HARMAC PACIFIC

Plant Report

Welcome to Harmac Pacific

From the Harmac website:

Harmac Pacific operates a Northern Bleached Softwood Kraft (NBSK) pulp mill located on the east coast of Vancouver Island near Nanaimo, British Columbia.

Nanaimo Forest Products Ltd., the owner of the Harmac Pacific trademark, restarted the mill with a single production line on October 3, 2008, producing NBSK at the rate of 226,000 tonnes per year. In 2009, a second production line is projected to start up, bringing the mill's production capacity to 331,000 tonnes of pulp per year. Future capital projects may allow the production of 370,000 tonnes per year from a two-line configuration.

The Harmac mill produces high quality kraft pulps made from custom blends of Douglas fir, western hemlock, Balsam fir and Western Red cedar. The pulp is sold in Europe, North America, the Pacific Rim and Latin America . With its strategic location on a deep water port, the mill is well situated for cost effective export of pulp and receipt of raw materials such as wood fiber.

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Playing my Part at Harmac Pacific

The Goon Spoon

The "goon spoon" is the slang name for a shovel. At Harmac, there are a variety of shovels for different kinds of material (wet, dry, dirt, hog ...). I became an expert with this tool in the first few weeks of working.

Welcome to Harmac! Grab a Shovel and a Broom

Clean up duties (Late May to Late June) - My father always told me that when you start at a company, you become "the low man on the totem pole." My first few weeks at Harmac had me on the cleaning crew with a fellow summer student, Jeremy, and it was a way to learn the layout of the plant. I also believe that it was a test to see if I can survive the first few weeks and if I was squeamish about cleaning a washroom.

During the first month, my most frequently-used tools were various shovels, brooms, mops, fire hoses and air lances. I was also certified in using gas testers and performing hole watch for the maintenance department.

I learned how to keep myself safe around conveyor belts and other pieces of machinery that couldn't tell the difference between a person's limb and hog fuel. This job was all about grunt work and helped me lose the weight I gained at BCIT.

I also got the chance to review my power engineering knowledge before for my exam by showing and explaining the different pieces of equipment to Jeremy.

Climbing the Totem Pole: Fireman Training

Fireman training (Late June to Mid-July) - After about a month working the clean up job, I was brought up to the recovery boiler operating floor to begin training for the Fireman position. The Fireman is responsible for the following:

» Cleaning air ports and glasses
» Safe operation of the smelt spouts
» Firing oil burners
» Taking black and green liquor samples
» Assisting the Operating Engineer
» Regulate the air dampers for liquor burning

Part of the training also included tracing out the black liquor lines and the green liquor lines. This took a lot of time as the supply lines zigged-zagged out of numerous buildings and pump locations. After proving I knew the job, the supervising shift energy, Fred Greer, signed my training papers as complete.

Fireman Duties:

Fireman (Mid-July to The End) - Immediately after finishing my training, I was assigned to follow two crews for their 12-hour day shifts; at least that was the plan.

However, due to people taking their leaves for school and vacation, I spent the majority of my time following one crew for their day and night shifts. The shift schedule was a simple four days on (two days and two nights) and four days off. I really liked this!

I can honestly say that I prefer working the night shifts; I'm not a morning person and I tend to do my best work at night (including writing this report). The night shifts are also calmer with the objective being to keep the boilers, and liquor production, running into the following morning.

The hard part, however, was resynchronizing my internal clock again for the day shifts but that was what the days off were for.

I took performing my duties seriously and made every effort to further my knowledge of the plant, including reading current and out-of-date manuals and plant schematics.

~ Nicknames Given/Earned ~

» Jason "Renegade" Rako

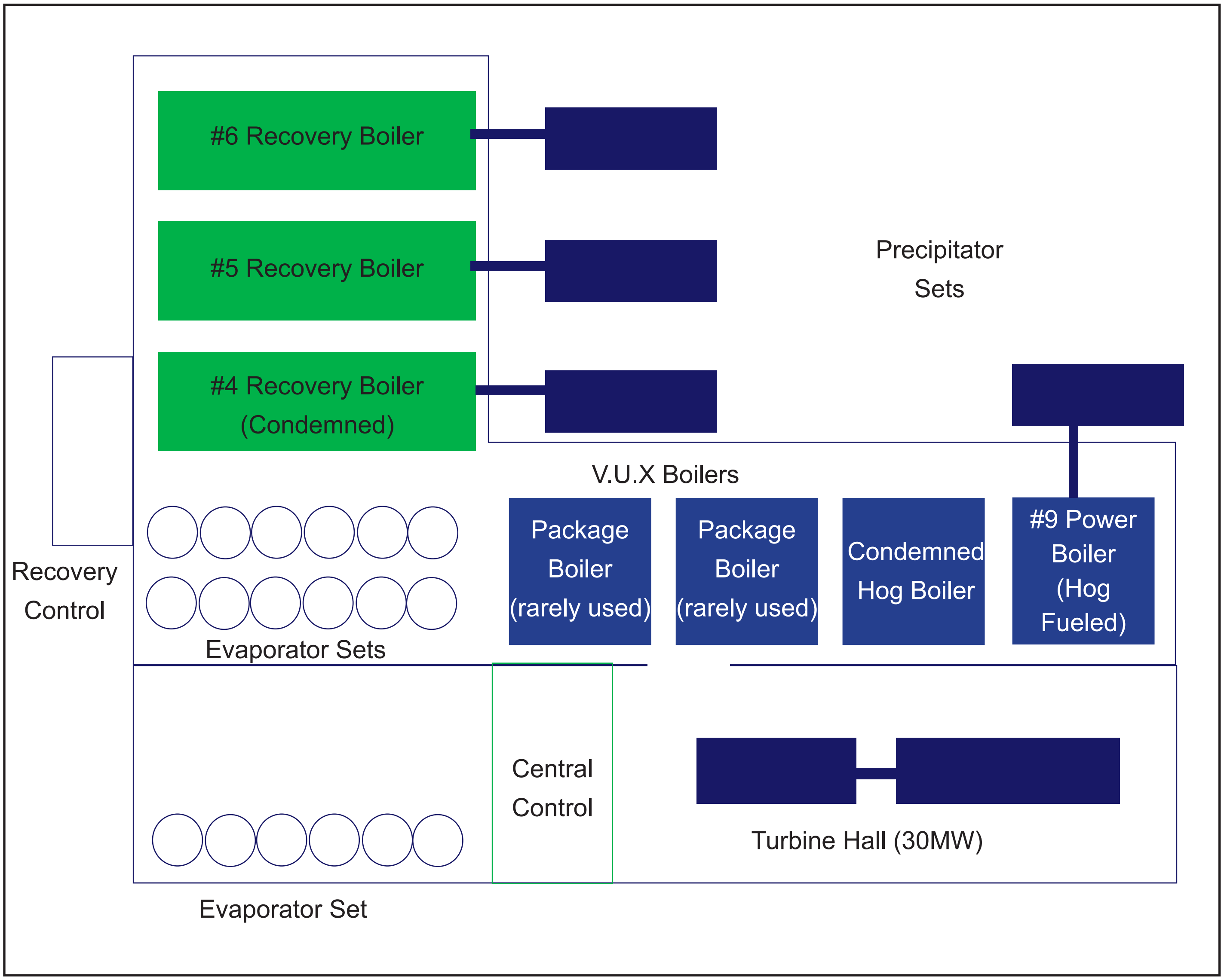
» Chester

» Go-Go Gadget

Night Shifts

Working the 12-hour night shift can wreak havoc with the body's "internal clock." To keep me awake, I packed a large meal, a light snack, an energy drink and chocolate and candy. My last line of defence against the sandman was a Five-Hour Energy™ shot. Having good reading material, during break time, also kept me awake.

Plant Layout and Boilers



A very simple map of the Harmac Steam Plant. As Fireman, I was responsible for keeping the ports on #5 and #6 boilers clean. I also assisted with #9 boiler (usually pulling grates in the morning)

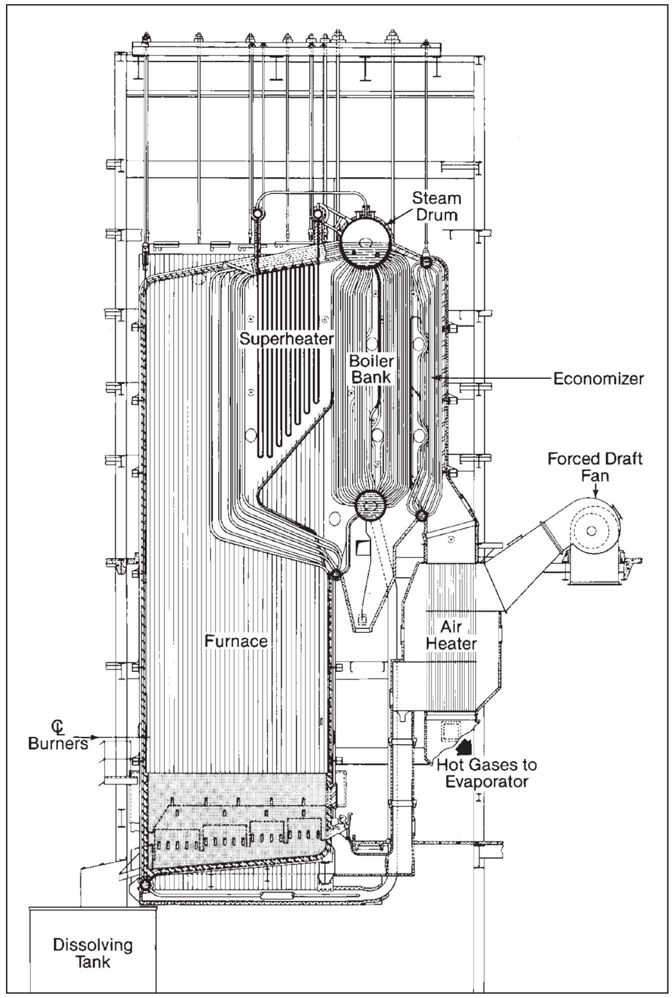
Plant Operation and Steam Use

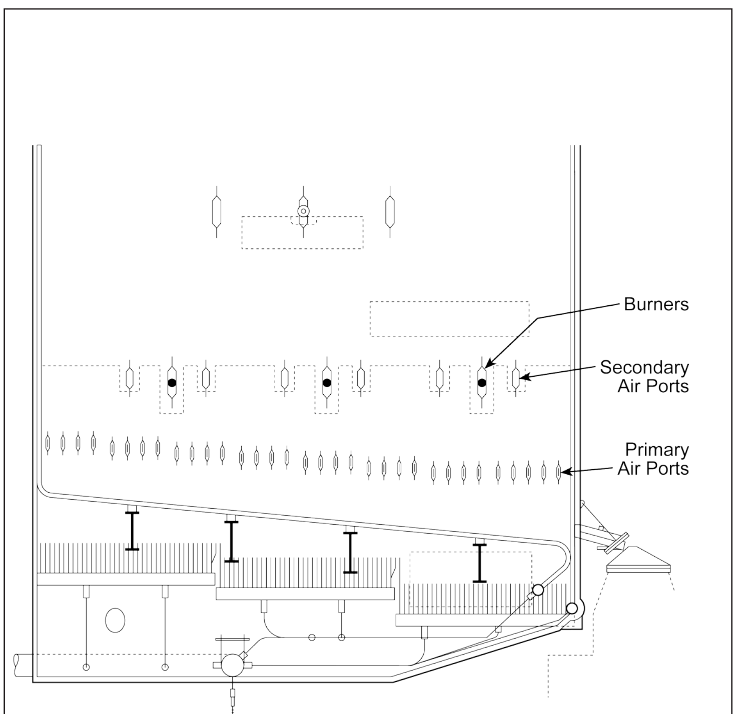
The Harmac Steam Plant is 70 years old and is a mix of old and new technology with large parts of the plan condemned (two large boilers and former control rooms). The purpose of the plant is to recover chemicals used in the pulping process. Steam generated, (ranging between 550 psi to 650 psi) is used to power a back-pressure turbo generator which produces roughly 30 MW to provide 60 percent of the mill's electrical needs. Steam is stepped down to 350 psi for in-plant use and is also reduced to 60 psi and 160 psi for mill use (digesters, etc.). Steam can also be reduced at a reducing station, bypassing the turbo generator, to provide mill steam in case of a turbine trip or shut down.

Recovery Boiler Design

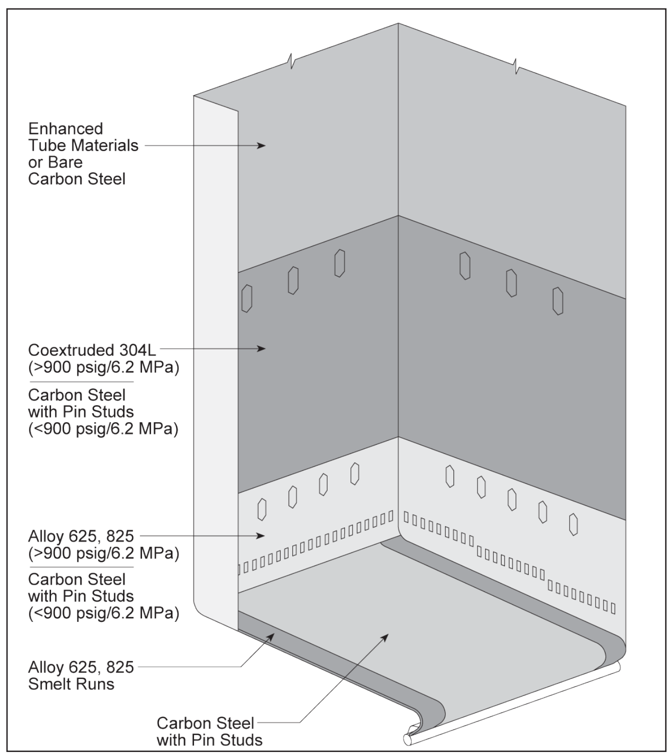
Both Number 5 and Number 6 boiler are old (circa 1940s design characteristics) Babcock and Wilcox boilers which have gone through a few rebuilds over the years. Both boilers have a sloped furnace bottom (with a 4 to 6 degree incline). The spouts are mounted slightly higher than the furnace floor to allow a pool of smelt to gather and "decant".

Both boilers have primary and secondary superheaters with steam temperature being controlled with attemperation via a sweet-water condenser which condenses a small amount of steam from the steam drum. Ash from the economizer, superheater and the generating bank is mixed with black liquor in "sluicing" bowls that are a part of the black liquor supply line.





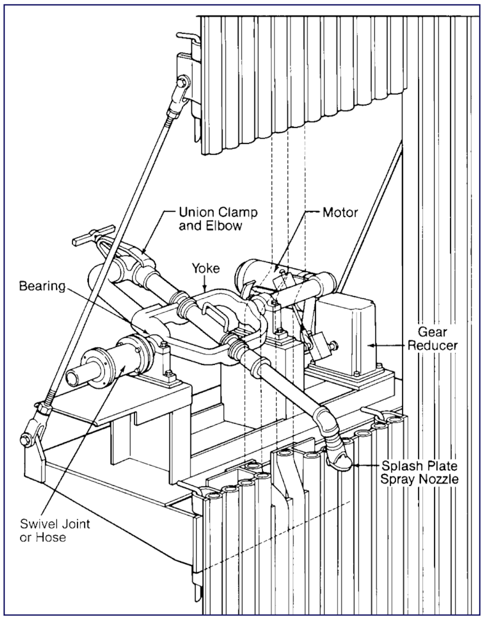
Sloped Furnace Bottom



Figures on this page are from the Babcock and Wilcox Company book "Steam; Its Generation and Its Use" (40th ed.)

Plant Layout and Boilers Cont'd

Black Liquor Nozzles (Liquor Guns)



The black liquor gun configurations on both #5 and #6 boiler are identical as illustrated in the figure on the left. However, the guns do not oscillate as the char bed is created on the furnace floor rather on the walls. (Note that the history and evolution of black liquor burning is quite extensive and will not be discussed in detail within this document.)

Liquor droplet size is controlled by the pressure, temperature (viscosity) and the tip size of the liquor nozzle. The goal is to ensure complete combustion and reduction of the liquor while minimizing the amount of carry over.

Depending on the quality of liquor, the liquor supply pressure, bed characteristics and the operating condition of the boiler (start-up, shut down), different sized gun tips are on hand to give the operator better control over black liquor distribution.

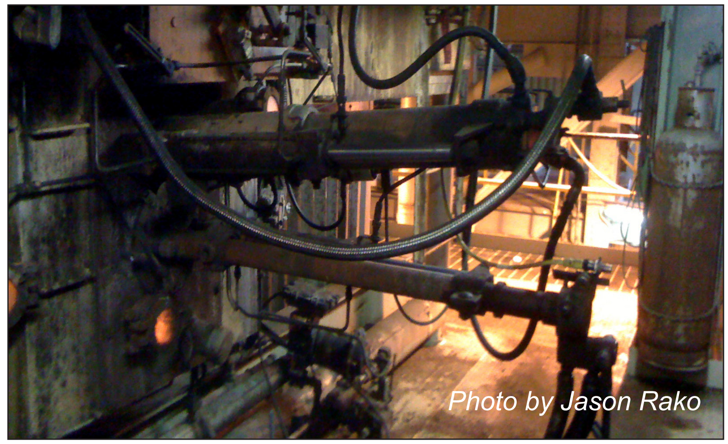

Photo by Jason Rako

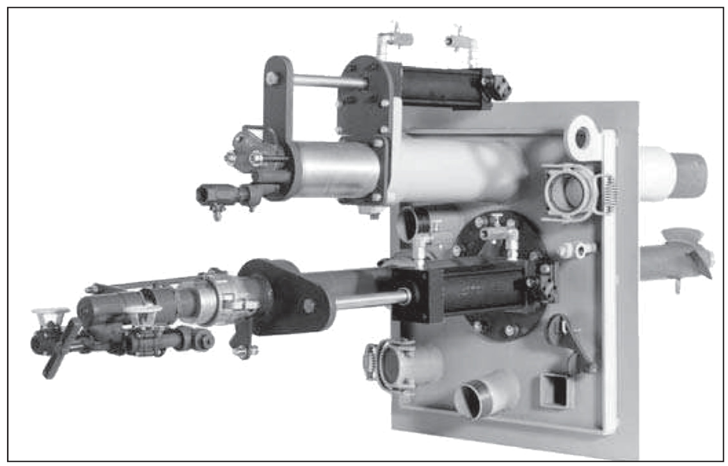
The method of black liquor distribution used in the steam plant is stationary firing, first introduced in the early 1980s. This type of firing is intended to produce a coarse spray from the nozzles (splash plate type) and to promote distinct combustion zones. Stationary firing creates an even char bed at the bottom of the furnace; it avoids spraying black liquor on the walls as was the practice with earlier burning techniques (wall drying and suspension burning). It should be noted that a very coarse spray will result in a wet bed which is undesirable.

The angle of a liquor nozzle can result in carryover of particles in the flue gases or a wet liquor bed. The proper angle of the liquor nozzle is best determined by operator experience.

Figures on this page are from the Babcock and Wilcox Company book "Steam; Its Generation and Its Use" (40th ed.)

Oil Burners





Both recovery boilers have numerous oil burners with three different designs (due to boiler age and retrofits). All burners use Bunker-C oil as primary fuel and the ignitors use propane gas.

While some of the burners had a pneumatic system of inserting both the ignitor and the primary burner, other oil guns required brute force (pushing and pulling) to insert and remove the burner components. These burners required more care as parts could get stuck and were very hot after extended periods of firing.

There are two main categories of oil burner used:

Hearth burners, located at the bottom of the boiler, are used to keep the char bed hot and to burn off remaining liquor prior to a shut down and prior to the resumption of liquor firing.

Load burners, located on the same level as the tertiary air ports, are used to provide heat to the steam-generating sections of the boiler.

Each oil burner has its own BMS system which communicate directly with the DCS in the recovery control room.

Two boiler trips, occurring on the same day, were attributed to one faulty circuit in the BMS of a single oil burner. It is amazing how one small system can bring down an entire boiler; luckily the operating engineers, with the help of the electricians, were able to quickly find the fault.

Figures on this page are from the Babcock and Wilcox Company book “Steam; Its Generation and Its Use” (40th ed.)

Recovery Boiler Combustion

Purpose of a Recovery Boiler

Black Liquor

According to Harmac Pacific's boiler reference manuals, black liquor is composed as follows (% by weight):

Nitrogen (N) 0.10
Sodium (Na) 19.0
Sulfur (S) 4.5
Hydrogen (H_2) 3.5
Carbon (C) 36
Oxygen (O_2) 35.4
Inerts 0.2
Potassium (K) 1.00
Chlorine (Cl) 0.3

The primary purpose of a recovery boiler is to oxidize sodium sulfate into sodium sulfide. The main fuel for a recovery boiler is a mixture of sodium sulfate and sodium carbonate. Heat generated from the chemical recovery process is used for steam generation, the secondary purpose of a recovery boiler. Before analyzing the chemical reactions taking place, the combustion air supply should be discussed in brief detail.

Combustion Air Delivery

Combustion air is used to completely burn the fuels in Harmac's recovery boilers. It is delivered in three stages:

Primary Air (35% to 45% of total air; 2" W.C. Pressure):

Primary air, supplied a few feet above the furnace floor, reacts chemically with sodium, sulphur and carbon in the char bed. The primary air reacts with the carbon in the bed to form carbon monoxide, which is intentional; the rest of the oxygen required for complete combustion is supplied by the reduction of sodium sulfate:

$$Na_2SO_4 + 4\ CO + Heat \text{ ------> } Na_2S + 4\ CO_2$$

The sodium sulfate transfers addition oxygen to the carbon in the char bed and the sodium sulfate reverts to sodium sulfide. The carbon then, ideally, converts to carbon dioxide.

The heat produced from these reactions help to keep the furnace bed temperature high and continues the chain reaction of oxidation. High temperatures are necessary for high reduction efficiencies and to reduce the amount of total residual sulphur (TRS) gas production.

Too high of a bed temperature will vapourize the sodium elements which will then carry over with the flue gas. The vapourized sodium will also react with sulphur in the flue gas which forms an ash in the back-passes of the boiler.

Number Six boiler's FD fan, which supplies both primary and secondary air.

Secondary Air (40% to 45% of total air; 4 to 8" W.C. pressure):

The secondary air ports are about four feet above the furnace floor. Secondary air is used to control the char bed height and to keep the bed temperature high.

Combustible compounds are constantly being vapourized from the char bed and from the liquor raining down upon it. Secondary air provides the oxygen necessary to burn these combustible gasses.

The addition of oxygen at this level also creates a fireball above the char bed which radiates heat on to the char bed and also dries the drops of black liquor falling on to the char bed.

Tertiary Air (10% to 20% of total air; 8 to 20" W.C. Pressure):

Tertiary air is situated just above the boiler's load burners. Unlike primary and secondary air, tertiary air is delivered to the boiler cool and at high pressure. Tertiary air finishes the burning of any combustibles that pass through the secondary zone.

Tertiary air is the last-line of oxygen supplied to the boiler and ensures that no unburned combustible gases, including TRS, leave the high-temperature zone of the furnace.

The Importance of Combustion Air

Sufficient air must be delivered to the furnace at the right location and conditions for complete fuel and air mixing. Combustion must also take place at the proper locations within the furnace. Thus, proper control of air delivery is crucial to achieving proper furnace conditions.

Failure to control air distribution and liquor drop conditions can result in low reduction efficiency, increased carryover, pluggage, air pollution and flames reaching into the upper furnace (nasty).

Recovery Boiler Combustion Cont'd

Theoretical Products of Combustion in a Recovery Boiler

The theoretical products of combustion in a recovery boiler, according the Harmac Steam Plant reference books, are as follows:

Flue Gases:

Carbon Dioxide	CO_2	13% to 17%
Carbon Monoxide	CO	250 ppm
Water Vapour	H_2O	20% to 25%
Sulphur Dioxide	SO_2	< 100 ppm
Sulphur Trioxide	SO_3	< 10 ppm
Oxygen (excess)	O_2	2% to 3%
Nitrogen gas	N_2	60%
Hydrogen Sulfide	H_2S	< 5 ppm

Particulate Matter:

Sodium Sulfate	Na_2SO_4	92%
Sodium Carbonate	Na_2CO_3	5%
Sodium Chloride	NaCL	3%

Smelt

Sodium Carbonate	Na_2CO_3	75%
Sodium Sulfide	Na_2S	22%
Sodium Sulfate	Na_2SO_4	3%

Stochiometric Calculations

Calculating the stochimoetric reactions for a recovery boiler is one of the hardest assignments I have been tasked with so far in my power engineering career. Even the engineers at Harmac were not sure where to begin. I decided to read through a bunch of the plant manuals and online literature.

Problems to consider:

The air supplied in a recovery boiler goes beyond ensuring complete combustion; it is used to control the bed shape and the bed height. The primary concern is to ensure a high reduction efficiency of the chemicals in the furnace rather than maintaining efficient steam production (the power boilers are used to makeup any extra steam required for the turbine).

Also, the boiler is kept at a negative pressure and air inside the plant can easily leak into the furnace through the multiple ports and openings on the boiler exterior.

An issue that caught me off guard is the fact that oxygen, at the primary air level, may combine first with sodium sulfide and revert it back to sodium sulfate (which is avoided by the operator at all costs). Limiting the excess oxygen at the primary air belt is important.

Simplifying a complex problem:

Reviewing the theoretical makeup of the flue gas (and having a few discussions with my fellow engineers) made me realize that the combustion equation for a recovery boiler boils down to the basics of any stochiometric calculation: the reaction of hydrogen, carbon and oxygen make up the greatest part of the flue gases. The other reactants only make up a small part (parts per million) of the flue gas. Sodium and sulfur, for the most part, are drained from the bottom of the boiler as smelt.

Therefore, as part of this research report, the organic stochiometric reactions that will be considered are:

1. $4C + 2O_2$ ------> $4CO$ + Lots of Heat
2. $Na_2SO_4 + 4\,CO$ + Some Heat ------> Na_2S (inorganic) + $4\,CO_2$
3. $2H_2 + O_2$ ------> $2H_2O$

Note: For the sake of keeping the calculations simple, an assumption will be made that all of the sulfur is in the smelt. In reality, this is untrue as per the theoretical flue gas analysis.

Stochiometric Calculations

Crunching the Numbers for Number 6 Recovery Boiler

The stochiometric calculations for number 6 recovery boilers will be done on the following sample data:

Date	Fuel Consumption (lb/min)	Excess Oxygen
July 23	2319	-
July 28	2407	-
August 06	2467	-
August 14	2348	-
August 21	2388	1.71%
August 22	2470	1.95%
August 23	2181	2.61%
August 24	2191	2.32%

Example Calculation

Organic Reactants

Taking August 23 as an example, we have 2181 lbs (989.28 kg) of fuel entering the furnace per minute. Therefore, we have the following organic reactive elements:

Reactant	Mass per kg of Fuel	Total mass
Nitrogen	0.010 kg	9.893 kg
Hydrogen	0.035 kg	34.625 kg
Carbon	0.36 kg	356.141 kg

Note that oxygen, sulfur and other inert material are not included since they are assumed to exit the boiler as smelt.

Example Calculation Cont'd

Please Note

Day-to-day results are listed in Appendix I on page 20.

Applicable Formulas:

For the combustion of carbon:

$4C + 2O_2$ ------> $4CO$ + Lots of Heat
(48) (64) (112)

Therefore, to partially combust 356.141 kg of Carbon, 474.85 kg of oxygen (1,046.88 lbs) per minute is required.

For the combustion of hydrogen:

$2H_2 + O_2$ ------> $2H_2O$
(4) (32) (36)

Therefore, to fully combust 34.625kg of hydrogen, 277 kg of oxygen (610.68 lbs) per minute is required.

The total amount of oxygen, for the combustion of carbon and hydrogen, is 751.85 kg per minute or 1,657.55 lbs per minute. Since 100 kg of air contains 23.3 kg of oxygen, 3226.82 kg (or of air is required per minute.

Since all of the instruments at Harmac use imperial units, the total amount of air is 7,113.92 lbs per minute or 426.84 kilo-pounds per hour (KPPH; Harmac unit, not mine).

Since the boiler was using 2.61% excess oxygen that day, the total amount of air supplied to the boiler was 437.98 KPPH.

However, the theoretical calculations don't seem to add up to the actual air supplied:

Air Belt	Supply (KPPH)
Primary	294
Secondary	213
Tertiary	137

The primary and secondary, where most combustion takes place, total to 507 KPPH. I believe that taking fuel and air readings at different times (5 to 10 minutes apart), may have lead to inaccuracies. Also, I've learned that the instruments are not always precise.

Boiler Efficiencies

Which Boilers were Included

Both Number 5 and Number 6 boilers had their data recorded for efficiency calculations. The calculation is done by comparing the amount of fuel energy being used in the boiler compared to the amount of energy contained in the steam immediately exiting the boiler (the enthalpy of the steam leaving the super heater banks).

Method of Calculation

Boiler efficiency is determined as follows:

$$\text{Eff.} = [\ M\ (h_1 - h_4)\ ] / [\ m_f\ (CV)\ ]$$

Where:

M = steam flow

h_1 = Enthalpy of steam

h_4 = Enthalpy of Feed Water

m_f = Fuel flow

CV = Calorific Value of the fuel.

Example Calculation

Using Number 6 boiler's data for August 06:

$$\text{Eff.} = [\ 7667\ (\ 1377.40 - 257.03\ )\ ] / [\ 2467\ (5151)\ ] = 0.6759$$

The efficiency of Number 6 boiler for August 06 (at the moment the data was recorded) was 67.6 % .

A comparison of both boilers reveals that Number 5 boiler is the least efficient of the two.

Please see the tables to the right for the data collected and Appendix II, on page 22, for the time-efficiency diagrams.

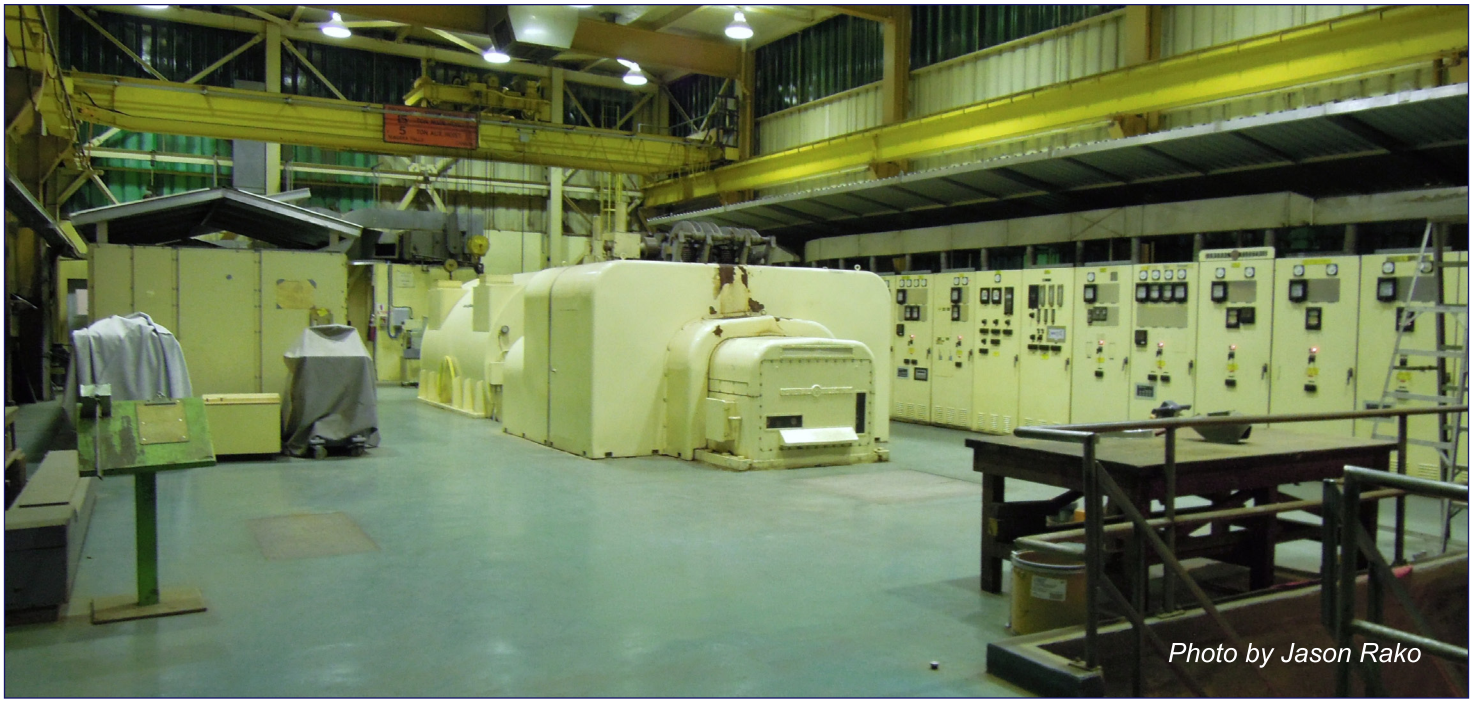
Number 6 Boiler

Date	Fuel Consumption (lb/min)	Fuel Heating Value (BTU/lb)	Feed Water Enthalpy (BTU/lb)	Steam Enthalpy (BTU/lb)	Steam Flow (lb/min)	Efficiency (%)
July 23	2319	5511	256.08	1373.85	7250	63.4
July 28	2407	5404	255.87	1375.33	7083	60.9
August 06	2467	5151	257.03	1377.40	7667	67.6
August 14	2348	5546	256.90	1378.07	7300	62.9
August 21	2388	5508	256.90	1383.23	7000	59.9
August 22	2470	5463	257.09	1375.28	7400	61.3
August 23	2181	5464	257.08	1374.80	6950	65.2
August 24	2191	5400	257.02	1372.32	6733	63.5

Number 5 Boiler

Date	Fuel Consumption (lb/min)	Fuel Heating Value (BTU/lb)	Feed Water Enthalpy (BTU/lb	Steam Enthalpy (BTU/lb)	Steam Flow (lb/min)	Efficiency (%)
July 23	1193	5511	256.07	1343.97	3333	55.2
July 28	1152	5404	255.56	1347.87	2917	51.2
August 06	1188	5151	255.99	1361.09	3250	58.7
August 14	1152	5546	255.51	1343.56	2783	47.4
August 21	1215	5508	255.98	1348.30	2950	48.2
August 22	1118	5463	255.98	1342.90	2950	52.5
August 23	1088	5464	255.51	1341.84	2850	52.1
August 24	1116	5400	256.07	1344.35	2867	51.8

The Rankine Cycle



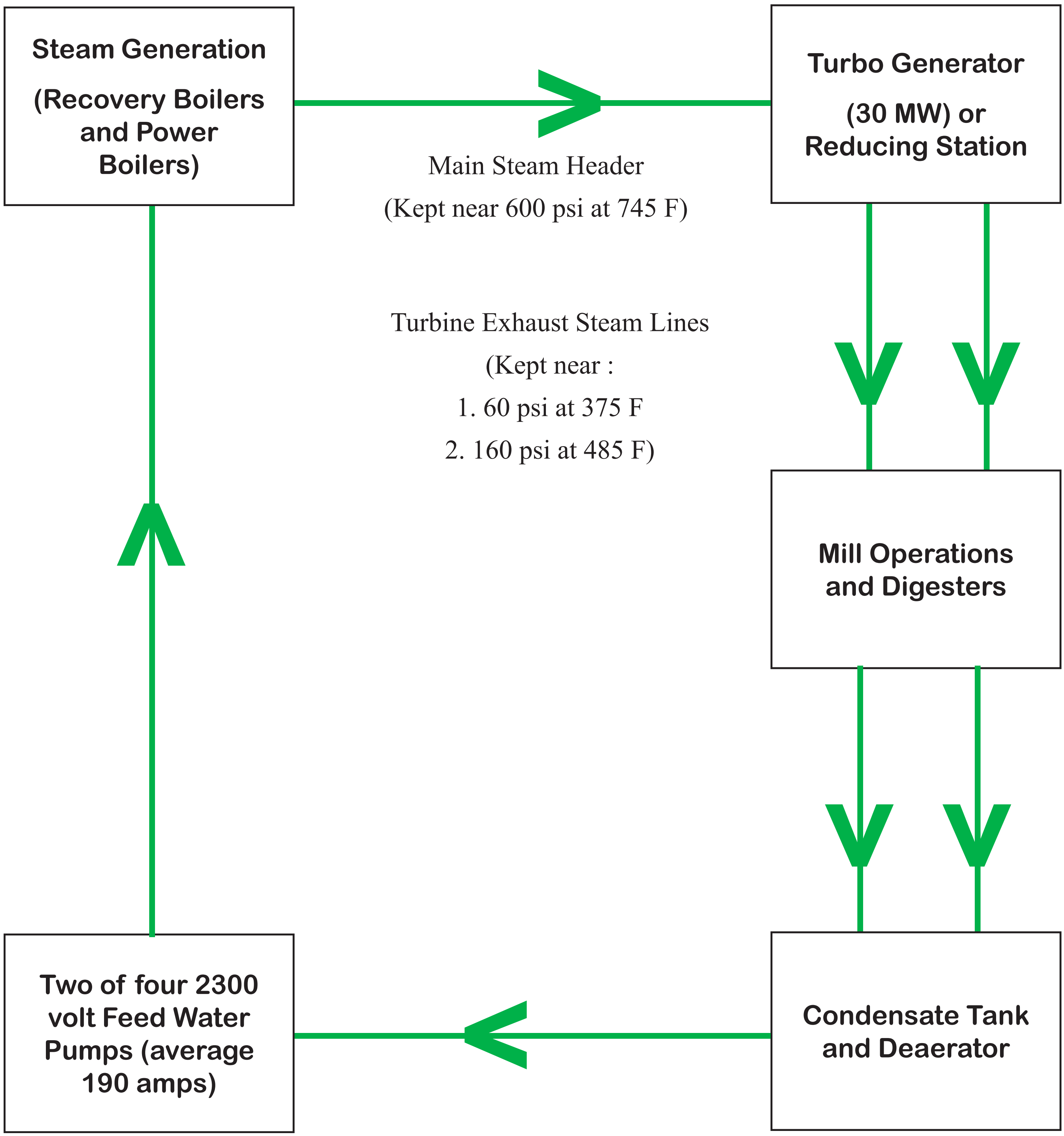
Harmac's 30MW Turbo Generator. It supplies 60 per cent of Harmac's power.

Where does all the steam go?

Harmac Pacific, like all pulp mills, uses a lot of steam. The steam produced by the recovery boilers and power boilers (in a header at about 600 psi superheated) is piped to a 30MW back-pressure turbo generator. This steam is then reduced to 60 psi and 160 psi (superheated) and is piped all over the mill. If the turbine were to fail, the steam can be bypassed through a reducing station.

The major users of steam at the mill are the wood digesters and pulp dryers. However, during my term at Harmac, I did not study the wood digesters in detail and do not know the exact amount of steam used or wasted by these systems.

The basic Rankine cycle is depicted on the opposite page.


Steam Generation
(Recovery Boilers and Power Boilers)
Main Steam Header
(Kept near 600 psi at 745 F)
Turbo Generator
(30 MW) or Reducing Station
Turbine Exhaust Steam Lines
(Kept near :
1. 60 psi at 375 F
2. 160 psi at 485 F)
Mill Operations and Digesters
Condensate Tank and Deaerator
Two of four 2300 volt Feed Water Pumps (average 190 amps)

So Simple.

The Rankine Cycle Cont'd

The Method of Calculation

The calculations will rely on actual numbers obtained from the DCS system. Fuel consumption for Number 9 power boiler were omitted from the data since it was extremely difficult to determine the fuel consumption for the boiler (the fuel stoker speed is expressed as a percentage rather than in volume or mass. Also, the fuel quality literally changed every hour).

Accounting for Number 9 Boiler

Number 9 power boiler is used to compensate for mill steam demand and therefore the heat energy produced by this boiler is constantly fluctuating. However, for the purposes of the mill's efficiency calculations, it will be assumed that Number 9 boiler produces 42.1 MW heat energy at an efficiency of 60 per cent. Therefore, it is assumed that Number 9 boiler requires 70.34 MW of energy and this amount will be added to the "Recovery Boiler Total Energy Consumption".

The Mill Steam Consumption Assumption

The mill uses the exhaust steam from the plant's turbo generator. However, it is assumed that not all of this steam is effectively used and some of it goes to waste. Therefore, an assumption is made that the mill is only 60 per cent efficient and that 40 per cent of the steam is wasted (condensed, leaked, etc.). I didn't have an opportunity to investigate the rest of the mill machinery.

The Calculations

The plant efficiency is determined as total work energy output divided by total energy output. Energy input is the sum of boiler fuel energy, feed pump energy and deaerator steam energy. Energy output is the sum of the energy from the turbo generator and the assumed energy use by the entire mill.

All values were converted to Megawatt units to make the overall calculation easier. Examples of these calculations can be found in Appendix III on page 24.

Sample Plant Data

Date	Recovery Boiler Total Energy Consumption (MW)	Total Boiler Energy Consumption (With #9 Offset)	Deaerator Steam Value (MW)	Feed Pump Energy Use (MW)	Generator Energy Output (MW)	Mill Steam Energy Use (MW)	Cycle Eff. (%)
August 21	348.9	419.2	20.75	0.897	28.5	161.7	43%
August 22	344.6	414.9	20.75	0.8648	27.5	150.33	41%
August 23	314.0	384.3	20.75	0.865	24.1	127.67	37%
August 24	313.9	384.2	20.75	0.8556	24.2	137.03	40%

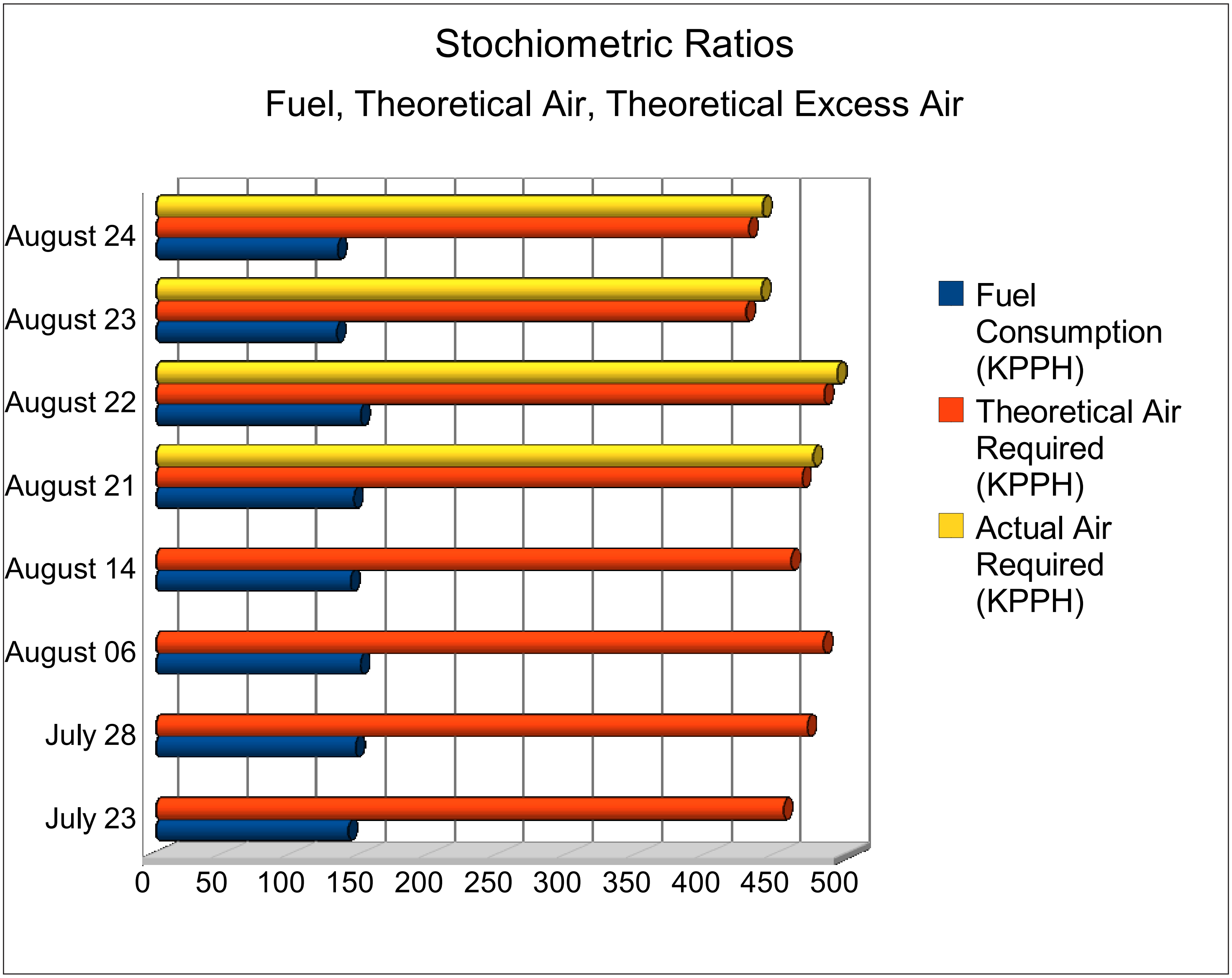
Note that the efficiency values and the efficiency-time graph can be found in Appendix III on page 24.

Appendix I - Stochiometric Calculations

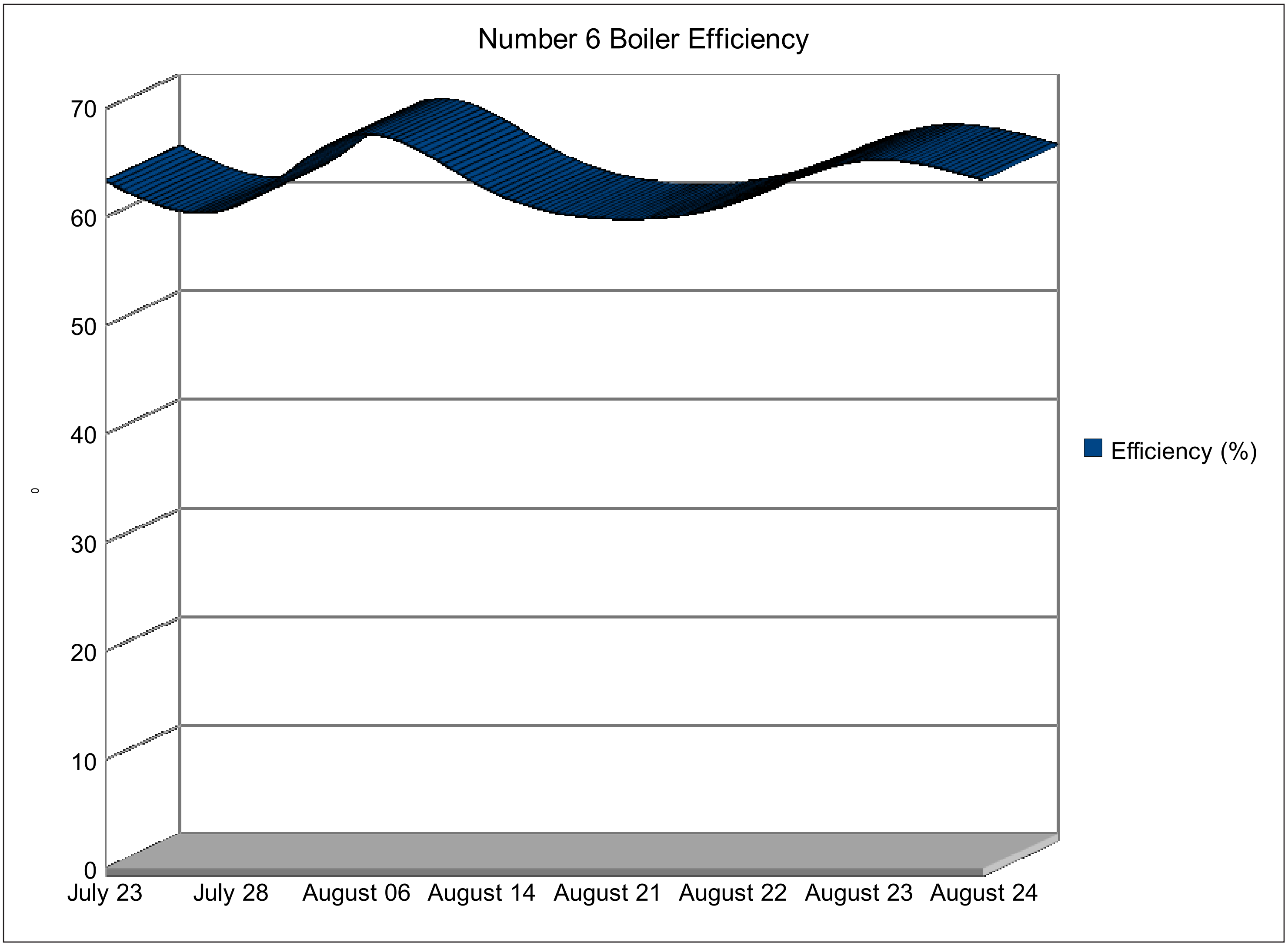
Stochiometric Data for Recovery Boiler

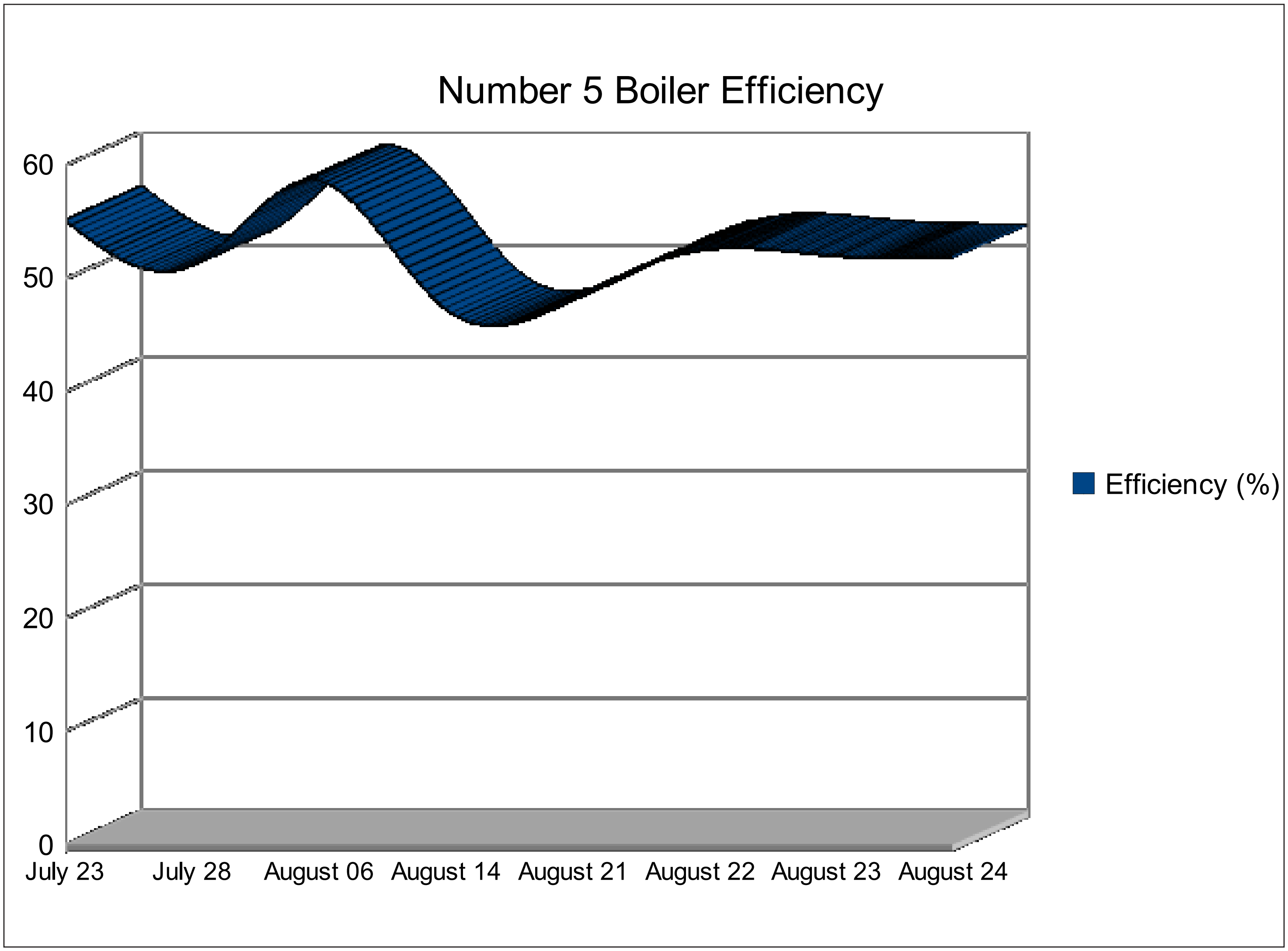
The following table shows the theoretical air required to burn a specific amount of black liquor, based on mass. It was noted earlier that some of the calculated numbers did not match the read out on the DCS instrument screens.

Date	Fuel Consumption (lb/min)	Excess Oxygen (as per instruments)	Theoretical Air Required (KPPH)	Actual Air Required (KPPH)
July 23	2319	-	453.85	-
July 28	2407	-	471.07	-
August 06	2467	-	482.81	-
August 14	2348	-	459.52	-
August 21	2388	1.71%	467.35	475.34
August 22	2470	1.95%	483.40	492.82
August 23	2181	2.61%	426.84	437.98
August 24	2191	2.32%	428.80	438.75


Stochiometric Ratios
Fuel, Theoretical Air, Theoretical Excess Air
August 24
August 23
August 22
August 21
August 14
August 06
July 28
July 23
0
50
100
150
200
250
300
350
400
450
500
Fuel Consumption (KPPH)
Theoretical Air Required (KPPH)
Actual Air Required (KPPH)

Appendix II Boiler Efficiencies




Number 5 Boiler Efficiency
60
50
40
30
20
10
0
July 23
July 28
August 06
August 14
August 21
August 22
August 23
August 24
Efficiency (%)

Appendix III Plant Cycle Efficiency

Plant Cycle Efficiency

Date	Plant Cycle Efficiency (%)
July 23	36
July 28	41
August 06	44
August 14	38
August 21	43
August 22	41
August 23	37
August 24	40

Calculations In-depth

Converting Boiler Fuel Values to Megawatts

([CV x M_f] / 0.948 BTU/S per kW) / 1 000 kW per 1 MW

Where:

CV = Calorific value of Black Liquor (BTU/lb)

M_f = Total mass flow of fuel (Black Liquor) to both boilers in lbs/second

Converting Feed Pump Energy to Megawatts

(I x V) / 1 000 000 W per 1 MW

Where

I = Current

V = Voltage

Note: Multiply the value by two for both feed pumps.

Converting Steam Energy to Megawatts

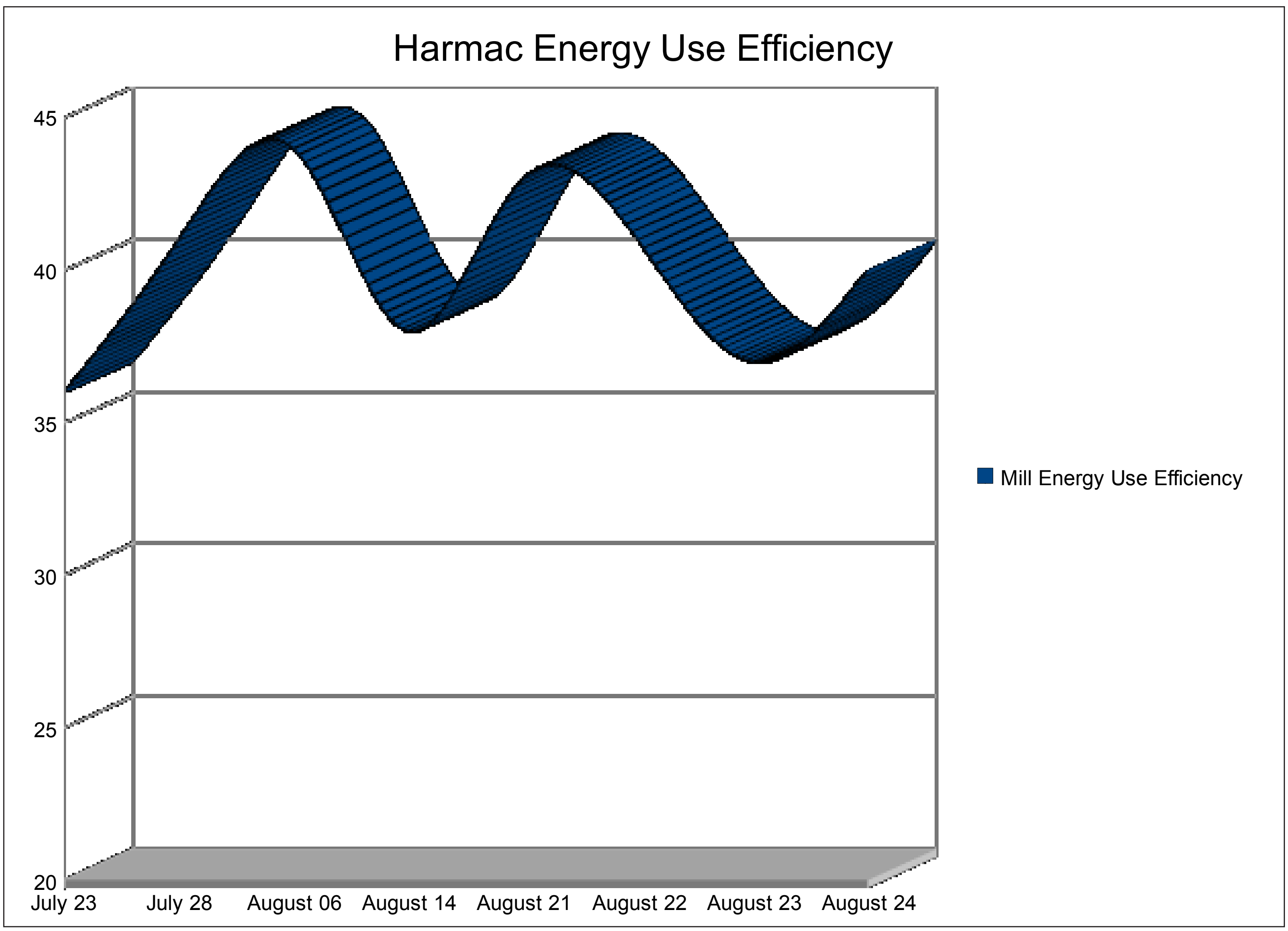
$$([H_g \times M_s] \;/\; 0.948 \text{ BTU/S per kW}) \;/\; 1\,000 \text{ kW per 1 MW}$$

Where:

H_g = Enthalpy of steam (BTU/lb)

M_s = Steam flow (lbs/second)

Note: Heating values of both turbine exhaust lines are added together and multiplied by 0.60 to account for mill energy losses.

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