DETAILED ENERGY AUDIT AND CONSERVATION IN A CEMENT PLANT

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Abstract: A Cement plant is an energy intensive industry both in terms of thermal and electrical energy and more than 40% of production cost is accounted for by the cost of energy. With intense competition in the market place on price, energy conservation offers itself as a low cost option to cut costs and create a market edge. Every effort in bringing down the thermal as well as electrical energy use would impact directly on the profitability of the company.

The energy audit and conservation project was carried out in the cement plant to assess the performance of its various sub-sections and utilities such as pyro-processes, fans, compressors for Cement Manufacturing. This project work also strives to identify potential avenues for energy and cost savings. The plant mainly relies on its 12 MW captive power plant (CPP) to meet its electricity requirements.

This project brings out in a holistic and simple fashion, the broad frame work and methodology required to be followed to conduct an energy audit and conservation study in a typical cement plant.

PROBLEM STATEMENT
Energy audit and conservation in a cement plant, involves pains taking task with enormous amount of duty parameters that need to be monitored measured and analyzed in a systematic manner to bring to maximum possible energy conservation options.

This project has attempted to address the potential energy conservation options which has a major impact on reduction of energy consumption and energy cost savings in a cement plant and with an objective to provide a frame work for instituting an energy audit in a cement plant along with evaluation methods and analysis to bring out meaningful and substantial energy conservation options, in a easy to implement manner.

This project work would serve as a reference guide to any practicing engineer to conduct with ease an energy audit, in a facility as complex as cement plant, in a professional manner.

1. INTRODUCTION
The Progressive management of this cement plant has been continuously improving its technology over the past four decades, since its establishment. It started with the wet process in three separate cement plants, and now these have been wholly converted to dry cement process and modern technology.

The management of this cement plant accords high importance to social responsibility and environmental values. This is manifest in the installation of the latest pollution control equipment in the plant.

To support the production of cement, the plant has modern vertical roller grinding mills along with tube mills both for raw meal as well as coal. Cement grinding is achieved exclusively by tube mills/horizontal ball mills.

The final products of the plant include PPC, OPC, PSG and other special cements. The major markets are Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Puducherry etc.

2. PROCESS DESCRIPTION
The production of cement involves two major processes,

a. **The Pyro-process**, where lime stone the main raw material along with other additives in the form of fine ground power is converted to clinker in multi stage cyclone preheater system and a rotary kiln.

b. **The grinding process**, where clinker along with other additives is ground to form different grades of cement.

c. The schematic of the overall cement production flow chart is given in the Figure 2.1 Overall Flow Diagram of Cement production process.
3. RAW MEAL PREPARATION

Limestone is obtained directly from the mines, which are located around 50 km away from the plant. The limestone boulders are crushed in primary and secondary Crusher at the mine site itself and transported to the factory. The limestone at the factory storage yard after unloading, is tested for quality standards after which it is segregated as high grade, medium grade and low grade limestone by the Stacker and Reclaimer.

Clinker Preparation. The finely ground and blended raw meal is sent to the Kiln via a five stage Preheater string and pre-calciner. The first stage of the Preheater is a double cyclone. Depending upon the various types of cements manufactured, appropriate additives are added to the clinker and are ground in the cement VRM.

4. ENERGY SCENARIO

4.1 Electrical Energy System

The cement plant receives electricity supply from the Captive Power Plant (CPP) (12 MW) and DG sets. It is distributed to various sections of the plant. An energy meter is installed on 110 kV feeder incomer, which records import and export values of power to the grid.

<table>
<thead>
<tr>
<th>Source</th>
<th>Annual power consumption in lakh kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNEB (Grid)</td>
<td>27.105</td>
</tr>
<tr>
<td>CPP</td>
<td>37.67</td>
</tr>
<tr>
<td>DG Set</td>
<td>930.55</td>
</tr>
</tbody>
</table>

The same is presented as a pie chart in the Figure 4.2, which gives the pictorial view of percentage of contribution of energy from each source.
From the above graph, it is clear that the CPP contributes about 93% (930.55 lakh kWh) of total cement plant electrical energy requirements followed by the DG set accounting for 4% (37.67 lakh kWh) and rest 3% (27.105 lakh kWh) from the EB grid supply.

### 4.2 Utilization of Electrical Energy

Electrical energy is being utilized in all the sections of the plant. The section wise specific power consumption per tonne of cement is presented in Table 4.2 below:

**Table 4.2: Section wise Break-up of Electrical Energy consumption**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Section</th>
<th>Specific power Consumption per tonne of cement YTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lime Stone Transport</td>
<td>0.49</td>
</tr>
<tr>
<td>2</td>
<td>Raw Mill-1 &amp; 2</td>
<td>17.35</td>
</tr>
<tr>
<td>3</td>
<td>Kiln</td>
<td>20.43</td>
</tr>
<tr>
<td>4</td>
<td>Coal Mill -3</td>
<td>3.77</td>
</tr>
<tr>
<td>5</td>
<td>Coal Mill - 1&amp;2</td>
<td>0.49</td>
</tr>
<tr>
<td>6</td>
<td>Total Cement Mill</td>
<td>29.25</td>
</tr>
<tr>
<td>7</td>
<td>Packing House</td>
<td>1.65</td>
</tr>
<tr>
<td>8</td>
<td>Miscellaneous</td>
<td>4.06</td>
</tr>
<tr>
<td>9</td>
<td>Quarry</td>
<td>1.17</td>
</tr>
<tr>
<td>10</td>
<td>Plant Stoppage Units</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>78.91</td>
</tr>
</tbody>
</table>

The above break up of SEC is represented as a pie chart in Figure 4.3.

### 4.3 Thermal Energy System

Various fuels are being used the cement plant, for process kiln. The various fuels used and annual consumption quantities are detailed in Table 4.3 below:

**Table 4.3: Annual Thermal Energy consumption in a cement plant and their share**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of Fuel</th>
<th>Annual consumption in tonnes</th>
<th>Calorific Value Kcal/kg</th>
<th>Energy Equivalent Million kals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coal (Indian)</td>
<td>111200</td>
<td>3263</td>
<td>362.85</td>
</tr>
<tr>
<td>2</td>
<td>Coal (Imported)</td>
<td>10580</td>
<td>5961</td>
<td>63.06</td>
</tr>
<tr>
<td>3</td>
<td>Furnace oil (F.O)</td>
<td>124347</td>
<td>10000</td>
<td>3.71</td>
</tr>
<tr>
<td>4</td>
<td>High Speed Diesel (HSD) (including consumption by material handling of 244 tonnes)</td>
<td>248.73</td>
<td>10399</td>
<td>2.59</td>
</tr>
</tbody>
</table>

The share of various thermal energy sources in terms of quantity is clearly represented in a pie chart in Figure 4.4.
From the above chart, it is evident that Indian coal constitutes the single largest thermal energy sources (90.28%) followed by Imported coal (8.59%) for pyro processing. The remaining 1.1% of Furnace oil and HSD are used for start-up and DG set operations.

The equivalent thermal energy contribution of each of the fuels towards cement production is depicted in the pie chart in Figure 4.5.

From the above pie chart, it is clear that the indian coal has a maximum share (82.29%; 362.85 Mkcals) in the overall cement plant’s total thermal energy use and Imported coal constitutes 14.30% (63.06Mkcals) followed by minimum contribution by both the liquid fuels.

4.4 Share of type of Energy in cement production

From the piechart in Figure 4.6, it is clear that in the production of cement in this plant 67.75% of total energy is contributed by Thermal Energy and 32.25% by Electrical energy from the grid and CPP together.( heat rate of CPP is considered).

Table 4.5: Specific Energy Consumption of Plant

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal SEC</td>
<td>kCal/kg Clinker</td>
<td>730</td>
</tr>
<tr>
<td>Electrical SEC (up to Clinkerization)</td>
<td>kWh/Tonne Clinker</td>
<td>59.74</td>
</tr>
<tr>
<td>Electrical SEC (Cement Grinding)</td>
<td>kWh/Tonne Cement</td>
<td>29.43</td>
</tr>
</tbody>
</table>

5. FIELD OBSERVATIONS AND FINDINGS

Table 5.1: Total Surface Heat losses (Radiation & Convention)
<table>
<thead>
<tr>
<th>S.no</th>
<th>Section Ref.</th>
<th>Surface Temp (°C)</th>
<th>Surface area</th>
<th>Radiation heat losses</th>
<th>Convection heat losses</th>
<th>Total Surface heat Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grain cooler</td>
<td>140</td>
<td>14091.84</td>
<td>4103.10</td>
<td>320.50</td>
<td>4423.60</td>
</tr>
<tr>
<td>2</td>
<td>Cooler take off</td>
<td>183</td>
<td>1837.31</td>
<td>14091.84</td>
<td>320.50</td>
<td>4423.60</td>
</tr>
<tr>
<td>3</td>
<td>Kiln chamber</td>
<td>254</td>
<td>2543.10</td>
<td>14091.84</td>
<td>320.50</td>
<td>4423.60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S.no</th>
<th>Section Ref.</th>
<th>Surface Temp (°C)</th>
<th>Surface area</th>
<th>Radiation heat losses</th>
<th>Convection heat losses</th>
<th>Total Surface heat Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Kiln (dist. from burner end in m)</td>
<td>25</td>
<td>250.60</td>
<td>250.60</td>
<td>250.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kiln (dist. from burner end in m)</td>
<td>3</td>
<td>250.60</td>
<td>250.60</td>
<td>250.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kiln (dist. from burner end in m)</td>
<td>4</td>
<td>250.60</td>
<td>250.60</td>
<td>250.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kiln (dist. from burner end in m)</td>
<td>5</td>
<td>250.60</td>
<td>250.60</td>
<td>250.60</td>
<td></td>
</tr>
</tbody>
</table>

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Overall Kiln Heat Balance

The kiln and grate cooler heat balance is based on the above input baseline parameters presented in table 5.1 and the overall heat input and output balance for the kiln are encapsulated in the tables 5.3 and 5.4. The output heat balance presents the magnitude of loss (kcal/kg clinker) as well as percentage of total loss.

5.2 Electrical system

Besides the thermal energy consumed in the pyro-process, good deal of electrical energy is also consumed in the process of production of cement. Fans account for a major portion of the electrical energy consumption apart from pumps, air compressors, lighting and material handling.

5.2.1 FANS

Methodology:

Towards analyzing the as-run performance of all the major Process fans, the average operational duty parameters were collected during the period of study by way of field measurement, design values and also from the Central Control Room (CCR). In order to identify the potential gaps in performance that could be bridged all the relevant fan operational duty parameters were compared with the designed and PG test values. All these were analyzed in depth and accordingly all the fan operating efficiencies were calculated. In addition, respective energy conservation options were identified and presented along simple payback periods which are discussed in ENCON chapter.
(*1) Originally the PH fan was designed for 1700 TPD kiln load and which has now been enhanced to 3000 TPD and further enhancement to 3500 TPD is being contemplated which is presently not possible due to PH fan capacity limitations.

(*2) Fan design efficiency is an assumed value, in the absence of actual data.

6. RESULTS AND DISCUSSIONS (ENCON Options)

6.1 Energy Conservation in Thermal Areas:

The following energy conservation options have been identified.

- Stray/false air ingress reduction.
- Pressure drop reduction.
- Grate cooler efficiency improvements.
- Reduction of radiation heat loss in cyclones & TAD
- The pre-heater exit gas heat is been utilized in rest-Raw mill and rest-coal mill. However there appears to be enough heat in the PH gas existing the GCT as the bypass line to RABH. This could be used to operate a VAM to mitigate electricity consumption in vapour compression system.

Table 6.1.1 ENCON Option1: Stray/false air ingress reduction

7. RECOMMENDATIONS AND CONCLUSIONS

Pyroprocess

Heat Balance: A detailed heat balance was conducted for the pyro-process of the cement plant. The heat balance was conducted for the system consisting of Grate Cooler, Kiln, Pre-calciner and the pre-heaters. It was found from the heat balance that the total heat input into the system was 815.25 kCal/kg clinker. Whereas, on the output side, around 51% of the energy input was used for the useful clinkerization process and the total heat loss from the system was 49%. That is, around 25% of the input energy was lost along with the pre-heater gases, 13% of the input energy was lost along with cooler exhaust air and 2.56% along with the hot exiting clinker from the grate cooler. The radiation and convective losses account for 5.3% of the total heat input.

Cooler Recuperation Efficiency: The Cooler recuperation efficiency is calculated based on indirect (heat loss) method and was evaluated to be 64.64%. The grate cooler efficiency can be improved by 2.8% by reducing the heat loss in (a) exit clinker (exit clinker temp reduction from
130°C to 100°C) and (b) in exhaust air (by reducing temperature of exhaust air from 275°C to 255°C).

**Gas Balance:** The gas balance of the system was drawn starting from the pre heater fan outlet to the RABH fan exhaust, which gives a snapshot of the gas flows, temperatures, static pressures, O₂% and corresponding stray air in-leakage across concerned equipment (like the Vertical Raw mill, Vertical Coal Mill (VCM), electrostatic precipitator (ESP), RABH, Cement Mills etc. A table has also been prepared and presented, which encapsulates the equipment wise values of all the relevant parameters.

**Stray air in-leakage reduction:** It is found from the field measurement that the false air in- leak across the raw-mill circuit is around 61%, Coal mill circuit is 50%, pre-heater RABH fan circuit is 61% and the cement mill1 circuit is 28% of individual input flows. It must be noted here that the major stray air in leaks through the feeding mechanism of the VRM, VCM and the Cement mill (hopper feeding), can be avoided by replacing the old and inefficient trip feed gates with modern rotary feeders. The detailed quantification of savings has been dealt with in the subsequent ENCON sections.

**Pressure drop reduction in Ducts:** The velocities of the gas in each duct connecting all the major cement equipment is calculated and related with the corresponding pressure drops in the ducts. It was found the gas velocities in the pre-heater down-comer duct, Raw mill ESP to ESP fan duct and the Cooler ESP to the Cement mill, are more than 18m/s, against the recommended duct gas velocity of 16m/s. The equivalent energy reduction projections, alongside energy and associated cost benefit savings, have been calculated.

**Fan Efficiencies:** The performance of the major process fans were analyzed based on the average operational duty parameters collected during the period of study, by way of field measurement, design values and also from the Central Control Room (CCR). The performance of the fans such as Raw mill ESP fan, RABH fan and the cement mill 1 fan are good and are operating at efficiencies more than 70%. Where-as, the other major fans, namely, pre-heater fan which is operating at 64% efficiency, coal mill fan and the cooler ESP fans which are operating at efficiencies less than 50% and the cement mill 2 Bag house fan is operating at an efficiency of 67%. As regards the performance of the cooler fans, except P1, 2L and CIS fans, all other fans are performing at efficiencies less than 60% and will yield sizable energy savings if replaced with energy efficient fans, which can perform with efficiencies of 80% and more.

8. **FUTURE SCOPE OF WORK**

This thesis report details the methodology for conducting and evaluating energy conservation and audit for a cement plant. Being a very complex in nature, it is observed that they are many other energy conservation options that can be tapped in future like having latest technologies like high pressure roller mills before raw mills and coal mills which reduces grinding energy by 15-25%, variable frequency drives for all grate cooler fans which reduces grate cooler fan energy consumption, waste heat recovery from preheater and grate cooler exhaust gases, from which about 70% of the existing power consumption can be generated, use of alternate fuels and raw materials etc.

9. **BIBLIOGRAPHY**


Book 1: General aspects of energy management and energy audit
Book 2: Energy efficiency in Thermal utilities
Book 3: Energy efficiency in Electrical Utilities


BIOGRAPHIES

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