

VIRTUAL ENERGY AUDIT

Your Power Plant on a desktop computer

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V.A.W

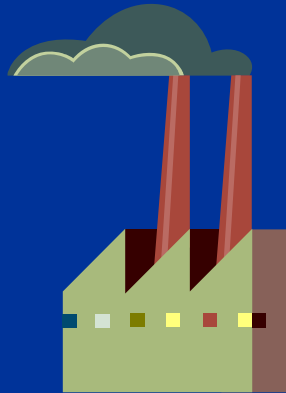
(Value Added by Werner)

COMPLEX ENVIRONMENT

FLUE TEMPERATURES

STEAM DEMAND

MECHANICAL FACTORS



FUEL MANAGEMENT

EXCESS AIR

DRIVER SELECTION

HISTORICAL FACTORS

- OPERATIONS BASED MAINLY ON INTUITION AND EXPERIENCE
- INSTRUMENTS PROVIDE THE MOST IMPORTANT DATA IN A VARIETY OF FORMATS
- ADEQUATE METHODS TO DATE
- NOTHING WRONG – BUT CAN BE IMPROVED

CONSEQUENCES

- INCOMPLETE PICTURE OF THE ENTIRE PLANT OPERATIONS
- RECORDS REFLECT ONLY A PORTION OF THE EQUIPMENT
- FORECASTING, PREDICTIONS, AND ESTIMATIONS ARE EMPIRICAL (BASED ON EXPERIENCE)

VEA

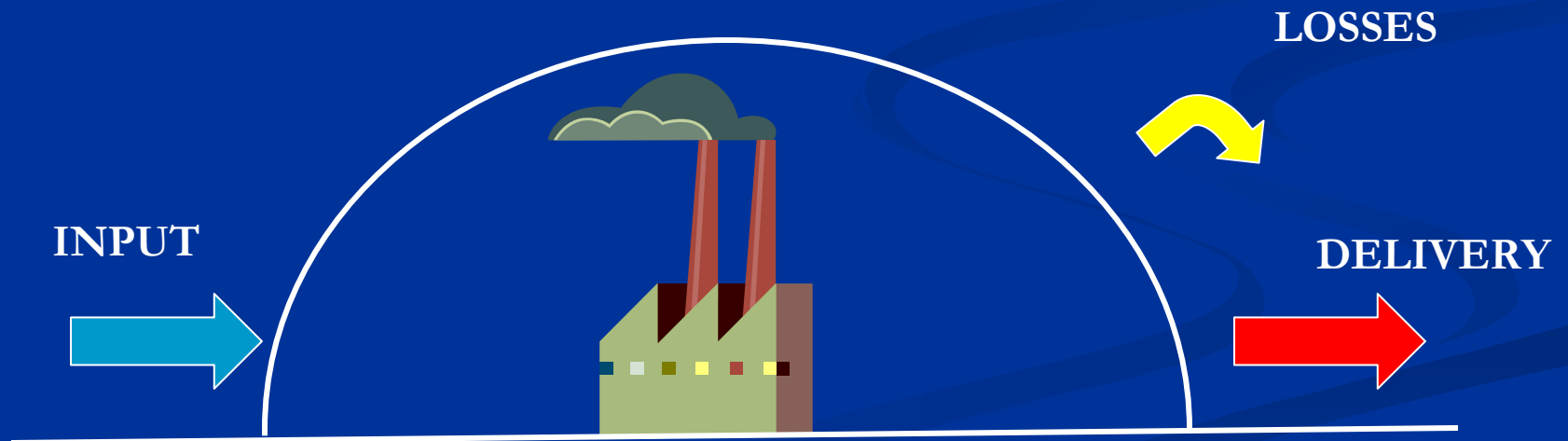
SOLUTION: The Virtual Energy Audit

- Whole plant basis – all parts working together
- Calculation with accounting leading to energy balance
- A virtual energy audit (balance) **on demand**
- Uses MS Excel – simple and direct

BASIS

ENERGY IN = ENERGY OUT*

* Product (Delivery) + Losses + Work



FUNDEMENTALS

STOICHIOMETRIC COMBUSTION

(the secret)

- *Water at temp + heat* → *Steam at pressure*
- BTU (British Thermal Unit): fixed unit
- Requirements from feed to output in a boiler is known and able to be calculated

FUEL

The fuel shown is natural gas (CH_4 mostly)

Solid Fuel (wood) given local data

Coal is common

Oil fuel given characteristics

Key: heating value at firing conditions

A LITTLE THERMODYNAMICS

- Natural Gas – most uniform
 - $\text{CH}_4 + 2 \text{O}_2 \longrightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$
 - 1 LB MOLE $\text{CH}_4 = 337,775 \text{ BTU/lb mole } \pm$
- OIL - *Varies by grade*
 - 137,000 – 150,000 BTU/gal
- Wood – *Varies by species, moisture, and dirt*
 - 8400 – 11,300 BTU/lb (dry), 8750-874 BTU/lb (wet)
- Coal – *Varies by type and location*
 - 9300 – 14,700 BTU/lb

COMBUSTION SHEET

Flue Gas Calculations

Basis		Gas Analysis		Higher Hf per lbmole		Component Value		Dry Make-Up A	
			%		%				%
Boiler Steam Product	150,000.00	Lb/hr		1.000	0.00	0.00		NG	0.7809
Flue Gas Temperature	562.30	oF						O ₂	0.2095
Excess air	15.8%	%	Oxygen	O ₂	0.000	0.00	0.00	CO ₂	0.0003
Dry bulb Temperature	400.35	oF	Carbon dioxide	CO ₂	1.000	0.00	0.00	Ar	0.0093
Dew Point Temperature	40.00	oF	Argon	Ar	0.000	0.00	0.00		
Barometric Pressure	14.66	psia	Carbon Monoxid	CO	0.000	121,759.47	0.00		
Water Inlet temperature	248.00	oF	Hydrogen	H ₂	0.000	123,163.85	0.00		
Combustion Efficiency	100.00	%	Methane	CH ₄	95.000	382,955.00	387636.80		
Blow Down	1.50	%	Ethane	C ₂ H ₆	3.000	671,252.61	20137.58		
Radiant Heat losses	2.00	%			100.00	Higher Heat Value	387,774.38	BTU/lbmole NG	
Boiler Steam Pressure	143.50	psig							
Boiler Steam Temperature	352.66	oF							

Boiler Efficiency ^{HH}	85%		NG heat	207,282,914.80	BTU/hr
Enthalpy of Steam	1,206.53	BTU/lb	Radiant	4,145,558.30	BTU/hr
Enthalpy of MJ water	216.00	BTU/lb	Blowdown	3,109,243.72	BTU/hr
Heat to generate Steam	990.53	BTU/lb			
Heat to generate Sat H ₂ O	146.86	BTU/lb			
Heat for Steam Production	992.75	BTU/lb			
Avail. Heat of Comb. NG	327,089.03	BTU/lbmole NG			

Natural Gas Heat Load	174,843,855.58	BTU/hr
Mole NG pound of Steam	329.47	#steam/lbmole NG
Mole of NG required	534.55	lbmole/hr

BASIS 1 LBMOLE/HR OF METHANE

Chemical Formula	Molecular Weight	Gross Heat of Combustion BTU/lb	Make-Up Air			Make-Up Gas			Flue Gas Produced			Steam Generated				
			Mass lb/hr	Molar lbmole/hr	Heat BTU/lb	Mass lb/hr	Molar lbmole/hr	Heat BTU/lb	lb/hr	Molar lbmole/hr	Heat BTU/lb	CV lb/hr	Molar lbmole/hr	Heat BTU/lb		
Nitrogen	N ₂	28.013	.000	211.781	7.569991	19,697.996	.280	.010	26.056	212.061	7.569991	28,394.991	.000		.000	
Oxygen	O ₂	31.999	.000	64.900	2.028196	5,378.977	.000	.000	.000	8.846	0.276459	1,055.519	.000		.000	
Argon	AR	39.948	.000	3.597	.090034	278.235	.000	.000	3.597	0.090034	400.537	.000		.000		
Carbon dioxide	CO ₂	44.010	.000	.128	.002904	10.554	.440	.010	36.475	45.465	1.032904	5,423.916	.000		.000	
Water Vapor	H ₂ O	18.015	.000	1.474	.081821	1,832.341	.000	.000	37.684	2.091821	45,521.934	.000		.000		
Carbon Monoxide	CO	28.010	4,347.000	.000	.000	.000	.000	.000	.000	0.000000	.000	.000	.000		.000	
Hydrogen	H ₂	2.016	61,095.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	
Methane	CH ₄	16.040	23,875.000	.000	.000	.000	15.388	.560	3,450.023	.000	.000	.000	.000		.000	
Ethane	C ₂ H ₆	30.070	22,523.000	.000	.000	.000	.900	.030	165.145	.000	.000	.000	.000		.000	
TOTAL	As noted			281.979	9.76295	27,198.133	17.021	1.010	3,688.704	307.647	11.06121	84,896.859	.000		.000	
Total Pressure	Psia			14.662				14.696				14.6616				
Partial Press H ₂ O	Psia			.123				400.351				2.7727				
Temperature	oF			400.3509215		54745		10.570				562.30				
Volumetric Flow	ACFM			102				.000				137.58				
Absolute Humidity	#Ain#H ₂ O			0.005256691				.000				.1396				

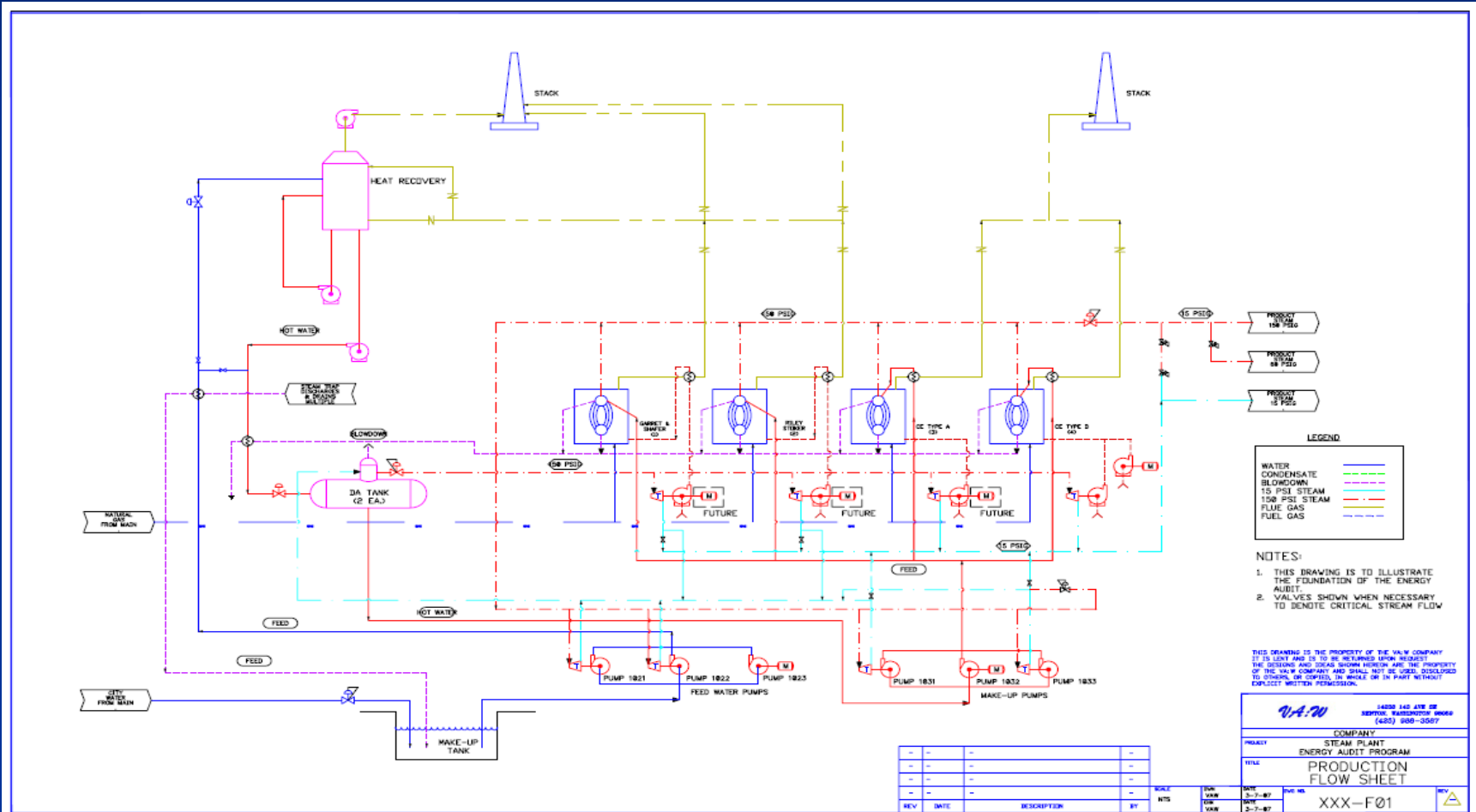
Components	Actual Flue Gas			Wet Molefraction		Dry Molefraction	
	lb/hr	lbmole/hr	BTU/hr				
Nitrogen	113,356.28	4,046.50	15,179,404.871	68.44%	84.40%		
Oxygen	4,728.78	147.78	564,222.475	2.50%	3.08%		
Argon	1,522.60	48.13	214,104.949	0.81%	1.00%		
Carbon dioxide	24,259.42	552.13	2,569,339.307	9.34%	11.52%		
Water Vapor	20,143.88	1,118.17	21,371,450.414	18.91%			
Carbon Monoxide	0.00	0.00	.000	0.00%	0.00%		
Hydrogen	0.00	0.00	.000	0.00%	0.00%		
Methane	0.00	0.00	.000	0.00%	0.00%		
Ethane	0.00	0.00	.000	0.00%	0.00%		
TOTAL	As noted	164,450.55	5,912.72	100.00%	100.00%		
Total Pressure	Psia		14.6616				
Partial Press H ₂ O	Psia		2.77				
Temperature	oF		562.30				
Volumetric Flow	ACFM		73,703.99				
Density	lb/ft ³		0.04				
Specific Heat	Btu/lb		26.89				
Absolute Humidity	#H ₂ O/Air		0.13959				
Dew Point Temperature	oF		138.274				

STOICHIOMETRIC BENEFITS

- Creates known requirements to heat water, add latent heat, and generate steam conditions
- Calculates combustion environment
 - Air flow
 - Flue conditions
 - Residual O₂ → Excess air
 - Efficiency contribution
- Can accommodate blowdown and radiant heat losses

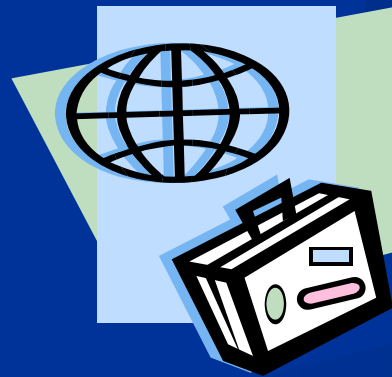
PLANT PROCESS DIAGRAM

THE START

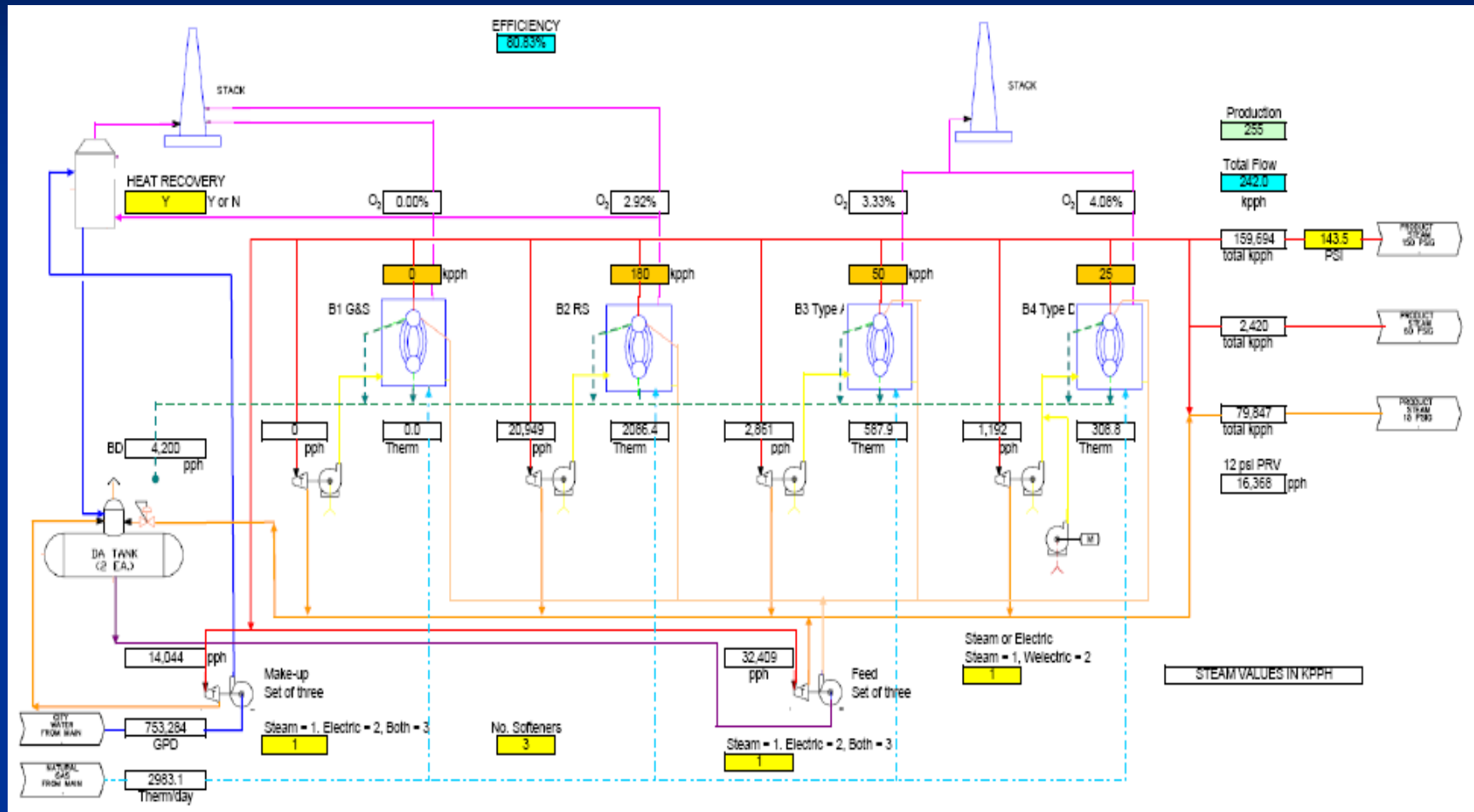


TOUR

- LOOK AT THE INTERNALS OF THE VEA
 - GET A FEEL FOR THE PARTS
 - LEAD TO MORE DETAILED DEMONSTRATION



SCHEMATIC SHEET



GOLD AND YELLOW BOXES = INPUT

OPERATOR LOG

Plant Operational Log

3/7/2008

10:35

Plant Load Total kpph kpph delivered kpph produced
 High Pressure set psig

	Boiler 1	Boiler 2	Boiler 3	Boiler 4
Load kpph	100	150	100	80
Boiler Load Factor	63%	75%	63%	67%
Plant Load Factor	23%	35%	23%	19%
Flue Gas O2 %				
Flue Gas Temp °F				
Flue Gas Flow %				
Fan Speed CFM				
RPM				
Delta Pressure in H2O				
Inlet Air Temp °F				
Inlet Water Temp °F				

Water Temp °F (required input)
 Heat Recovery Inlet °F
 Heat Recovery Outlet °F Heat Recovery Op. Y or N
 Deaerator Inlet Temp °F

Number of Softeners

Make-up Pump Mode 1= all steam, 2 = all electric, 3 = steam & electric
 Feed Pump Mode 1= all steam, 2 = all electric, 3 = steam & electric

Blowdown Waste Temp °F

Plant Efficiency %

Balance

OVERALL

OVERALL PLANT OPERATION

Date **3/7/2008**
Run ID **Working**

Set Overall Plant Operation Values

Net Steam Load **430,000** Lb/hr
15 Psi Header **133,484** Lb/hr
60 Psi Header **4,045** Lb/hr

Delivery **404,497** Lb/Hr
High Pressure **266,968** Lb/hr
High Pressure **143.5** psig

Proportioning Load
HP **66%** 404,497 pph
MP **1%** 266,968 pph
LP **33%** 4,045 pph

Boller Set Up:

Boller #	Load Factor	100%	640,000.00 lb/hr max
Boller # 1	100,000	23%	160,000.00 lb/hr max
Boller # 2	150,000	35%	200,000.00 lb/hr max
Boller # 3	100,000	23%	160,000.00 lb/hr max
Boller # 4	80,000	19%	120,000.00 lb/hr max

Barometric Pressure **14.696** psia
Feed Water Temp **55** *F
Deaerator Temp Out **226.99** *F
Deaerator Temp Data **226.99** *F
Outside Atmospheric Temp **40** *F
Inside Ambient Temperature **75** *F

Utility Unit Costs: Set values below
Natural Gas **\$ 1.00** per therm
Electricity **\$ 0.07** per kWh

Heat Recovery Used **Y**
Y or N
Set Heat Recovery to N for Type A or Type D only

Plant Output Values

PRV Flow **48,170.50** Lb/hr
Superheat Values 60 psi Header **22.59** *F
15 psi Header **27.35** *F

Natural Gas Consumption **6,148.28** Therms/hr
Electricity Consumption **131.6** kW/HR.
Feed Water Consumption **442,030** lb/hr
Basic Overall Steam Load **442,030** lb/hr
For production purposes only
882.30 GPM
1,270,505 GPD
Steam Losses **12,030** lb/hr
Equiv. Loss **15,061** lb/hr

Mass Loss Index 1.0630
Factor **1.0630**

Costs:

Natural Gas **\$ 6,148.28** per hour
\$ 147,558.82 per day (1)
(1) based on uniform load
Electricity **\$ 9.21** per hour
\$ 221.04 per day (1)

Efficiencies

	Produced	Consumed	Balance
Steam	480.56 MMBTU/hr		5.74%
Gas	614.83 MMBTU/hr		
Electricity	0.03 MMBTU/hr		
Steam η =	97.3%	Ratio of Steam delivered to steam used	
Basic η =	78.2%	Ratio of steam produced to NG energy consumed	
Plant η =	78.7%	Ratio of steam produced to output	

Equivalent losses = condensation losses for steam used to heat DA



BOILER #2

TYPICAL FOR
INDIVIDUAL
UNITS

Boiler #2			
Inputs			
Required Steam Load	150,000	lb/hr	200,000 lb/hr capacity
Load Factor	75%		
Pressure	143.5	psig	0 °F Superheat
Steam Temperature	382.7	°F	
Excess Air Used	15.8%		calculated by load
Excess Oxygen (Flue)	3.08%		wet mole fraction
Boiler Efficiency	85.2%		
Flue Gas Temperature	562.30	°F	dry bulb
Blowdown	set 1.5%		
Radiant Losses	set 2.0%		
Output			
Air Flow	150,677.27	Lb/hr	20,143.88 Lb/hr H2O
Flue Flow	164,450.95	Lb/hr	682.30 °F
Fuel Consumption	9,098.35	Lb/hr	
Blowdown	2,250	lb/hr	2,275,968 BTU/hr
Air Preheater			
Heating Medium	Flue Gas		
Temperatures	In 562.30	°F	Out 345.00
Air Flow	164,450.95	lb/hr	54,745.28 Cp =
Air Inlet Temperature	40	°F	ACFM
Air Outlet Temperature	400.38	°F	
FD Fan Drive 25 inch H2O maximum			
Gas Flow	54,745.28	ACFM	From Actual Flue Gas Flow
Speed Correction	600	RPM base	1139 RPM Actual
Head	4.0	Inch H2O	
Power Consumption	55.1	HP	required 140,300 BTU/hr
Ideal Fan Power	34.6	HP	
Actual Efficiency	63%		
Power Mode	set 1		1 = Steam 2=Electrical
Turbine:		Electrical: Note: Hypothetical	
Exhaust Pressure	15	psig	Ideal Electrical Load 0.00 kW
Assumed Turbine Efficiency	set 35%		Electrical Efficiency 98%
Energy Use	400,857	BTU/hr	Electrical Load 0.00 kW
Steam Flow	11,885.31	lb/hr	
Steam Power Factor, ref.	215.59	lb/hp-hr	

HEAT RECOVERY

CONDENSING ECONOMIZER

Heat Recovery Summary

Gas Flow In	112934.0	ACFM	Temperature	450.19	°F	
Water Flow In	868.83	GPM	Temperature	60.80	°F	
Water Flow Out	904.26	GPM	Temperature	134.76	°F	
Recovered Heat	32,224,230	BTU/Hr				
Recovered Water	35.43	GPM	17,750	lb/Hr.	51,019	GPD
Recirculation Pump	Flow	1303.24	GPM	Head	80.00	Ft. H2O
	Power	44.65	HP	Electricity	33.31	kW
Transfer Pump	Flow	904.26	GPM	Head	62.9	Ft. H2O
	Power	131.72	HP	Electricity	98.26	kW

PLANT USES 1

PLANT USES

Plant uses come from 15 psig and 150 psig steam headers

15 psig Steam

Steam Pressure	15 psig	29.696 psia
Steam Enthalpy	1,161.42 BTU/lb	
Latent Heat	970.2 BTU/lb	
Steam Temperature	249.7 °F	saturated
Net Plant Consumption	18,053.93 Lb/hr	
Header equivalent enthalpy	1,173.59 BTU/lb	29.696 psia
Header Temperature	277.10 °F	
Superheat	27.35 °F	

60 psig Steam

Steam Pressure	60 psig	74.696 psia
Steam Enthalpy	1,181.97 BTU/lb	
Steam Temperature	307.3 °F	saturated
Header equivalent enthalpy	1,195.15 BTU/lb	74.696 psia
Header Temperature	329.91 °F	
Superheat	22.59 °F	

150 psig Steam

Steam Pressure	143.5 psig	158.2 psia
Steam Enthalpy	1,195.15 BTU/lb	
Steam Temperature	362.7 °F	saturated
Net Plant Consumption	103,367.45 Lb/hr	

Barometric Pressure

Barometric Pressure	14.696 psia
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THERMODYNAMIC PARAMETERS

PLANT USES 2

COMMON EQUIPMENT

Plant Peripheral Equipment Values

Deaerator		Oper. Press.	5	psig	
Flow			34,922	Lb/hr	water flow
Temperature In			149.38	°F	
Temperature out			226.99	°F	
ΔT through cooler	set		80	°F	
Required Heat			40,368,386	BTU/hr	
Return from Condensate			0	lb/hr	
Total Steam Flow			34,922.31	lb/hr	
Steam Flow Split	6 psi		16,868.38	lb/hr	15 psi PRV 18,053.93 lb/hr
Equivalent Heating Loss			15,080.90	lb/hr	14,630,969 BTU/hr
Vent Loss			2,890.00	lb/hr	mass loss from system
			2,991,157	BTU/hr	

High Pressure Trap Cooler

Flow			1,135	lb/hr	
Incoming Trap Temperature			362.7	°F	hth 334.8 BTU/Lb
Incoming Water Temp			55.0	°F	hlc 23.1 BTU/Lb
Outlet Approach Temperature	set		-3	°F	
Heat Exchanged			352,978	BTU/hr	Variation -1025
Outgoing Trap Temperature			50.81	°F	hoh 18.9 BTU/Lb
Outgoing Water Temperature			55.815	°F	hoc 23.9 BTU/Lb
Incoming Temperature gain			0.8	°F	

PLANT USES 3

Blowdown Cooler

Blowdown Flow	9,150.00 lb/hr	Obtain from collection of all blowdown flows mass loss from system
Incoming Blowdown Temp.	362.66 °F	hjh 334.8 BTU/Lb
Incoming Water Temp.	134.76 °F	hic 101.1 BTU/Lb
Outlet Approach Temperature	set -10 °F	
Outgoing Blowdown Temp.	2,095.096 BTU/hr	Variation -4533048
Outgoing Water Temperature	139.38 °F	hoh 105.8 BTU/Lb
Incoming Temperature gain	149.38 °F	hoc 116.1 BTU/Lb
	14.6 °F	

Feed Water Pumps (turbines)

Make-up Pumps

	15 psi output	
Number of Softeners	0 1, 2 or 3	
Power split	set 1 1 - steam only, 2 - electric only, 3 - steam & electric	
Water Flow	16,868.38 lb/hr	Equal all steam flow 882.30 GPM
Flow per pump	441.15 GPM	800 GPM basis
Head	508.64 ft. H2O	
Pump RPM	3676 RPM	
Steam: High press .	143.5 psig	Electric:
Power Consumption/pump	89 HP	required - HP required
Ideal Power	57 HP	Electricity - kW
Pump Efficiency	63%	Motor η 96%
Exhaust Pressure	set 6 psig	Net Electricity - kW
Exhaust Enthalpy	1,156.42 BTU/lb	
Assumed Turbine Efficiency	set 40%	
Energy Use	568,921 BTU/hr	
Steam Flow	16,868.38 lb/hr	
Steam Power Factor, ref.	188.64 lb/hp-hr	

Feed Pumps

Power split	set 1 1 - steam only, 2 - electric only, 3 - steam & electric	
Water Flow	430,009 lb/hr	DA Tank Output 858.30 GPM
Head	542.9 ft. H2O	800 GPM Basis
Steam: High press .	143.5 psig	Electric:
Power Consumption	233.8 HP	required - HP required
Ideal Power	117.7 HP	Electricity - kW
Pump Efficiency	50%	Motor η 96%
Exhaust Pressure	set 15 psig	Net Electricity - kW
Assumed Turbine Efficiency	set 40%	
Energy Use	1,487,625 BTU/hr	
Steam Flow	44,107.72 lb/hr	
Steam Power Factor, ref.	188.64 lb/hp-hr	

COMMON
EQUIPMENT

MASS BALANCE

Mass Balance

Produced Steam	#1	#2	#3	#4	Net
150 psig	100,000	150,000	100,000	80,000	430,000 pph

Delivered Steam	
15 psig	133,484 pph
60 psig	4,045 pph
150 psig	266,968 pph
Net	404,497 pph

Steam Uses	6 PSI	15 PSI	140 PSI			
6 psig exhaust	16,868			pph	#1 FD	16,219 lb/hr
15 psig exhaust		42,391		pph	#2 FD	11,885 lb/hr
Fan Turbines			(42,391)	pph	#3 FD	8,211 lb/hr
Make-Up Pump		16,868	(16,868)	pph	#4 FD	6,078 lb/hr
Feed Pump		44,108	(44,108)	pph		
Deaerator (15 psi letdown)		(18,054)		pph		
Deaerator (6 psi feed)	(16,868)					
Net	-	85,314	(103,367)			

Losses	
Blowdown	9,150 pph
Vent	2,880 pph
	12,030

PRV	48,170 pph
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Reconciliation	15 PSI	140 PSI
Produced	-	430,000 pph
Used	85,314	(103,367) pph
PRV (140 to 15, less 60)	48,170	(44,126) pph
Losses		(12,030) pph
Net	133,484	270,477 pph
Variation	-	3,509 pph

ENERGY BALANCE

The Bottom Line

Plant Energy Balance							
In			Out				
			Energy		Mass		
Natural Gas	614.83	MMBTU/hr	150 psi Steam	319.07	MMBTU/hr	286.97	KPPH
Air	12.96	MMBTU/hr	60 psi Steam	4.83	MMBTU/hr	4.04	KPPH
Water	10.17	MMBTU/hr	15 psi Steam	158.66	MMBTU/hr	480.56	133.48 KPPH
			#1 Fan Turbine	0.55	MMBTU/hr		
			#2 Fan Turbine	0.40	MMBTU/hr		
			#3 Fan Turbine	0.28	MMBTU/hr		
			#4 Fan Turbine	0.20	MMBTU/hr		
			MU Pump	0.57	MMBTU/hr		
			FW Pump	1.49	MMBTU/hr	3.49	
			DA Heating	14.63	MMBTU/hr		
			DA vent	-	MMBTU/hr		0.00 KPPH
			Steam Trap Cond.	1.37	MMBTU/hr		
			BD	13.09	MMBTU/hr		9.15 KPPH
			Radiant Losses	9.56	MMBTU/hr	38.65	
			Flue Gas 1 & 2	17.14	MMBTU/hr		
			Flue Gas 3 & 4	61.48	MMBTU/hr	78.62	
Total	638	MMBTU/hr		601	MMBTU/hr	404.50	KPPH Delivery
						9.15	KPPH Losses
Balance	37	MMBTU/hr					
	5.74%						
			$\dot{\eta} =$	78.2%	Basic Thermal Efficiency		
			$\dot{\eta}' =$	78.7%	Overall Plant Efficiency		
			Losses	19.1%			

PAUSE

SO, WHAT WAYS WOULD YOU SEE TO
MAKE THE VEA WORK FOR YOU?

(There is no quiz, therefore there is no pressure.)

FEATURES

- Stand-alone program or integrated into an automated control program
- Adaptable to future changes to remain unique to a specific plant
- Operates in many modes (see later)
- Accounts for all significant equipment

Fans, Pumps, Deaerator-heaters, Pre-heaters, Economizers, Heat Recovery, Generators, Hot wells, Turbines/motors, chillers, pulverizers, and more...

TOOLS

- **OPTIMIZER** – FORECASTING OPERATING EFFICIENCY
- **DOCUMENTATION** – RECORDS FOR TOTAL PLANT EQUIPMENT
- **MODIFICATIONS** – RESEARCH W/O HIGH COST
- **AUTOMATION**
- **TRAINING TOOL**



OPERATING EFFICIENCY

Plant Operational Log 3/9/2008 10:42

Plant Load Total kpph 242.9 kpph delivered 268 kpph produced

High Pressure set 143.5 psig

	Boiler 1	Boiler 2	Boiler 3	Boiler 4
Load kpph	105	0	144	19
Boiler Load Factor	80%	0%	80%	18%
Plant Load Factor	39%	0%	54%	7%
Flue Gas O2 %				
Flue Gas Temp °F				
Flue Gas Flow %				
CFM				
Fan Speed RPM				
Delta Pressure in H2O				
Inlet Air Temp °F				
Inlet Water Temp °F				

Water Temp °F 57 (required input)

Heat Recovery Inlet °F

Heat Recovery Outlet °F Heat Recovery Op. Y Y or N

Deaerator Inlet Temp °F

Number of Softeners

Make-up Pump Mode 1= all steam, 2 = all electric, 3 = steam & electric

Feed Pump Mode 1= all steam, 2 = all electric, 3 = steam & electric

Blowdown Waste Temp °F

Plant Efficiency % 74.8%

Balance 2.22%

Case 1
 $\dot{\eta} = 74.8\%$

Plant Operational Log 3/9/2008 10:41

Plant Load Total kpph 252.8 kpph delivered 268 kpph produced

High Pressure set 143.5 psig

	Boiler 1	Boiler 2	Boiler 3	Boiler 4
Load kpph	144	0	105	19
Boiler Load Factor	80%	0%	80%	18%
Plant Load Factor	54%	0%	39%	7%
Flue Gas O2 %	2.48		2.46	4.64
Flue Gas Temp °F	807.1		680	418
Flue Gas Flow %				
CFM				
Fan Speed RPM	933		1140	815
Delta Pressure in H2O	8.3		11.6	6.6
Inlet Air Temp °F				
Inlet Water Temp °F			243.3	

Water Temp °F 57 (required input)

Heat Recovery Inlet °F 58

Heat Recovery Outlet °F 134.8 Heat Recovery Op. Y Y or N

Deaerator Inlet Temp °F 140.2

Number of Softeners 3

Make-up Pump Mode 1 1= all steam, 2 = all electric, 3 = steam & electric

Feed Pump Mode 1 1= all steam, 2 = all electric, 3 = steam & electric

Blowdown Waste Temp °F 130.2

Plant Efficiency % 79.9%

Balance 3.62%

Case 2 – documented
 $\dot{\eta} = 79.9\%$

TRAINING TOOL

Plant Operational Log		3/7/2008 10:35	
Plant Load Total	kpph	404.5	kpph delivered
High Pressure	set	143.5	psig
			430 kpph produced
Load	kpph	Boiler 1	Boiler 2
Boiler Load Factor		100	150
Plant Load Factor		63%	75%
Flue Gas O2	%	23%	35%
Flue Gas Temp	°F		
Flue Gas Flow	CFM		
Fan Speed	RPM		
Delta Pressure	in H2O		
Inlet Air Temp	°F		
Inlet Water Temp	°F		
Water Temp	°F	55	(required input)
Heat Recovery Inlet	°F		
Heat Recovery Outlet	°F		
Deaerator Inlet Temp	°F		
Number of Softeners			
Make-up Pump Mode		1	1= all steam, 2 = all electric, 3 = steam & electric
Feed Pump Mode		1	1= all steam, 2 = all electric, 3 = steam & electric
Blowdown Waste Temp	°F		
Plant Efficiency	%	78.7%	
Balance		5.74%	

Customized simulation of the specific power plant to learn how to operate and optimize quickly and without actual operation.

OVERALL PLANT OPERATION		Size	100,000
Set Overall Plant Operation Values			
Net Steam Load	430,000 lb/hr	Capacity	500,000 lb/hr
12 psi header	130,000 lb/hr	High Pressure	200,000 lb/hr
10 psi header	2,500 lb/hr	High Pressure	125,000 lb/hr
Boiler Set-Point		High Pressure	125,000 lb/hr
Boiler # 1	150,000 lb/hr	150,000 lb/hr	150,000 lb/hr
Boiler # 2	150,000 lb/hr	200,000 lb/hr	200,000 lb/hr
Boiler # 3	100,000 lb/hr	100,000 lb/hr	100,000 lb/hr
Boiler # 4	10,000 lb/hr	100,000 lb/hr	100,000 lb/hr
Maximum Pressure	14.500 psia	Outside Ambient Temp	70°F
Feed Water Temp	200°F	Inside Ambient Temperature	70°F
Deaerator Temp Cold	200°F		
Deaerator Temp Warm	200°F		
Utility Unit Costs	Net Utility Load	Electricity	1.000 \$/kWh
Natural Gas	1.000 \$/MMBtu		
Heat Recovery Load	0	Y or N	20% Heat Recovery to H for Type A or Type C only
Plant Output Issues			
PHV Flow	45,000 lb/hr	10 psi header	2,500 lb/hr
Deaerator Issues	45,000 lb/hr		
Natural Gas Consumption	1,000,000 Btu/hr	PHV production	100,000 lb/hr
Electricity Consumption	100,000 kWh/hr	PHV production	100,000 lb/hr
Feed Water Consumption	2,500,000 lb/hr	PHV production	100,000 lb/hr
Basic Overall Steam Load	430,000 lb/hr	Steam Losses	10,000 lb/hr
Steam Loss Index	1.000	Factor	1.000
Costs:			
Natural Gas	1,000,000 \$/hr	Electricity	1,000,000 \$/hr
Electricity	1,000,000 \$/hr		
Efficiencies:			
Steam	78.7%	Balance	5.74%
Gas	78.7%		
Electricity	78.7%		
Steam to H	78.7%	Ratio of steam delivered to steam used	
Plant to H	78.7%	Ratio of steam produced to H2 energy consumed	
Plant to S	78.7%	Ratio of steam produced to output	

Boiler #1	
Inputs:	
Required Steam Load	150,000 lb/hr
Load Factor	75%
Pressure	14.5 psig
Steam Temperature	550 °F
Excess Air Load	15.0%
Screen Oxygen (Ppt)	3.0%
Boiler Efficiency	88.2%
Flue Gas Temperature	550 °F
Blowdown	0.5%
Plant Losses	2.5%
Output:	
Air Flow	150,000 lb/hr
Fuel Flow	1,000,000 Btu/hr
Fuel Consumption	1,000,000 Btu/hr
Blowdown	2,500 lb/hr
Air Preheater:	
Heating Medium	Flue Gas
Temperatures	In: 550 °F, Out: 340 °F
Air Flow	150,000 lb/hr
Air Inlet Temperature	70 °F
Air Outlet Temperature	400 °F
ID Fan Drive:	
Gas Flow	54,740 ACFM
Speed Correction	1.00
Head	2.5 in-H2O
Power Consumption	300 hp
Ideal Fan Power	24 hp
Actual Efficiency	8%
Power Mode	1 = Steam, 2 = Electrical
Options:	
Exhaust Pressure	14.5 psig
Assumed Turbine Efficiency	70%
Energy Use	400,000 Btu/hr
Steam Flow	150,000 lb/hr
Steam/Fuel Factor, ref	1.000 \$/Btu
Electrical	Ideal Electrical Load: 0.00 MW, Electrical Efficiency: 8%
Hydrothermal	Electrical Load: 0.00 MW

Overall

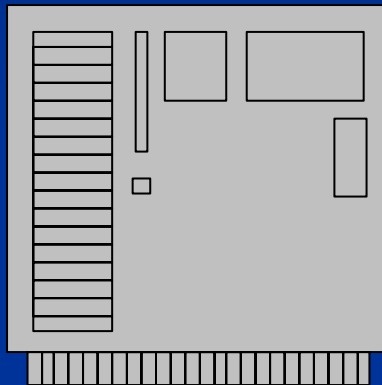
Specific Component

DOCUMENTATION

Plant Operational Log		3/8/2008 10:41	
Plant Load Total	kpph	252.6	kpph delivered
High Pressure	set	143.5	psig
			268 kpph produced
		Boiler 1	Boiler 2
		Boiler 3	Boiler 4
Load	kpph	14.4	0
Boiler Load Factor		90%	0%
Plant Load Factor		54%	0%
Flue Gas O2	%	2.48	2.46
Flue Gas Temp	°F	607.1	680
Flue Gas Flow	%		416
	CFM		
Fan Speed	RPM	933	1140
Delta Pressure	in H2O	8.3	11.6
Inlet Air Temp	°F		6.6
Inlet Water Temp	°F		243.3
Water Temp	°F	57	(required input)
Heat Recovery Inlet	°F	58	
Heat Recovery Outlet	°F	134.8	Heat Recovery Op. Y or N
Deaerator Inlet Temp	°F	140.2	Y
Number of Softeners		3	
Make-up Pump Mode		1	1= all steam, 2 = all electric, 3 = steam & electric
Feed Pump Mode		1	1= all steam, 2 = all electric, 3 = steam & electric
Blowdown Waste Temp	°F	130.2	
Plant Efficiency	%	79.8%	
Balance		3.62%	

Record and document specific plant conditions with all details

AUTOMATION



SERVER



Plant Operational Log 3/7/2008 10:35

Plant Load Total kpph 404.5 kpph delivered 430 kpph produced
 High Pressure set 143.5 psig

	Boiler 1	Boiler 2	Boiler 3	Boiler 4
Load kpph	100	150	100	80
Boiler Load Factor	63%	75%	63%	67%
Plant Load Factor	23%	35%	23%	19%
Flue Gas O2 %				
Flue Gas Temp °F				
Flue Gas Flow %				
CFM				
Fan Speed RPM				
Delta Pressure in H2O				
Inlet Air Temp °F				
Inlet Water Temp °F				
Water Temp °F	55	(required input)		
Heat Recovery Inlet °F				
Heat Recovery Outlet °F				
Deaerator Inlet Temp °F				
Heat Recovery Op.	Y Y or N			
Number of Softeners				
Make-up Pump Mode	1 1= all steam, 2 = all electric, 3 = steam & electric			
Feed Pump Mode	1 1= all steam, 2 = all electric, 3 = steam & electric			
Blowdown Waste Temp °F				
Plant Efficiency %	78.7%			
Balance	5.74%			

VEA

TIE-IN BETWEEN SYSTEM AUTOMATION AND VEA TO ENABLE SPECIFIC DATA RETREIVAL AND OPTIMIZATION.

MODIFICATIONS

- COMPARE TWO (OR MORE) MODIFICATIONS
- DETERMINE EFFECT ON PLANT OPERATIONS - WITHOUT ACTUAL CHANGES
- CONDUCT FEASIBILITY ANALYSIS

Contact Data

VA:W

(Value Added by Werner)

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