Foreword:

The boiler is the key utility facility in a paper mill in as much as the thermodynamics going into the process is vital for ensuring both the productivity and the quality of the product lines.

Having observed the process in the capacity of the consultant in the shop floor, I have formed a technical opinion that is significantly different from the practices followed by the industry.

In order to showcase the key differences and the concomitant performance guarantees that accompany this draft, I have justified the technical recommendations in my white paper and stand by it in the perspectives of accountability for realizing the promised gains.

Hence this white paper going into the details of the recommendations have been classified into three main categories:

A. **Determinants in the process**

B. **BOILER DESIGN Recommendations for the Fortuna Industries Limited – tissue paper mills plant:**

C. **ACCOUNTABLITY STATEMENT OF THE CONSULTING ENGINEER / PROCESS MANAGER**

The detailing of the recommendations is my responsibility and there from flows the accountability as well for realizing the promised gains.

The OEM must stick to the recommendations in the letter and the spirit of the fabrication and the subsequent installation and commissioning.

The business owners – Fortuna Industries Limited should stand by their commitment of allowing the implementation of the design recommendations and the ones in the accompanying white paper on the paper industry for the cumulative results to flow in.

A. Determinants in the process

A.1. Heat and thermodynamics

A.1.1. Specific Heat dynamics

Specific heat at the source and at the transfer zones is of vital importance in the paper making process; unfortunately it is **oft ignored** in the contemporary industry in the **context of the Kenyan industry** and hence is the primary cause of bringing in **production inefficiency**, **major equipment breakdowns** and finally in causing the **depreciation in the quality of the product**.

The managing points for the specific heat are the areas of interest in the white paper and shall serve to be instructive to the discerning process technician keen on improving on the operating fundamentals of both productivity and quality besides maintaining the optimized equipment performances.

Managing points for specific heat are enumerated as below:

a) Furnace volume utilization and combustion efficiency

a.i) The furnace defines the **volume of enthalpy** in the system. If the space is utilized at sub-**optimal levels of below 75%,** the consequences on enthalpy drops and fuel combustion quality are severely impaired leading to energy efficiency and more importantly on significant drops in the specific heat transferred to the paper making process.

a.ii) The **refractory lining (reads the same for the stainless steel shell)** in the furnace is the vital **lifeline - determinant** for retention of heat and hence in achieving the peaks in the specific heat corresponding to the basic fundamentals of the enthalpy configuration. The typecast refractory lining would normally have 40-50% of alumina compounds and the balance made of silica. Alumina and silica differ significantly in thermal strains. Greater the Young's modulus of thermal strain, higher is the propensity to resist the heat differentials on a time axis and thus better is the insulating properties associated with effective heat retention and concomitant transfer of specific heat at source as well as at user points.

ILLUSTRATION – I - (A.1.1.a.ii) delineates the relationship graphically.

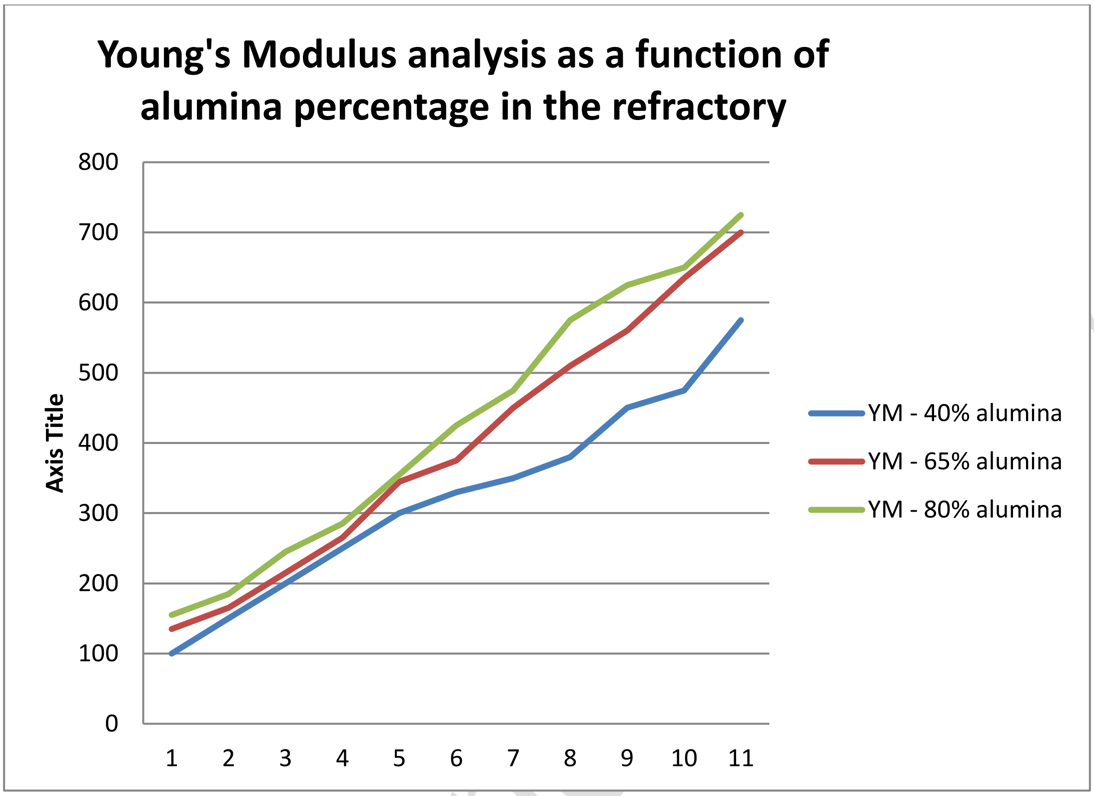
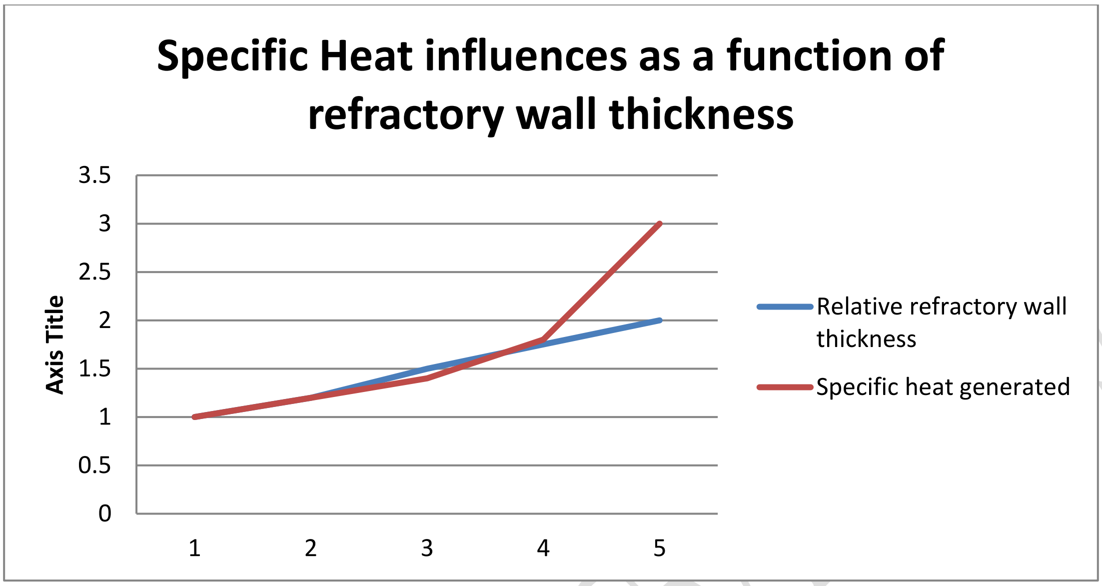
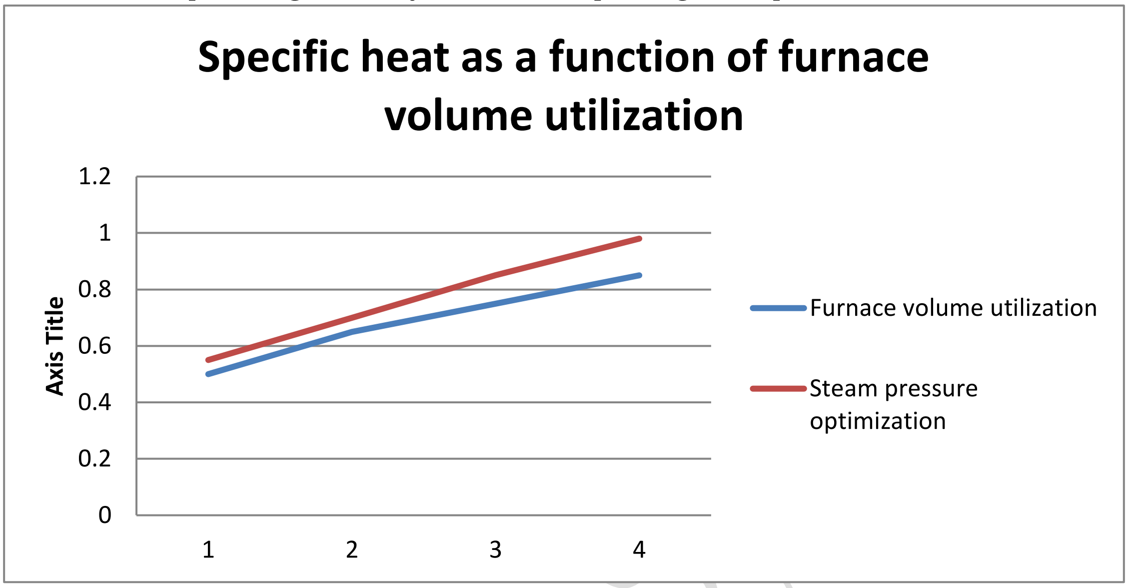


ILLUSTRATION – II (A.1.1.a.ii) portrays the impact of the wall thickness in defining the specific heat. Higher quantum of enthalpy is a function of heat retention; a determinant of the properties of the refractory lining as well as the fundamental thickness of the wall as is elucidated in the graphical representation hereunder.



a.iii) Influences of operating steam pressure on super-saturated steam, the distribution network and the losses in the network elements are the other important determinants for the specific heat dynamics. The utilization of furnace volume is an exponential mathematical function with the steam pressure generated since the heat is defined by the ignition point; the temperature at which the states change. The optimized furnace volume utilization is influenced strongly by the proximity to safety limits in the operating steam pressure as is evinced by the following illustration.

ILLUSTRATION – III (A.1.1.a.iii) portrays the relationship between utilization for furnace volume and the percentage of safety limits in the operating steam pressure.



a.iv) Frictional reduction in the passageway of biomass boilers is imperative to enable optimized enthalpy generation and distribution thereon. In the fossil fuel boilers, emphasis is required for minimizing the dielectric forces within the fluid systems through the neutralization of the static charges that result from the degradation of fluids and release of free radicals from the octane-rich hydrocarbons. Higher pathway friction in the fluid systems causes severe losses in combustibility, enthalpy volume and eventually the specific heat levels in the paper process; hence the dominating need to correct the disruptive influences.

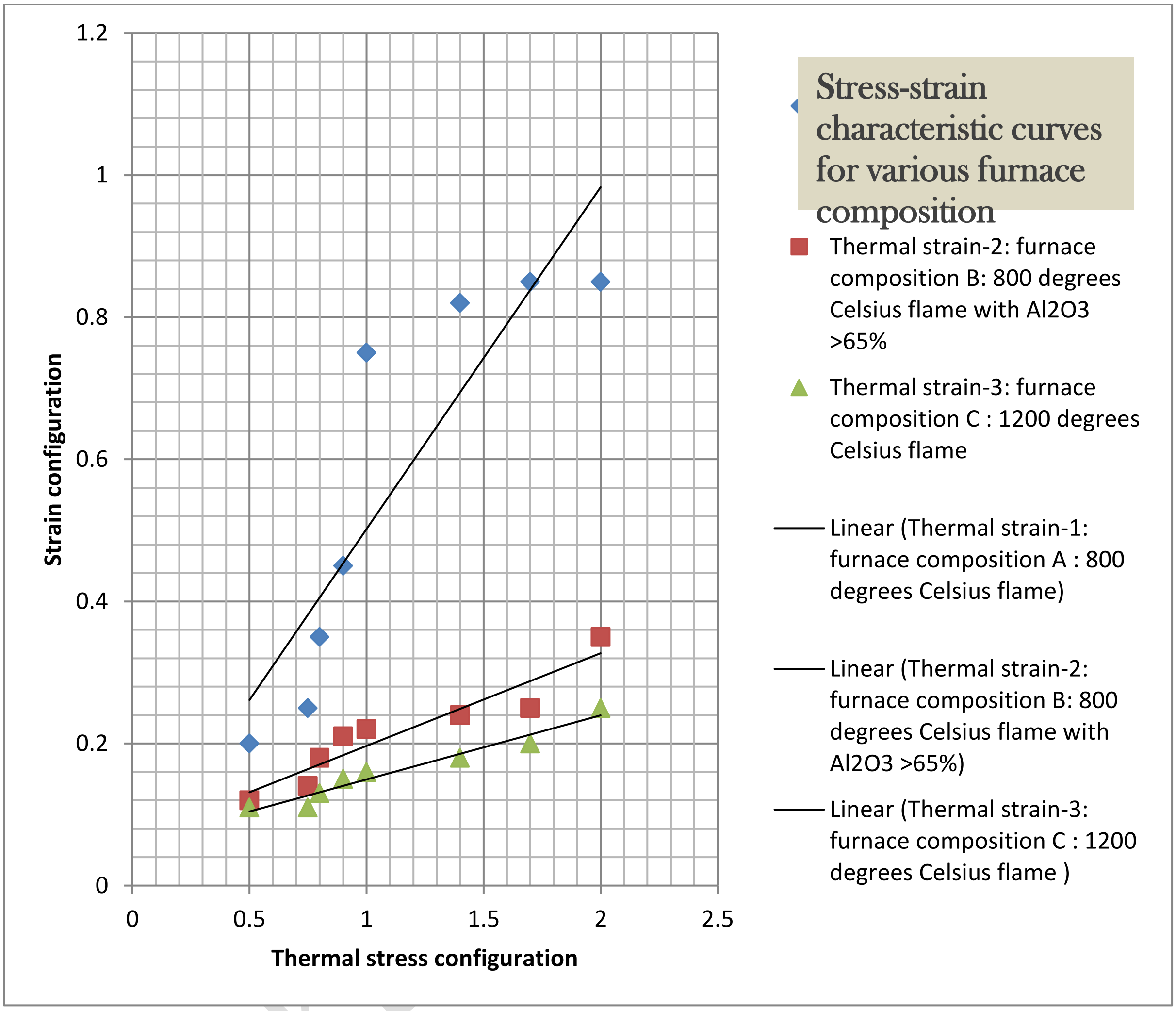
a.v) Insulating medium is the last of the important determinants for the generation and maintenance of the specific heat requirements at the terminal points in the process. The best medium is the LRB – low resin bond that traps the heat effectively and prevents the dissipation to a large extent owing to the high glass transition temperatures of beyond 280 degrees Celsius (way beyond the 170-190 degrees Celsius) requirements for the actual ground conditions at peak heat transfer levels.

A.2. Combustion mechanism and stress-strain curves of the furnace material

Stress-strain analytical curves for furnace heats of various compositions - a comparative model			
Thermal **stress** benchmark units	Thermal **strain-1: furnace composition A : 800 degrees Celsius flame**	Thermal **strain-2: furnace composition B: 800 degrees Celsius flame with Al_2O_3 >65%**	Thermal **strain-3: furnace composition C : 1200 degrees Celsius flame**
0.5	0.2	0.12	0.11
0.75	0.25	0.14	0.11
0.8	0.35	0.18	0.13
0.9	0.45	0.21	0.15
1	0.75	0.22	0.16
1.4	0.82	0.24	0.18
1.7	0.85	0.25	0.2
2	0.85	0.35	0.25

1_{stress}= Thermal stress on peak operating conditions

1 $_{strain}$ = Strain corresponding to permanent loss in thermal elasticity



Notes on the furnace composition:

1. **Young's modulus is a genetic value derived primarily by the metallurgical condition; more importantly the trade-off ratio between the alumina oxide and silica.**

2. **Characteristics of the stress-strain curves and the configurations therein define the retention of heat, the effective flame temperature, the concomitant combustion conditions and the resultant flue gas emissions characterization in terms of lost heat and carbon di-oxide, carbon monoxide and more importantly the excess air and oxygen content.**

3. **The ignition point for bringing in the state change in water would require energy states that would consume fuel as a function of the thermal curves of the furnace composition and hence remains a distinctly differentiating derivative governed by the furnace composition.**

Final conclusions (these observations hold good for stainless steel shell as well on an analogy) :

A. **Alumina rich composition would be desired owing to higher strain resistance across and between heat peaks and troughs.**

B. **Composition meant for reheating furnaces of the tune of 1200 degrees Celsius would be ideal for improving substantially on the combustion characteristics and reducing heat losses, excess air characteristics and the concomitant loss in oxygen – the key burning component.**

C. **The effective burning shall reduce significantly the TDS levels in water going into the steam as is illustrated by the enclosed real time case study:**

Conditions for the case study:

1. **The empirical refractory states were considered after 1 year of run in the operations in the paper industry.**
2. **The refractory lining was changed to new with the original specifications in September – 2017 prior to the repeat study:**

So.No.	Characteristics	Requirement Limits	Results with empirical refractory states	Results after changing refractory lining
i)	Raw Water			
	a) *p*H value	8·5 to 12.0	9.4	9.3
	b) Total alkalinity‡ (as $CaCO_3$), mg/l, *Max*	300	-	-
	c) Residual sodium sulphite (as Na_2SO_3), mg/l	30 to 50		
	d) Total dissolved solids‡ mg/l, *Max*	1200	319	325

	e) Conductivity (micromhos/cm)	-	477	485
ii)	Boiler Water.			
	a) *p*H value	10·5 to 12.0	11.4	11.9
	b) Total alkalinity‡ (as $CaCO_3$), mg/l, *Max*	700	-	-
	c) Residual sodium sulphite (as Na_2SO_3), mg/l	30 to 50	32	41
	d) Total dissolved solids‡ mg/l, *Max*	3500	3296	**1334**
	e) Conductivity (micromhos/cm)	7000	4920	**1992**
iii)	Boiler *Condensate.*			
	a) *p*H value	8·5 to 9.5	8.6	10.3
	b) Iron	0.3	-	0.01
	c) Total dissolved solids‡ mg/l, *Max*	15	96	**10**
	d) Conductivity (micromhos/cm)	30 uS/cm	161	**17**

Conclusions:

1. **pH should be construed as the function of changes in chemistry in the pulp mill of the paper factory.**

2. **The significant changes in TDS validate the studies above and the concomitant changes in conductivity imply that the ionic imbalances are corrected through these measures.**

B. BOILER DESIGN Recommendations for the Fortuna Industries Limited – tissue paper mills plant:

1. **Rakhoh Make Optipac (OP-50)**
2. **Volume of furnace: 5 MT**
3. **Volume of water/ steam : 3 MT**
4. **Safety limit for operating pressure: 17.5 bar**
5. **Actual operating pressure (recommended) : 16 bar**
6. **Operating pressure at the terminal points of the dryer : 14 bar (for the sole dryer at site as of now or for each dryer – assuming the second line is installed as planned)**
7. **Temperature of steam at the steam point: 205 degrees Celsius**
8. **Temperature at the dryer point: 198 degrees Celsius**
9. **Temperature on the web sheet after exchange of heat: 135 degrees Celsius**
10. **Flue gas temperature: 175 – 180 degrees Celsius**
11. **INSULATION FOR FURNACE: 125 MM thickness ASBESTOS WOOL / LRB(low resin bond) *– to be part of the design of the OEM***
12. **INSULATION FOR FLUE GAS EXHAUST: 70 MM thickness ASBESTOS WOOL / LRB (low resin bond) *– to be as per the design acceptance by the OEM***

C. ACCOUNTABLITY STATEMENT OF THE CONSULTING ENGINEER / PROCESS MANAGER

Following are the performance guarantees for Fortuna Industries Limited, Nairobi on implementing the recommendations for the boiler design herein:

1. **Productivity on existing line: 150 mpm with 7 MT / day on 22 hours working and with 2.03 meter working width for the web on 0.0175 GSM.**

2. **Fuel consumption: 500 Kg. of wood per MT of production of paper**

3. **Mechanical Breakdown in the drives: Not possible unless the electrical issues of drive quality related to harmonics and low PF persist and are not taken care of**

4. **Felt life : minimum of 3 months or 500 MT of production run instead of 100-150 Mt life as of now**

5. **Quality consistency in terms of GSM variations and strength consistency: 30% improvement on current standards of variation**

The undersigned shoulders the responsibility and the accountability for the above performance guarantees provided the OEM covers the design recommendations in the letter and spirit and the business owners allow the implementation of the same as guided by the White paper on the paper industry – the document that is accompanying this draft.

Signed and submitted on the 23rd day of October, 2017 by:

BLACKSTONE SYNERGY CONSULTING GROUP LIMITED
PIN NO: P 051523207 T
NAIROBI - 00604

Debashish Banerjee
CEO
Blackstone Synergy Consulting Group Limited,
Nairobi, Kenya