Honeywell

Modular Integrated Energy Systems

Task 6 Field Monitoring
Interim Report
Period Covered:
January 2005–April 2005

July 22, 2005

Prepared for:

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

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Table of Contents

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 Services 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.)

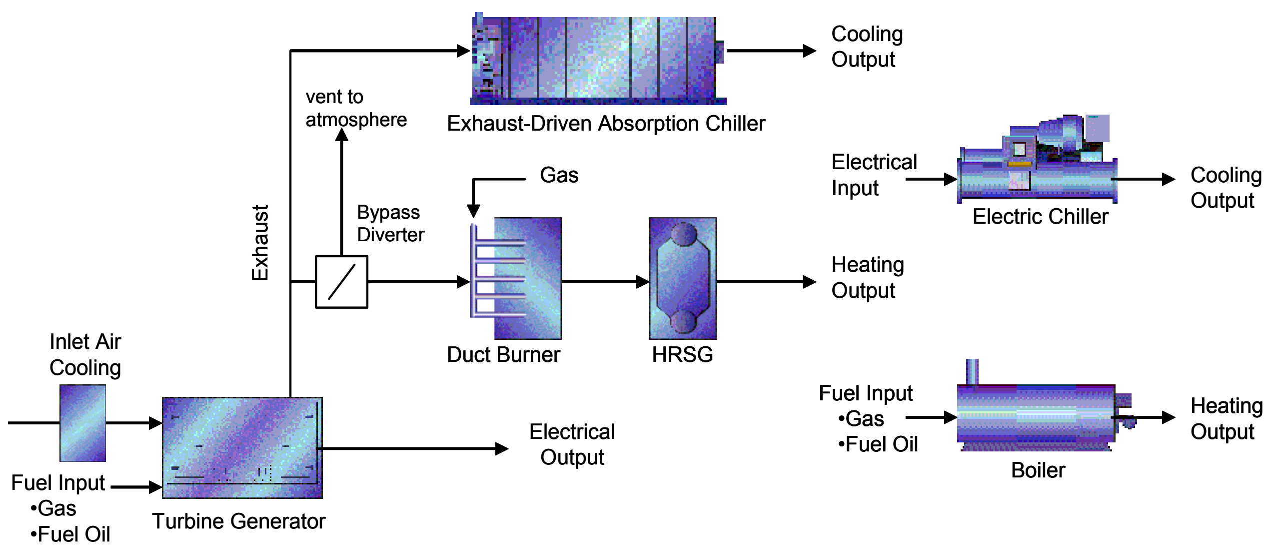
- Sharing of equipment operating data with researchers at Oak Ridge National Lab. These groups are using the data to construct advanced models of IES equipment, as part of other technical work that is not directly associated with this project.
- Sharing of system operational data with researchers at 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 Services 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.



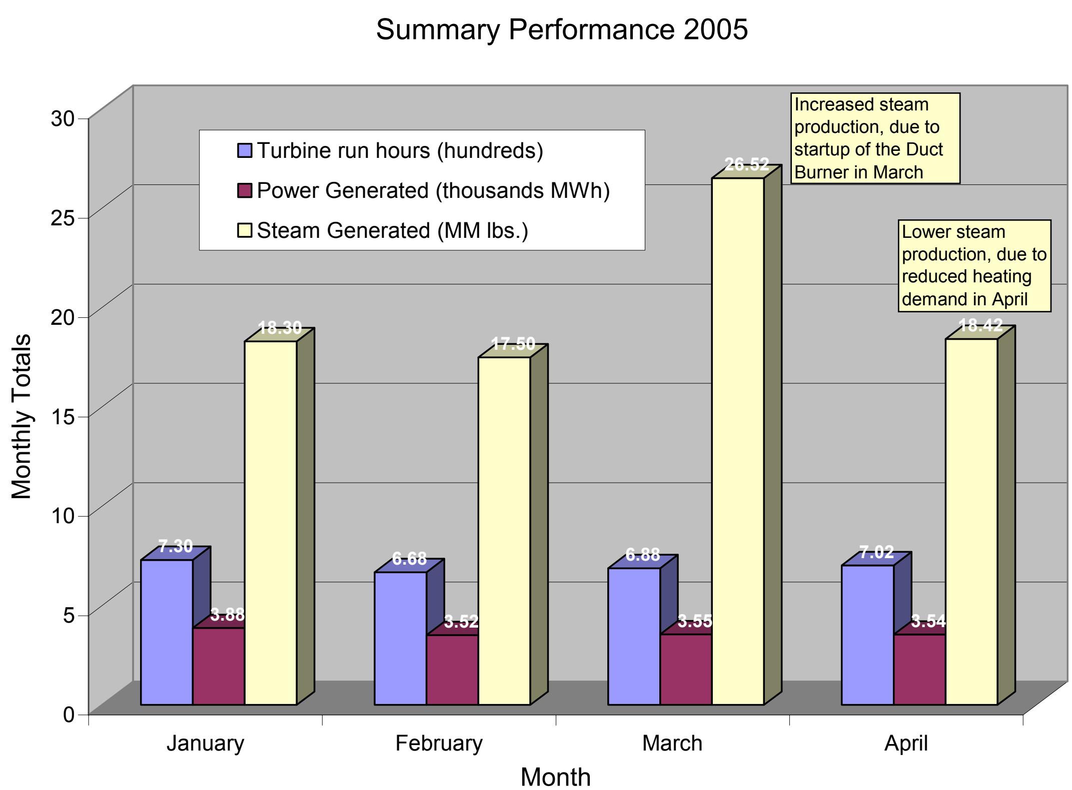
The major equipment in the system consists of a 5MW gas turbine generator, a 1000 ton exhaust-driven absorption chiller, a heat recovery steam generator (HRSG), and a duct burner. Additional technical information is included in a later section of this report.

Section 2. Summary Performance Results

An earlier report covered the period of June thru December of 2004. This document presents the performance results for the period of January thru April 2005. Summary performance results for the period are presented in the following sections.

2.1 Summary Performance Results: Winter 2005

The high level summary results for the winter months of 2005 are shown in the following figure and table.



	Summary Performance Data		
Month	Turbine run hours	Power Generated (kWh)	Steam Generated (MM lbs.)
January	730	3,876,281	18,302,123
February	668	3,515,882	17,495,770
March	688	3,553,763	26,515,075
April	702	3,543,983	18,422,213

Section 3. Detailed Performance Results: Winter 2005

Detailed performance results for the winter period (January thru April) 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 and the boiler/HRSG feedwater pump.
Daily Performance	Daily totals for key performance indices
System Net Energy Efficiency	Hourly data for overall system net energy efficiency (power output plus steam output, divided by fuel energy input) plotted as a function of outdoor ambient temperature. Error bars showing the degree of uncertainty in the data, are shown in the figures. The design data curve includes an estimated 2% in energy losses from the system (for diverter losses, heat loss from ductwork, leaks, etc.). The design data curve also assumes that all exhaust is sent to the HRSG (no diverter losses required to match the thermal load, and no operation of the absorption chiller). As such, this design curve is valid only for the conditions stated above (data analysis for cooling months with operation of the absorption chiller will be handled in a different manner). Note: Some outliers are seen in the plotted data, due to startup periods (or due to bad data and the very limited amount of data cleaning and filling that was done).
Diverter Energy Losses	Selected hourly data for overall net system energy efficiency (power output plus steam output divided by fuel energy input) plotted as a function of diverter damper position. This plot shows the effect of unrecovered energy that is lost thru the diverter in order to maintain the specified steam pressure leaving the heat recovery steam generator (HRSG). This is selected data representing periods of low diverter losses. Error bars showing the degree of uncertainty in the data, are shown in the figures.
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 very limited amount of data cleaning and filling that was done).
HRSG Performance (Overall)	Selected hourly data for the HRSG steam output, plotted as a function of inlet exhaust temperature. This is selected data representing periods of low diverter losses. Error bars showing the degree of uncertainty in the data, are shown in the figures. This data includes periods of unfired as well as fired operation.
HRSG Performance (Fired)	Similar to the above chart, but covering only selected periods of fired operation.

3.1 Detailed Performance Results: January 2005

Detailed performance results for the month of January 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 during the first few hours of New Year's Day.
- Very little simultaneous operation of the auxiliary boiler early in the month (more operation toward the end of the month).
- The duct burner was not operational during this period (still waiting for replacement of control components that were damaged by rain water seeping into the motor operators earlier in the project). The problems with the duct burner controls were corrected in March 2005.

Data analysis comments for the month are:

Table or Figure	Analysis Comments
Summary Data Table	The system's operational performance was very good during the month (very little downtime).
Monthly Overview	The system's energy performance was very good during the month (even without the availability of the Duct Burner).
Daily Performance	See comments above.
System Net Energy Efficiency	System net energy efficiency was within the expected range, although there were some periods of diverter losses required to match the steam load. Overall, the measured data matches well with the design data (within the expected uncertainty).
Diverter Energy Losses	See comment above.
Turbine Generator Performance	Very good performance, the measured data matches well with the design data (within the expected uncertainty).
HRSG Performance (Overall)	Good performance, given the diverter losses that were present during some periods in the month.
HRSG Performance (Fired)	(Not applicable during this month.)

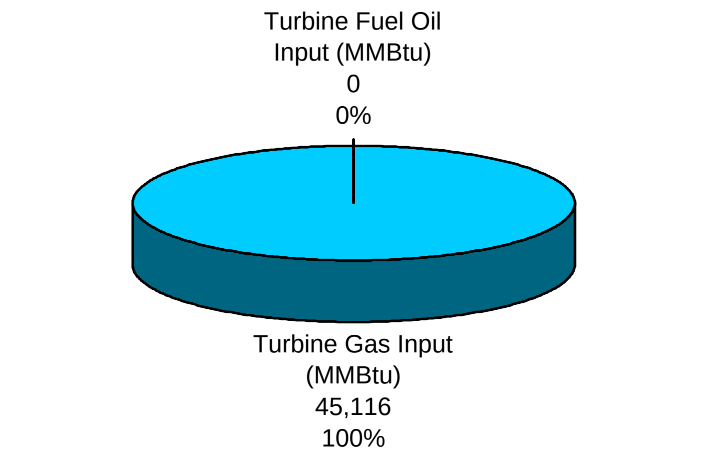
Additional plots of more detailed operating data are presented in Appendix A.

	Measured Data						Calculated Results							
Date	Generated Power (MWh)	HRSG Steam Generated (lbs.)	Turbine Nat. Gas Consumed (MCF)	Turbine Fuel Oil Consumed (gal.)	Turbine Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Turbine Natural Gas Input (MMBtu)	Turbine Fuel Oil Input (MMBtu)	Turbine Total Energy Input (MMBtu)	HRSG Steam Output (MMBtu)	Turbine Power Output (MMBtu)	Total CHP Output (MMBtu)	Net Daily System Efficiency (%)	Parasitic Energy (MWh)
1-Jan-05	50	227,742	569	0	11	8	590	0	590	243	171	413	68.9	1.1
2-Jan-05	125	523,951	1,411	0	24	0	1,463	0	1,463	559	426	984	66.7	2.5
3-Jan-05	123	568,721	1,398	0	24	0	1,450	0	1,450	606	420	1,027	70.3	2.5
4-Jan-05	121	554,337	1,375	0	24	0	1,425	0	1,425	591	411	1,002	69.7	2.5
5-Jan-05	120	551,579	1,367	0	24	0	1,417	0	1,417	588	409	997	69.7	2.5
6-Jan-05	118	551,097	1,351	0	24	0	1,401	0	1,401	587	404	991	70.2	2.5
7-Jan-05	121	533,762	1,379	0	24	0	1,430	0	1,430	569	413	982	68.1	2.5
8-Jan-05	120	485,222	1,363	0	24	0	1,413	0	1,413	517	409	926	64.9	2.5
9-Jan-05	126	544,703	1,424	0	24	0	1,477	0	1,477	581	430	1,011	67.8	2.5
10-Jan-05	125	586,884	1,409	0	24	0	1,461	0	1,461	626	425	1,051	71.3	2.5
11-Jan-05	124	560,078	1,403	0	24	0	1,455	0	1,455	597	423	1,020	69.5	2.5
12-Jan-05	121	558,937	1,374	0	24	0	1,425	0	1,425	596	412	1,008	70.1	2.5
13-Jan-05	119	555,964	1,355	0	24	0	1,405	0	1,405	593	405	998	70.4	2.5
14-Jan-05	123	536,153	1,394	0	24	0	1,446	0	1,446	572	421	992	68.0	2.5
15-Jan-05	132	628,976	1,476	0	24	0	1,531	0	1,531	670	449	1,120	72.6	2.5
16-Jan-05	131	673,126	1,475	0	24	1	1,530	0	1,530	718	448	1,166	75.6	2.5
17-Jan-05	134	682,029	1,495	0	24	1	1,550	0	1,550	727	457	1,184	75.8	2.5
18-Jan-05	138	688,896	1,495	0	24	1	1,550	0	1,550	734	470	1,204	77.1	2.5
19-Jan-05	133	664,258	1,448	0	24	18	1,501	0	1,501	708	452	1,160	76.5	2.5
20-Jan-05	130	675,023	1,438	0	24	11	1,491	0	1,491	720	443	1,162	77.4	2.5
21-Jan-05	131	654,857	1,468	0	24	11	1,522	0	1,522	698	448	1,146	74.7	2.5
22-Jan-05	131	644,007	1,466	0	24	24	1,520	0	1,520	687	449	1,135	74.1	2.5
23-Jan-05	134	596,218	1,484	0	24	24	1,538	0	1,538	636	456	1,092	70.4	2.5
24-Jan-05	133	554,403	1,457	0	24	24	1,511	0	1,511	591	455	1,046	68.8	2.5
25-Jan-05	129	638,696	1,440	0	24	24	1,493	0	1,493	681	439	1,119	74.4	2.5
26-Jan-05	124	630,379	1,398	0	24	24	1,450	0	1,450	672	422	1,094	74.9	2.5
27-Jan-05	130	641,508	1,459	0	24	24	1,513	0	1,513	684	444	1,128	74.0	2.5
28-Jan-05	136	652,746	1,515	0	24	24	1,571	0	1,571	696	465	1,160	73.3	2.5
29-Jan-05	135	650,877	1,495	0	24	24	1,550	0	1,550	694	459	1,153	73.8	2.5
30-Jan-05	130	641,277	1,459	0	24	24	1,513	0	1,513	684	443	1,127	73.9	2.5
31-Jan-05	131	645,719	1,468	0	24	24	1,522	0	1,522	688	447	1,135	74.0	2.5
totals	3,876	18,302,123	43,507	0	730	295	45,116	0	45,116	19,510	13,226	32,736	72.0	77.2

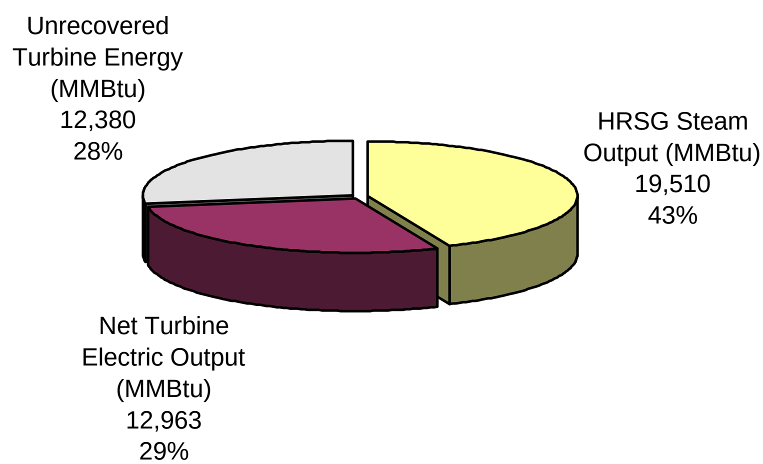
Month

January 2005 Performance Data

Input Energy = 45,116 MMBtu



Output Energy = 44,853 MMBtu

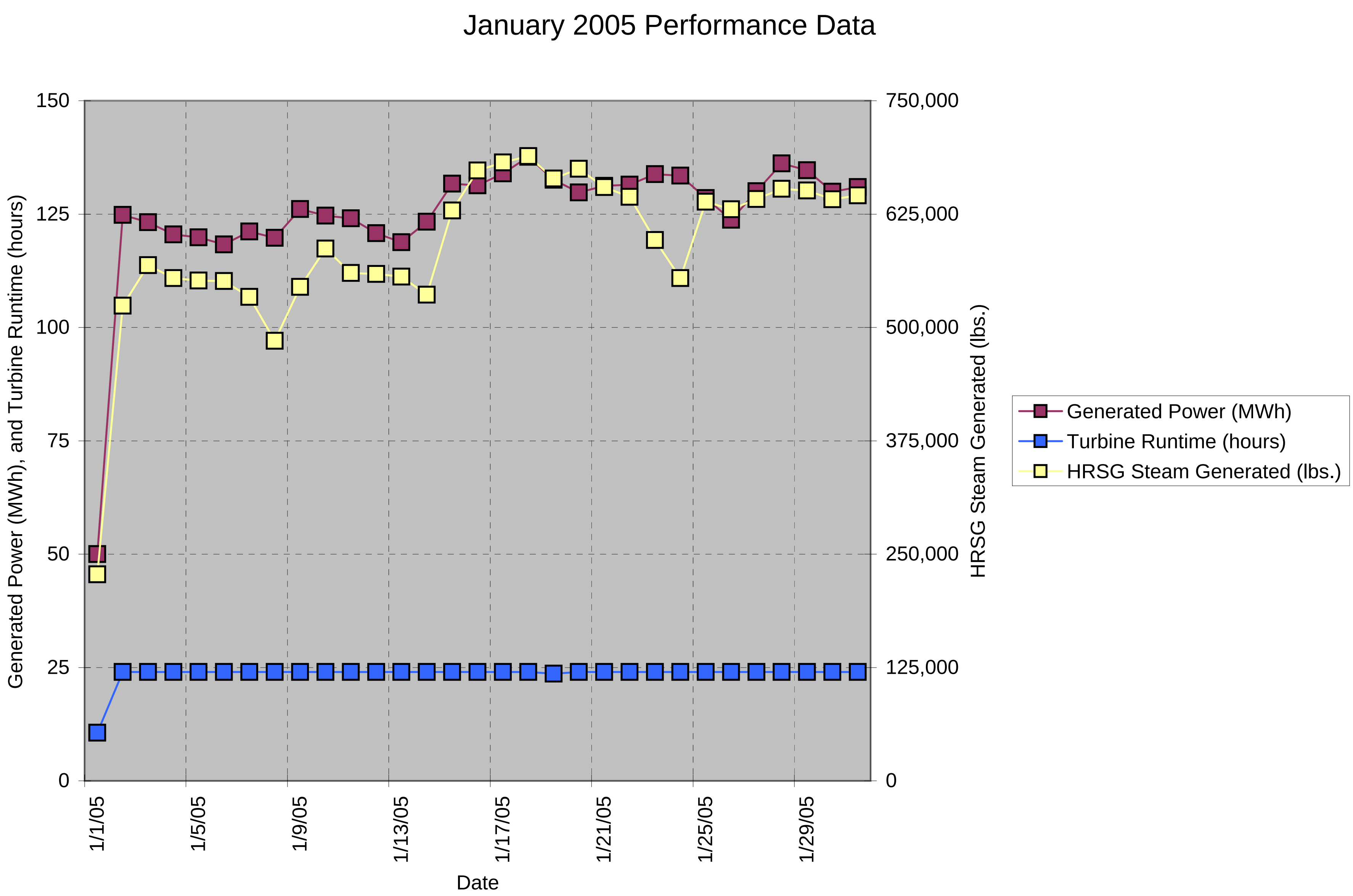


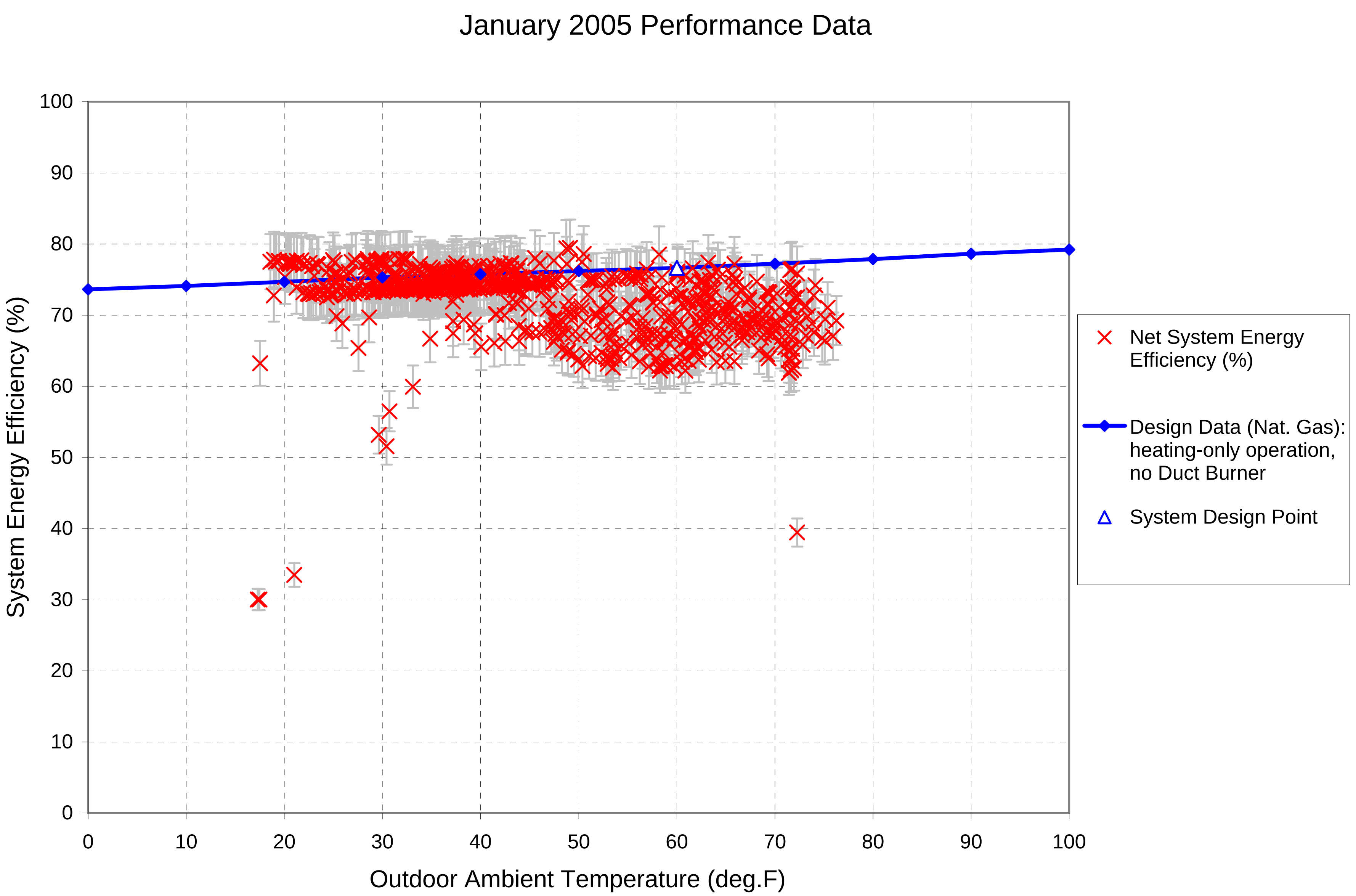
Net CHP Efficiency *

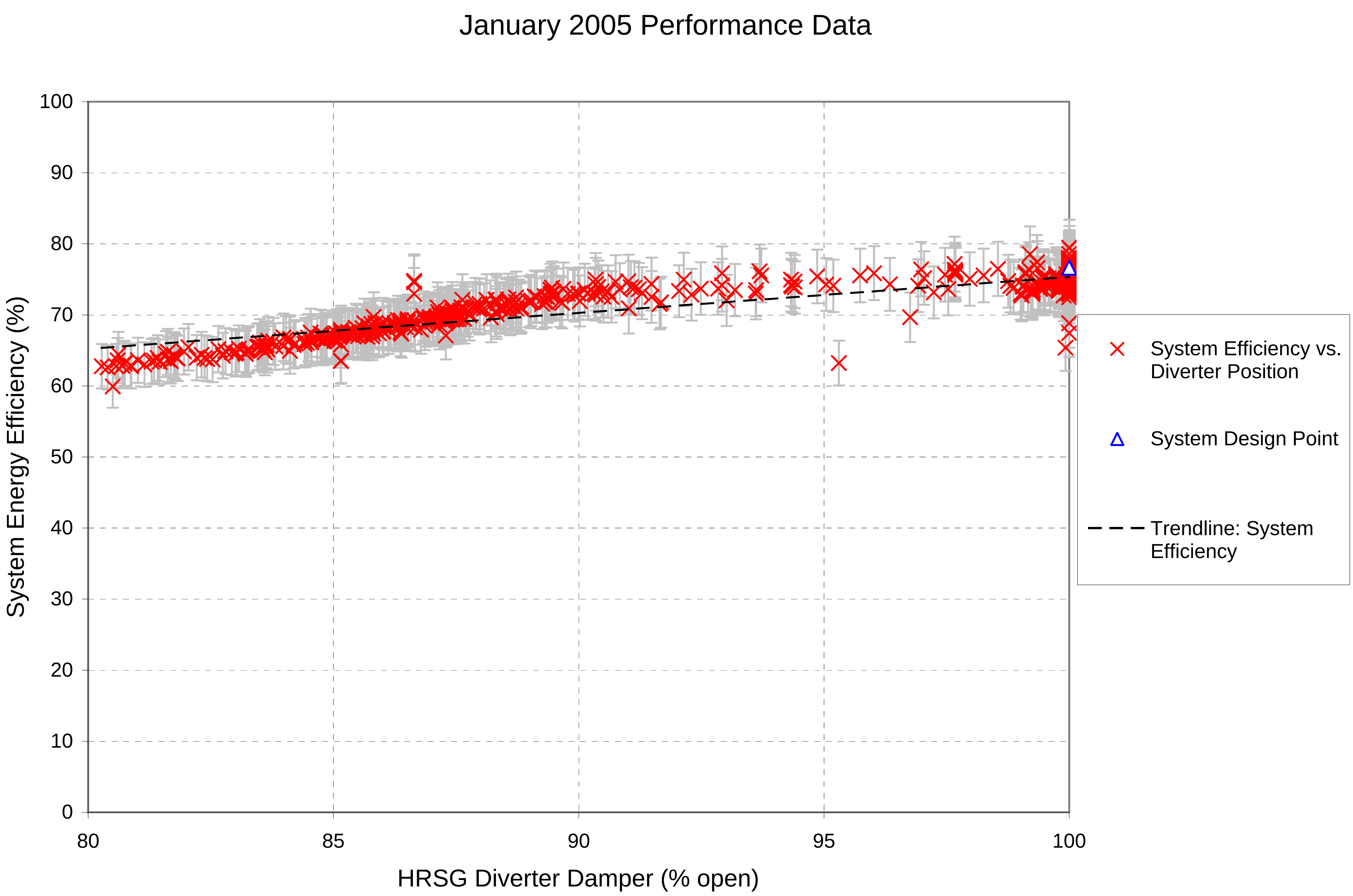
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

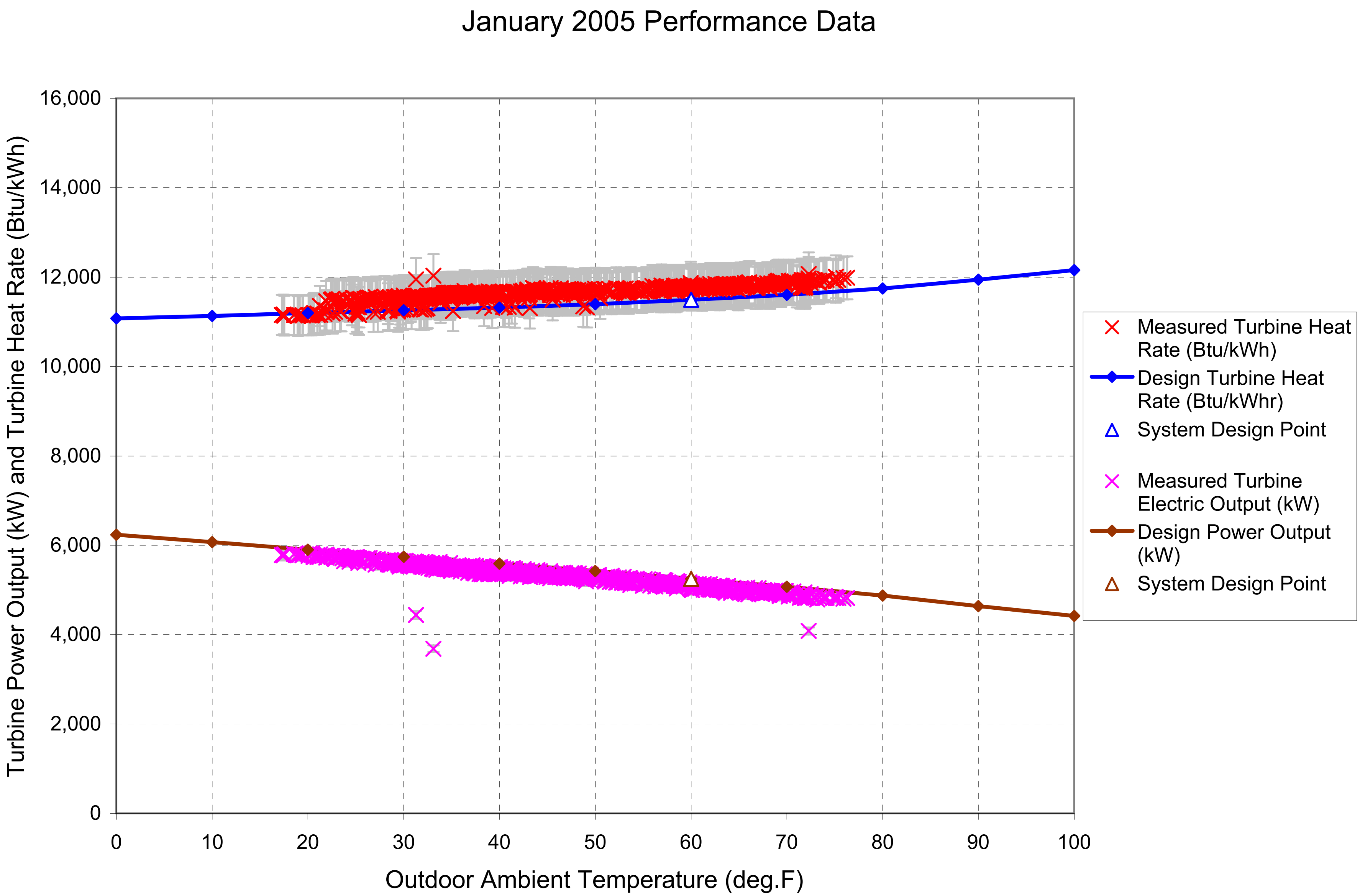
= **72.0%**

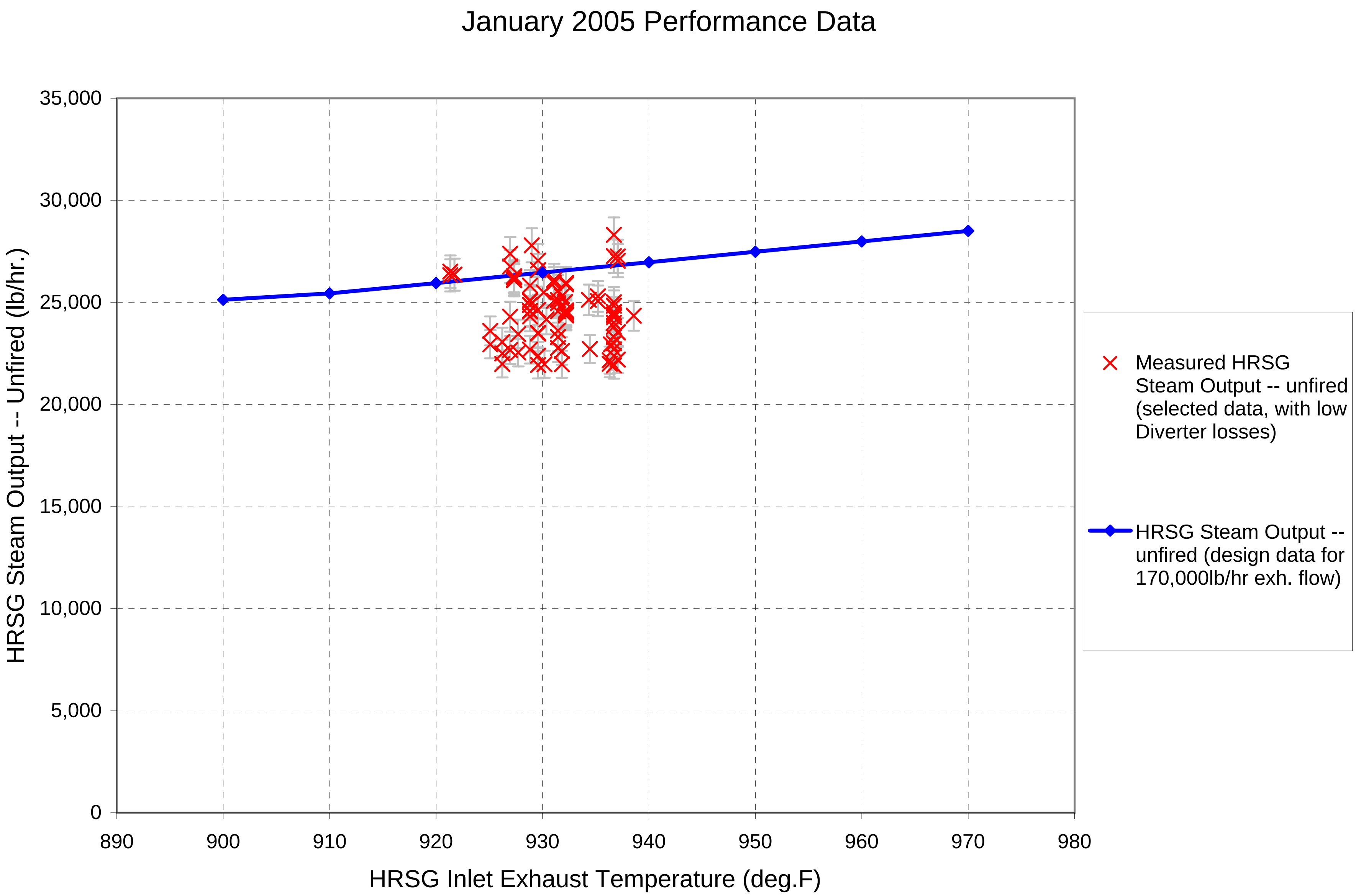
* as defined on page 27 of: “Distributed Generation Combined Heat and Power Long Term Monitoring Protocols” Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

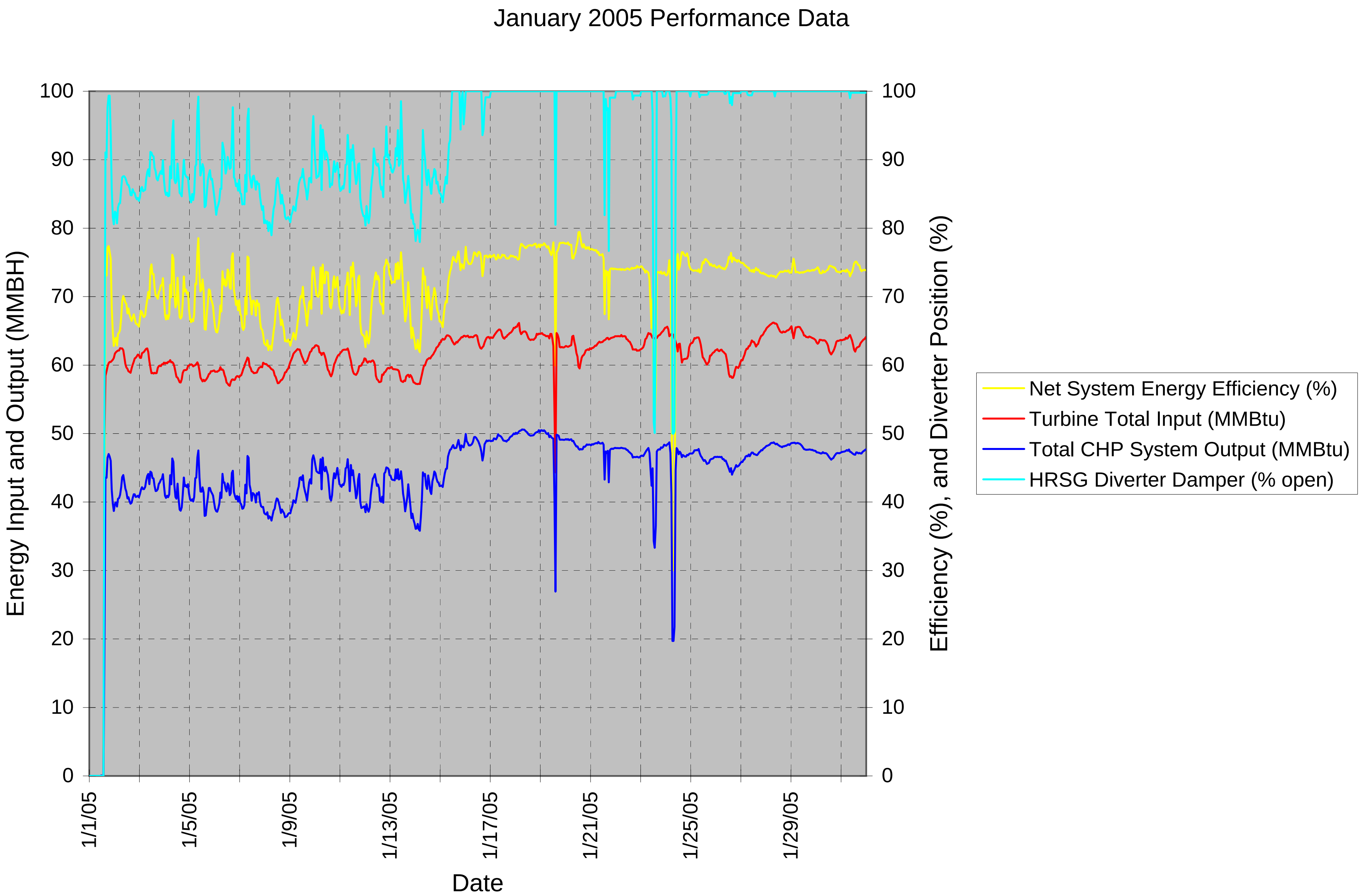

January 2005 Performance Data
150
125
100
75
50
25
0
750,000
625,000
500,000
375,000
250,000
125,000
0
Generated Power (MWh), and Turbine Runtime (hours)
HRSG Steam Generated (lbs.)
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
Date
Generated Power (MWh)
Turbine Runtime (hours)
HRSG Steam Generated (lbs.)


January 2005 Performance Data
System Energy Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Net System Energy Efficiency (%)
Design Data (Nat. Gas): heating-only operation, no Duct Burner
System Design Point

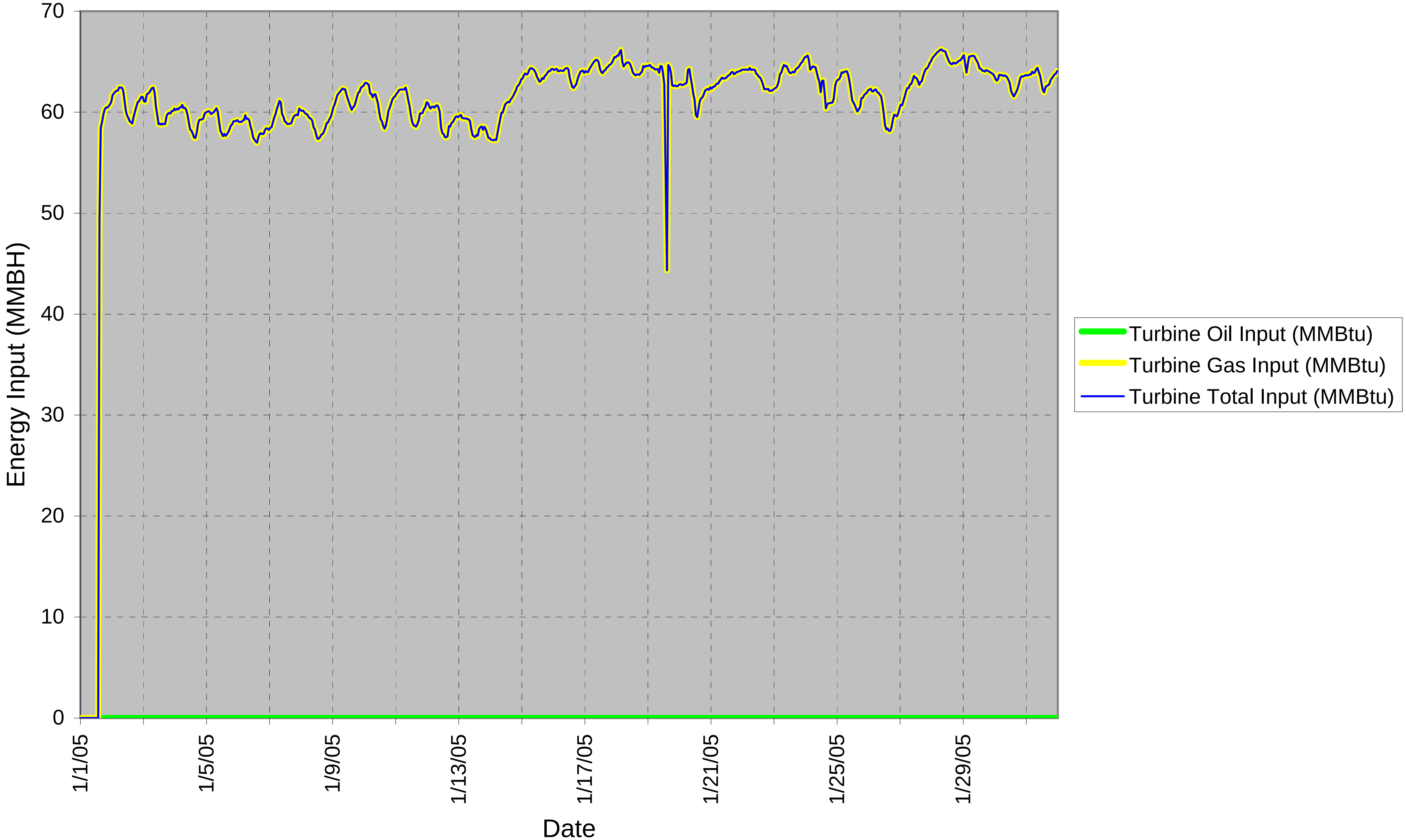

January 2005 Performance Data
System Energy Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
80
85
90
95
100
HRSG Diverter Damper (% open)
System Efficiency vs. Diverter Position
System Design Point
Trendline: System Efficiency

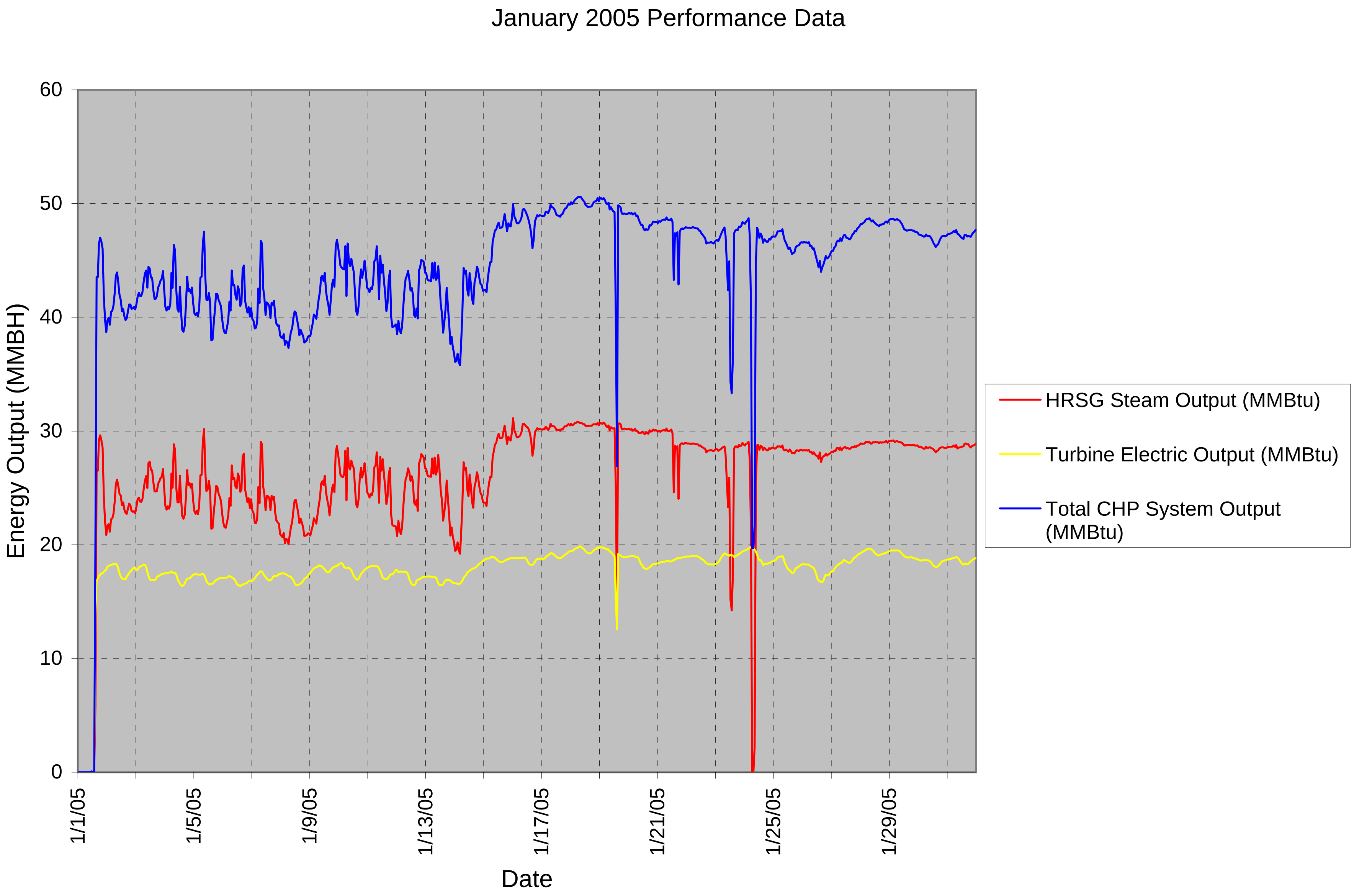

January 2005 Performance Data
Turbine Power Output (kW) and Turbine Heat Rate (Btu/kWh)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Measured Turbine Heat Rate (Btu/kWh)
Design Turbine Heat Rate (Btu/kWhr)
System Design Point
Measured Turbine Electric Output (kW)
Design Power Output (kW)
System Design Point


January 2005 Performance Data
HRSG Steam Output -- Unfired (lb/hr.)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
890
900
910
920
930
940
950
960
970
980
HRSG Inlet Exhaust Temperature (deg.F)
Measured HRSG Steam Output -- unfired (selected data, with low Diverter losses)
HRSG Steam Output -- unfired (design data for 170,000lb/hr exh. flow)


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

January 2005 Performance Data





January 2005 Performance Data
Energy Output (MMBH)
60
50
40
30
20
10
0
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
Date
HRSG Steam Output (MMBtu)
Turbine Electric Output (MMBtu)
Total CHP System Output (MMBtu)

3.2 Detailed Performance Results: February 2005

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

Field observations noted during the month are:

- Very few hours when the IES system was off-line during the month.
- During most of the month, the auxiliary boiler was operated to provide supplemental steam to meet the thermal load. However, there were not significant periods of diverting some exhaust energy in order to maintain the desired steam pressure. This helped to maintain a good system energy efficiency.
- The duct burner remained off-line, as described earlier.

Data analysis comments for the month are:

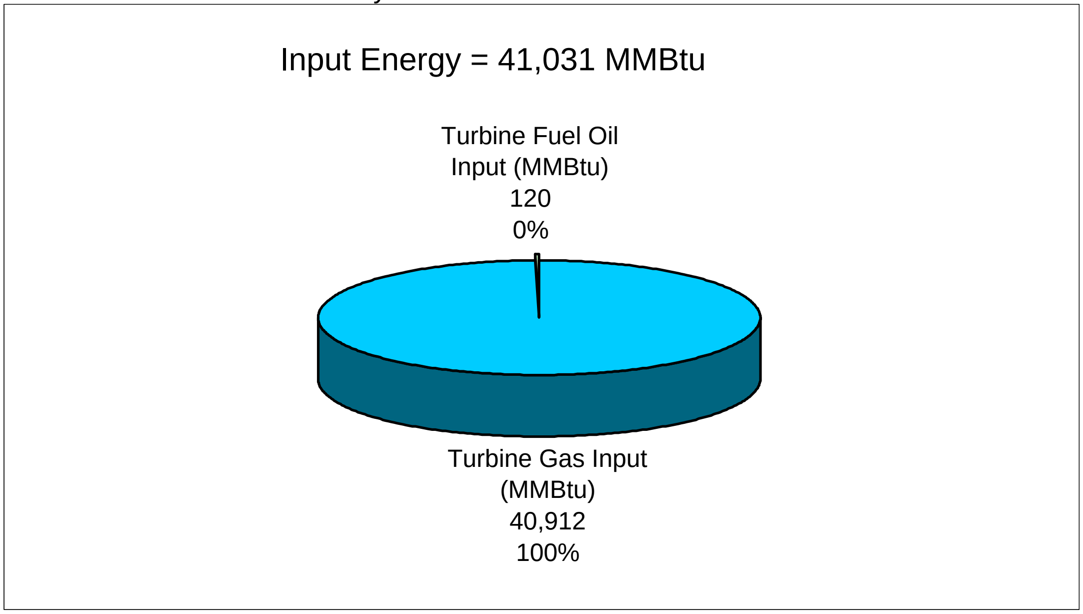
Table or Figure	Analysis Comments
Summary Data Table	The system's operational performance was very good during the month (very little downtime).
Monthly Overview	The system's energy performance was very good during the month (even without the availability of the Duct Burner).
Daily Performance	See comments above.
System Net Energy Efficiency	System net energy efficiency was within the expected range, and there were relatively few periods of diverter losses required to match the steam load. Overall, the measured data matches well with the design data (within the expected uncertainty).
Diverter Energy Losses	See comment above.
Turbine Generator Performance	Very good performance, the measured data matches well with the design data (within the expected uncertainty).
HRSG Performance (Overall)	Very good performance, the measured data matches well with the design data (within the expected uncertainty).
HRSG Performance (Fired)	(Not applicable during this month.)

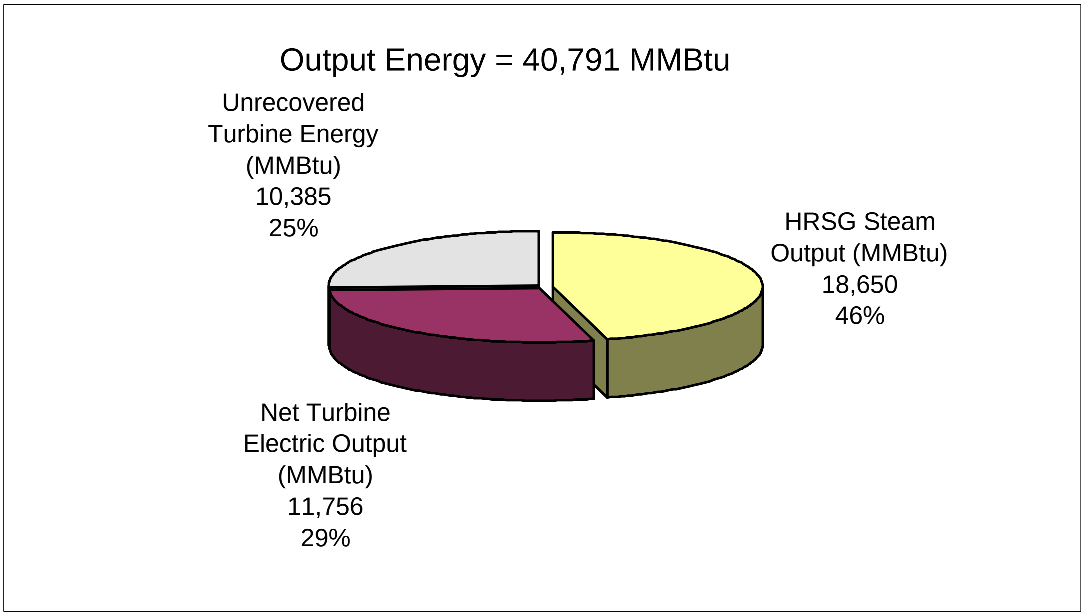
Additional plots of more detailed operating data are presented in Appendix B.

Date	Measured Data: Generated Power (MWh)	HRSG Steam Generated (lbs.)	Turbine Nat. Gas Consumed (MCF)	Turbine Fuel Oil Consumed (gal.)	Turbine Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Calculated Results: Turbine Natural Gas Input (MMBtu)	Turbine Fuel Oil Input (MMBtu)	Turbine Total Energy Input (MMBtu)	HRSG Steam Output (MMBtu)	Turbine Power Output (MMBtu)	Total CHP Output (MMBtu)	Net Daily System Efficiency (%)	Parasitic Energy (MWh)
1-Feb-05	131	646,547	1,470	0	24	24	1,525	0	1,525	689	447	1,136	74.0	2.5
2-Feb-05	131	648,377	1,472	0	24	24	1,527	0	1,527	691	447	1,138	74.0	2.5
3-Feb-05	130	643,662	1,470	0	24	24	1,524	0	1,524	686	445	1,131	73.7	2.5
4-Feb-05	129	645,577	1,457	0	24	24	1,511	0	1,511	688	441	1,130	74.2	2.5
5-Feb-05	127	639,566	1,436	0	24	24	1,489	0	1,489	682	434	1,115	74.3	2.5
6-Feb-05	127	644,762	1,437	0	24	24	1,490	0	1,490	687	435	1,122	74.7	2.5
7-Feb-05	126	641,278	1,425	0	24	24	1,478	0	1,478	684	431	1,115	74.8	2.5
8-Feb-05	122	635,090	1,390	0	24	15	1,441	0	1,441	677	417	1,094	75.4	2.5
9-Feb-05	122	582,609	1,271	0	24	0	1,318	0	1,318	621	418	1,039	75.5	2.5
10-Feb-05	125	633,210	1,406	0	24	0	1,458	0	1,458	675	425	1,100	74.9	2.5
11-Feb-05	129	637,784	1,449	0	24	1	1,503	0	1,503	680	441	1,121	74.0	2.5
12-Feb-05	126	636,082	1,416	0	24	0	1,469	0	1,469	678	429	1,107	74.8	2.5
13-Feb-05	124	637,907	1,405	0	24	0	1,457	0	1,457	680	424	1,104	75.2	2.5
14-Feb-05	124	638,043	1,403	0	24	1	1,455	0	1,455	680	423	1,103	75.2	2.5
15-Feb-05	123	638,668	1,395	0	24	1	1,446	0	1,446	681	420	1,101	75.5	2.5
16-Feb-05	103	511,620	1,061	867	21	4	1,100	120	1,220	545	350	895	70.6	2.0
17-Feb-05	125	618,752	1,410	0	24	9	1,463	0	1,463	660	427	1,087	73.7	2.5
18-Feb-05	129	599,797	1,448	0	24	24	1,502	0	1,502	639	441	1,080	71.4	2.5
19-Feb-05	129	643,691	1,450	0	24	24	1,504	0	1,504	686	441	1,127	74.4	2.5
20-Feb-05	127	630,526	1,435	0	24	24	1,488	0	1,488	672	434	1,106	73.7	2.5
21-Feb-05	122	631,134	1,392	0	24	24	1,443	0	1,443	673	417	1,090	74.9	2.5
22-Feb-05	122	567,702	1,378	0	24	24	1,429	0	1,429	605	415	1,020	70.7	2.5
23-Feb-05	123	578,044	1,388	0	24	24	1,440	0	1,440	616	419	1,035	71.3	2.5
24-Feb-05	127	623,549	1,437	0	24	24	1,490	0	1,490	665	435	1,100	73.2	2.5
25-Feb-05	129	639,229	1,455	0	24	24	1,509	0	1,509	681	442	1,123	73.9	2.5
26-Feb-05	128	640,019	1,442	0	24	24	1,495	0	1,495	682	438	1,120	74.4	2.5
27-Feb-05	127	633,399	1,429	0	24	24	1,482	0	1,482	675	432	1,107	74.1	2.5
28-Feb-05	126	629,146	1,424	0	24	24	1,477	0	1,477	671	430	1,101	73.9	2.5
totals	3,516	17,495,770	39,452	867	668	464	40,912	120	41,031	18,650	11,996	30,647	74.1	70.5

Month

February 2005 Performance Data





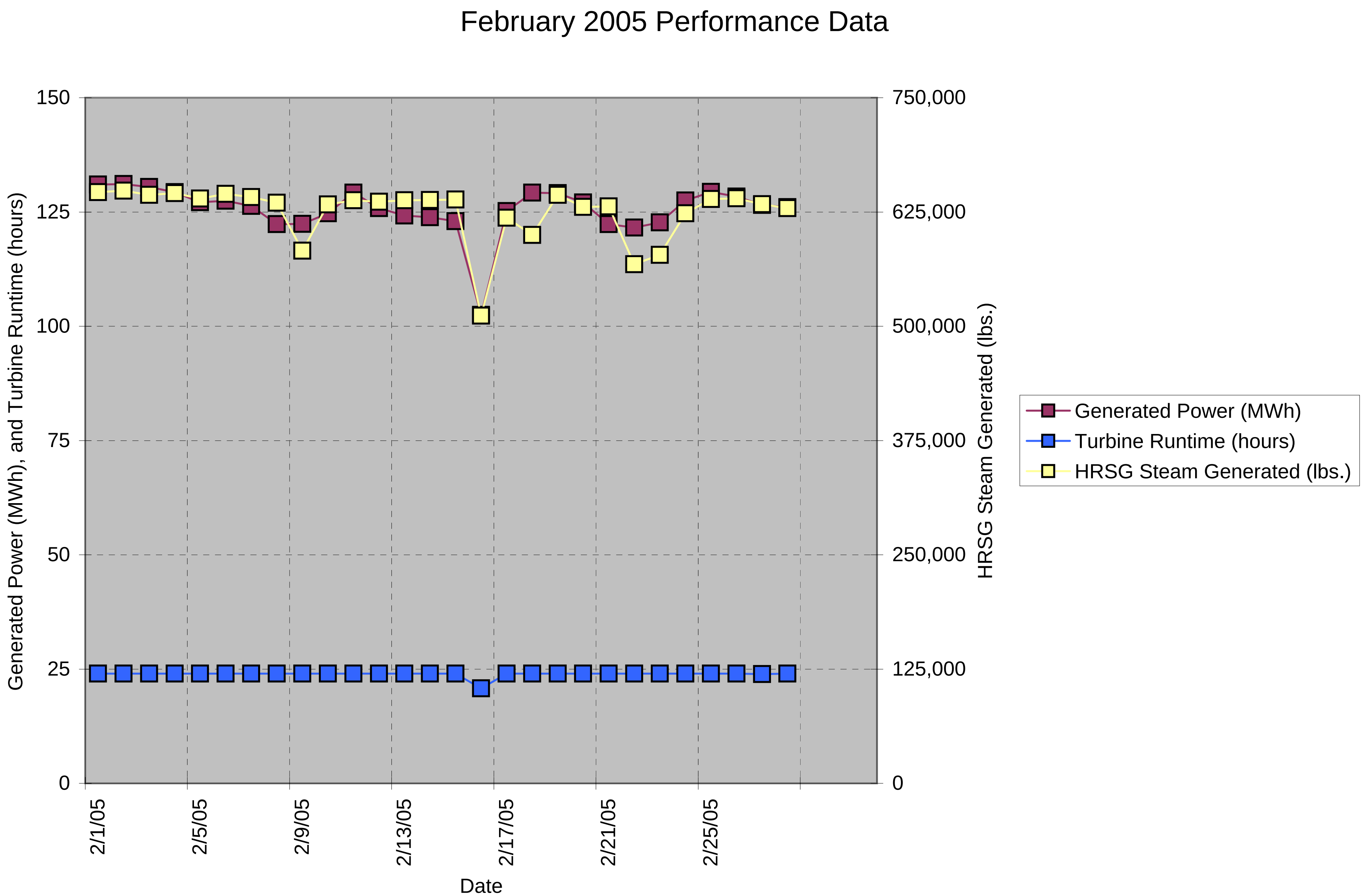
Net CHP Efficiency *

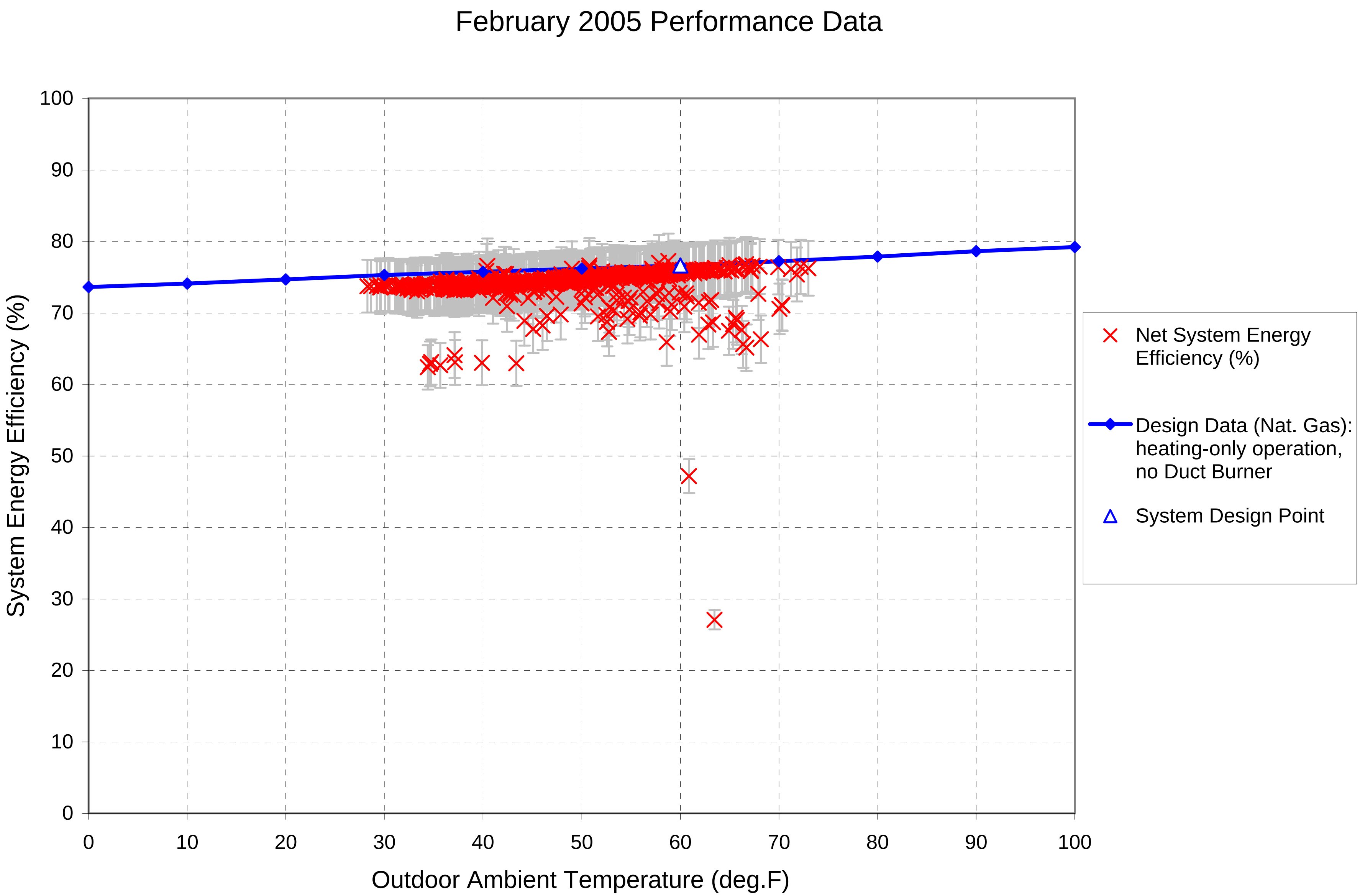
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

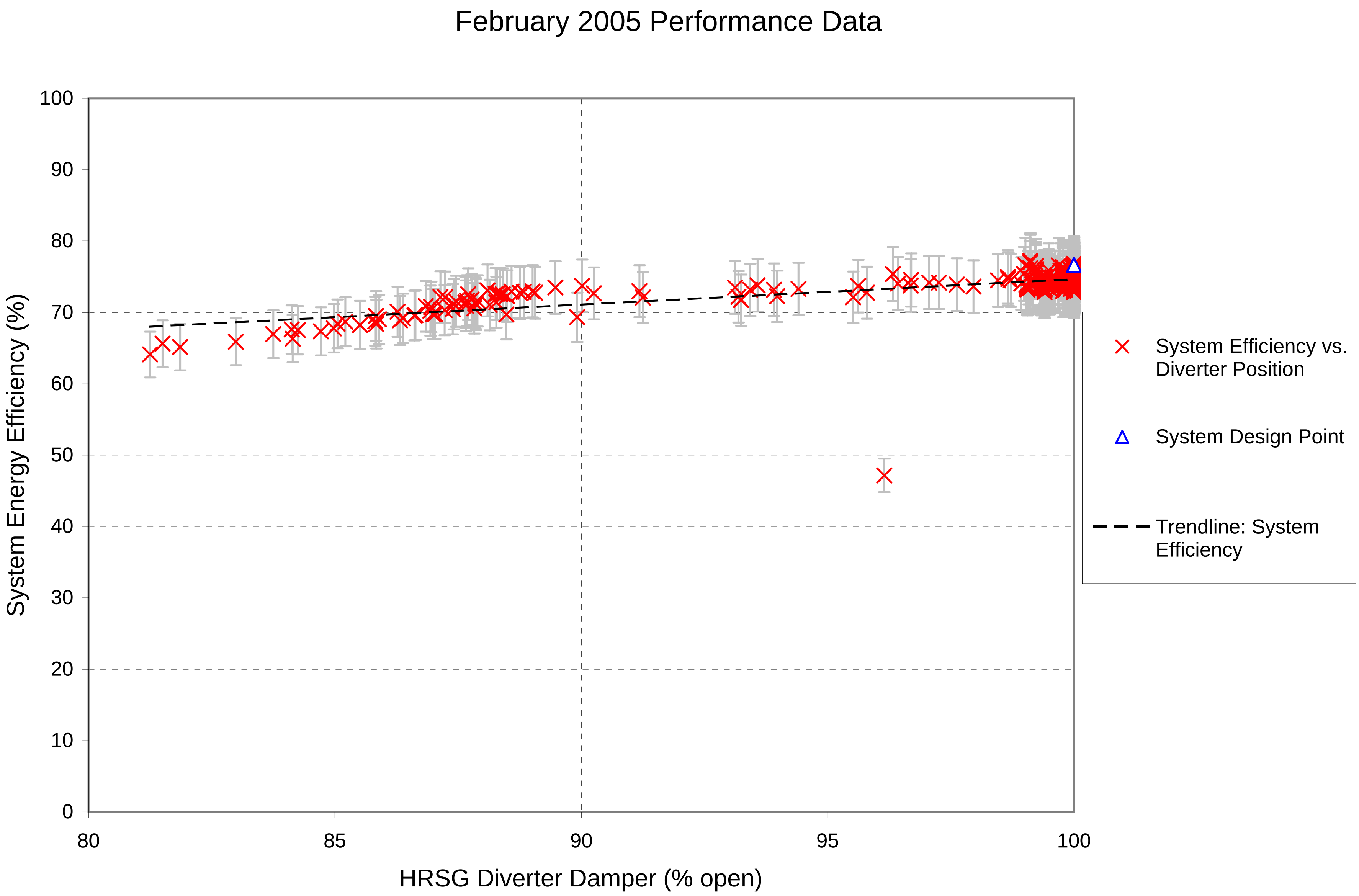
= **74.1%**

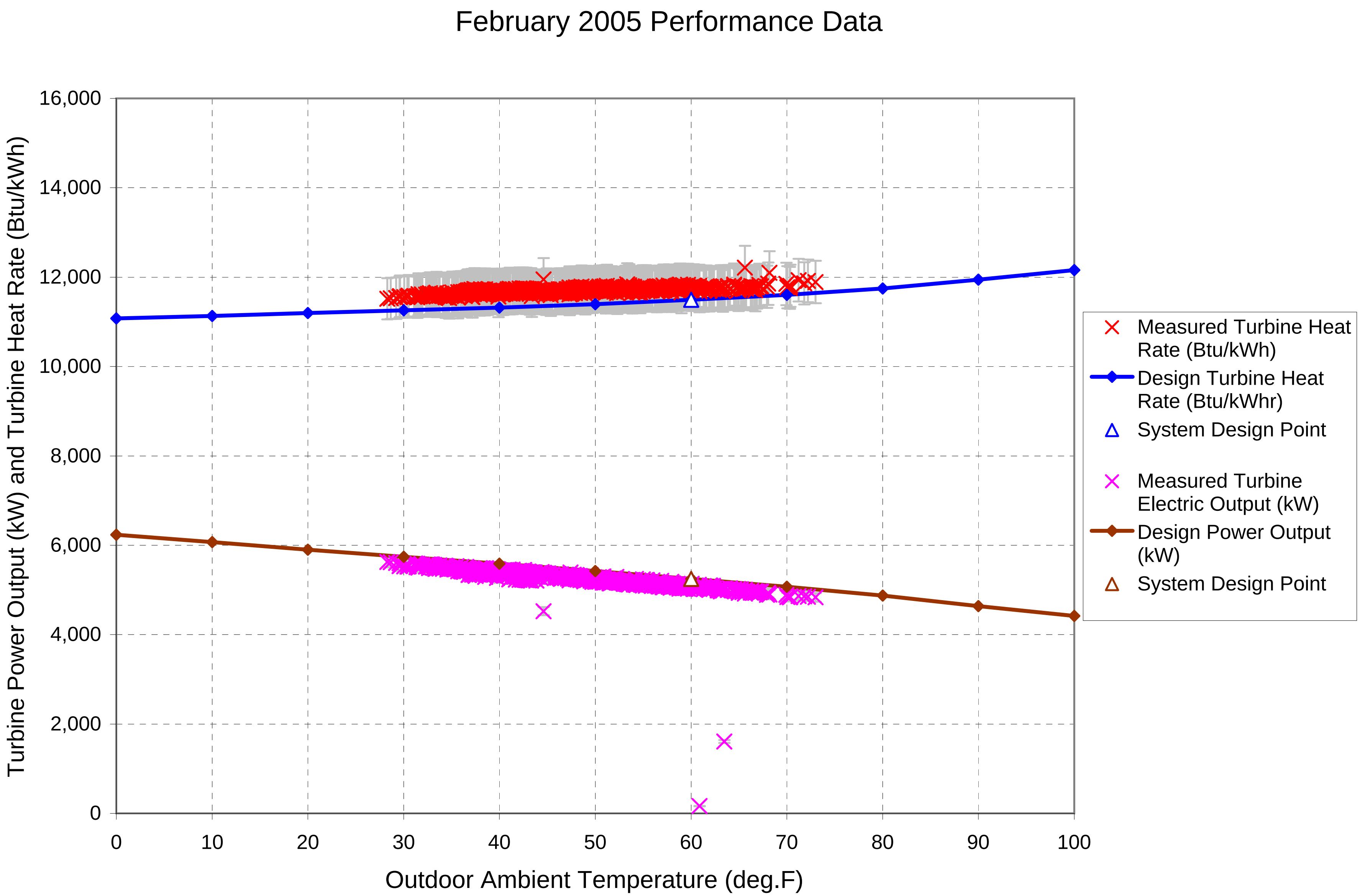
* as defined on page 27 of: "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

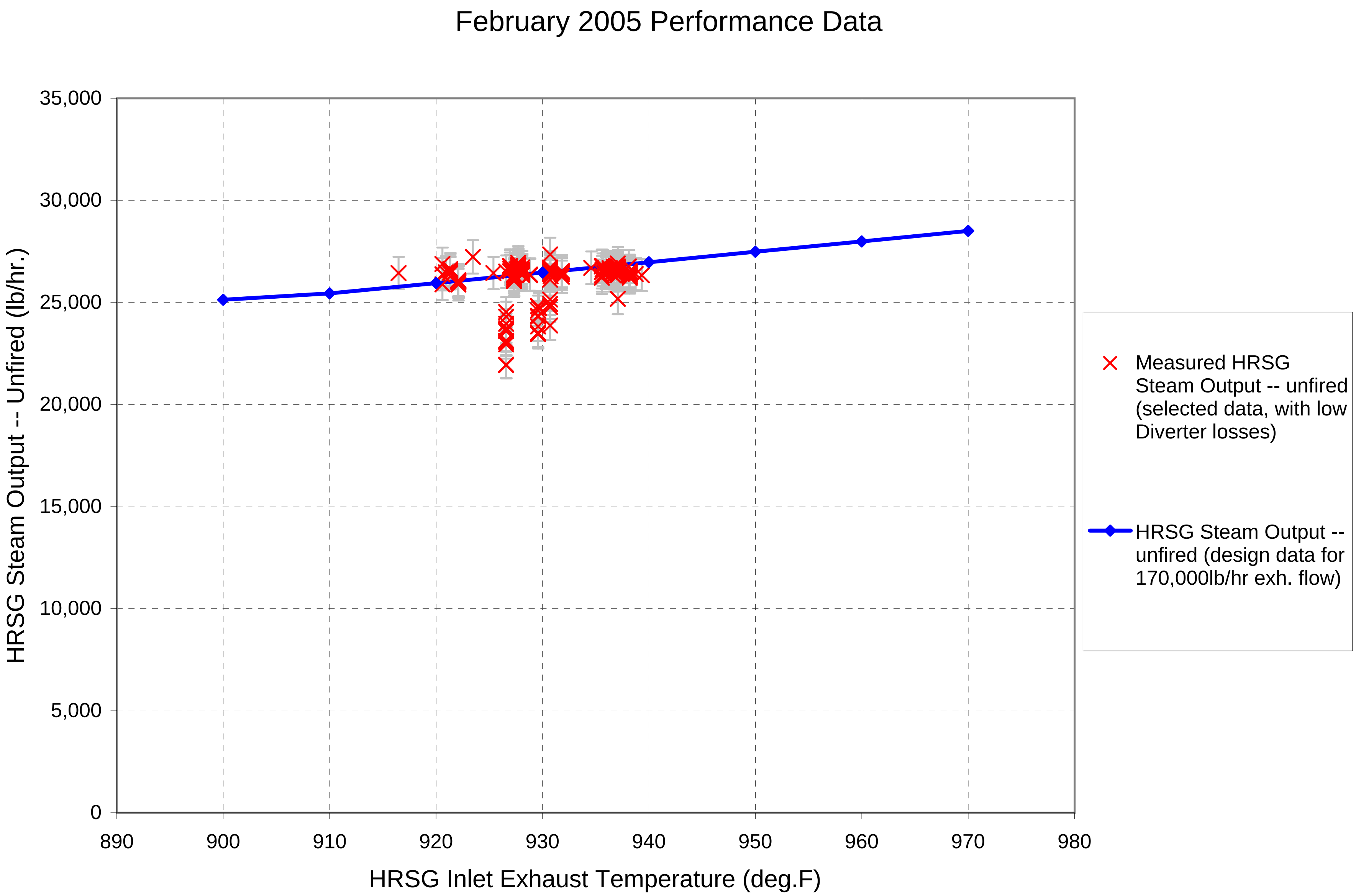
Daily

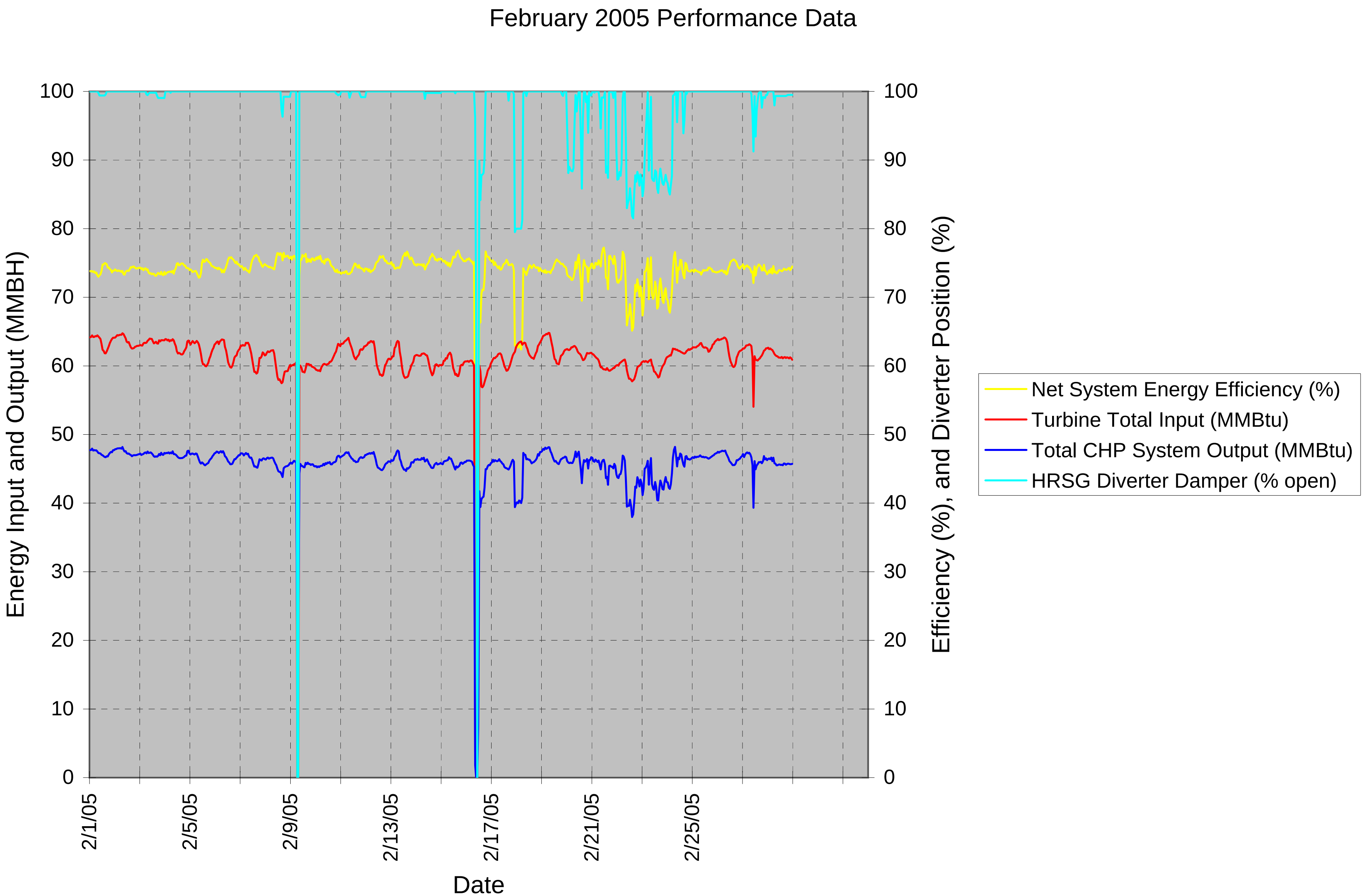

February 2005 Performance Data
Generated Power (MWh), and Turbine Runtime (hours)
150
125
100
75
50
25
0
HRSG Steam Generated (lbs.)
750,000
625,000
500,000
375,000
250,000
125,000
0
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
Date
Generated Power (MWh)
Turbine Runtime (hours)
HRSG Steam Generated (lbs.)

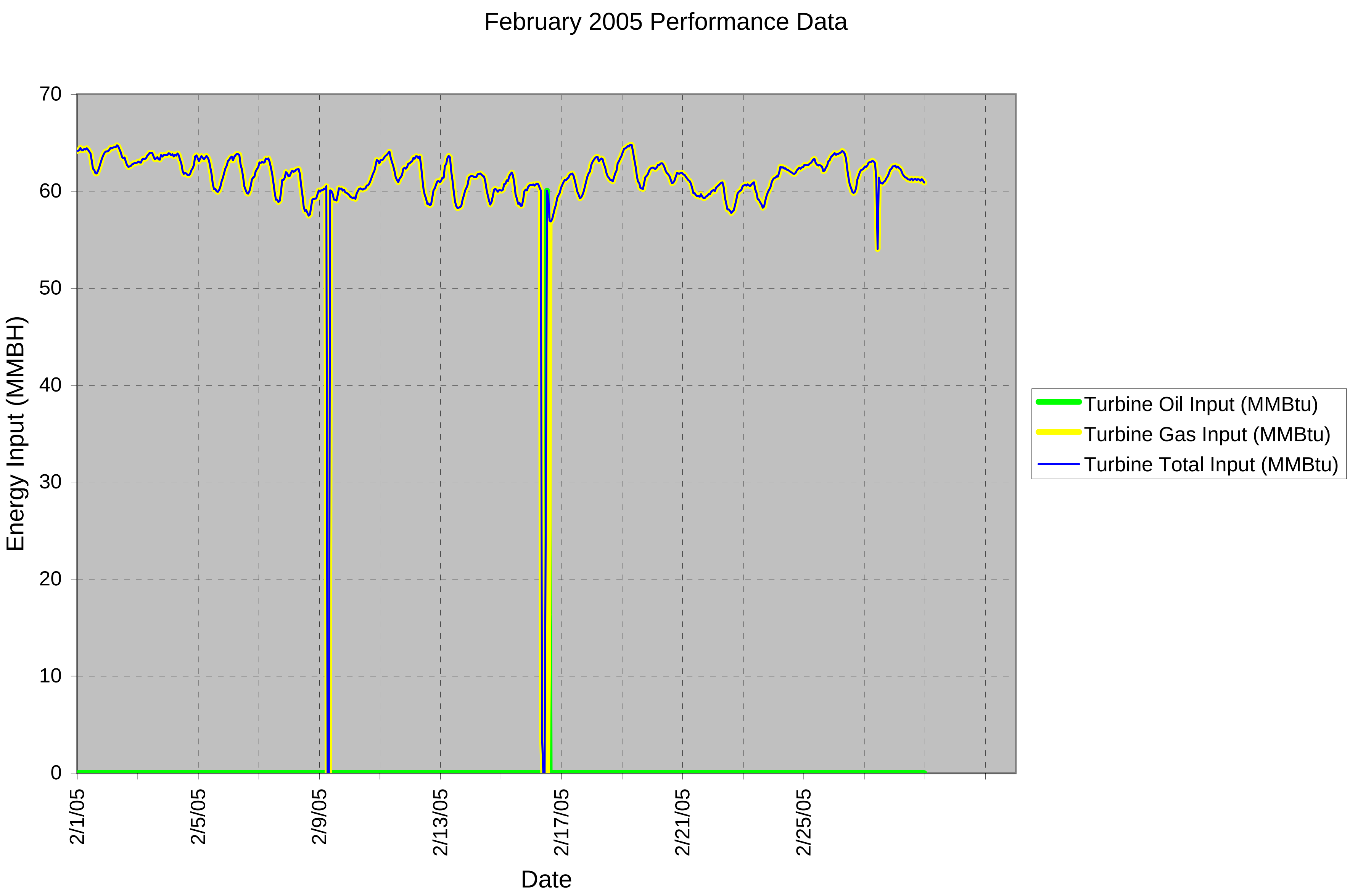

February 2005 Performance Data
System Energy Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Outdoor Ambient Temperature (deg.F)
Net System Energy Efficiency (%)
Design Data (Nat. Gas): heating-only operation, no Duct Burner
System Design Point

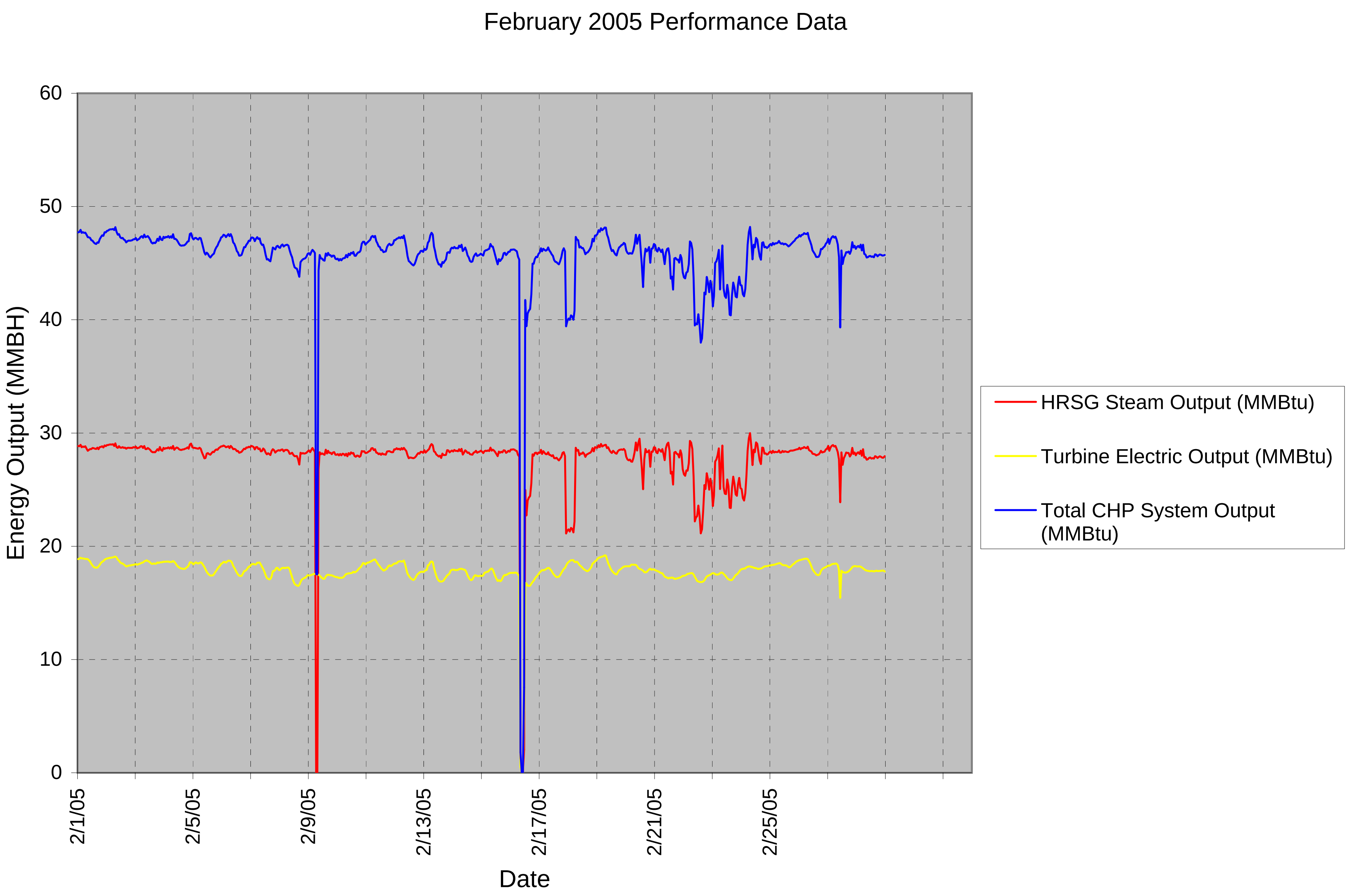

February 2005 Performance Data
System Energy Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
80
85
90
95
100
HRSG Diverter Damper (% open)
System Efficiency vs. Diverter Position
System Design Point
Trendline: System Efficiency


February 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)
Measured Turbine Heat Rate (Btu/kWh)
Design Turbine Heat Rate (Btu/kWhr)
System Design Point
Measured Turbine Electric Output (kW)
Design Power Output (kW)
System Design Point


February 2005 Performance Data
HRSG Steam Output -- Unfired (lb/hr.)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
890
900
910
920
930
940
950
960
970
980
HRSG Inlet Exhaust Temperature (deg.F)
Measured HRSG Steam Output -- unfired (selected data, with low Diverter losses)
HRSG Steam Output -- unfired (design data for 170,000lb/hr exh. flow)


February 2005 Performance Data
Energy Input and Output (MMBH)
Efficiency (%), and Diverter Position (%)
Date
100
90
80
70
60
50
40
30
20
10
0
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
Net System Energy Efficiency (%)
Turbine Total Input (MMBtu)
Total CHP System Output (MMBtu)
HRSG Diverter Damper (% open)


February 2005 Performance Data
Energy Input (MMBH)
0
10
20
30
40
50
60
70
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
Date
Turbine Oil Input (MMBtu)
Turbine Gas Input (MMBtu)
Turbine Total Input (MMBtu)


February 2005 Performance Data
Energy Output (MMBH)
60
50
40
30
20
10
0
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
Date
HRSG Steam Output (MMBtu)
Turbine Electric Output (MMBtu)
Total CHP System Output (MMBtu)

3.3 Detailed Performance Results: March 2005

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

Field observations noted during the month are:

- There were only a few hours when the IES system was off-line during the month.
- The Duct Burner was started up on March 3rd, following repair of the gas valve operator. Operation of the Duct Burner helped to provide excellent overall system energy efficiency.
- The turbine was down for scheduled cleaning of the turbine blades on March 28-29. When the unit was restarted, it exhibited an expected slight increase in energy efficiency.
- There was little operation of the auxiliary boiler during the month. This allowed the diverter to direct all exhaust flow thru the HRSG during most of the month, thereby maximizing the amount of recovered energy.

Data analysis comments for the month are:

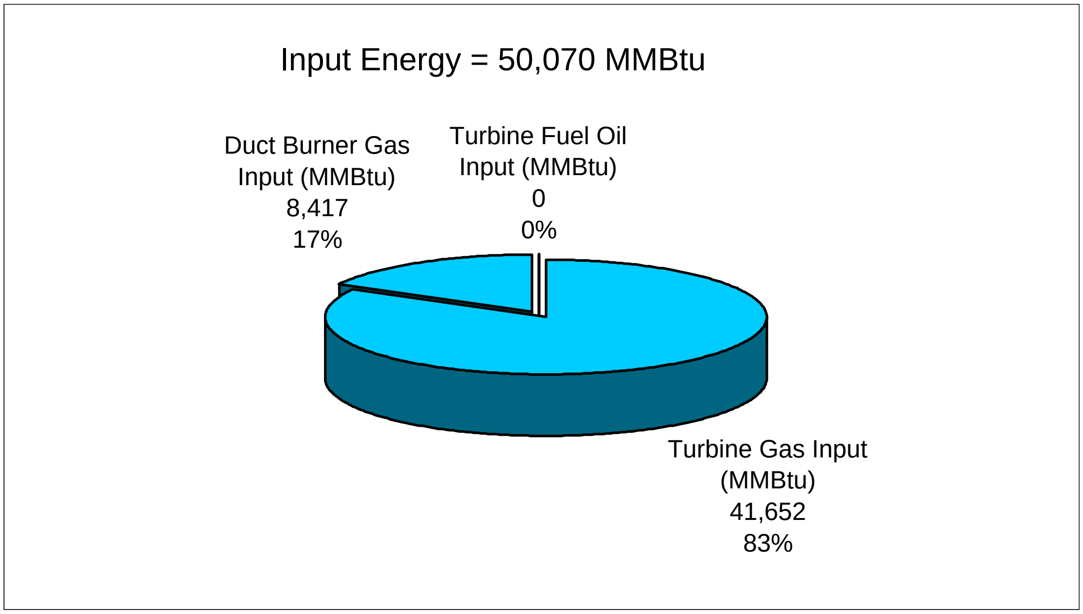
Table or Figure	Analysis Comments
Summary Data Table	The system's operational performance was very good during the month (very little downtime).
Monthly Overview	The system's energy performance was excellent during the month (in part, due to the use of the Duct Burner).
Daily Performance	See comments above.
System Net Energy Efficiency	System net energy efficiency was very good. During most of the month, the energy efficiency was increased due to the use of the Duct Burner. This figure shows the benefit provided by the Duct Burner over the basic (non-fired) performance of the HRSG.
Diverter Energy Losses	See comments above (most of the exhaust flow was directed thru the HRSG during the month -- little diverter loss during the month).
Turbine Generator Performance	The performance had been slowly falling off earlier, due to dirt accumulation on the turbine blades (prior to cleaning on March 28-29). After cleaning, the performance was very good -- the measured data matches well with the design data (within the expected uncertainty).
HRSG Performance (Overall)	Good performance, the effect of the Duct Burner can be seen in the data.
HRSG Performance (Fired)	Good performance -- the measured data matches well with the design data (within the expected uncertainty).

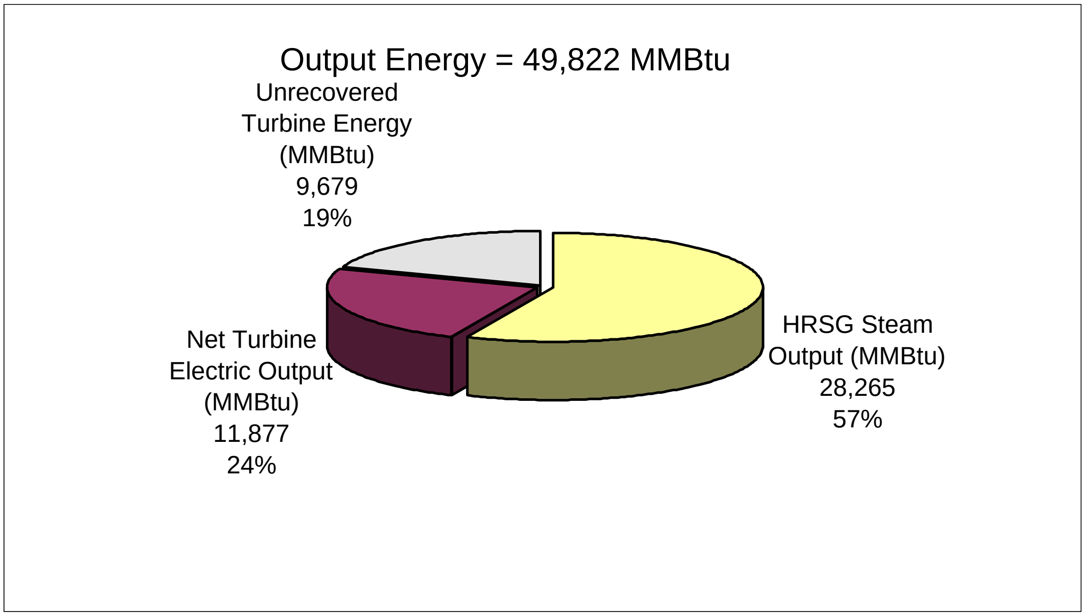
Additional plots of more detailed operating data are presented in Appendix C.

	Measured Data							Calculated Results								
Date	Generated Power (MWh)	HRSG Steam Generated (lbs.)	Turbine Nat. Gas Consumed (MCF)	Turbine Fuel Oil Consumed (gal.)	Duct Burner Nat. Gas Consumed (MCF)	Turbine Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Turbine Natural Gas Input (MMBtu)	Turbine Fuel Oil Input (MMBtu)	Turbine Total Energy Input (MMBtu)	Duct Burner Natural Gas Input (MMBtu)	HRSG Steam Output (MMBtu)	Turbine Power Output (MMBtu)	Total CHP Output (MMBtu)	Net Daily System Efficiency (%)	Parasitic Energy (MWh)
1-Mar-05	124	615,392	1,386	0	33	24	24	1,438	0	1,438	35	656	422	1,078	72.9	2.5
2-Mar-05	124	602,218	1,360	0	353	23	24	1,410	0	1,410	366	642	423	1,065	63.2	2.5
3-Mar-05	128	915,761	1,409	0	256	24	10	1,461	0	1,461	266	976	438	1,414	80.9	2.5
4-Mar-05	126	1,111,154	1,418	0	447	24	0	1,470	0	1,470	464	1,184	430	1,615	83.0	2.5
5-Mar-05	123	1,005,645	1,396	0	339	24	1	1,448	0	1,448	351	1,072	420	1,492	82.5	2.5
6-Mar-05	125	1,002,707	1,411	0	344	24	0	1,464	0	1,464	357	1,069	427	1,496	81.7	2.5
7-Mar-05	120	966,699	1,362	0	316	24	0	1,413	0	1,413	328	1,031	408	1,439	82.1	2.5
8-Mar-05	122	1,031,911	1,374	0	378	22	1	1,425	0	1,425	392	1,100	416	1,516	82.9	2.3
9-Mar-05	129	1,126,262	1,451	0	453	24	0	1,504	0	1,504	470	1,201	440	1,640	82.6	2.5
10-Mar-05	126	1,007,054	1,425	0	350	24	0	1,478	0	1,478	363	1,074	431	1,505	81.2	2.5
11-Mar-05	123	994,913	1,391	0	339	24	0	1,442	0	1,442	352	1,061	420	1,480	82.1	2.5
12-Mar-05	122	949,291	1,378	0	297	24	0	1,429	0	1,429	308	1,012	415	1,427	81.7	2.5
13-Mar-05	119	865,819	1,355	0	220	24	0	1,405	0	1,405	228	923	406	1,329	80.9	2.5
14-Mar-05	127	966,012	1,433	0	309	24	0	1,486	0	1,486	321	1,030	433	1,463	80.5	2.5
15-Mar-05	127	997,170	1,438	0	330	24	0	1,491	0	1,491	342	1,063	435	1,498	81.2	2.5
16-Mar-05	128	1,059,099	1,436	0	394	24	0	1,489	0	1,489	409	1,129	435	1,564	81.9	2.5
17-Mar-05	129	1,180,685	1,450	0	518	24	0	1,503	0	1,503	538	1,259	440	1,699	82.8	2.5
18-Mar-05	126	1,128,227	1,424	0	465	24	0	1,477	0	1,477	482	1,203	430	1,632	82.9	2.5
19-Mar-05	124	986,270	1,411	0	324	24	0	1,463	0	1,463	336	1,051	424	1,475	81.5	2.5
20-Mar-05	121	915,251	1,374	0	260	24	0	1,425	0	1,425	270	976	411	1,387	81.4	2.5
21-Mar-05	123	882,406	1,390	0	226	24	0	1,441	0	1,441	235	941	418	1,359	80.6	2.5
22-Mar-05	122	894,220	1,391	0	240	24	0	1,443	0	1,443	249	953	418	1,371	80.5	2.5
23-Mar-05	116	829,152	1,335	0	187	24	0	1,384	0	1,384	194	884	397	1,280	80.6	2.5
24-Mar-05	119	824,460	1,358	0	166	24	0	1,409	0	1,409	172	879	407	1,286	80.8	2.5
25-Mar-05	121	815,299	1,377	0	163	24	0	1,428	0	1,428	169	869	413	1,282	79.7	2.5
26-Mar-05	123	792,240	1,393	0	140	24	0	1,444	0	1,444	145	845	418	1,263	78.9	2.5
27-Mar-05	121	770,132	1,375	0	121	24	0	1,426	0	1,426	126	821	412	1,233	78.9	2.5
28-Mar-05	43	274,631	501	0	38	9	16	519	0	519	39	293	148	441	74.9	0.9
29-Mar-05	0	0	0	0	0	0	24	0	0	0	0	0	0	0	N/A	0.0
30-Mar-05	51	265,857	576	0	30	11	16	597	0	597	31	283	173	456	68.3	1.1
31-Mar-05	122	739,137	1,390	0	78	24	0	1,442	0	1,442	81	788	418	1,206	78.6	2.5
totals	3,554	26,515,075	40,166	0	8,117	688	124	41,652	0	41,652	8,417	28,265	12,125	40,391	80.2	72.8

Month

March 2005 Performance Data





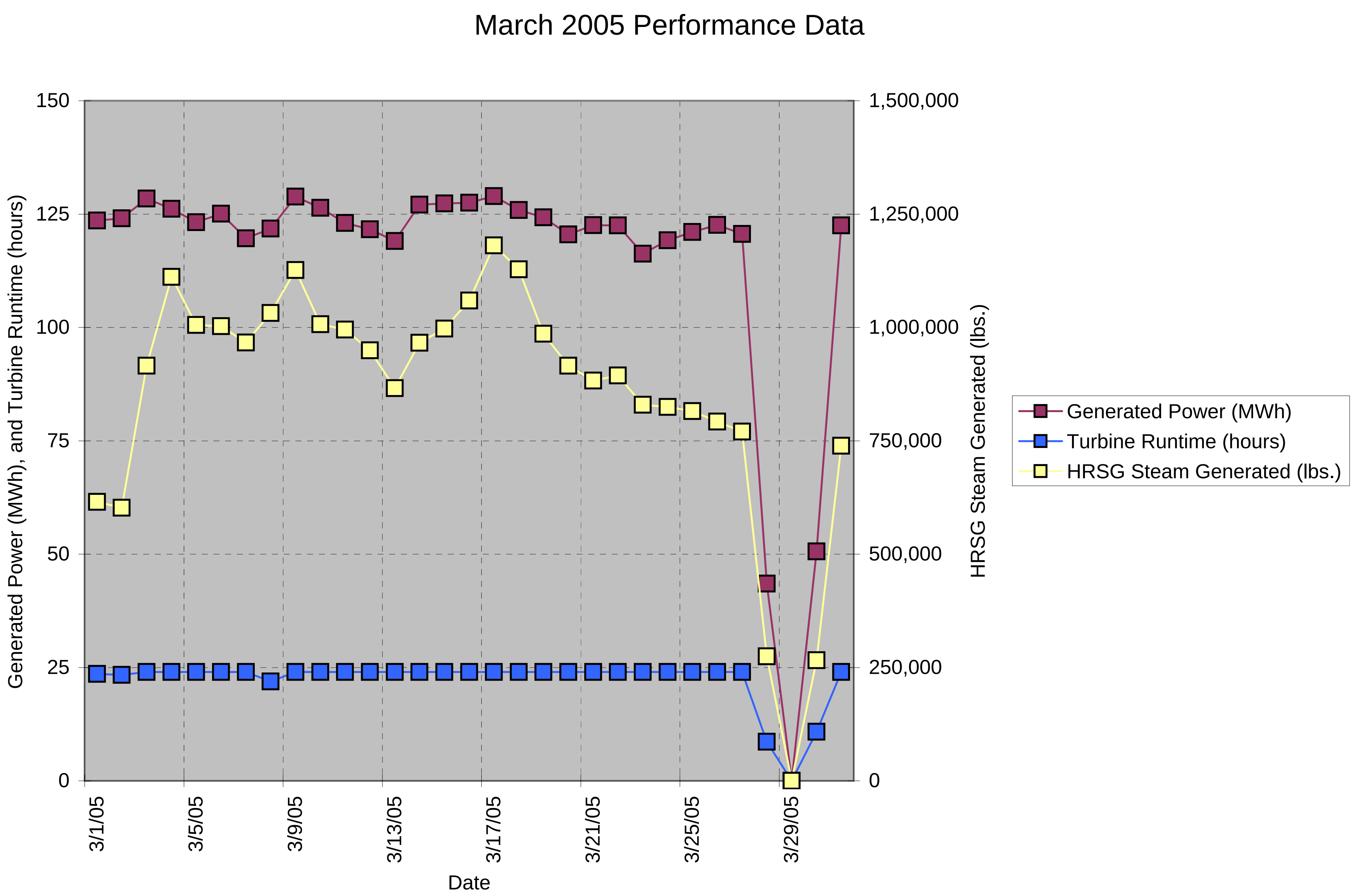
Net CHP Efficiency *

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

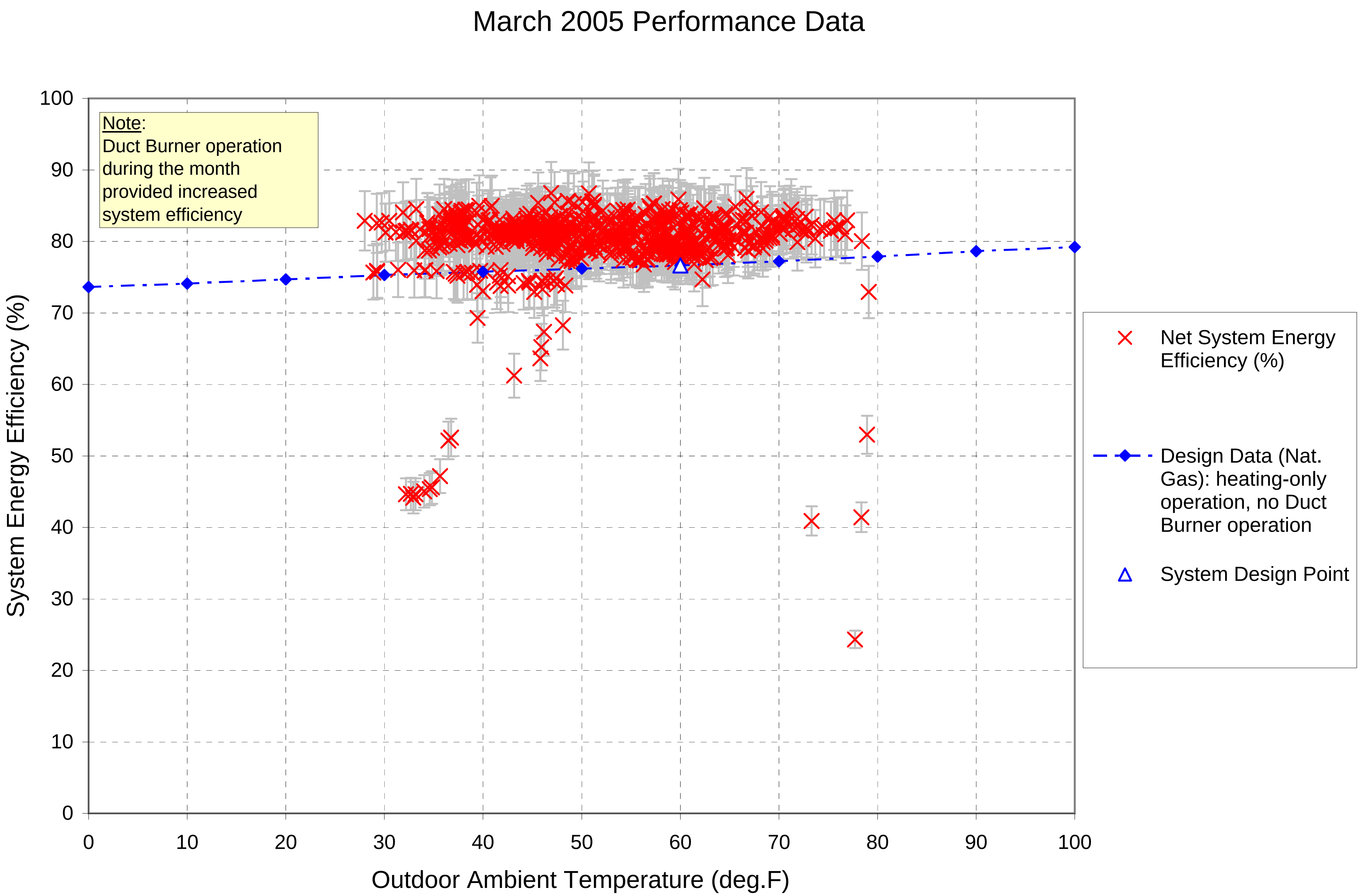
= **80.2%**

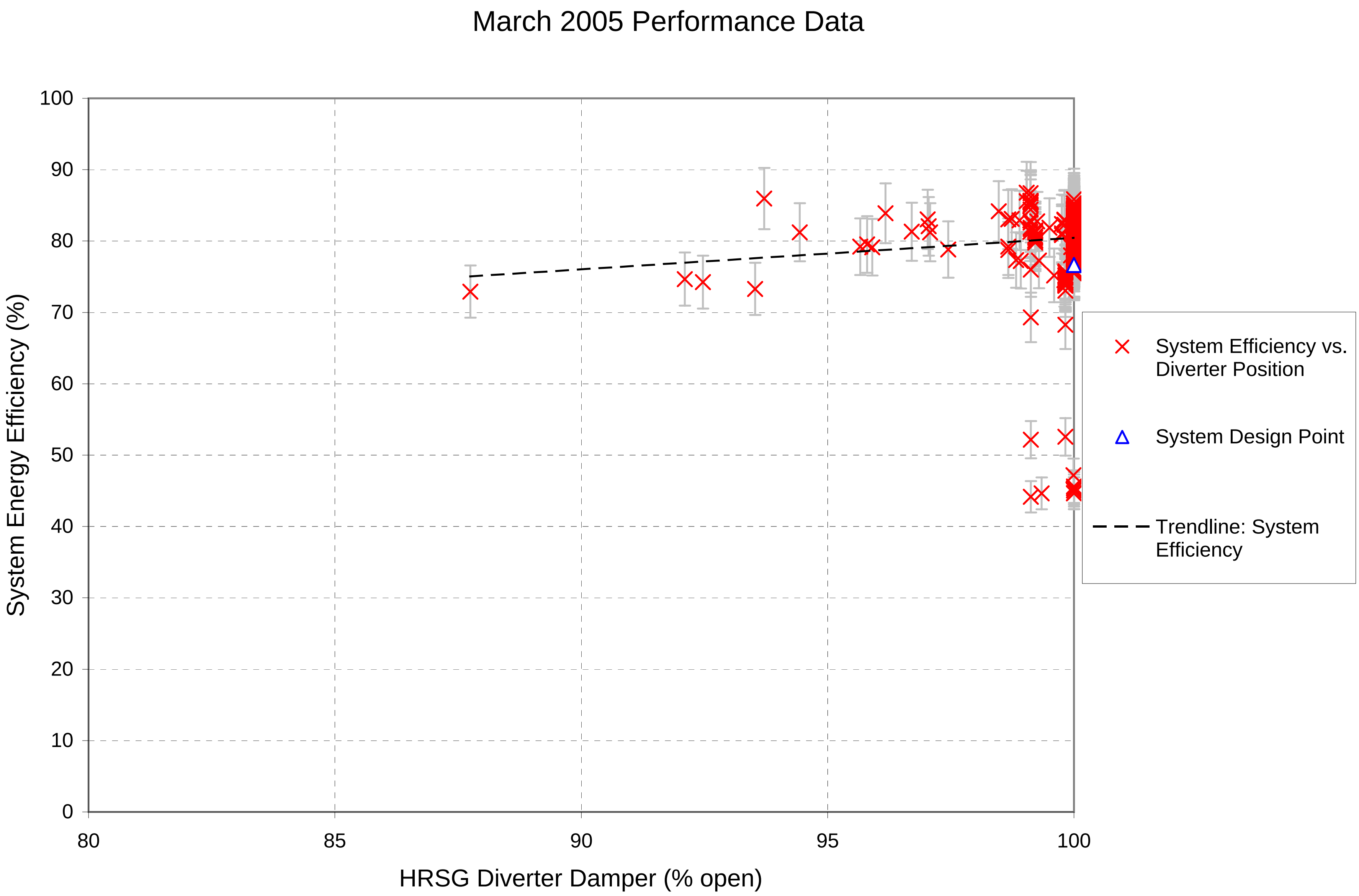
* as defined on page 27 of: "Distributed Generation Combined Heat and Power Long Term Monitoring Protocols" Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

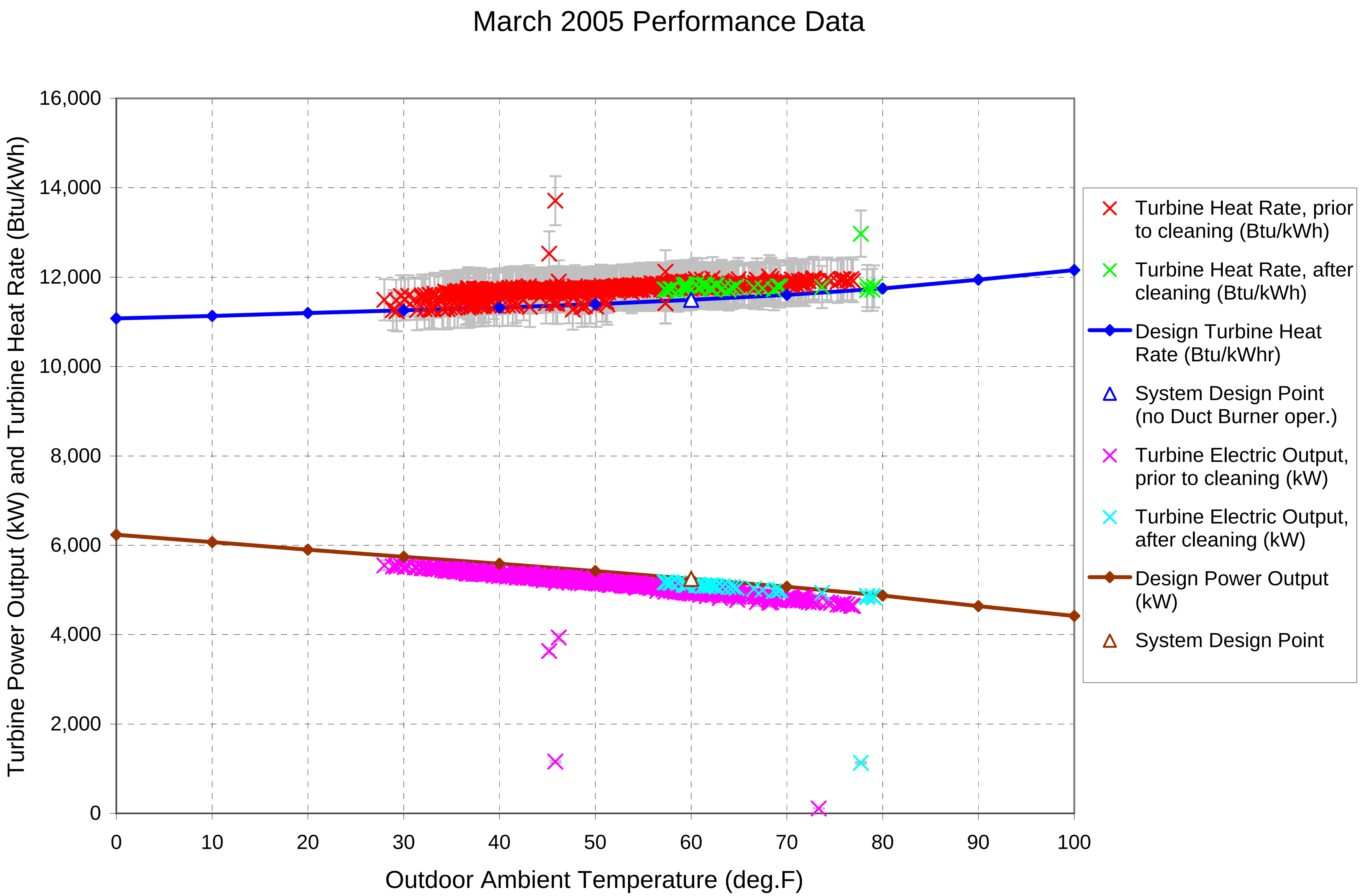
Daily

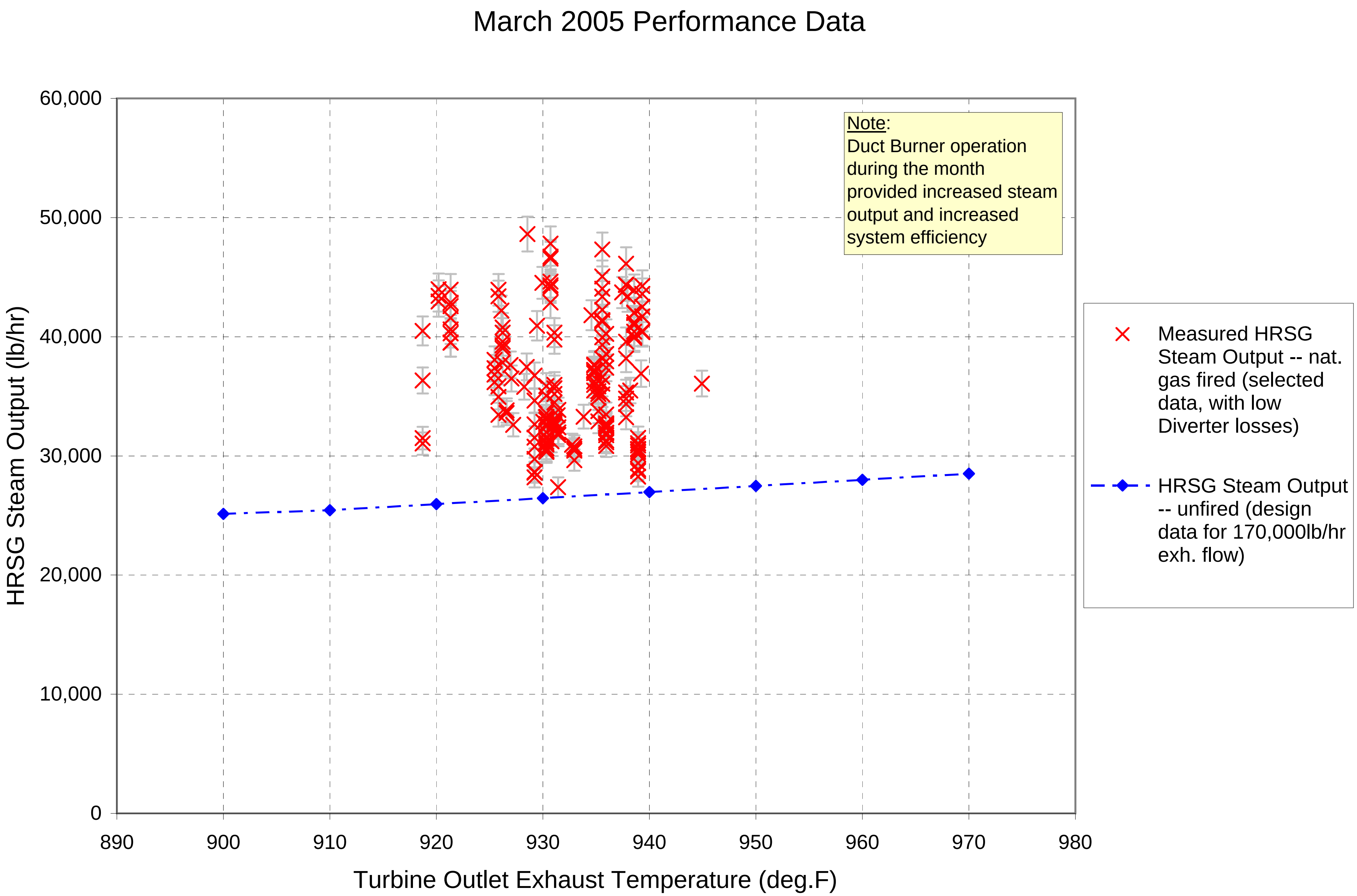


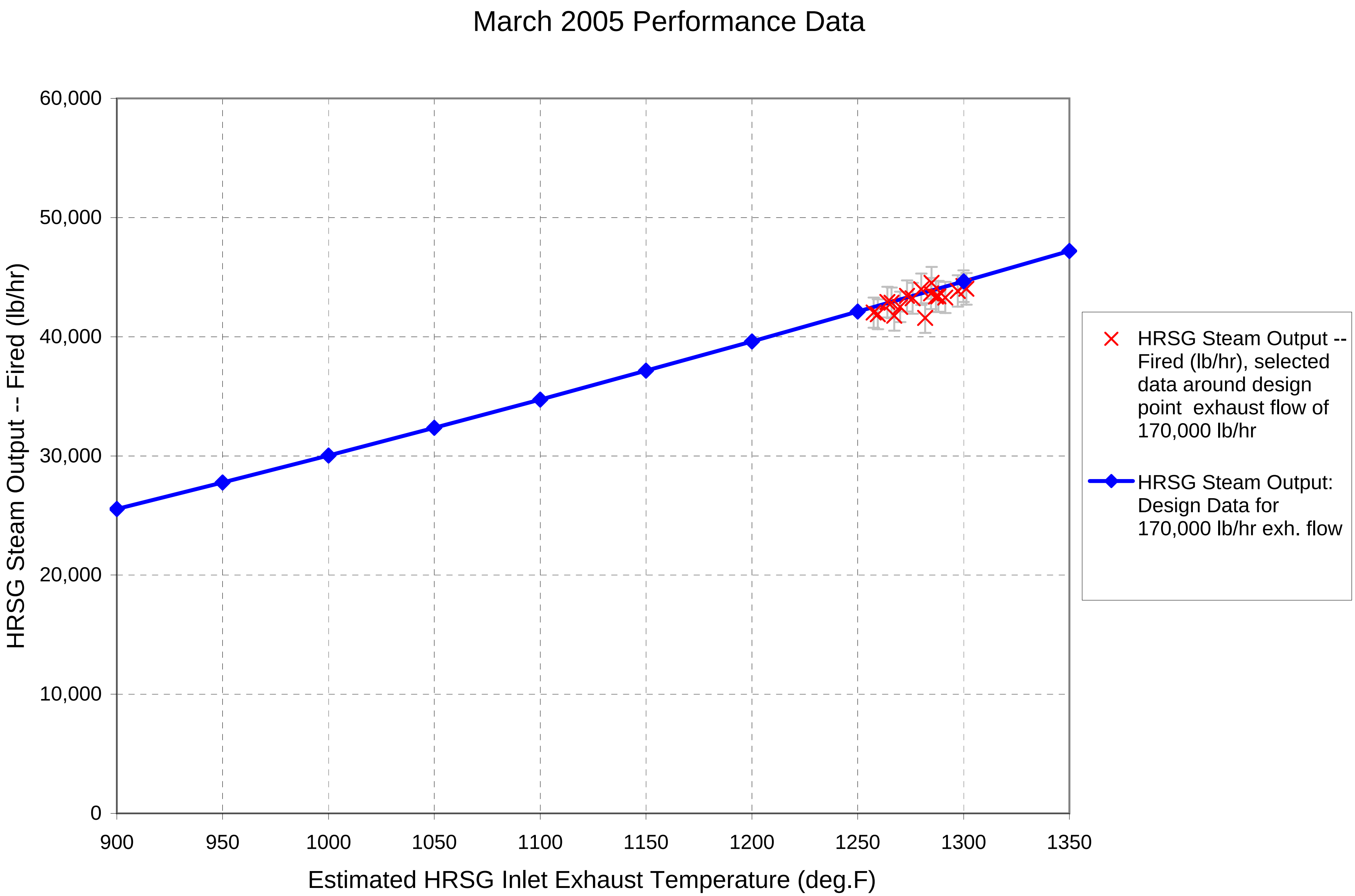
March 2005 Performance Data
150
125
100
75
50
25
0
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
Generated Power (MWh), and Turbine Runtime (hours)
HRSG Steam Generated (lbs.)
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Date
Generated Power (MWh)
Turbine Runtime (hours)
HRSG Steam Generated (lbs.)

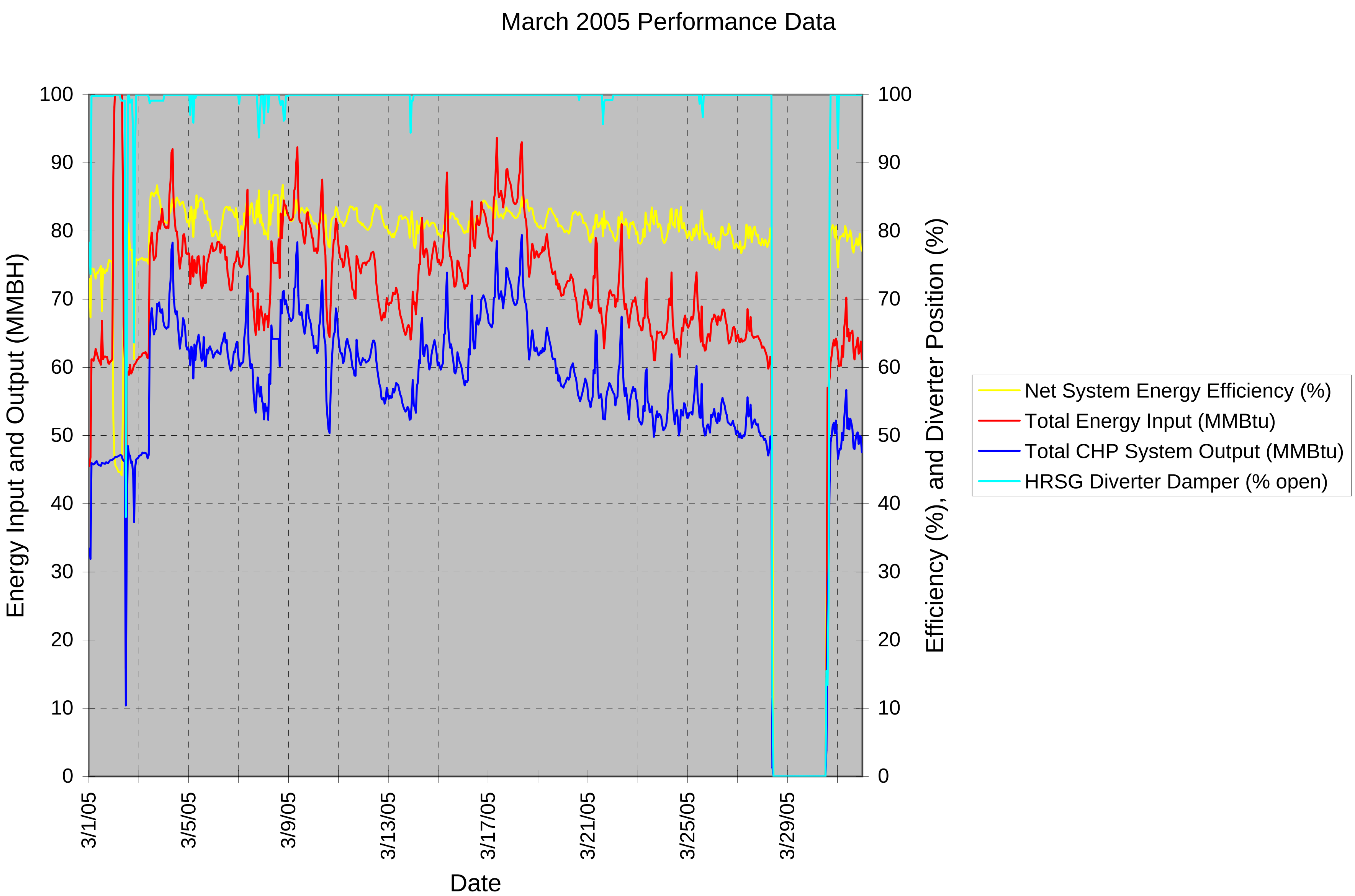

March 2005 Performance Data
Note:
Duct Burner operation during the month provided increased system efficiency
System Energy Efficiency (%)
Outdoor Ambient Temperature (deg.F)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Net System Energy Efficiency (%)
Design Data (Nat. Gas): heating-only operation, no Duct Burner operation
System Design Point

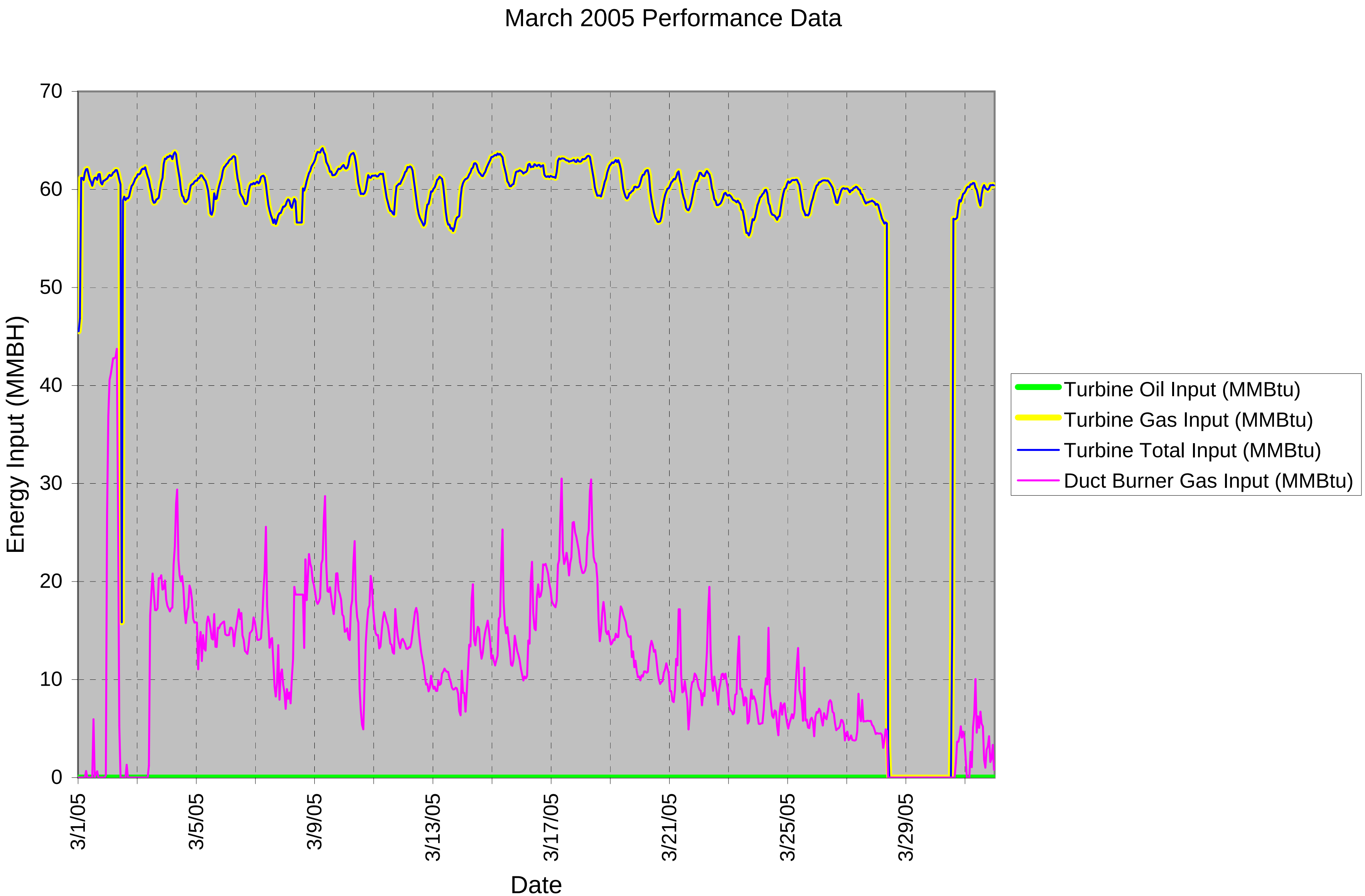

March 2005 Performance Data
System Energy Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
80
85
90
95
100
HRSG Diverter Damper (% open)
System Efficiency vs. Diverter Position
System Design Point
Trendline: System Efficiency


March 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, prior to cleaning (Btu/kWh)
Turbine Heat Rate, after cleaning (Btu/kWh)
Design Turbine Heat Rate (Btu/kWhr)
System Design Point (no Duct Burner oper.)
Turbine Electric Output, prior to cleaning (kW)
Turbine Electric Output, after cleaning (kW)
Design Power Output (kW)
System Design Point

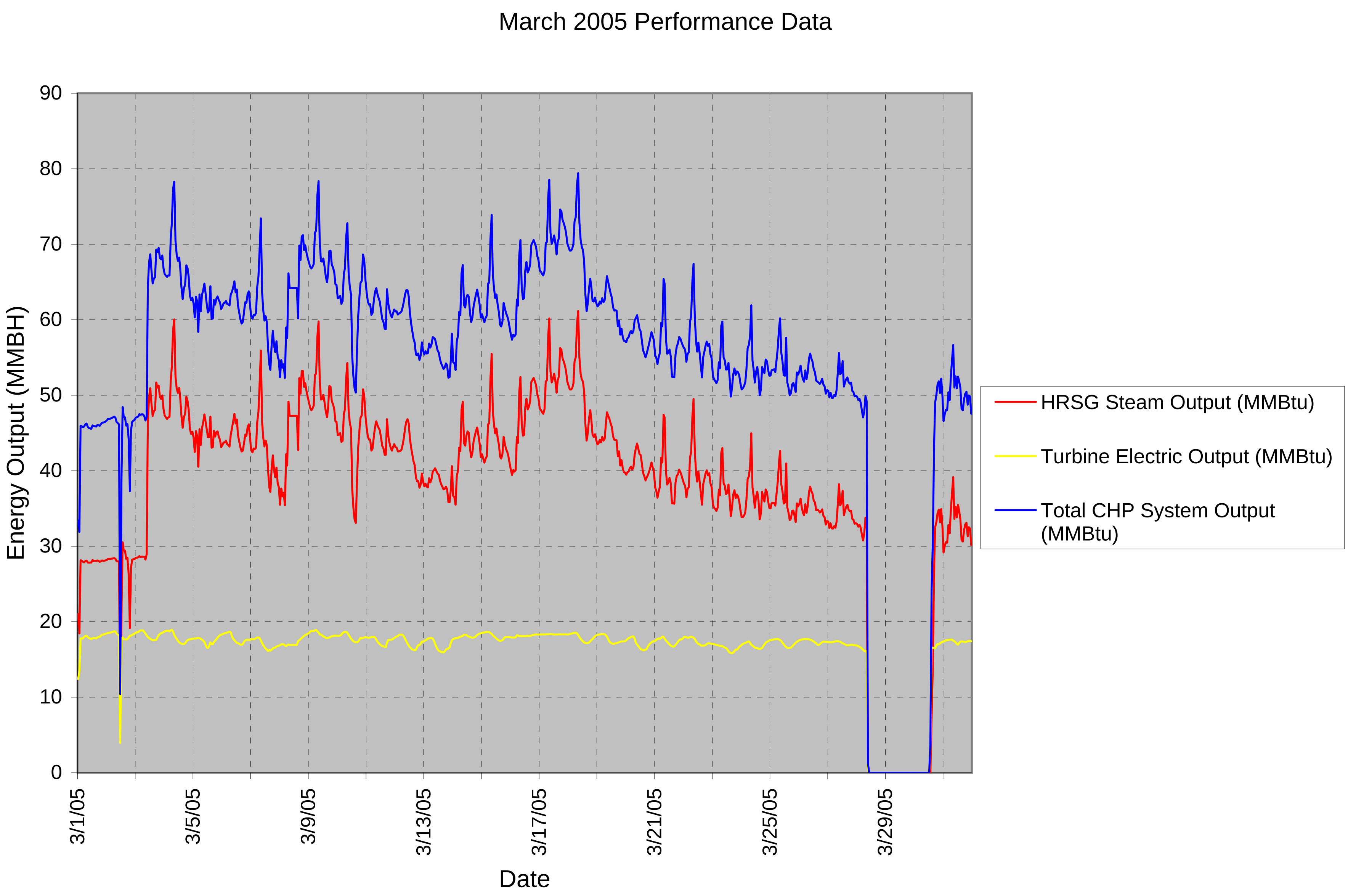

March 2005 Performance Data
HRSG Steam Output (lb/hr)
60,000
50,000
40,000
30,000
20,000
10,000
0
890
900
910
920
930
940
950
960
970
980
Turbine Outlet Exhaust Temperature (deg.F)
Note:
Duct Burner operation during the month provided increased steam output and increased system efficiency
Measured HRSG Steam Output -- nat. gas fired (selected data, with low Diverter losses)
HRSG Steam Output -- unfired (design data for 170,000lb/hr exh. flow)


March 2005 Performance Data
60,000
50,000
40,000
30,000
20,000
10,000
0
900
950
1000
1050
1100
1150
1200
1250
1300
1350
HRSG Steam Output -- Fired (lb/hr)
Estimated HRSG Inlet Exhaust Temperature (deg.F)
HRSG Steam Output -- Fired (lb/hr), selected data around design point exhaust flow of 170,000 lb/hr
HRSG Steam Output: Design Data for 170,000 lb/hr exh. flow


March 2005 Performance Data
Energy Input and Output (MMBH)
Efficiency (%), and Diverter Position (%)
Date
100
90
80
70
60
50
40
30
20
10
0
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Net System Energy Efficiency (%)
Total Energy Input (MMBtu)
Total CHP System Output (MMBtu)
HRSG Diverter Damper (% open)



March 2005 Performance Data
Energy Input (MMBH)
0
10
20
30
40
50
60
70
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Date
Turbine Oil Input (MMBtu)
Turbine Gas Input (MMBtu)
Turbine Total Input (MMBtu)
Duct Burner Gas Input (MMBtu)



March 2005 Performance Data
Energy Output (MMBH)
0
10
20
30
40
50
60
70
80
90
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Date
HRSG Steam Output (MMBtu)
Turbine Electric Output (MMBtu)
Total CHP System Output (MMBtu)

3.4 Detailed Performance Results: April 2005

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

Field observations noted during the month are:

- There were only a few hours when the IES system was off-line during the month.
- Occasional operation of the Duct Burner helped to provide very good overall system energy efficiency.
- The turbine was down to allow modifications to the absorption chiller on April 30.
- There was little operation of the auxiliary boiler during the month. Additional steam production was provided, when needed, by the Duct Burner.

Data analysis comments for the month are:

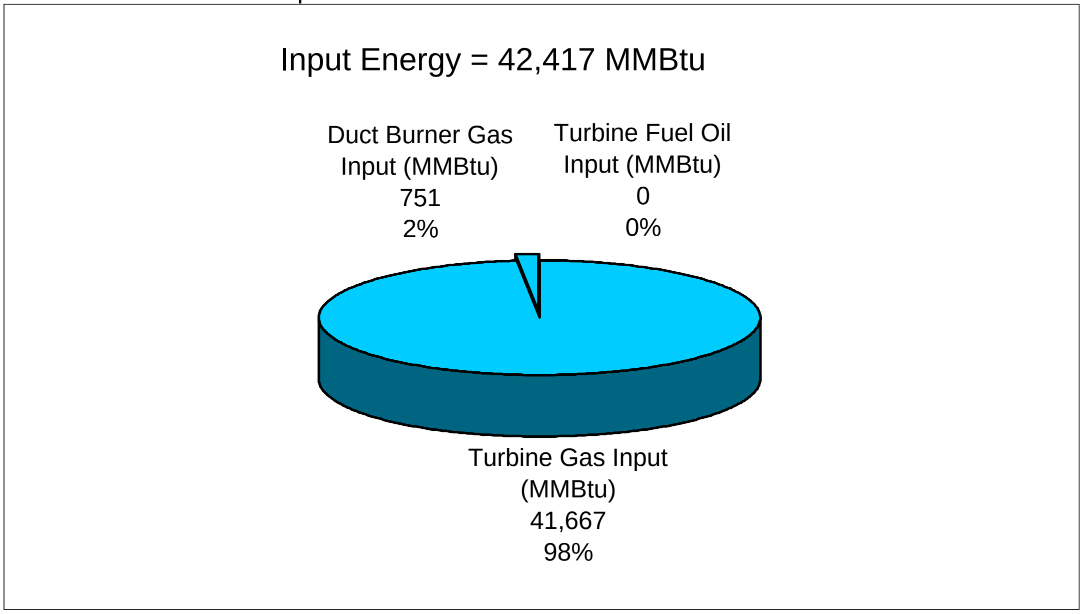
Table or Figure	Analysis Comments
Summary Data Table	The system's operational performance was very good during the month (little downtime).
Monthly Overview	The system's energy performance was very good during the month (in part, due to the use of the Duct Burner).
Daily Performance	See comments above.
System Net Energy Efficiency	System net energy efficiency was very good. During much of the month, the energy efficiency was increased due to the use of the Duct Burner. This figure shows the benefit provided by the Duct Burner over the basic (non-fired) performance of the HRSG.
Diverter Energy Losses	See comments above.
Turbine Generator Performance	Very good performance, the measured data matches well with the design data (within the expected uncertainty).
HRSG Performance (Overall)	Good performance, the effect of the Duct Burner can be seen in the data.
HRSG Performance (Fired)	Good performance -- the measured data matches well with the design data (within the expected uncertainty). The data points shown covered a lower temperature (and steam production) range than seen in March, due to lower heating demand in April.

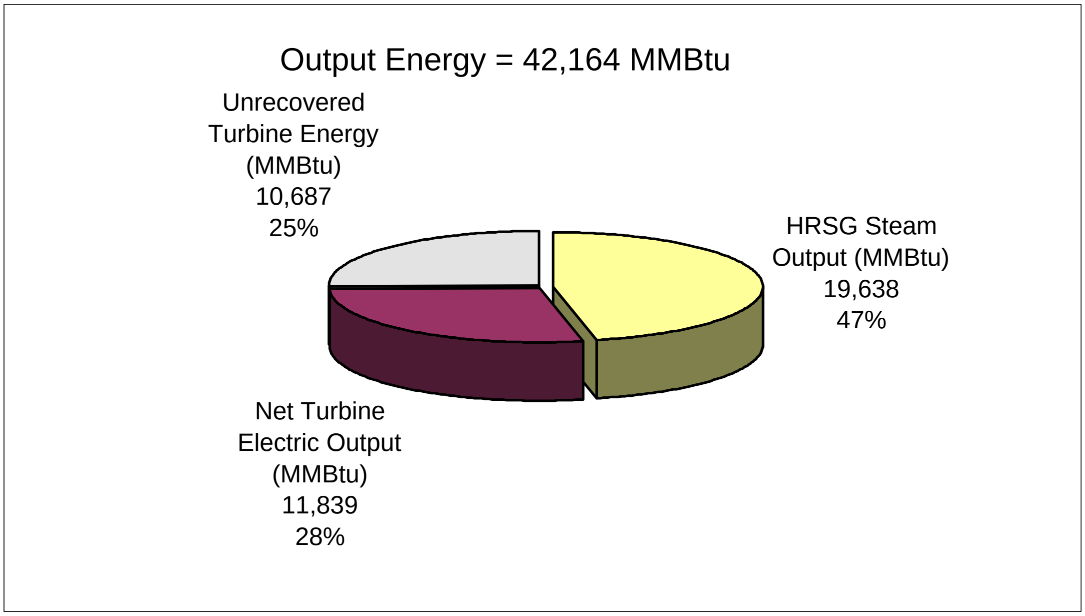
Additional plots of more detailed operating data are presented in Appendix D.

Date	Measured Data							Calculated Results								
Date	Generated Power (MWh)	HRSG Steam Generated (lbs.)	Turbine Nat. Gas Consumed (MCF)	Turbine Fuel Oil Consumed (gal.)	Duct Burner Nat. Gas Consumed (MCF)	Turbine Runtime (hours)	Aux. Boiler#5 Runtime (hours)	Turbine Natural Gas Input (MMBtu)	Turbine Fuel Oil Input (MMBtu)	Turbine Total Energy Input (MMBtu)	Duct Burner Natural Gas Input (MMBtu)	HRSG Steam Output (MMBtu)	Turbine Power Output (MMBtu)	Total CHP Output (MMBtu)	Net Daily System Efficiency (%)	Parasitic Energy (MWh)
1-Apr-05	118	681,670	1,340	0	44	24	1	1,390	0	1,390	46	727	402	1,128	77.9	2.5
2-Apr-05	121	695,593	1,365	0	53	24	0	1,416	0	1,416	55	742	412	1,153	77.8	2.5
3-Apr-05	117	709,029	1,320	0	89	23	0	1,369	0	1,369	92	756	400	1,156	78.6	2.4
4-Apr-05	121	719,339	1,365	0	70	24	1	1,416	0	1,416	72	767	412	1,178	78.6	2.5
5-Apr-05	116	667,058	1,337	0	57	23	2	1,386	0	1,386	59	711	397	1,109	75.6	2.5
6-Apr-05	119	687,856	1,364	0	45	24	0	1,414	0	1,414	47	733	408	1,141	77.5	2.5
7-Apr-05	119	655,820	1,360	0	31	24	1	1,410	0	1,410	33	699	407	1,106	76.0	2.5
8-Apr-05	119	605,229	1,347	0	7	24	1	1,397	0	1,397	7	645	405	1,050	74.2	2.5
9-Apr-05	122	595,153	1,375	0	1	24	1	1,426	0	1,426	1	634	415	1,050	73.0	2.5
10-Apr-05	123	602,819	1,386	0	0	24	1	1,438	0	1,438	0	643	420	1,062	73.3	2.5
11-Apr-05	120	584,850	1,355	0	0	24	0	1,405	0	1,405	0	623	408	1,031	72.8	2.5
12-Apr-05	123	608,299	1,386	0	7	24	1	1,437	0	1,437	7	648	418	1,067	73.2	2.5
13-Apr-05	126	706,066	1,422	0	74	24	1	1,475	0	1,475	77	753	430	1,183	75.6	2.5
14-Apr-05	126	727,514	1,419	0	74	24	1	1,471	0	1,471	77	776	430	1,206	77.3	2.5
15-Apr-05	126	722,752	1,415	0	57	24	0	1,468	0	1,468	59	770	430	1,200	78.0	2.5
16-Apr-05	128	683,880	1,429	0	28	24	1	1,482	0	1,482	29	729	435	1,164	76.4	2.5
17-Apr-05	126	666,421	1,414	0	16	24	1	1,467	0	1,467	17	710	429	1,139	76.2	2.5
18-Apr-05	121	646,178	1,374	0	21	24	0	1,425	0	1,425	22	689	413	1,102	75.5	2.5
19-Apr-05	118	612,244	1,345	0	8	24	1	1,395	0	1,395	9	653	401	1,054	74.5	2.5
20-Apr-05	116	599,796	1,335	0	8	24	0	1,384	0	1,384	8	639	397	1,037	73.8	2.5
21-Apr-05	116	569,900	1,333	0	2	24	0	1,382	0	1,382	3	608	396	1,004	71.9	2.5
22-Apr-05	115	536,296	1,327	0	0	24	1	1,376	0	1,376	0	572	394	965	69.5	2.5
23-Apr-05	119	534,221	1,344	0	0	24	0	1,394	0	1,394	0	569	405	974	69.3	2.5
24-Apr-05	124	597,943	1,403	0	10	24	1	1,455	0	1,455	10	637	424	1,061	71.9	2.5
25-Apr-05	123	609,086	1,385	0	9	24	1	1,436	0	1,436	10	649	419	1,068	73.3	2.5
26-Apr-05	121	575,478	1,372	0	4	24	1	1,422	0	1,422	4	613	413	1,027	71.4	2.5
27-Apr-05	119	564,248	1,344	0	4	24	1	1,393	0	1,393	4	601	404	1,006	71.4	2.5
28-Apr-05	122	543,610	1,376	0	3	24	1	1,427	0	1,427	3	579	416	995	69.0	2.5
29-Apr-05	102	466,333	1,153	0	0	20	4	1,196	0	1,196	0	497	347	844	69.8	2.1
30-Apr-05	60	247,534	689	0	0	13	13	714	0	714	0	264	206	470	63.1	1.4
totals	3,544	18,422,213	40,180	0	724	702	34	41,667	0	41,667	751	19,638	12,092	31,730	74.2	74.3

Month

April 2005 Performance Data





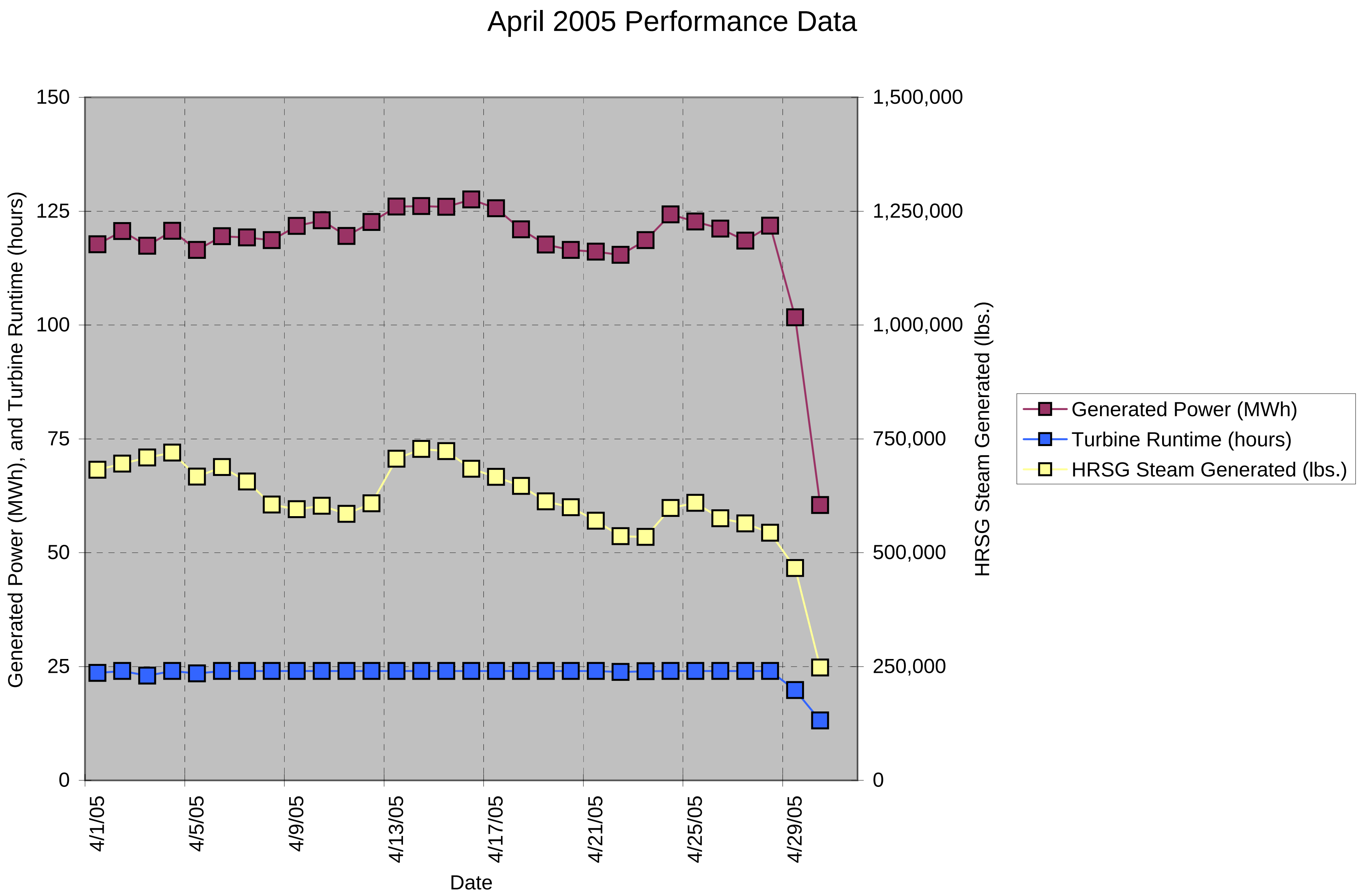
Net CHP Efficiency *

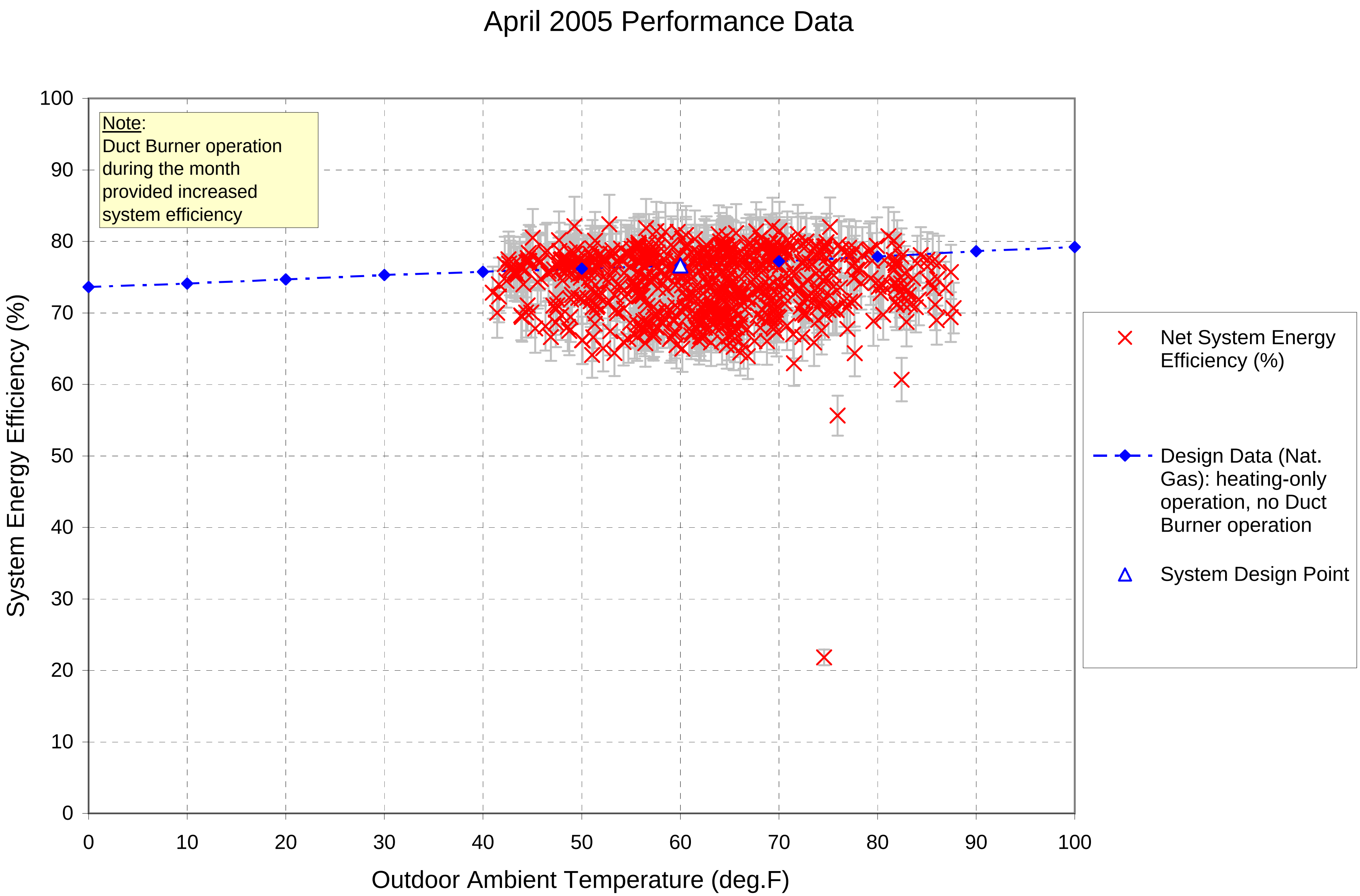
$$n_{CHP \cdot NET} = \frac{NET\ P_{REAL}(kW) + P_{QNET}(kW)}{P_{FUEL \cdot INPUT}(kW)} \times 100$$

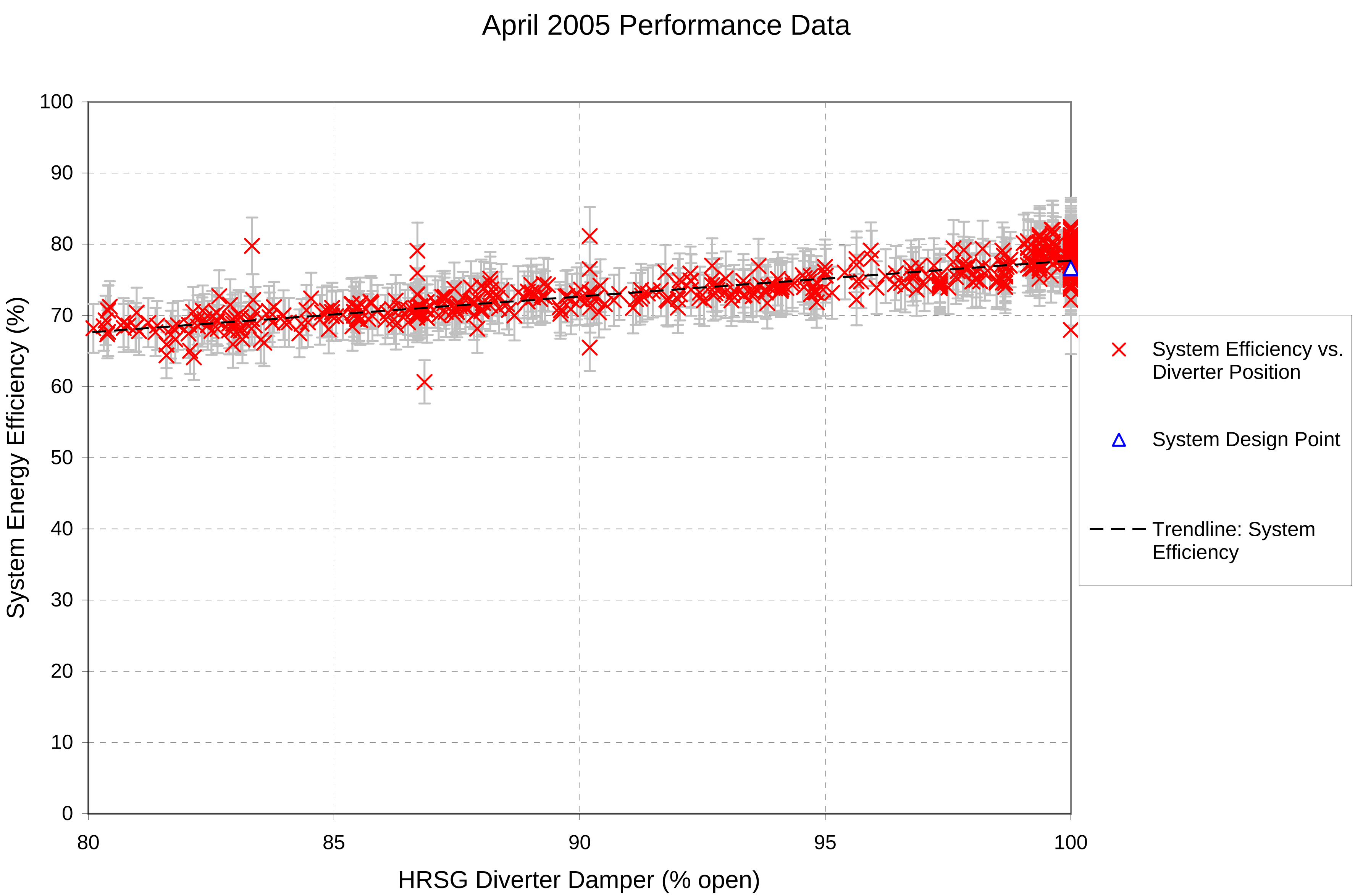
= **74.2%**

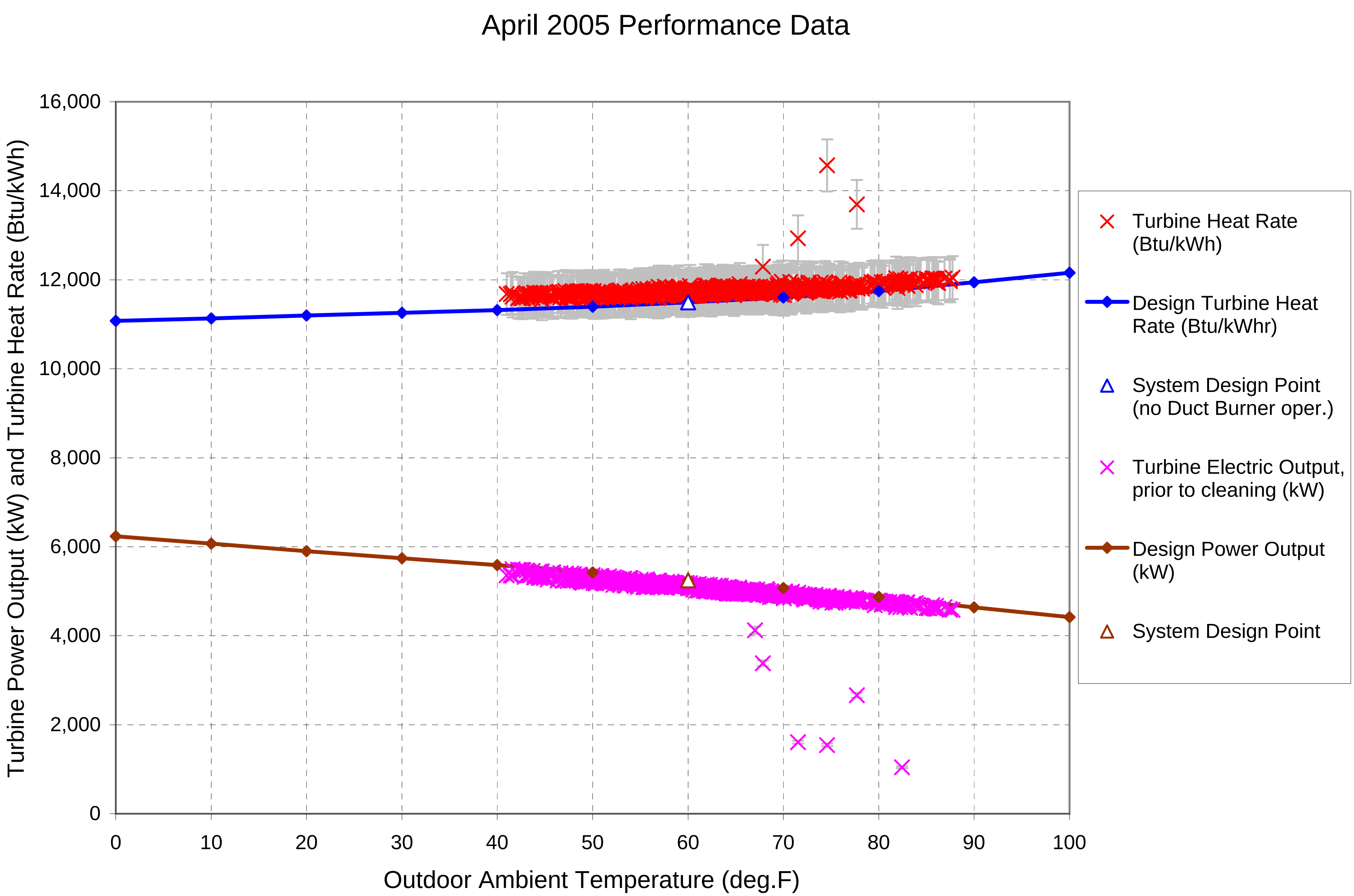
* as defined on page 27 of: “Distributed Generation Combined Heat and Power Long Term Monitoring Protocols” Interim Version, October 29, 2004, prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) http://www.asertti.org

Daily

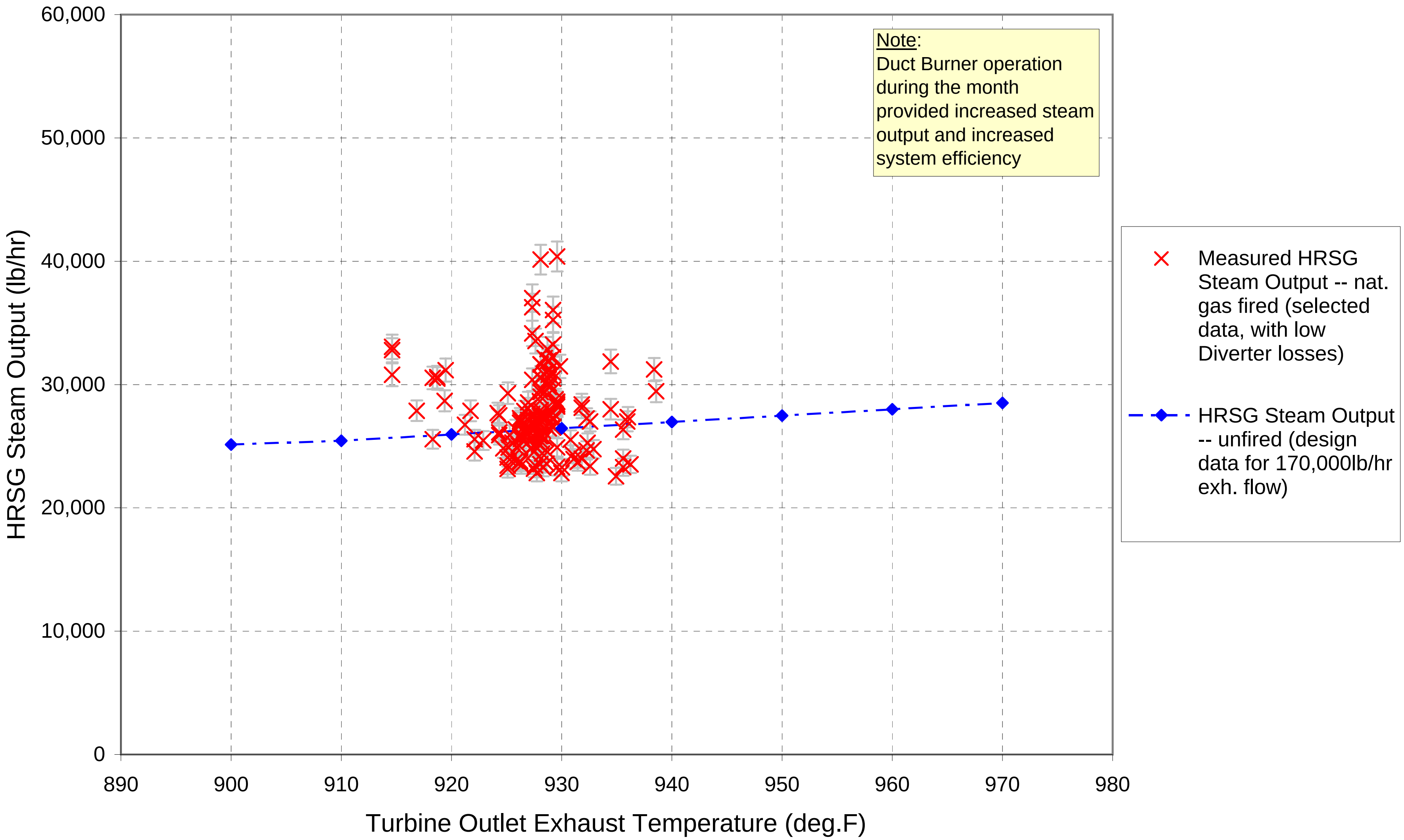

April 2005 Performance Data
Generated Power (MWh), and Turbine Runtime (hours)
HRSG Steam Generated (lbs.)
150
125
100
75
50
25
0
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Date
Generated Power (MWh)
Turbine Runtime (hours)
HRSG Steam Generated (lbs.)

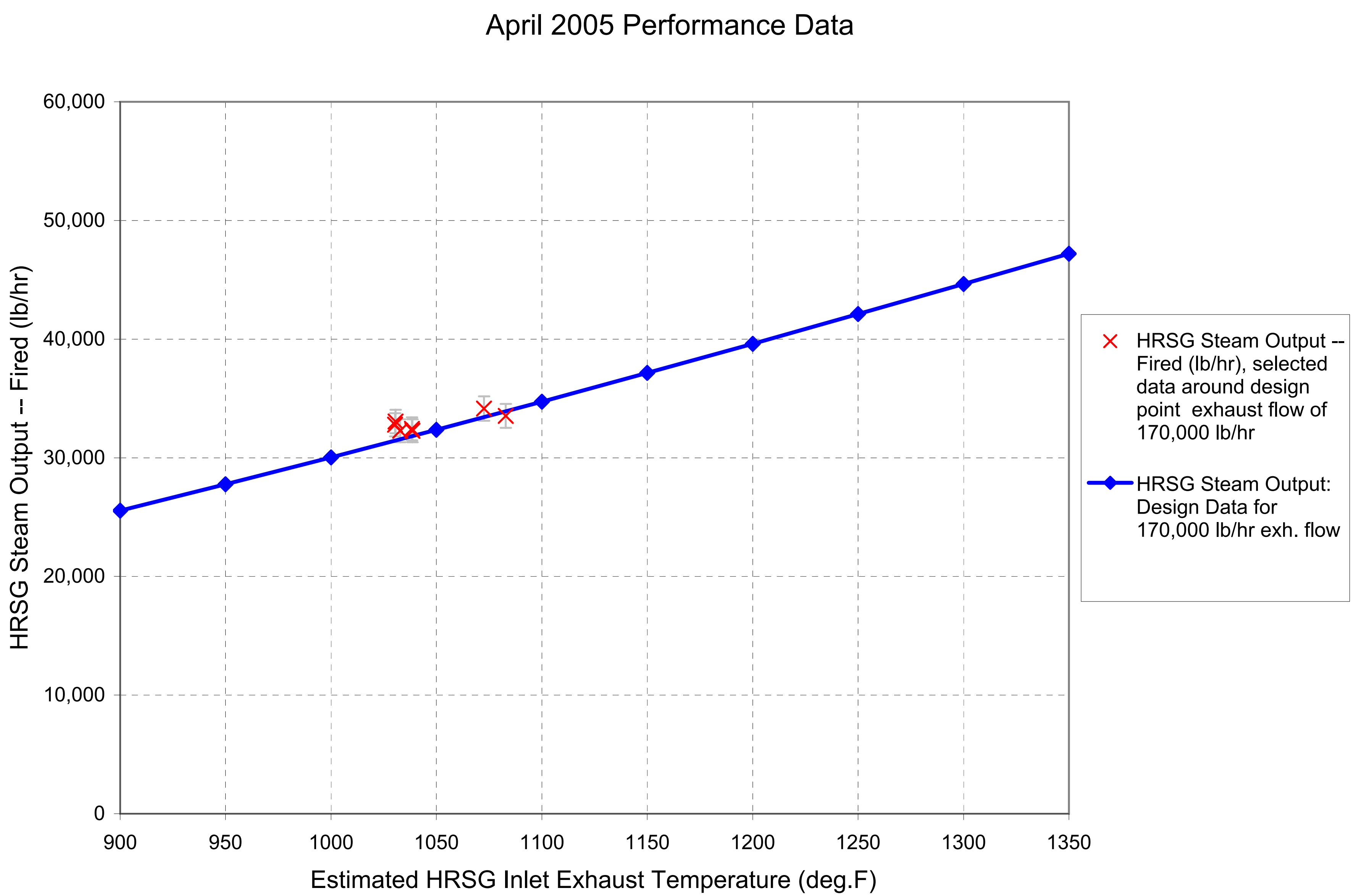

April 2005 Performance Data
Note:
Duct Burner operation during the month provided increased system efficiency
System Energy Efficiency (%)
Outdoor Ambient Temperature (deg.F)
0
10
20
30
40
50
60
70
80
90
100
Net System Energy Efficiency (%)
Design Data (Nat. Gas): heating-only operation, no Duct Burner operation
System Design Point

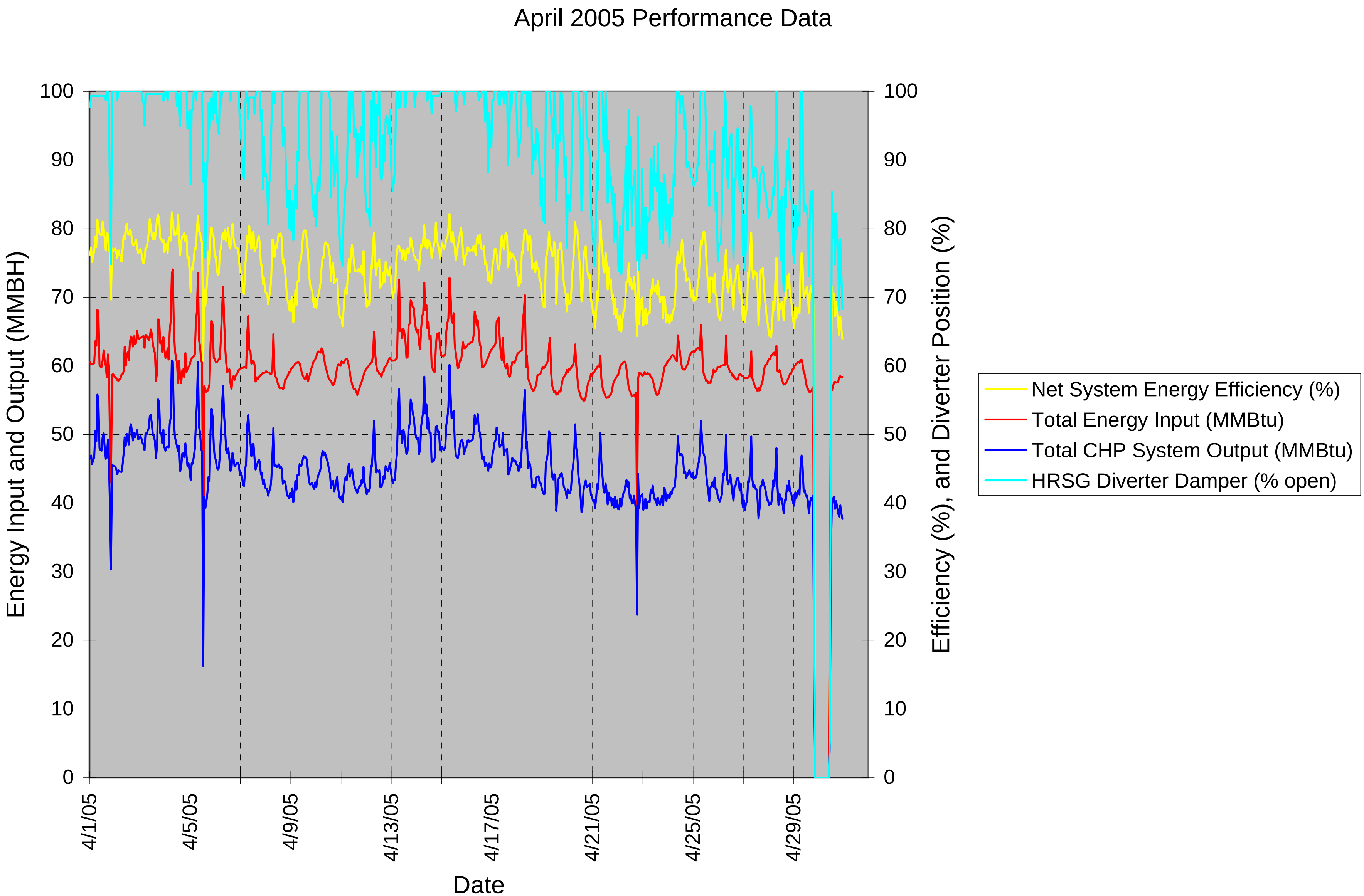

April 2005 Performance Data
System Energy Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
80
85
90
95
100
HRSG Diverter Damper (% open)
System Efficiency vs. Diverter Position
System Design Point
Trendline: System Efficiency


April 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/kWhr)
System Design Point (no Duct Burner oper.)
Turbine Electric Output, prior to cleaning (kW)
Design Power Output (kW)
System Design Point

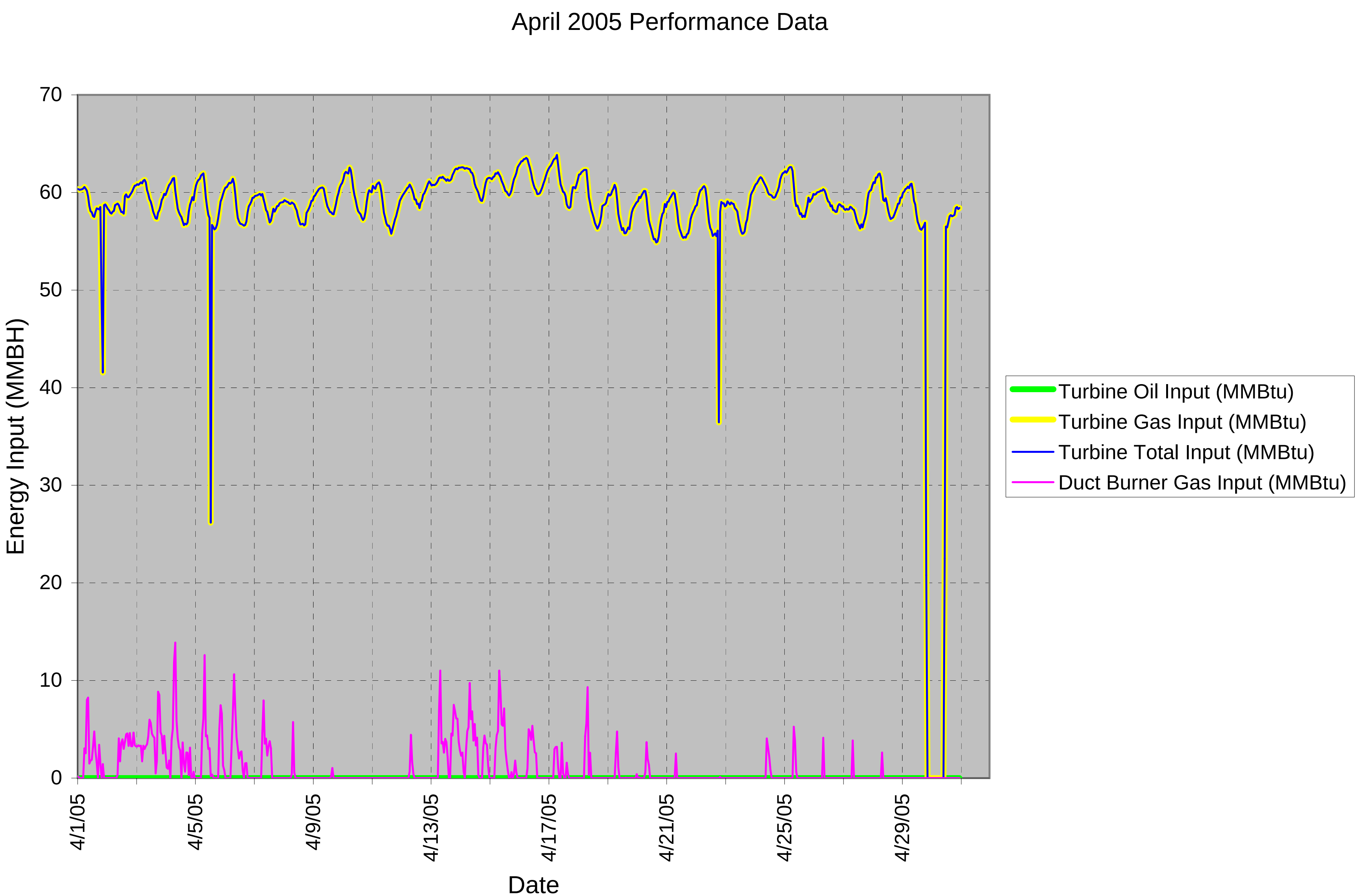
April 2005 Performance Data




April 2005 Performance Data
60,000
50,000
40,000
30,000
20,000
10,000
0
HRSG Steam Output -- Fired (lb/hr)
900
950
1000
1050
1100
1150
1200
1250
1300
1350
Estimated HRSG Inlet Exhaust Temperature (deg.F)
HRSG Steam Output -- Fired (lb/hr), selected data around design point exhaust flow of 170,000 lb/hr
HRSG Steam Output: Design Data for 170,000 lb/hr exh. flow

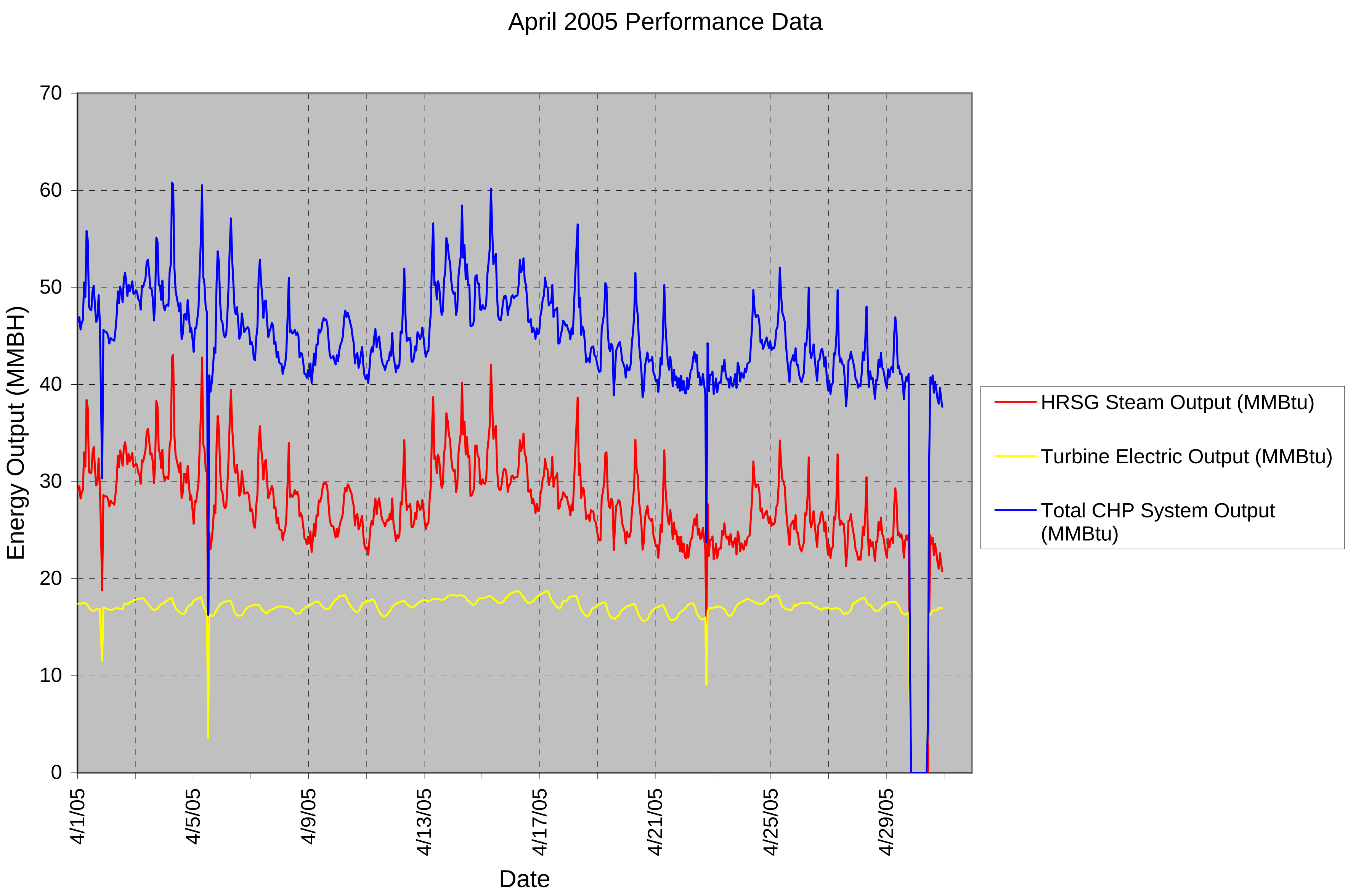

April 2005 Performance Data
Energy Input and Output (MMBH)
Efficiency (%), and Diverter Position (%)
Date
0
10
20
30
40
50
60
70
80
90
100
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Net System Energy Efficiency (%)
Total Energy Input (MMBtu)
Total CHP System Output (MMBtu)
HRSG Diverter Damper (% open)

Input



April 2005 Performance Data
Energy Input (MMBH)
70
60
50
40
30
20
10
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Date
Turbine Oil Input (MMBtu)
Turbine Gas Input (MMBtu)
Turbine Total Input (MMBtu)
Duct Burner Gas Input (MMBtu)

Output


April 2005 Performance Data
Energy Output (MMBH)
0
10
20
30
40
50
60
70
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Date
HRSG Steam Output (MMBtu)
Turbine Electric Output (MMBtu)
Total CHP System Output (MMBtu)

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 the 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	Honeywell Sensor	Solar Sensor
AN_Engine_Fired_Hours	Cumulative Operating Hours for Turbine	hours	- - -		x
AN_Total_Kw	Turbine Generator kW Output	kW	up to 5000		x
Boiler_5_Status	Aux. Boiler#5 On/Off Status	binary	- - -	x	
HPNG_Flow_A	Natural Gas Flowrate to Turbine	lb per hr.	up to 3000	x	
HRSG_Div_Dmpr	HRSG Diverter Damper Position	% open	- - -	x	
HRSG_Steam_Flow_A	Steam Flowrate from HRSG	lb per hr.	up to 28,000 (unfired) up to 80,000 (fired)	x	
AN_T1_Temperature	Outdoor Ambient Temperature	deg. F	- - -		x
TurbFOflow_A	Turbine Fuel Oil Consumption Rate	lb per min.	up to 50	x	
AN_Exhaust_Gas_Flow	Turbine Exhaust Flow Rate	lb per hr.	up to 190,000		x
HRSG_InltDct_Tmp_A	HRSG Exhaust Inlet Temperature	deg. F	up to 990F	x	
Deaerator_Temp	Deaerator Temperature	deg. F	up to 190F	x	
Boiler_Outlet_PSI	Steam Header Pressure	psig	120 to 130	x	

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

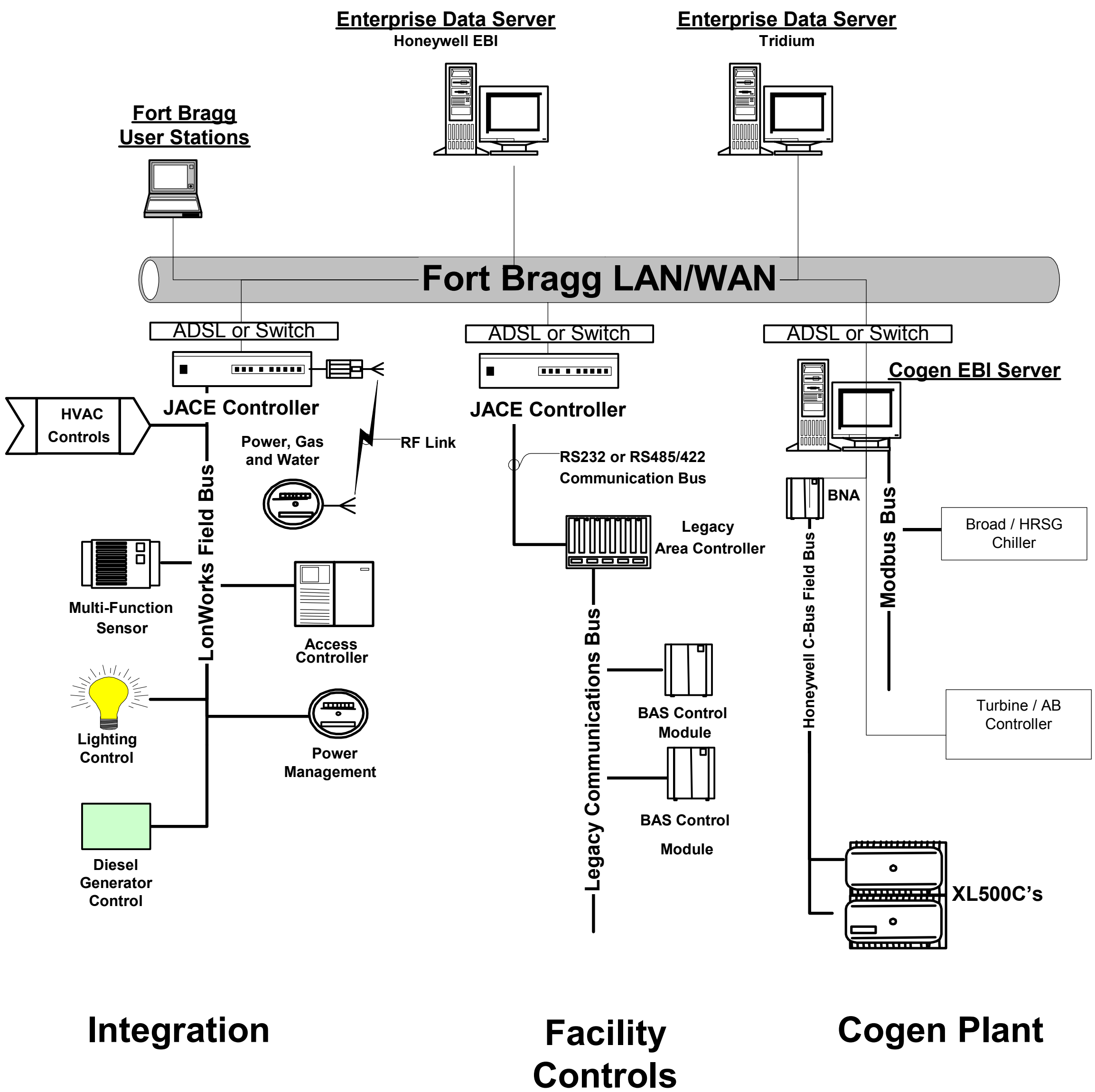
Selected LTM sites will be assessed in project case studies. Case studies are unique because their goal is to assess financial measures (e.g. energy cost, equipment cost) and certain qualitative aspects (e.g. major reasons to install DG/CHP, lessons learned from the installation) of DG/CHP performance.

Webmaster | Home

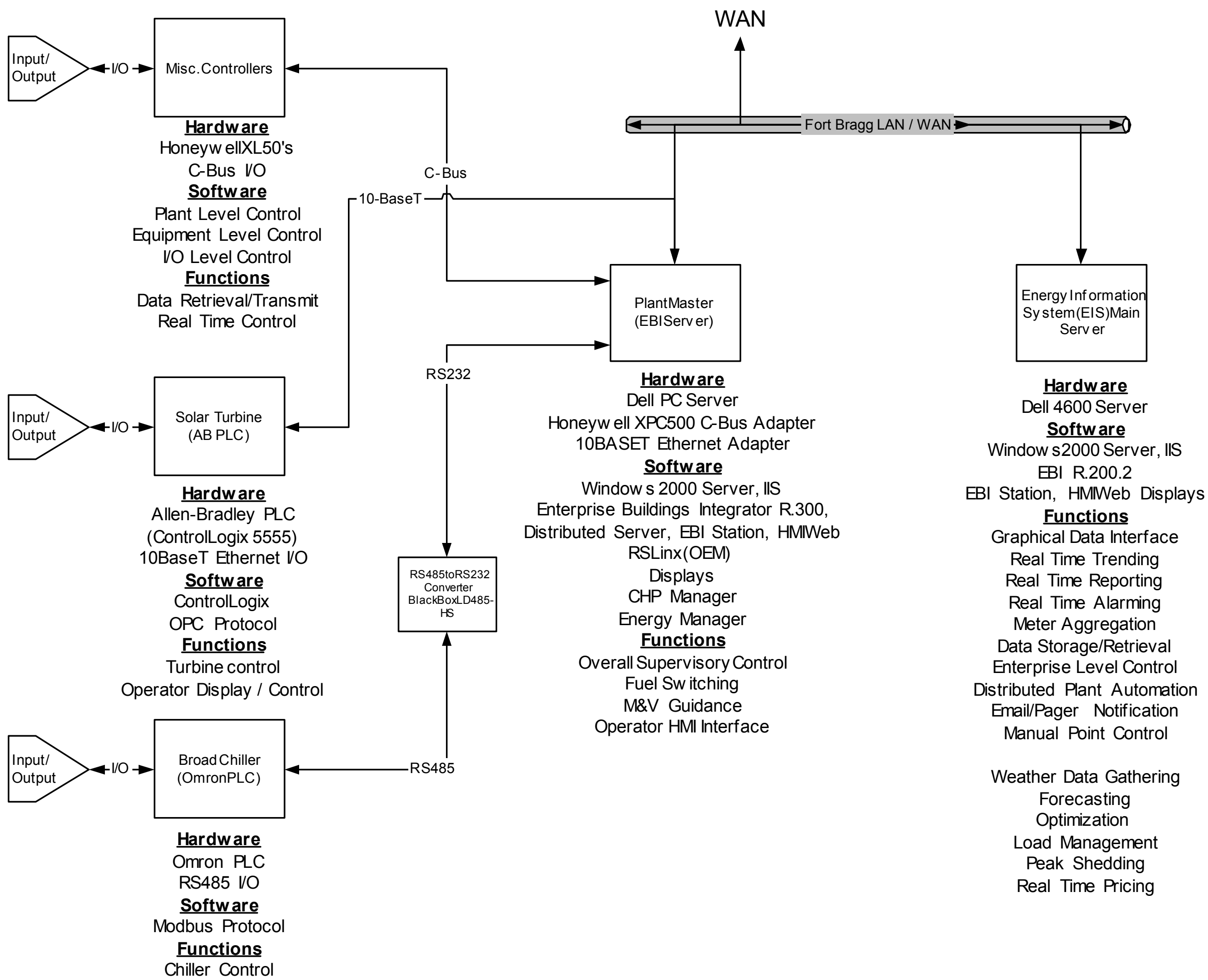
Content Last Updated: 03/01/2005

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

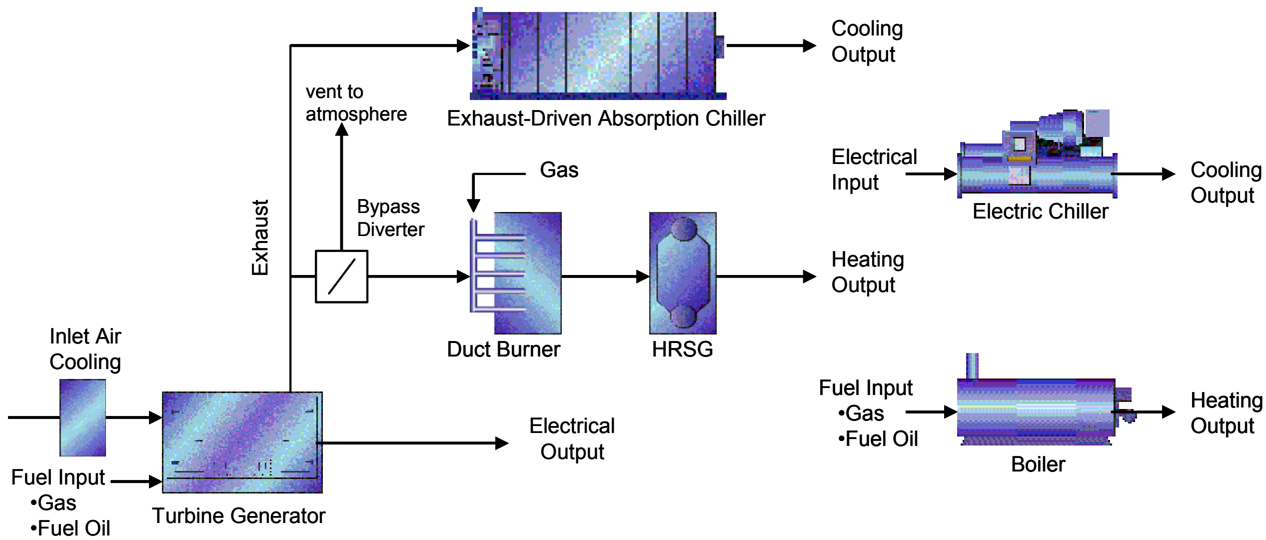
Measured Data	Estimated Error	Source
HPNG_Flow	3.0%	field instrumentation
TurbFO_Flow	3.0%	field instrumentation
HRSGSteam_Flow	3.0%	field instrumentation
TurbineGenerator_kW	2.0%	internal turbine generator instrumentation, (uncertainty also accounts for outdoor ambient temperature effects, as applied to turbine output plots)

Calculated Data	Estimated Error	Source
GasFuel_Input	3.77%	(HPNG_Flow)*(HPNG_Correction)*(Gas_Density)*(Gas_LHV)
OilFuel_Input	3.50%	(TurbFO_Flow)*(Oil_LHV)/(Oil_Density)
HRSGSteam_Output	3.61%	(HRSGSteam_Flow)*(Thermal_Content)

Calculated Results	Estimated Error	Source
MeasuredSystem_EnergyEfficiency	5.22%	(Energy_Output)/(GasFuel_Input), or (Energy_Output)/(OilFuel_Input)
Heat_Rate	4.27%	(GasFuel_Input)/(TurbineGenerator_kW), or (OilFuel_Input)/(TurbineGenerator_kW)

4.6 System Description

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



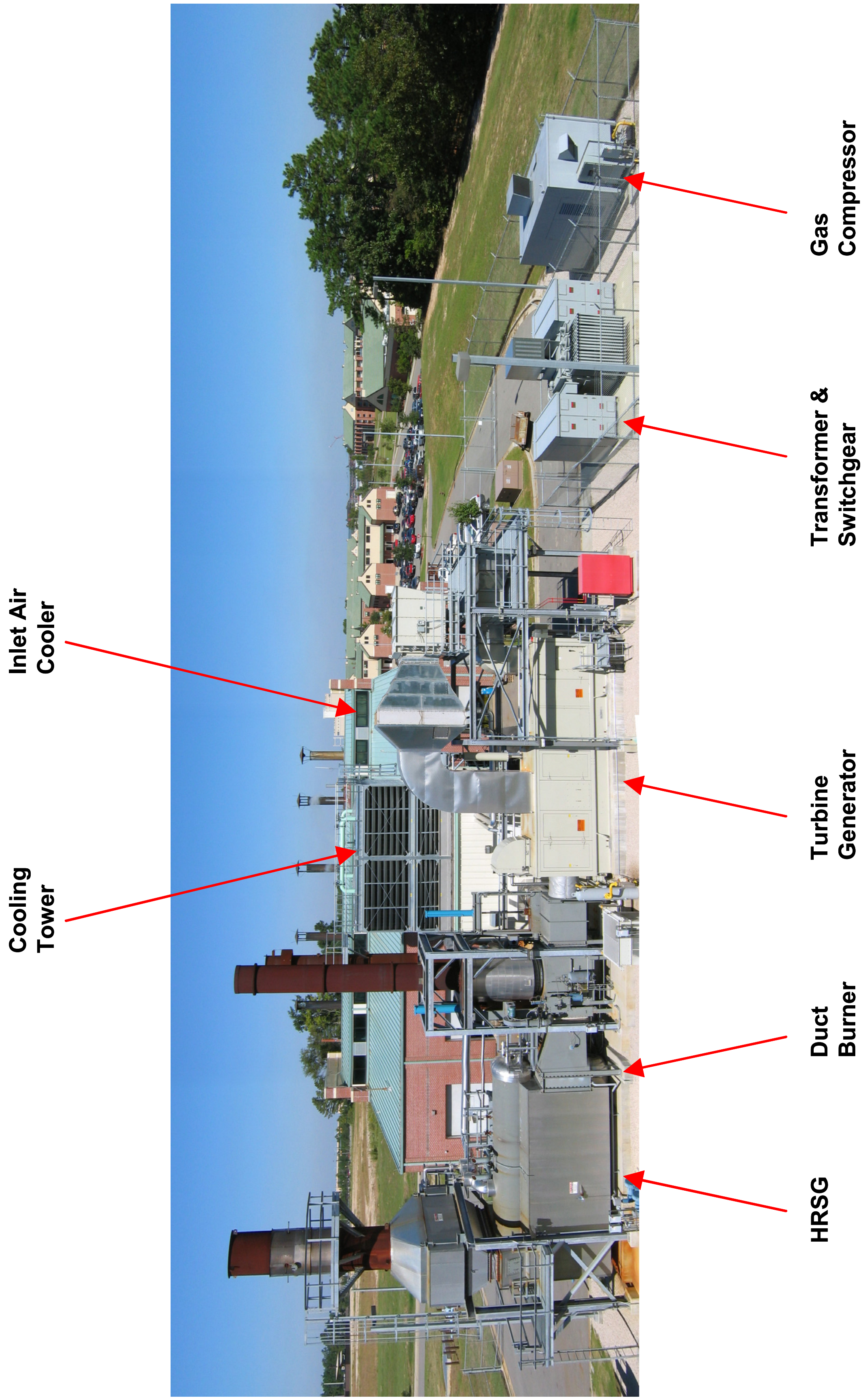
The major IES equipment in the system is described in the following table.

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

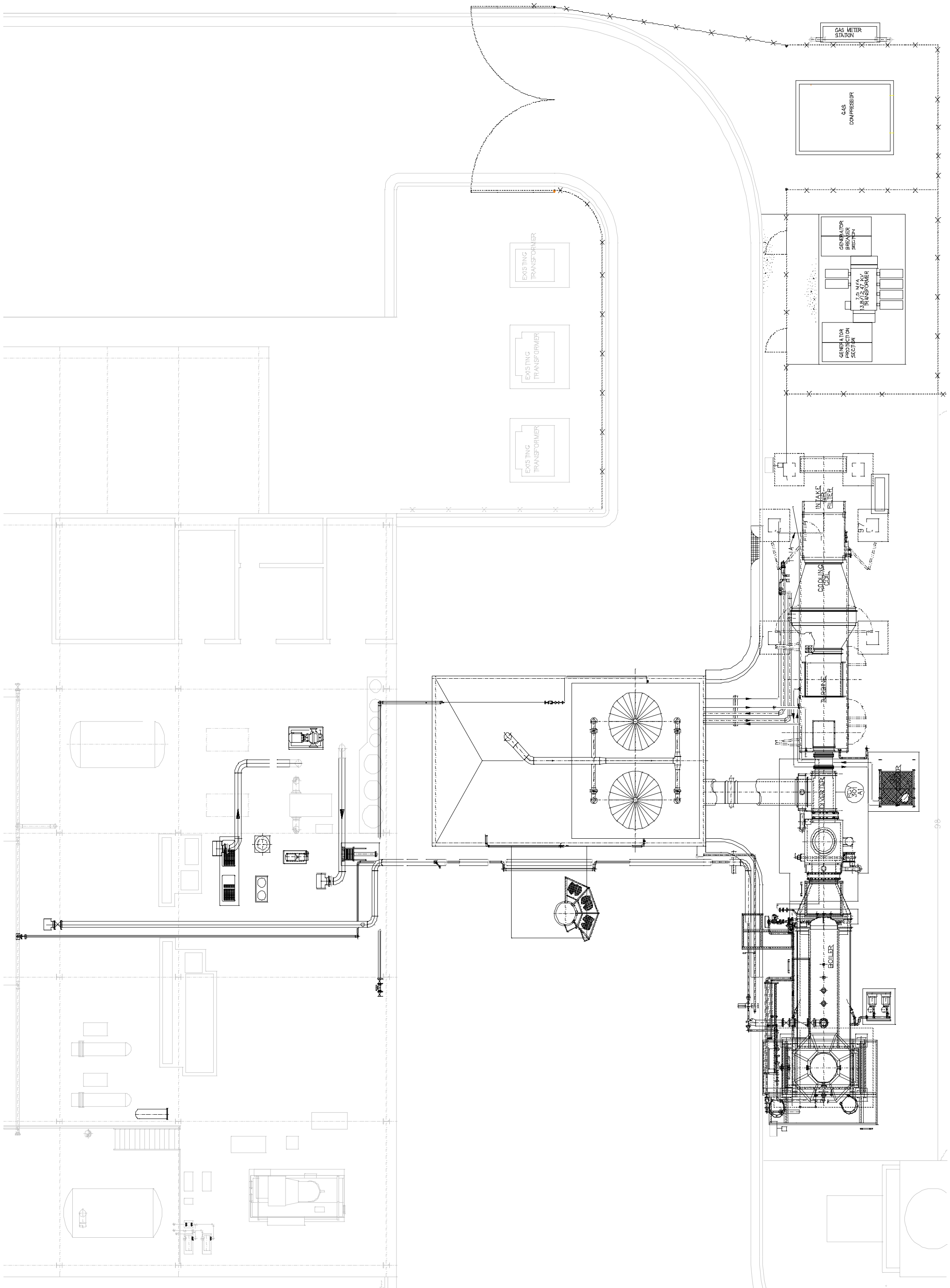
The major auxiliary equipment in the system is described in the following table.

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

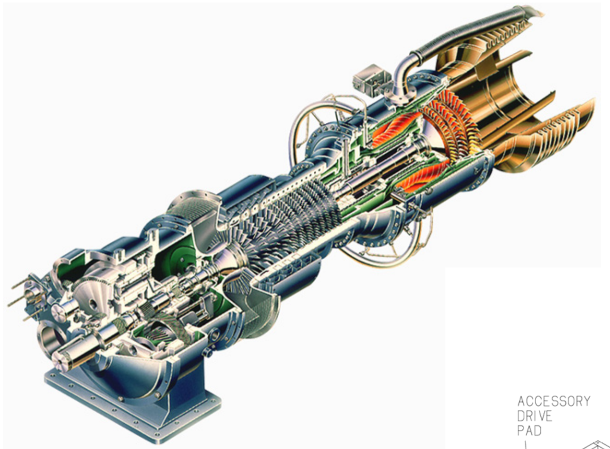
The equipment installation is shown in the photo below.

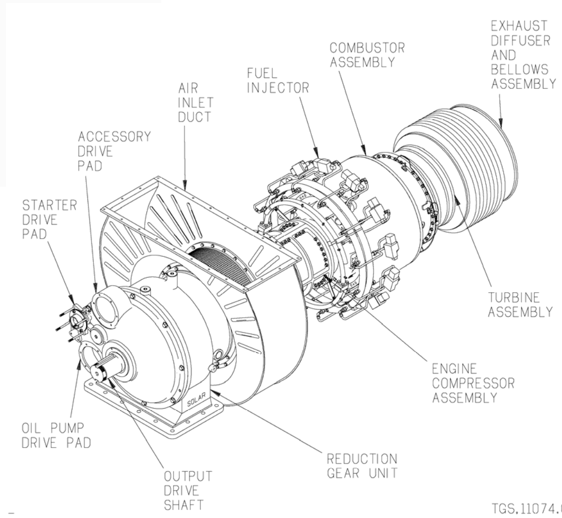


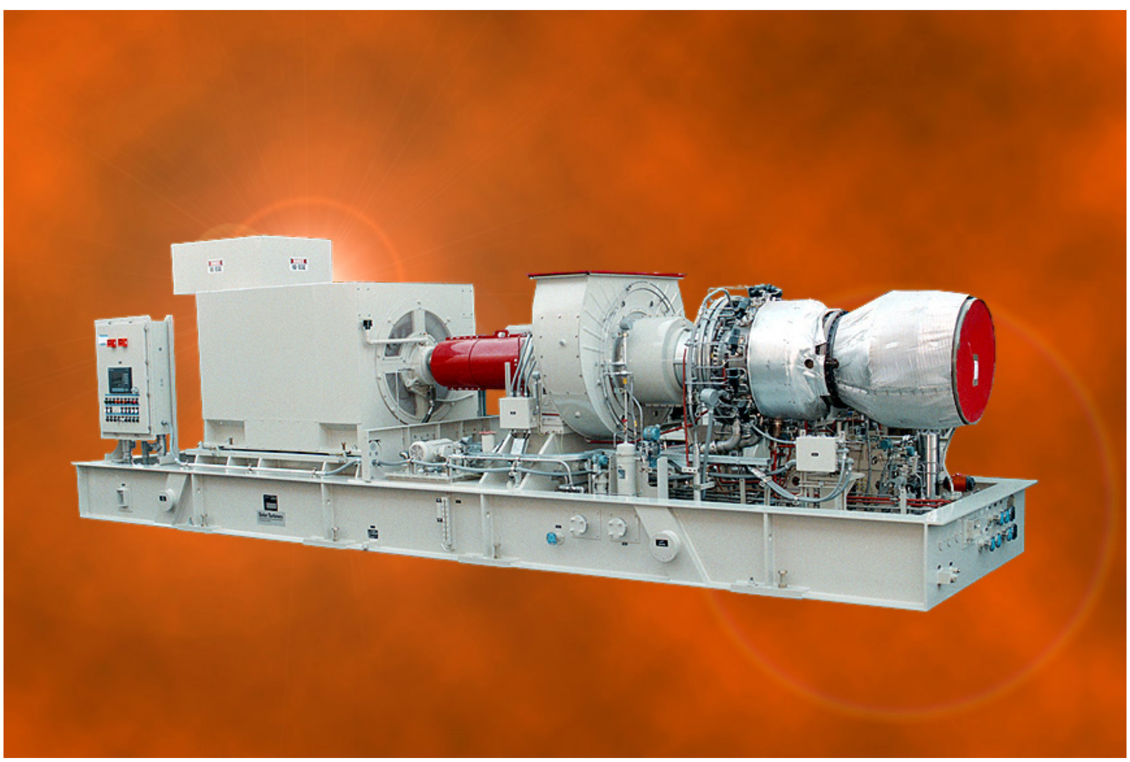
The physical arrangement of the equipment is shown in the figure below.



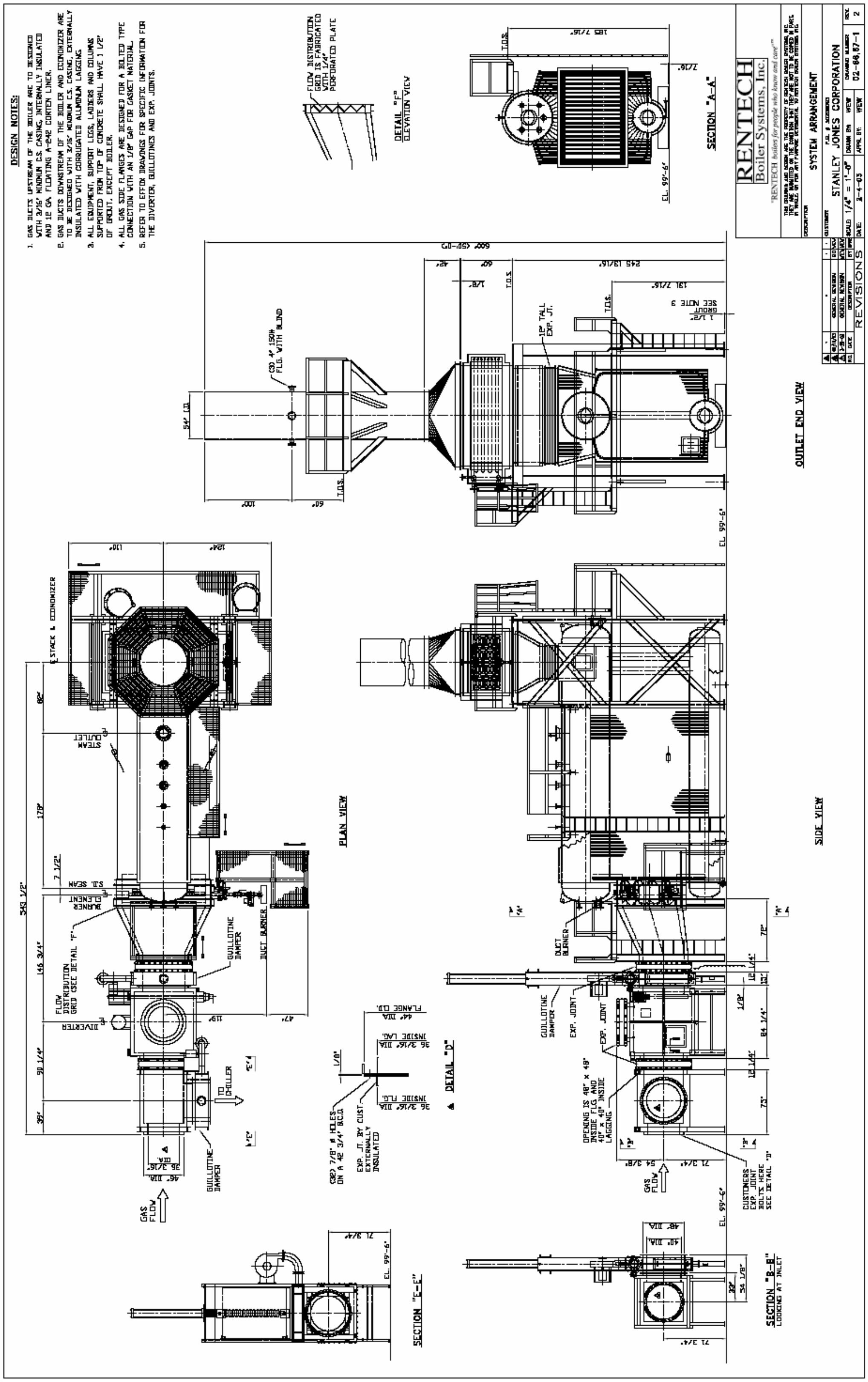
The details of the turbine generator are shown in the figures below.







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



The absorption chiller is shown in the figure below.

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.

4.7 Site Description

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

4.7.1 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 Services 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.

4.7.2 Relevance to Federal Energy Policy

This project adheres to the requirements 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 Services 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.

4.7.3 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.

4.7.4 Honeywell Energy Services at Ft. Bragg

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

4.7.5 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:

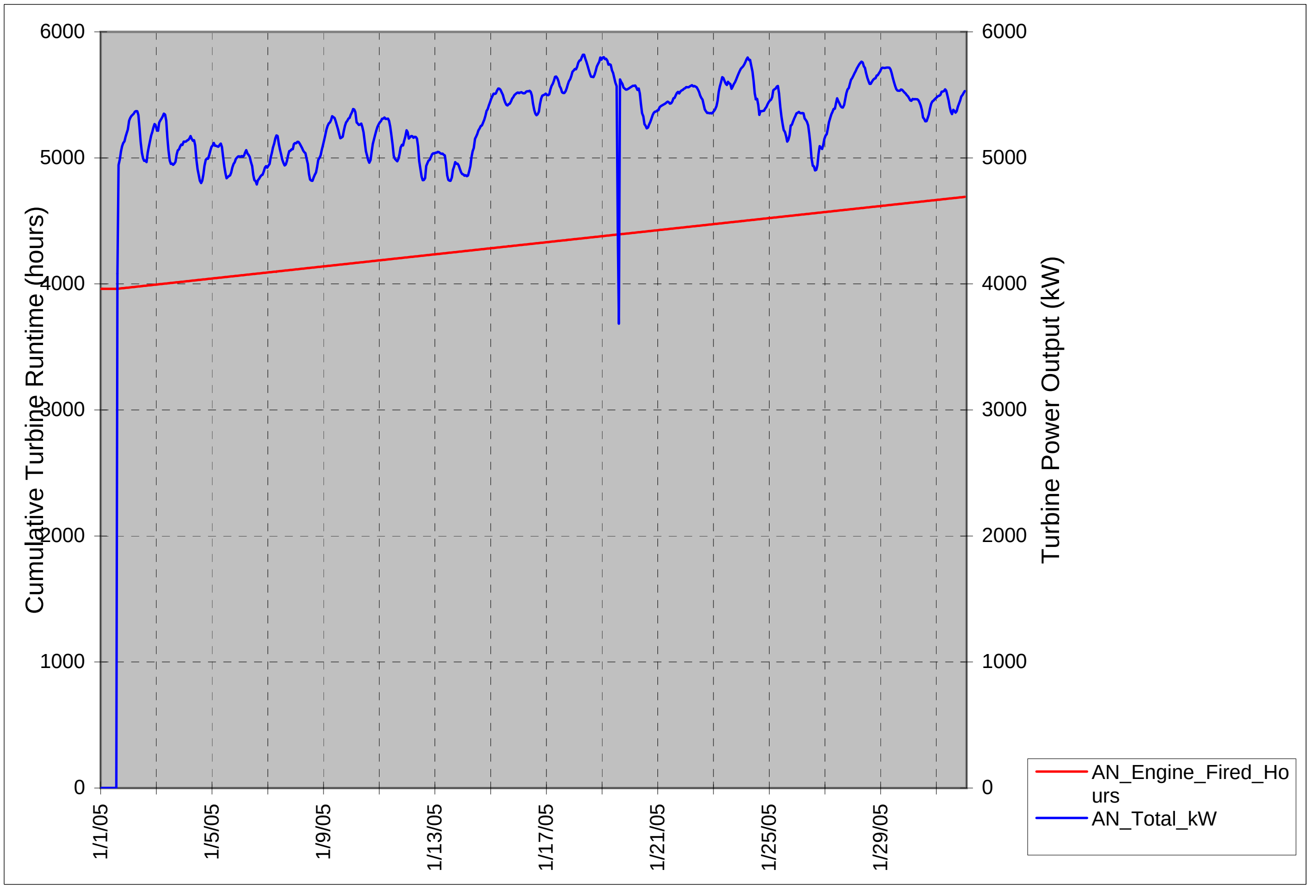
- An $11 million, five megawatt (MW) co-generation cooling, heating and power plant was installed to reduce Fort Bragg's energy costs by an additional $1.5 million annually and provide on-site generation to support the hospital or other critical loads. Honeywell and several technology partners won a 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

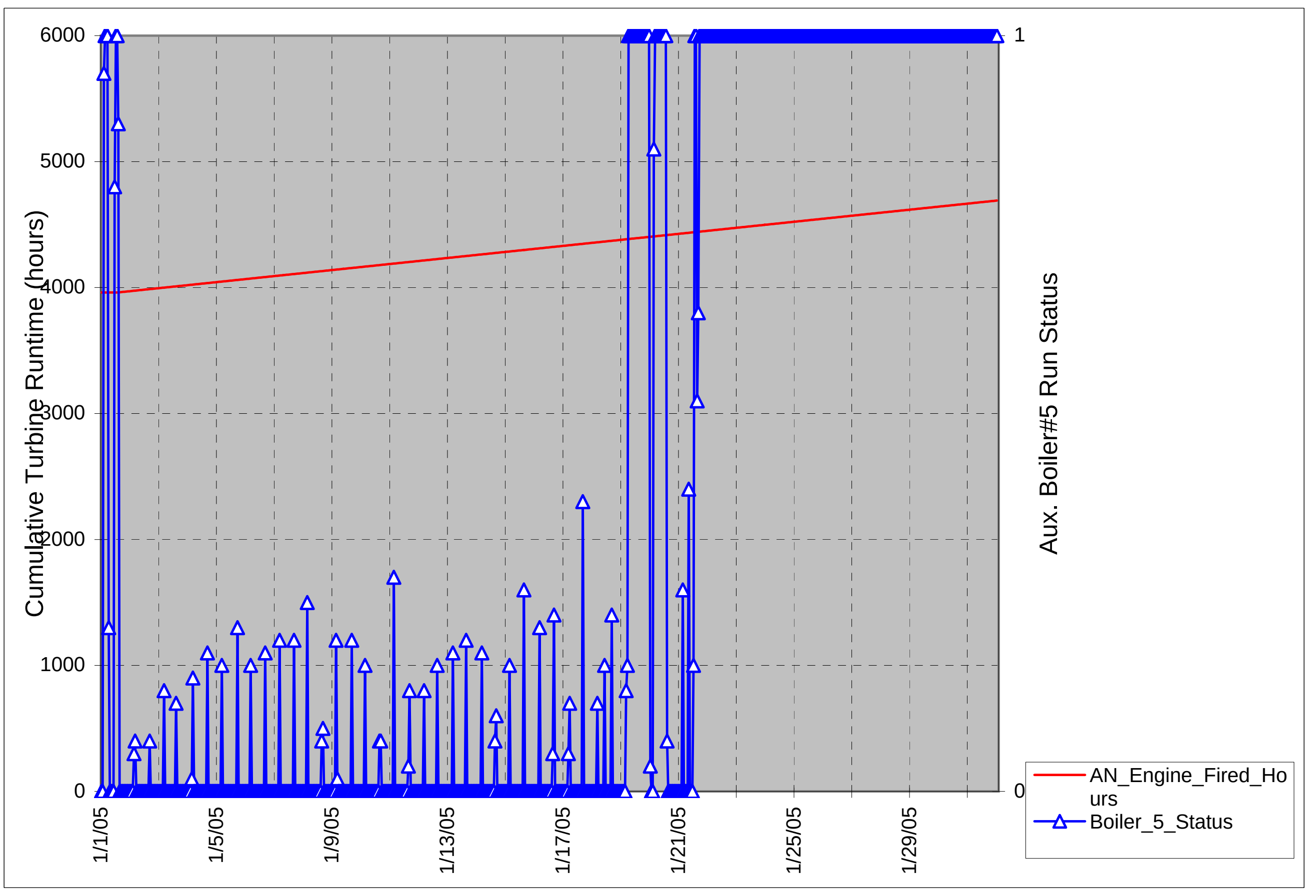
Appendix A

Detailed Operational Data: January 2005

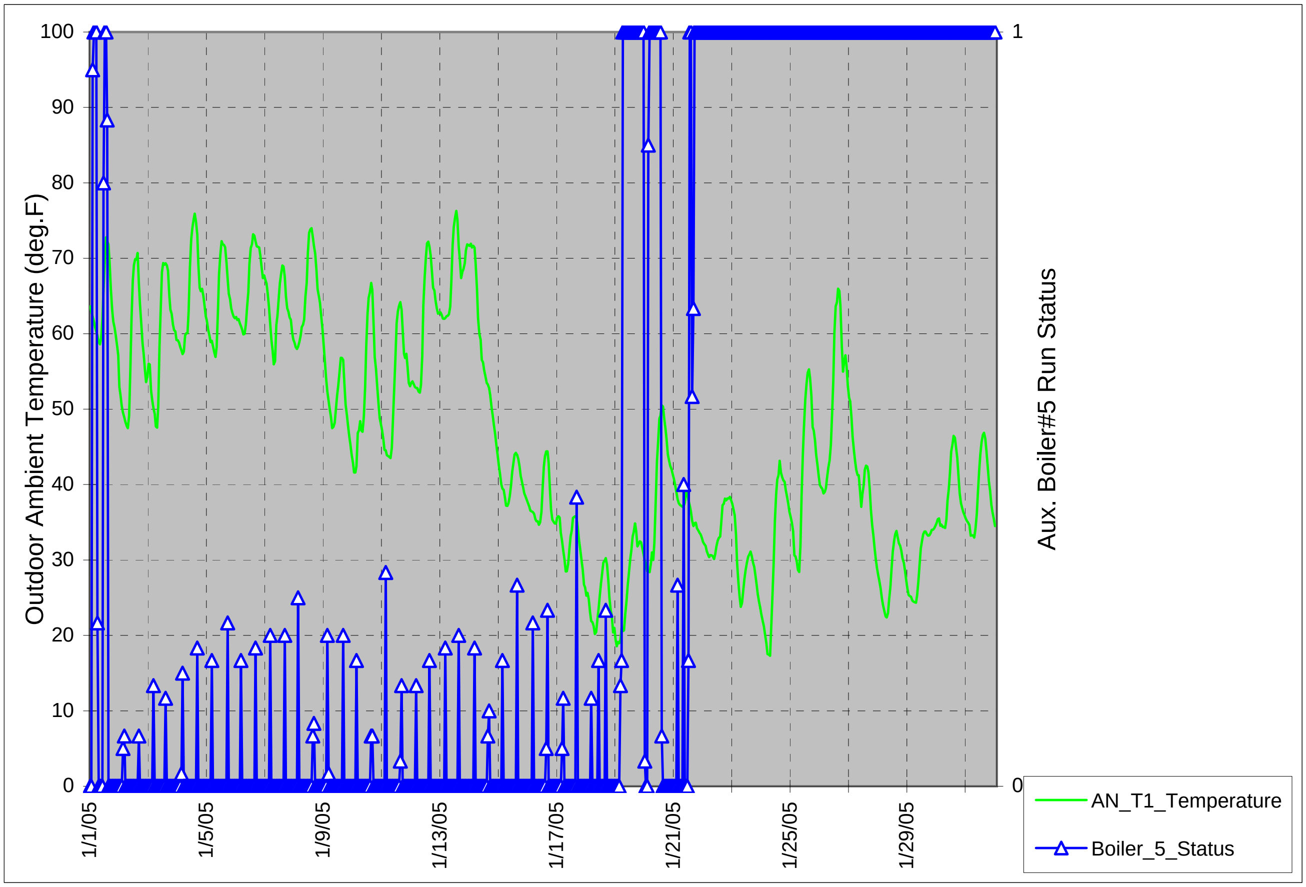
Misc. Plots



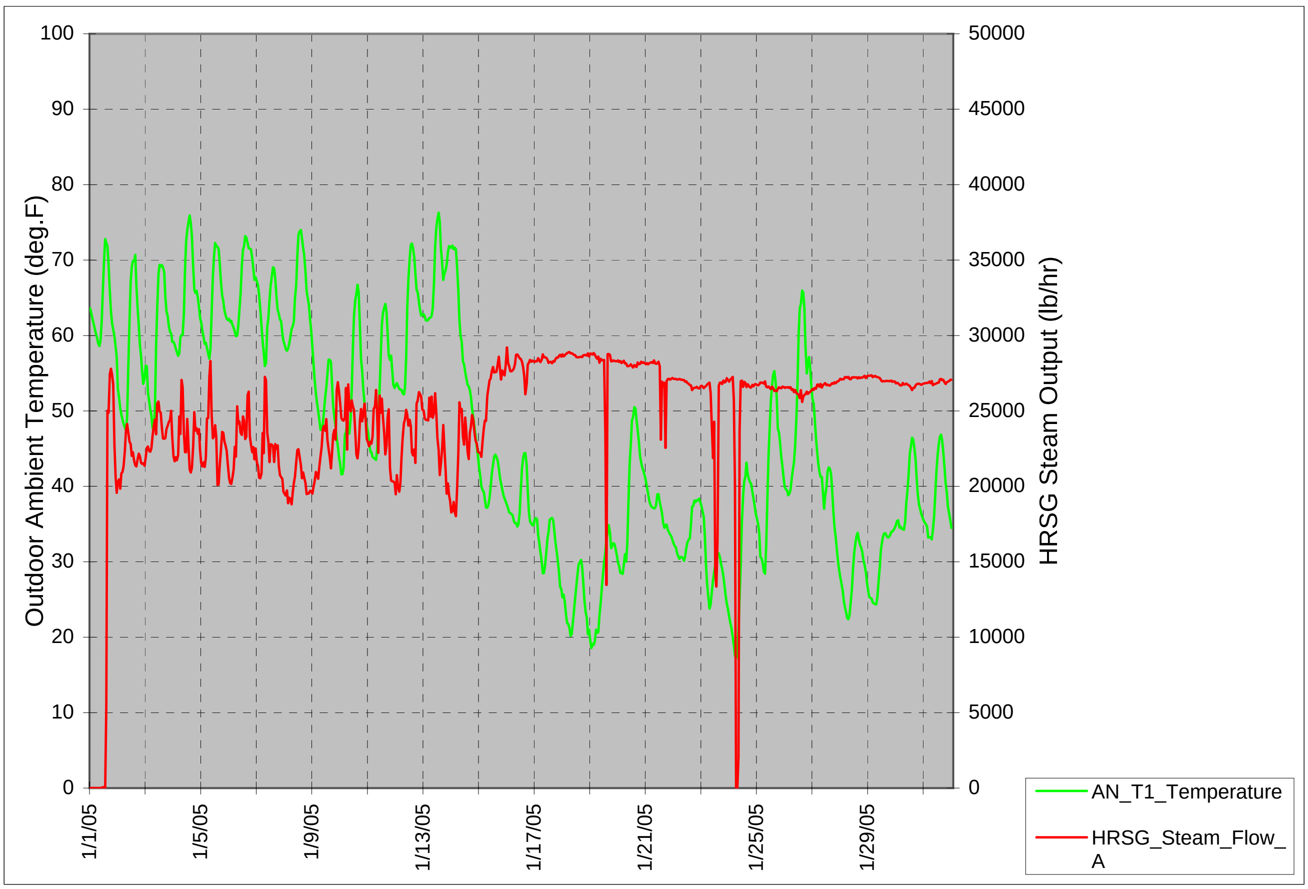
6000
5000
4000
3000
2000
1000
0
Cumulative Turbine Runtime (hours)
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
AN_Engine_Fired_Hours
AN_Total_kW



6000
5000
4000
3000
2000
1000
0
Cumulative Turbine Runtime (hours)
1
0
Aux. Boiler#5 Run Status
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
AN_Engine_Fired_Hours
Boiler_5_Status

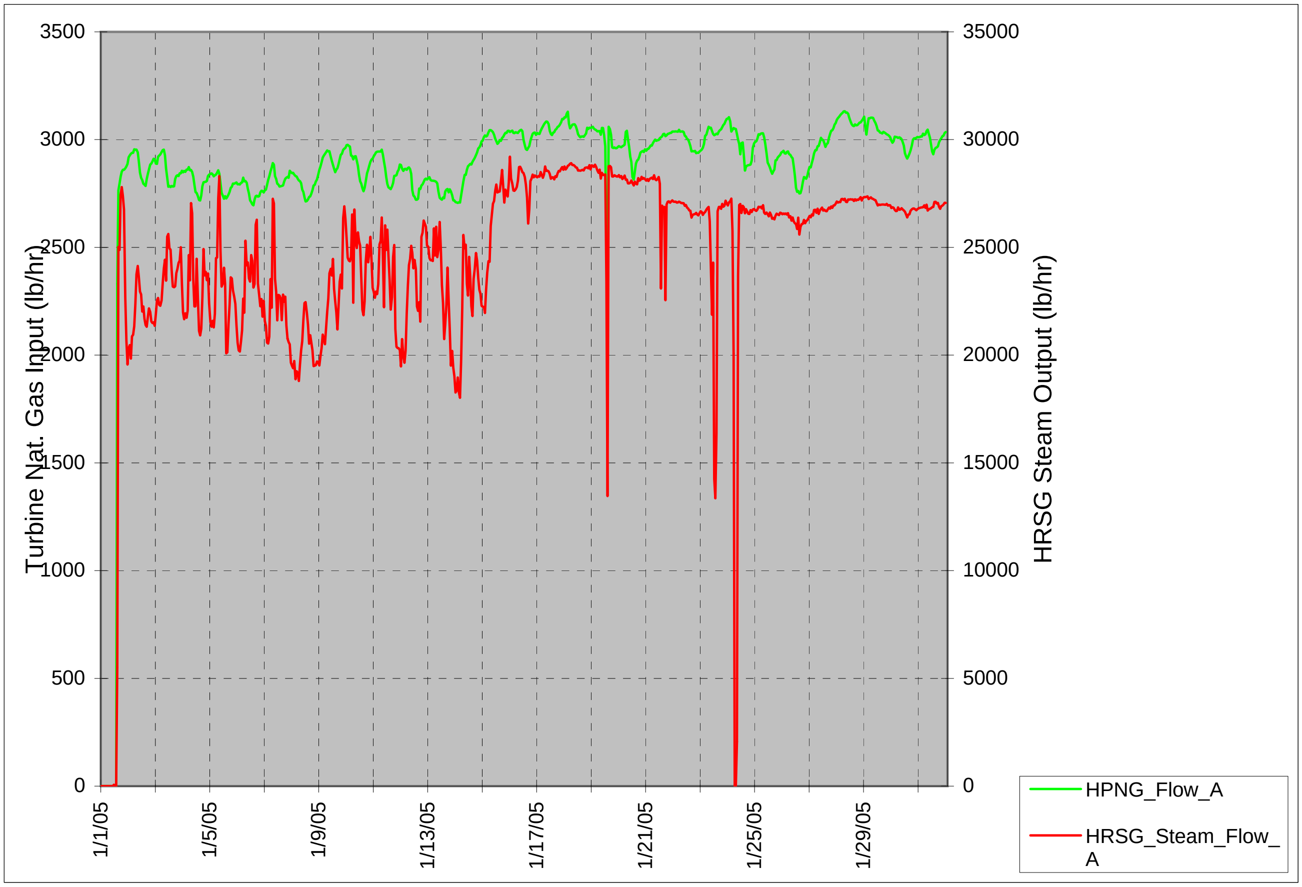


Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
100
90
80
70
60
50
40
30
20
10
0
1
0
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
AN_T1_Temperature
Boiler_5_Status

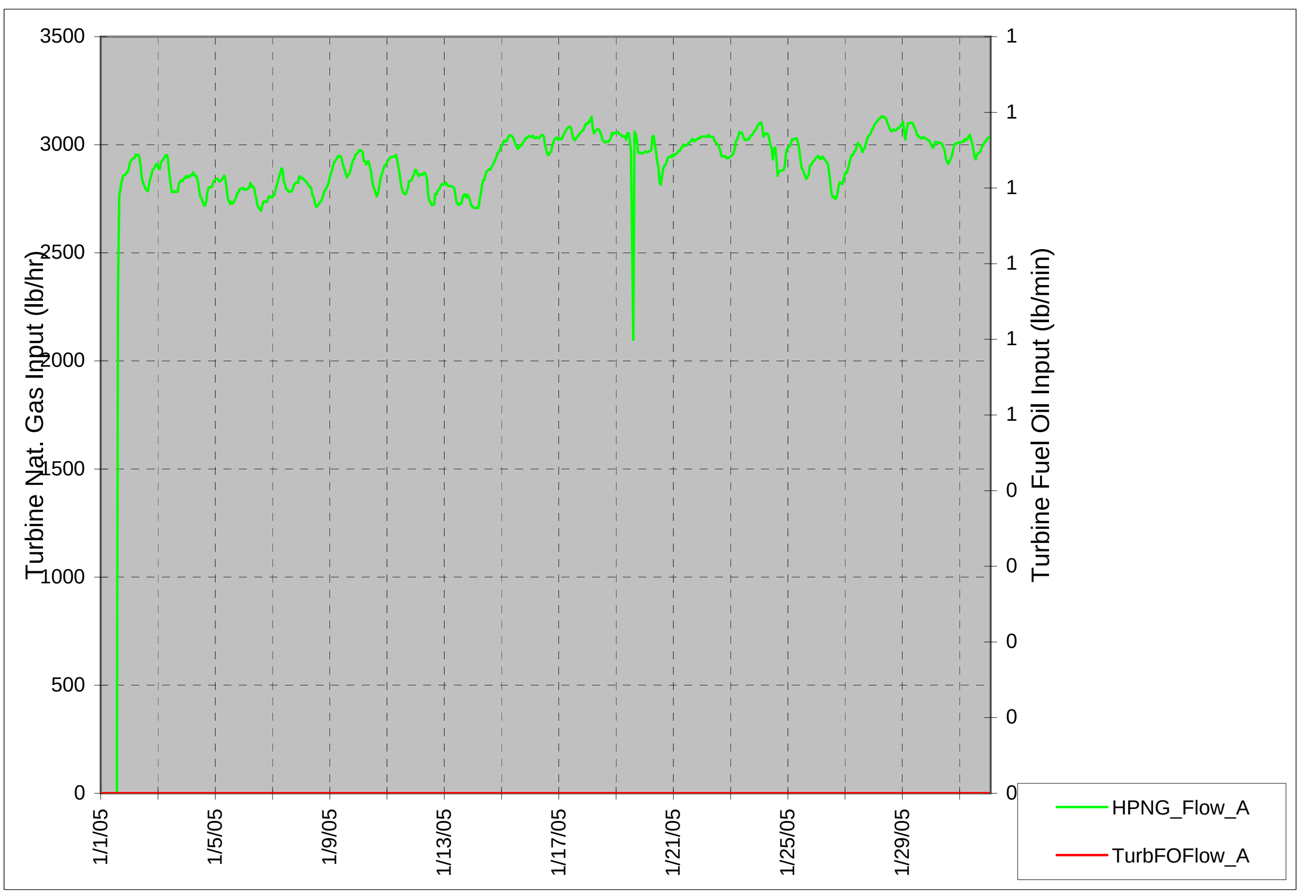


Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
100
90
80
70
60
50
40
30
20
10
0
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
AN_T1_Temperature
HRSG_Steam_Flow_A

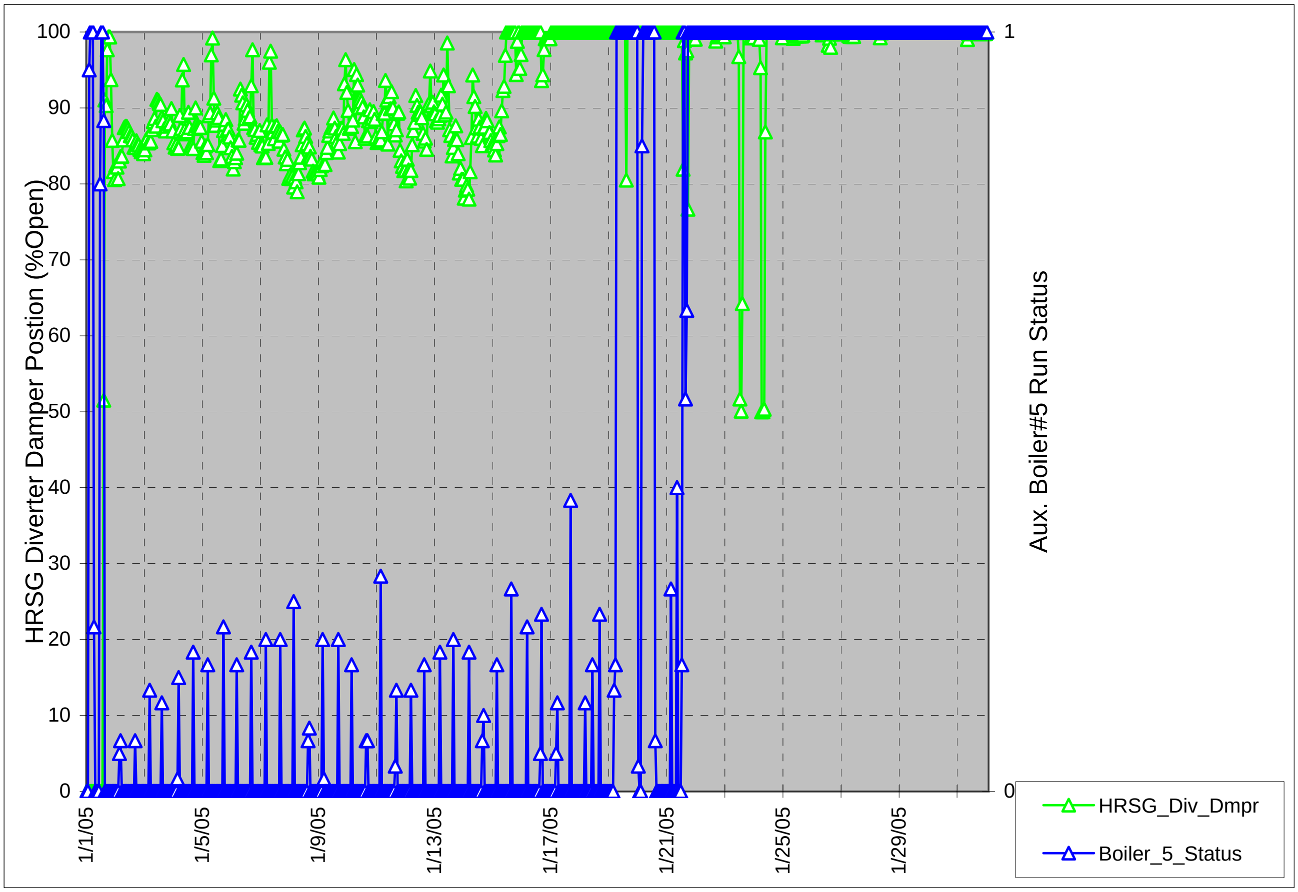
Misc. Plots

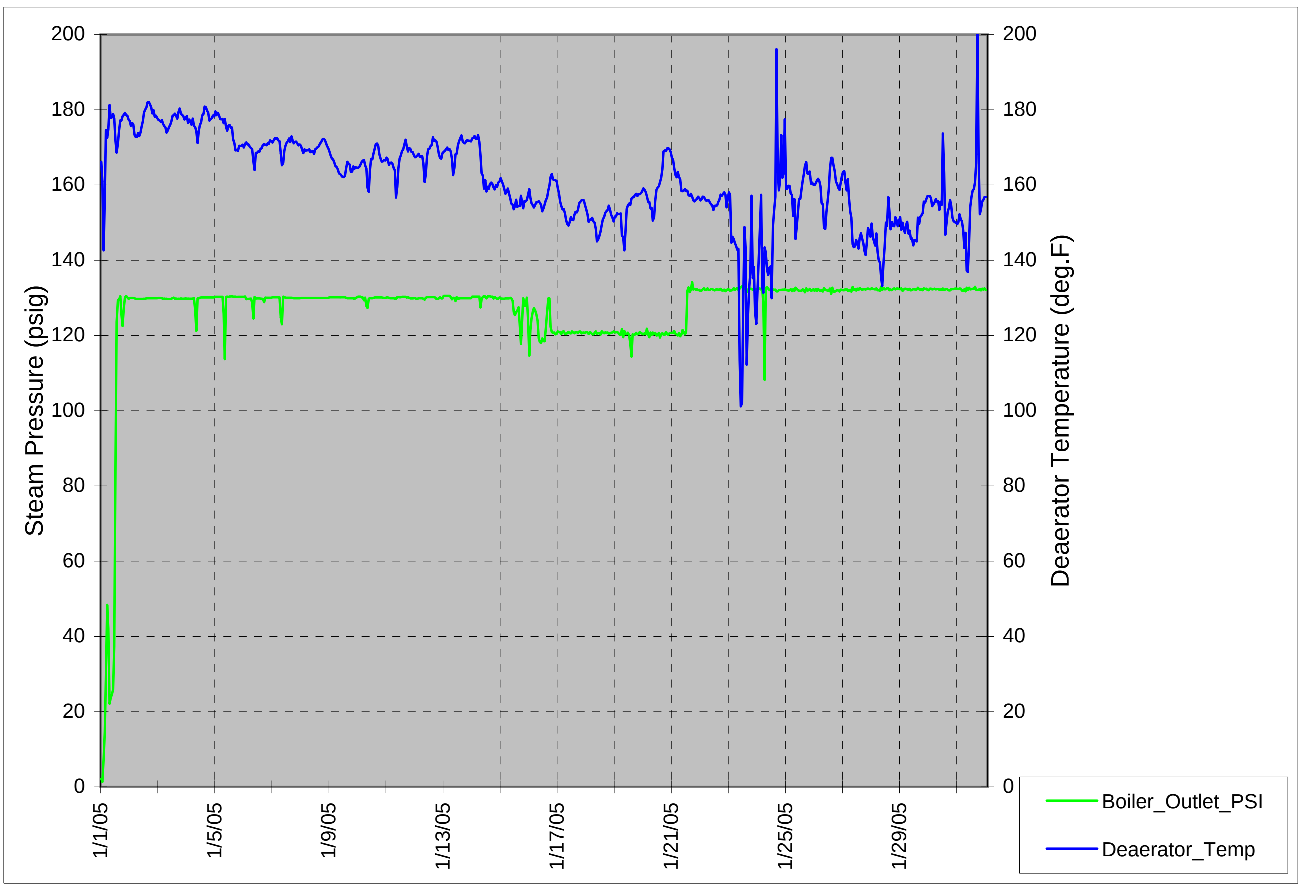


Turbine Nat. Gas Input (lb/hr)
HRSG Steam Output (lb/hr)
3500
3000
2500
2000
1500
1000
500
0
35000
30000
25000
20000
15000
10000
5000
0
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A

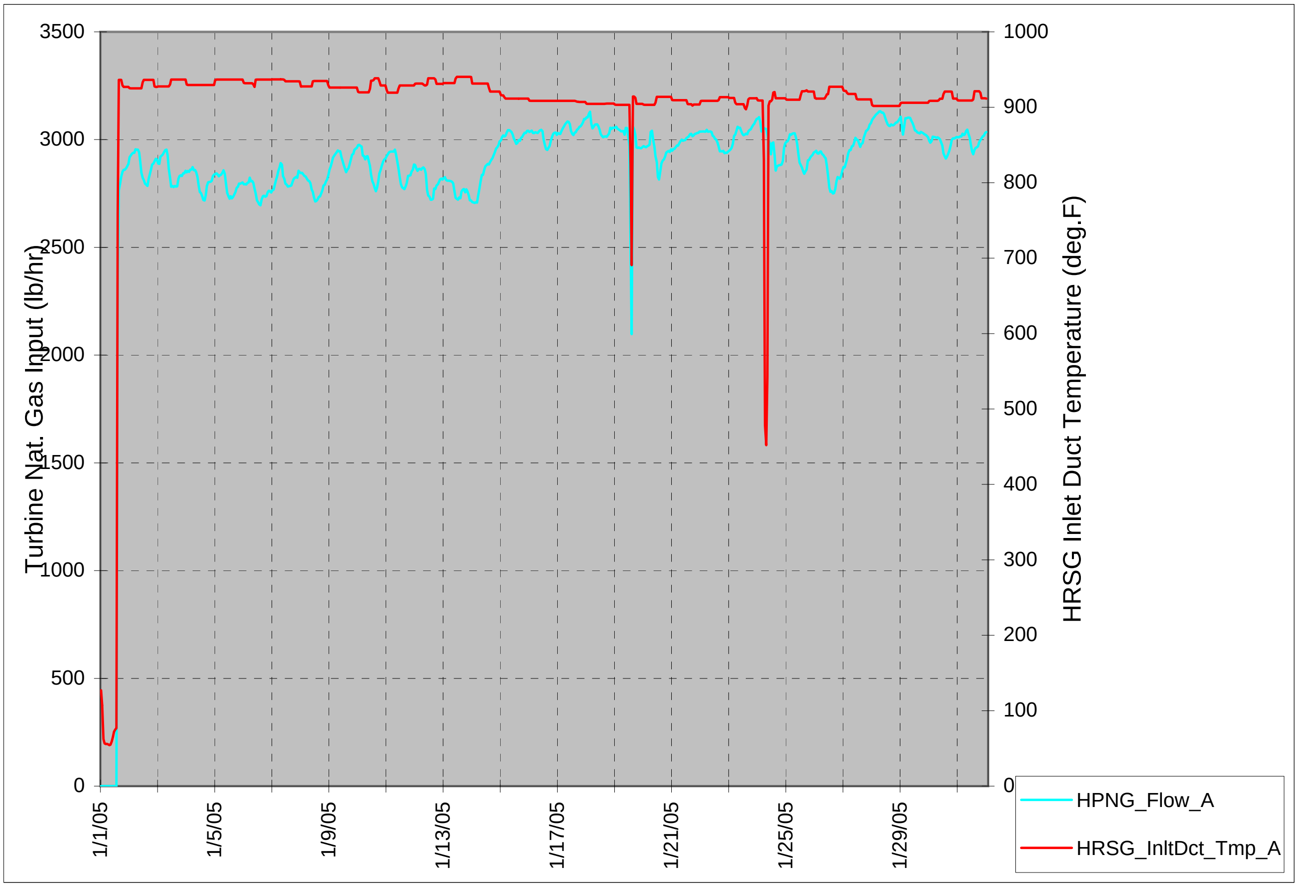


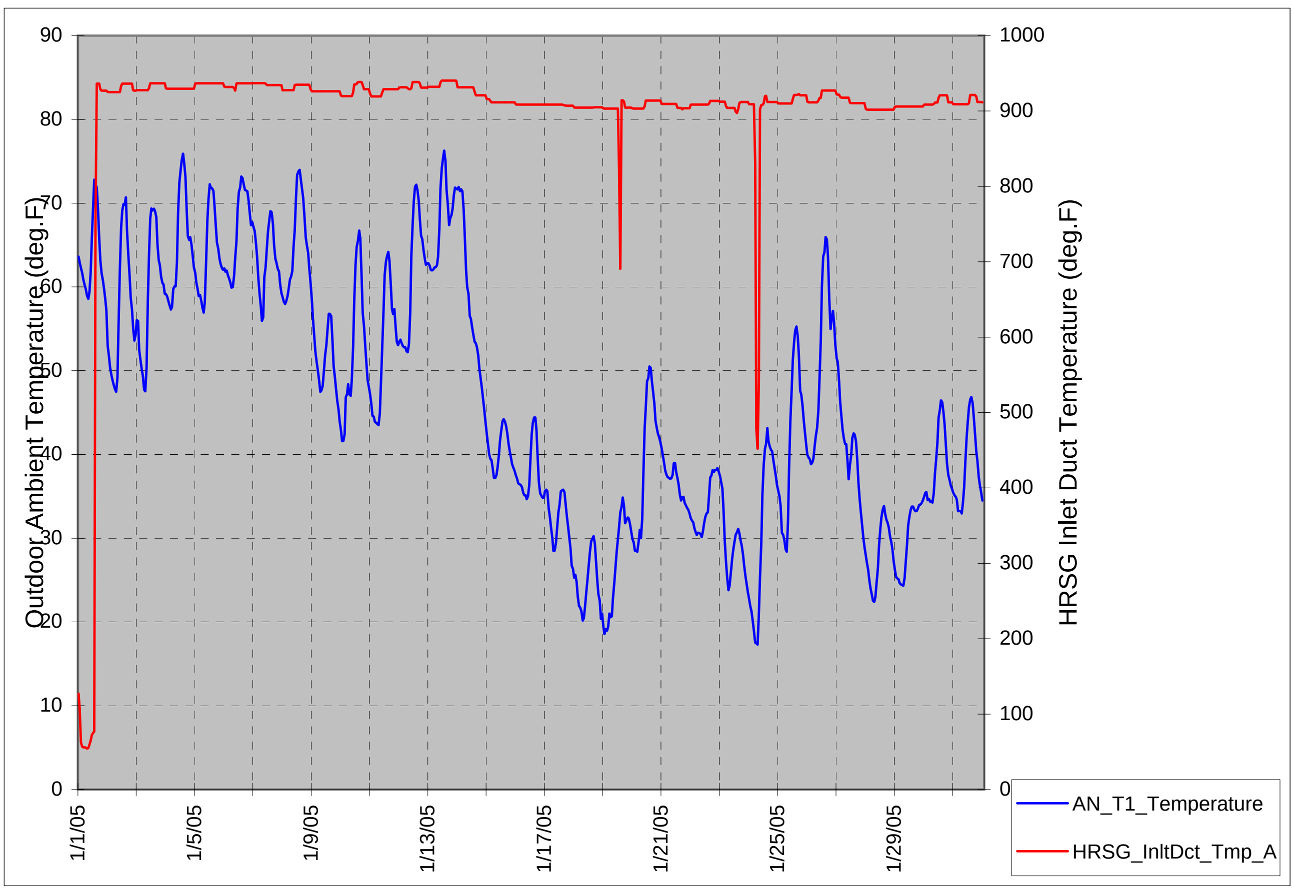
Turbine Nat. Gas Input (lb/hr)
Turbine Fuel Oil Input (lb/min)
3500
3000
2500
2000
1500
1000
500
0
1
1
1
1
1
1
0
0
0
0
0
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
HPNG_Flow_A
TurbFOFlow_A

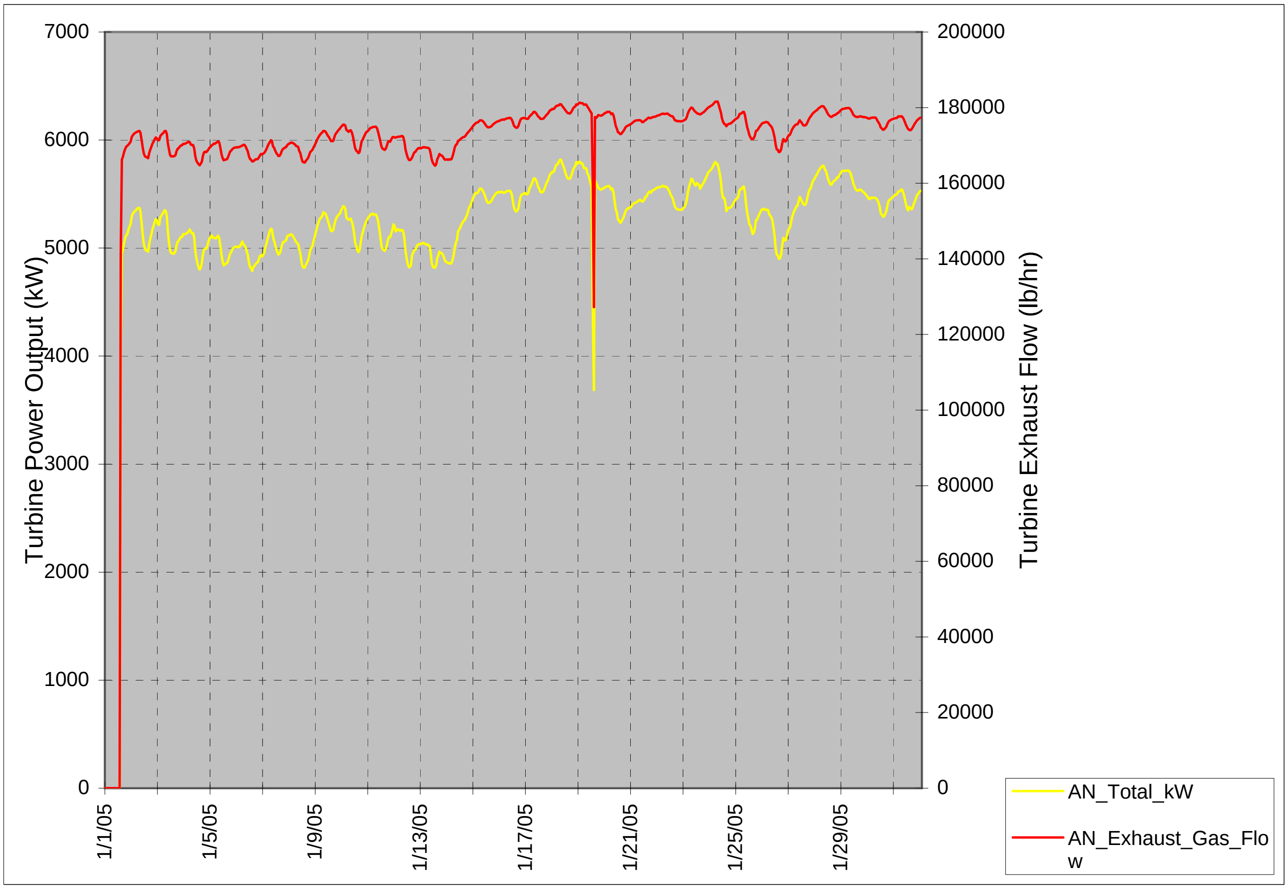

100
90
80
70
60
50
40
30
20
10
0
HRSG Diverter Damper Postion (%Open)
1
0
Aux. Boiler#5 Run Status
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
HRSG_Div_Dmpr
Boiler_5_Status

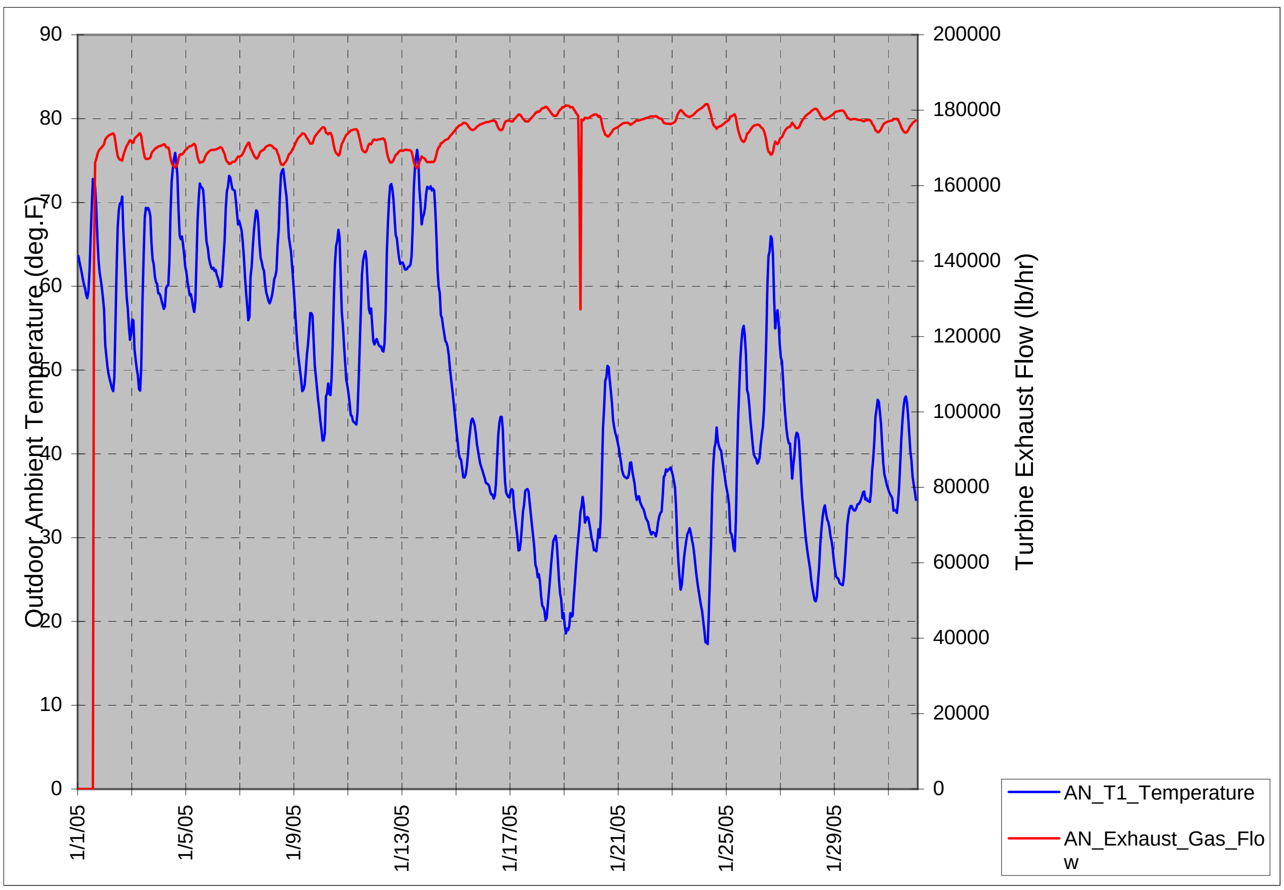

200
180
160
140
120
100
80
60
40
20
0
Steam Pressure (psig)
Deaerator Temperature (deg.F)
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
Boiler_Outlet_PSI
Deaerator_Temp

Misc. Plots


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


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

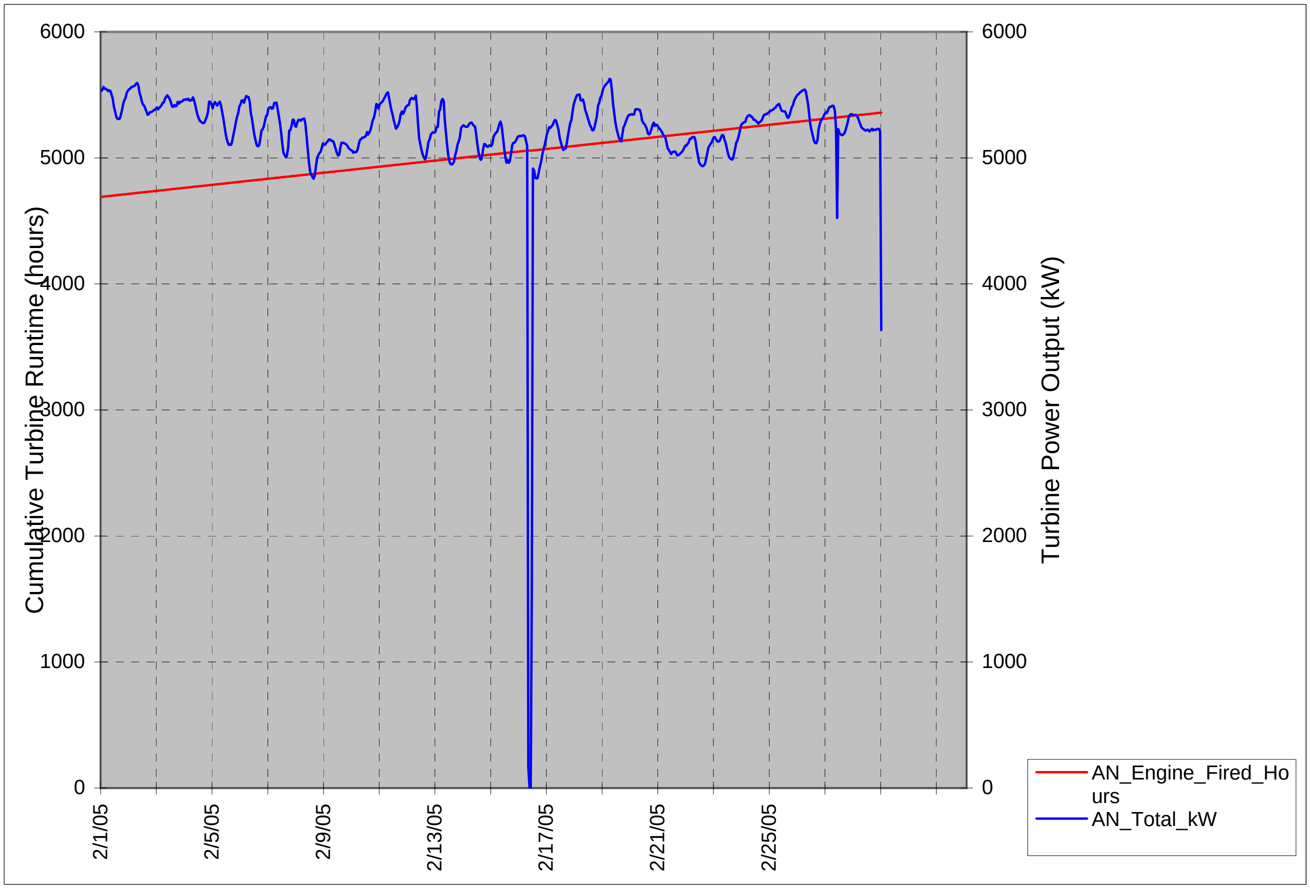

7000
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Exhaust Flow (lb/hr)
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow


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)
1/1/05
1/5/05
1/9/05
1/13/05
1/17/05
1/21/05
1/25/05
1/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

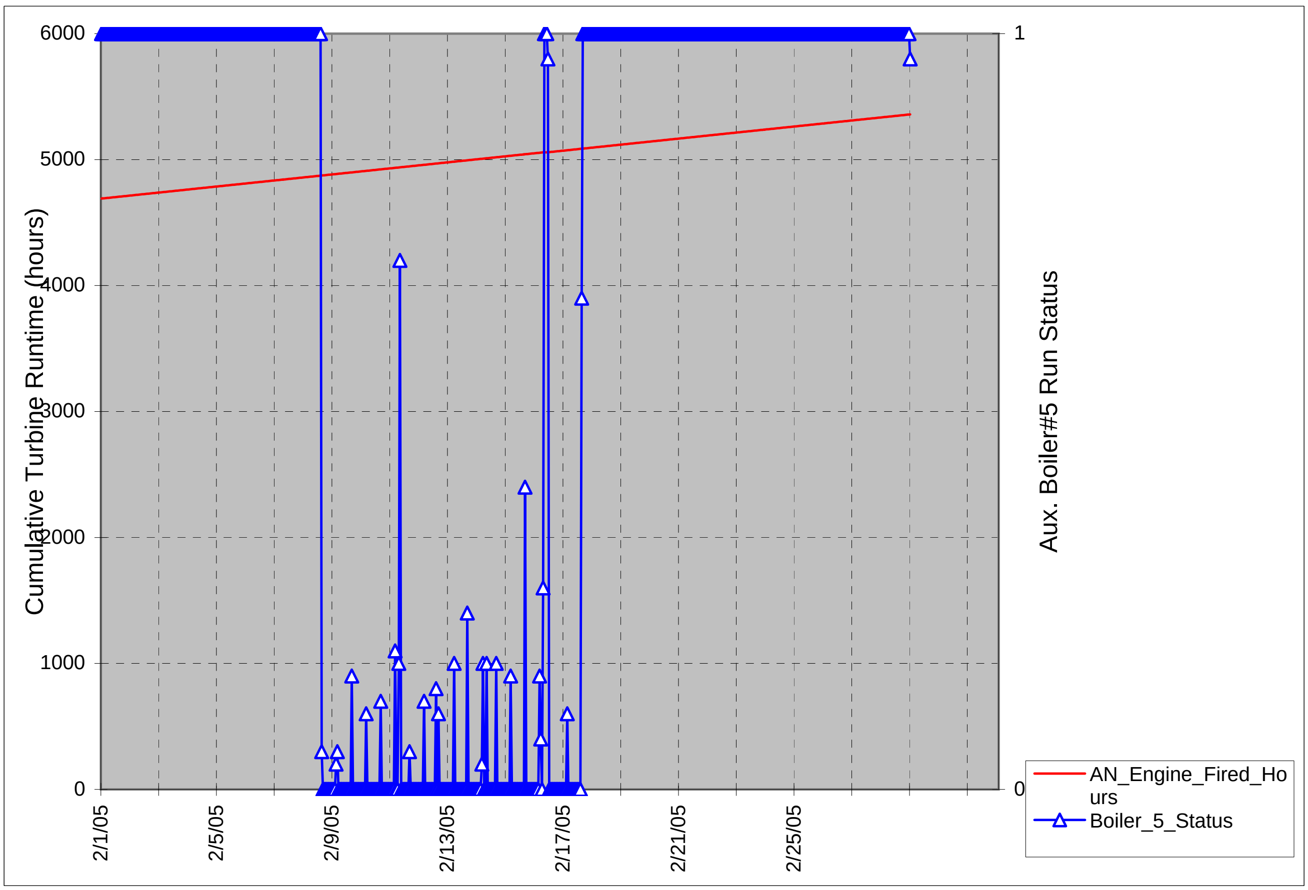
Appendix B

Detailed Operational Data: February 2005

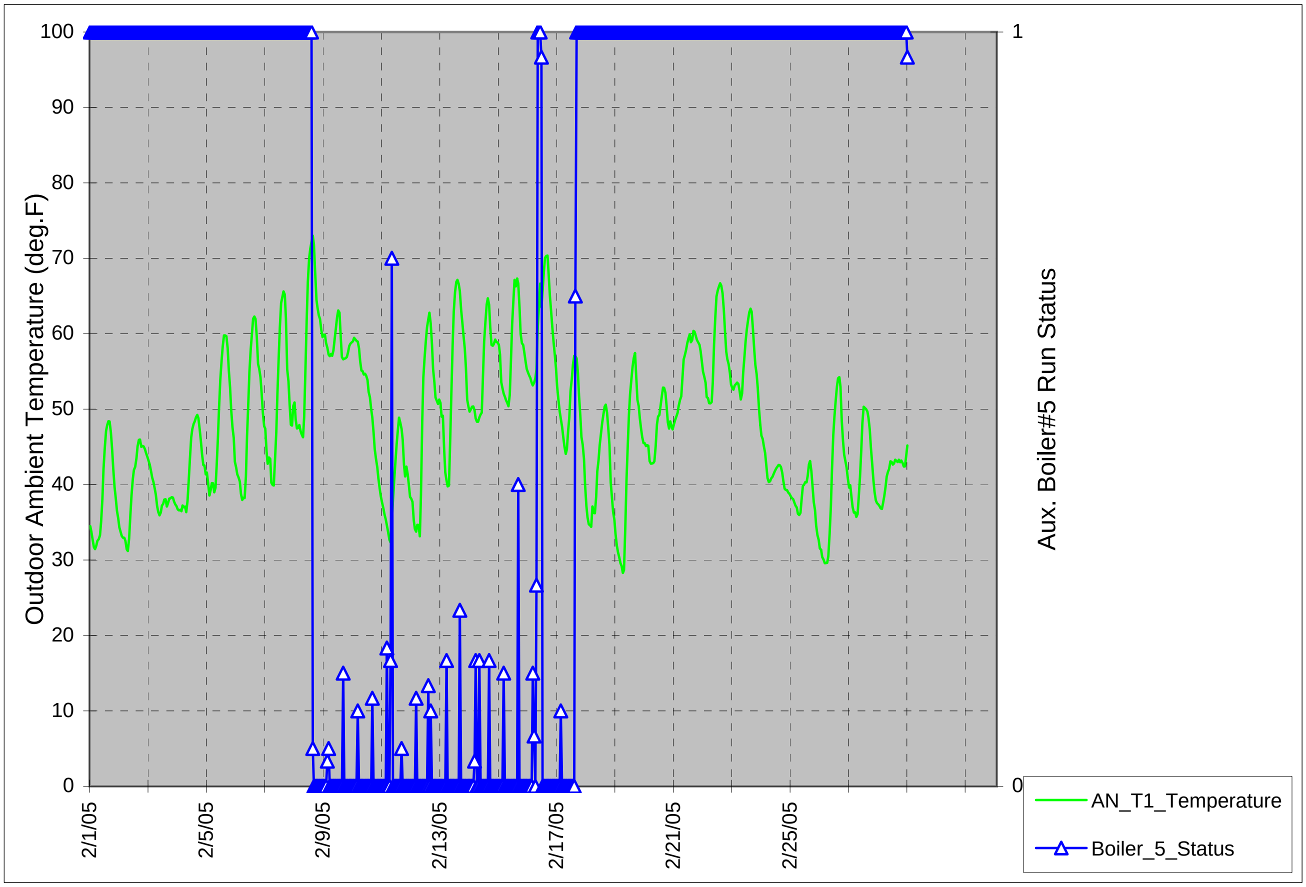
Misc. Plots



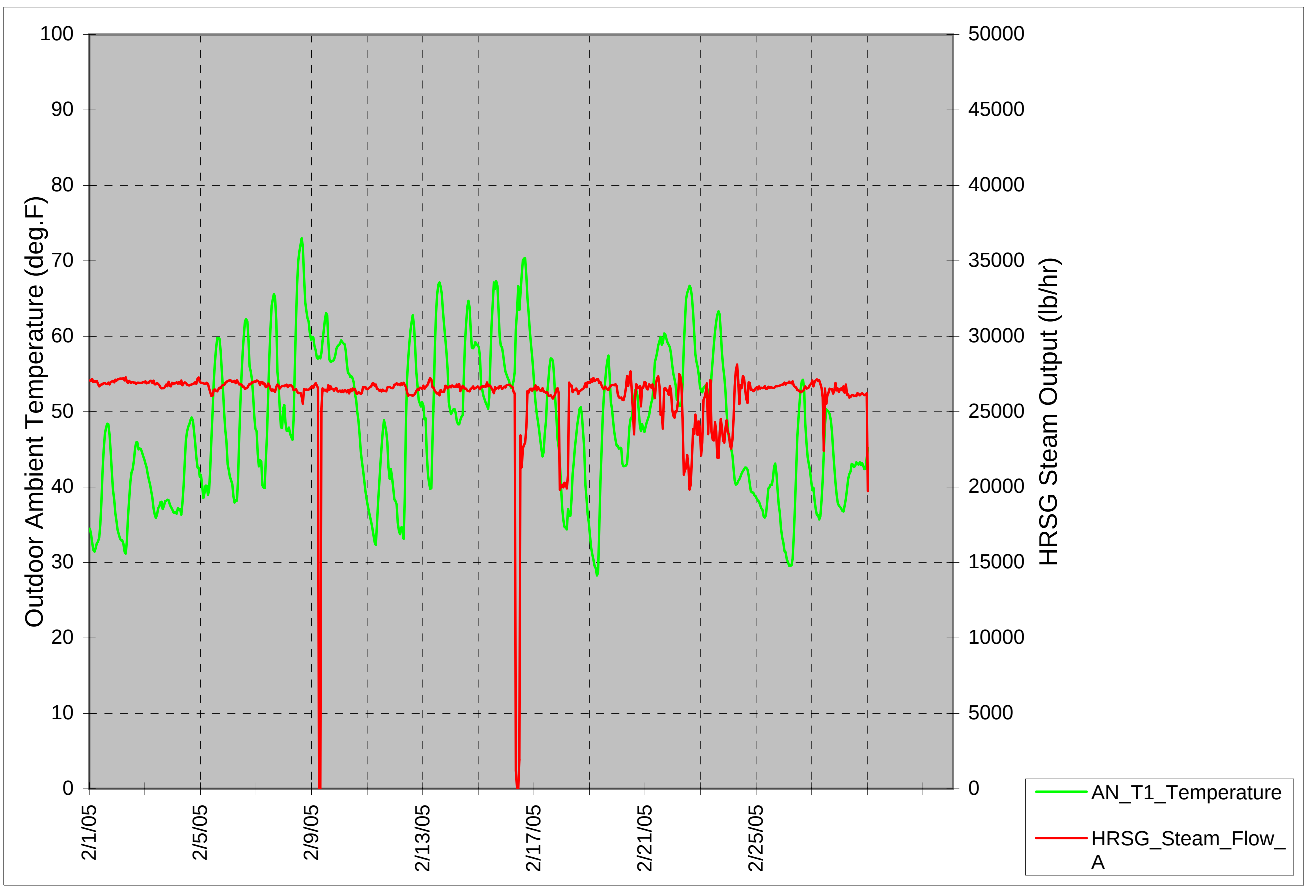
6000
5000
4000
3000
2000
1000
0
Cumulative Turbine Runtime (hours)
Turbine Power Output (kW)
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
AN_Engine_Fired_Hours
AN_Total_kW



6000
5000
4000
3000
2000
1000
0
1
0
Cumulative Turbine Runtime (hours)
Aux. Boiler#5 Run Status
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
AN_Engine_Fired_Hours
Boiler_5_Status

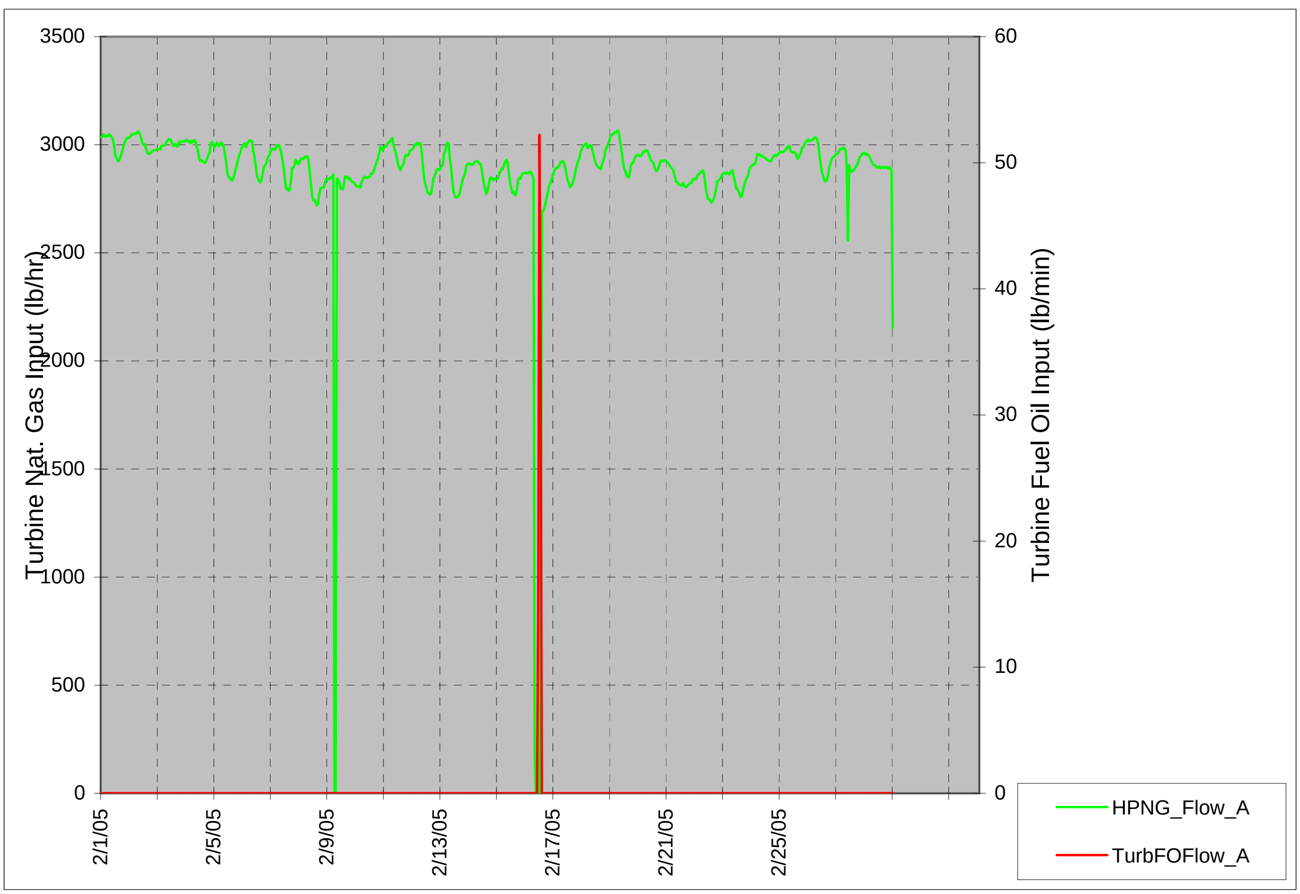


100
90
80
70
60
50
40
30
20
10
0
Outdoor Ambient Temperature (deg.F)
1
0
Aux. Boiler#5 Run Status
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
AN_T1_Temperature
Boiler_5_Status



100
90
80
70
60
50
40
30
20
10
0
Outdoor Ambient Temperature (deg.F)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
HRSG Steam Output (lb/hr)
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
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
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
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
60
50
40
30
20
10
0
2/1/05
2/5/05
2/9/05
2/13/05
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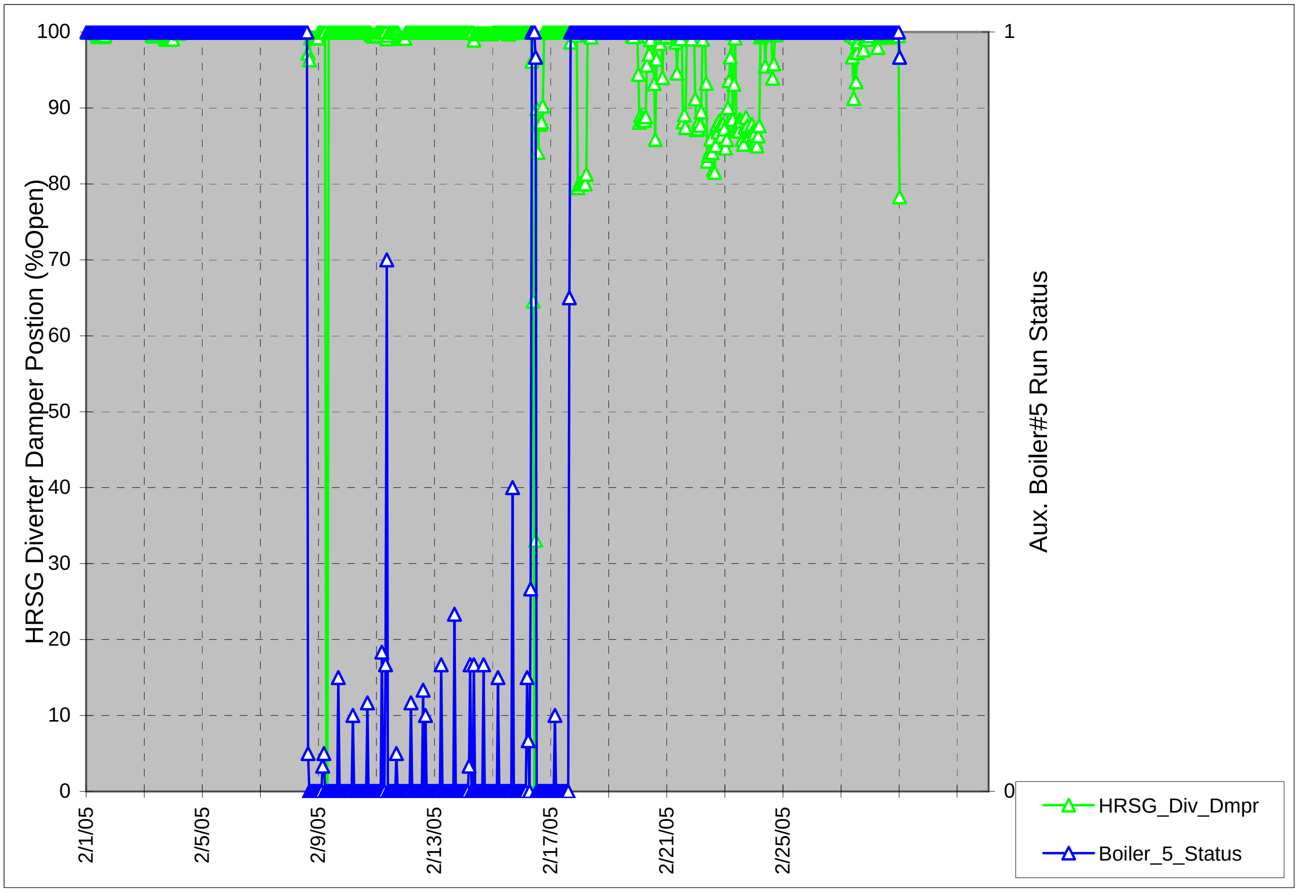
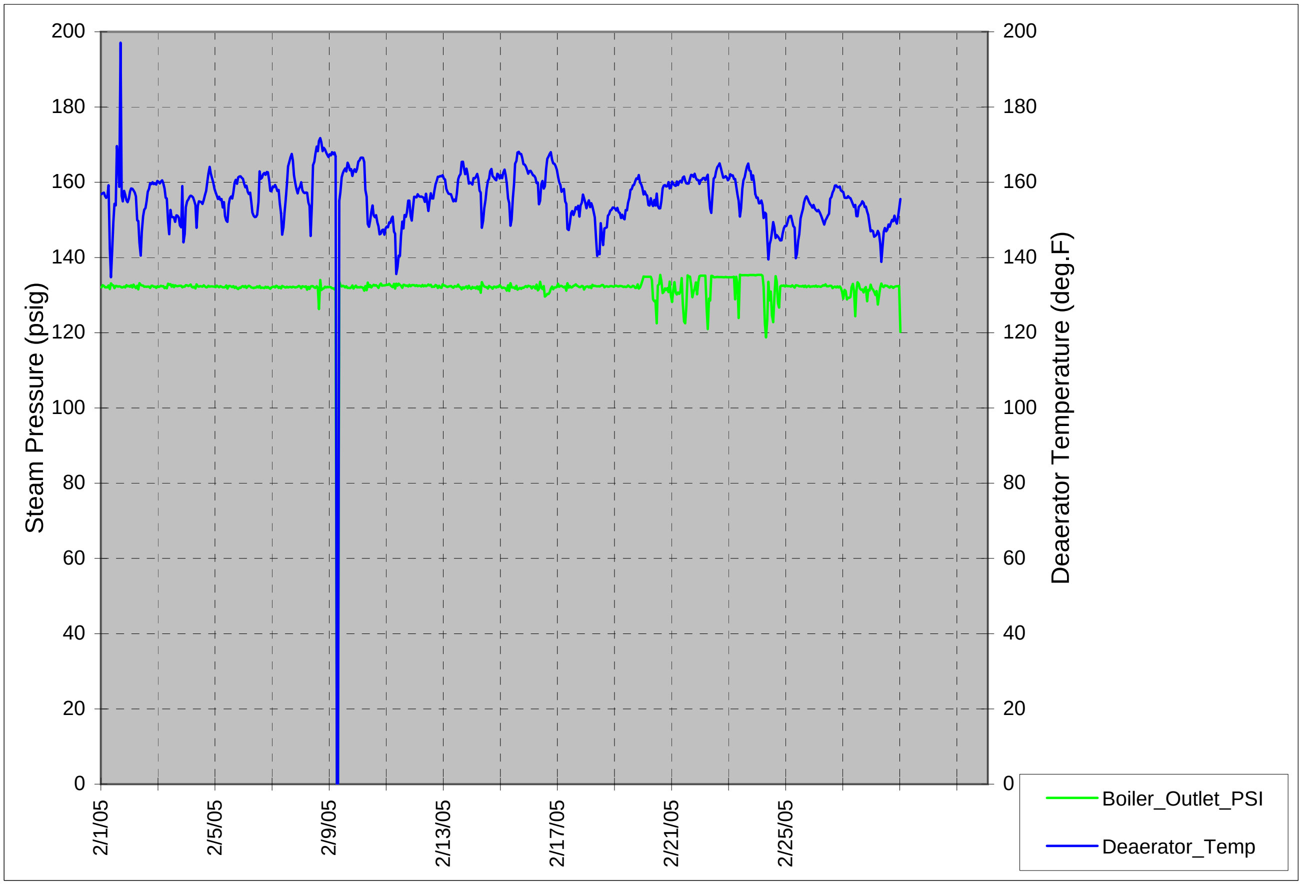
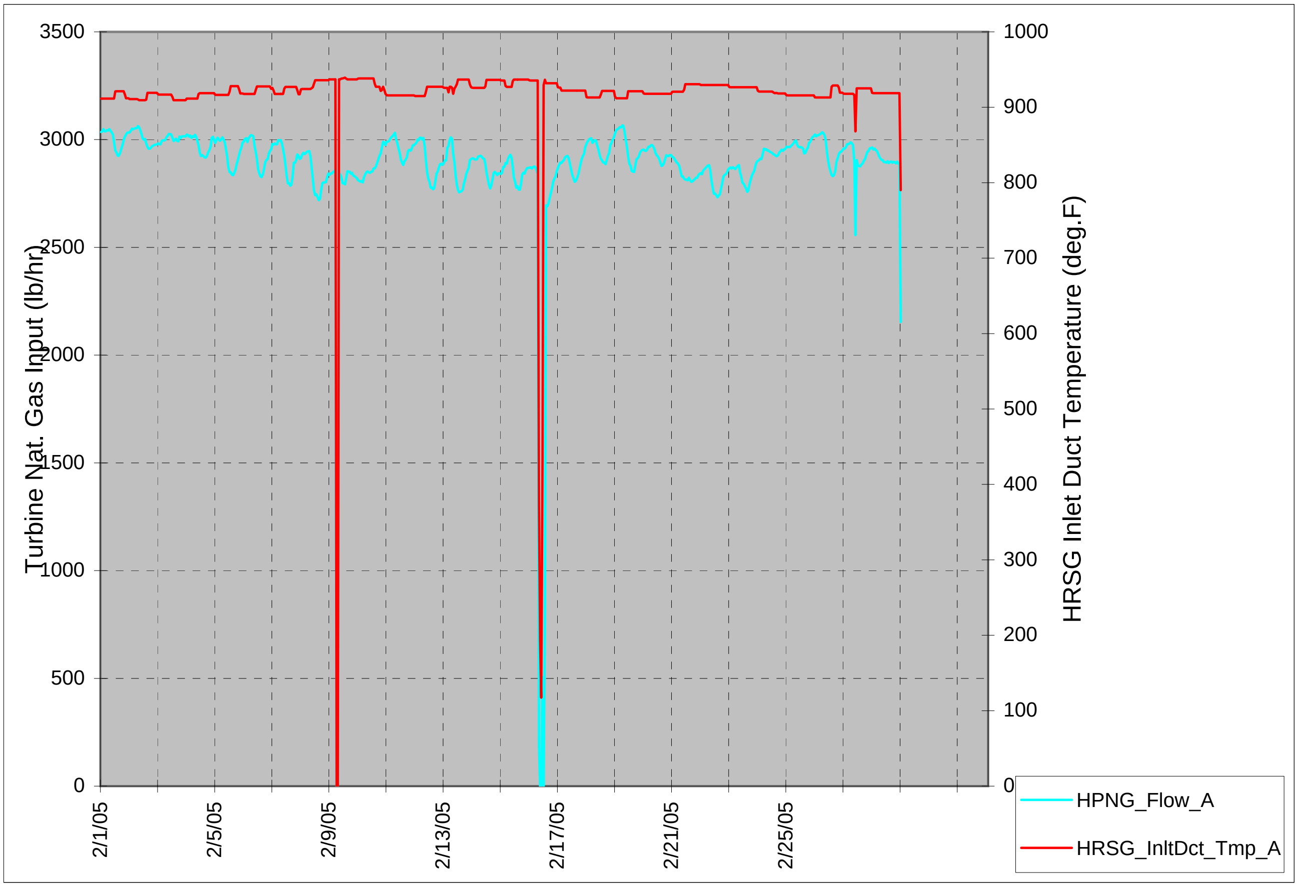
2/21/05
2/25/05
HPNG_Flow_A
TurbFOFlow_A

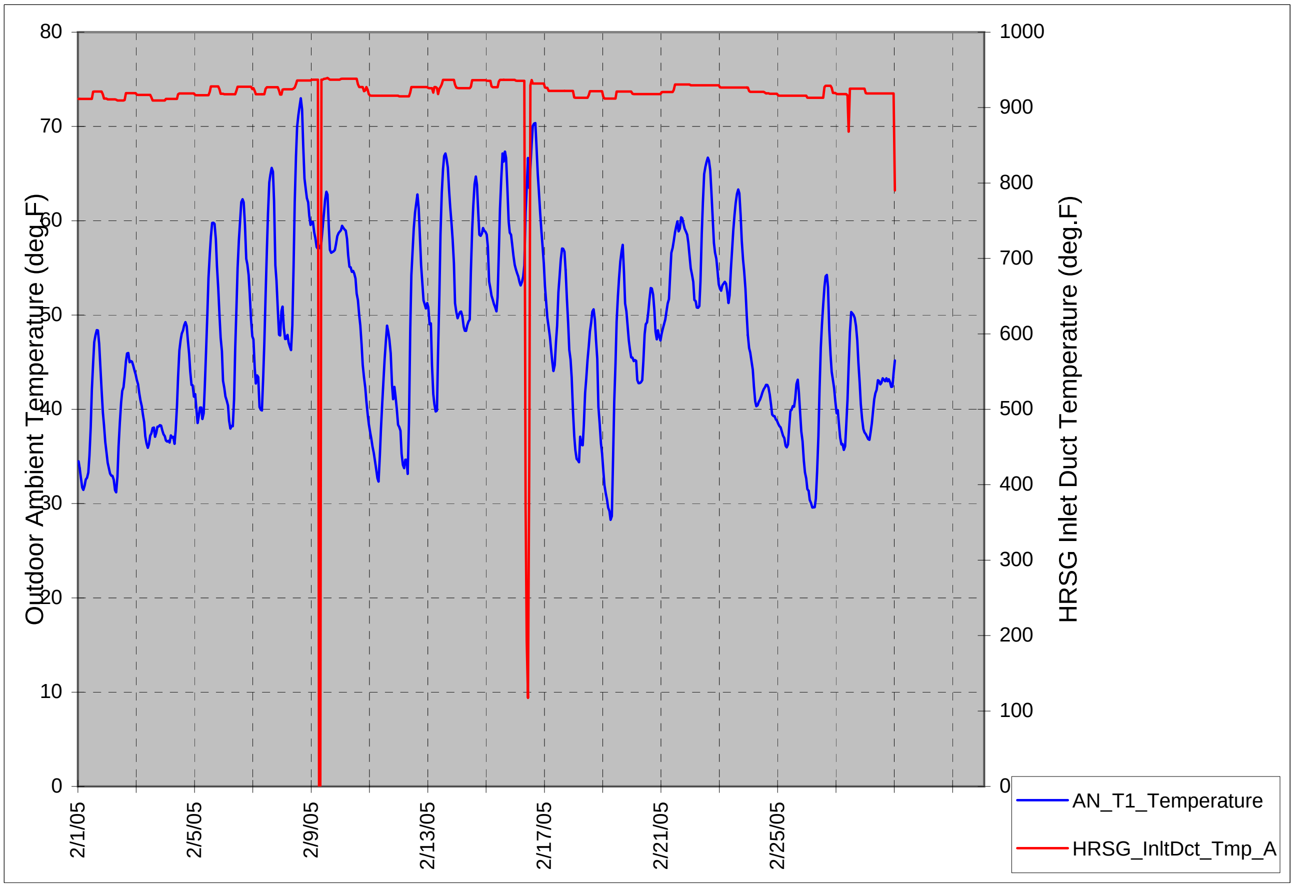

100
90
80
70
60
50
40
30
20
10
0
1
0
HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
HRSG_Div_Dmpr
Boiler_5_Status


200
180
160
140
120
100
80
60
40
20
0
Steam Pressure (psig)
Deaerator Temperature (deg.F)
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
Boiler_Outlet_PSI
Deaerator_Temp

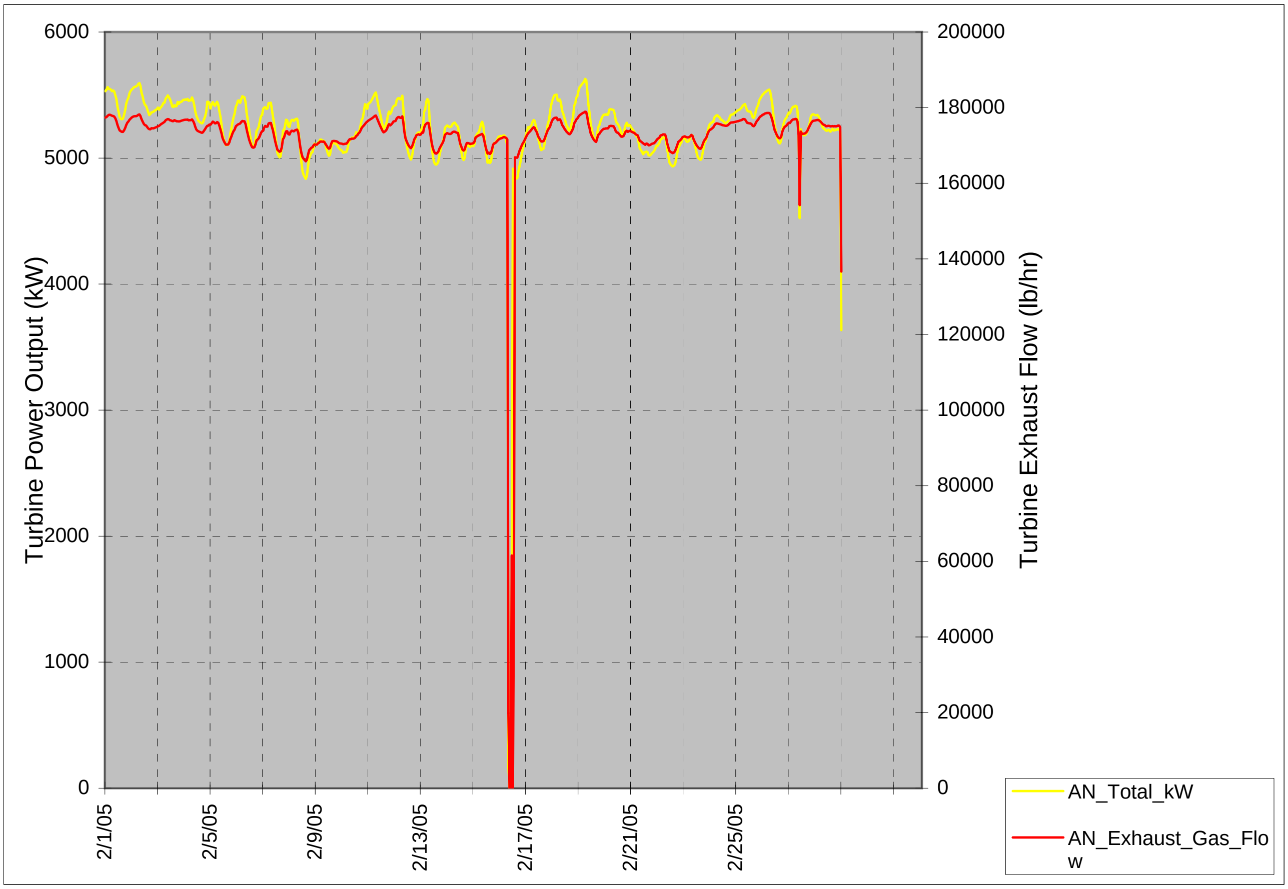
Misc. Plots



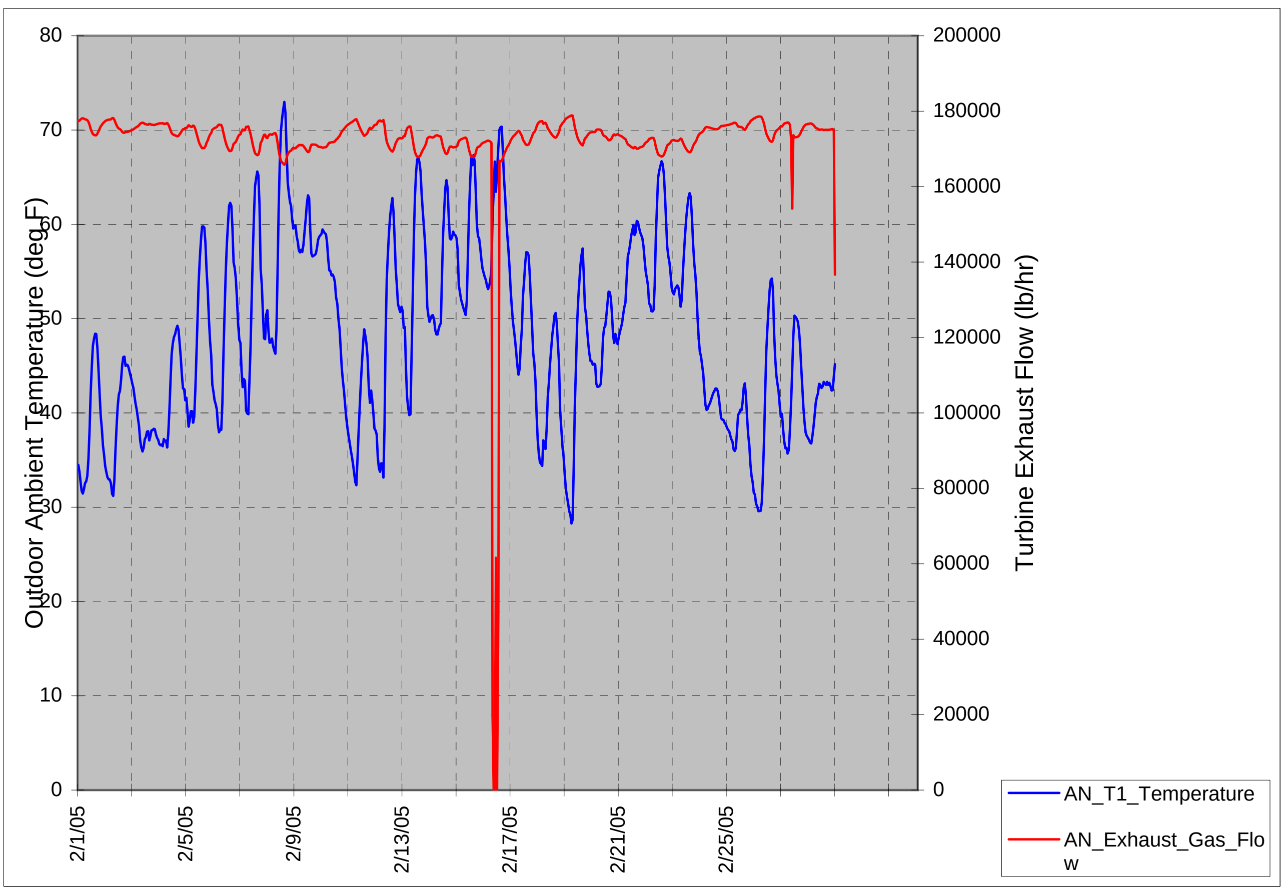
Turbine Nat. Gas Input (lb/hr)
HRSG Inlet Duct Temperature (deg.F)
3500
3000
2500
2000
1500
1000
500
0
1000
900
800
700
600
500
400
300
200
100
0
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A



Outdoor Ambient Temperature (deg.F)
HRSG Inlet Duct Temperature (deg.F)
80
70
60
50
40
30
20
10
0
1000
900
800
700
600
500
400
300
200
100
0
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A



6000
5000
4000
3000
2000
1000
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Turbine Power Output (kW)
Turbine Exhaust Flow (lb/hr)
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
AN_Total_kW
AN_Exhaust_Gas_Flow

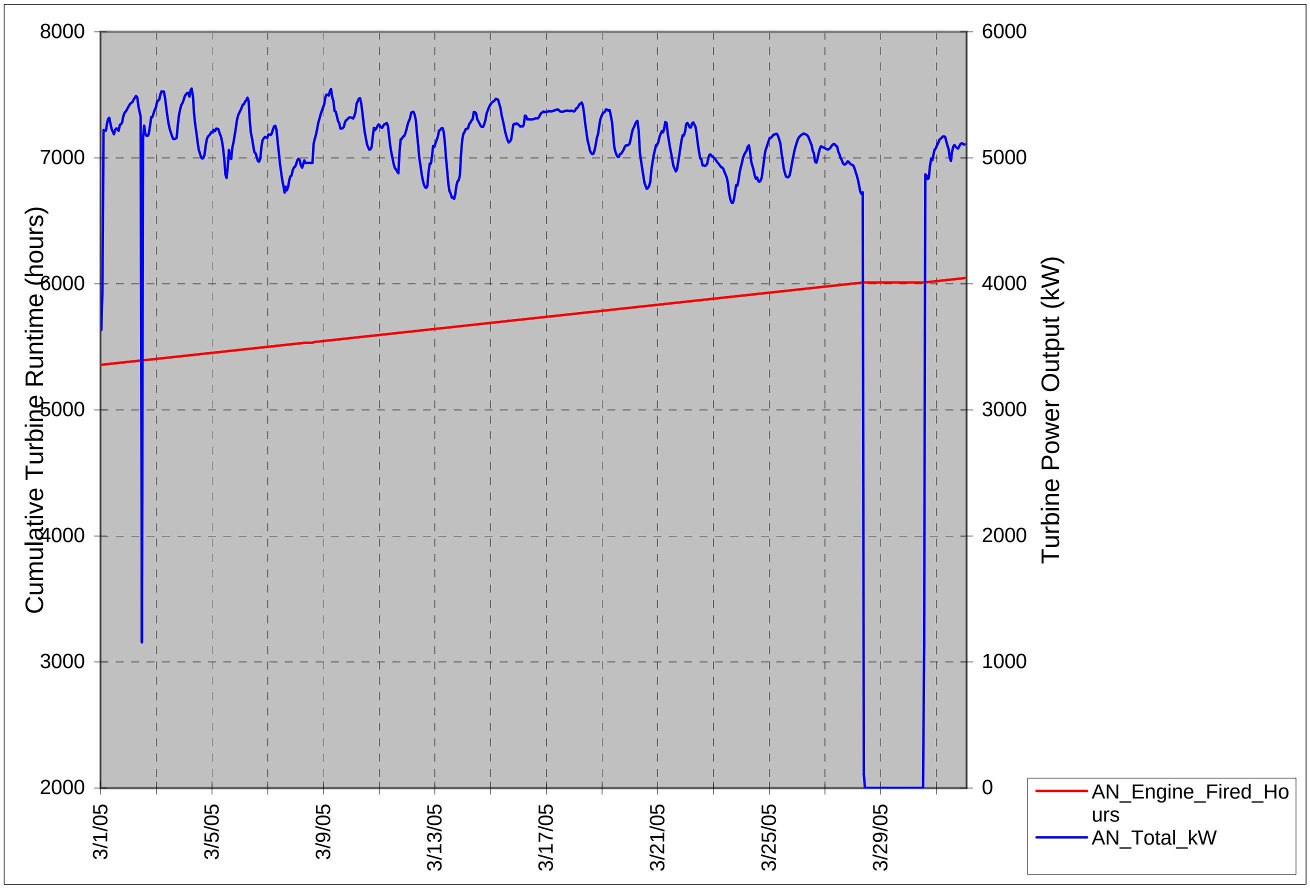


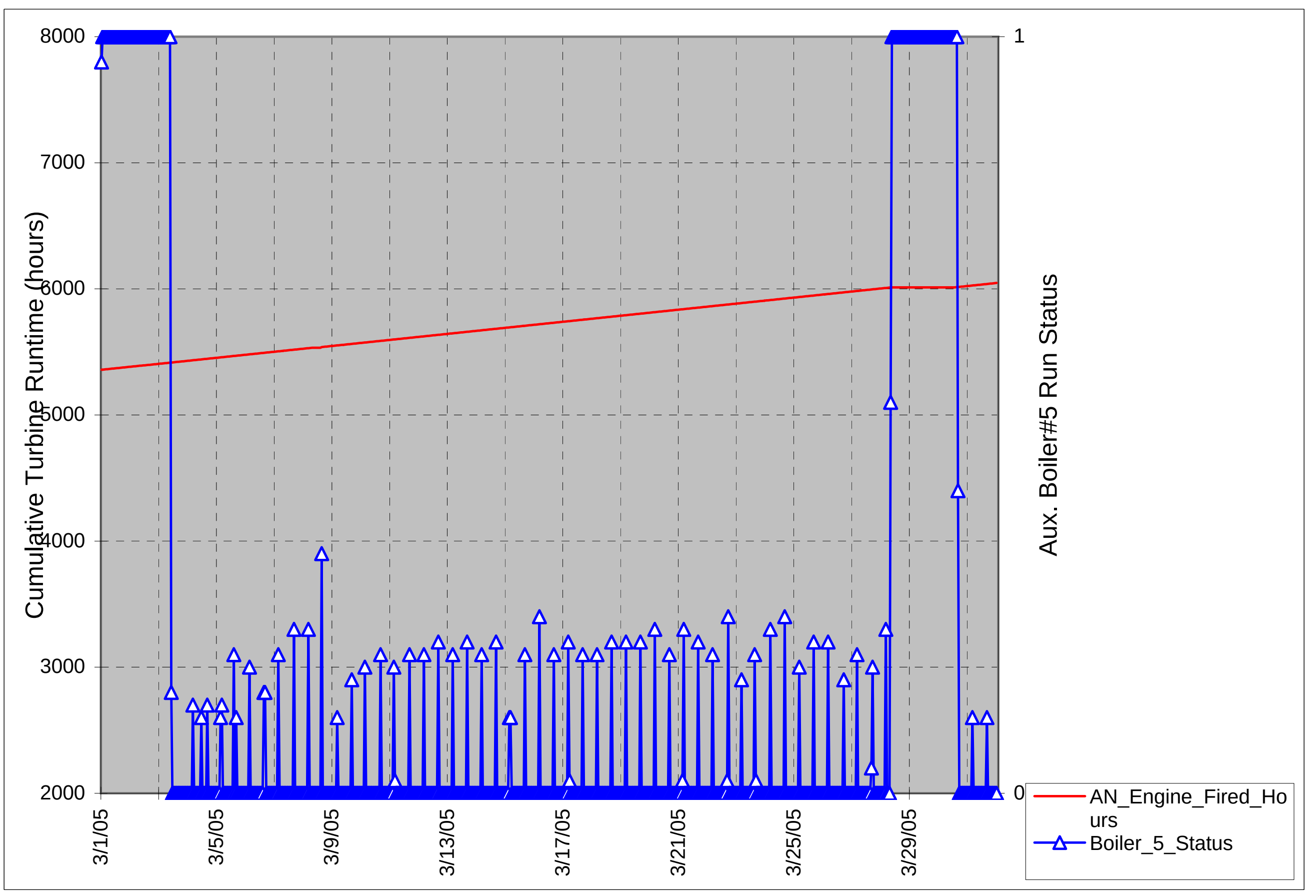
80
70
60
50
40
30
20
10
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Outdoor Ambient Temperature (deg F)
Turbine Exhaust Flow (lb/hr)
2/1/05
2/5/05
2/9/05
2/13/05
2/17/05
2/21/05
2/25/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

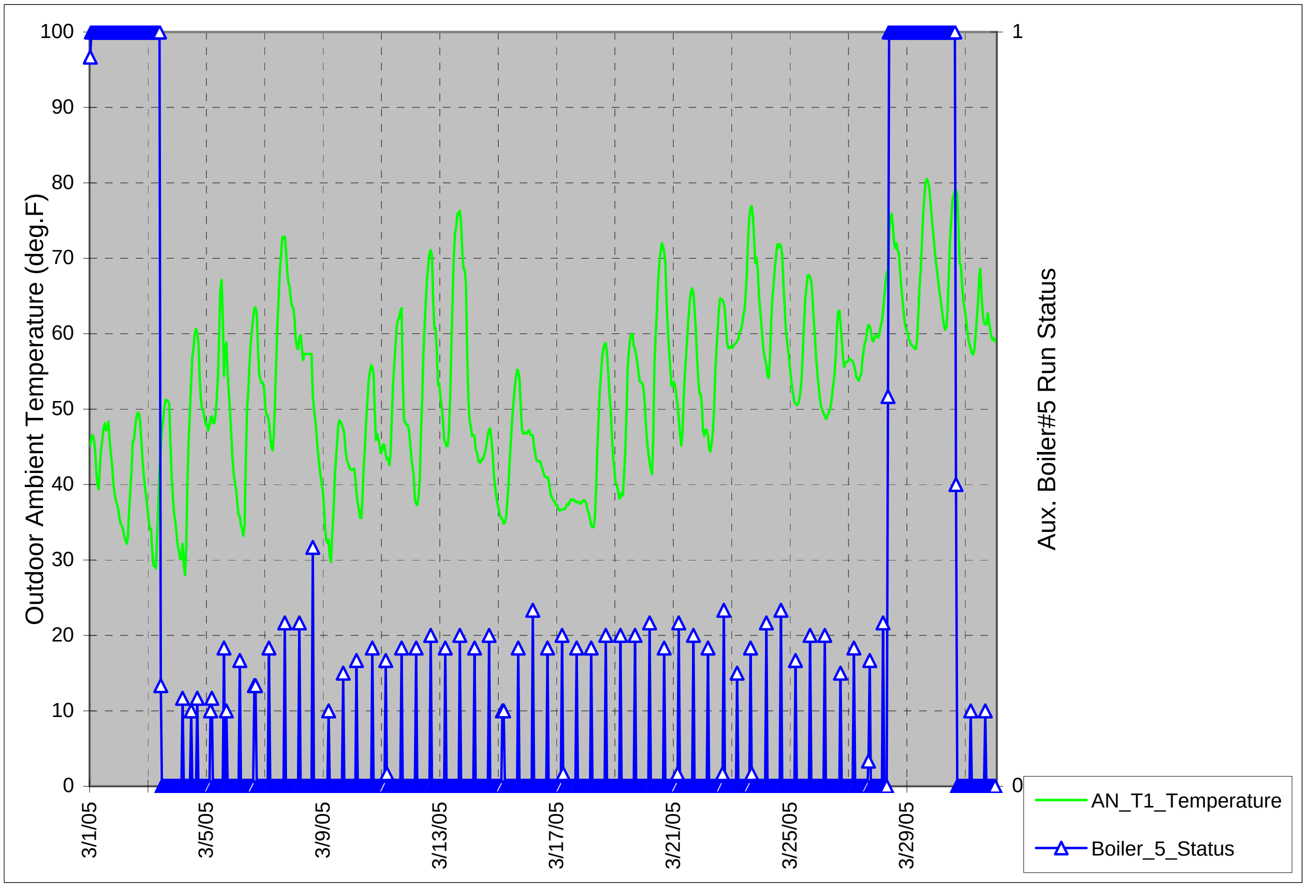
Appendix C

Detailed Operational Data: March 2005

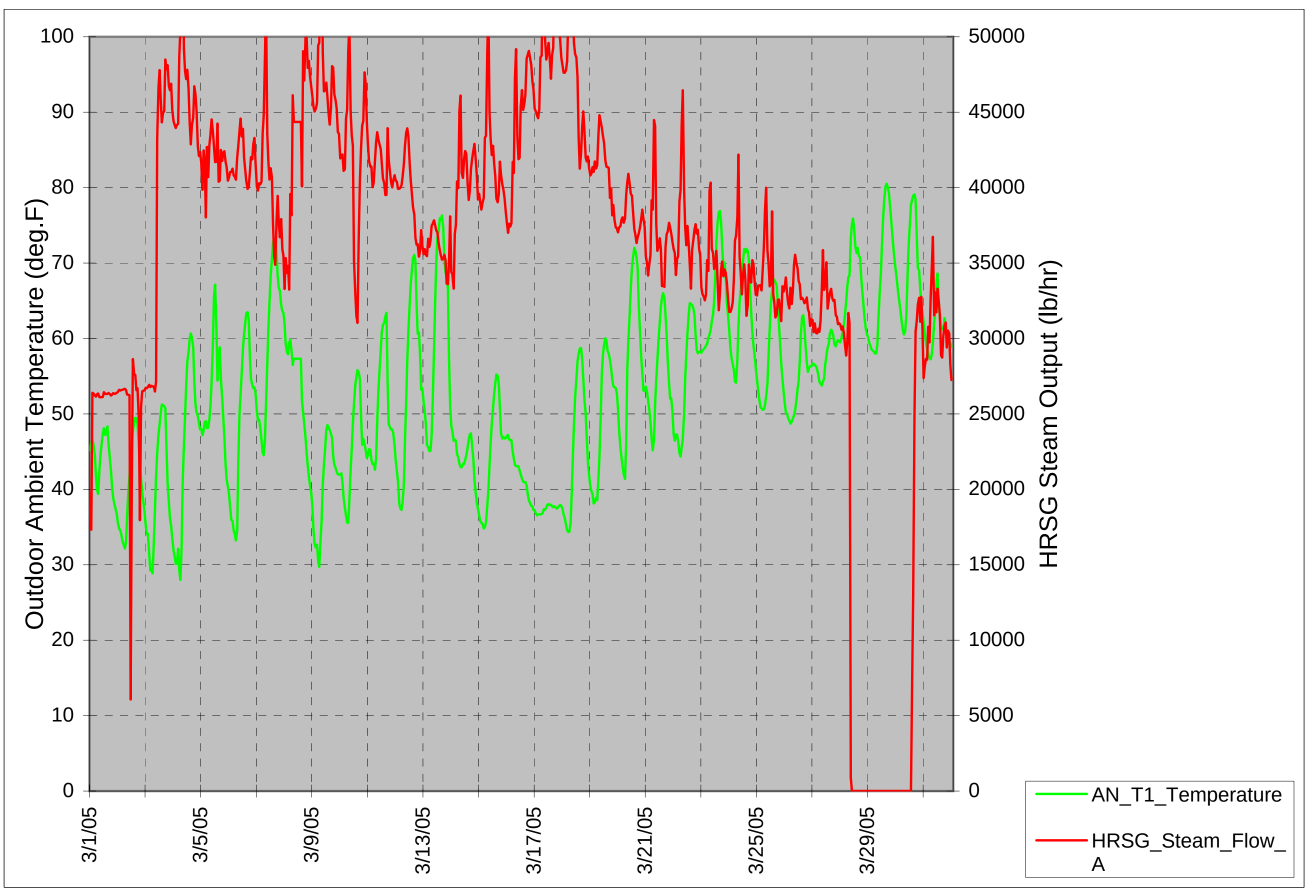
Misc. Plots


8000
7000
6000
5000
4000
3000
2000
Cumulative Turbine Runtime (hours)
6000
5000
4000
3000
2000
1000
0
Turbine Power Output (kW)
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
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
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
AN_Engine_Fired_Hours
Boiler_5_Status

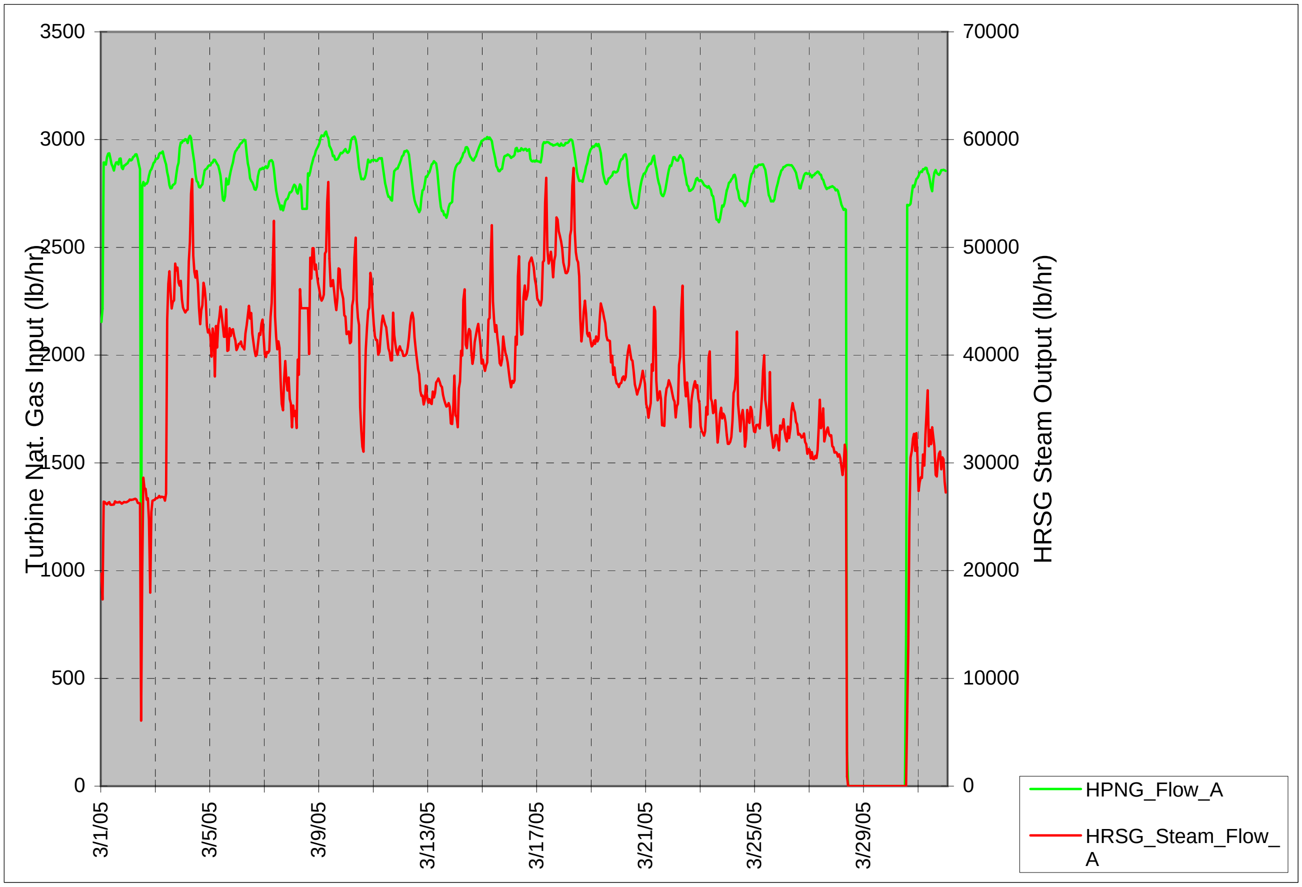


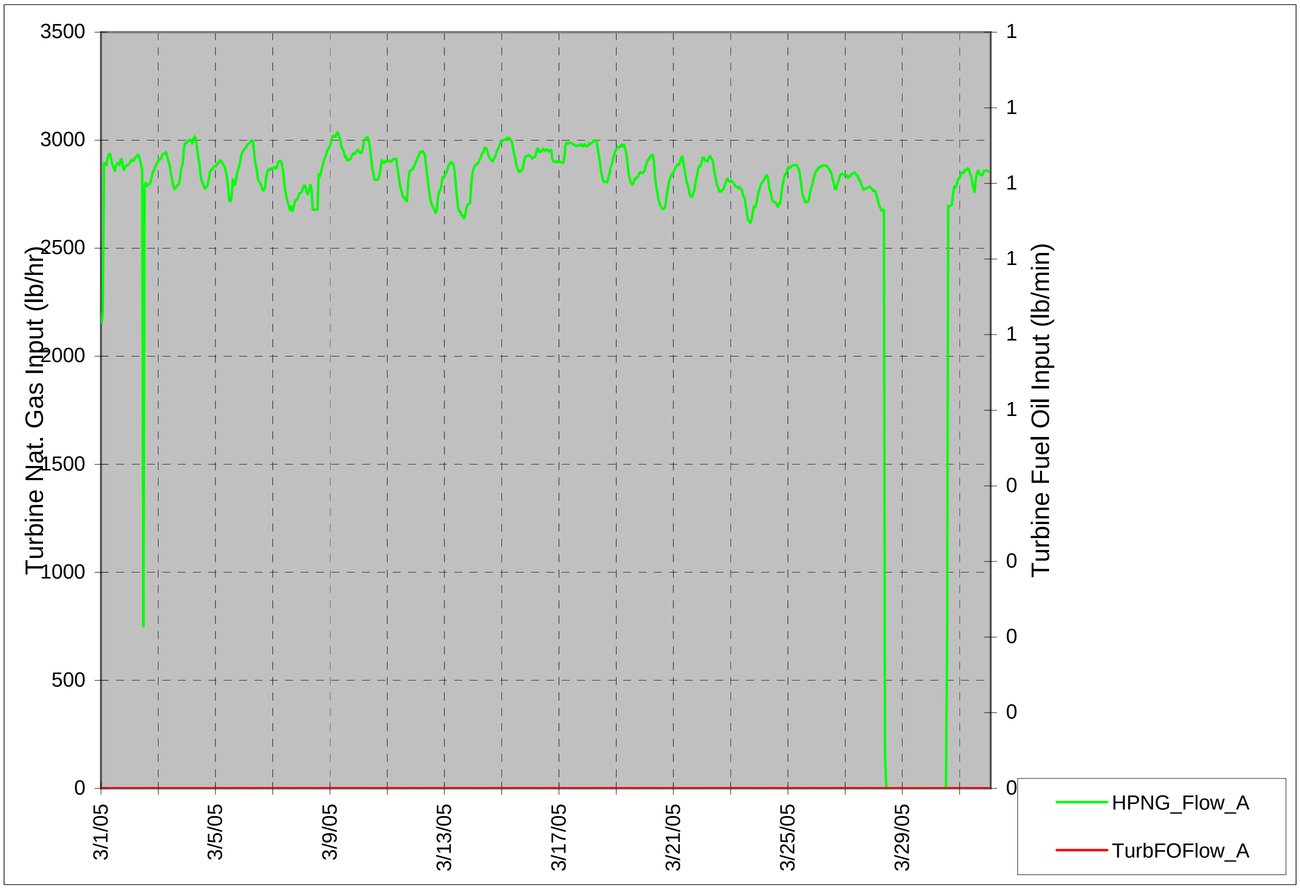
100
90
80
70
60
50
40
30
20
10
0
1
0
Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
AN_T1_Temperature
Boiler_5_Status

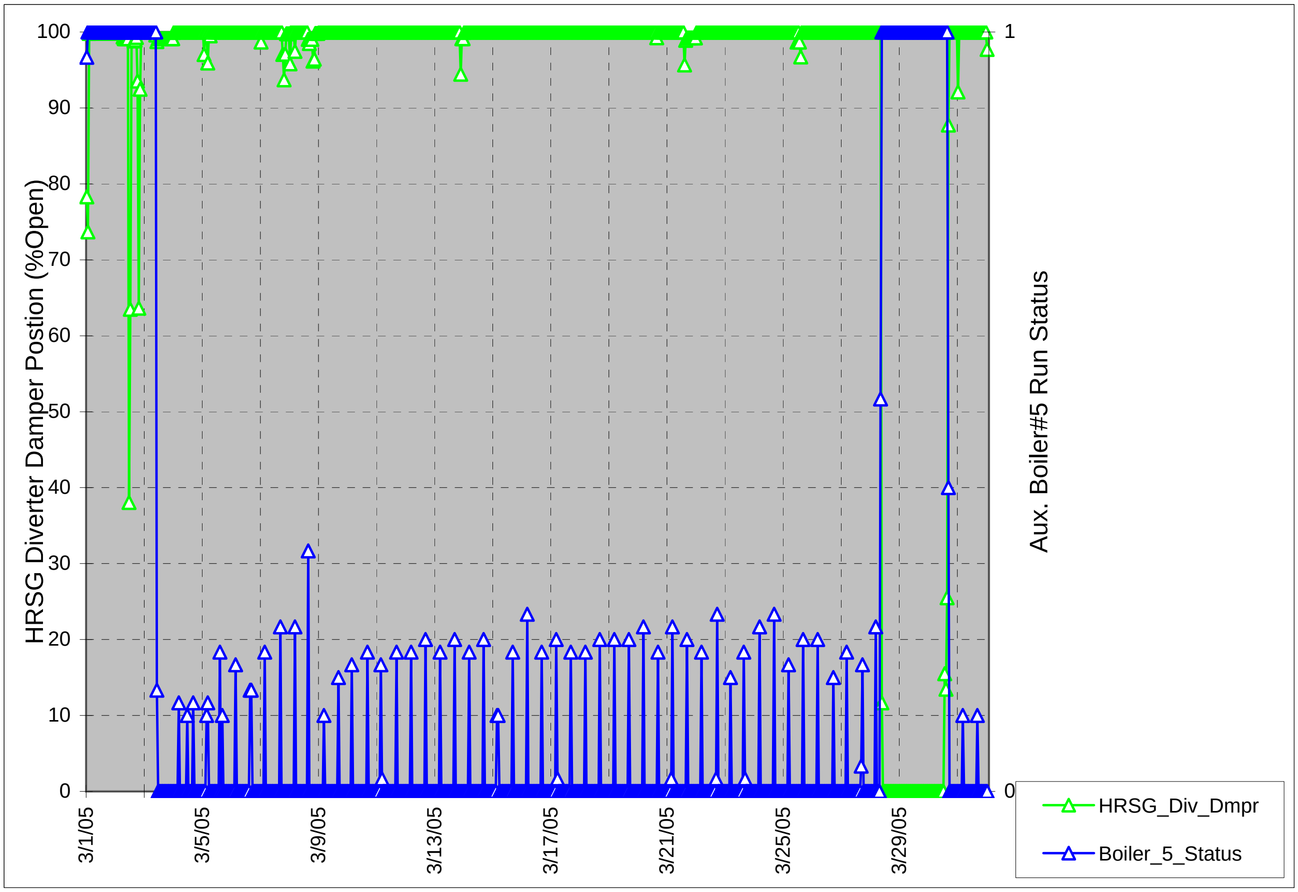


100
90
80
70
60
50
40
30
20
10
0
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
AN_T1_Temperature
HRSG_Steam_Flow_A

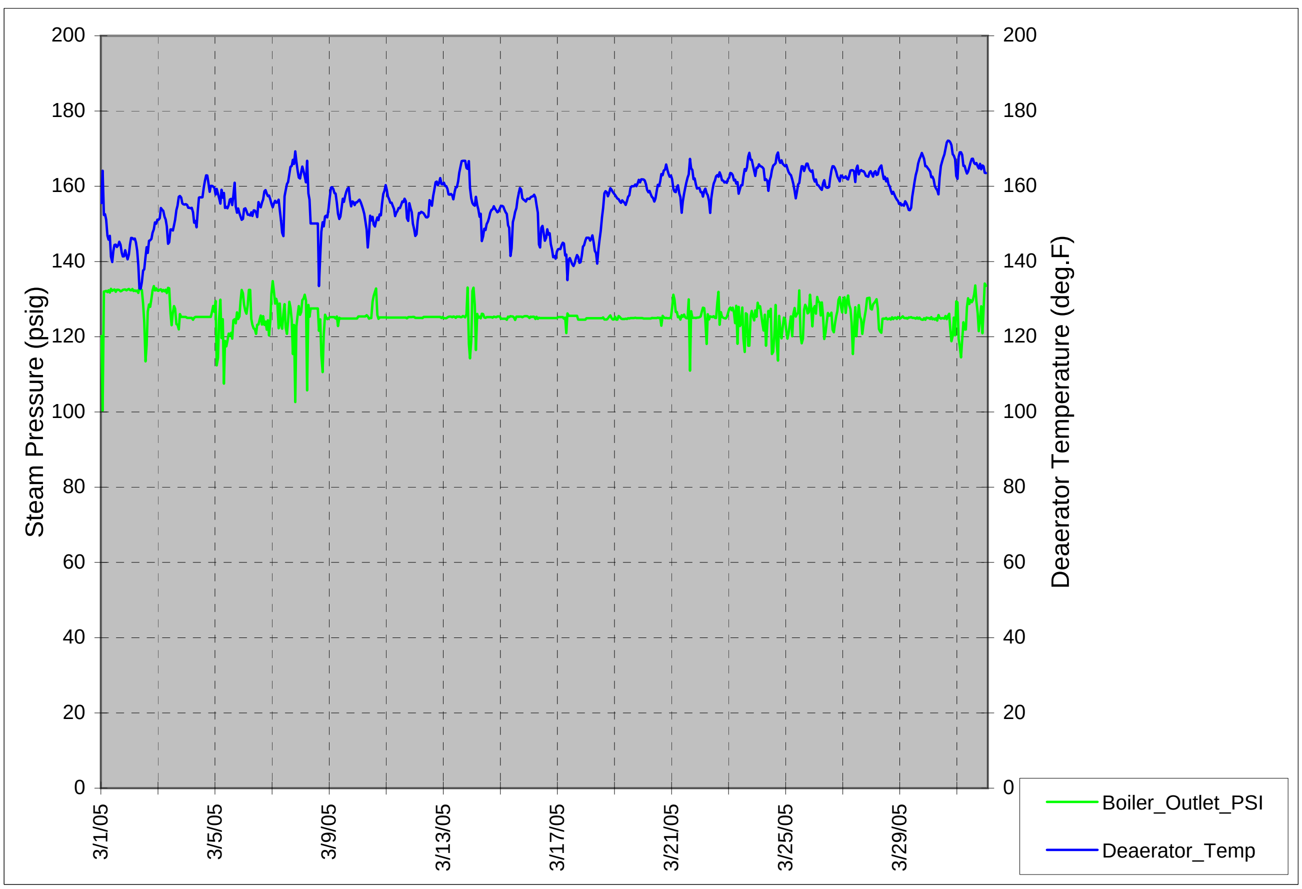
Misc. Plots


3500
3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
70000
60000
50000
40000
30000
20000
10000
0
HRSG Steam Output (lb/hr)
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A


3500
3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
1
1
1
1
1
1
0
0
0
0
0
Turbine Fuel Oil Input (lb/min)
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
HPNG_Flow_A
TurbFOFlow_A

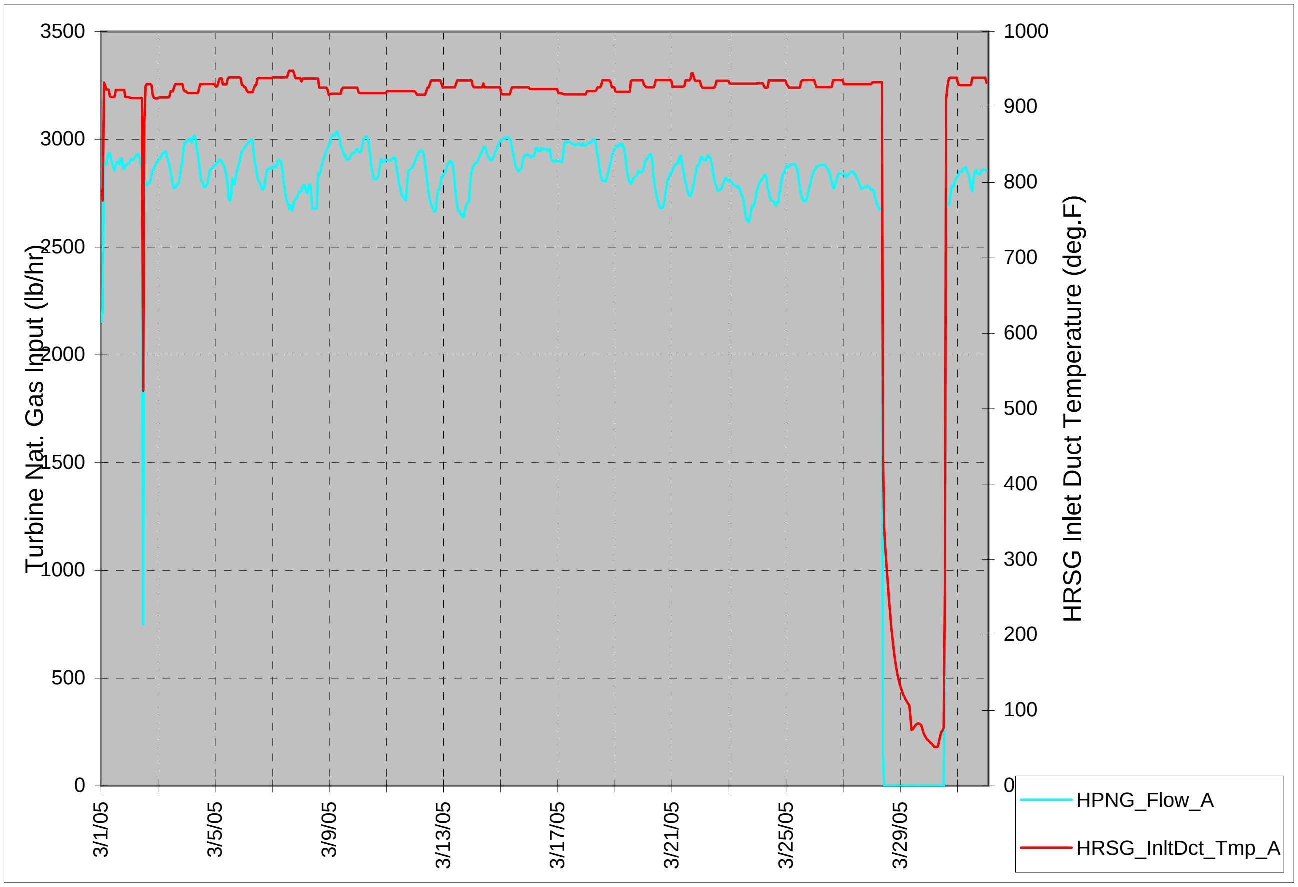


100
90
80
70
60
50
40
30
20
10
0
1
0
HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
HRSG_Div_Dmpr
Boiler_5_Status

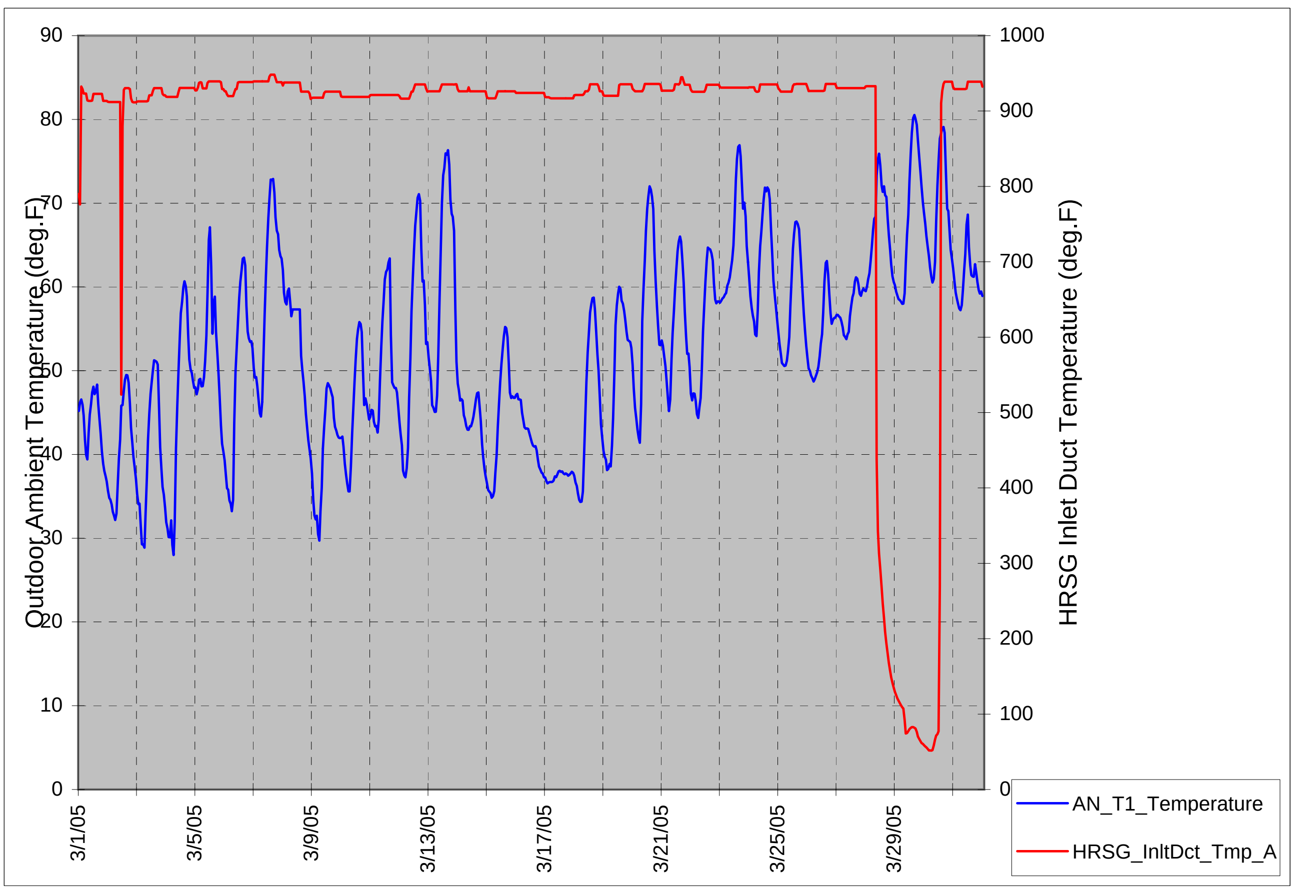


200
180
160
140
120
100
80
60
40
20
0
Steam Pressure (psig)
Deaerator Temperature (deg.F)
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Boiler_Outlet_PSI
Deaerator_Temp

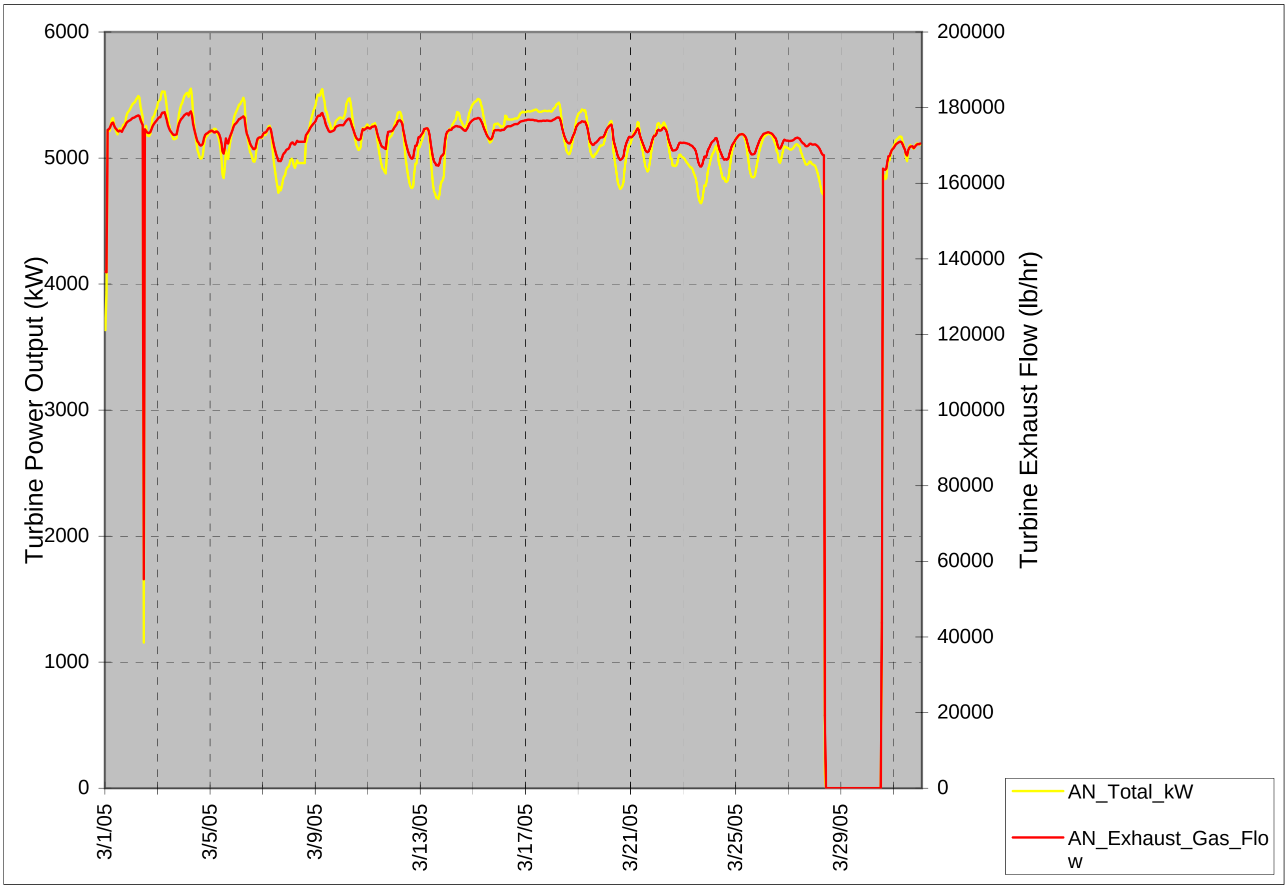
Misc. Plots

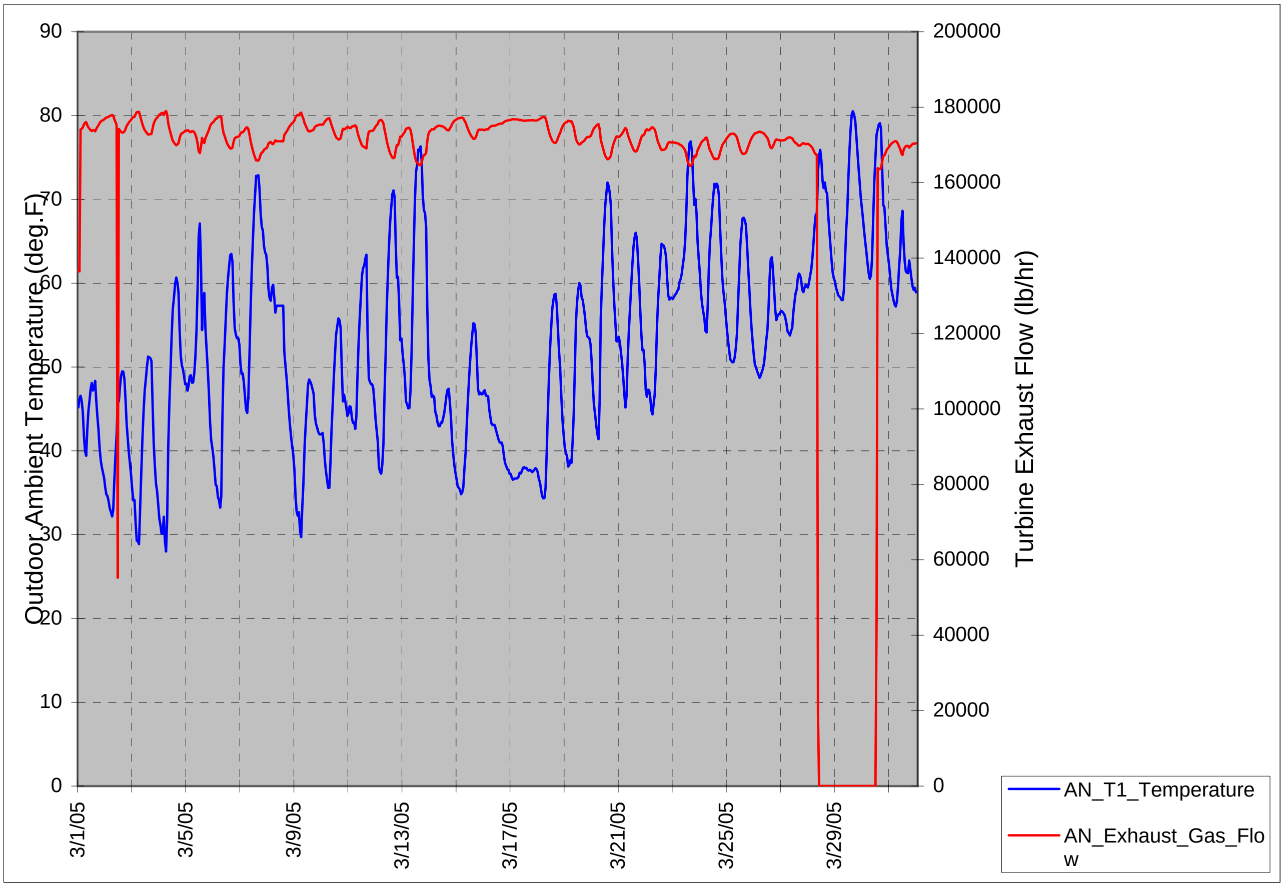


Turbine Nat. Gas Input (lb/hr)
HRSG Inlet Duct Temperature (deg.F)
3500
3000
2500
2000
1500
1000
500
0
1000
900
800
700
600
500
400
300
200
100
0
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A

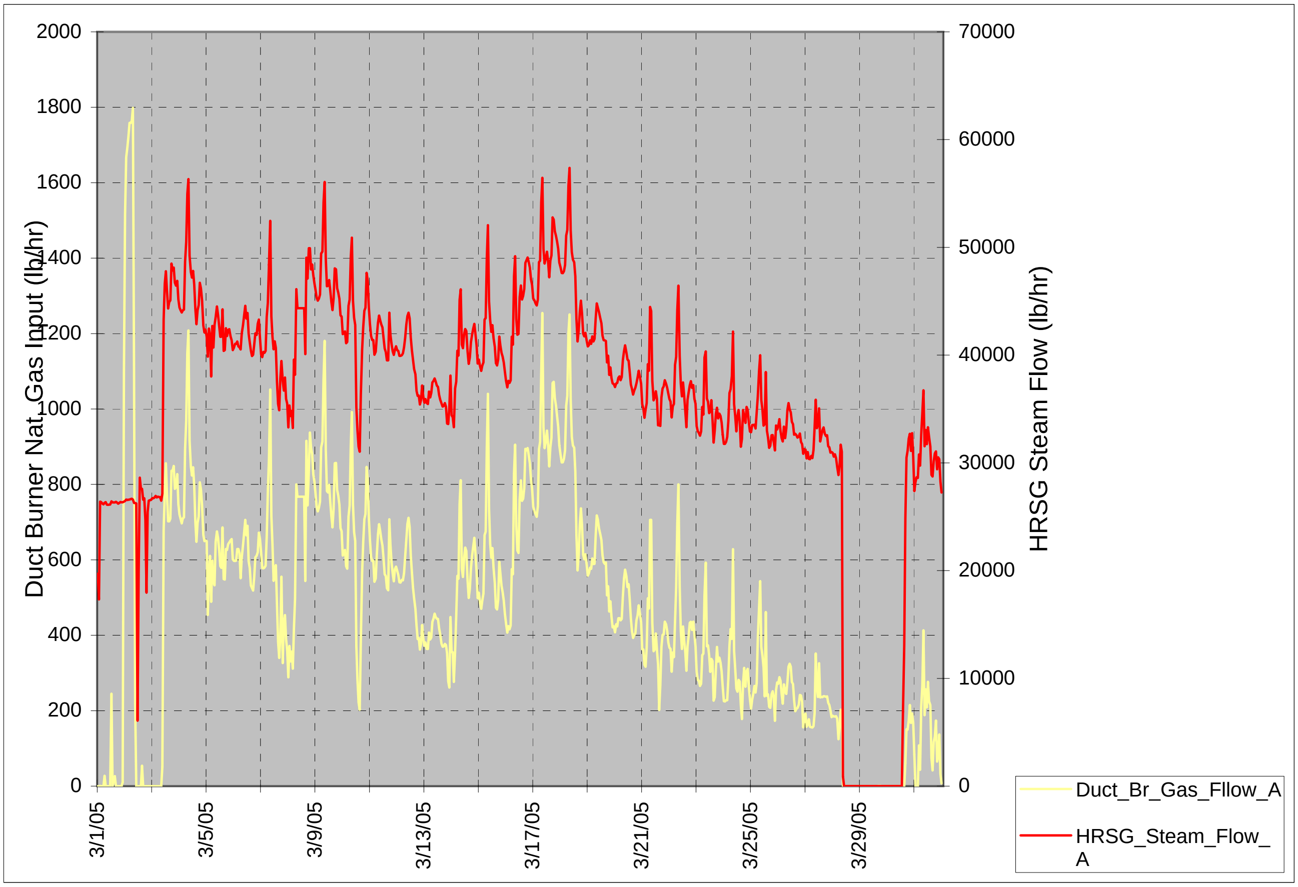


Outdoor Ambient Temperature (deg.F)
HRSG Inlet Duct Temperature (deg.F)
90
80
70
60
50
40
30
20
10
0
1000
900
800
700
600
500
400
300
200
100
0
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A

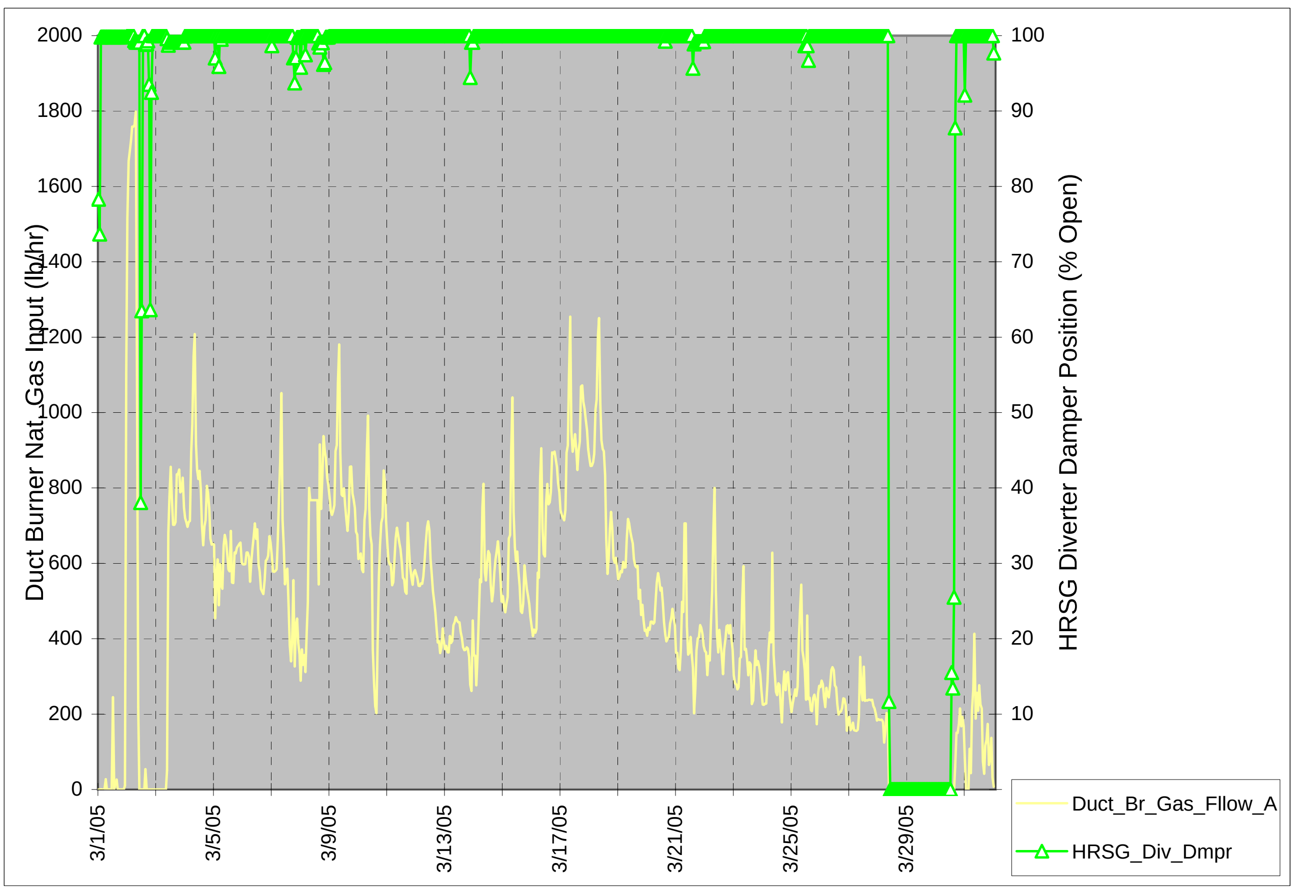

Turbine Power Output (kW)
Turbine Exhaust Flow (lb/hr)
6000
5000
4000
3000
2000
1000
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow


Outdoor Ambient Temperature (deg.F)
Turbine Exhaust Flow (lb/hr)
90
80
70
60
50
40
30
20
10
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow

Misc. Plots



Duct Burner Nat. Gas Input (lb/hr)
HRSG Steam Flow (lb/hr)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
70000
60000
50000
40000
30000
20000
10000
0
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Duct_Br_Gas_Fllow_A
HRSG_Steam_Flow_A

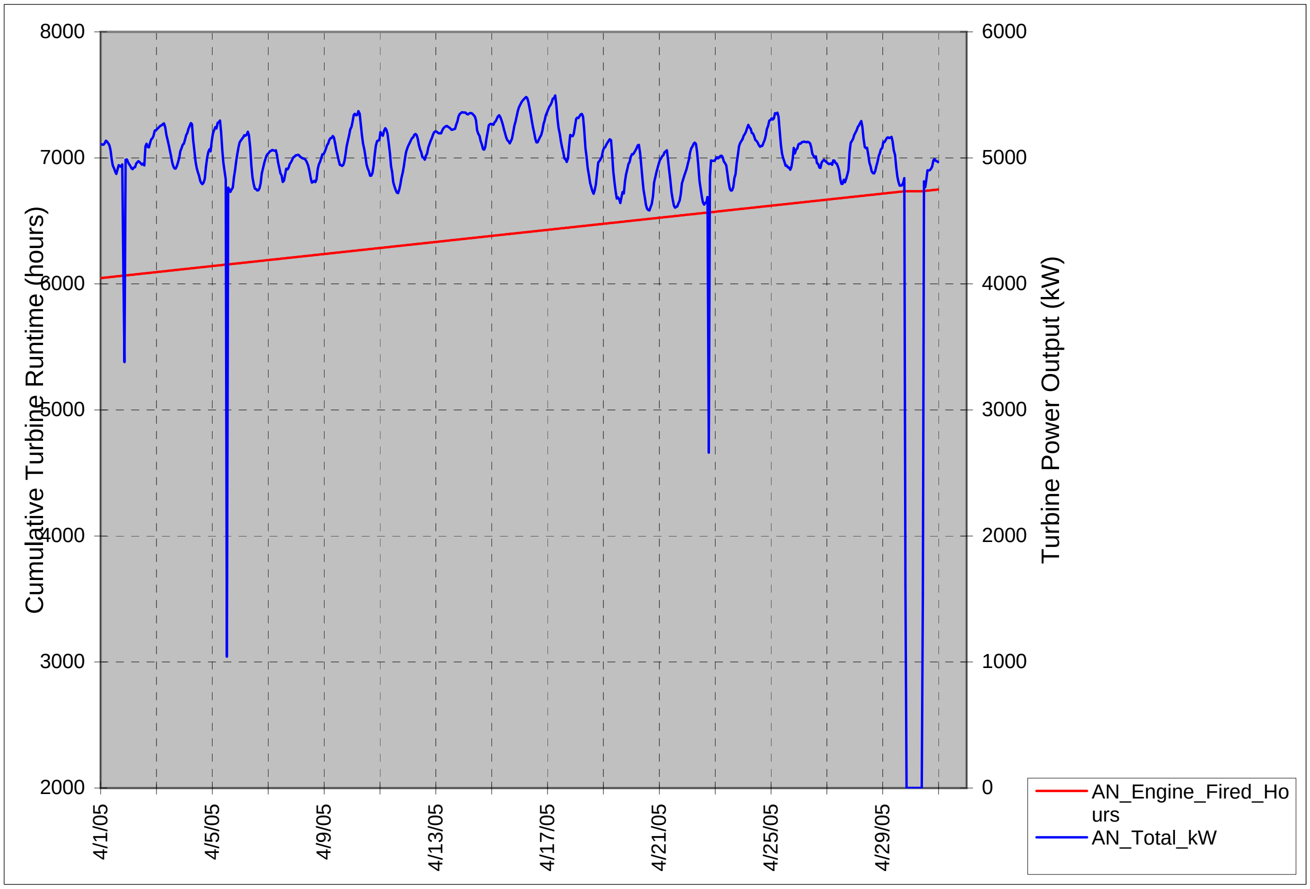


Duct Burner Nat. Gas Input (lb/hr)
HRSG Diverter Damper Position (% Open)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
100
90
80
70
60
50
40
30
20
10
3/1/05
3/5/05
3/9/05
3/13/05
3/17/05
3/21/05
3/25/05
3/29/05
Duct_Br_Gas_Fllow_A
HRSG_Div_Dmpr

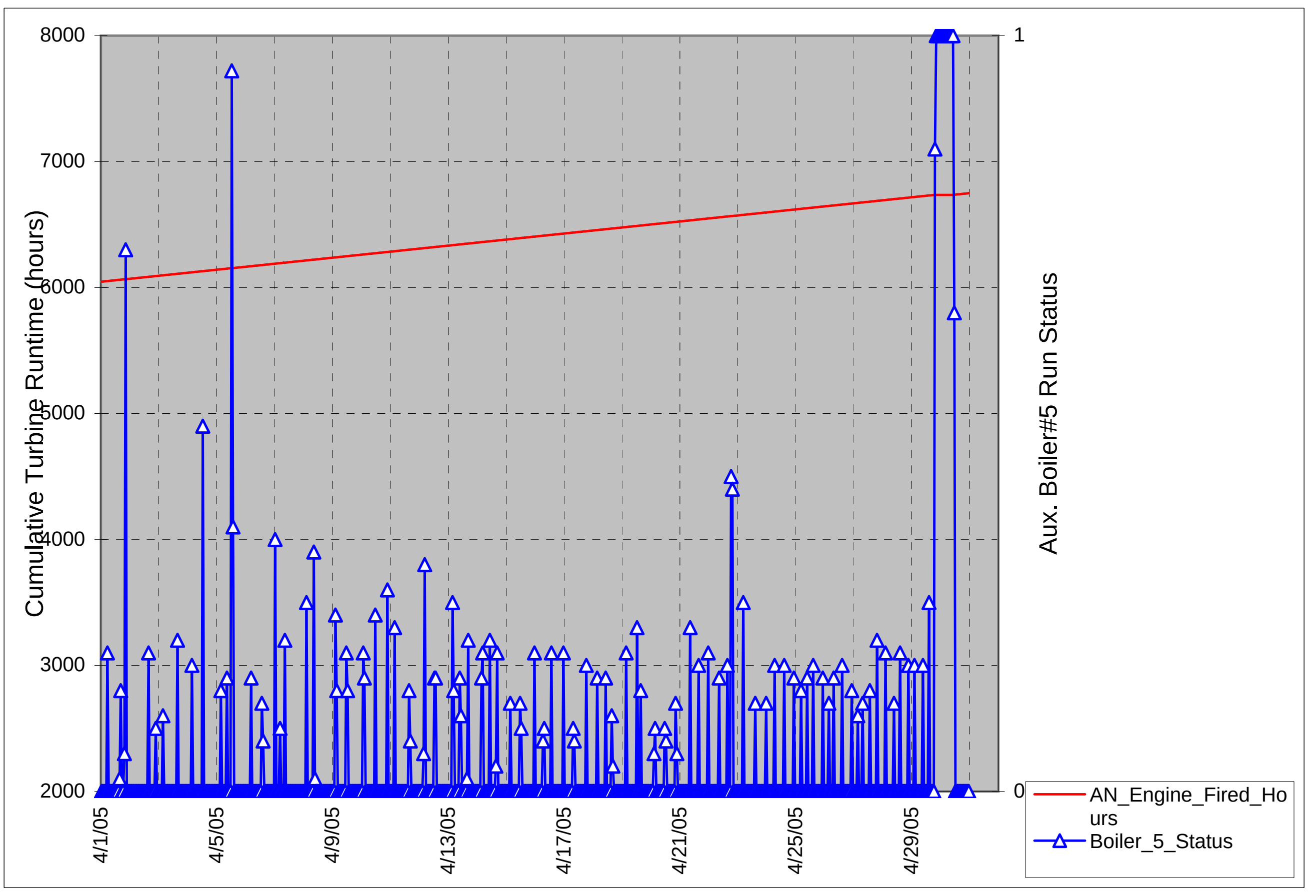
Appendix D

Detailed Operational Data: April 2005

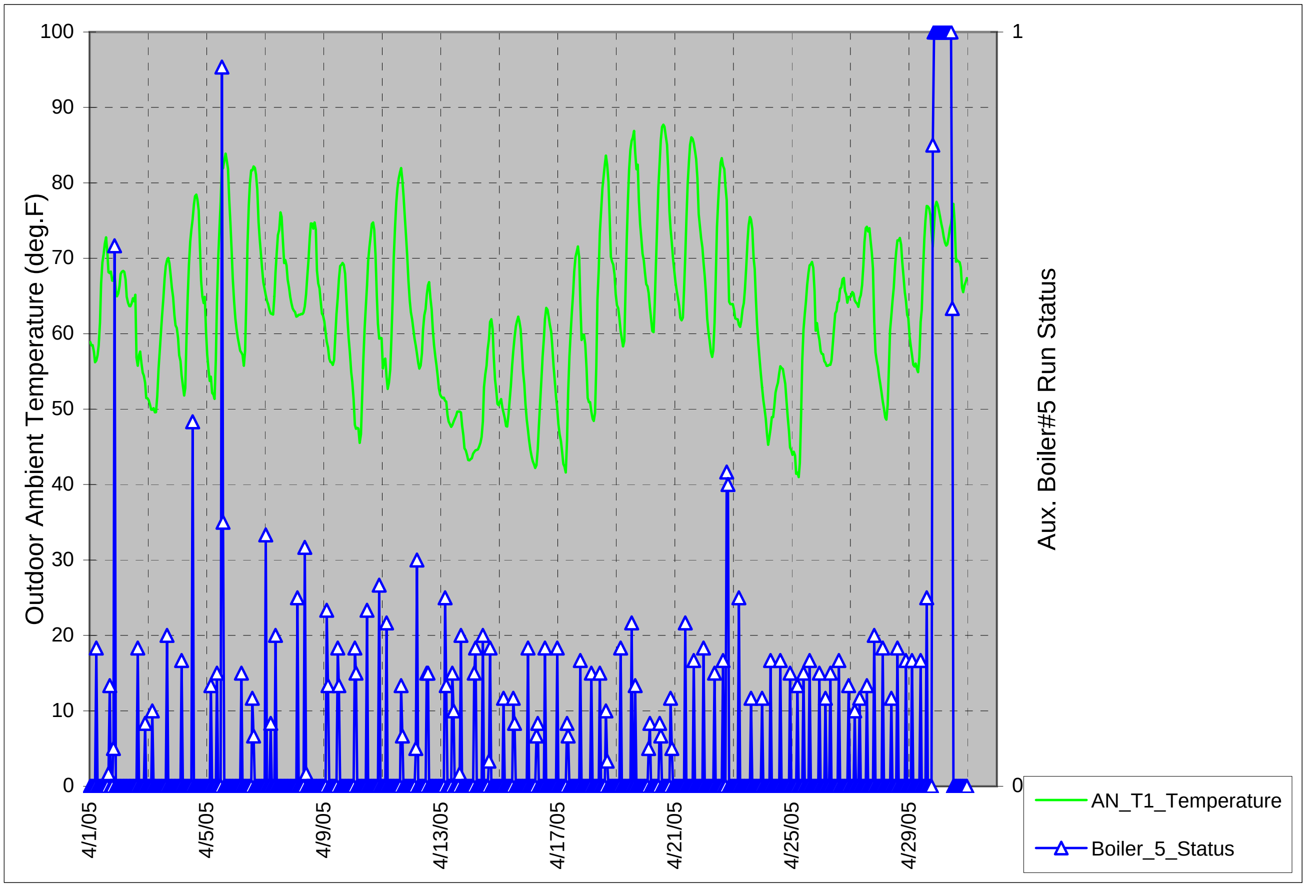
Misc. Plots



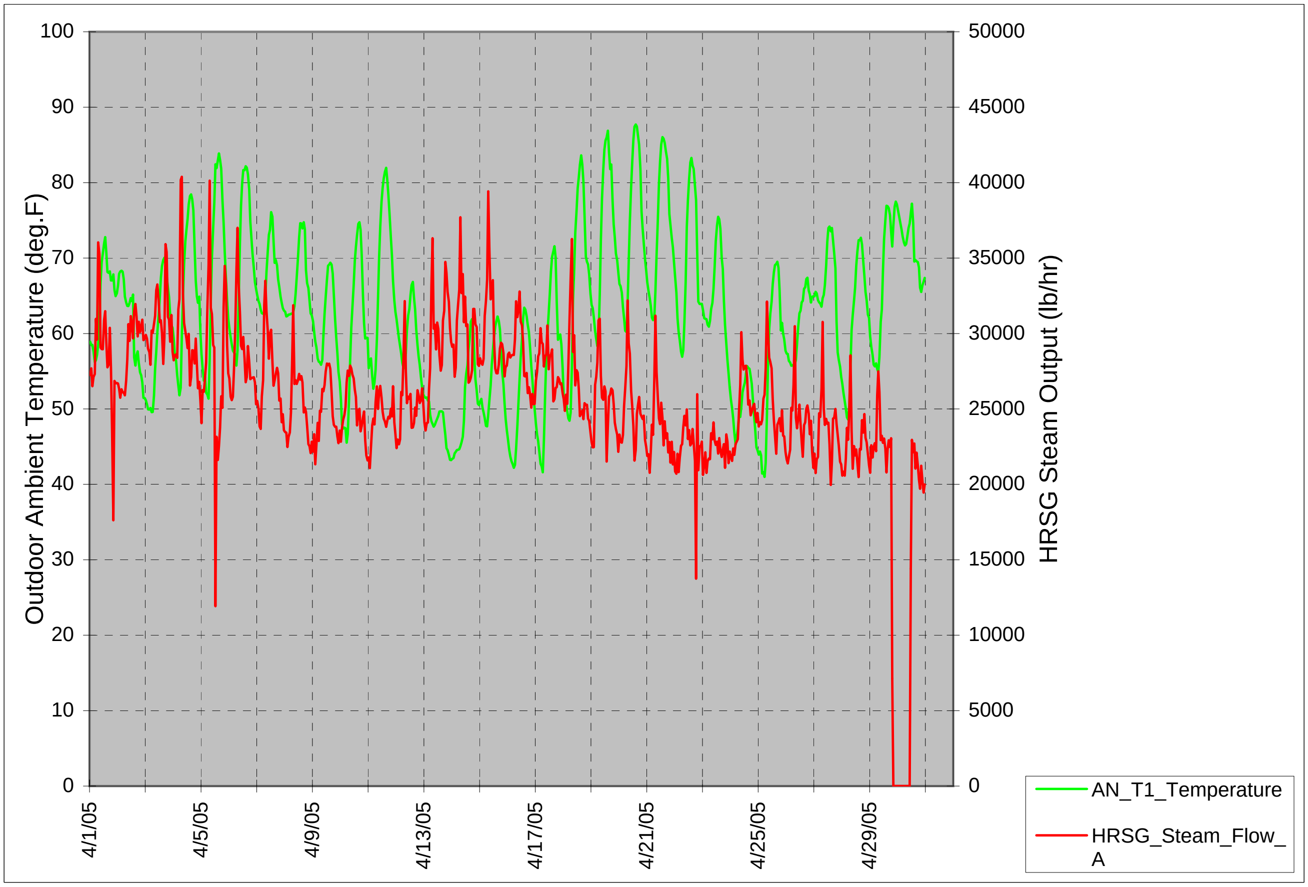
8000
7000
6000
5000
4000
3000
2000
6000
5000
4000
3000
2000
1000
0
Cumulative Turbine Runtime (hours)
Turbine Power Output (kW)
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_Engine_Fired_Hours
AN_Total_kW



8000
7000
6000
5000
4000
3000
2000
1
0
Cumulative Turbine Runtime (hours)
Aux. Boiler#5 Run Status
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_Engine_Fired_Hours
Boiler_5_Status

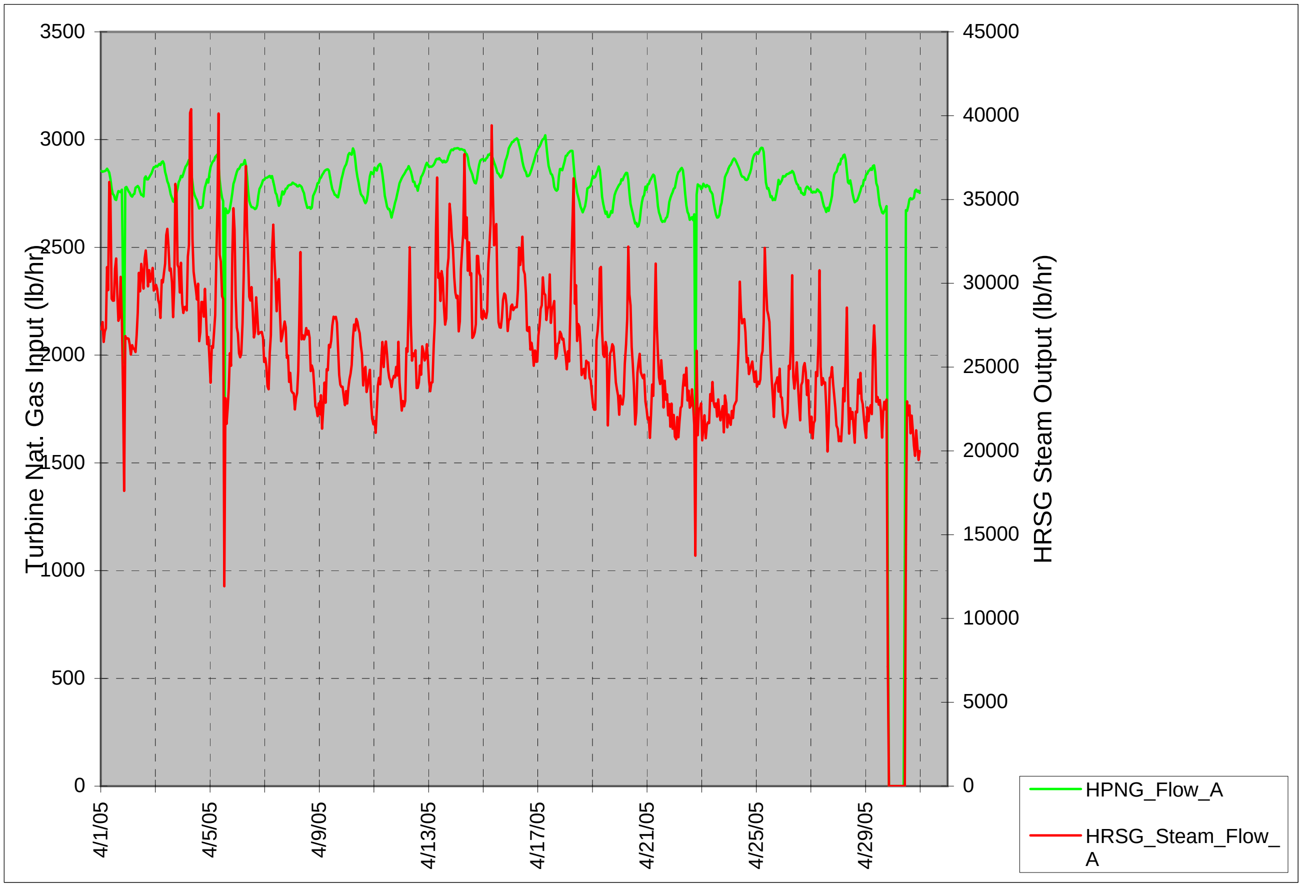


Outdoor Ambient Temperature (deg.F)
Aux. Boiler#5 Run Status
100
90
80
70
60
50
40
30
20
10
0
1
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_T1_Temperature
Boiler_5_Status

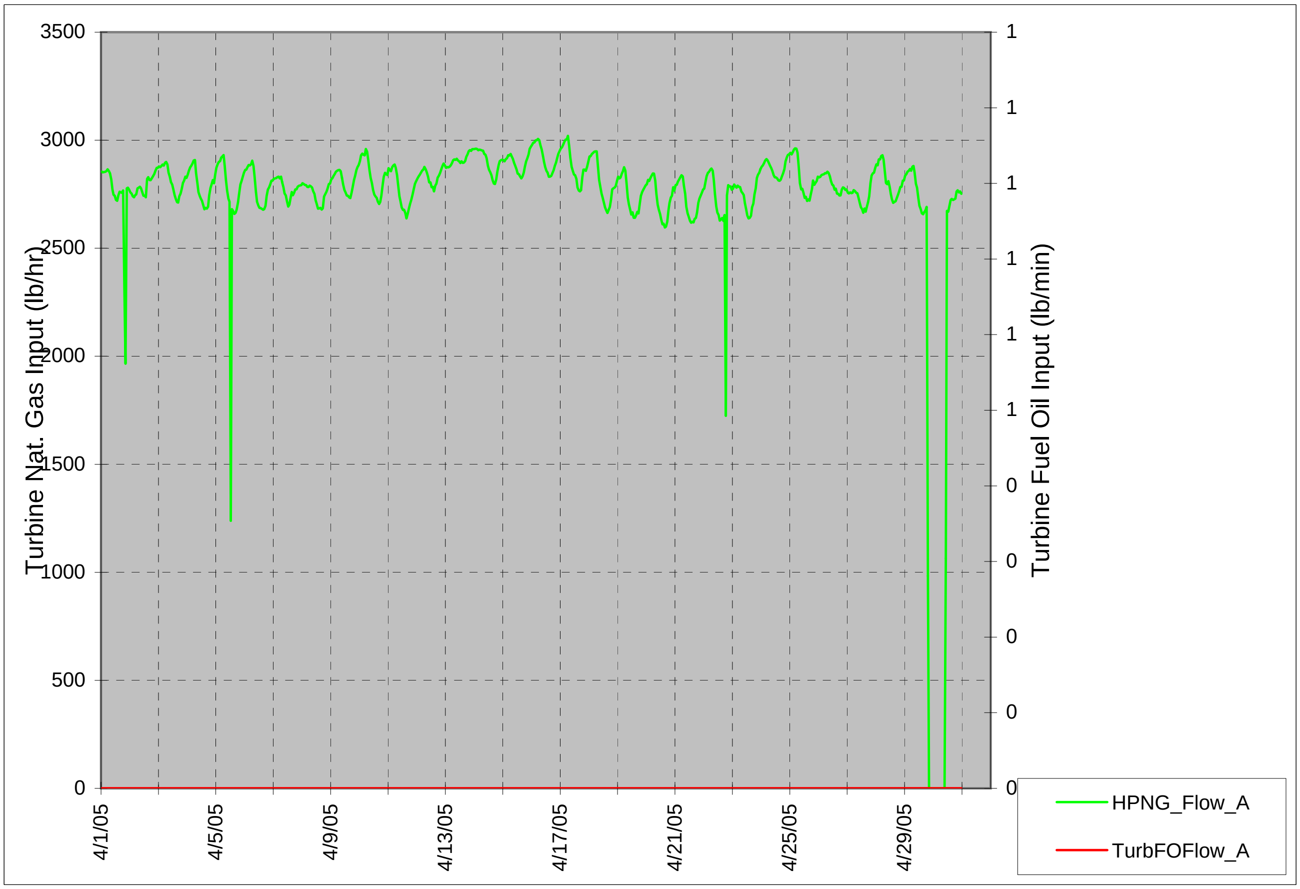


Outdoor Ambient Temperature (deg.F)
HRSG Steam Output (lb/hr)
100
90
80
70
60
50
40
30
20
10
0
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_T1_Temperature
HRSG_Steam_Flow_A

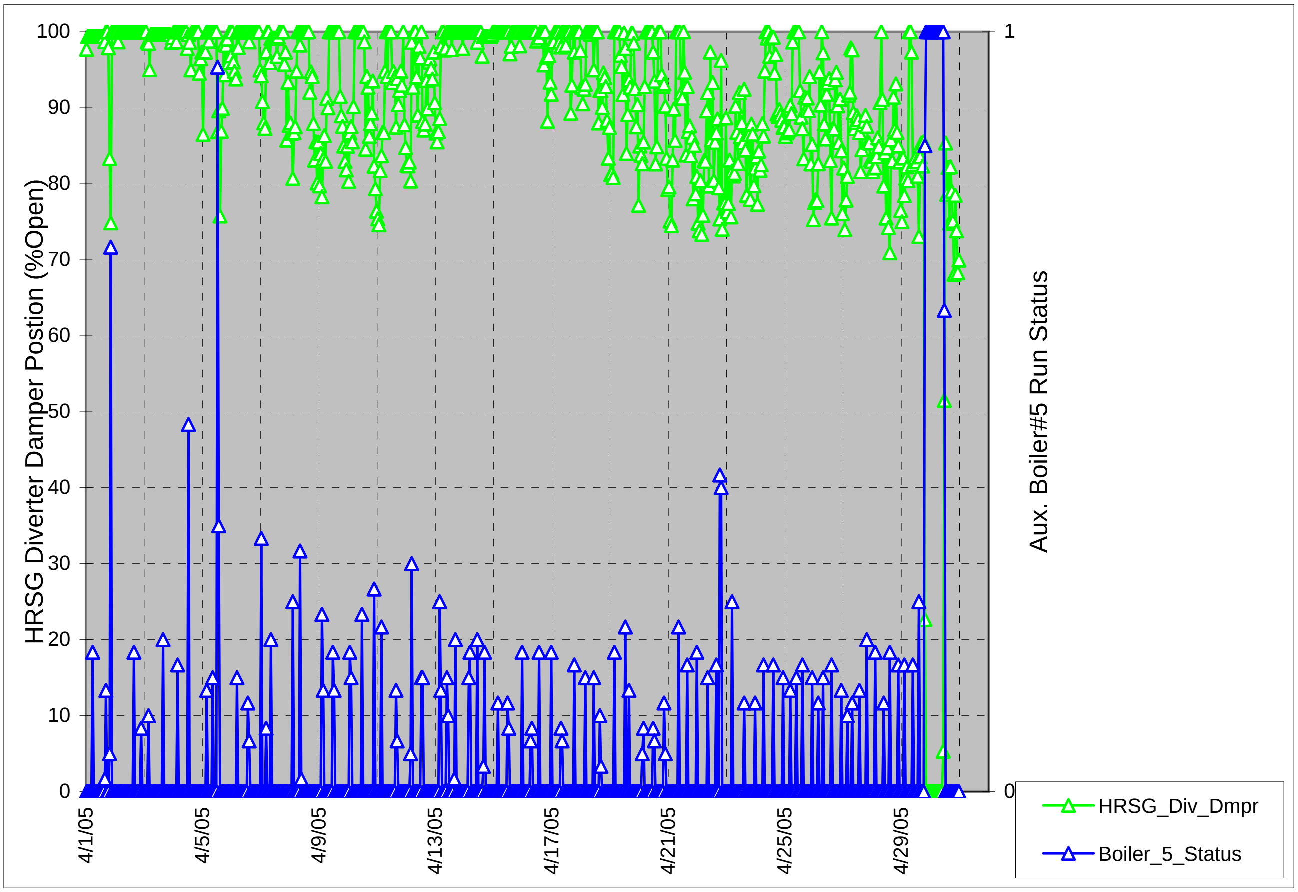
Misc. Plots



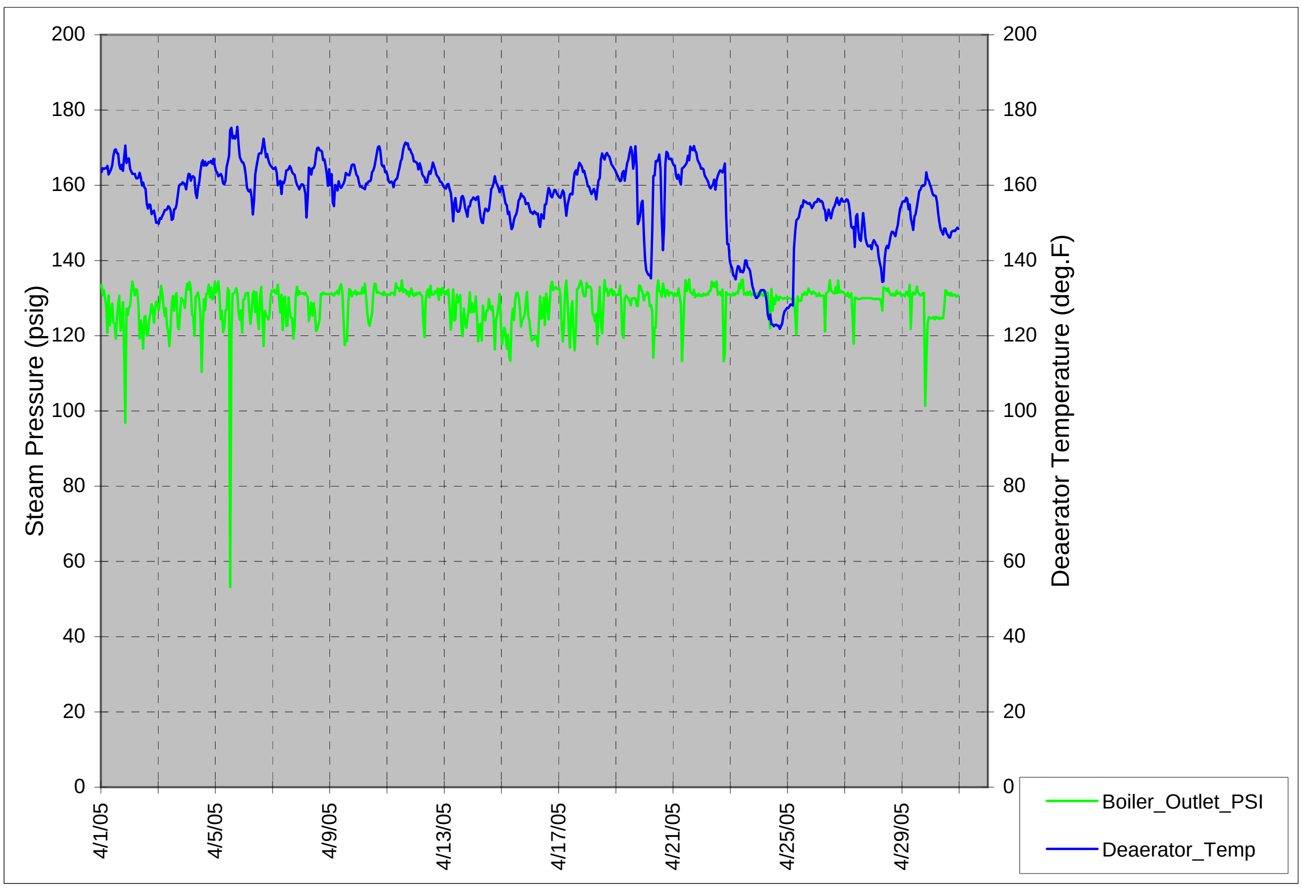
3500
3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
HRSG Steam Output (lb/hr)
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
HPNG_Flow_A
HRSG_Steam_Flow_A



3500
3000
2500
2000
1500
1000
500
0
Turbine Nat. Gas Input (lb/hr)
1
1
1
1
1
1
0
0
0
0
0
Turbine Fuel Oil Input (lb/min)
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
HPNG_Flow_A
TurbFOFlow_A



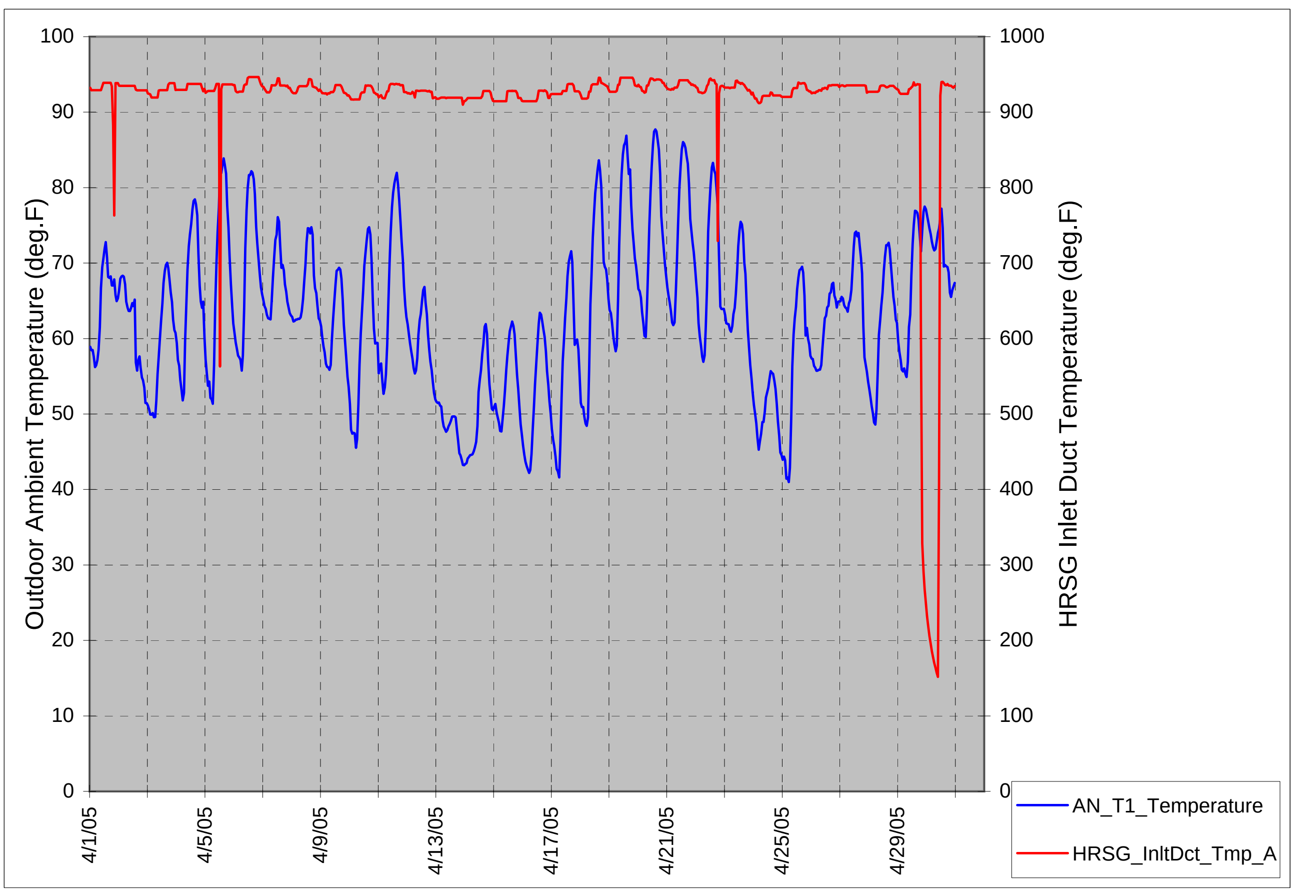
HRSG Diverter Damper Postion (%Open)
Aux. Boiler#5 Run Status
100
90
80
70
60
50
40
30
20
10
0
1
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
HRSG_Div_Dmpr
Boiler_5_Status



Steam Pressure (psig)
Deaerator Temperature (deg.F)
200
180
160
140
120
100
80
60
40
20
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Boiler_Outlet_PSI
Deaerator_Temp

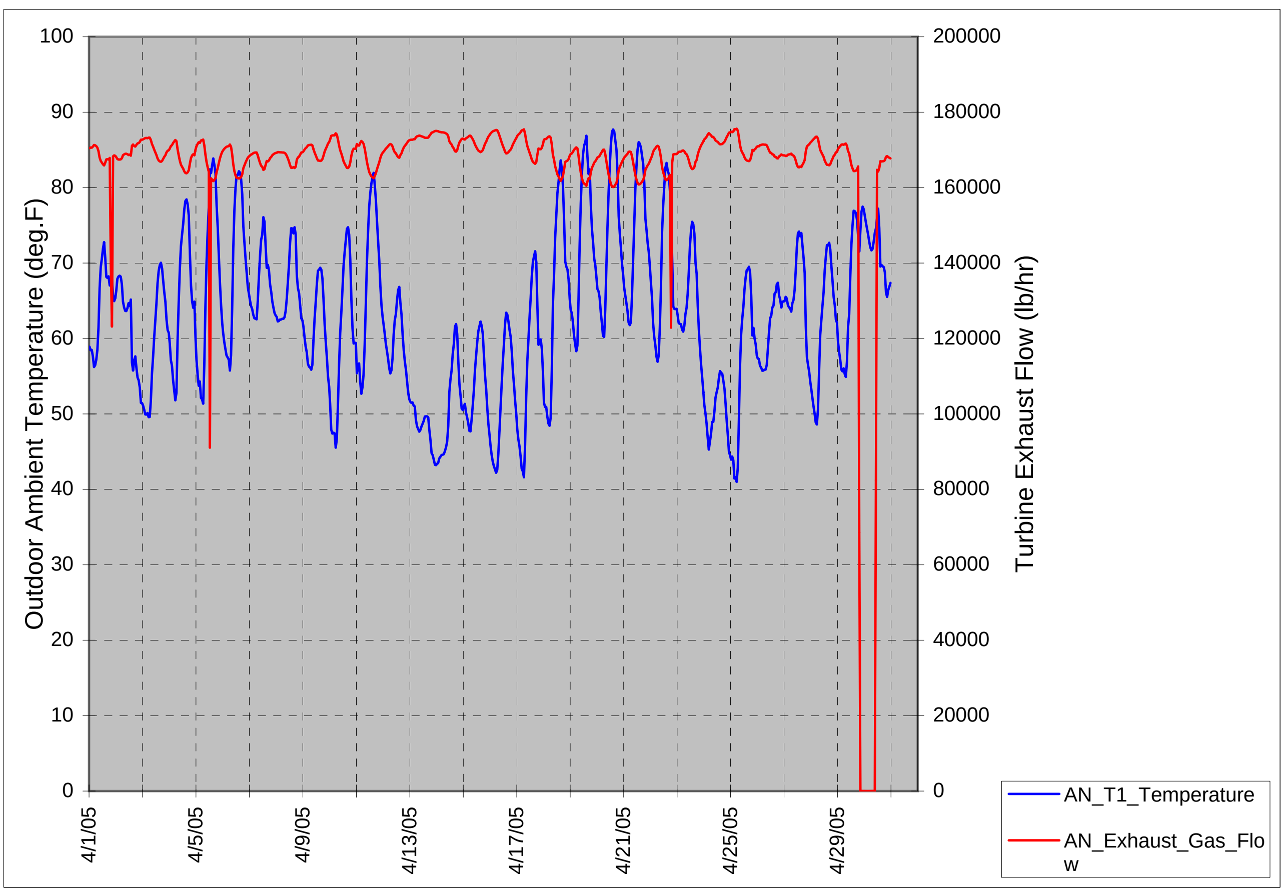
Misc. Plots

Turbine Nat. Gas Input (lb/hr)
HRSG Inlet Duct Temperature (deg.F)
3500
3000
2500
2000
1500
1000
500
0
1000
900
800
700
600
500
400
300
200
100
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
HPNG_Flow_A
HRSG_InltDct_Tmp_A

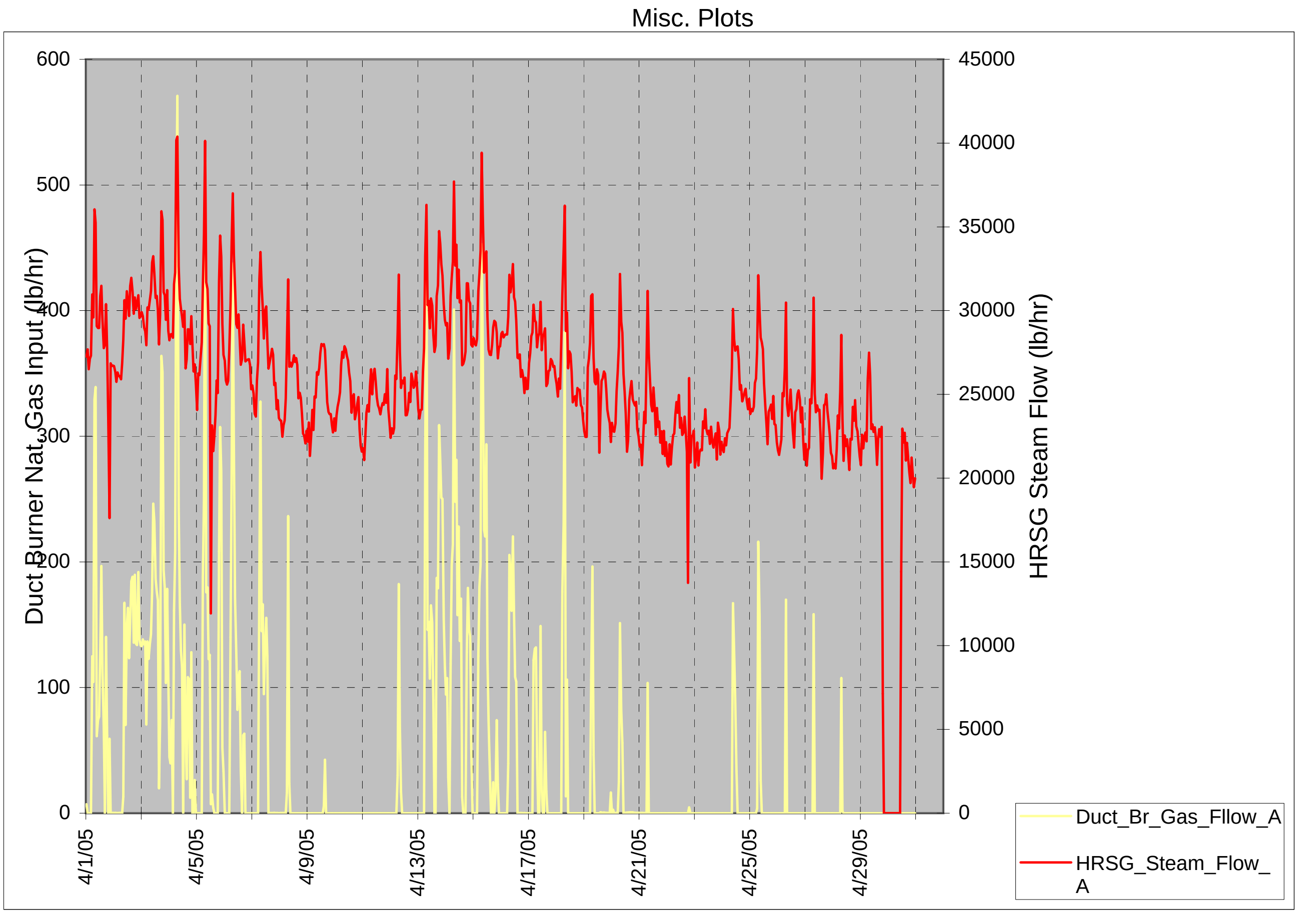


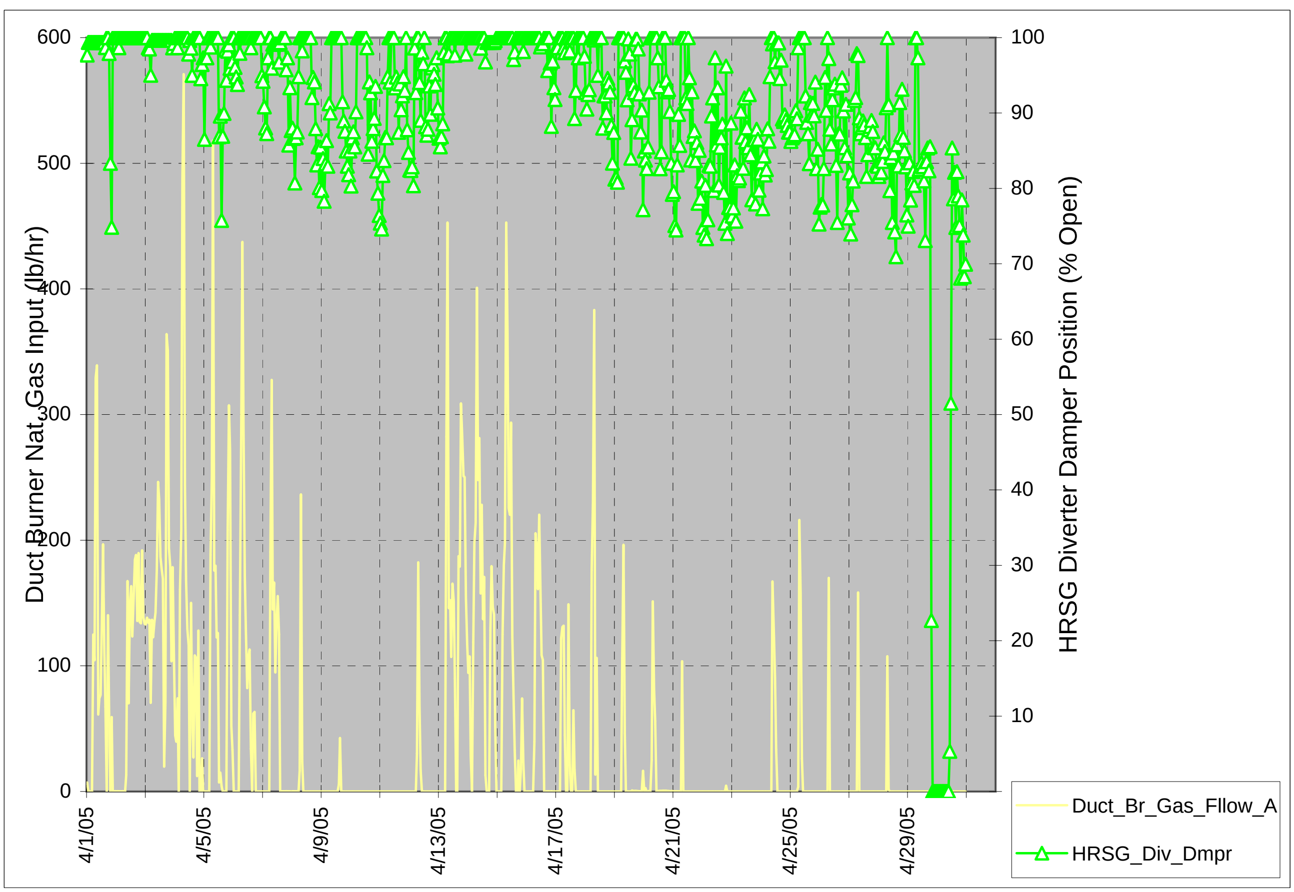
Outdoor Ambient Temperature (deg.F)
HRSG Inlet Duct Temperature (deg.F)
100
90
80
70
60
50
40
30
20
10
0
1000
900
800
700
600
500
400
300
200
100
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_T1_Temperature
HRSG_InltDct_Tmp_A

Turbine Power Output (kW)
Turbine Exhaust Flow (lb/hr)
6000
5000
4000
3000
2000
1000
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_Total_kW
AN_Exhaust_Gas_Flow



Outdoor Ambient Temperature (deg.F)
Turbine Exhaust Flow (lb/hr)
100
90
80
70
60
50
40
30
20
10
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
AN_T1_Temperature
AN_Exhaust_Gas_Flow


Misc. Plots
600
500
400
300
200
100
0
Duct Burner Nat. Gas Input (lb/hr)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
HRSG Steam Flow (lb/hr)
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Duct_Br_Gas_Fllow_A
HRSG_Steam_Flow_A


600
500
400
300
200
100
0
Duct Burner Nat. Gas Input (lb/hr)
100
90
80
70
60
50
40
30
20
10
HRSG Diverter Damper Position (% Open)
4/1/05
4/5/05
4/9/05
4/13/05
4/17/05
4/21/05
4/25/05
4/29/05
Duct_Br_Gas_Fllow_A
HRSG_Div_Dmpr