Monitoring Heat Rates as a Troubleshooting Tool

GMRC – Engine Analyzer &
Reliability Workshop
July 27 – 29, 2011
Loews Vanderbilt
Nashville, Tennessee

Introduction

Charlie Harrison

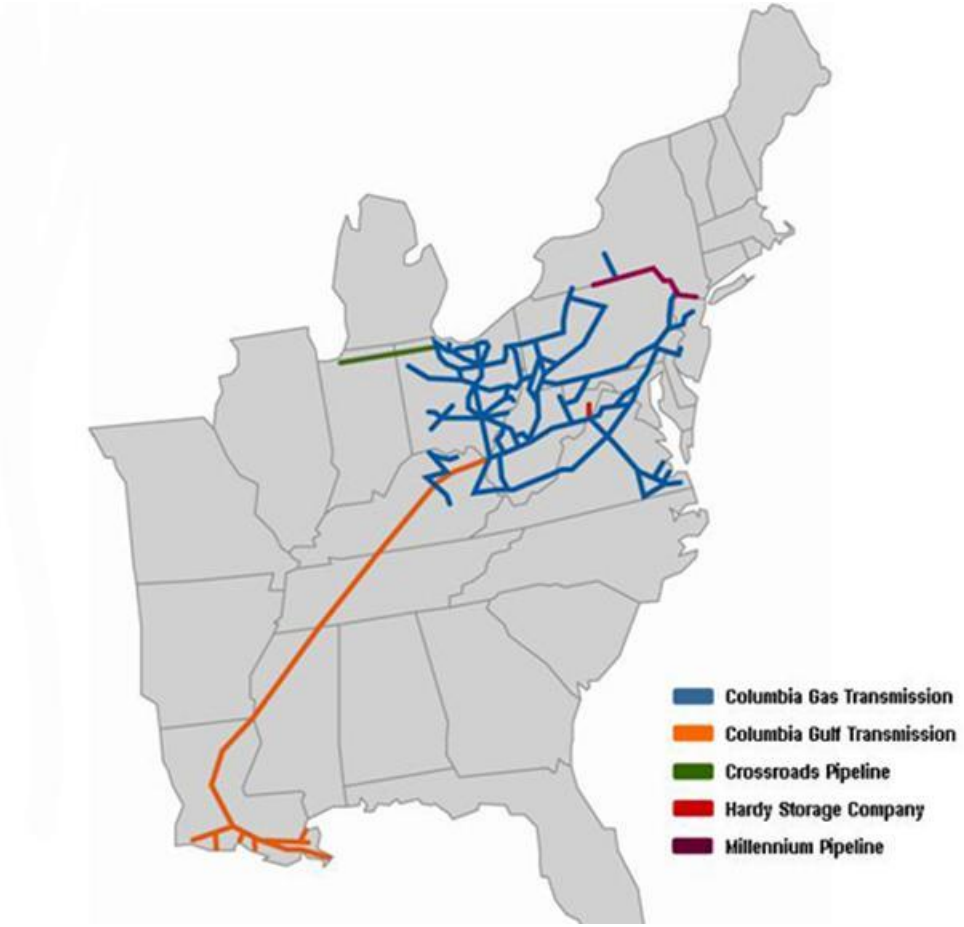
Lead Engineer

Columbia Gas Transmission

NiSource

- Columbia Gas of Pennsylvania (CPA)
- Columbia Gas Transmission (TCO)
- Columbia Gulf Transmission (CGT)
- Crossroads
- Hardy County Storage
- Midstream
- Millennium

NiSource


Columbia Gas Transmission
Columbia Gulf Transmission
Crossroads Pipeline
Hardy Storage Company
Millennium Pipeline

NiSource

	CPA	TCO	CGT	Crossroads	Hardy Storage	Midstream	Millennium	Totals
Compressor Stations	1	90	11	1	1	1	2	107
Total Horsepower	800	620,209	470,238	3000	7100	5280	19,020	1,125,647
Compressor Units	1	320	77	1	2	4	4	409
Reciprocating Units	1	232	53	0	2	4	3	295
Turbine Units	0	72	22	0	0	0	1	95
Electric Motor Units	0	16	2	1	0	0	0	19

Why on-line monitoring ?

- Infrastructure exists
- Programming tools exist
- Need to verify torque control programming
- Need to verify horsepower
- Need to verify surge control programming
- Need supporting tool for verifying the health of engines & compressors
- Need a tool for indicating trouble spots

Information – Reciprocating Engines & Compressors

- Horsepower
- Heat Rate / Fuel Consumption
- Throughput
- Unloading step
- Gas compressor discharge temperature
- Rod load
- Degrees of pin reversal

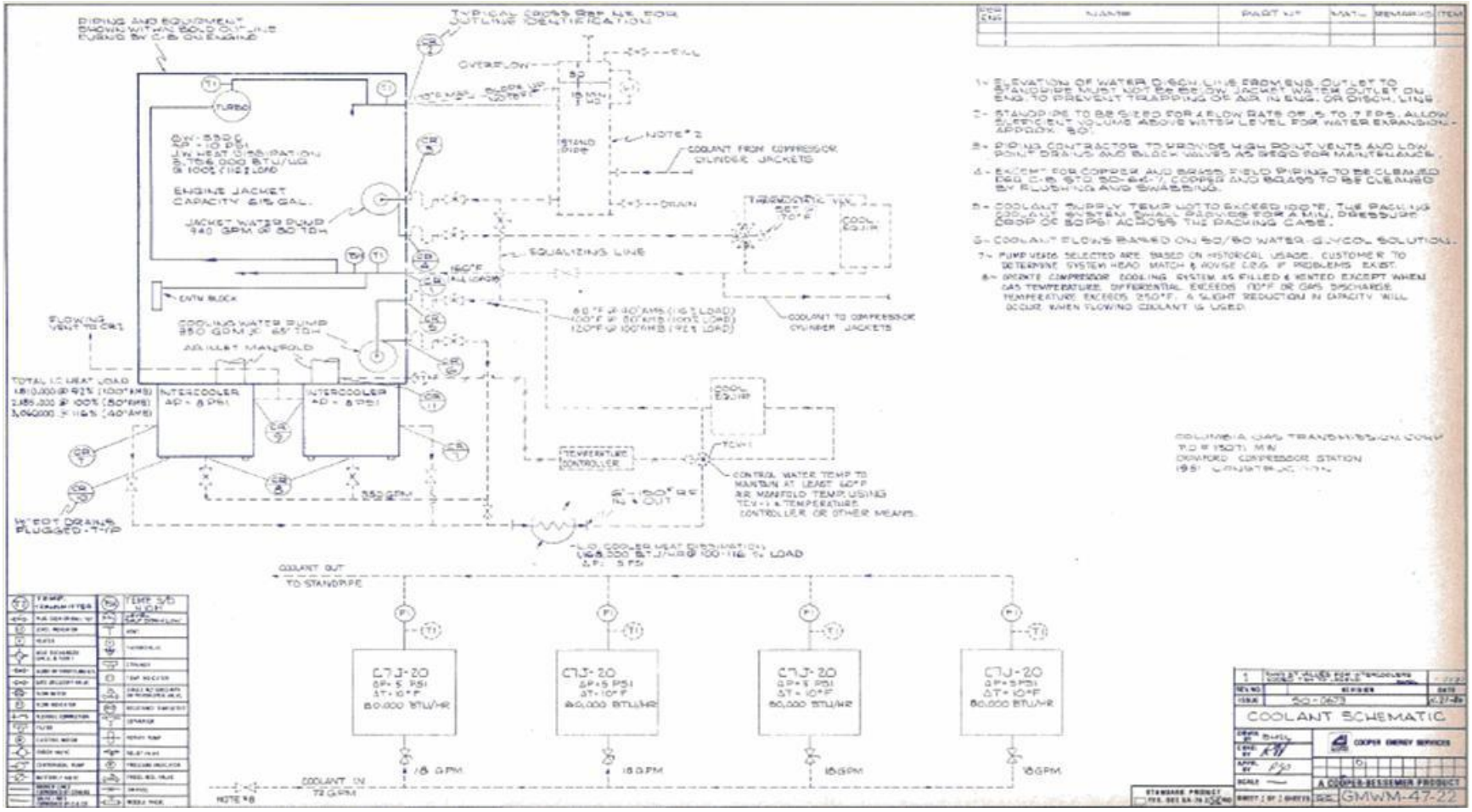
Information – Gas Turbine & Centrifugal Compressor

- Horsepower
- Heat Rate / Fuel Consumption
- Throughput
- Gas Compressor Discharge Temperature
- Surge Margin / Turndown
- Air compressor discharge pressure (Pcd)
- T5 (Solar)
- Exhaust Temperature (T7 – Solar)

Heat Rate

- Can be defined as the rate of fuel energy needed to produce one (1) unit of power.
- In the ‘perfect world,’ an engine would have a heat rate of 2545 BTU/BHP-hr.
- Is another way of representing thermal efficiency.

Coolant Schematic



BTU

- “BTU” stands for British Thermal Unit
- Equivalent to 778.26 ft-lbf
- Units of ‘work’ are also “ft-lbf”

Horsepower

- A horsepower is equivalent to 33,000 ft-lbf/minute
- Can also be described as “the rate of doing work”

Heating Value of Fuel – Higher and Lower

- “Higher Heating Value” is abbreviated as “HHV”
- HHV assumes that the water content of the exhaust condenses
- “Lower Heating Value” is abbreviated as “LHV”
- LHV assumes that the water content of the exhaust remains in vapor form.
- LHV can be approximated as 91.5% of HHV

Heat Rate Models – Reciprocating Engines

CAT
G3606
G3612
G3616

Cooper-Bessemer
LSV-12
LSV-16
GMV-6TF
GMV-8TF
GMV-10TF
GMV-6STF
GMV-8STF
GMVA-6
GMVA-8
GMVC-8
GMVH-10
GMWA-8
GMWC-8
GMWH-8

Clark
TLA-6
TLA-8
TLA-10
TLAD-10
TRA-6
HSRA-8T

Ingersoll-Rand
36KVS
36KVSRA
410KVG-1
412KVG-1
412KVGB
48KVS
83KVG-1

Superior
6GTLB
8GTLB

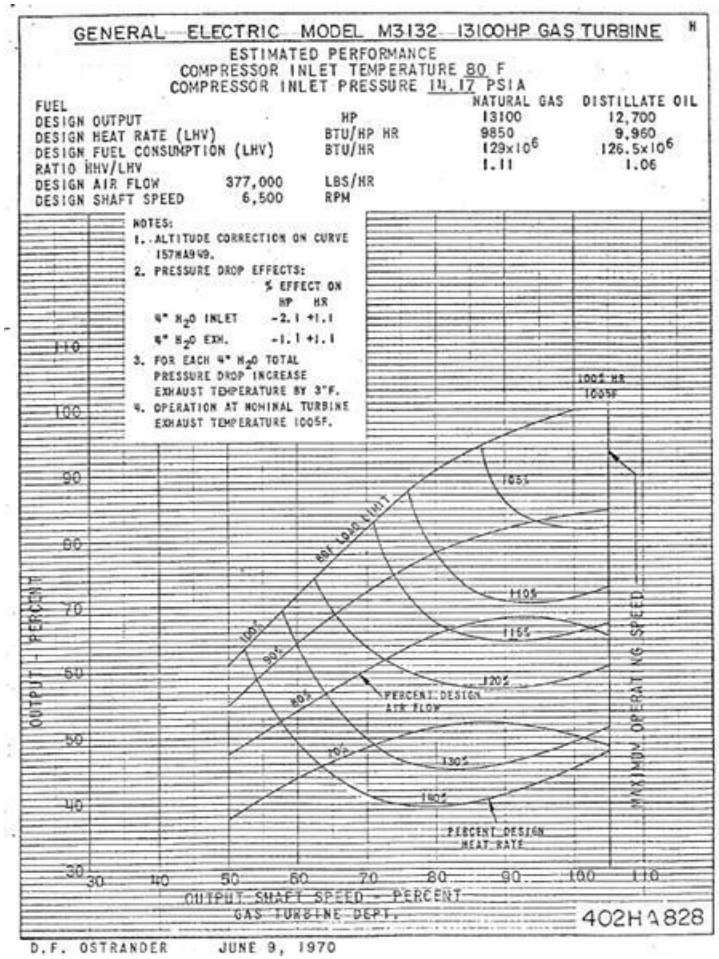
Waukesha
3711GU
5108G
7042G
H2475GU

Worthington
ML-10

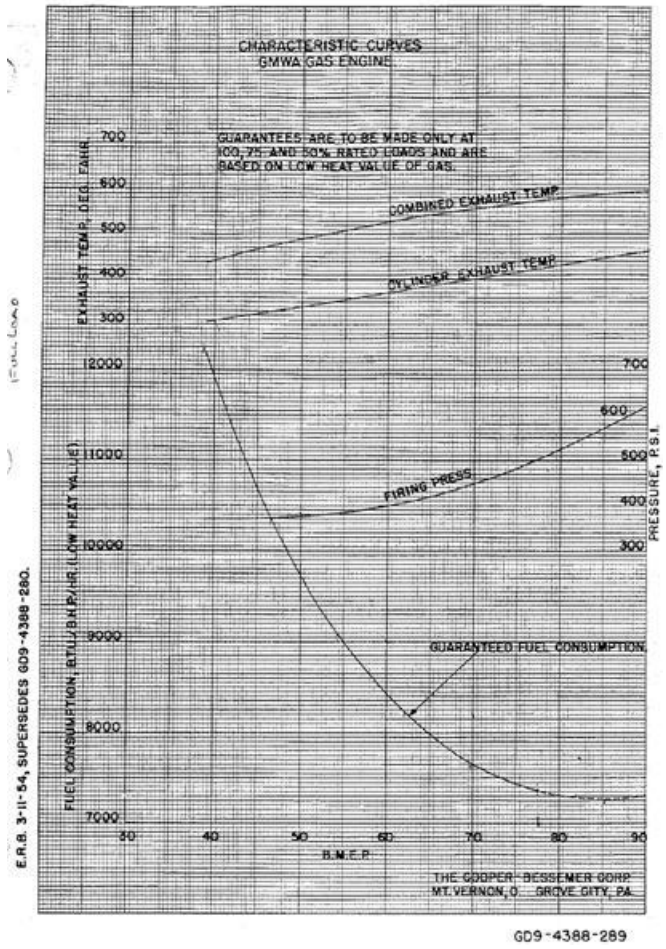
Heat Rate Models – Gas Turbines

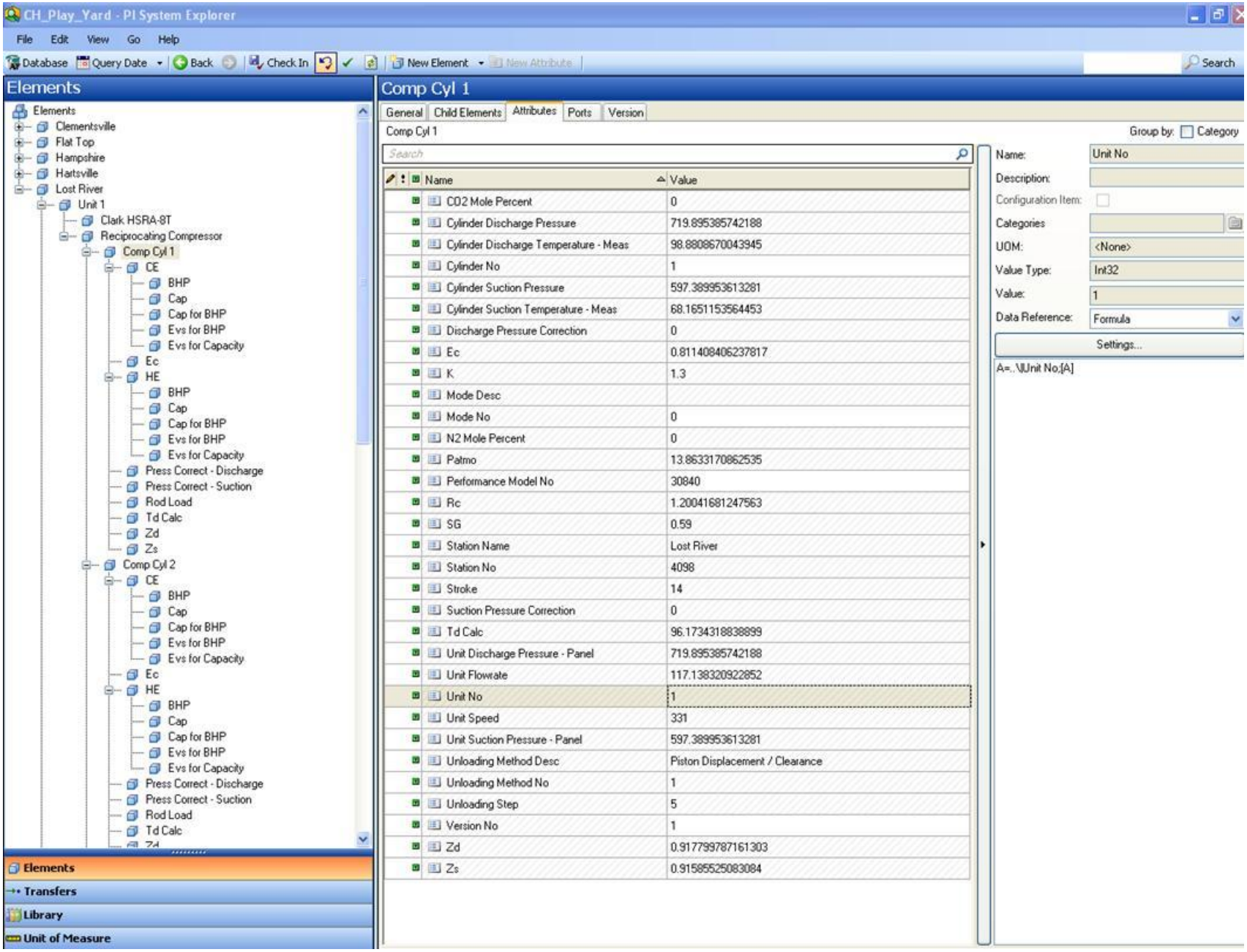
Dresser-Rand	**Solar**
D-R 22 (Allison)	Saturn T1002
	Saturn T1202
Pratt & Whitney	Saturn T1302
GG3	Centaur 40 T4002
GG4	Centaur 40 T4502
	Centaur 40 T4702S
Rolls-Royce	Taurus 60 T7002S
Avon	Taurus 60 T7302S
	Taurus 60 T7802S
	Mars 90 T12002
	Mars 100 T15002S
	Titan 130 T19502S
	Titan 130 T19802S
	Titan 250 T30002S

Heat Rate – Manufacturer's Info
2-shaft Gas Turbine



Heat Rate – Manufacturer's Info
Reciprocating Engine




CH_Play_Yard - PI System Explorer
File Edit View Go Help
Database Query Date Back Check In New Element New Attribute Search
Elements
Elements
Clementsville
Flat Top
Hampshire
Hartsville
Lost River
Unit 1
Clark HSRA-8T
Reciprocating Compressor
Comp Cyl 1
CE
BHP
Cap
Cap for BHP
Evs for BHP
Evs for Capacity
Ec
HE
BHP
Cap
Cap for BHP
Evs for BHP
Evs for Capacity
Press Correct - Discharge
Press Correct - Suction
Rod Load
Td Calc
Zd
Zs
Comp Cyl 2
CE
BHP
Cap
Cap for BHP
Evs for BHP
Evs for Capacity
Ec
HE
BHP
Cap
Cap for BHP
Evs for BHP
Evs for Capacity
Press Correct - Discharge
Press Correct - Suction
Rod Load
Td Calc
Zd
Elements
Transfers
Library
Unit of Measure
Comp Cyl 1
General Child Elements Attributes Ports Version
Comp Cyl 1
Group by: Category
Search
Name Value
CO2 Mole Percent 0
Cylinder Discharge Pressure 719.895385742188
Cylinder Discharge Temperature - Meas 98.8808670043945
Cylinder No 1
Cylinder Suction Pressure 597.389953613281
Cylinder Suction Temperature - Meas 68.1651153564453
Discharge Pressure Correction 0
Ec 0.811408406237817
K 1.3
Mode Desc
Mode No 0
N2 Mole Percent 0
Patmo 13.8633170862535
Performance Model No 30840
Rc 1.20041681247563
SG 0.59
Station Name Lost River
Station No 4098
Stroke 14
Suction Pressure Correction 0
Td Calc 96.1734318838899
Unit Discharge Pressure - Panel 719.895385742188
Unit Flowrate 117.138320922852
Unit No 1
Unit Speed 331
Unit Suction Pressure - Panel 597.389953613281
Unloading Method Desc Piston Displacement / Clearance
Unloading Method No 1
Unloading Step 5
Version No 1
Zd 0.917799787161303
Zs 0.91585525083084
Name: Unit No
Description:
Configuration Item:
Categories
UOM: <None>
Value Type: Int32
Value: 1
Data Reference: Formula
Settings...
A=..\Unit No,[A]

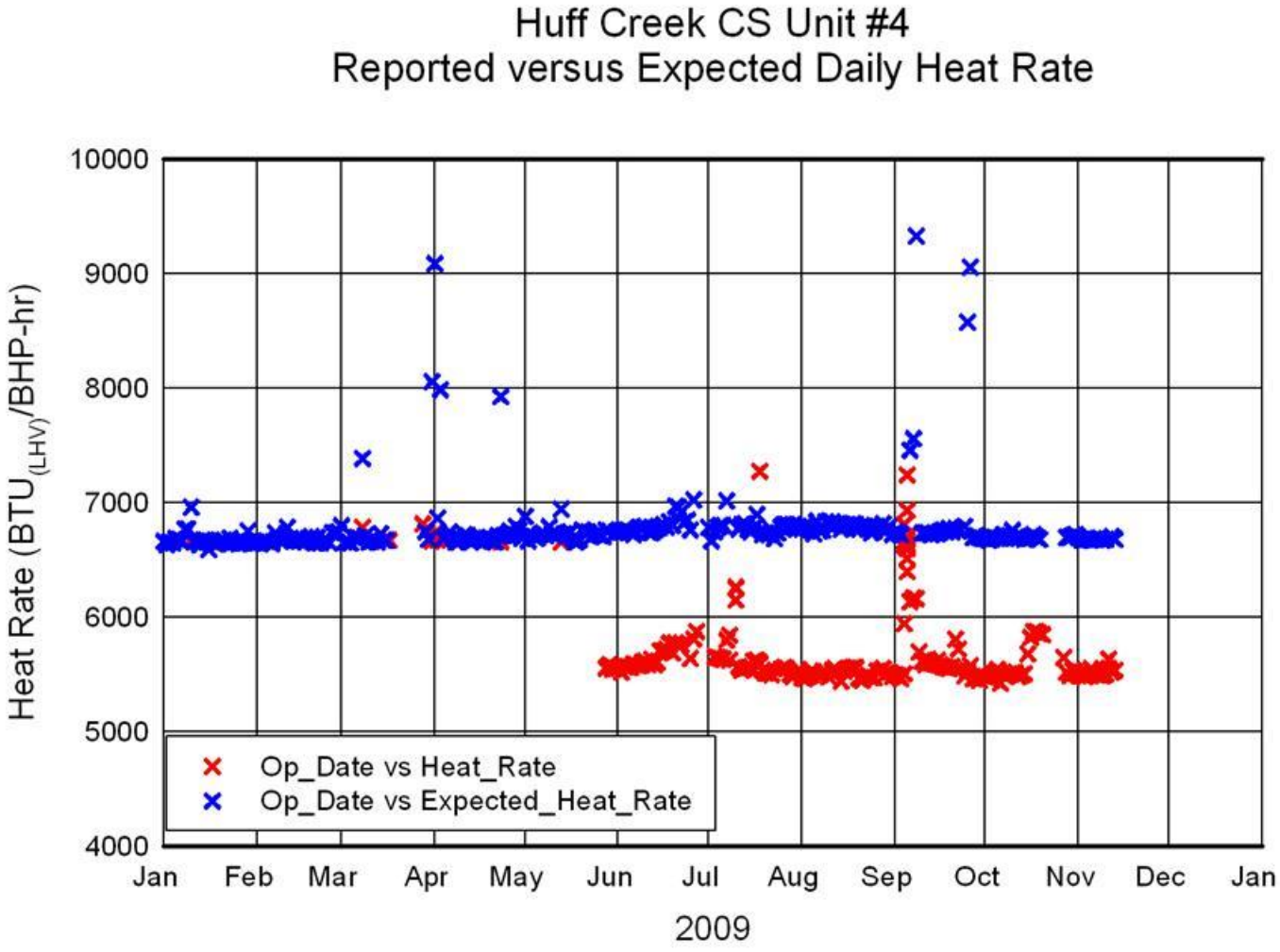
Discerning Between 'Operational" or 'Maintenance' Related Issues

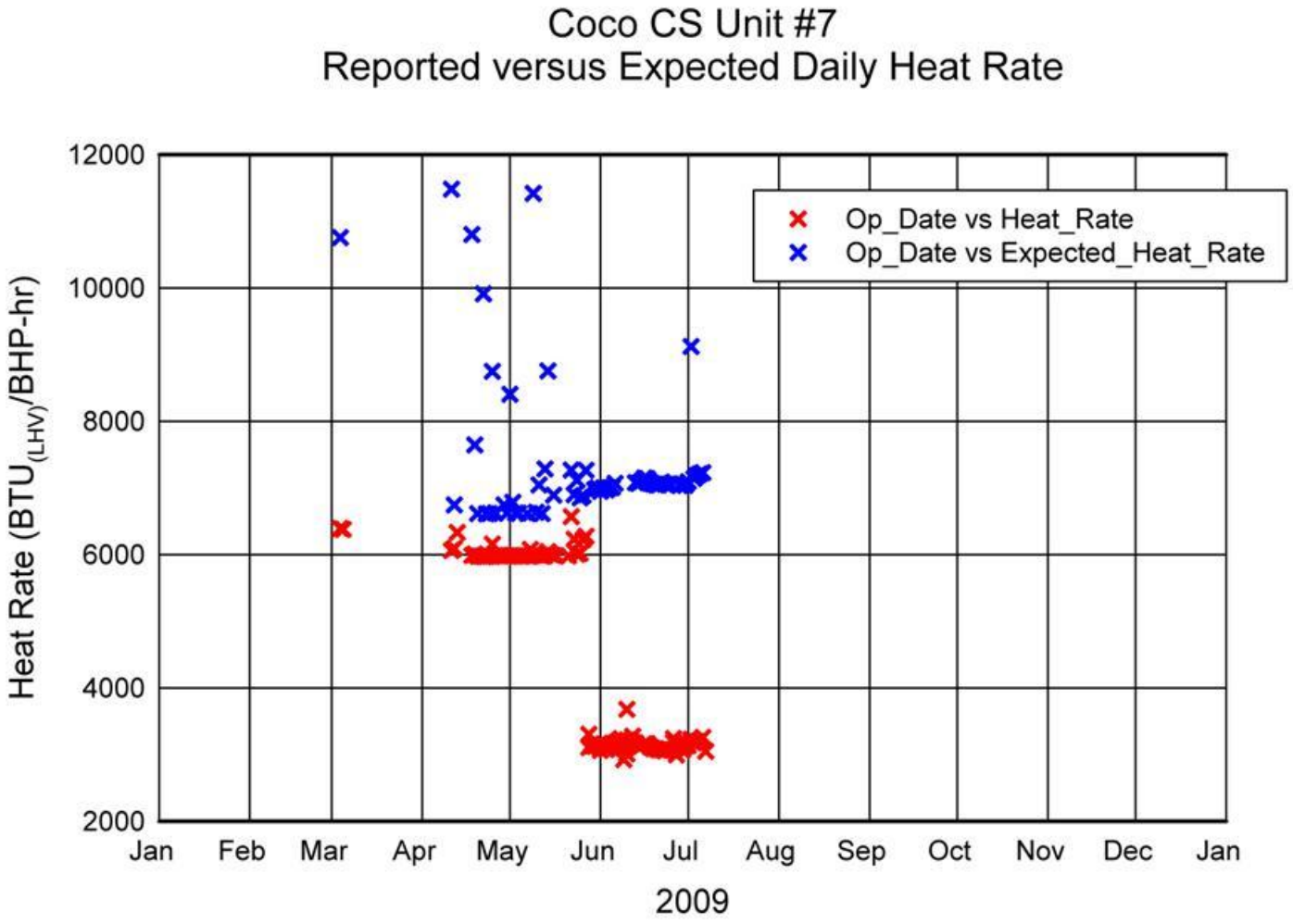
$$OperationalDifferenc\,e = \left(1 - \frac{ActualHeat\,Rate}{T\,\mathrm{arg}\,etHeatRate}\right)$$

$$Ma\,\mathrm{int}\,enanceDiff\,erence = \left(1 - \frac{ActualHeat\,Rate}{ExpectedHe\,atRate}\right)$$

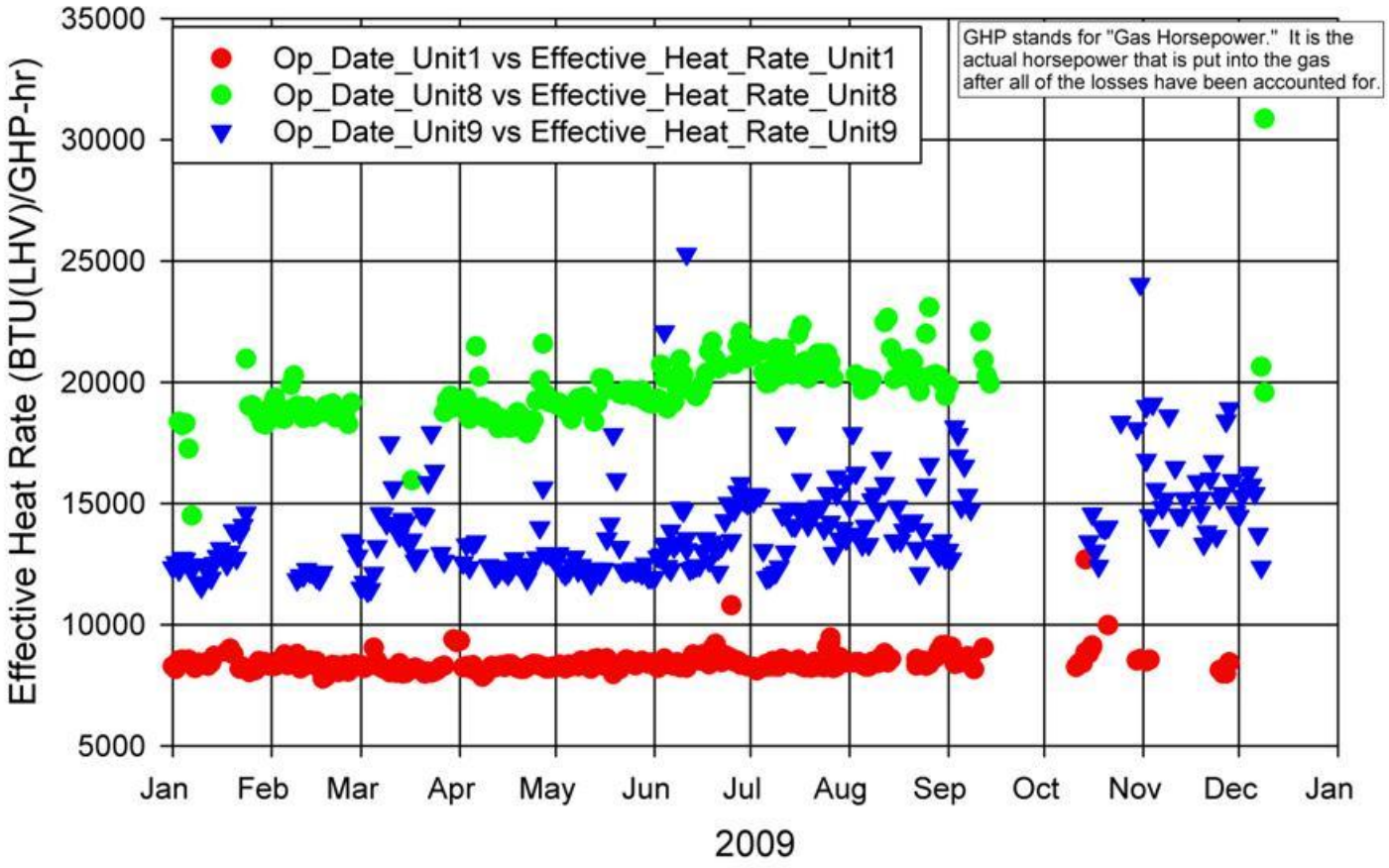
Heat Rate using Gas Horsepower

$$EffectiveHeatRate = \frac{BTU_{(LHV)}}{GasHp \cdot hr}$$

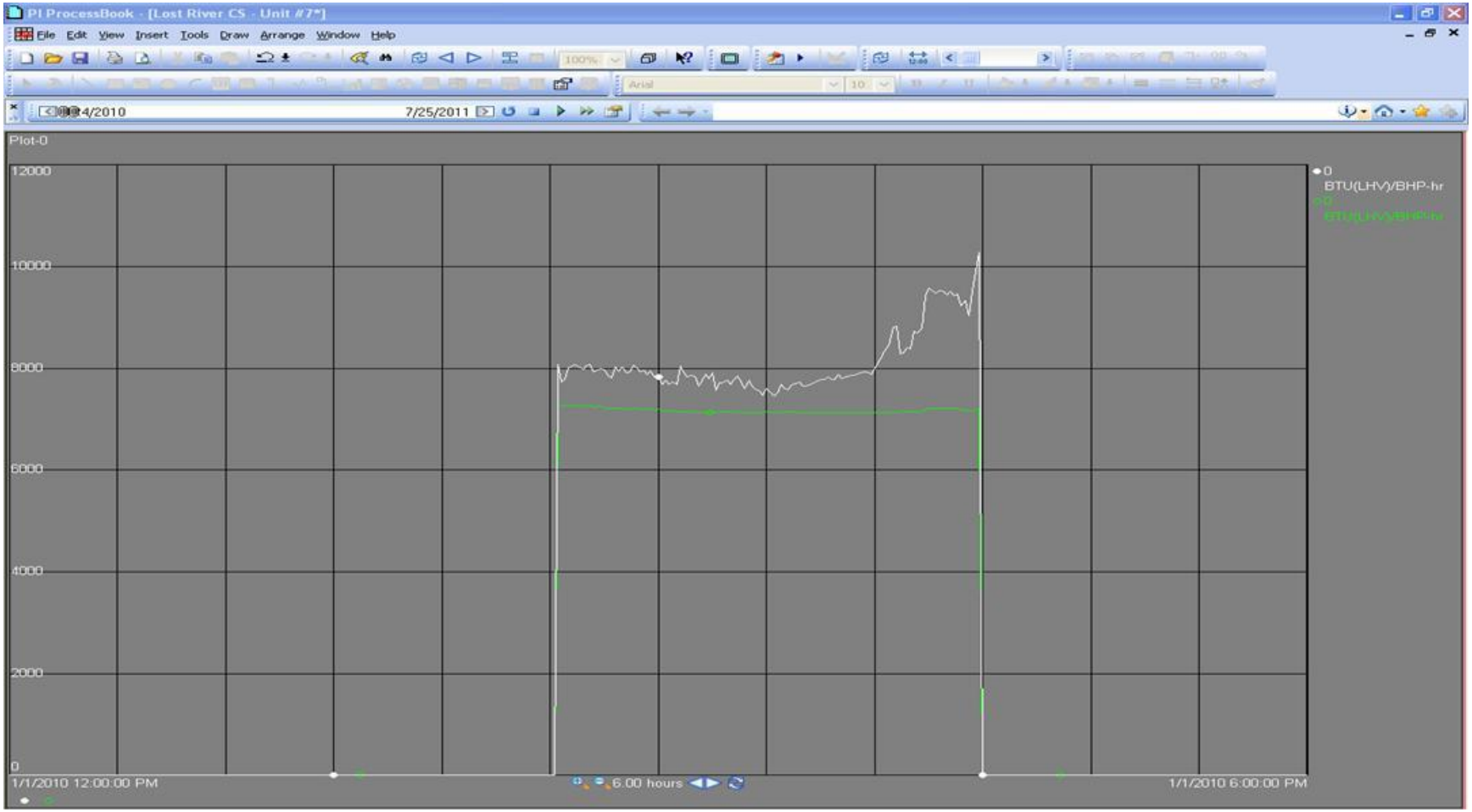

Huff Creek CS Unit #4
Reported versus Expected Daily Heat Rate
Heat Rate (BTU(LHV)/BHP-hr)
10000
9000
8000
7000
6000
5000
4000
Op_Date vs Heat_Rate
Op_Date vs Expected_Heat_Rate
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2009


Coco CS Unit #7
Reported versus Expected Daily Heat Rate
Heat Rate (BTU(LHV)/BHP-hr)
12000
10000
8000
6000
4000
2000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2009
Op_Date vs Heat_Rate
Op_Date vs Expected_Heat_Rate

Ceredo CS
Effective Heat Rate Comparison - 2009



Lost River CS Unit #7 – Failure 1/1/2010



Parting Thoughts….

- Compressor calculations whether reciprocating or centrifugal are fairly easy to build into an on-line monitoring system
- Modeling the expected performance of the engine is more difficult
- Before an on-line monitoring tool can indicate a true problem, a lot of work has to be done to verify data inputs and supporting calculations