Recoverable Quantity of Waste Heat from Kiln and Preheater Systems and Economic Analysis (Case of Messebo Cement Factory)

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Abstract

This project entitled “Recoverable quantity of waste heat at Messebo cement factor y” has tried to quantify the amount of heat loss, the amount of energy and cost saved from the waste heat. Here both primary and secondary data collection methods were included to carry out the study. So, the projects present starts by identifying the main source of waste (which part of cement have high loss), following calculated heat lost from the identified places or machines and final calculating the possible money saved if the waste heat changed to use full form or if it recovered Successful recovery waste heat contributes to lower fuel cost, lower electricity consumption. Kiln surface zones, Preheater cyclone 4 and 5 are the main areas in which high waste was occur. From Kiln surface zones (959.13 kJ), Preheater cyclone 4 and 5(587.199 kJ) amount of heat is lost. From this lost we can recover around 62 kW power is recovered, 44155kwhr/month energy and 26492birr/month could be saved. It recommended the energy management department should invite and support others participation and to study on the heat recovery from the loosing of energy and to study on the alternative energy sources of the company.

Keywords: Waste heat, waste heat recovery system, Preheater, Kiln, energy,
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1. INTRODUCTION

There are more than 10 cements factories in Ethiopia.Mesebo cement factory is among the largest and former plants which provides cement for the African largest dam which is known as great Ethiopian renaissance dam which has the capacity to produce 6050 mega Watt. In the country majority of cement factories their main source of power is electricity from of utility grid and imported fossil fuels like coal. Thus, they consume a lot of powers to perform their daily activity. As stated in [1 and 2] cement factories are among sector’s which consumes high energy especially the clinker calcination process.

Due to the increase of human population and their demand of electricity increases parallelly. So, peoples are search an alternative option to meet their energy demand. Thus, they do either by introducing renewable source of energy, by hybridization different energy mixes or by optimization and increasing the efficiency of energy materials and equipment’s. Besides these methods peoples are also started recovering the waste heat to generate power for different purposes. A model example of countries which are successfully produced power from waste of cement plants as indicated in [1] are India, China and South-east Asian countries.

As written in [3] the first heat recovery system was established in Japan in 1980 by Kawasaki Heavy Industry KHI at Sumitomo Osaka Cement. Then after, a key project with 15 MW capacity has been released in Kumagaya plant (Taiheiyo Cement). After almost two decades later as stated in [4] China was plant installed its first system in 1998 in partnership with a Japanese manufacturer. So, after many obstacles and modification we have reached in technology of waste heat recovery system to generate power from the flue gases. As described [5] some new generation of heat recovery installations in cement kilns producing up to 45 kWh per ton of clinker currently worldwide.

Messebo cement factory utilize a large quantity of fuel and electricity that ultimately produce heat for a process and generates large amounts of exhaust heat during these manufacturing processes, as much as of the energy consumed is ultimately lost via waste heat, that simply passes out through the gas tubes (chimneys) into the atmosphere or into the surrounding without any recovery.

1.1 waste heat

A lot of authors and researches define in different ways .for examples as defined in [3] Waste heat is heat generated in a process by way of fuel combustion or chemical reaction and then goes into the environment without using it .Reference [4] also define waste heat as the extra heat that escapes from the system .Reference such as [7] also says Waste heat is the energy associated with waste streams of air, exhaust gases, and/or liquids that leave the boundaries of an industrial facility and enter the environment.
The amount of waste heat (Q) can be calculated by using equation (1) [6]

$Q= C.\, m.\, \Delta T$……………………………………………………………………………………[1]

Where m= the mass of the heat carrying medium,
C=the heat capacity of the medium and
ΔT= the temperature difference between the waste heat and ambient temperature

1.2 Heat recovery

As defined in [3] Heat recovery is a method of reducing the overall energy consumption of your site and therefore reducing the running costs. [8] Waste heat to power (WHP) is the process of capturing heat discarded by an existing industrial process and using that heat to generate power (see Figure 1) [8]

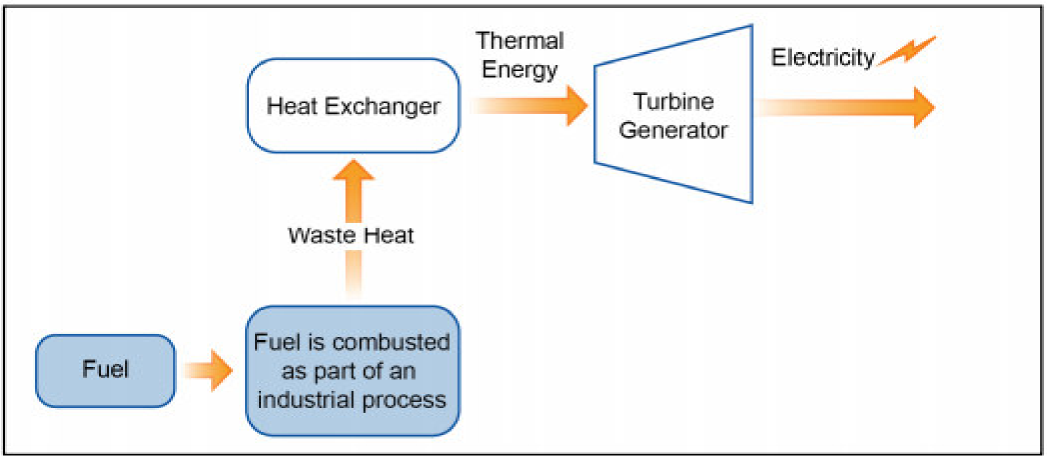

Figure 1: Waste Heat to Power Diagram [8]

Waste heat recovery has the following advantages [3 and 9]

- Reduces purchased power consumption (or reduces reliance on captive power plants), which in turn reduces operating costs.
- Mitigates the impact of future electric price increases
- Enhances plant power reliability
- Improves plant competitive position in the market
- Lowers plant specific energy consumption, reducing greenhouse gas emissions (based on credit for reduced

2. METHODOLOGY

2.1. Description of the study area

Messebo Cement Factory Private Limited Company (MCF PLC) is one of EFFORT (Endowment Fund for the Rehabilitation of Tigray) group companies established in accordance with the commercial code of Ethiopia. The company is located in Mekelle town in the Regional State of Tigray, 780 km from Addis Ababa, capital city of Ethiopia. The plant is located 7 km to the north-west of Mekelle town near Messebo hills. The machineries of the plant are designed and supplied by world renowned cement technology supplier FLSmidth of Denmark. The construction of the Messebo Cement Factory started in February 1997 G.C and was completed at the end of 1999.

Figure 2: Messebo Cement factory

2.2 Data collection

In order to conduct this study, methods and procedures have great contribution for reaching the final result and of the paper. The methods used are discussed below in detail.

2.2.1 Primary Data

I. Direct measurement and observation

For this particular work the data were collected through measurements, formal and informal interview of company experts, machine manuals and direct observation. The temperatures of hot gases and air that loss to the atmosphere, heat loss by radiation were measured using the infrared thermometer,and direct observation from control class room (CCR) .

Figure 3: infrared thermo meter

Figure 4: (A) top view of cyclone 4 (B) cyclone 5

II. .Interview

For those conditions where the required information is not available written form or not directly measured (difficult to measure) making an interview is one part of data collection method.

2.2.2 Secondary data

Other sources are also used as complementary data source agents. Among these sources' internet and reference books, different literature survey and documents of the company were used.

3. Result and discussion

3.1 Existing system

3.1.1 Use of hot gases in existing system

In Messebo Building Materials Production Plc the exhausted gases from Rotary kilns, pre-heater and Calciners are used to heat the incoming feed material and gases then exhausted to the atmosphere. The exhaust gas temperature is averagely around 325℃.Part of this gas is used in raw mills & coal mills for drying purpose. The solid material (i.e. Clinker) coming out of the Rotary kiln is at around 1300-1650 °C and is cooled to 100-120 °C using ambient air. This generates hot air of about 280-300 °C which simply is exhausted to the atmosphere.

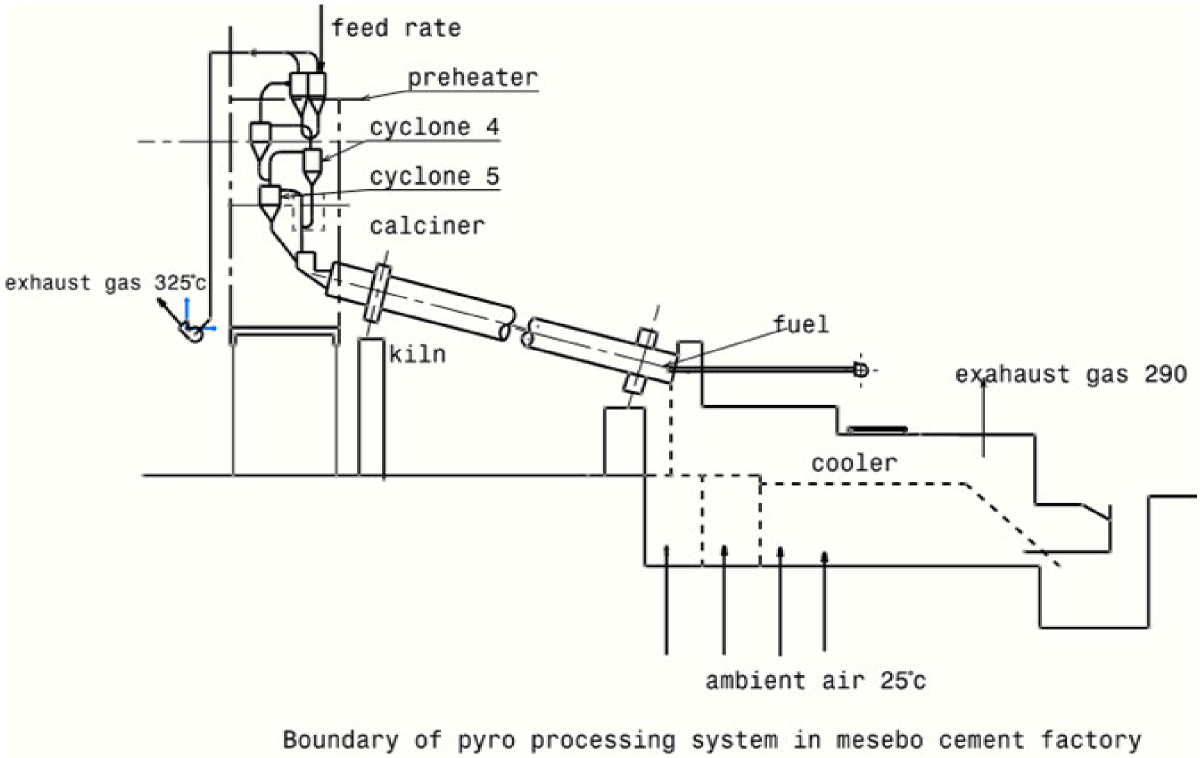

Figure 5: existing system of pyro processing drawing on Catia software

3.1.2 Numerical calculation and thermodynamic analysis

In this portion we are calculating the amount of energy (heat) lost from 1kg of clinker the system and heat inputs to system required to 1kg of clinker .Besides the above figure 5 information we are also consider different data's on each stage of calculation which recorded from CCR and we have used different thermo dynamics laws and principles to analyze the collected data such as Ideal gas laws, first law of thermodynamics thus we take the following thermodynamic assumptions .

- Our reference is 1kg
- Steady state working conditions.
- The change in the ambient temperature is neglected.
- Cold air leakage (false air) into the system is negligible i.e. no false air enters to the system and exit from the system
- Consider the mass flow rate of air through tertiary air duct is negligible
- the system is control volume or open system
- The coal used is south Africa coal which has calorific value(heating value) of 4000-6500kcal/kg

Table 1: some calculated and given value

parameter	Value	Unit
Kiln output rate clinker	101.9	Tone per hour
Clinker temperature	120	Degree Clausius
Kiln feed temperature	80	Degree Clausius
Ambient temperature	25	Degree Clausius
Reference temperature	20	Degree Clausius
Atmospheric pressure	101.325	Kilo pascal
Moisture in fine coal	0.5	Percent
Moister in kiln feed	0.5	Percent
Kiln feed rate (mkf)	130.97	Tone per hour
Mass of coal to feed calciner (mcc)	34000	Kg
Mass of coal feed to kiln (mck)	8000	Kg

So based on above assumptions and given data's(Table 1 and figure 5) lets calculate the following heat loss or the output heat

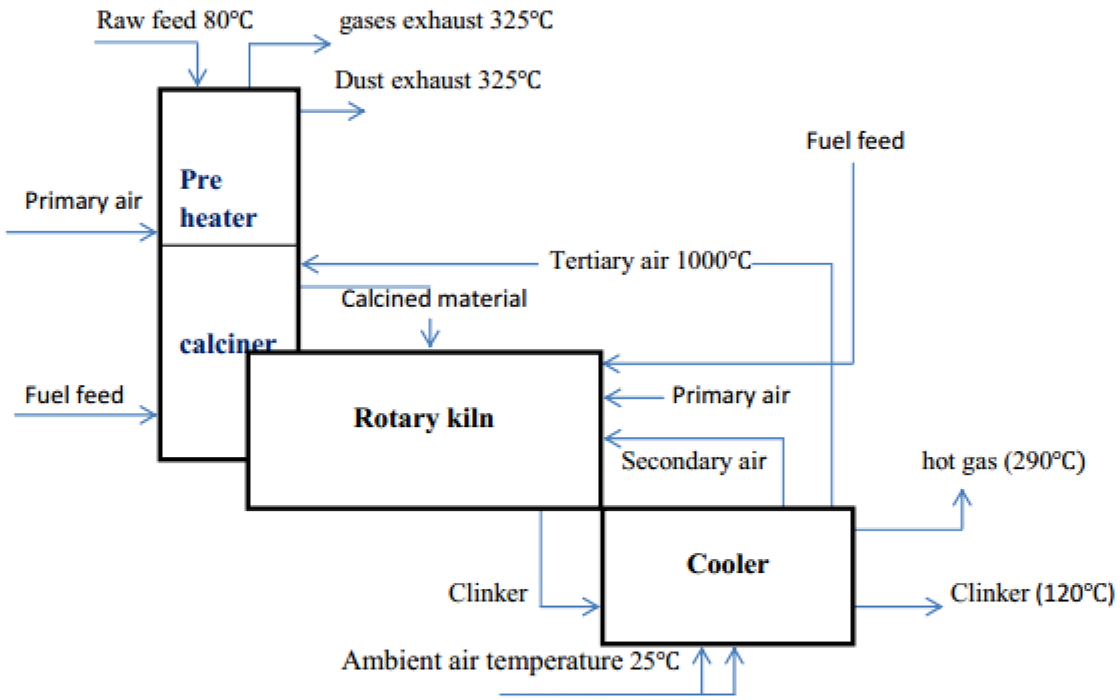

Figure 6: control volume of pyro processing system

The general formula for heat output is given in equation (1) above is .

1. **Sensible heat in kiln feed** (Q1)= $C_{kf}. m_{kf}. \Delta T$ ………………………….………………………..… (2)

Where mkf= mass of kiln feed ,Ckf =specific heat of kiln feed

With kiln feed of typical lime saturation and calcium carbonate content the kiln feed to clinker factor would be expected to be around 1.54 due to loss of CO2 from the CaCO3. That factor is increased by the dust losses from the preheater to the raw mill and dust filters. If the factor is 1.75 then you must have high dust losses from the preheater so improving collection efficiency will reduce the factor. The true raw meal to clinker factor is given by: 1/(1 – Loss on ignition of kiln feed) the given percentage loose of material chemical lab. There is 34%-36% lost.

2. **Sensible heat due to cooling air (Q2)**=m_{co} Cp_{air} (T_a-T_r)……………………..……………….……..(3)

Where m_{co}= mass of cooling air, kg/kg clinker

3.1.3 Cooling air fans Cooler fans:

Instead of **cooling** the **air** itself, **fans** circulate **air** inside an ambient space. Circulation of **air** speeds up the evaporation of sweat on our body, hence giving a **cool** feeling. So, where a **fan** is only circulating the **air**, an **air cooler** is actually providing **cool air** for relief from hot weather

As stated in [10] Heat Capacities of different Gas mixtures(Cp) is the average of the heat capacities of the components: given by the equation below

$C^{ig}P_{mixture} = Y_A C^{ig}P_A + Y_B C^{ig}P_B + Y_C C^{ig}P_C + Y_D C^{ig}P_D$ ……………………………...………. (4)

Where, y is mole fraction or **molar fraction** (**yi**) is defined as the amount of a constituent (expressed in moles), ni, divided by the total amount of all constituents in a mixture (also expressed in moles),n_{tot}[11]

$Yi=\sum_{i=1}^{N} ni = ntot; \sum_{i=1}^{N} Yi$……………………………………………………….………. …. (5)

Therefore Cmixture=($m1/m_{mixture}$) Cp1+($m2/m_{ixture}$) Cp2+($m3/m/_{mixture}$) Cp3………..……………... (6)

So let us calculate and Lets assume the gases will be modeled as ideal gases with constant specific heats.

The molar masses of N2, O2, H2O, and CO2are 28.0, 32.0, 18.0, and 44.0 kg/kmol respectively

The constant-pressure specific heats of these gases at room temperature are 1.039, 0.918, 1.8723, and 0.846 kJ/kg.K, respectively. The air properties at room temperature are cp= 1.005 kJ/kg.K ,

cv= 0.718 kJ/kg.K, and k =1.4 which is the ratio of Cp and Cv

1. **Sensible heat in kiln feed(Q1):**

$Q_1 = m_{kf} \times C_{Pkf} \times (T_{kf} - T_r)$ °C

m_{kf} = Kiln feed rate/ Kiln output rate clinker

With kiln feed of typical lime saturation and calcium carbonate content the kiln feed to clinker factor would be expected to be around 1.54 due to loss of CO2 from the CaCO3. That factor is increased by the dust losses from the preheater to the raw mill and dust filters. If the factor is 1.75 then you must have high dust losses from the preheater so improving collection efficiency will reduce the factor. The true raw meal to clinker factor is given by:

1/(1 – Loss on ignition of kiln feed) the given percentage loose of material chemical lab. There is 34%-36% lost. $\frac{\text{Raw material feed to kiln}}{\text{clinker production}} = \frac{100}{100-\text{lost}}$,but take the average lost is = 35% $\frac{100}{100-35} = \frac{100}{65}$ =1.5384. But the raw material feed to kiln is 130.97$\frac{\text{ton}}{\text{hour}}$.Then the amount of clinker production from 130.97 $\frac{\text{ton}}{\text{hour}}$ raw materials is given by $\frac{130.97\frac{\text{ton}}{\text{hour}}}{\text{clinker production}}$ =1.5384, then

Clinker production = $\frac{1309.7\frac{\text{ton}}{\text{hour}}}{1.5384}$ =85.13 $\frac{\text{ton}}{\text{hour}}$. But the total clinker out let from the burner includes Ash from coal. But the percentage of Ash is 2.43%-3.01% of the total coal feed see the table 2 below .

Table 2:percentage of coal constituents in Messebo cement factory

Elements found in coal	Percentage %
C	72-73
H	3-3.5
O	5.5-6
N	1.5-1.75
S	1.5-1.59
Ash	2.43-3
Moisture	0.25-0.3
Volatile	3.77-4.67
Fixed carbon	3.77-4.67

Material feed to kiln (m_{kf}) = 130.97$\frac{\text{kg}}{\text{hour}}$, Mass of coal to feed calciner (m_{cc}) = 34$\frac{\text{kg}}{\text{hour}}$

Mass of coal feed to kiln (m_{ck}) = 8 $\frac{\text{kg}}{\text{hour}}$ M_k =130.97 $\frac{\text{kg}}{\text{hour}}$

Total mass of the coals inter in to main burning system= M_{cc}+ M_{ck} =34000 $\frac{\text{kg}}{\text{hour}}$ +8000$\frac{\text{kg}}{\text{hour}}$ =42000$\frac{\text{kg}}{\text{hour}}$

Then the amount of Ash produced from total coal feed is given by Ash = $\frac{\%\text{ Ash}}{100}$ *42000$\frac{\text{kg}}{\text{hour}}$ let take us 3% from the interval of the above.

Ash =$\frac{3}{100}$ *42000$\frac{\text{kg}}{\text{hour}}$ =1260$\frac{\text{kg}}{\text{hour}}$.

Then the total clinker production = clinker production from raw material +Ash = 85.13$\frac{\text{ton}}{\text{hour}}$ +21$\frac{\text{kg}}{\text{min}}$

Total clinker production = 1418.83$\frac{\text{kg}}{\text{min}}$ +1260$\frac{\text{kg}}{\text{hour}}$ = 1439.83$\frac{\text{kg}}{\text{min}}$.

Then the above equation be comes

Q1=1.5384 × C_{Pc} $\frac{\text{cal}}{\text{kg°C}}$ ×(80-20) ℃ CPc=1.09-1.55J/gk (0.937073-1.24 cal/kg℃)

For this calculation take 1.24cal/kg k Therefor Q1 = 114.45 kcal/kg clinker

2. Sensible heat due to cooling air (Q2)

Q2 = m_{co}× C_{Pair} × (T_a - T_r)

Where, m_{co}= mass of cooling air, kg/kg clinker

3.1.4 Cooling air fans Cooler fans

Cooling air fans are centrifugal fans used to cool the clinker by sucking atmospheric fresh air before crushed by the clinker crusher. As the atmospheric air is meet with the clinker heat exchange takes places. Then the atmospheric air becomes hot air. Part of this hot gas is suck to the kiln burner by the ID fan. But they remain is goes through the cooler Chimney by pulling of EP fan. See the below data that the system has nine fans and data was recorded from CCR computers of the cooler funs volume flow rate and pressure when the system runs.

Table 3: volume flow rat of cooler fans

Fan	Volume flow rate(**m**^{3}/min)	Suction pressure(mbar)
1	74	52
2	74	48
3	91	45.5
4	639	60.8
5	146	62.2
6	221	45.4
7	208	69.1
8	237	57.6
9	259.8	55.3
total	1949.8	495.9

But mass flow rate of a given system is given by the ration of volumetric flow rate to specific volume. As stated in equation (7) below.

$m_{co} = \frac{\sum_1^9 \bar{\upsilon}}{v}$ ………………………………………………………………………………… (7)

but from ideal gas law PV = nRT where P is the pressure of the gas, V is the volume of the gas, n is the amount of substance of gas (also known as number of moles), T is the temperature of the gas and R is the ideal, or universal, gas constant. From this the specific volume of a substance is the ratio of the substance's volume to its mass. It is the reciprocal of density

specific volume (v) = v/m = RT/p……………………………………………………………….……(8)

p v = RT thus v = RT/P here T = 20 °C which is the reference temperature and the universal gas constant (R) = 287 N.m/kg.k

P is the average of the 9 cooler funs: p = 495.9/9 = 55.1mbar = 5510pa = 5510N/m^2

So $v = RT/P = \frac{287 N.m/kg.k \times 293k}{5510 N/m2} = 15.26 m^3/kg$

$m_{co} = \frac{\sum_1^9 \bar{\upsilon}}{v} = 1949.8 \mathbf{m^3}/min / 15.26 m^3/kg = 127.77 kg/min$

So $Q2 = m_{co} \times CP_{air} \times (T_a - T_r) = 127.77 kg/min \times \frac{1.005 kcal}{kg°C} (\times 25 - 20)°C = 642 kcal/$ min of clinker

3. **Sensible heat in primary air (Q3):** this includes both mass of primary air to kiln and mass of primary air to calciner. To calculate the mass of this air the primary fun flow rate and suction pressure is important.

Primary air fans: Primary air fans are a fan that are used to suck fresh air for starting calcinations by calciner side and for starting burning by the main kiln side as the coal is feed from coal mill by the help of blower to both sides. See the table below

Table 4: primary air fans

Fan	Direction that fan in side	Suction pressure(mbar)	Suction capacity(m^3/min)	Atmospheric temperature (T_p,)
1	Calciner	19	67.36	25
2	Kiln	20.8	73.75	25

- So mass of primary air to Calciner = volume of flow rate of primary air funs to calciner divided by specific volume of air and
- mass of primary air to kiln = volume flow rate of the fun that sucks the kiln air divide by specific volume of the air
- mass of primary air to calciner = $\acute{\upsilon}/v = \acute{\upsilon} = 67.36 m^3/min$ $v = RT/P = = \frac{287 N.m/kg.k \times 298k}{1900 N/m2} = 45.01 m^3/kg$ so

  mass of primary air to calciner = $\frac{67.36 m3/min}{45.01 m3/kg} =$ mass of primary air to calciner $= 1.49$ kg/min
- mass of primary air to kiln=$\acute{\upsilon}/v$: $\acute{\upsilon} = 73.75 m^3/min$, $v = RT/P = \frac{287 N.m/kg.k \times 298k}{2080 N/m2} = 41.12 m^3/kg$
- mass of primary air to kiln = $\acute{\upsilon}/v = \frac{73.75 m3/min}{41.12 m3/kg} = 1.79 kg/min$

So $Q3 = m_p \times CP_{air} \times (T_p - T_r)$ but m_p = mass of primary air to kiln+ mass of primary air to calciner; m_p = 1.79kg/min+1.49 kg/min =3.28 kg/min $Cp_{air} = 1.005 \frac{cal}{Kg\ K}$

Then $Q3 = m_p \times CP_{air} \times (T_p - T_r) = 3.28 kg/min \times 1.005 \frac{KJ}{Kg\ K} (25 - 20)°C$

Q3 = 16.4 kcal/ min of clinker

4. **Sensible heat of fuel(Q4):** before directly goes to calculation see the following necessary date's or points

- The coal temperature is increasing from atmospheric temperature to 75°C during drying by absorbing heat from hot gas
- The temperature of the hot gas used for coal mill is maximum-minimum(220-210°C) and the outlet after drying is from(90-80)°C

The temperature of the hot gas used for raw mill is the same as the temperature outlet from pre heater (mostly 325°C) and the out let after drying the raw material is mostly 110°C.Having these points in mind let us calculate Q4

$Q4 = m_{fuel} \times C_{Pfuel} \times (T_{fuel} - T_r) = m_{fuel} \times \frac{1.24 kcal}{kg°C} \times (75 - 25)°C$ here the mass of fuel is not known. We can get as follow

1kg clinker = 780 k cal

1kg of South Africa coal = 6500kcal

? y kg SA = 780 kcal
1kgSA × 780kcal = y kg SA× 6500kcal /kg of clinker
y = 0.12kg which is m_{fuel}
$\therefore Q4 = 0.12kg \times \frac{1.24kcal}{kg°C} \times (75 - 25)°C$
Q4 = 7.44 kcal/kg of clinker

5. **Heat from combustion of coal(Q5):**

Q5 = m_{fue}× calorfic value of the South Africa coal
Q5 = 0.12kg ×6500kcal/kg of clinker = 780 kcal /kg of clinker

3.1.5 Heat out put

6. **Heat formation clinker (ΔH_R)**: Heat of formation of clinker: This is the heat to convert the raw material to clinker. This is termed the theoretical heat of formation of the raw meal, from first principles by using heat of reaction data. A more rapid estimation of this heat can be done by using a formula developed by ZurStrassen (1957) which gives good agreement with basic calculations. This formula is: Qth = 2.22A + 7.64C – 5.116S –0.59F

Where Qth = theoretical heat of the formation
A, M, C, S and F are the percentage of AW3, MgO, CaO, SiO2 and Fe2Os in the clinker
(ΔH_R): = 2.22Al2O3 + 6.4MgO + 7.646CaO – 5.116SiO2 – 0.59Fe2O3
= 2.22(13.5) + 6.4(0.0004) + 7.646(79.9) – 5.116(5.4) – 0.59(1.5)
= 612.408 kcal/kg clinker

7. **Heat in preheater exit dust(Q6)**

Q6 = $m_d \times CP_d \times$ (Te – Tr)
Where m_d = mass of dust

From table the company uses averagely 130.976t/h from this 90% of this fed is going to the system the rest is returned as a dust through preheater to the atmosphere. That means from the total 130.976 TPH i.e. 130.976 $\times \frac{90}{100}$ = 117.84 TPH is go to the system and 13.097 TPH is return as a dust. 13.097 TPH=218kg/min is its mass flow rate.

Then mass of dust = kiln feed to clinker factor ×preheater return dust %
m_d =1.5384 × 0.01= 0.015384
Q6 = 0.015384 × 0.23 kcal/kg°C × (325 - 20)°C
Q6 = 1.079.7 kcal/min of clinker

8. **Heat in preheater exit gases (Q7):**

Q7 = $m_e \times CP_e \times$ (Te – Tr)

The exhaust gases through the preheater cyclone are O2, CO and NOx let as calculate their density on their dry bases because the moisture from kiln feed and coal in preheater is very small. Average of O2 is 26.36 and total average of CO is 0.62257 and the amount of NOx is 2000-3000ppm which is averagely around 0.0025.so the totally is 26.98

Table 5: pre heater exhaust gases %

Exhaust gas	%	Molecular Weight
O2	97.70	32
CO	2.3075	28
NOx	0.0098	72

As written in different literatures at standard conditions, 0°C and one atmosphere, one kilomole of gas occupies 22.414m^3 and the universal gas constant is 8314.5 J/(kmol. K). So the density of the above gases at standard temperature and pressure (stp) is calculated as follow using equations (9 and 10).

Mass= number of moles substance ×molecular weight of the substance ………………………… (9)

$$\rho_{stp} = \frac{(O2\% \times MW)+(C0\% \times MW)+(NOx\% \times MW)}{22.4 \times 100} \quad \ldots\ldots (10)$$

$$\rho_{stp} = \frac{(97.7 \times 32)+(2.307\% \times 28)+(0.0098\% \times 72)}{22.4 \times 100}$$

$$\rho_{stp} = \frac{3126.4+64.61+0.7056}{22.4 \times 100}$$

ρstp =1.42 kg/m^3
Area cross-sectional = $\frac{\pi}{4}(d_o - 2d_i)^2 = \frac{\pi}{4}(2.61 - 2 \times .11) = 4.5m^2$ where
Volume flow rate of the hot gas = $\bar{\upsilon} = \frac{m}{\rho}$ where $\bar{\upsilon}$ = volume flow rate

- The temperature of exhaust gas averagely 325.16°C
- The pressure is vary from 51.68 mbar but we take the most repeated 56mbar.(taken from CCR)
- The volume flow rate of the hot gas and we take from CCR(central control room) is 9500m^3/min

Volume flow rate of the hot gas = $\bar{\upsilon} = \frac{m}{\rho}$ = so the mass flow rate = $\bar{\upsilon} \times \rho$

= $9500m^3/min \times 1.42\ kg/m^3$ =13490kg/min

Q7 =13490kg/min×CPof thegases × (325.16 − 20)℃

But specific heat of mixture is given by $\frac{\sum micpi}{\sum mi}$

Where m_i = mass of the gases

CP_i = specific heat of individual gases

Specific heat of mixture is given as follow

$$= \frac{\sum micpi}{\sum mi} = \frac{\sum(28kg/mol\times 1.02\mathbf{kJ/kg\ K})+32kg/mol\times 0.919\mathbf{kJ/kg\ K})+28kg/mol\times\ 0.995\mathbf{kJ/kg\ K})) + 46kg/mol\times 1.013kj/kgk}{\sum 134kg/mol}$$

So specific het of the gases = 0.9817 kJ/kg K

Then heat in pre heater exit gases (Q7) is calculated as follow

Q7 = 13490kg/min× 0.9817 kJ/kg K × (325.16 − 20)℃

Q7= 4041274kj℃/kmin =1103267802kj/min

Q7 =18387796.8kj/sec

9. Heat in clinker from cooler discharge (Q8):

Q8 = m_c× CP_c× (Tc – Tr)

Q8= 1× 0.193kcal/kg℃ × (120℃ – 20℃)

Q8=19.3kcal/kg clinker

10. Heat in cooler exhaust air (Q9):

Q9 = m_{ce}× CP_{ce}× (Tce – Tr)

the clinker grate cooler produces 1 - 2 kg/h of exhaust air per kilogram of clinker. Under normal operating conditions, this exhaust air has a temperature of approximately 280- 300° C, which can temporarily increase to 350° C or decrease to ≤ 230° C under abnormal operation(condition).

Q9 = 1.5kg/h× 0.25 kcal. kg − 1. ℃ − 1 × (290 – 20) ° C

Air: $CP_{ce} = 1.005\frac{KJ}{Kg\ K}$

Q9 = 1.6875 kcal/min of clinker

11. Heat loss due to the radiation from the preheater cyclones and kiln surface:

Radiation loss = σ ×(Ts^4 - Tr^4) × surface area

- ✓ Radiation loss from pre heater cyclones surface considered as cylindrical in geometry. So formula for finding the surface area of a cylinder is, with h as height, r as radius, and S as surface area is S=2(π)rh+2(π)r

That is Surface area = $2\pi r^2 + 2\pi rh$

Table 6: area and surface temperature of cyclone4 and 5

Cyclones	**Length (m)**	**Diameter(m)**	**Surface area = $2\pi r^2 + 2\pi rh$**	**Max temp(℃)**	**Min temp(℃)**
Cyclone4	18	5.7	373.17	196	132
Cyclone5	18	5.7	373.17	291	155

Radiation loss from pre heater cyclone (Qc1) = σ ×(T_{max}^4 - T_{min}^4) ×surface area……………… (11)

Where σ = $4.88\times10^{-8}kcal/m^2 - k^4$

- ✓ Qc4 = $4.88\times10^{-8}kcal/m^2\text{-}k^4(196^4\text{-}132^4)$ 373.17 m^2

Qc4 = 20256.95kcal

- ✓ Qc5 = $4.88\times10^{-8}kcal/m^2\text{-}k^4(291^4\text{-}155^4)$ 373.17 m^2

  Qc5 =120020kcal

So the total Radiation loss from pre heater cyclones surface = Qc4 + Qc5 = 140276.95 kcal = 587.199kJ

- ✓ Radiation loss from kiln system: the kiln found in the company is 57m in length and 3.7 m in diameter and is divided in to 3 main zones. Kiln is cylindrical in geometry. So formula for finding the surface area of a cylinder is, with h as height, r as radius, and S as surface area is S=2(π)rh+2(π)r

That is Surface area = $2\pi r^2 + 2\pi rh$

Figure 5: kiln of the company

As shown in the above figure the kin system have cylindrical shape.so we calculating the formula which is used to calculate surface area of cylinder's as shown in the table below

Table 7: kiln surface temperature and surface area

Kiln zone	Length (m)	Diameter(m)	Surface area = $2\pi r^2 + 2\pi rh$ in m^2	Max temp(°C)	Min temp(°C)
In let zone	16.5	3.7	213.187	291	149
Transition zone	33	3.7	404.88	298	151
Higher burning zone	1.5	3.7	38.97	300	161

So the heat loss due to radiation from the kiln surface calculated as follow using equation (10)

Radiation loss = $\sigma \times (T_{max}^4 - T_{min}^4) \times$surface area

$Qi = Ai \sum_{j=1}^{3} \times \sigma(Ts^4 - Tr^4)$

- Radiation Heat loss from inlet zone(Qiz) = $\sigma \times (T_{max}^4 - T_{min}^4) \times$surface area

Where $\sigma = 4.88 \times 10^{-8}$kcal/$m^2$-$k^4$

Qiz = 4.88×10^{-8}kcal/m^2 - k^4 $(291^4 - 149^4) \times 213.187\ m^2$

Qiz = 69474.61kcal

- Radiation Heat loss from transition zone(Qtz):

= 4.88×10^{-8}kcal/m^2-k^4 $(298^4 - 151^4)$ 404.88 m^2 = 145543.72 kcal

Radiation Heat loss from higher burning zone (Qhbz):

= 4.88×10^{-8}kcal/m^2-k $^4(300^4 - 161^4)$ 38.97 m^2 =14126.28kcal

So the total heat loss from the kiln surface by radiation = Qiz + Qtz + Qhbz =229143.28kcal
= 959.13MJ

Then total amount of heat output = ΔHr + Q6 + Q7 + Q8 + Q9 + Radiation loss from cyclone4 and 5+radion loss from kiln surface

There for the total amount of heat output = 612.48kcal/clinker+1.079kcal/min clinker+1103267802kj/min+ 19.3kcal/kgclinker+1.6875kcal/min clinker+587.199kJ +959.13kJ
= 2649.267kJ

Let us calculate the power gained from the heat loss for one month period of time. Power is the rate of using or supplying energy and is given by the following formula:

Power (p) = $\frac{\text{energy}}{\text{time}}$ ………………………………………………………………………………(11)

Where: Power is measured in watts (W)
: Energy is measured in joules (J)
: Time is measured in minute

N.B 1kcal=4186J

3.1.5 summary of powers which is gained from heat loss and the amount birr saved

P1 (from exhaust dust) = Q6/1 month (hr) = 1.079kcal/kg min clinker/43200min = 0.1045w

P2 (from pre heater exit gases) = Q7/1month (min) =1103267802kj/min/43200min = 25538w

P3 (from clinker from cooler discharge (Q8)) = 19.3kcal/kg clinker/43200 =1.87w
P4 (cooler exhaust air (Q9)) =1.6875kcal/min clinker/43200=0.163 W
P5 (from cyclone 4 and 5) =587.199kJ/43200min =13.59KW
P6 (from kiln surface) = 959.13kJ/43200min=22.20kw

But the average unit of price of the electric city is **0. 6birr /kw** .having this point then let us calculate the Cost saving and Energy saved.

- Energy saved = power gained (generated) ×hours of usage in full capacity per month
- Cost saving = energy saving × energy cost

Energy saved (from p1) = 0.1045w× 720hr = 75.274whr/month=0.07527kwhr/month
- Cost saving = 0.6 birr/kw× 0.07524kwhr/month =0.045 birr/month

Energy saved (from p2) = 25538w× 720hr =18387360whr/month =18387.734kwhr/month
- Cost saving = 0.6 birr/kw× 18387.734kwhr/month =11032 birr/month

Energy saved (from p3) = 1.87w× 720hr=1346whr/month =1.34kwhr/month
- Cost saving = 0.6 birr/kw× 1.34kwhr/month = 0.80 birr/month

Energy saved (from p4) = 0.163w× 720hr = 117.36 whr/month = 0.11736kwhr/month
- Cost saving = 0.6 birr/kw× 0.11736kwhr/month=0.07 birr/month

Energy saved (from p5) = 13.59KW × 720hr=9784kwhr/month
- Cost saving=0.6 birr/kw× 9784kwhr/month=5870 birr/month

Energy saved (from p6) = 22.20KW × 720hr=15984kwhr/month
- Cost saving=0.6 birr/kw× 15984kwhr/month=9590 birr/month

4. CONCLUSION

The cement sector is one of the most energy highly uses industries. The clinker Calcination process is the most energy consuming in cement production, because of the exit gases from the clinker cooler and pre-heater and from the kiln surface.

The aim of this study was to determine the amount of heat loss energy and to identify the main source of the heat losses, and to set possible solutions

The amount of heat loss and major heat losses for the system were identified as the preheater exhaust gases and heat carried away by cooler vent air (grate cooler). In addition to this the power generated and cost saved was discussed. See the table below main parts.

Table 8: summarized recoverable heat from selected devices

Source of the heat loss	Amount of heat loss	1.60Power generated(kw)	1.61Energy saved (kwhr/month)	1.62Amount of 1.63cost saved(birr/month)
Preheater exhaust gases	1103267802 J/min	25.53	18387.73	11032
Kiln surface	959.13 kJ	22.20	15984	9590
Preheater cyclone4 4 and 5	587.199 kJ	13.59	9784	5870

The power generated is used to powered 2480 light bulbs with 25-watt capacity. Generally important efforts are being made to continue for saving the energy for the cement industry, Successful reduction of fuel consumption contributes to lower fuel cost, higher clinker production, lower electricity consumption by recover the waste heat.

5. References

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