BGM
COMBUSTÃO INDUSTRIAL LTDA.

ATCP

XIII ANNUAL TECHNICAL MEETING

CHILE

INFRA RED ENERGY

THE MOST EFFICIENT ALTERNATIVE

A REAL CASE

BGM Combustão Industrial Ltda
Rua Joaquim Janus Penteado 261- Cajamar - Jordanésia – SP
Ph: 55 11 4407-1558 - Fax: 55 11 4407-1561
vendas@bgmcomb.com.br - www.bgmcomb.com.br

IR ENERGY

THE MOST EFFICIENT ALTERNATIVE

INTRODUCTION:

During these difficult times when production increase is not necessarily the immediate goal, in order to remain competitive while at lower than full capacity, and even then, paper producers must look at better ways to accomplish the tasks carried out by "traditional ways" for years. Energy weighs heavily in today's cost per unit produced: reducing its impact is a **MUST**.

Even though the amount of energy required to perfect a given physical process is the same, no matter the mechanism employed, the *efficiency of said mechanism is the determining factor towards achieving the goal at a lower cost.*

Gas generated Infra-Red energy, with its inherent higher overall efficiency for evaporation of water when compared to either convection or conduction mechanisms, has been widely accepted as the option for production increase.

Adapting to the times, IR higher efficiency also allows for energy savings, with excellent paybacks even from a perspective of purely economics.

BGM Combustão Industrial Ltda
Rua Joaquim Janus Penteado 261- Cajamar - Jordanésia – SP
Ph: 55 11 4407-1558 - Fax: 55 11 4407-1561
vendas@bgmcomb.com.br - www.bgmcomb.com.br

Following please find an exercise to illustrate the above reasoning, applied to process conditions while running 756 g/m^2 board at 46 m/min:

Parameters:

Boiler:

Steam generated at	185 psig, saturated
Steam, energy to generate	1.45 MMBtu/1000 lb
Cost of electricity	U$0.045/kW.h
Cost of Natural Gas	U$5.5/MMBtu
Overall energy consumption	7.9 MMBtu/ton of paper

Line Shaft Turbine:

Inlet steam to LST	170 psig
Exhaust steam from LST	75 psig

Paper Machine:

Type	Cylinder, with high PLI press
Basis weight	756 g/m^2
Machine speed	46 m/min
Moisture after the presses	52.5%
Sheet temperature	51.7^{o}C
Reel moisture	5%

Dryers:

First thermal section	15 cylinders x 42” dia @ 30 psi
Second thermal section	40 cylinders x 48” dia @ 70 psi
Mechanical	All dryers with sleeve bearings

BGM Combustão Industrial Ltda
Rua Joaquim Janus Penteado 261- Cajamar - Jordanésia – SP
Ph: 55 11 4407-1558 - Fax: 55 11 4407-1561
vendas@bgmcomb.com.br - www.bgmcomb.com.br

Other processes:

1. Steam Boxes:
   - ✓ Three: Two @ 5 psi & one @ 25 psi
2. Feedwater pump:
   - ✓ Feedwater @ 212°F, from deaerator

COMMENTS:

1. Line Shaft Turbine:
   1.1. Dry steam is a must for the LST in order to guarantee no condensate droplets impinging onto the steam nozzles; otherwise, wheel most likely would be eroded over time, causing unbalance, vibration, damage to sleeve bearing, etc. Maintenance troubles in general.
   1.2. Since in the real world precise control of steam is not practical, common accepted procedure is to have 20°F– 40°F of superheat in order to avoid eventual low pressure steam –wet steam- due to inherent oscillations of the process.
   1.3. Taking 170 psi as inlet steam would imply only ≅ 7°F of superheat, assuming NO losses between boiler and PM.
   1.4. Fact is that LST has been running for years, which favors the assumption that higher than 7°F of superheat in the inlet steam seems to be reasonable.
   1.5. Hence my choosing of inlet steam to LST as: 145 psig @ 382°F (18.5°F of superheat)

Note: Chose this specific value for precise entrances in steam tables

2. Cylinder Machine:

   A 2.1 m wide cylinder machine producing the reference grade (756 g/m^2 @ 46 m/min), with no helper drives in the cylinder molds, while running under normal operating conditions will draw following HP from LST (approx):
   - ✓ Wet end, up to main press: 45 HP
   - ✓ Second press: 12 HP
   - ✓ Dryers, sleeve bearings: 15 HP

- ✓ Calan: 10 HP
- ✓ Pope reel: 2 HP

Sum: 84 HP

- ✓ Line shaft losses: 15%

TOTAL ≅ 100 HP

3. Feedwater pump turbine:
   - ✓ Being the same type as the LST, it is assumed to have the same efficiency

CALCULATIONS:

1. Line Shaft Turbine:

1.1. Steam consumption:

Physical process in a LST is characterized as both Isentropic & Adiabatic

1.1.1. For constant entropy:

- ✓ $S_{f1} + (X_1 * S_{fg1}) = S_{f2} + (X_2 * S_{fg2})$
- ✓ Since we are working with dry steam, by definition:
- ✓ $S_{g1} = S_{f2} + (X_2 * S_{fg2})$

1.1.2. In a reversible adiabatic expansion:

- ✓ $h_2 = h_{f2} + (X_2 * h_{fg2})$
- ✓ From steam tables: TSR ≅ 54 lb/HP.h
- ✓ From Mollier diagram: TSR ≅ 52 lb/HP.h
- ✓ Averaging the two values: TSR ≅ 53 lb/HP.h

1.2. Efficiency:

- ✓ Rankine cycle efficiency at calculated HP ≅ 45%
- ✓ Corrected for degree of superheat (no significant correction for < 20^{o}F of superheat) and for back-pressure of 75 psi ≅ 37%
- ✓ Steam Flow: (53*100)/(0.37) ≅ 14,325 lb/h
- ✓ Power extracted from inlet steam ≅ 530,000 Btu/h (≅ 210 HP)

2. Total steam generated in boiler:

2.1. Production of reference grade @ 100% efficiency ≅ 116.6 tons/day (9,717 lb/h)

2.2. @ 7.9 MMBtu/ton produced ⇒ 38.4 MMBtu/h

2.3. @ 842 Btu/lb ⇒ ≅ 45,600 lb/h generated

3. Boiler Feedwater pump:

3.1. The energy to increase the pressure of the feed water into the steam drum is provided by the boiler feedwater pump, as after this point, the boiler is essentially an isobaric process, providing latent heat only.

- ✓ Total feedwater ≅ 91 gpm

3.2. In order to increase the pressure of the feedwater from atmospheric up to 185 psig, the power required is:

- ✓ BHP ≅ {(91*425*1)/(3960*0.85)} ≅ 11.5 HP

3.3. Assuming same efficiency for the turbine driving the pump, total power @ turbine efficiency of 37% ≅ 31 HP ≅ 79,200 Btu/h

- ✓ @ 858 Btu/lb ⇒ ≅ 92 lb/h steam consumed

4. Steam Boxes:

4.1. Two (2) @ 5 psi: 0.25 lb/lb ⇒ ≅ 4,860 lb/h

4.2. One (1) @ 25 psi: 0.30 lb/lb ⇒ ≅ 2,915 lb/h

5. Steam Data:

Pressure (psig)	Temperature (^oF)	Enthalpy (h_{fg}, Btu/lb)
185	382	842
145	364	858
75	320	895
70	316	898
59	306	905
30	273	928

6. Summary for reference grade:

   6.1. Boiler:
   - ✓ Steam generated ≅ 45,600 lb/h
   - ✓ Power associated ≅ 38.4 MMBtu/h

   6.2. Feedwater pump:
   - ✓ Steam consumed ≅ 92 lb/h
   - ✓ Power associated ≅ 0.08 MMBtu/h

   6.3. Steam boxes:
   - ✓ Steam consumed ≅ 7,775 lb/h
   - ✓ Power associated ≅ 7.4 MMBtu/h

   6.4. Line shaft turbine:
   - ✓ Power drawn ≅ 0.53 MMBtu/h

   6.5. Total input power to dryer section ≅ 30.4 MMBtu/h
   - ✓ Energy consumed ≅ 6.26 MMBtu/ton

7. Efficiency of the convection (steam) mechanism:

   7.1. Efficiency of Boiler:
   - ✓ Theoretical amount of energy required: 842 x 1000 = 842,000 Btu/1000 lb
   - ✓ Actual amount used: 1.45 MMBtu/1000 lb
   - ✓ Efficiency: 58.1%

   7.2. Efficiency of dryer section (overall):
   - ✓ @ 6.26 MMBtu/tonpaper ⇒ 3,128 Btu/lbpaper
   - ✓ Water evaporated: (95/47.5) – 1 = 1 lbwater/lbpaper
   - ✓ Average steam pressure: {(15 x 30) + (40 x 70)}/55 = 59 psi
   - ✓ Enthalpy @ 59 psi = 905 Btu/lbsteam
   - ✓ Efficiency = (905/3128)*100 = 28.9%

   7.3. Combined efficiency, whole system: (0.581*0.289)*100 ≅ 16.8%

Note: Losses in piping from boiler to PM not included; in some installations could be significant (10%+).

8. Steam required for warm-up the web:
   - ✓ Amount of steam needed to warm-up the water contained: 577.2 lb/h
   - ✓ Amount needed to warm-up cellulose: 182.8 lb/h
     - ⇒ Total steam savings: 760 lb/h

   This is the input power required to "do the job". From this point on, the cost is determined by the efficiency of the convection system used to carry it out.

9. Amount of energy required "to do the job":

   9.1. Using the conventional conduction (steam) drying mechanism:
   - ✓ Warm-up is done with 30 psi steam; hence, hfg = 928 Btu/lb
   - ✓ Total cost: {(760*928)/(0.168)}*(24*350)*(5.5 x 10^{-6}) = U$193,952/year

   9.2. With IR mechanism:

   9.2.1. Total warm-up power required: 96.9 kW/m_{cd}
   - ✓ Heat-up power for water in web: 71.8 kW/m_{cd}
   - ✓ Heat-up power for cellulose: 25.1 kW/m_{cd}

   9.2.2. IR input power:
   - ✓ Power/row_{IR} (7 emitters/row.m_{cd} @ 8.1 kW/emitter: 56.7 kW/row.m_{cd}
   - ✓ Solaronics IRT guarantees 54% minimum efficiency
   - ✓ Effective energy to the web: 56.7*0.54 = 30.6 kW/ row.m_{cd}
   - ✓ Amount of rows required: 96.9/30.6 = 3.16 rows of 16 emitters/row
   - ✓ Input power: 3.16*16*8.1 ≅ 410 kW
   - ✓ Total cost: 410*3414.4*(24*350)* (5.5 x 10^{-6}) = U$64,675/year

SAVINGS: U$129,277/year

NOTE*: When better times come,* ***there is potential for increasing the speed of the machine*** *from both the almost one-row still available and from the warm-up dryers that now will be in the constant evaporation zone:* *<u>WE HAVE INCREASED THE EFFECTIVE DRYING AREA.</u>*