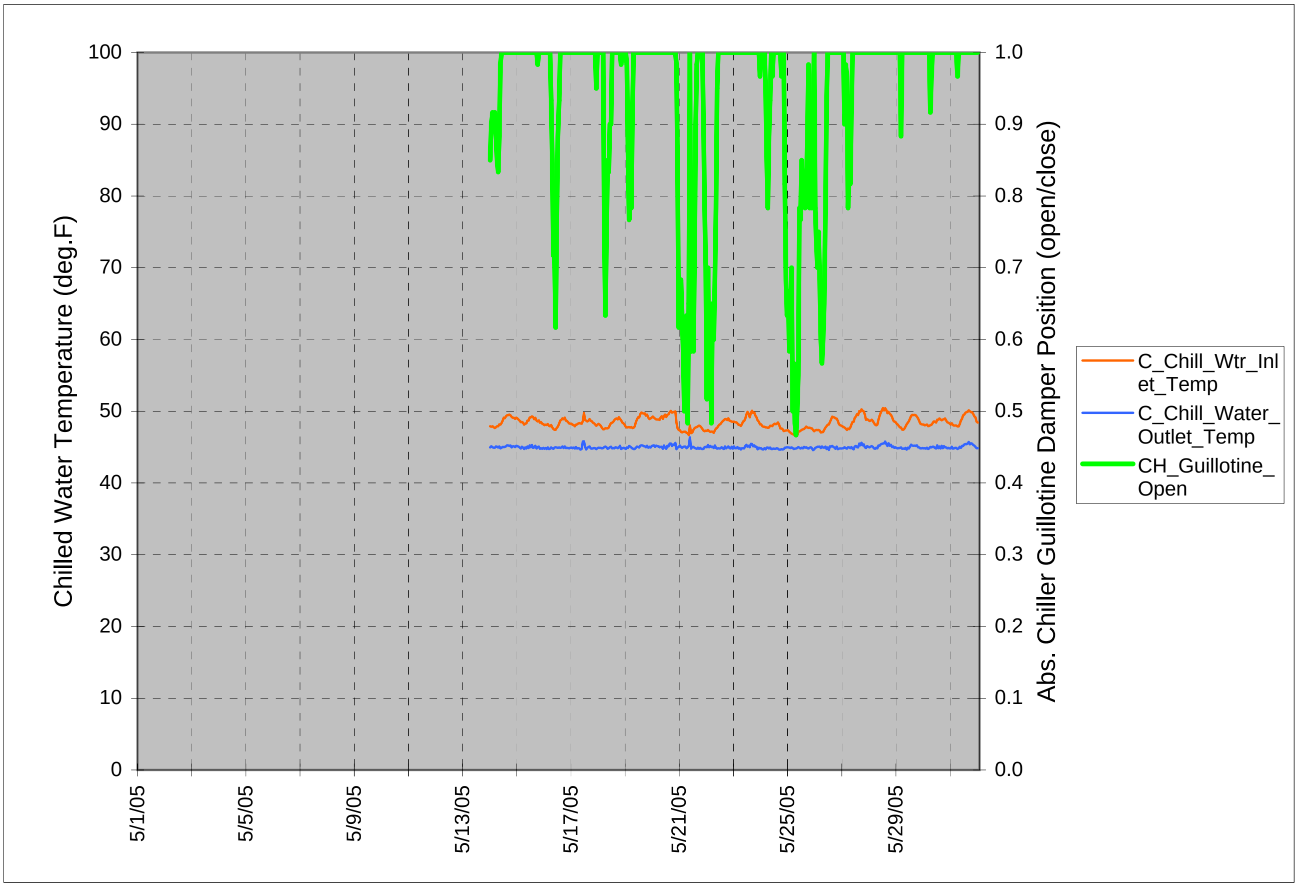


6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow

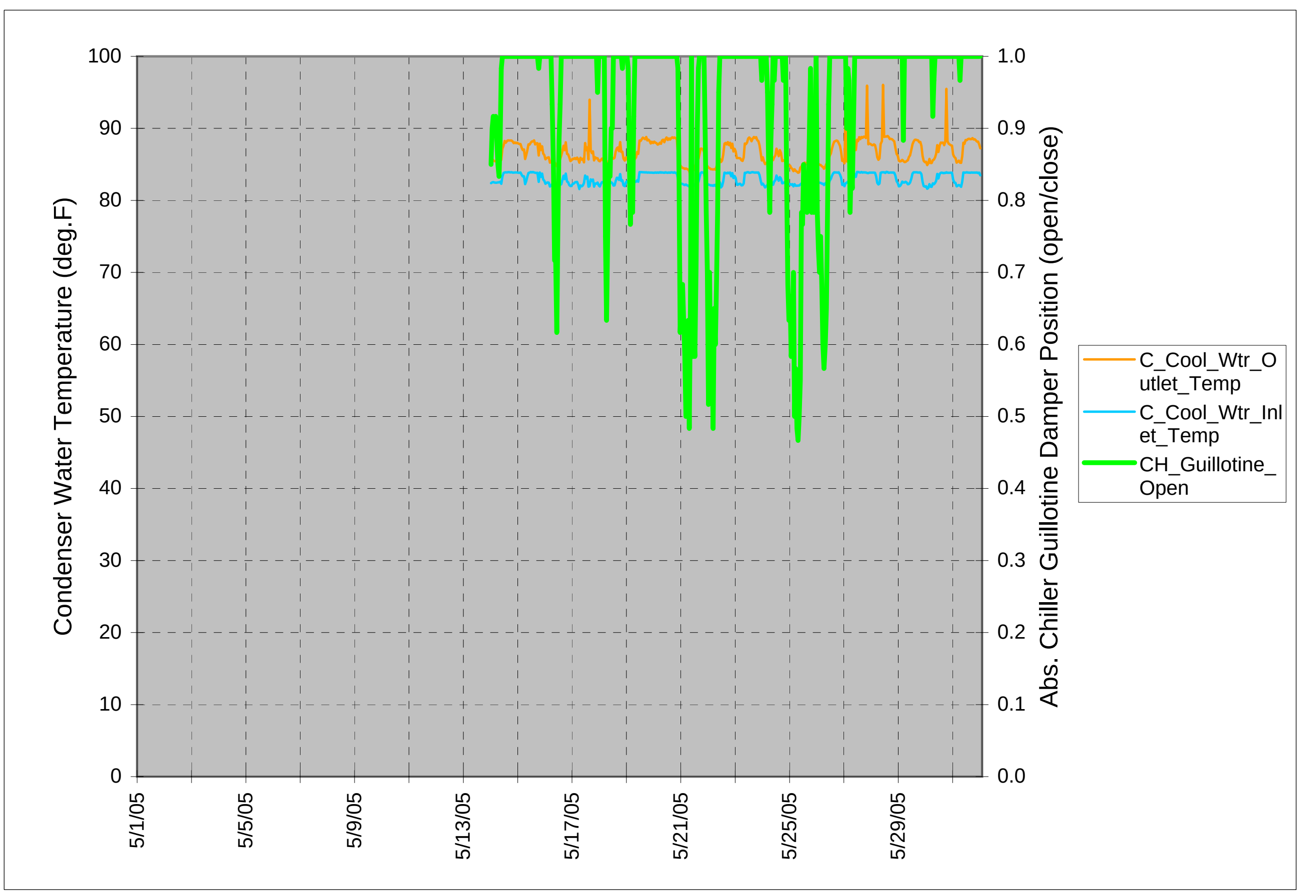


90
80
70
60
50
40
30
20
10
0
Outdoor Ambient Temperature (deg.F)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

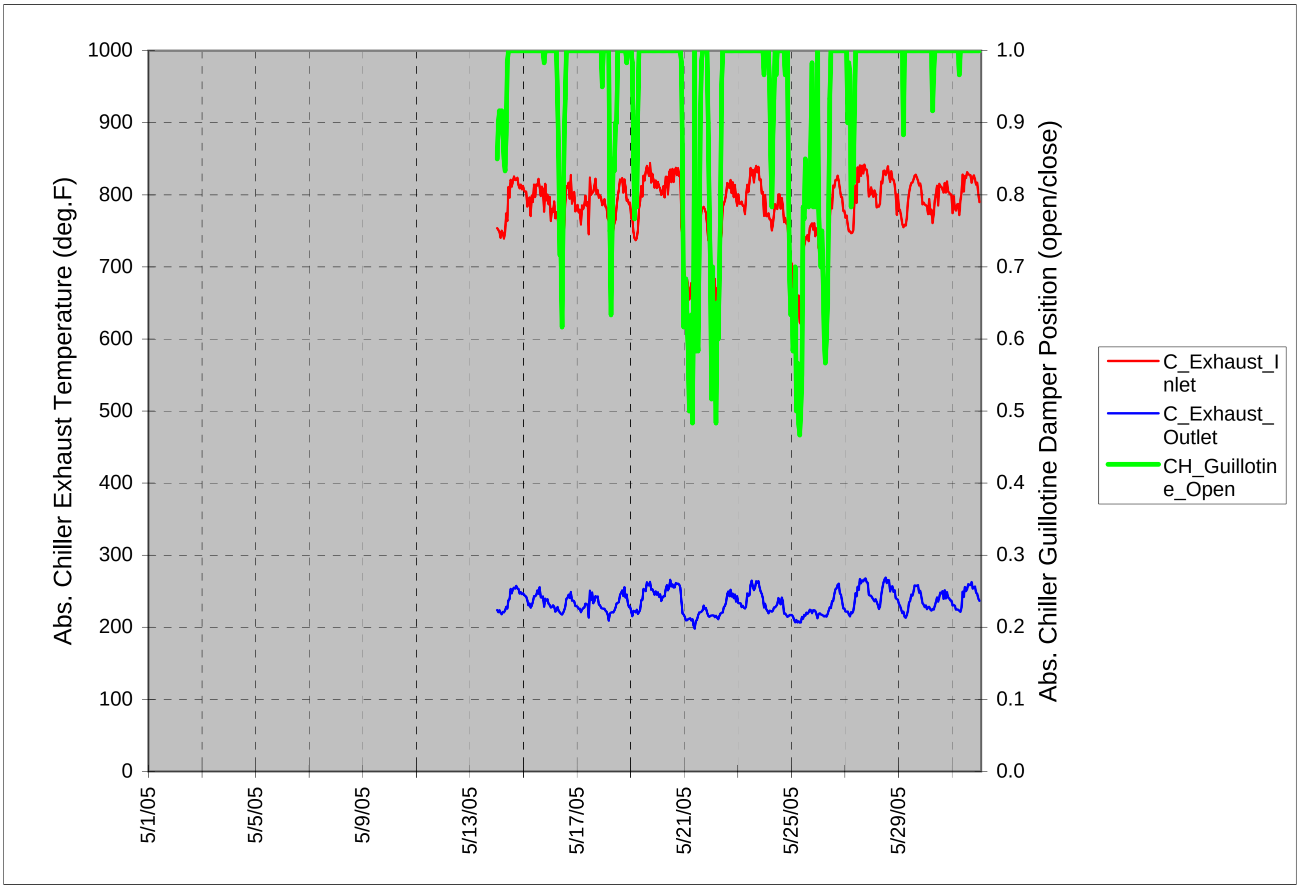
Misc. Plots



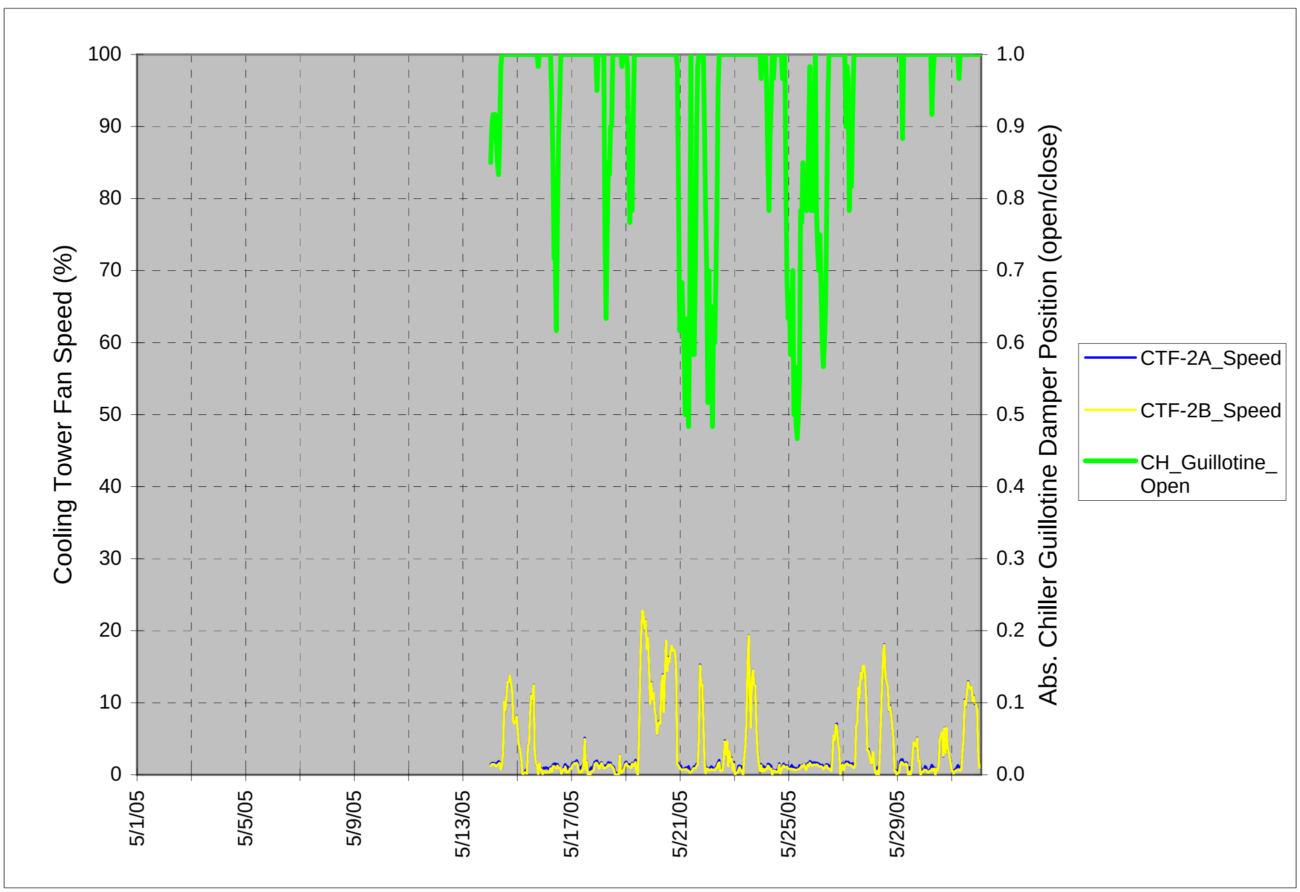
Chilled Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
C_Chill_Wtr_Inlet_Temp
C_Chill_Water_Outlet_Temp
CH_Guillotine_Open



Condenser Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
C_Cool_Wtr_Outlet_Temp
C_Cool_Wtr_Inlet_Temp
CH_Guillotine_Open



Abs. Chiller Exhaust Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
1000
900
800
700
600
500
400
300
200
100
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
C_Exhaust_Inlet
C_Exhaust_Outlet
CH_Guillotine_Open

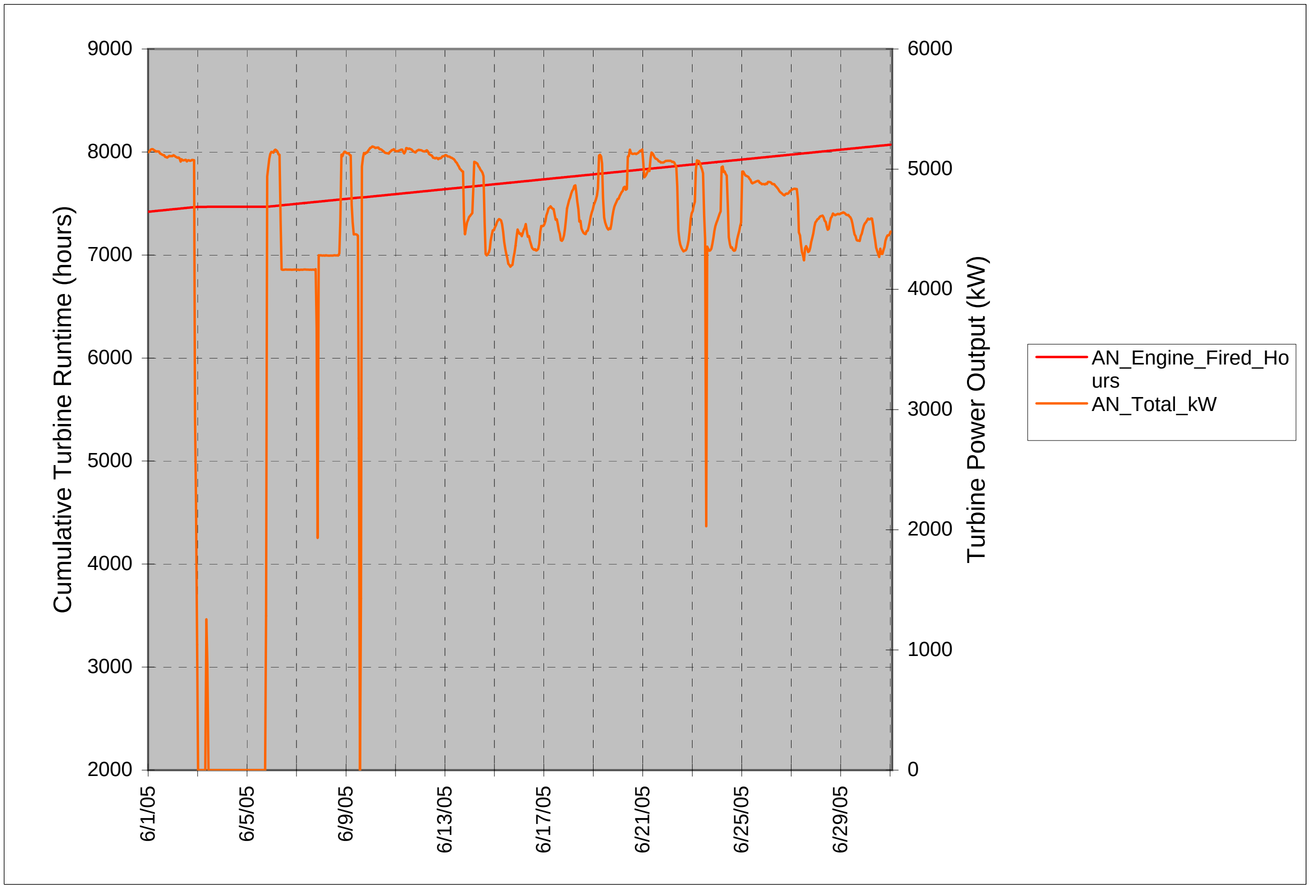


Cooling Tower Fan Speed (%)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5/1/05
5/5/05
5/9/05
5/13/05
5/17/05
5/21/05
5/25/05
5/29/05
CTF-2A_Speed
CTF-2B_Speed
CH_Guillotine_Open

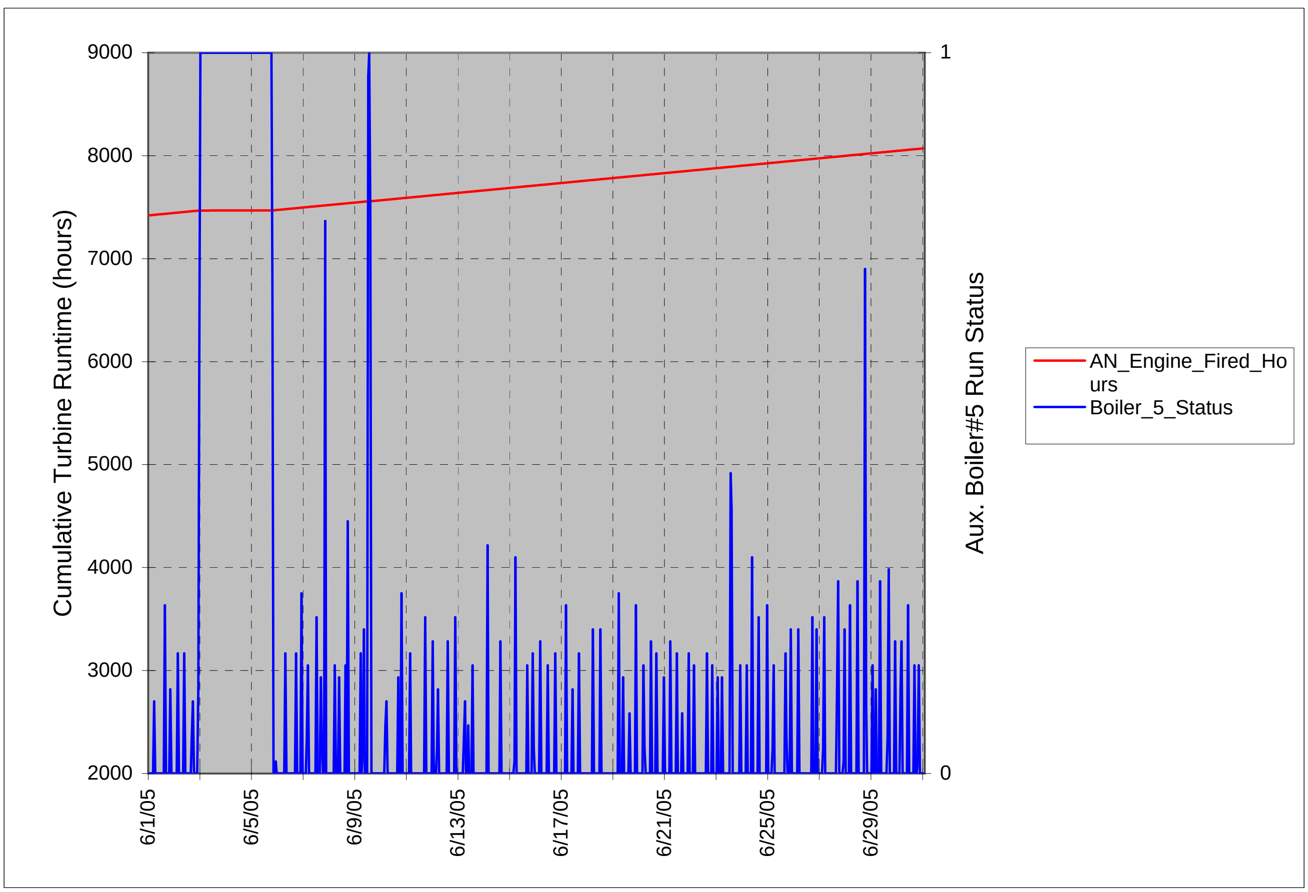
Appendix B

Detailed Operational Data: June 2005

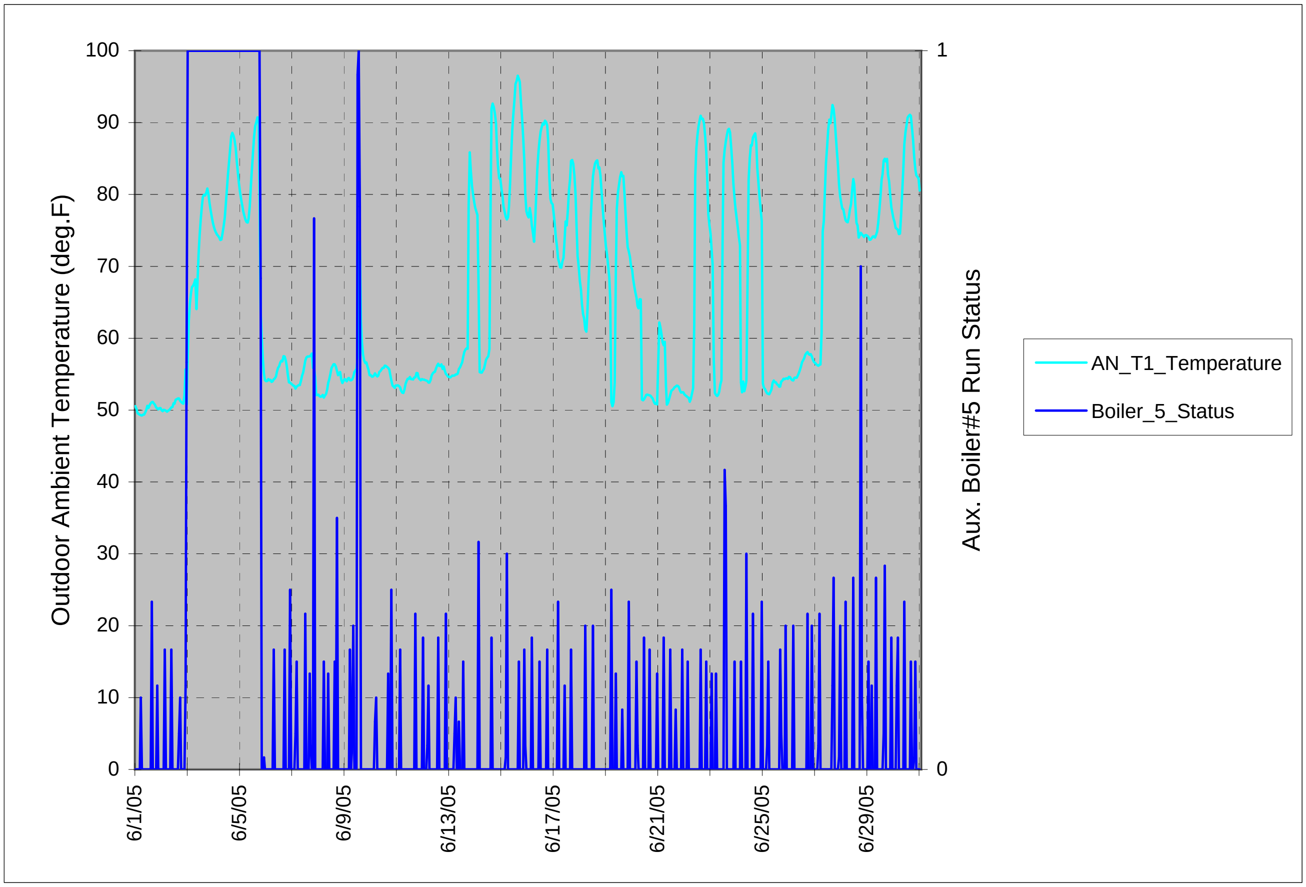
Misc. Plots



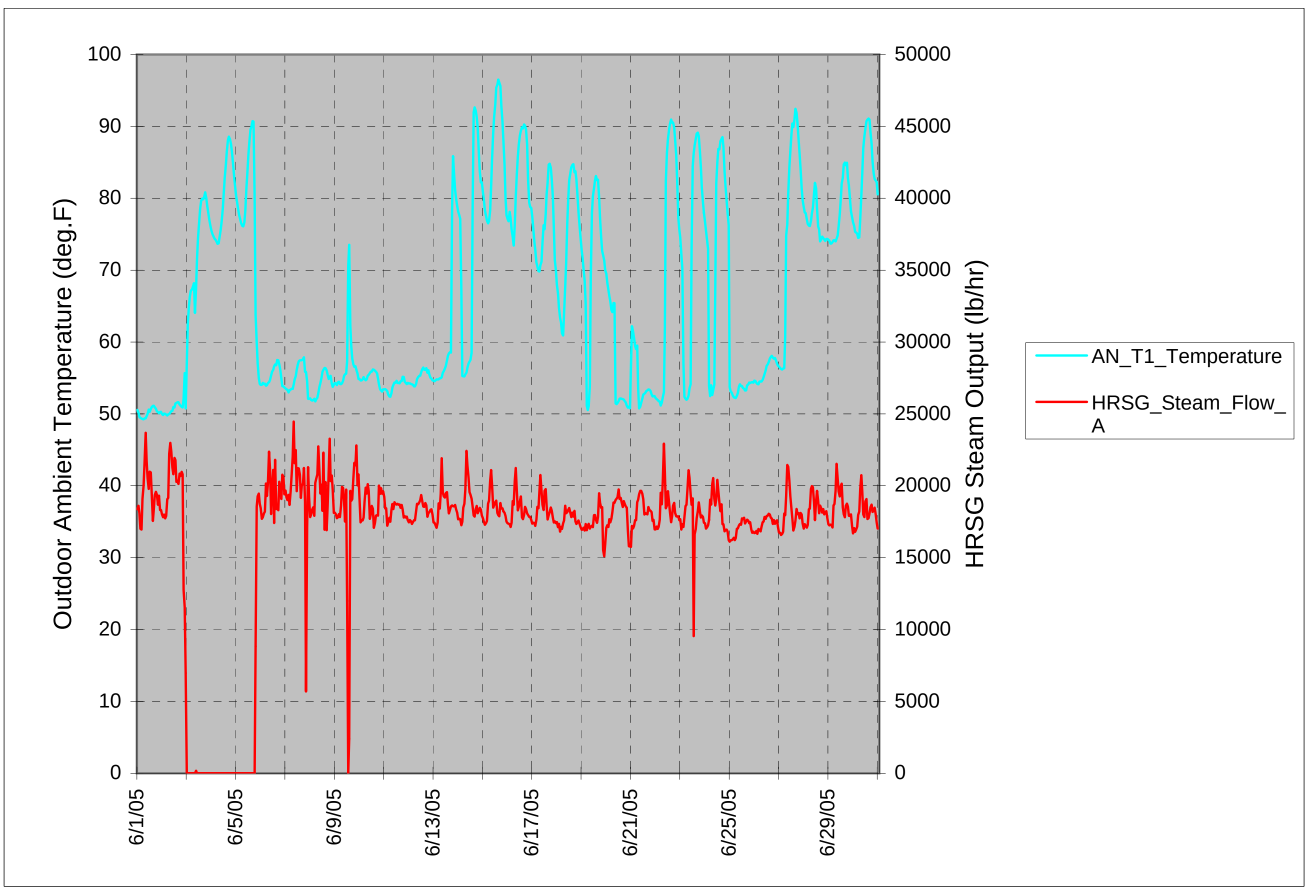
9000
8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_Engine_Fired_Hours
AN_Total_kW



9000
8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
1
0
Aux. Boiler#5 Run Status
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_Engine_Fired_Hours
Boiler_5_Status

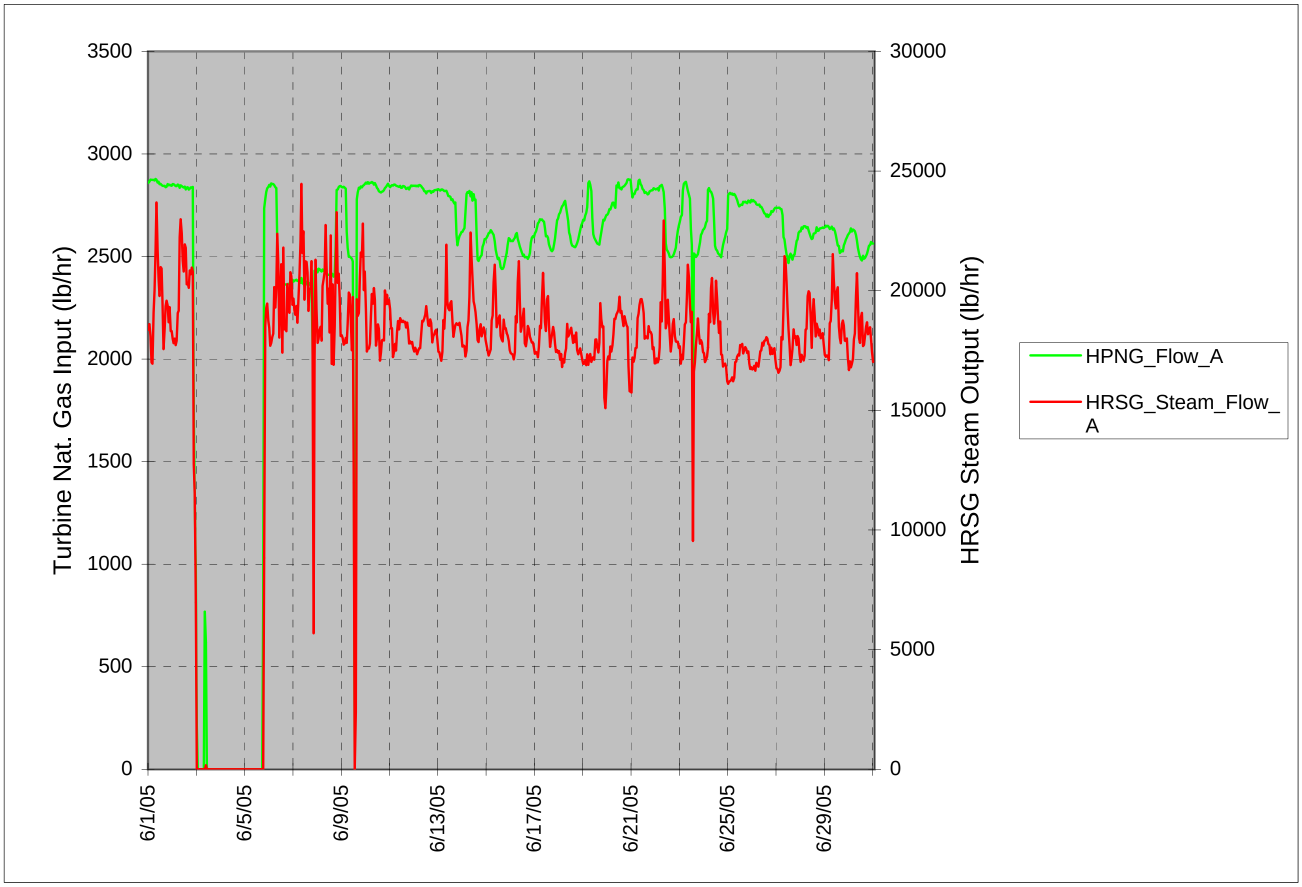


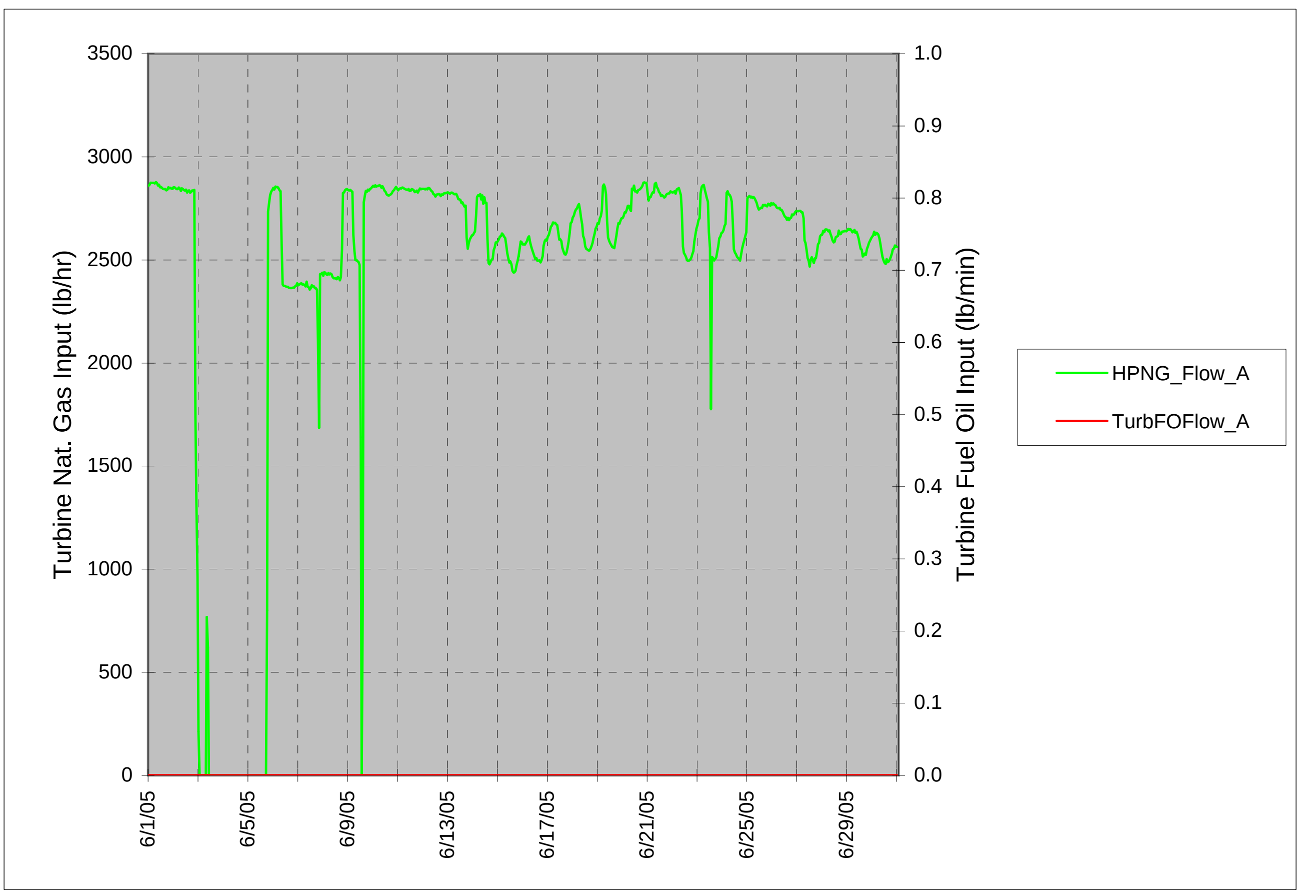
100
90
80
70
60
50
40
30
20
10
0
1
0
Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_T1_Temperature
Boiler_5_Status

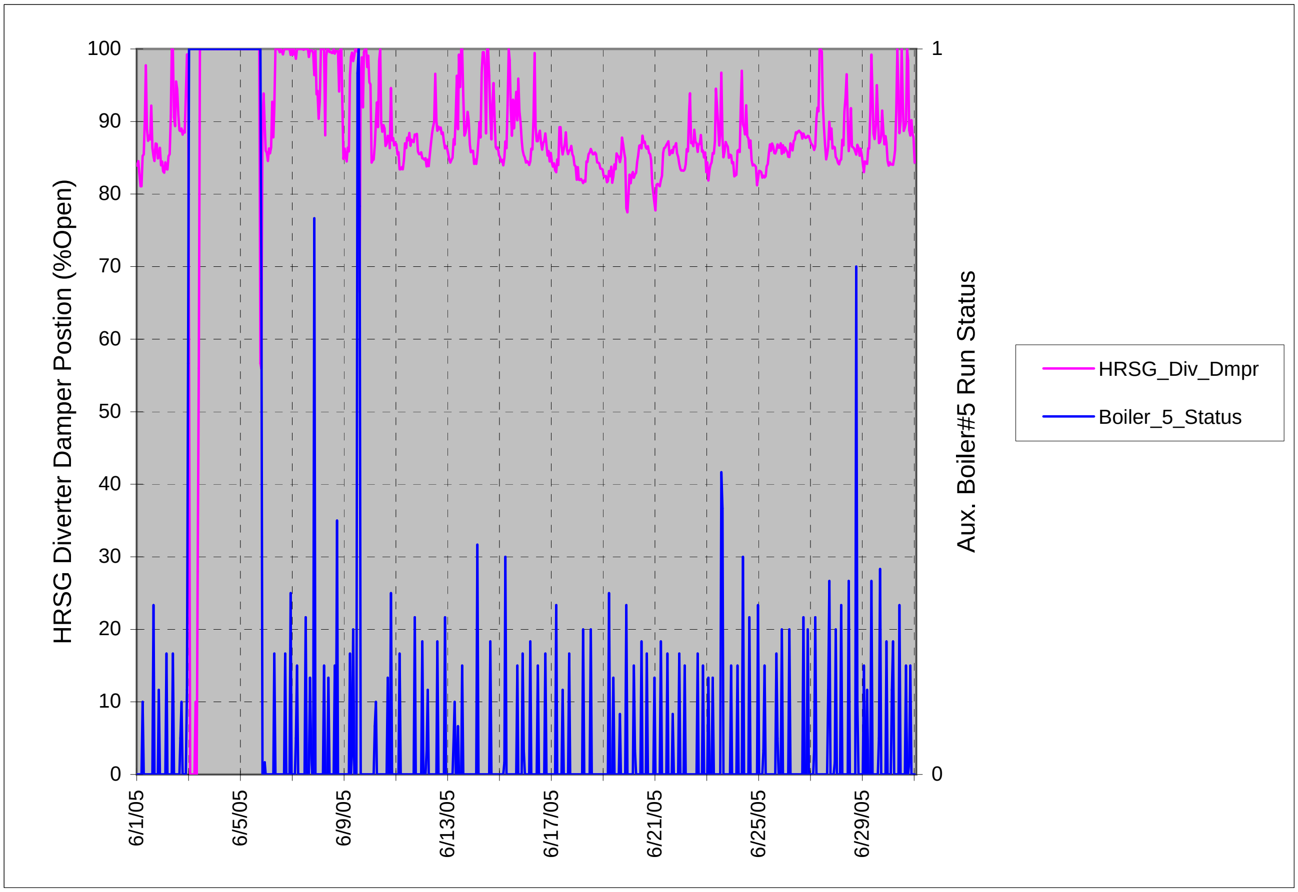


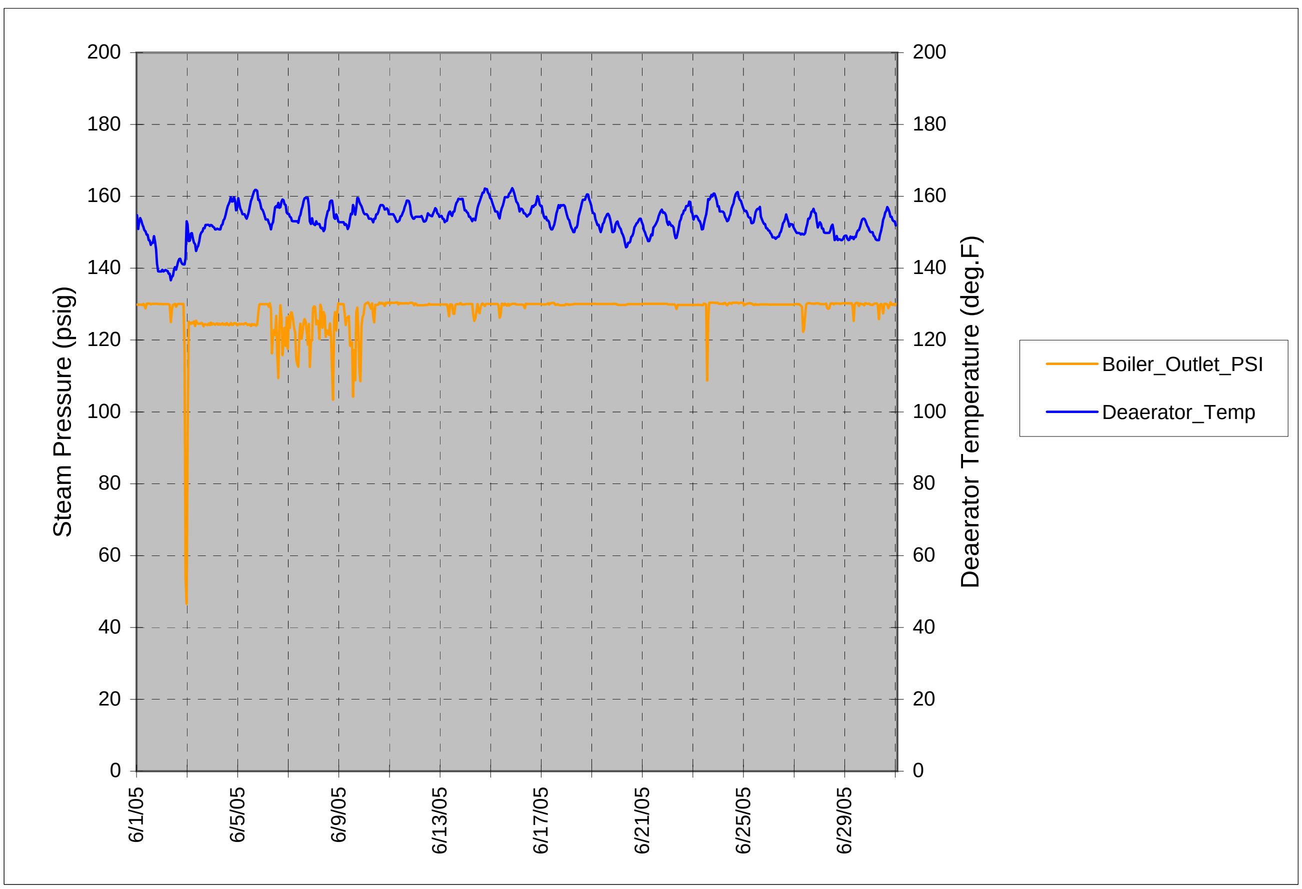
100
90
80
70
60
50
40
30
20
10
0
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_T1_Temperature
HRSG_Steam_Flow_A

Misc. Plots

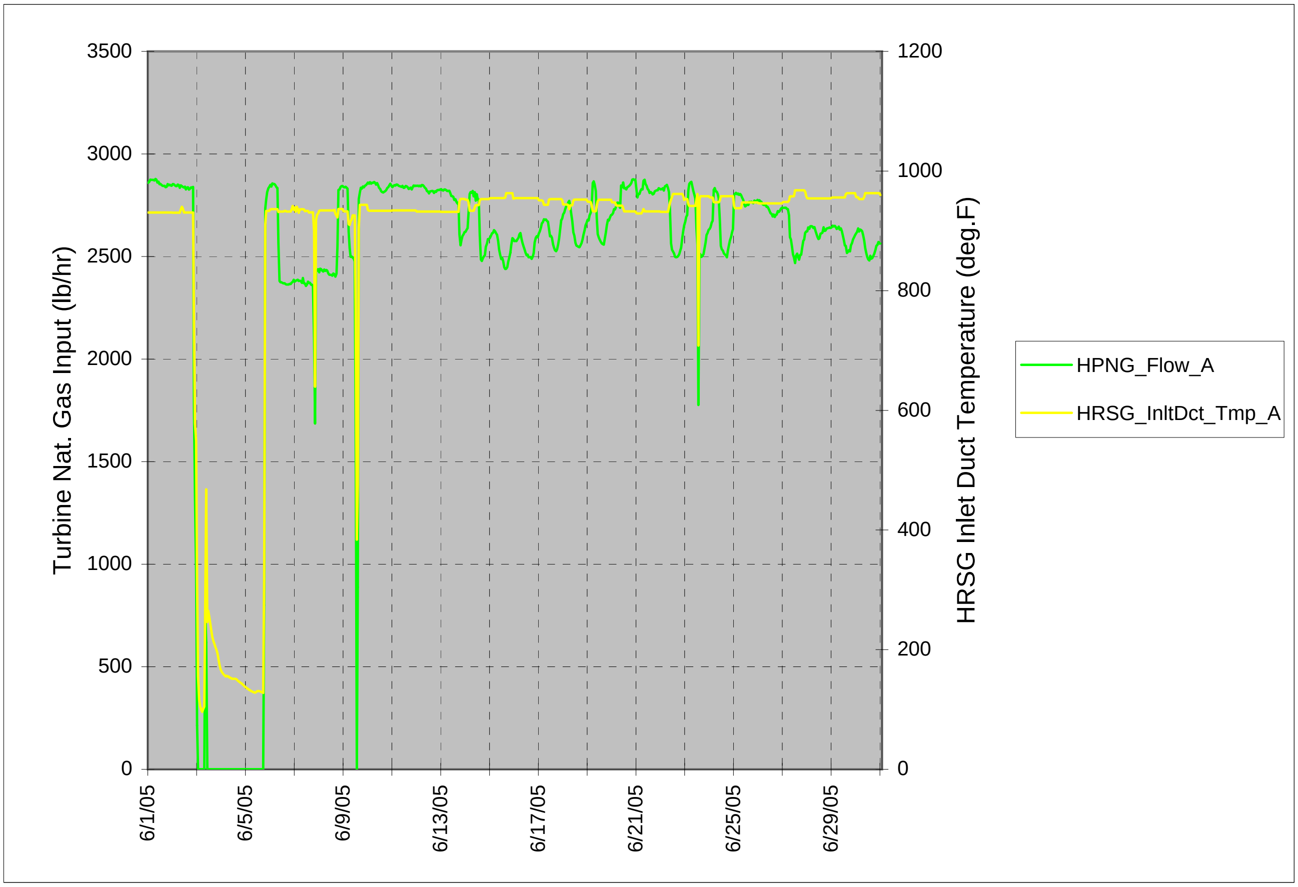

Turbine Nat. Gas Input (lb/hr)
HRSG Steam Output (lb/hr)
3500
3000
2500
2000
1500
1000
500
0
30000
25000
20000
15000
10000
5000
0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A


Turbine Nat. Gas Input (lb/hr)
Turbine Fuel Oil Input (lb/min)
3500
3000
2500
2000
1500
1000
500
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
HPNG_Flow_A
TurbFOFlow_A

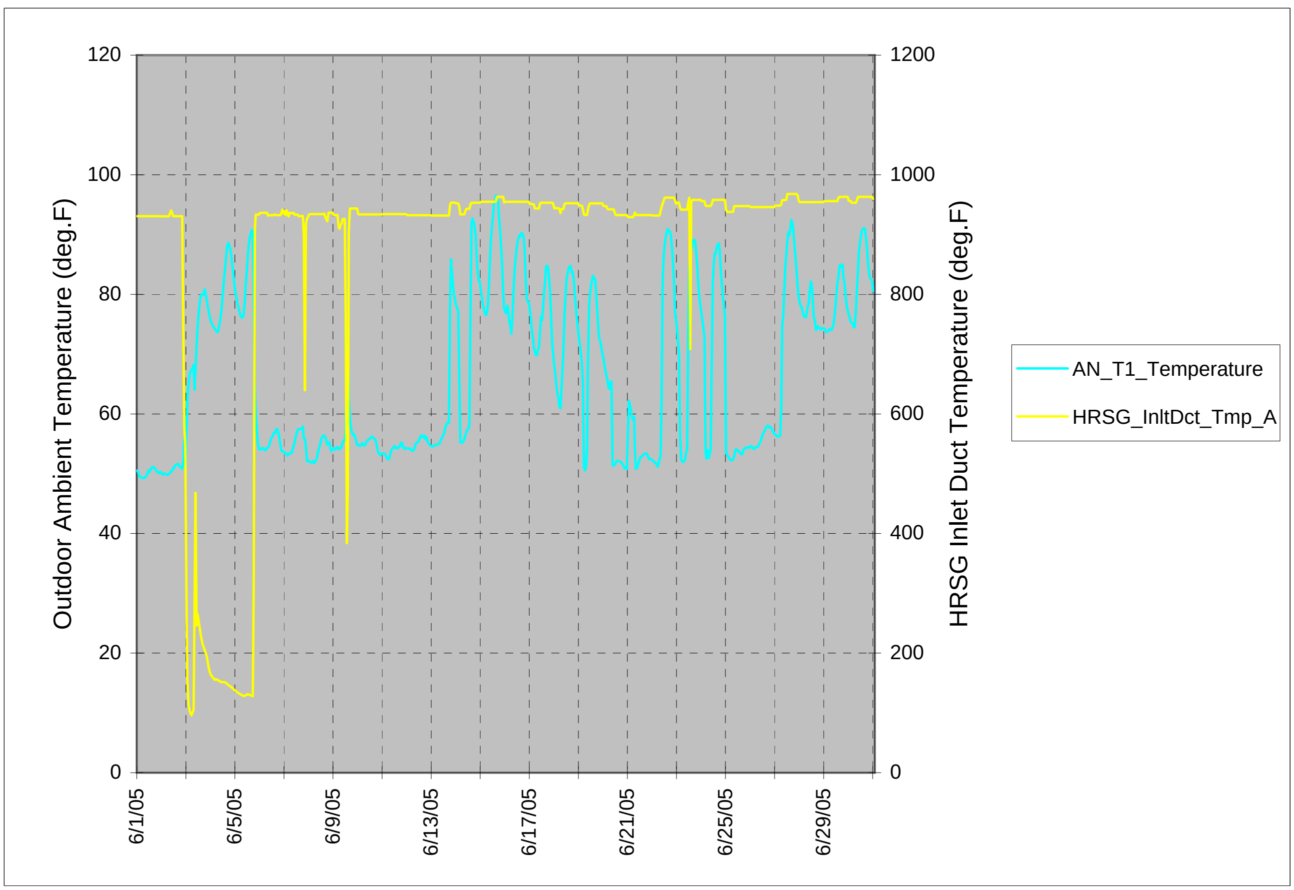

100
90
80
70
60
50
40
30
20
10
0
1
0
HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
HRSG_Div_Dmpr
Boiler_5_Status


200
180
160
140
120
100
80
60
40
20
0
Steam Pressure (psig)
Deaerator Temperature (deg.F)
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
Boiler_Outlet_PSI
Deaerator_Temp

Misc. Plots

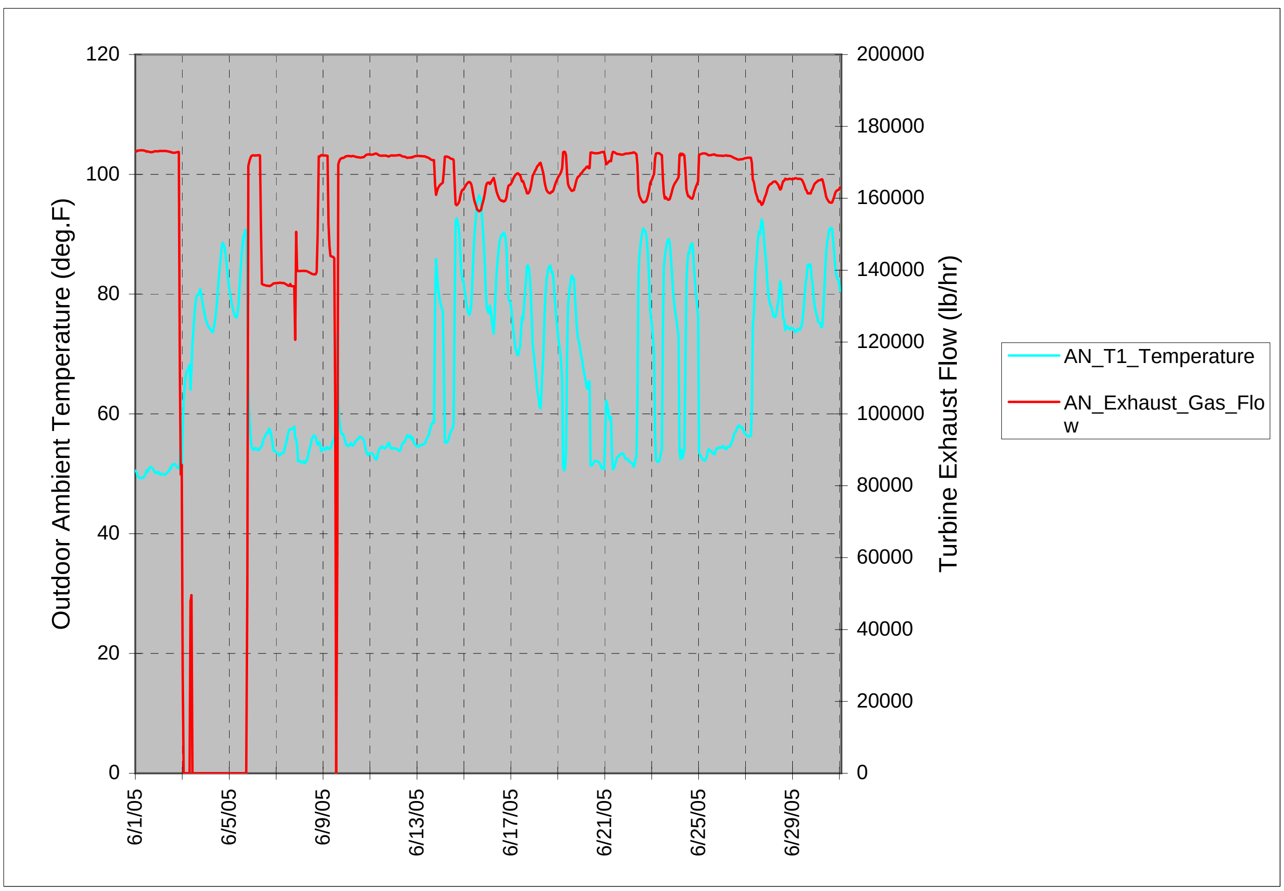


Turbine Nat. Gas Input (lb/hr)
HRSG Inlet Duct Temperature (deg.F)
3500
3000
2500
2000
1500
1000
500
0
1200
1000
800
600
400
200
0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A



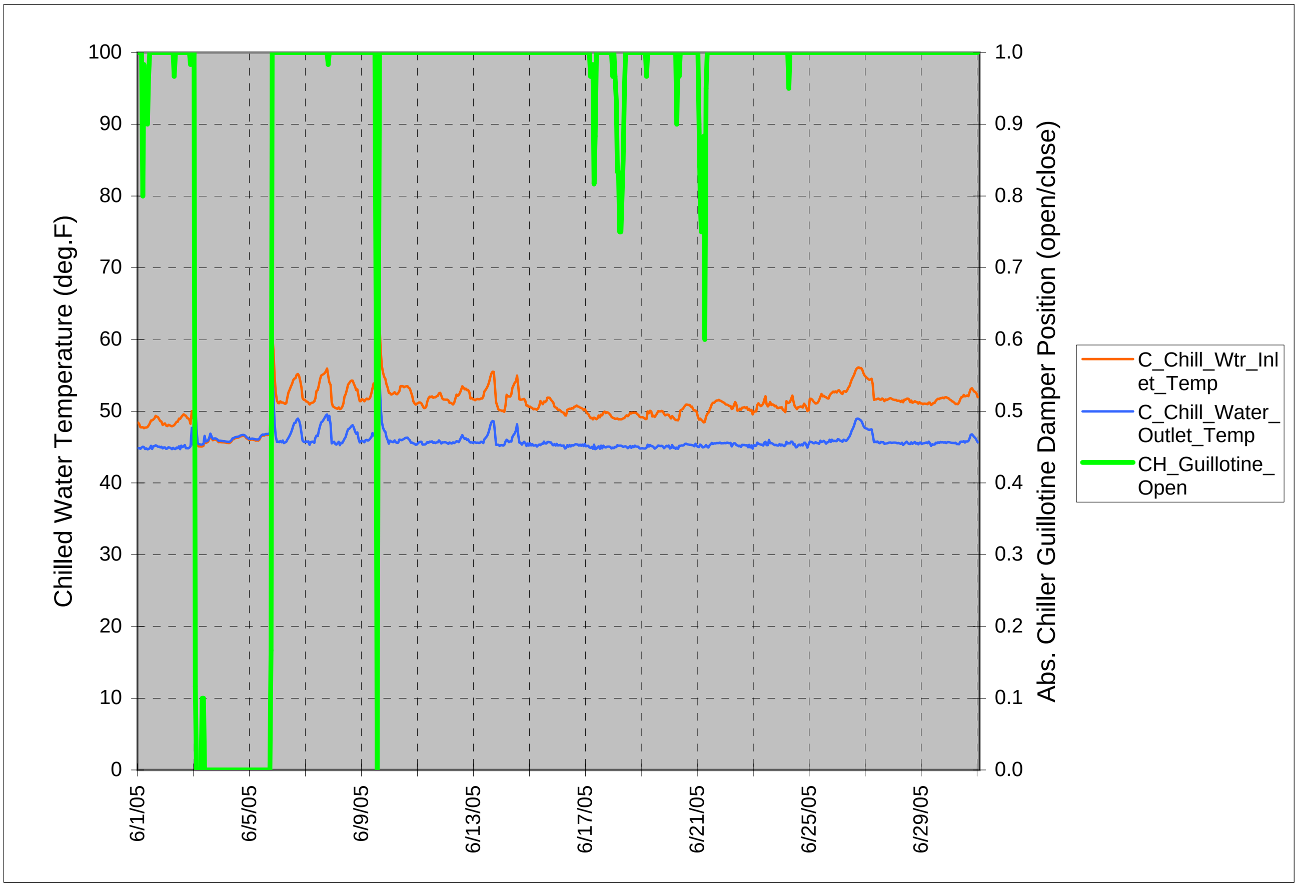
Outdoor Ambient Temperature (deg.F)
HRSG Inlet Duct Temperature (deg.F)
120
100
80
60
40
20
0
1200
1000
800
600
400
200
0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A

6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow

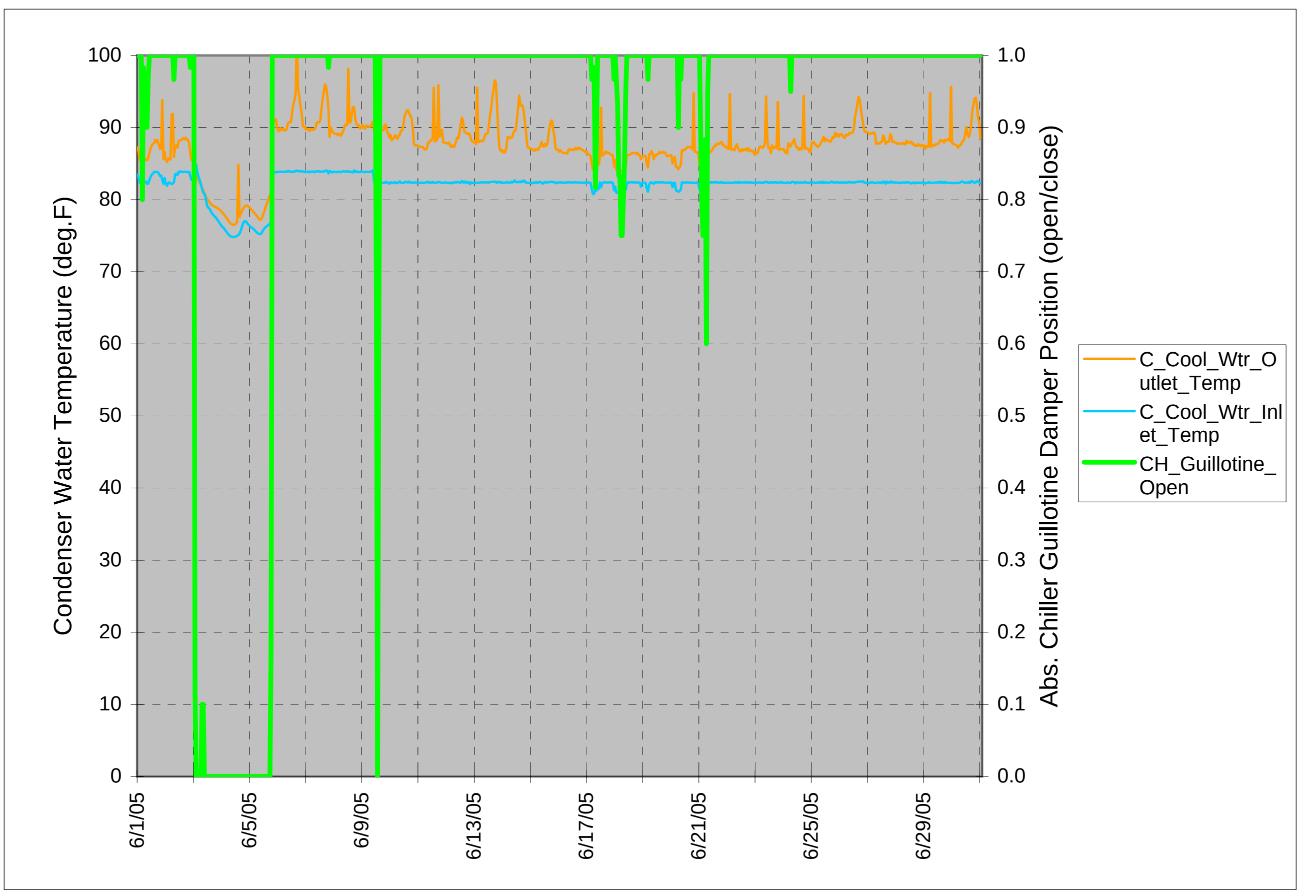


120
100
80
60
40
20
0
Outdoor Ambient Temperature (deg.F)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

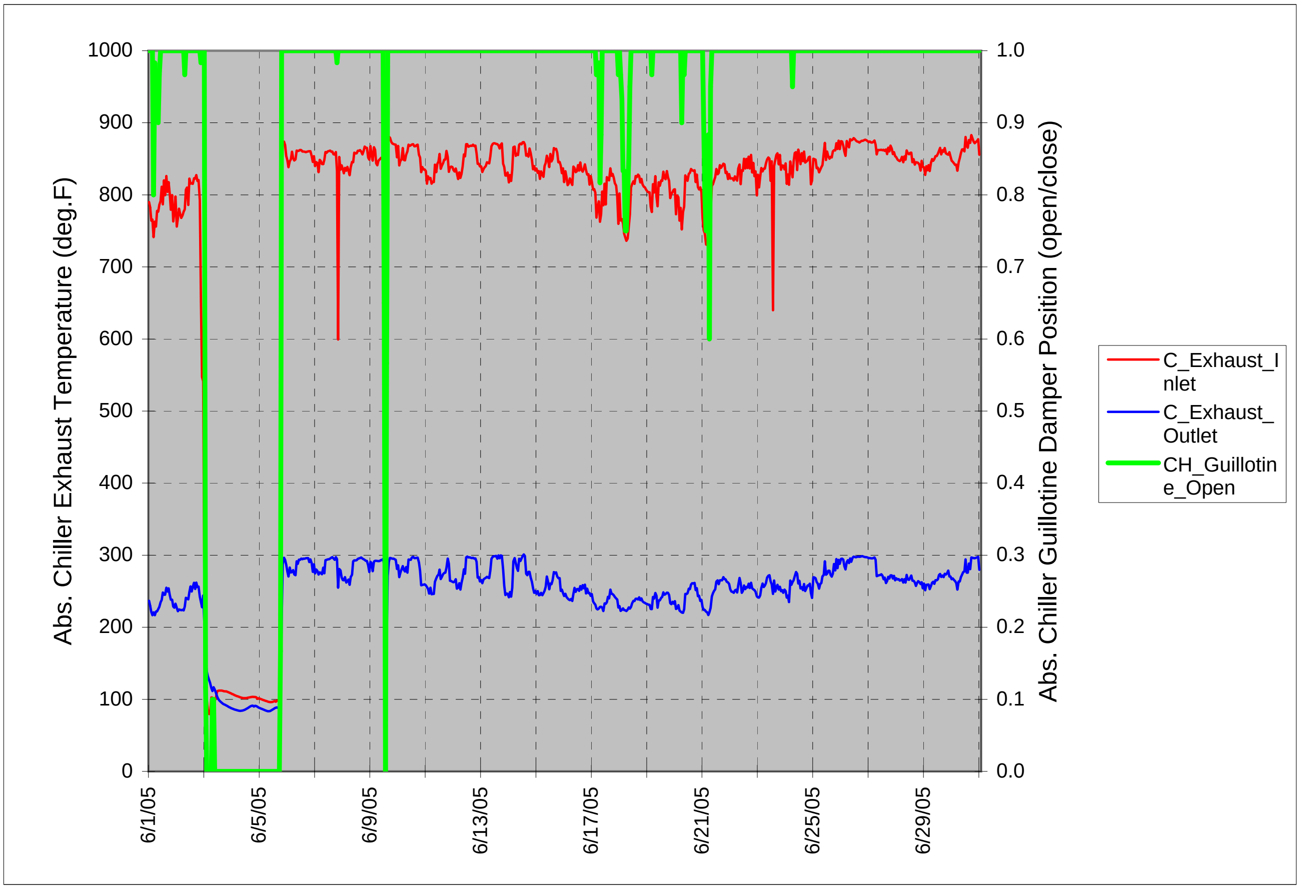
Misc. Plots

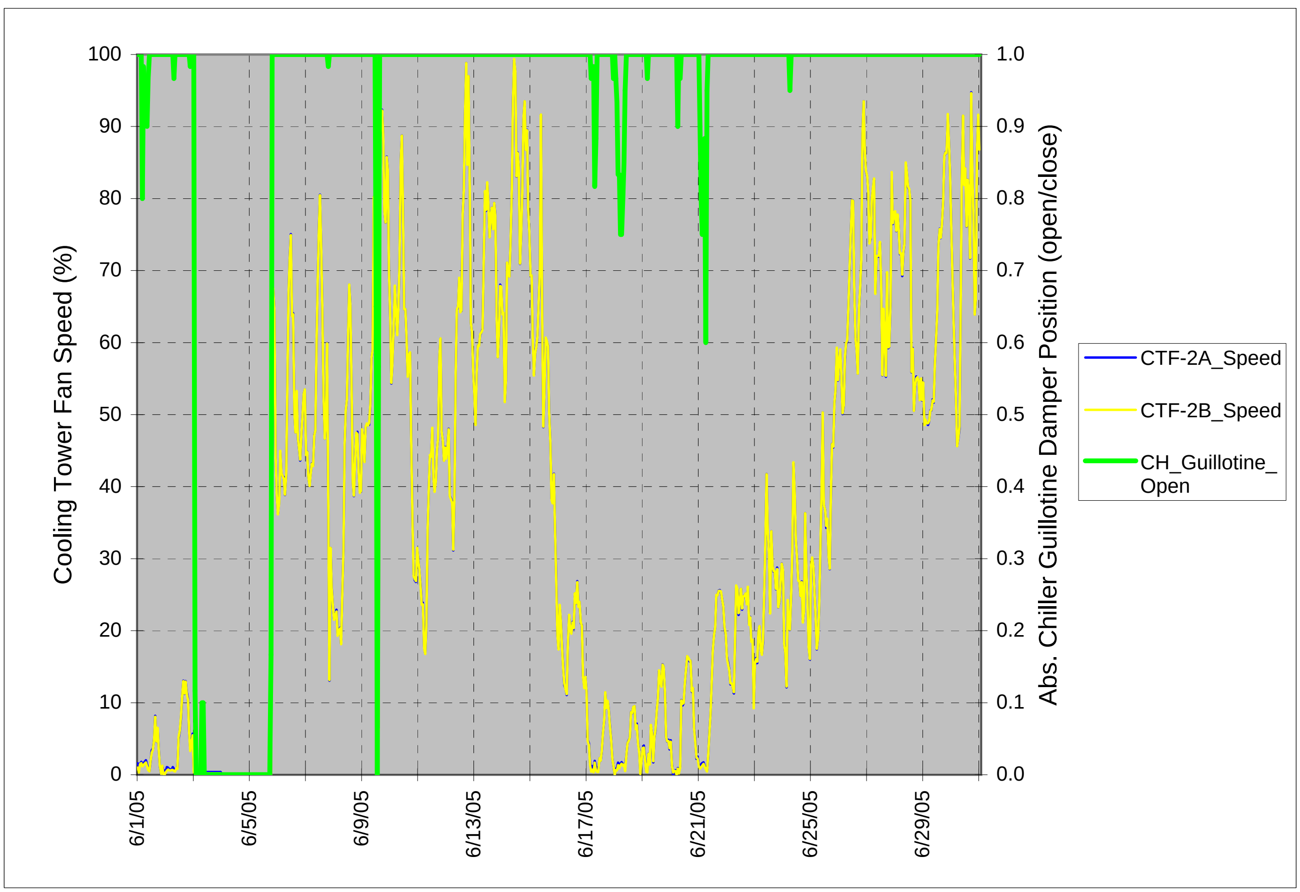


Chilled Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
C_Chill_Wtr_Inlet_Temp
C_Chill_Water_Outlet_Temp
CH_Guillotine_Open



Condenser Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
C_Cool_Wtr_Outlet_Temp
C_Cool_Wtr_Inlet_Temp
CH_Guillotine_Open

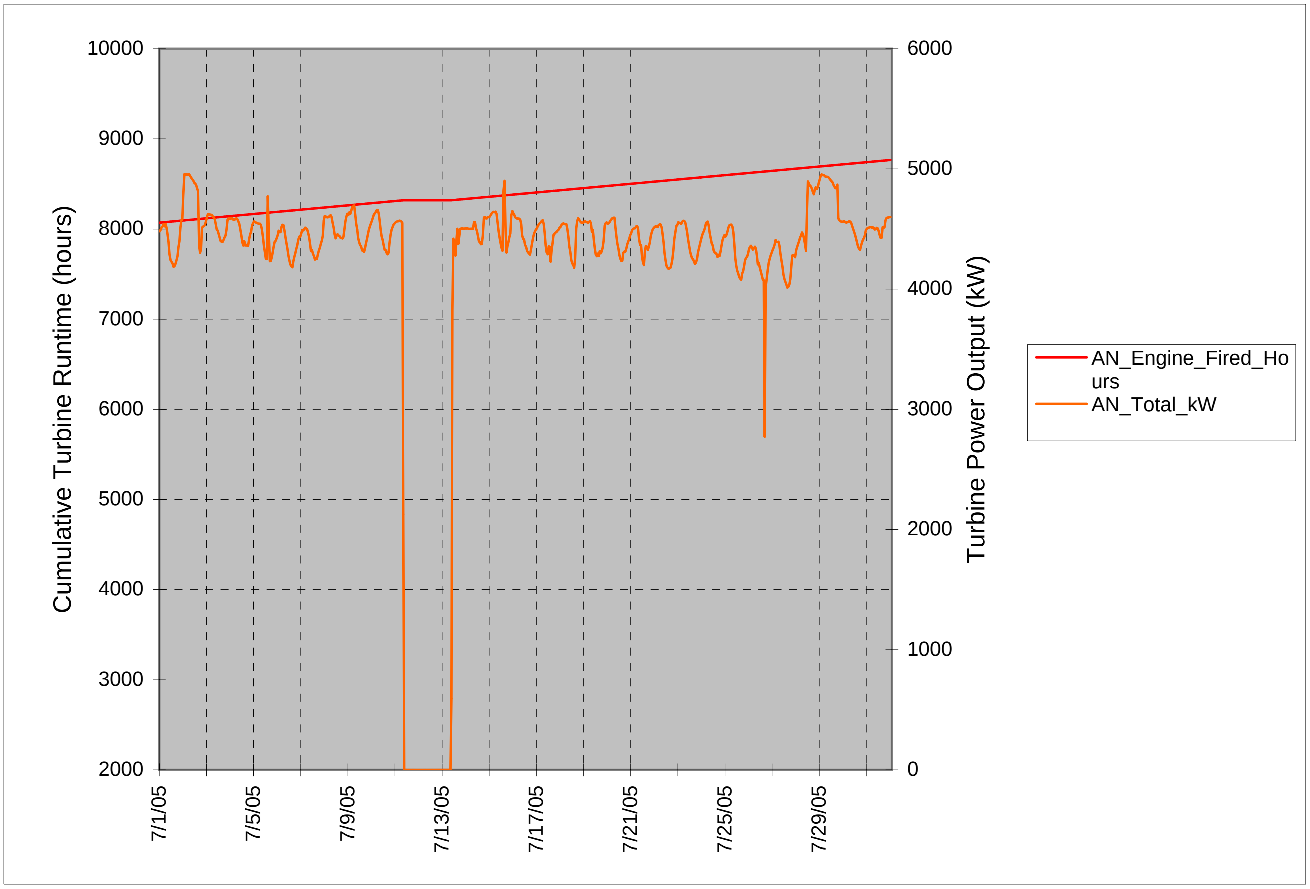

Abs. Chiller Exhaust Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
1000
900
800
700
600
500
400
300
200
100
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
C_Exhaust_Inlet
C_Exhaust_Outlet
CH_Guillotine_Open


Cooling Tower Fan Speed (%)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
6/1/05
6/5/05
6/9/05
6/13/05
6/17/05
6/21/05
6/25/05
6/29/05
CTF-2A_Speed
CTF-2B_Speed
CH_Guillotine_Open

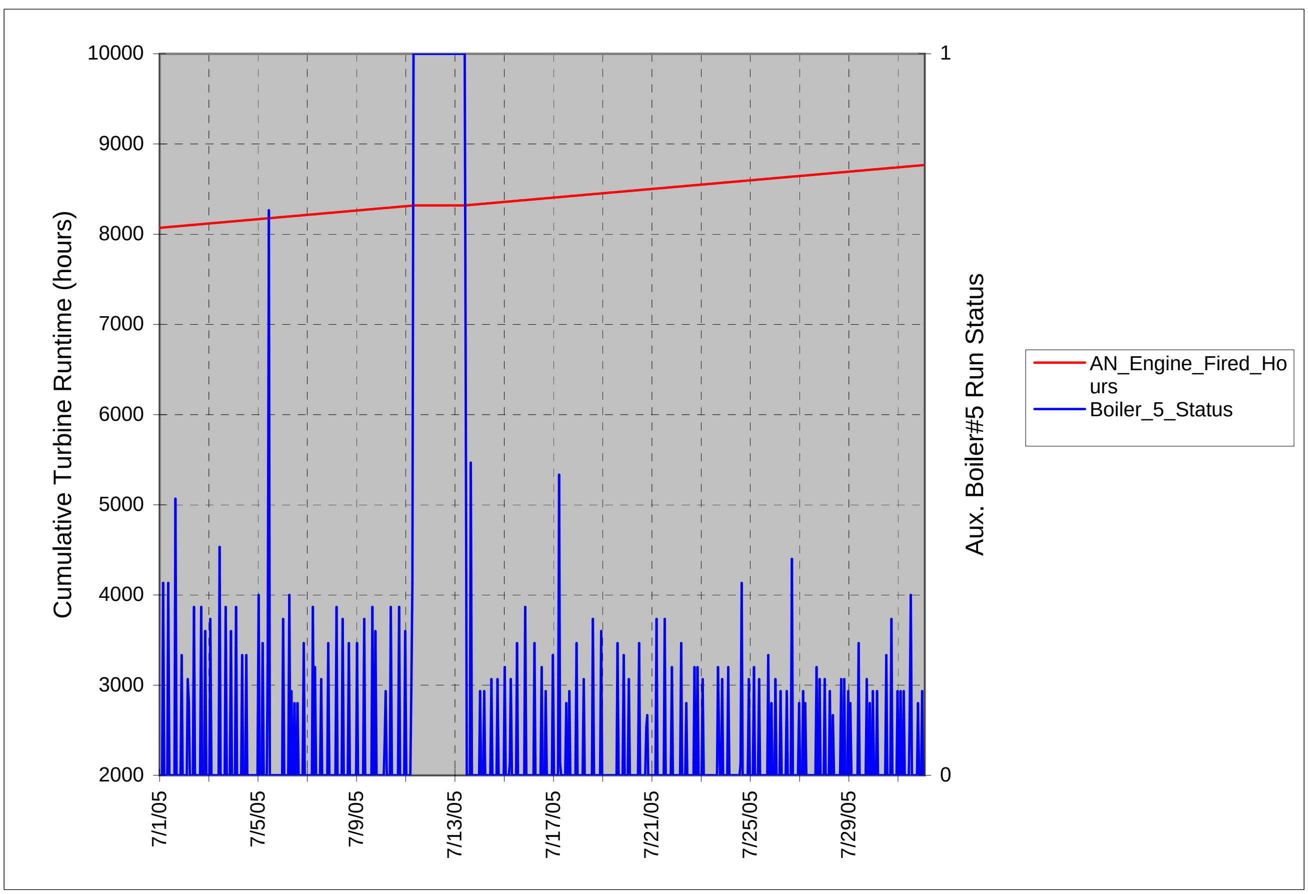
Appendix C

Detailed Operational Data: July 2005

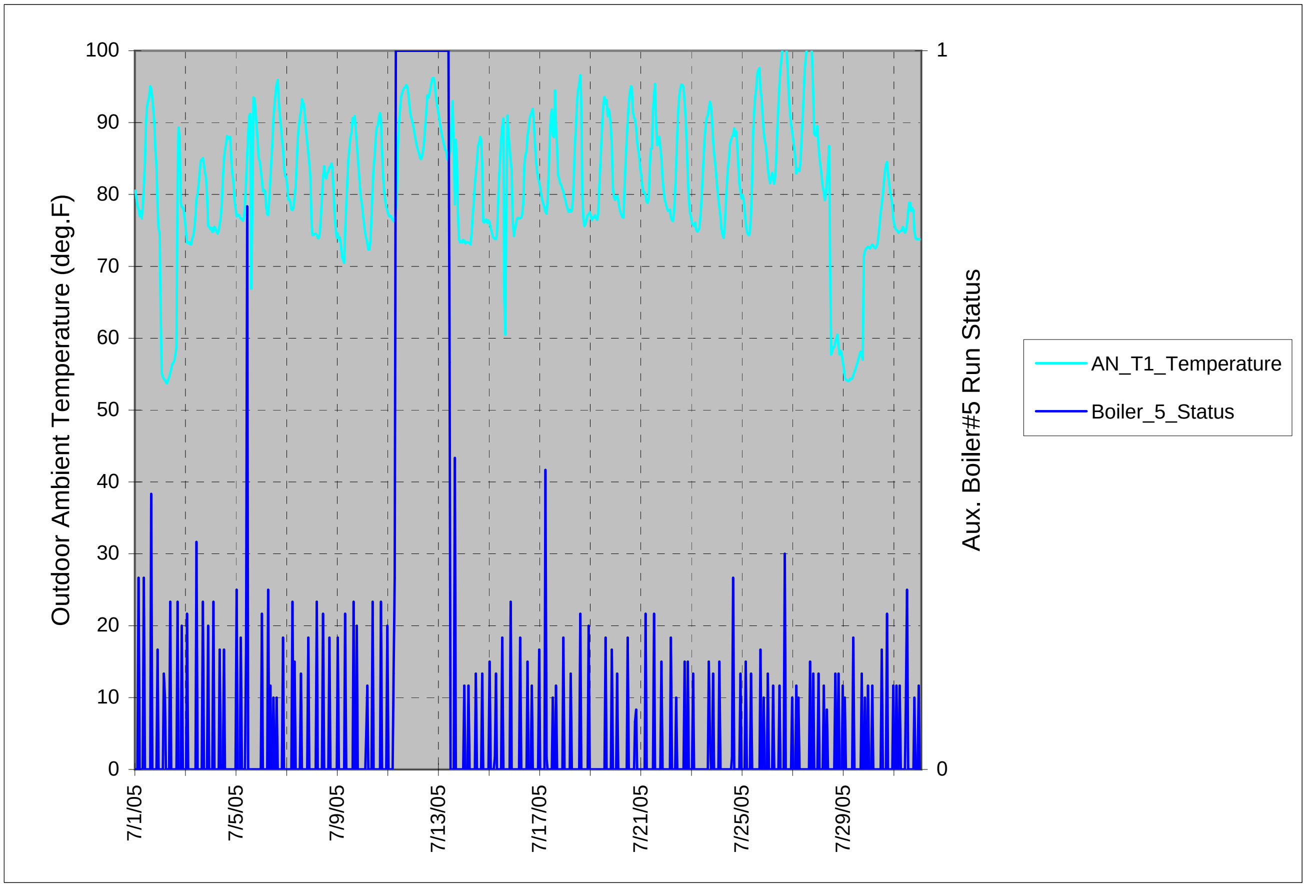
Misc. Plots



10000
9000
8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
AN_Engine_Fired_Hours
AN_Total_kW

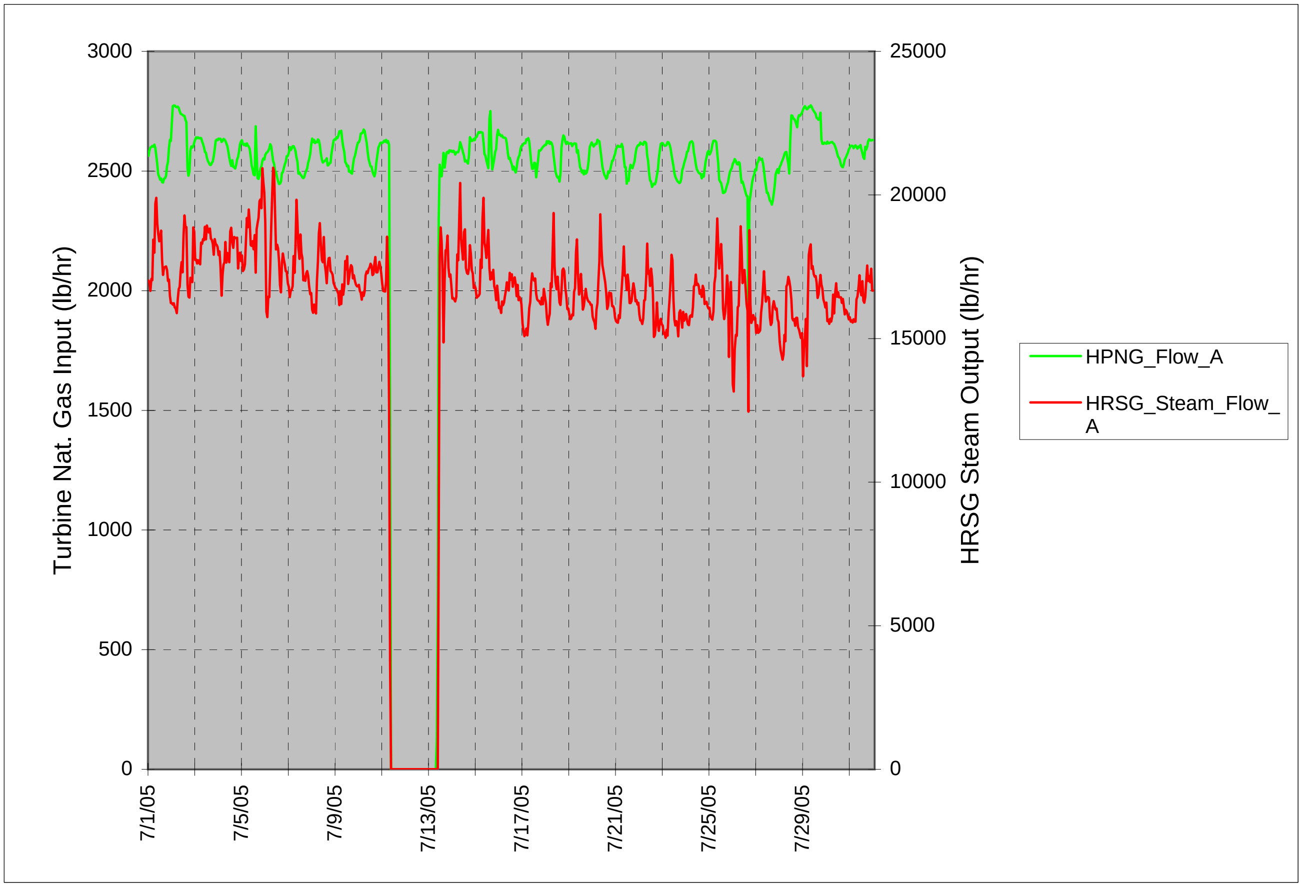


10000
9000
8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
1
0
Aux. Boiler#5 Run Status
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
AN_Engine_Fired_Hours
Boiler_5_Status

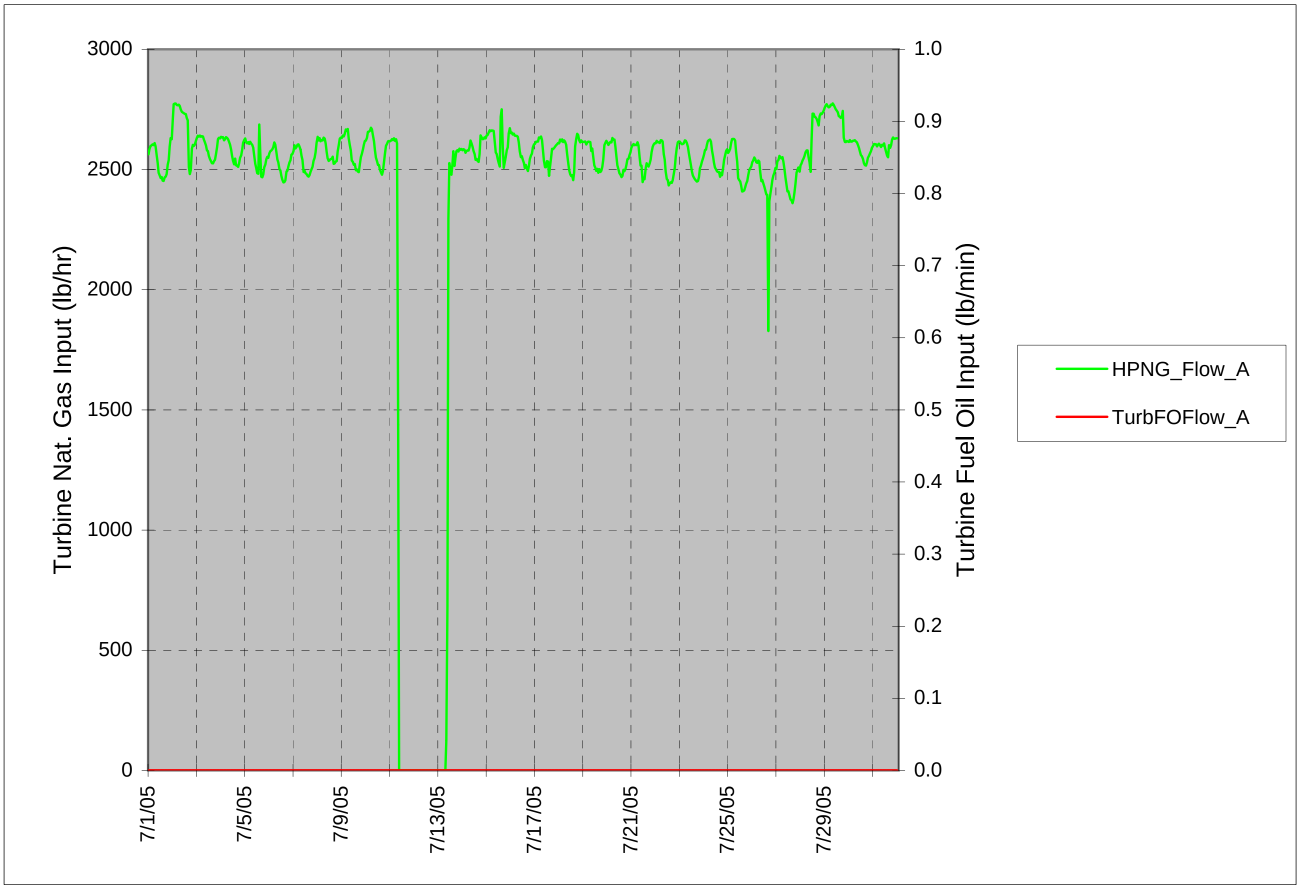

Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
AN_T1_Temperature
Boiler_5_Status
0
10
20
30
40
50
60
70
80
90
100
1
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05


Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
AN_T1_Temperature
HRSG_Steam_Flow_A
0
10
20
30
40
50
60
70
80
90
100
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05

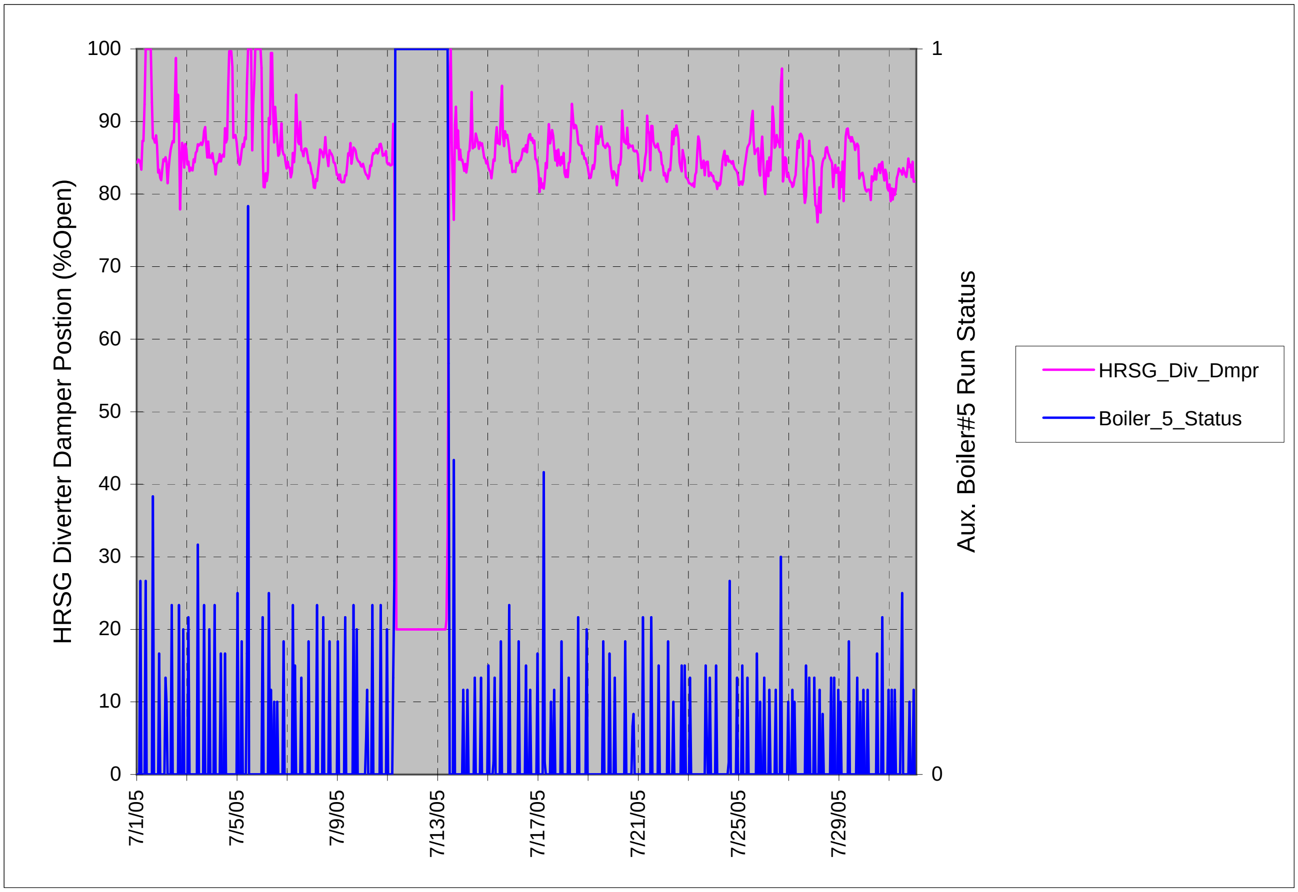
Misc. Plots

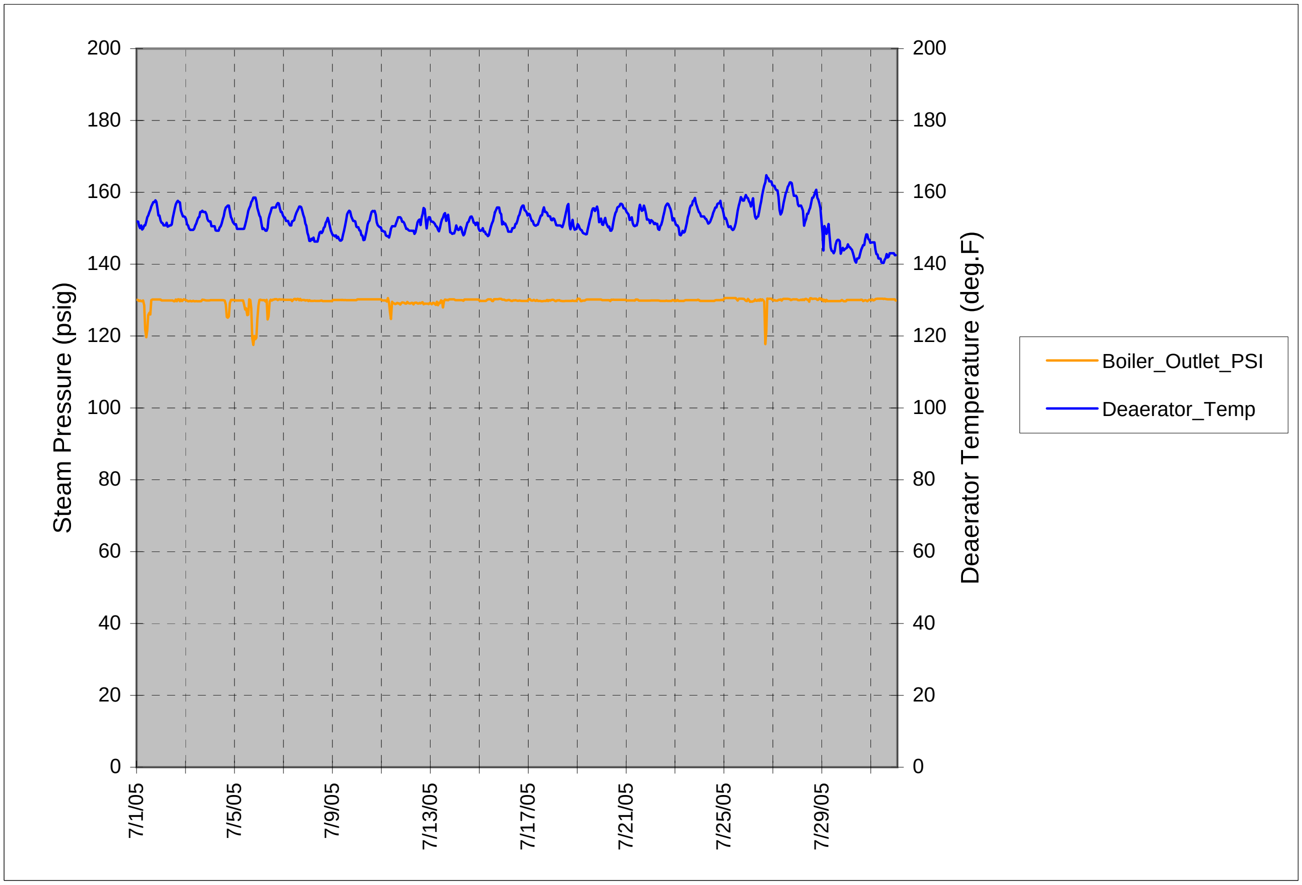


3000
2500
2000
1500
1000
500
0
25000
20000
15000
10000
5000
0
Turbine Nat. Gas Input (lb/hr)
HRSG Steam Output (lb/hr)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A

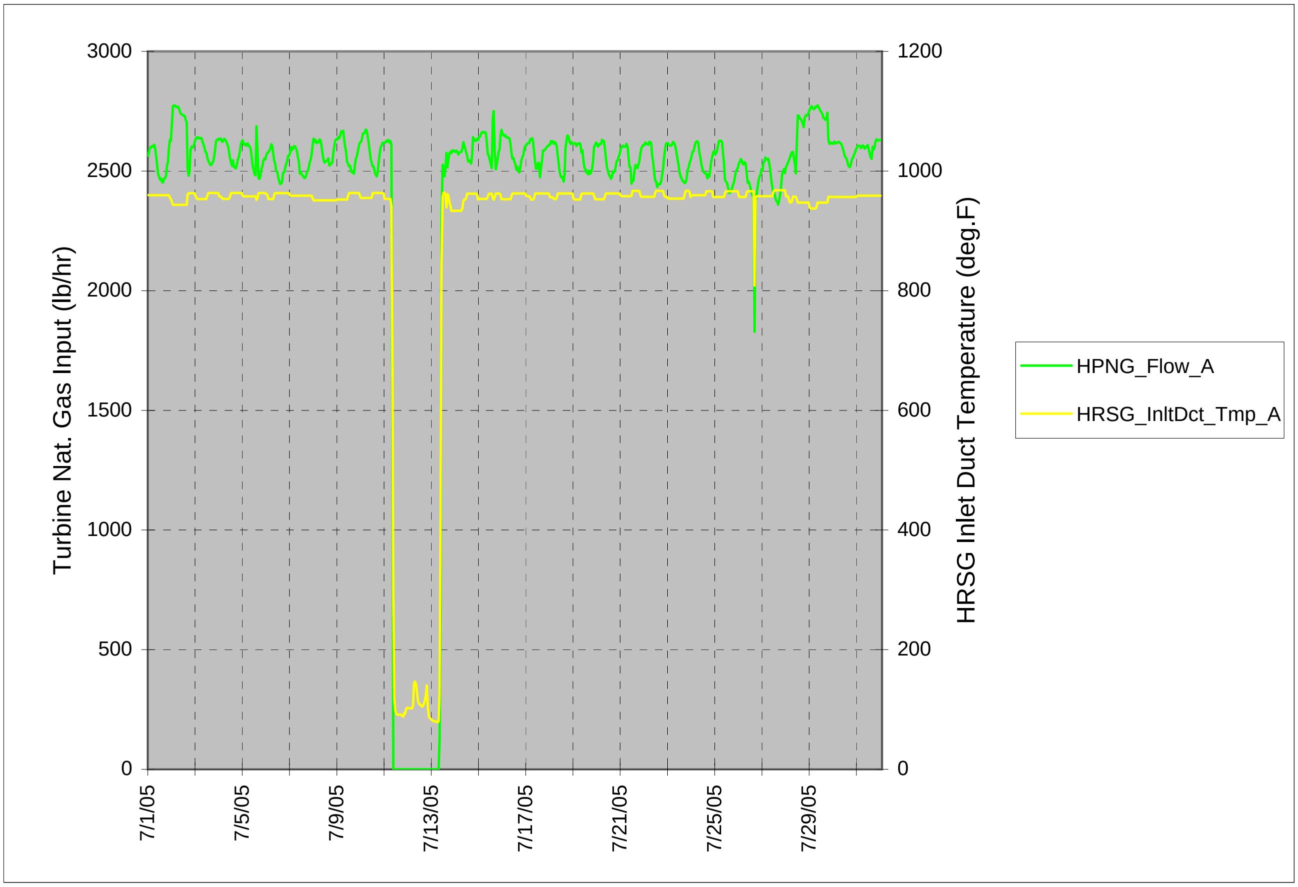


3000
2500
2000
1500
1000
500
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Turbine Nat. Gas Input (lb/hr)
Turbine Fuel Oil Input (lb/min)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
HPNG_Flow_A
TurbFOFlow_A

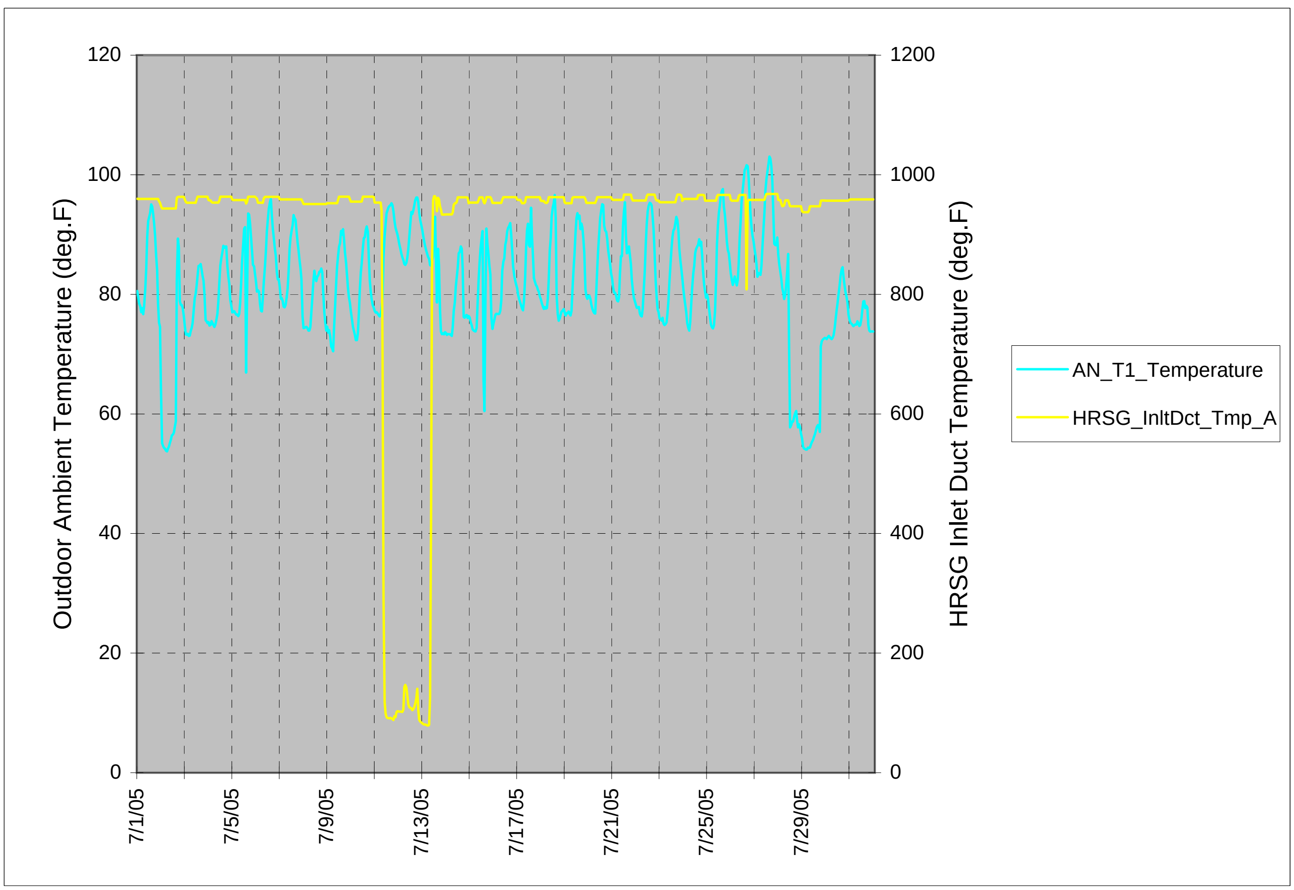

100
90
80
70
60
50
40
30
20
10
0
1
0
HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
HRSG_Div_Dmpr
Boiler_5_Status


200
180
160
140
120
100
80
60
40
20
0
Steam Pressure (psig)
Deaerator Temperature (deg.F)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
Boiler_Outlet_PSI
Deaerator_Temp

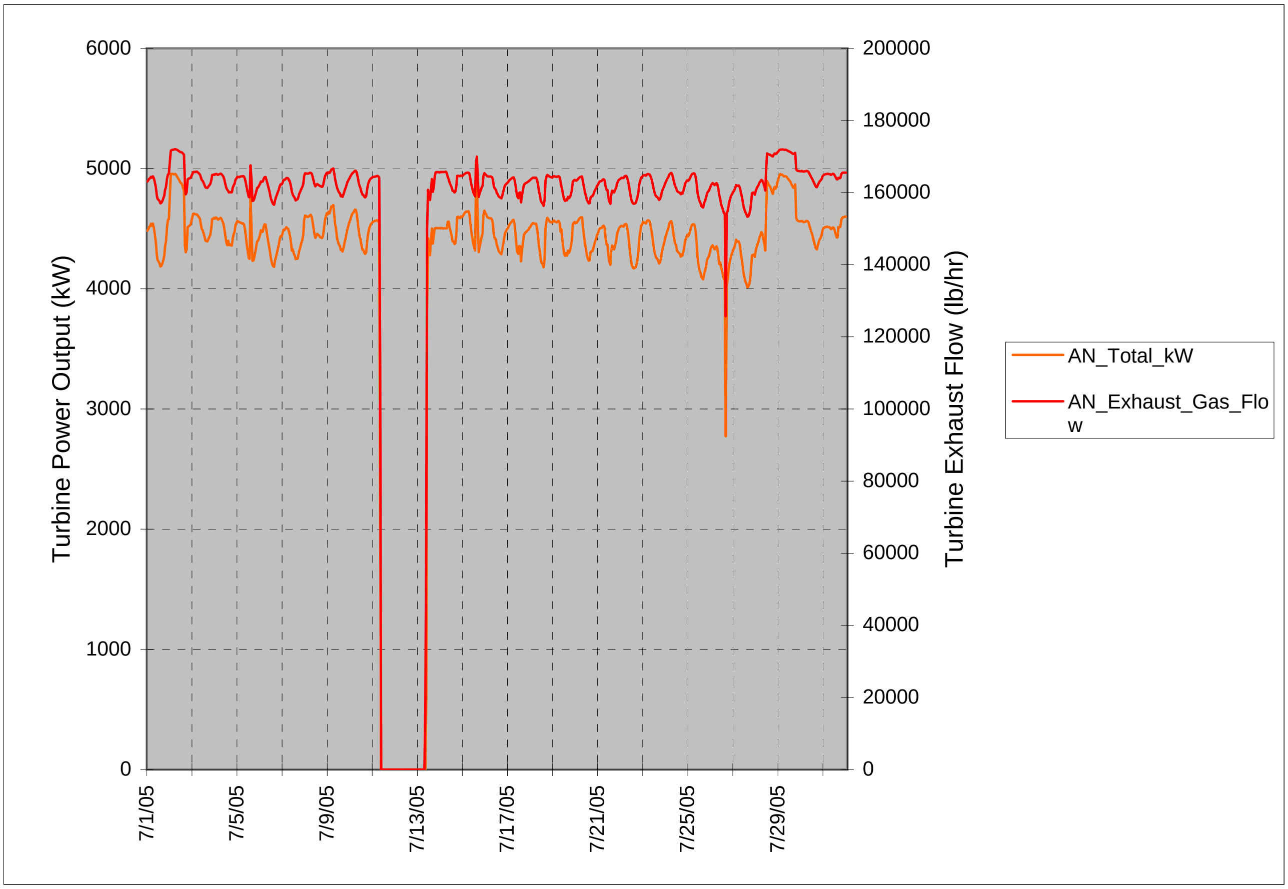
Misc. Plots

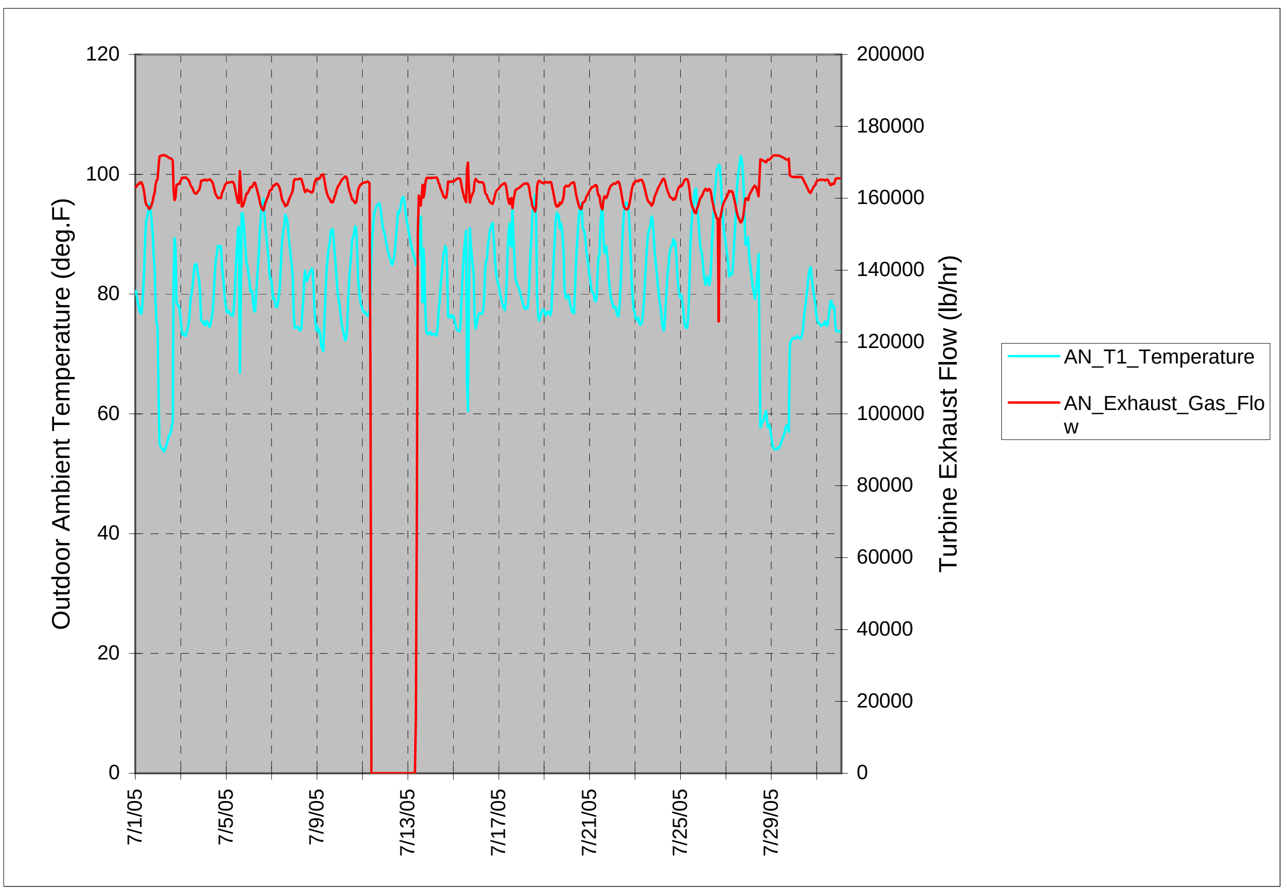


3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
1200
1000
800
600
400
200
0
HRSG Inlet Duct Temperature (deg.F)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A

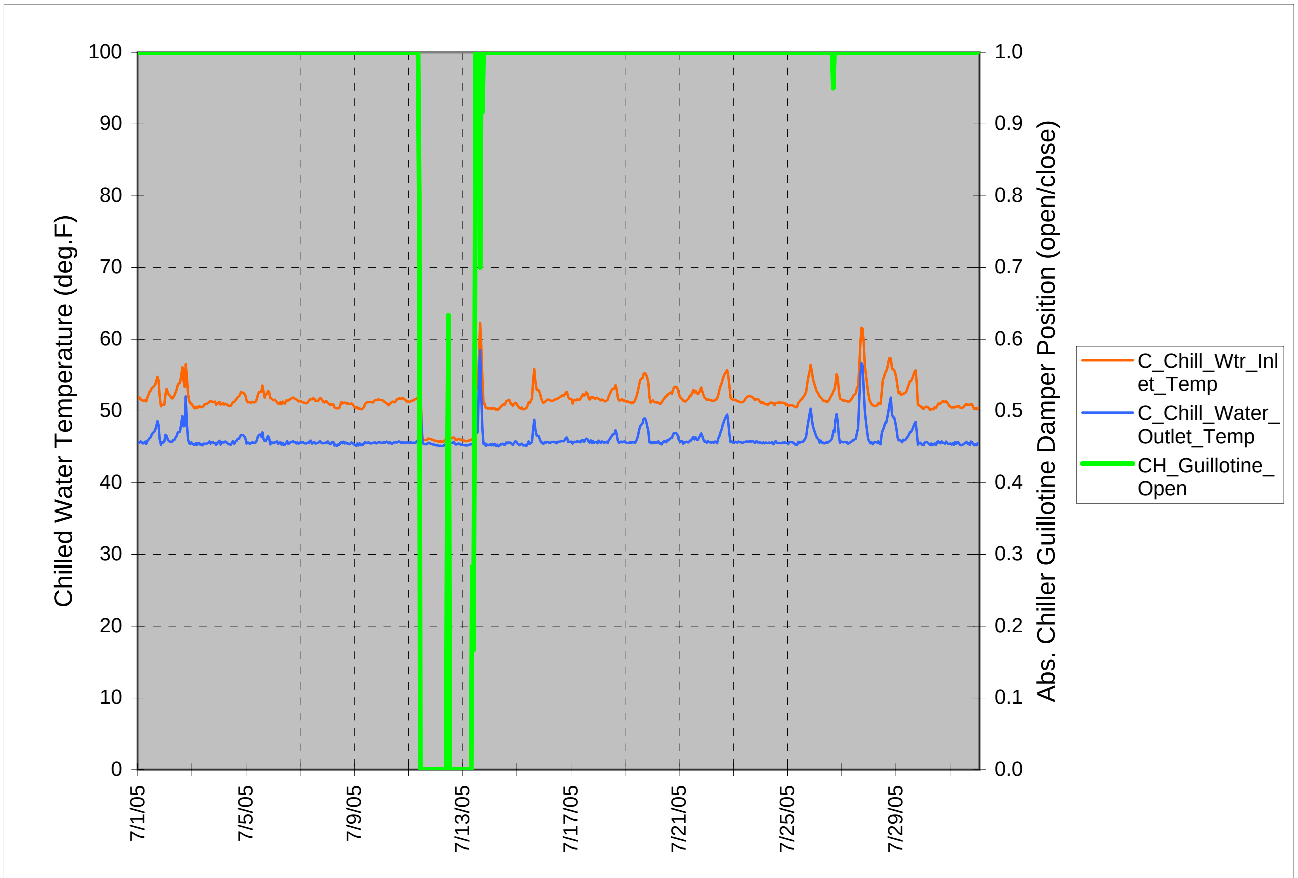


120
100
80
60
40
20
0
Outdoor Ambient Temperature (deg.F)
1200
1000
800
600
400
200
0
HRSG Inlet Duct Temperature (deg.F)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A


6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow

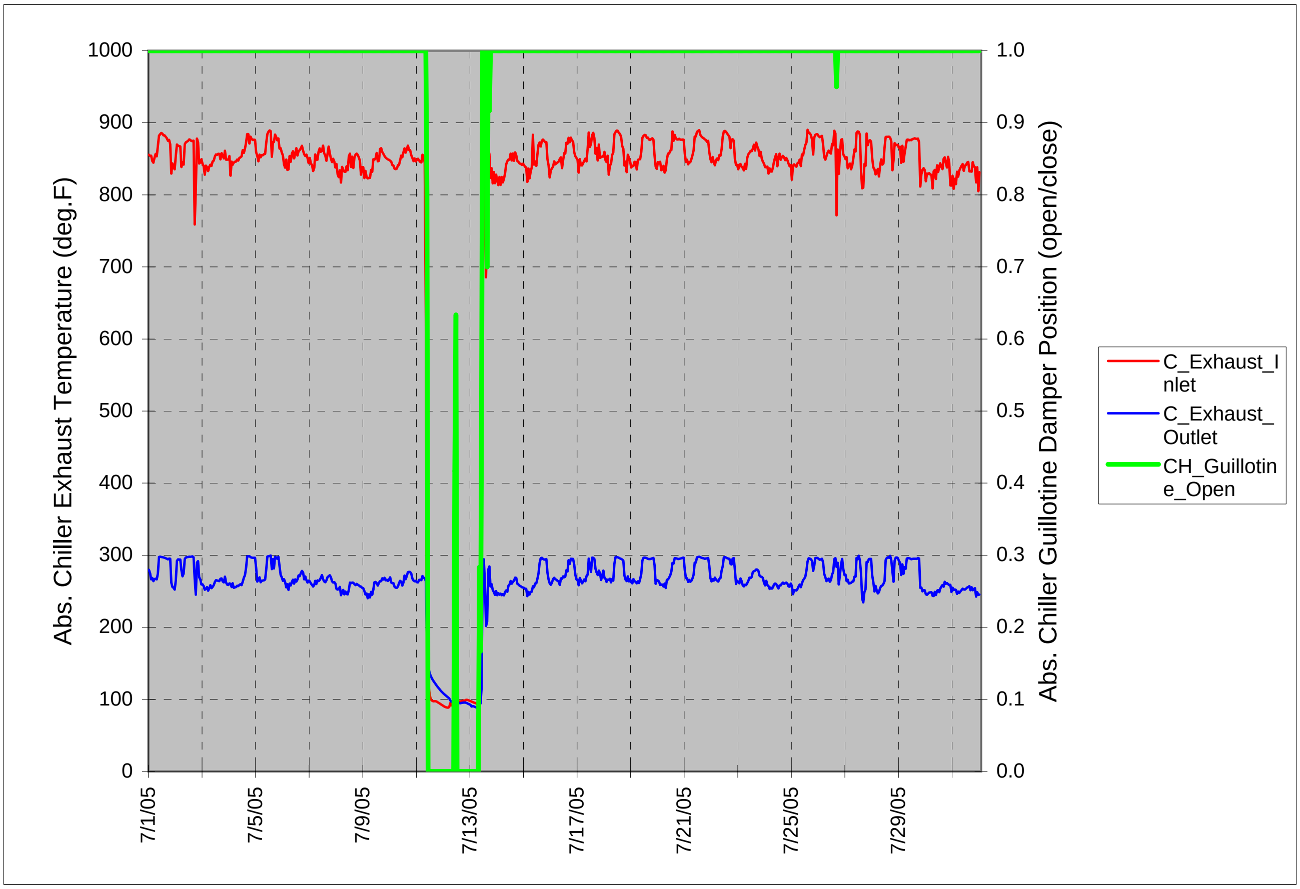

120
100
80
60
40
20
0
Outdoor Ambient Temperature (deg.F)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

Misc. Plots

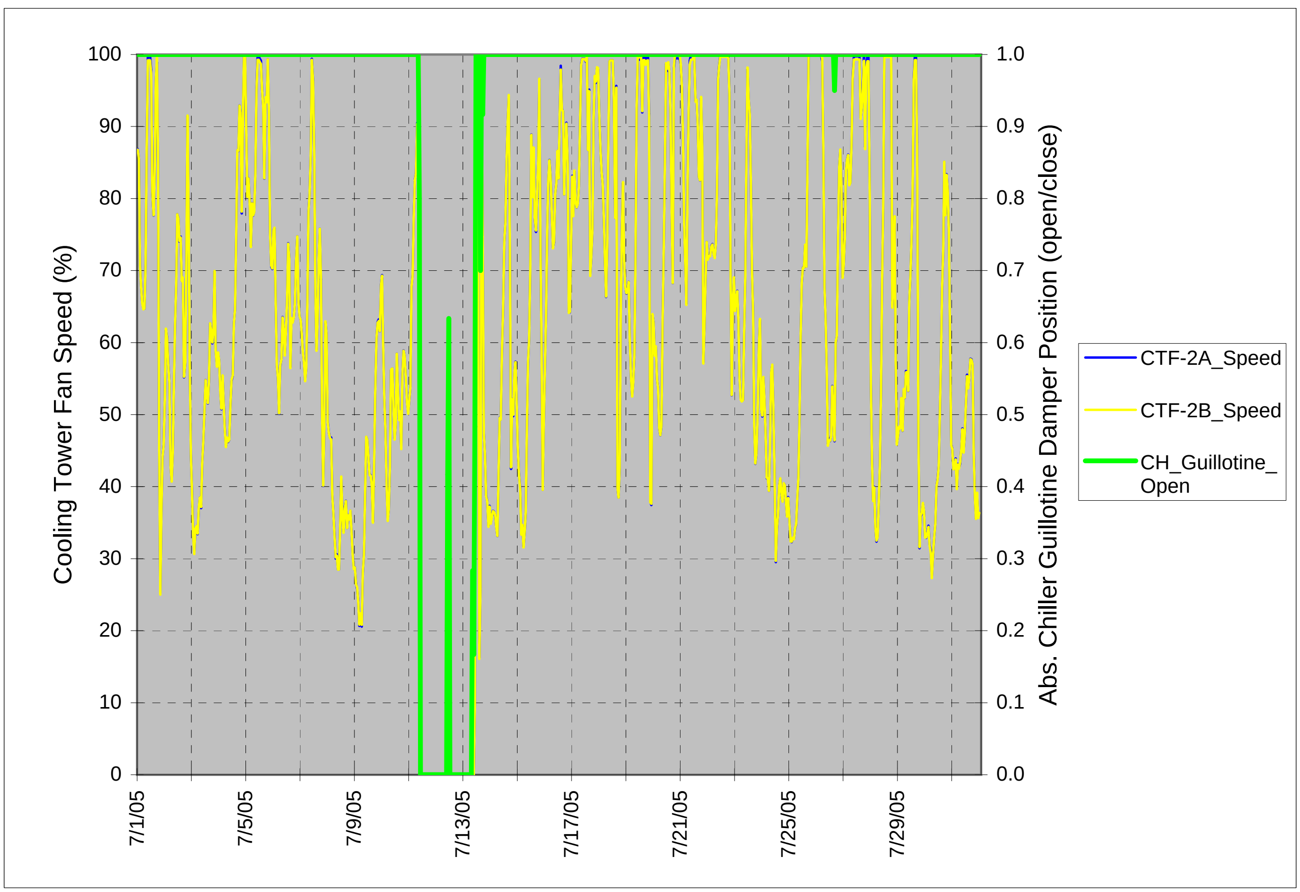


Chilled Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
C_Chill_Wtr_Inlet_Temp
C_Chill_Water_Outlet_Temp
CH_Guillotine_Open

Condenser Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
C_Cool_Wtr_Outlet_Temp
C_Cool_Wtr_Inlet_Temp
CH_Guillotine_Open



Abs. Chiller Exhaust Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
1000
900
800
700
600
500
400
300
200
100
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
C_Exhaust_Inlet
C_Exhaust_Outlet
CH_Guillotine_Open

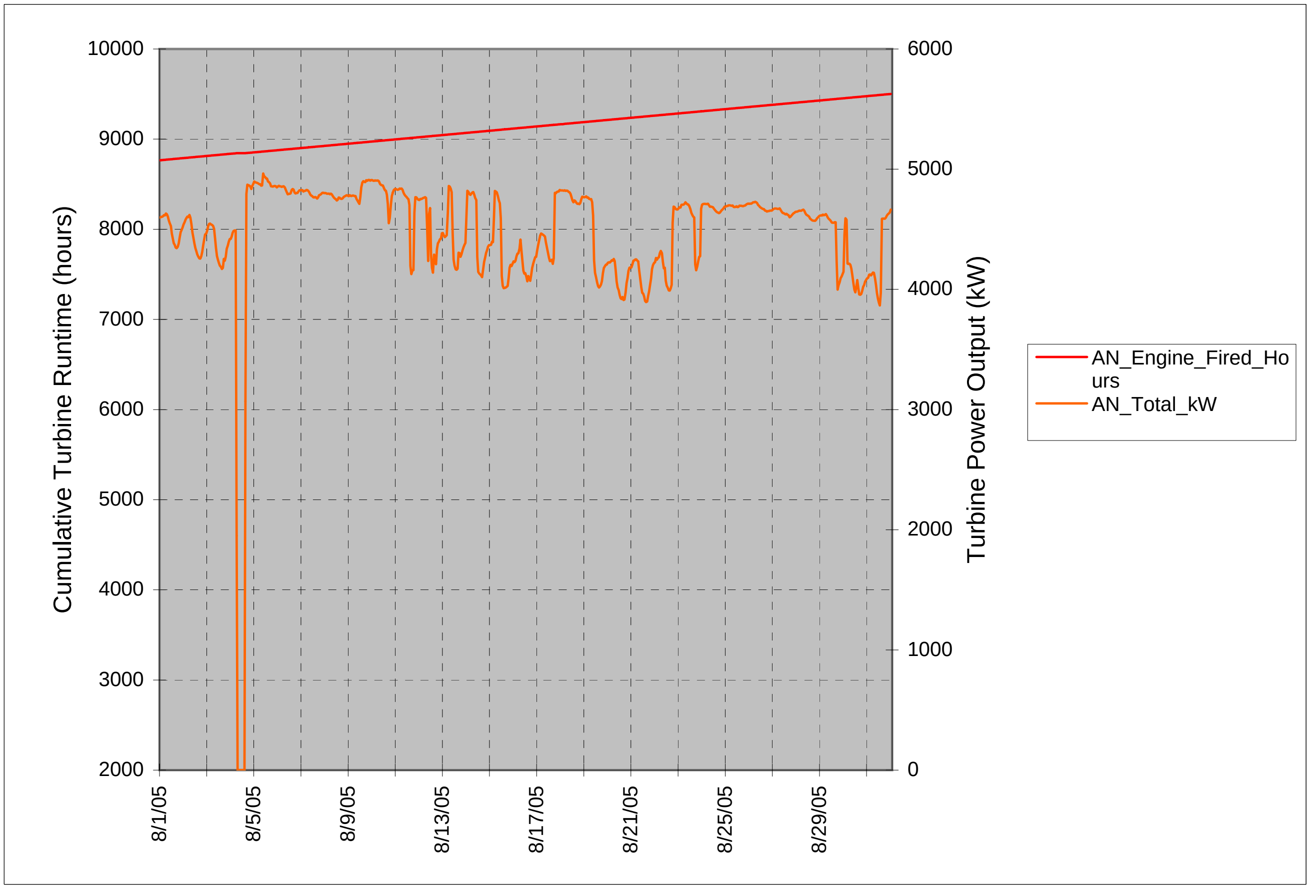


Cooling Tower Fan Speed (%)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
7/1/05
7/5/05
7/9/05
7/13/05
7/17/05
7/21/05
7/25/05
7/29/05
CTF-2A_Speed
CTF-2B_Speed
CH_Guillotine_Open

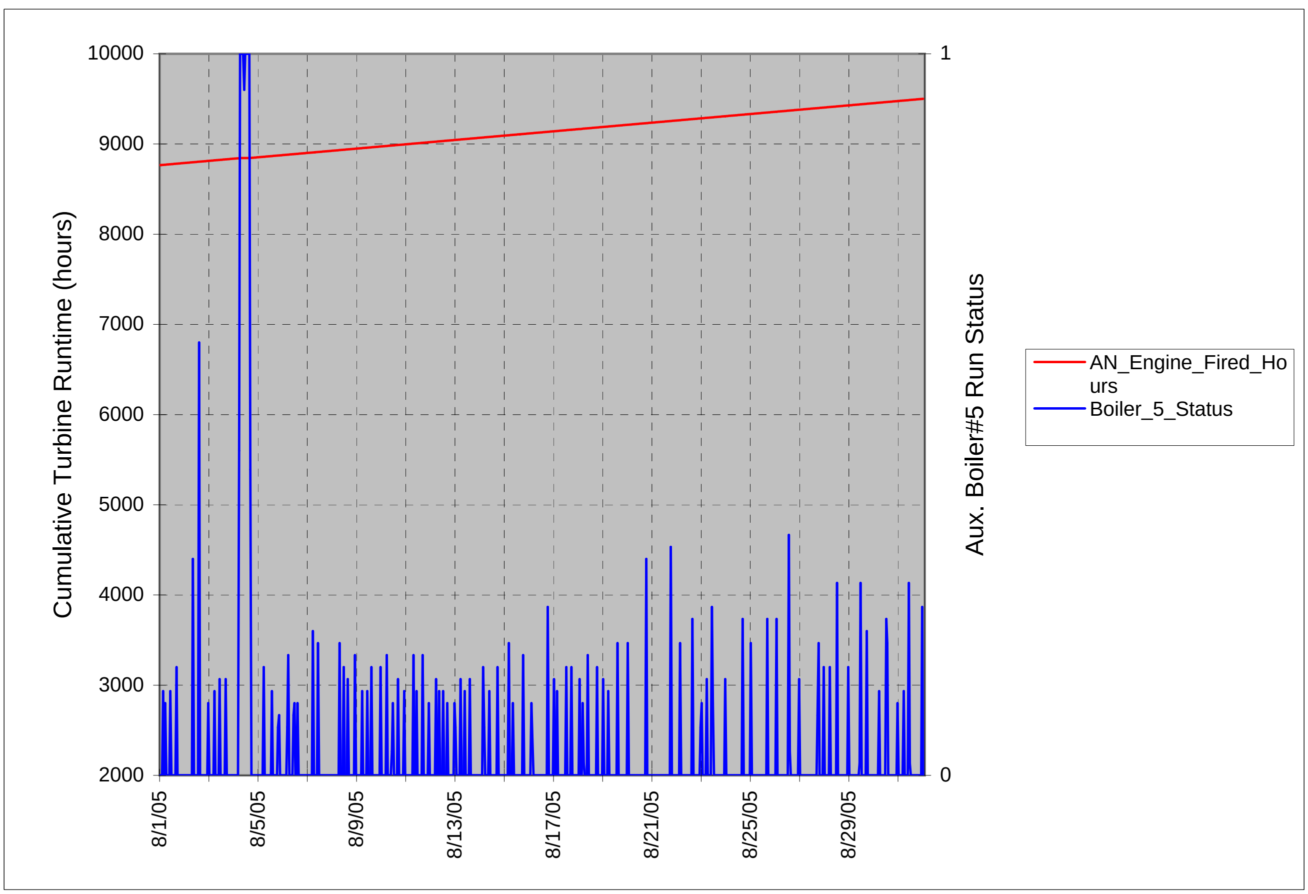
Appendix D

Detailed Operational Data: August 2005

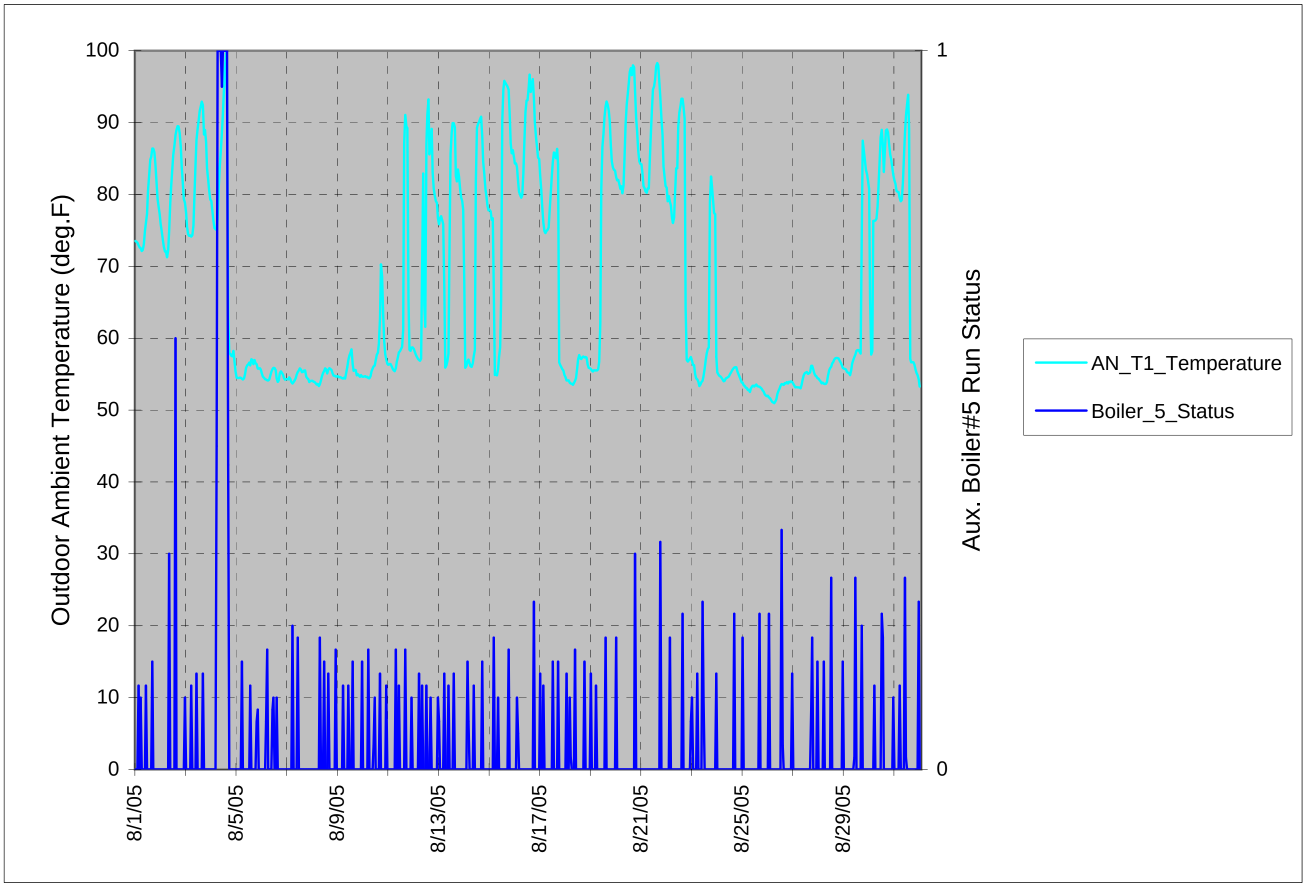
Misc. Plots



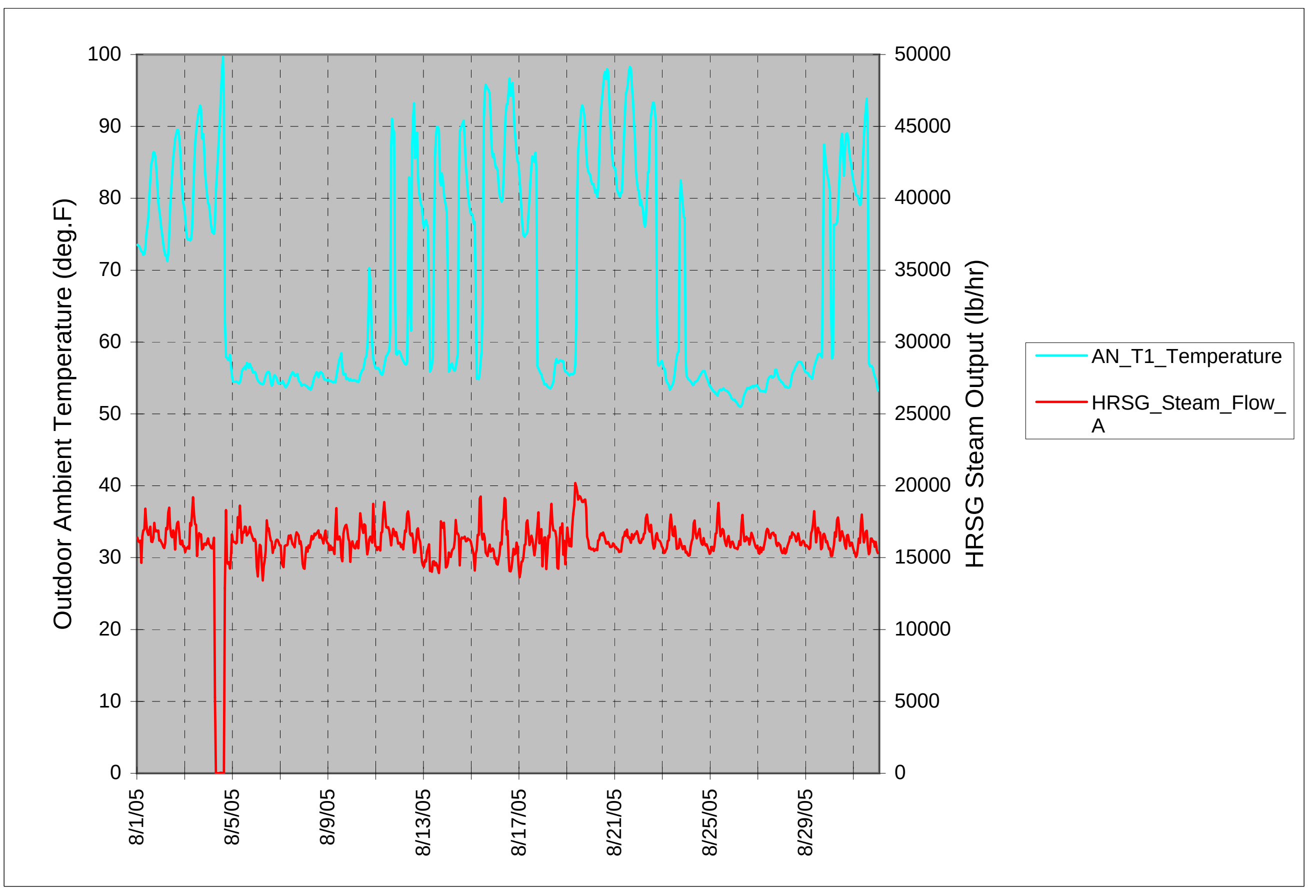
10000
9000
8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
AN_Engine_Fired_Hours
AN_Total_kW



10000
9000
8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
1
0
Aux. Boiler#5 Run Status
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
AN_Engine_Fired_Hours
Boiler_5_Status

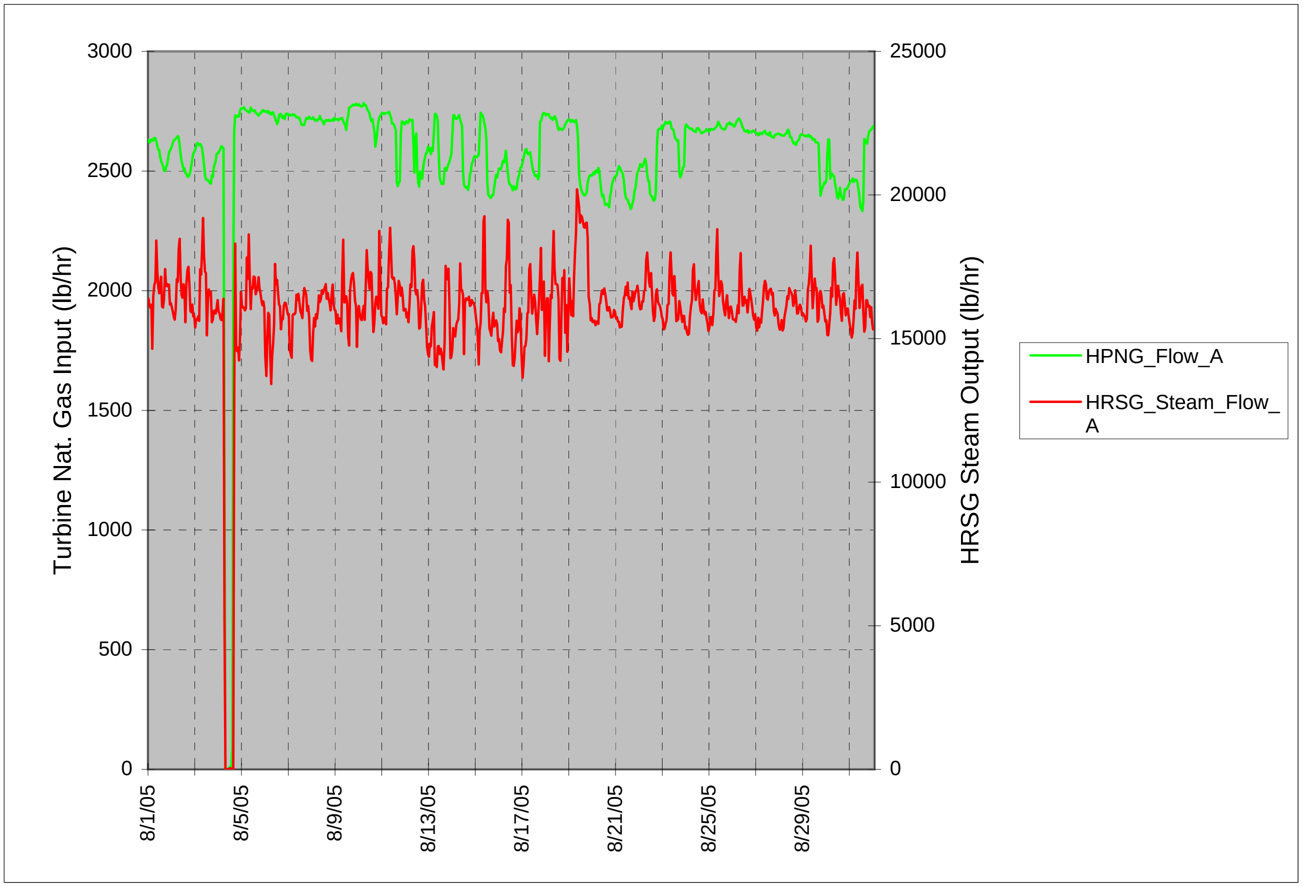


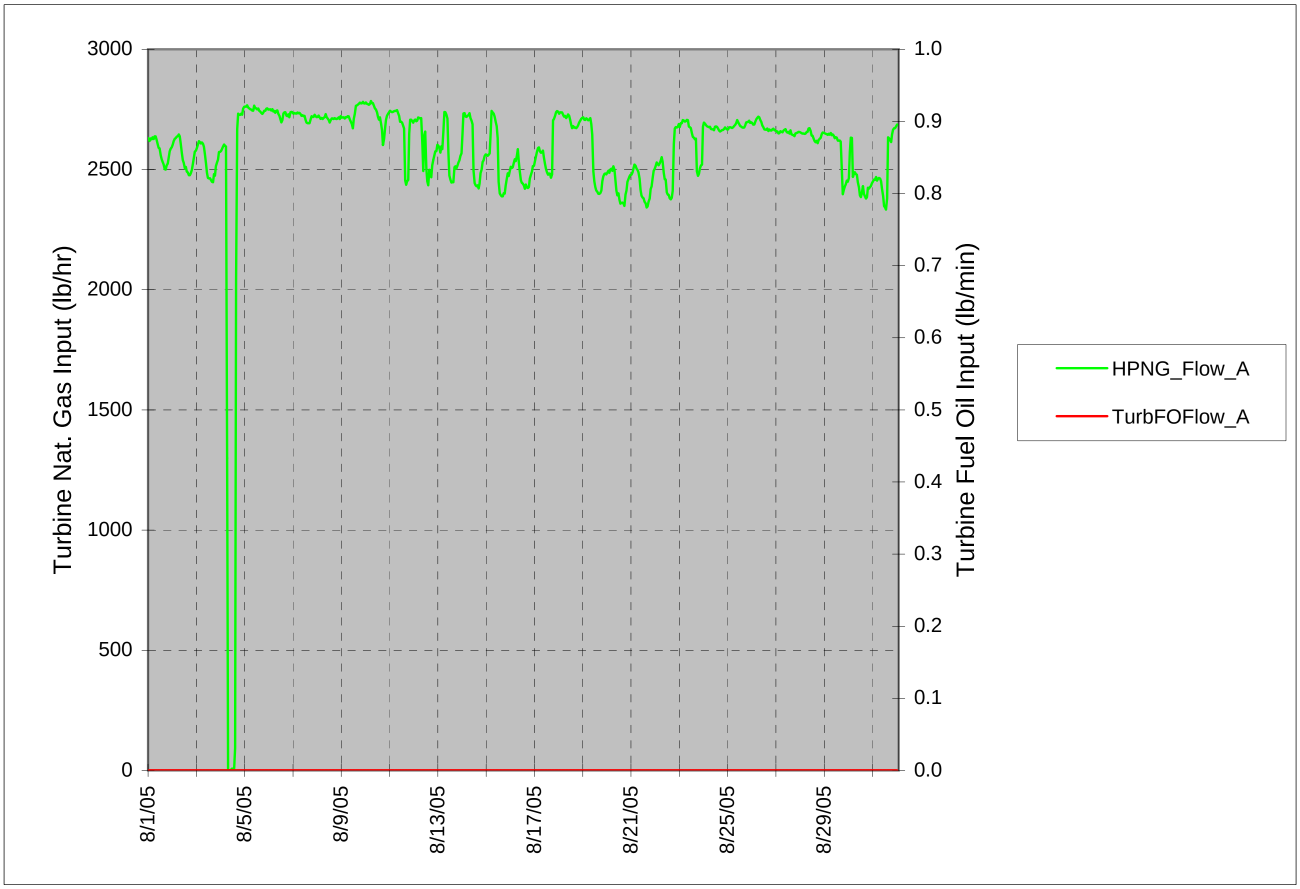
Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
AN_T1_Temperature
Boiler_5_Status
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05

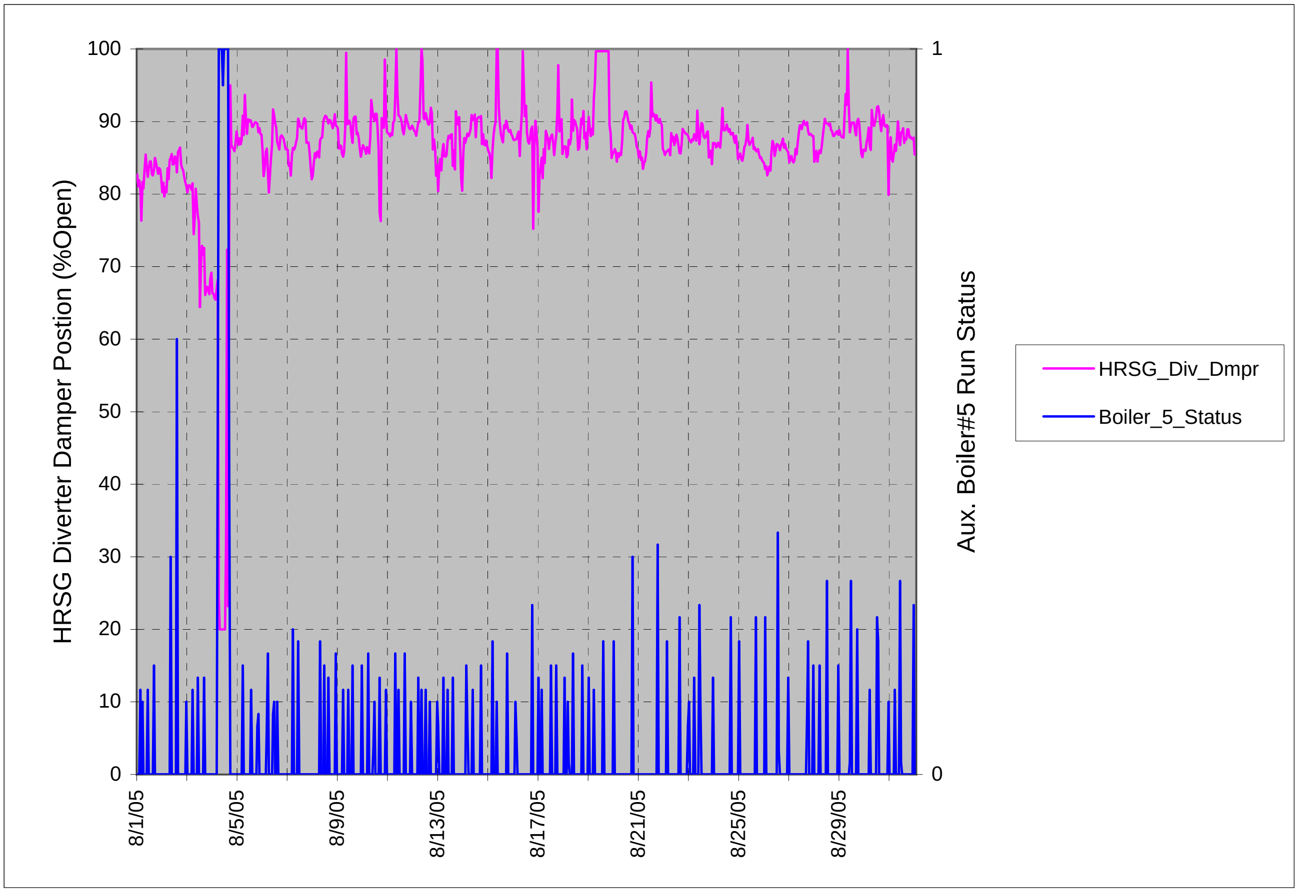


Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
AN_T1_Temperature
HRSG_Steam_Flow_A
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05

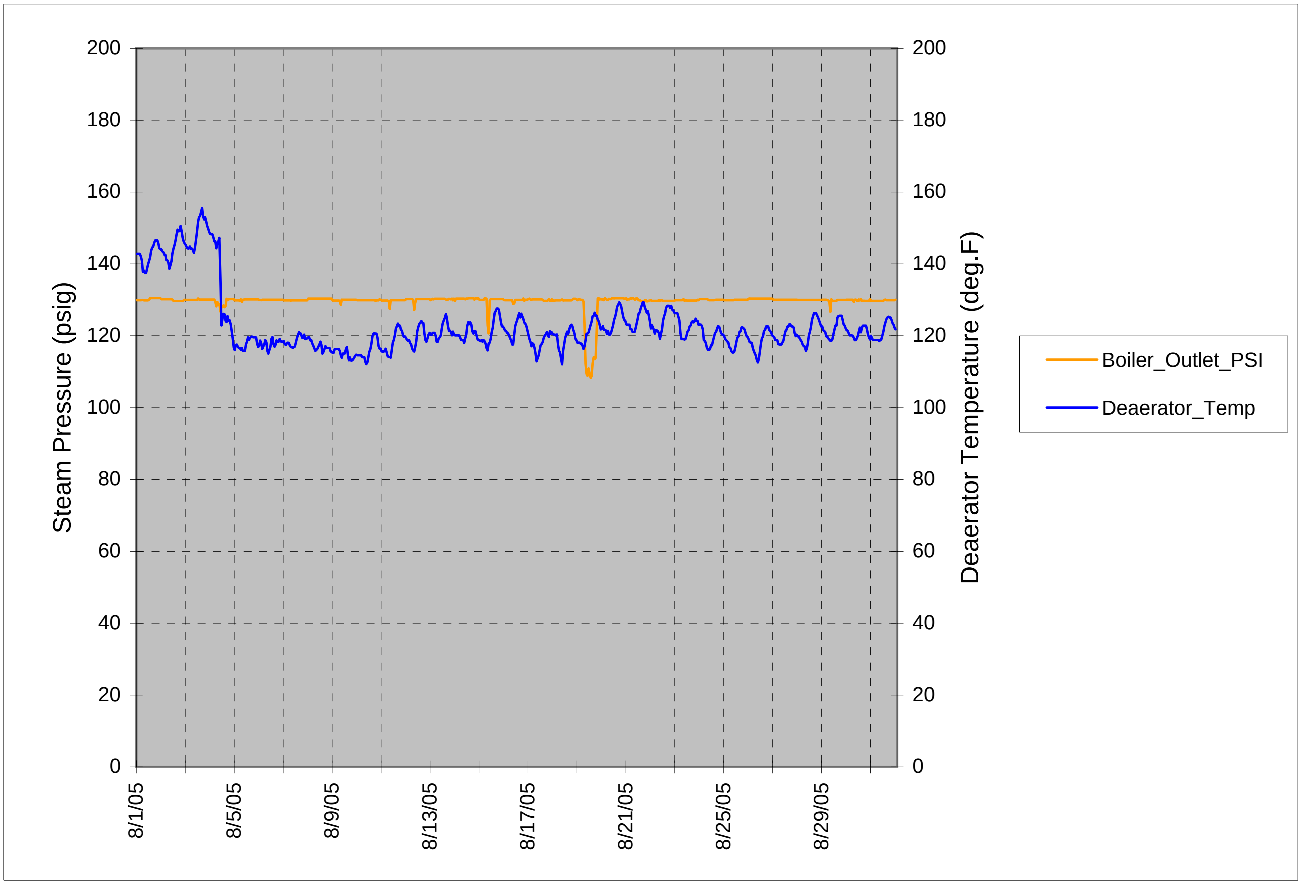
Misc. Plots


3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
25000
20000
15000
10000
5000
0
HRSG Steam Output (lb/hr)
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A


3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Turbine Fuel Oil Input (lb/min)
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
HPNG_Flow_A
TurbFOFlow_A

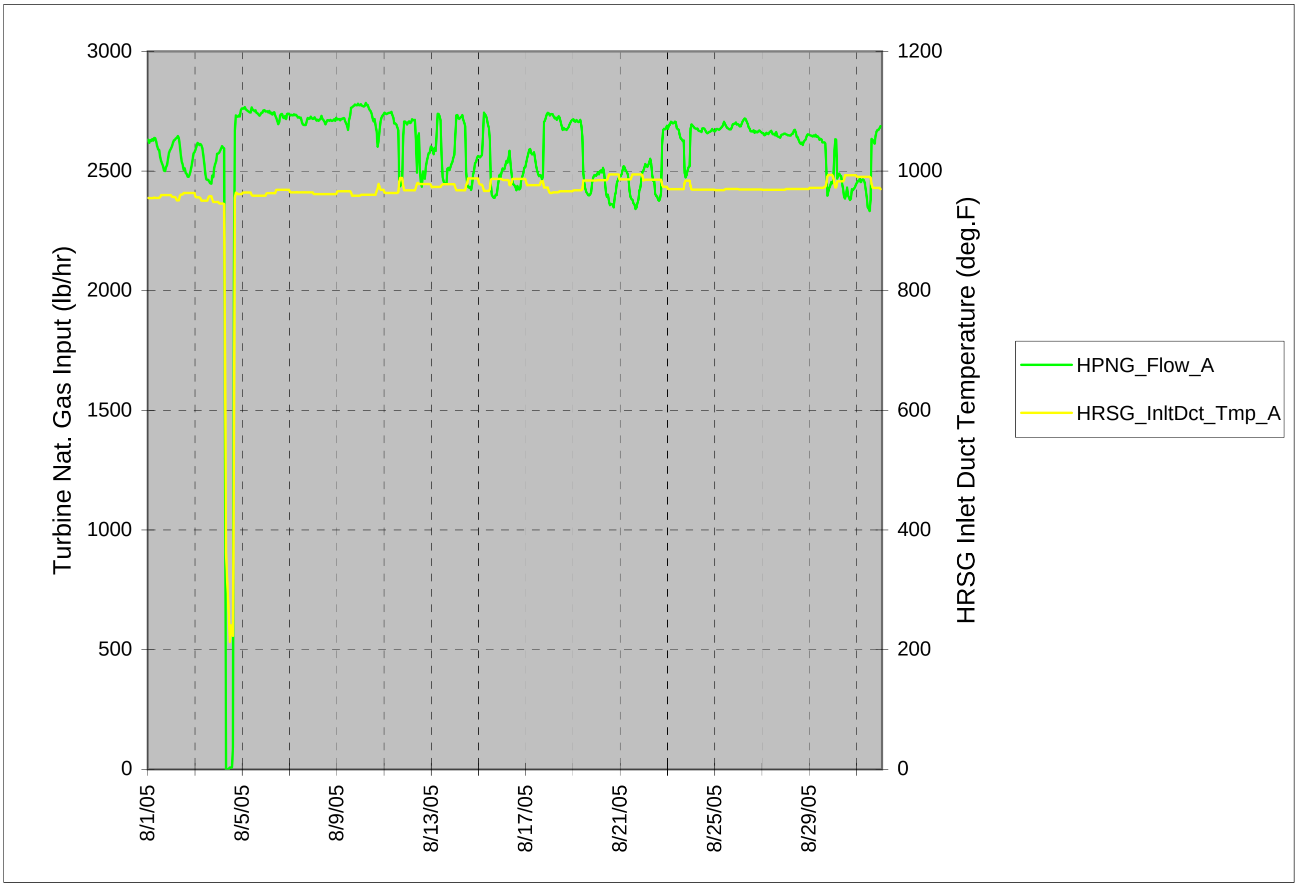


HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
HRSG_Div_Dmpr
Boiler_5_Status
100
90
80
70
60
50
40
30
20
10
0
1
0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05

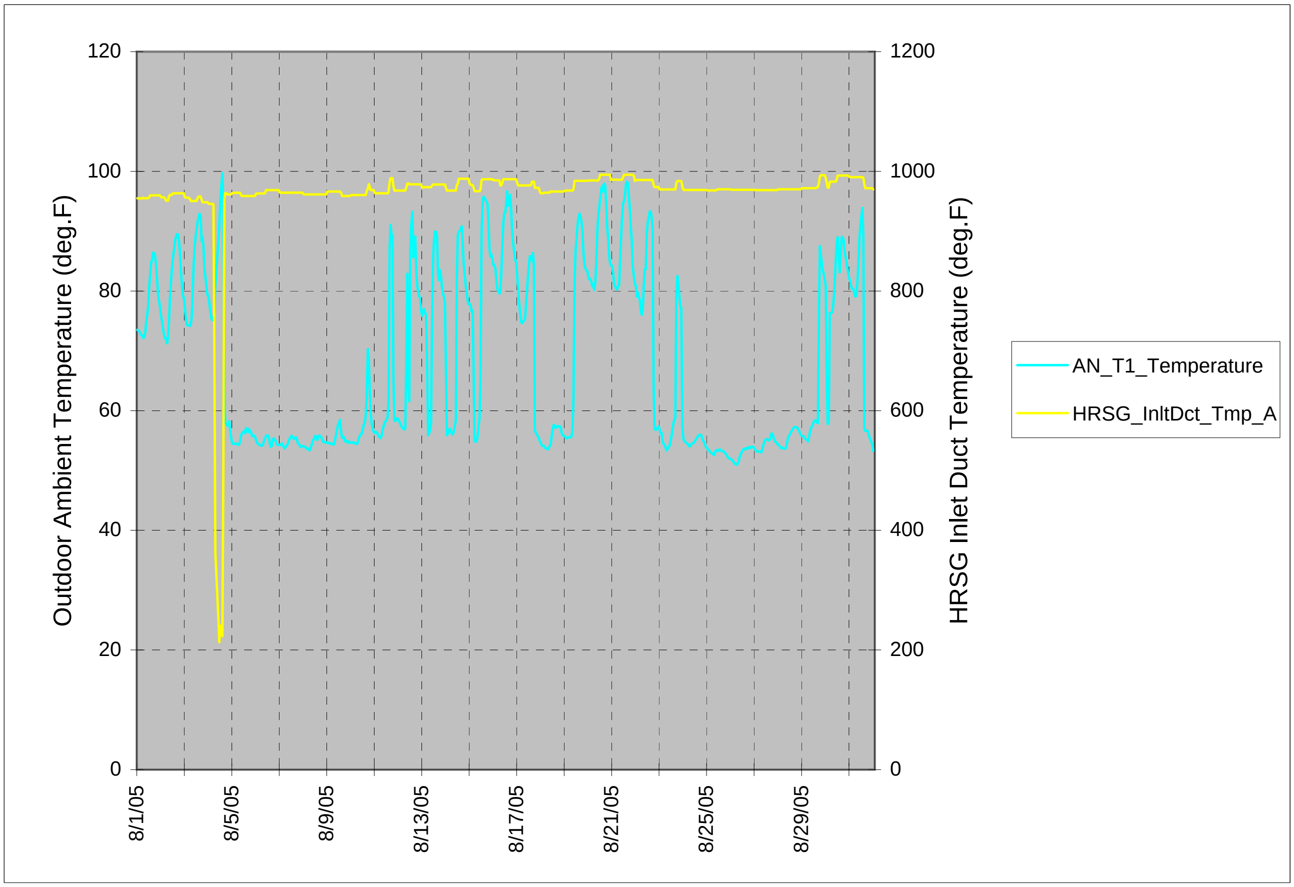


Steam Pressure (psig)
Deaerator Temperature (deg.F)
Boiler_Outlet_PSI
Deaerator_Temp
200
180
160
140
120
100
80
60
40
20
0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05

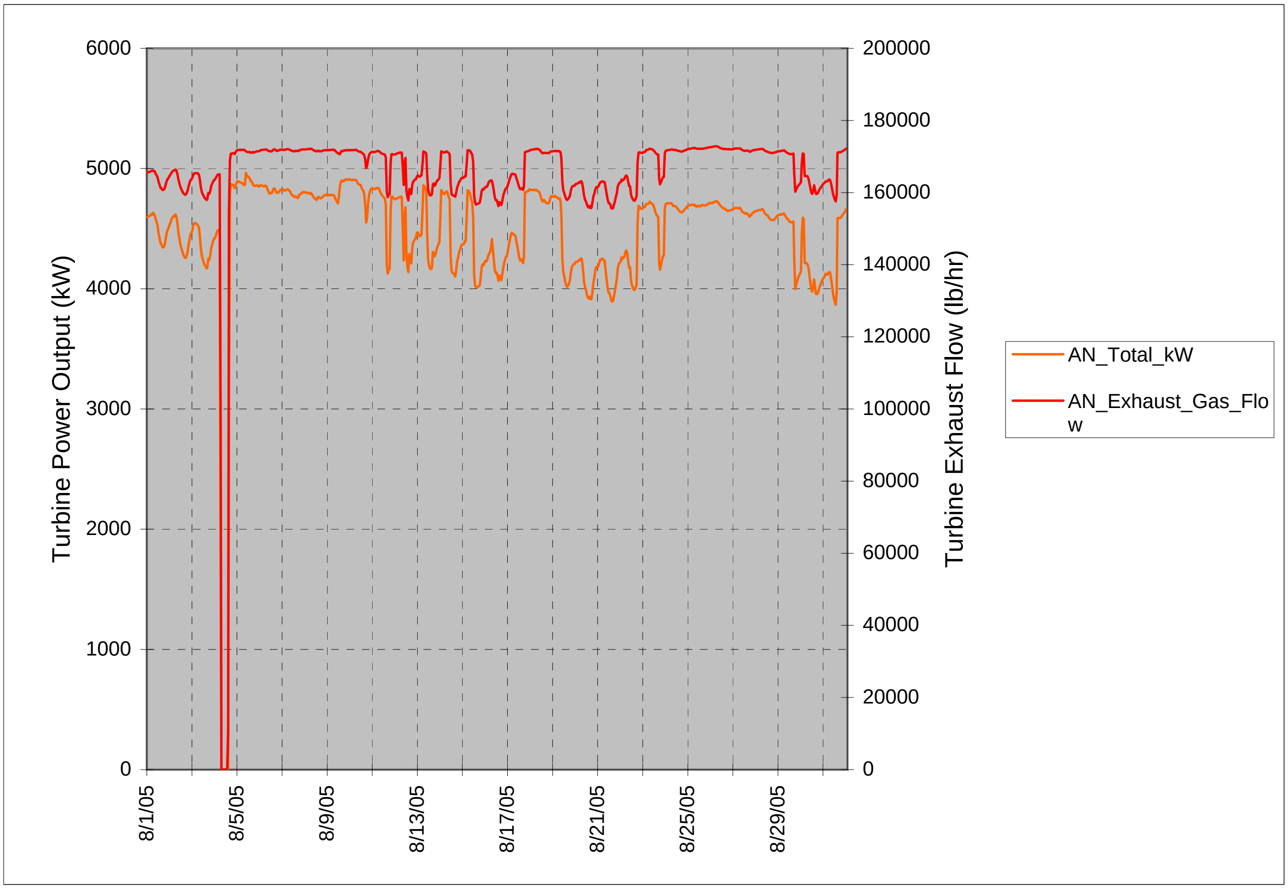
Misc. Plots

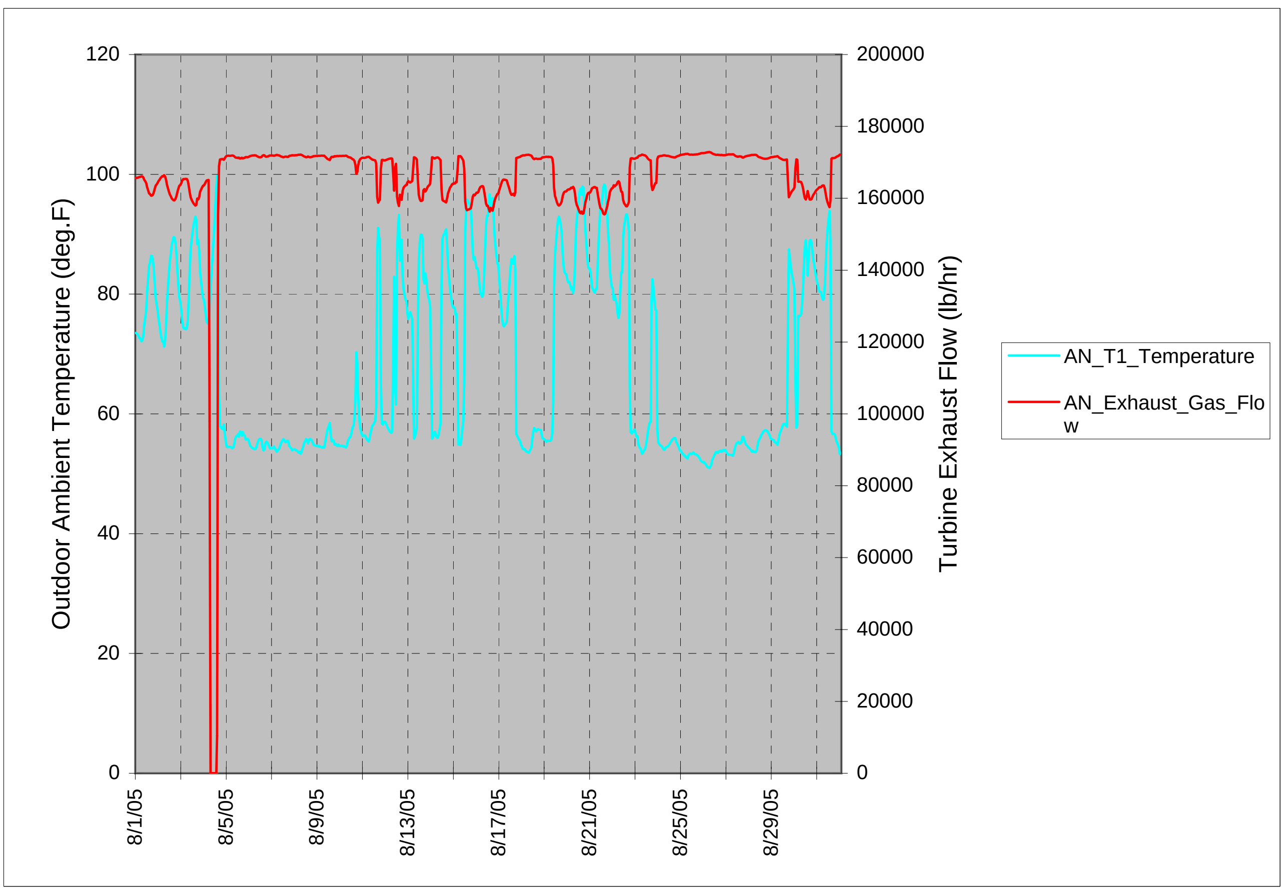


3000
2500
2000
1500
1000
500
0
1200
1000
800
600
400
200
0
Turbine Nat. Gas Input (lb/hr)
HRSG Inlet Duct Temperature (deg.F)
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A

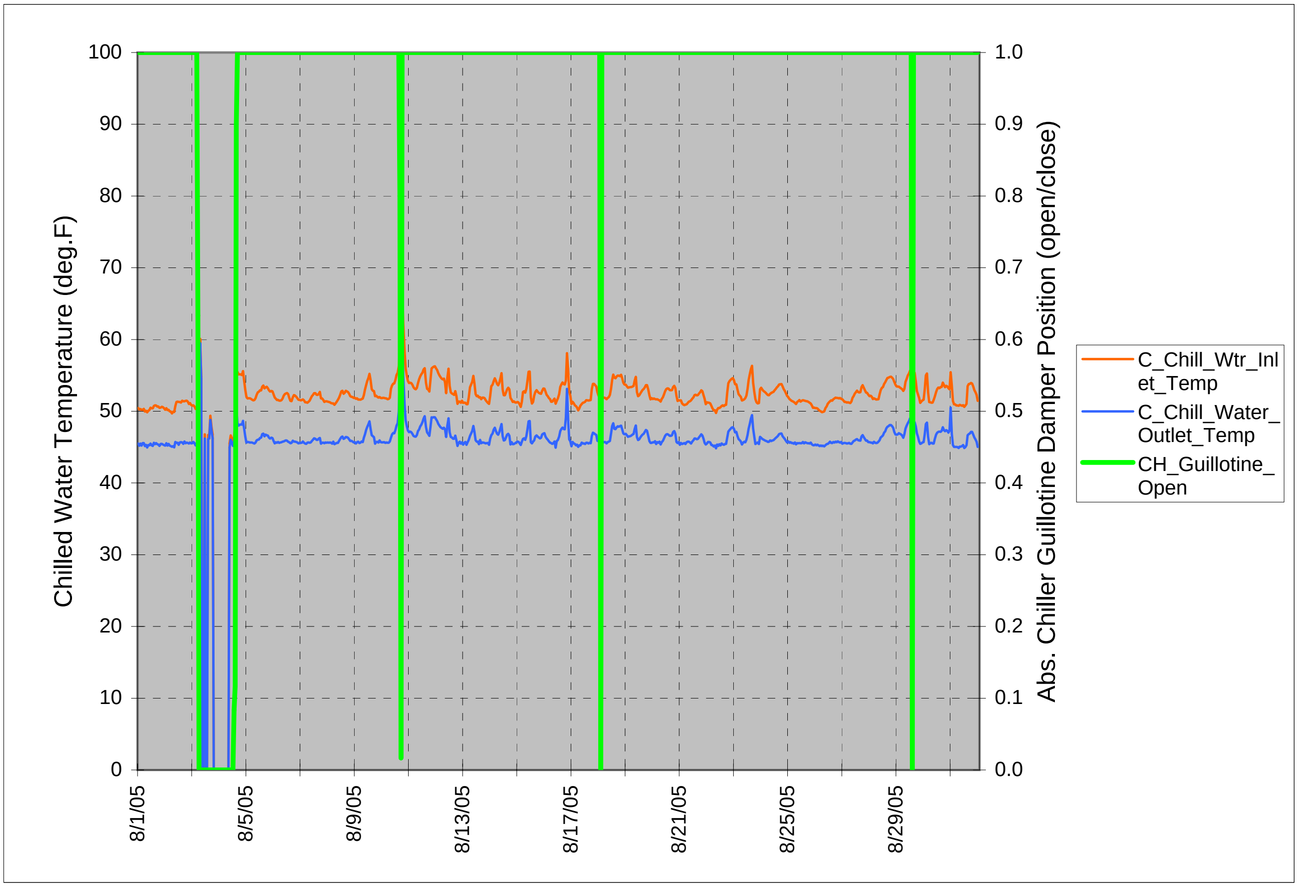


120
100
80
60
40
20
0
1200
1000
800
600
400
200
0
Outdoor Ambient Temperature (deg.F)
HRSG Inlet Duct Temperature (deg.F)
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A

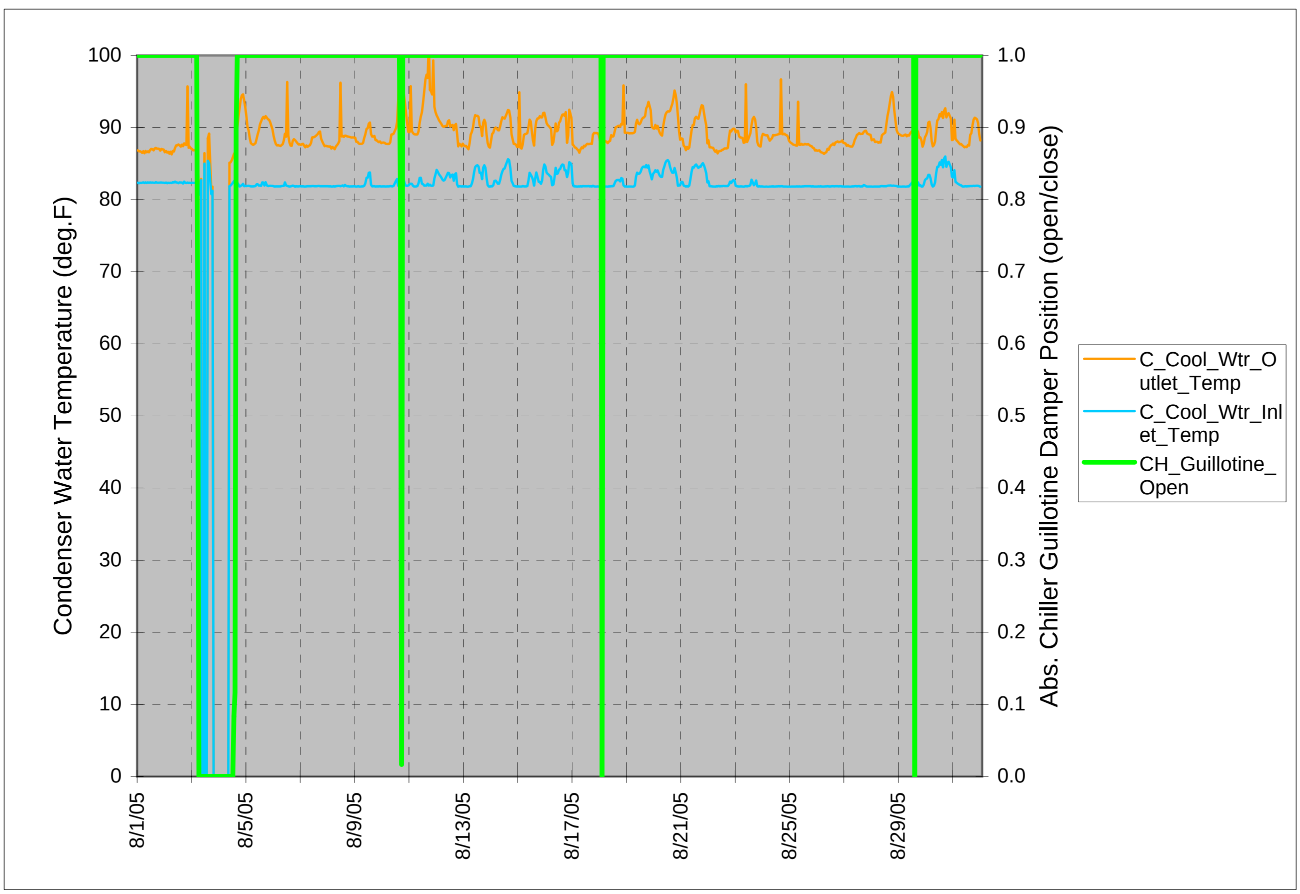

Turbine Power Output (kW)
6000
5000
4000
3000
2000
1000
0
Turbine Exhaust Flow (lb/hr)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow


Outdoor Ambient Temperature (deg.F)
120
100
80
60
40
20
0
Turbine Exhaust Flow (lb/hr)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

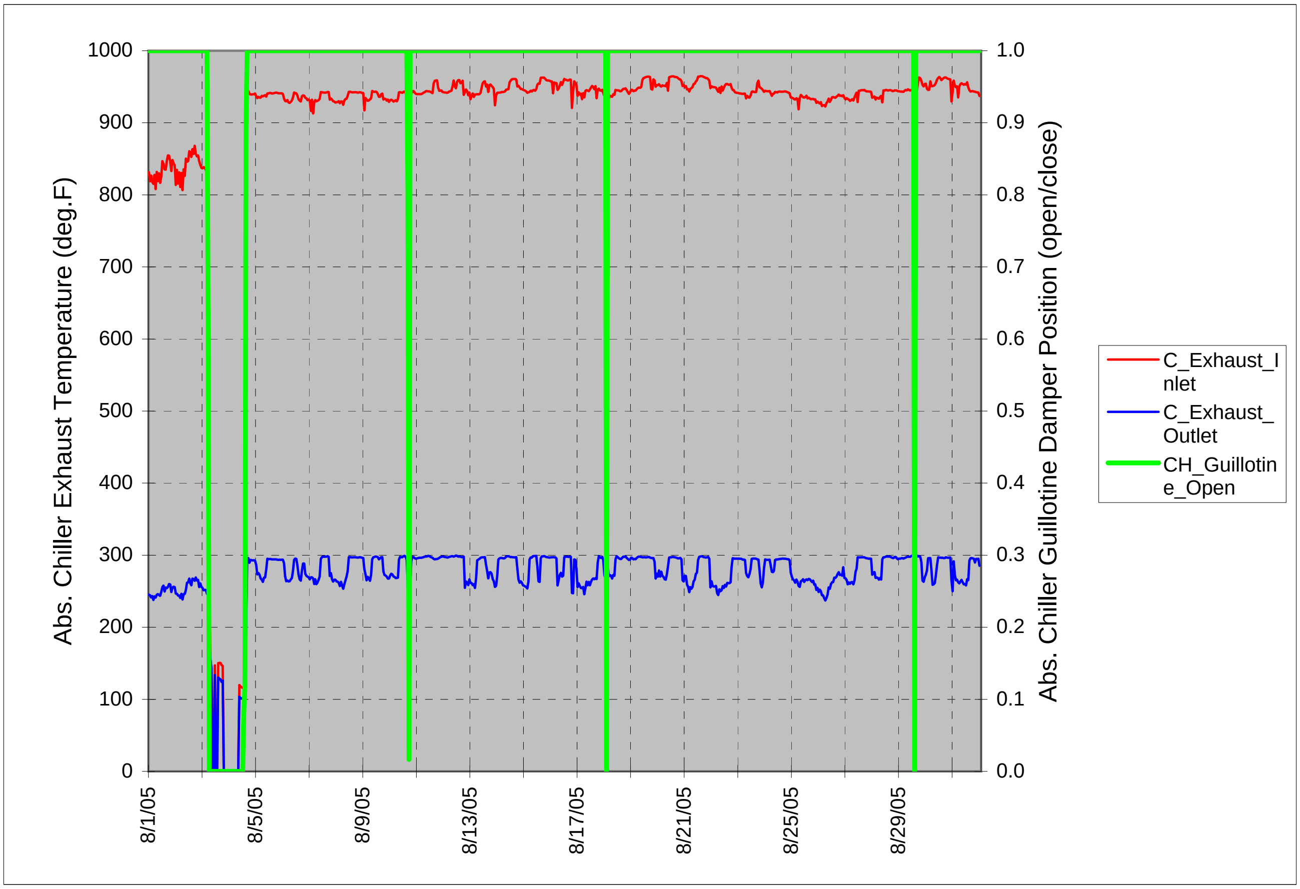
Misc. Plots



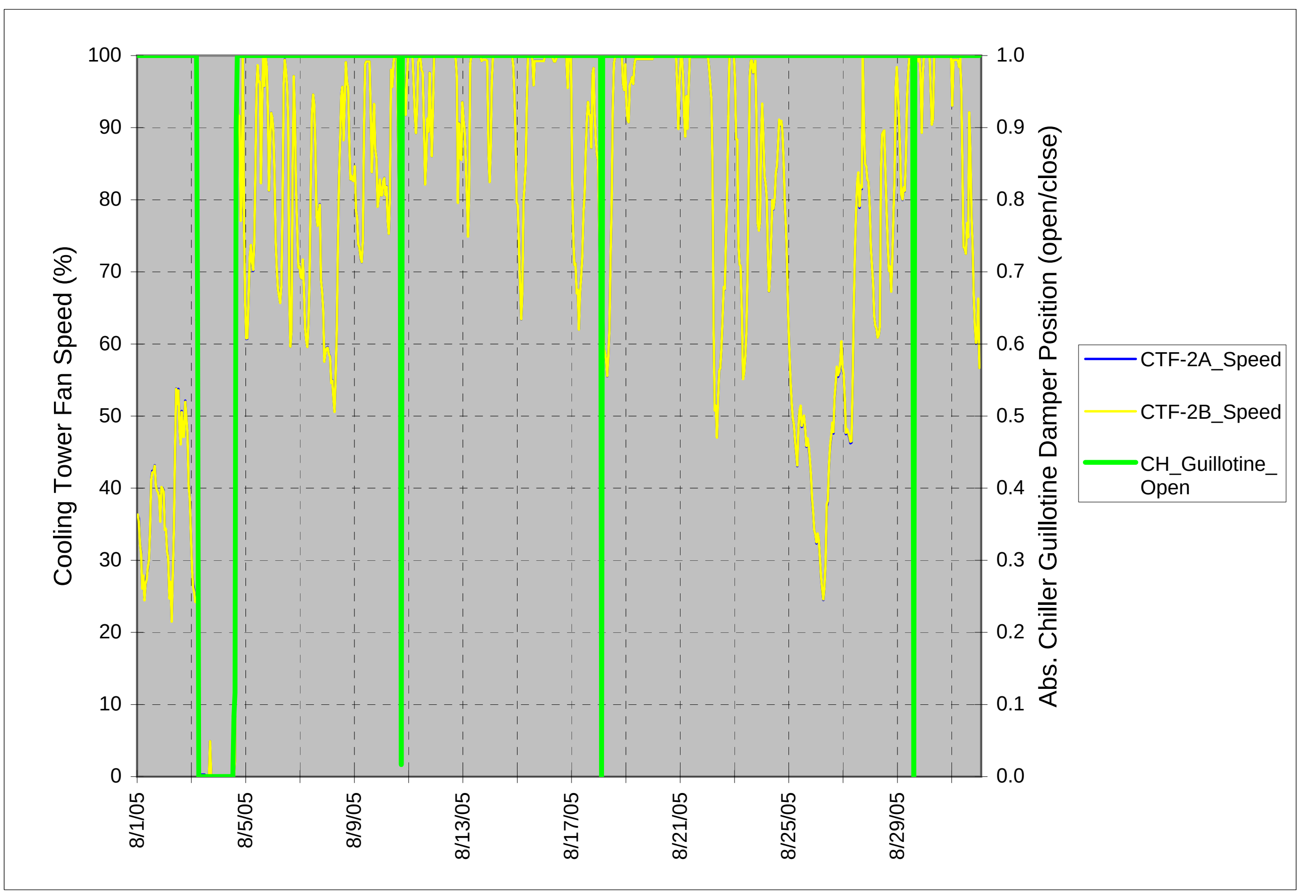
Chilled Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
C_Chill_Wtr_Inlet_Temp
C_Chill_Water_Outlet_Temp
CH_Guillotine_Open



Condenser Water Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
100
90
80
70
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05
C_Cool_Wtr_Outlet_Temp
C_Cool_Wtr_Inlet_Temp
CH_Guillotine_Open



Abs. Chiller Exhaust Temperature (deg.F)
Abs. Chiller Guillotine Damper Position (open/close)
C_Exhaust_Inlet
C_Exhaust_Outlet
CH_Guillotine_Open
0
100
200
300
400
500
600
700
800
900
1000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05



Cooling Tower Fan Speed (%)
Abs. Chiller Guillotine Damper Position (open/close)
CTF-2A_Speed
CTF-2B_Speed
CH_Guillotine_Open
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
8/1/05
8/5/05
8/9/05
8/13/05
8/17/05
8/21/05
8/25/05
8/29/05