ENERGY AUDITING KIT FOR CEMENT INDUSTRIES

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Abstract—Energy is now a costly and scarce commodity in any manufacturing industry, and hence, it is essential for each industry to develop an energy auditing kit to find the energy conservation opportunities and methods to reduce energy consumption. Such energy auditing would be unique, depending on the type and need of the specific industry. The auditing kit needs essential tools such as (i) subdivision of the production system of any commodity in several blocks or departments and (ii) a reliable metering or measurement system in each block. The reasons to have the subdivision or smaller pockets of a particular stage of production is to pinpoint the location of the higher energy consumption where greater attention is needed. The reasons to have a suitable metering system is to provide data for the energy audit, allow proper distribution of electrical energy costs to individual departments and to provide historical data on which performance evaluation can be done.

Energy conservation audit kit Cement industry

INTRODUCTION

The cement industry is one of the major energy consuming industries having a high priority in energy conservation. In India, energy conservation is particularly important in view of the present size of the industry and the rapid expansion that is taking place in it.

Manufacture of cement is basically an energy intensive process in that the chemical and physical process reactions take place at high temperature, besides a considerable amount of electrical energy being needed for grinding of raw materials and clinker. There are basically two types of cement manufacturing technologies—the wet process and the dry process. The wet process is an old or original process in which water is added when the crushed and proportioned amounts of raw materials are ground in the raw mill, and the kiln feed is taken in a slurry. The dry process is a new and modern process wherein the raw materials are dried with hot gases obtained from the kiln, while the raw materials are being ground in the raw mill. Here, the kiln feed is in the form of a powder which is completely dry. In the kiln, the feed moves down the kiln, and the gases move up the kiln with heat exchange and calcination taking place. Hot gases are drawn through the kiln by powerful fans. In the kiln burning zone, the temperature is maintained at around 1500–1600°C, and the chemical reaction takes place and clinker is formed. Beyond the zone of burning, both processes follow the same path, and they are identical.

Out of the total production cost of the cement, fuel and electricity alone is 50%. In the wet process, the contribution of fuel is 30%, and power is 20%, while in the dry process, the reverse is true. It can be easily appreciated that even a marginal reduction in total energy, whether fuel or electricity, will ensure considerable savings in the cost of production. Besides, it will preserve fast depleting valuable fuel reserves in the country.

The primary sources of energy in cement manufacturing technology are oil, coal, gas and electricity, and the secondary sources are utilization of waste heat of one phase of production to the other phase of production. The main uses of energy are (i) grinding of raw materials and (ii) pyroprocessing in the rotary kiln.

Grinding consumes mainly electricity, whereas pyroprocessing consumes thermal energy in the form of coal, oil or gas. The heat content of the waste gas from the kiln is used in predrying and preheating of materials in the raw mill and the kiln preheater, respectively. Waste heat from the exhaust gas of the clinker cooler is used to preheat combustion air, or part of that gas may be directly used as combustion air in an improved version of burners.
It may be mentioned here that the major consumption in areas of electrical energy are: (i) grinding mills, (ii) fans, (iii) pumps, (iv) compressors in the pyroprocessing and homogenization areas, and (v) raw material crushing plant and all material handling systems.

The electrical energy consumption varies from 80 to 160 kWh/tonne of cement.

SECTIONS OF PLANT

A model is required to calculate the specific energy consumption for producing a commodity. We shall take the example of manufacture of cement. The cement manufacturing process can be divided into 14 subsections depending on the unit processes of cement manufacturing technology and the centre of electricity consumption. These sections are as follows:

1. Mining where limestone is raised.
2. Crushing section where bigger size limestone is crushed to smaller pieces.
3. Raw mill section where the crushed limestone is powdered in a ball mill or vertical roller mill along with some specific additions as demanded by raw mill design warranted by the quality and grade of limestone. Here, blending is also carried out to prepare a homogenous raw mill which is to have quality clinker and ultimately quality cement.
4. Kiln is the section where powdered limestone is burned with coal at high temperatures of 1500–1600°C, and clinker is produced. Thereafter, the clinker is taken out at nearly 70–80°C.
5. Coal mill is the section where pulverized coal is made from raw and coarse coal. The pulverized coal is fired in a kiln to burn limestone to produce clinker.
6. Cement mill is the section where the clinker and appropriate additives are powdered to produce cement of the type required by the market.
7. Packing plant is the section where cement is packed.
8. Compressors have been kept in a separate section, as they consume huge amounts of energy, and they should be monitored strictly.
10. Workshop.
11. Overhead crane for handling of raw material, clinker, etc.
12. DG set where auxiliary power is required.
13. Transformer loss is also a considerable amount of energy and is to be measured separately.
14. Measurement of energy for light in plant, colony and quarry is also to be metered separately.

All the locations of metering devices have been shown in Fig. 1.

A mathematical model for the specific energy consumption of each section of the plant can be made as follows. The production line has been shown in Fig. 2.

Quarry

Electric energy consumption is the addition of measurements at points 18 and 20, say it is \( q_t \) kWh in a particular small period considered for regular monitoring purposes. Now, the production of material at various sections during this period has been shown in Fig. 2. We can have cement production from the complete model. In the quarry, calculated cement is

\[
Q \times \frac{C_1}{C_1} \times \frac{R_1}{R_1} \times \frac{K_1}{K_1} \times \frac{T_1}{T_1} = q_m \text{ tonnes.}
\]

Therefore, the specific energy consumption for the quarry

\[
= \frac{q_t}{q_m}
\]

kWh per tonne of cement.

Crusher

Electric energy consumption in the crushing section is the summation of the measurements at points 14 and 19, say it is \( C_c \) kWh. Calculated cement can be modelled as

\[
C_c \times \frac{R_1}{C_1} \times \frac{K_1}{R_1} \times \frac{T_2}{K_1} = C_m \text{ tonnes.}
\]
Fig. 1. Location of metering of sections load has been indicated as . Besides each individual load above 50 h.p. should have separate metering devices for kWh, voltage, current and power factor.

Therefore, the specific energy consumption for the crushing section

\[ \frac{C_s}{C_m} \text{ kWh per tonne of cement.} \]

Fig. 2. Production line of cement plant.
Raw mill

Electric energy consumption in the raw mill section is the summation of the measurements at points 33, 11 and 33, say it is $P_1$ kWh.

Calculated cement can be modelled as

$$R_1 \times \frac{K_1}{R_2} \times \frac{T_1}{K_2} = \frac{r_1}{r_m} \text{ tonnes.}$$

Therefore, the specific energy consumption for the raw mill section

$$= \frac{r_1}{r_m} \text{ kWh per tonne of cement.}$$

Kiln

Electric energy consumption in the coal mill is also taken in this section. Of course, a separate data of consumption per MT of coal pulverized is also maintained separately to monitor effectively the additions of measurements at points 18, 12, 35, 36, 39 and 16, say it is $P_2$ kWh. Cement manufactured is calculated as

$$K_1 \times \frac{T_1}{K_2} = \frac{r_2}{r_m} \text{ tonnes.}$$

Therefore, the specific energy consumption of the kiln

$$= \frac{K_2}{T_1} \text{ kWh per tonne of cement.}$$

Cement mill

Electric energy consumption in the cement mill is the summation of the measurements at points 13 and 42, say it is $P_3$ kWh. Cement production is calculated as $T_1$ tonnes.

Therefore, the specific energy consumption for the crushing section

$$= \frac{T_1}{T_3} \text{ kWh per tonne of cement.}$$

Packing plant

Electric energy consumption is the measurement at point 45, say it is $P_4$. Calculated cement is $T_2$ tonnes.

Therefore, the specific energy consumption for the packing plant

$$= \frac{T_2}{T_3} \text{ kWh per tonne of cement.}$$

Thus, considering all the departments as mentioned above, the energy consumption to produce 1 tonne of cement would be equal to the addition of the sectional specific consumptions.

Services

These loads can be categorized in different heads as follows:

(a) compressors at point 46; (b) water supply (plant) 44; (c) water supply (colony) 43; (d) workshop 34, (e) OH crane 47; (f) DG set aux. 48, (g) welding 24 + 32 + 37 + 41; (h) lighting (1) colony 22, (2) plant 17, (3) quarry 18, (i) canteen 25, (j) guest house 23, (k) school 28, (l) admin. building 29, (m) hospital 26, (n) community centre 27, (o) houses of colony 22, (p) TR losses (1 - 2)+, (3 - 4)+, (5 - 6)+, (7 - 8)+, (9 - 10).

The consumption of the above locations can also be calculated as specific consumption per MT of cement for monitoring purposes. A sample sheet has been shown in the Appendix.

DIFFICULTIES OF METERING SYSTEM

Some typical problems in providing a first class metering system include:

—Insufficient funds to monitor as many circuits as desired,
Poor location of conductors that do not lend themselves to proper potential transformer (PT) and current transformer (CT) locations,
- Meters in hard to reach places (dangerous places),
- Engineers unfamiliar with what is needed and lack of trained calibration and maintenance personnel,
- Inadequate funds for maintenance and spare parts,
- Lack of time or qualified staff to read the meters,
- Meter readings that do not reconcile (for example, meters that indicate more energy was consumed than was purchased from the utility).

RESULTS

With regards to audits of the electrical power system, metering results can be used to compile an energy profile that can
- Aid in refining energy use by department,
- Improve energy use accountability, e.g.,
- Allow measurement of cost accountability,
- Help determine equipment capability and load factors for future modifications and plant expansion,
- Provide data for analysing results that vary from established standards.

In addition, an energy profile will be likely to reveal areas where conservation projects are most beneficial.

The second reason for metering in values is the need to distribute the charges for energy accurately to each department on a periodic basis. In the old days, only a single kWh metering point might have been available, as decided by the utility company. Now, greater need exists to provide sufficient metering to identify completely the users and allow charges to be made to the individual departments. Once a metering system is installed and is operating, a 2–3% energy saving can be expected as a result of the detection of system losses.

Third reason for metering is to gather historical consumption data so as to measure performance against the standard. The specific consumption in kWh tonne of the production can be calculated as shown in the preceding section, and a graph of specific energy consumption vs time in weeks can be drawn as shown in Fig. 3 to watch the performance of the plant.

WEEKLY ANALYSIS

Now, the specific energy consumption of each section and of the plant as a whole can be compared to the plant design norm and against the existing industry norm, and the deviation, if any, can be analysed properly as adequate data are available. In case it has gone down, the reasons are to be established, and the same to be maintained or further improvements be attempted. If, on the other hand, the energy consumption has increased, the reasons thereof have to be established and necessary corrective measures taken to reduce the same.

CONCLUSIONS

It is, thus, imperative that good monitoring and auditing kits will certainly increase the probability of energy savings by indicating the areas where power is unnecessarily drained. Hence,
each and every industry must pay attention to developing its own energy audit kit based on the above principles. A typical energy audit kit table has been shown in the Appendix.

REFERENCES

### APPENDIX

**Table A1. Energy audit kit**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Block (1)</th>
<th>Material consumption (MT) (2)</th>
<th>Production achieved (MT) (3)</th>
<th>Calculated clinker (MT) (4)</th>
<th>Calculated cement (MT) (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quarry</td>
<td>373,302</td>
<td>357,916</td>
<td>228,686</td>
<td>239,274</td>
</tr>
<tr>
<td>2</td>
<td>Crushing</td>
<td>380,635</td>
<td>391,420</td>
<td>250,093</td>
<td>261,672</td>
</tr>
<tr>
<td>3</td>
<td>Raw mill</td>
<td>386,671</td>
<td>386,210</td>
<td>243,203</td>
<td>254,465</td>
</tr>
<tr>
<td>4</td>
<td>Kiln</td>
<td>243,067</td>
<td>243,485</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>5</td>
<td>Coal mill</td>
<td>—</td>
<td>55,901</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>6</td>
<td>Cement mill</td>
<td>—</td>
<td>254,330</td>
<td>—</td>
<td>254,330</td>
</tr>
<tr>
<td>7</td>
<td>Packing plant</td>
<td>—</td>
<td>256,996</td>
<td>—</td>
<td>256,996</td>
</tr>
<tr>
<td>8</td>
<td>Compressor</td>
<td>—</td>
<td>—</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>9</td>
<td>Water supply (Plant)</td>
<td>—</td>
<td>—</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>10</td>
<td>Workshop</td>
<td>—</td>
<td>—</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>11</td>
<td>OH crane</td>
<td>—</td>
<td>—</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>12</td>
<td>DG set</td>
<td>—</td>
<td>—</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>13</td>
<td>TR loss</td>
<td>—</td>
<td>—</td>
<td>243,485</td>
<td>254,758</td>
</tr>
<tr>
<td>14</td>
<td>Lighting</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(a) Colony</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(b) Plant</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(c) Water supply-colony</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>kWh consumption (1)</th>
<th>kWh/MT clinker (2)</th>
<th>kWh/MT cement (3)</th>
<th>Deviation (4)</th>
<th>Reasons and necessary steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>278,232</td>
<td>1.22</td>
<td>1.16</td>
<td>0.16</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>1,348,648</td>
<td>5.39</td>
<td>5.15</td>
<td>1.15</td>
<td>Frequent jamming, idle running, wearing out of hammers</td>
</tr>
<tr>
<td>3</td>
<td>9,707,484</td>
<td>39.91</td>
<td>38.15</td>
<td>8.15</td>
<td>Higher feed size, higher moisture content of feed, low charging of mill, damaged classifier, drought shifted from optimum, return of air separate very high, idle running, frequent tripplings, etc.</td>
</tr>
<tr>
<td>4</td>
<td>10,035,190</td>
<td>41.21</td>
<td>39.39</td>
<td>9.35</td>
<td>Leaks in seals, preheater tower and fuel duct lines, low output rate, frequent tripplings on account of bad quality of power, higher air to burn low quality coal, incipient loss of power</td>
</tr>
<tr>
<td>5</td>
<td>2,349,761</td>
<td>9.65</td>
<td>9.22</td>
<td>1.22</td>
<td>High moisture in coal, big coal size, bull charging out not optimized output rate low, incipient loss of power</td>
</tr>
<tr>
<td>6</td>
<td>9,189,719</td>
<td>—</td>
<td>36.13</td>
<td>6.13</td>
<td>Big size of clinker, hard burnt clinker, hot clinker, draught of mill shifted from optimum, bad bearings, mill not changed properly, cement too fine</td>
</tr>
<tr>
<td>7</td>
<td>496,181</td>
<td>—</td>
<td>1.93</td>
<td>1.0</td>
<td>+0.43</td>
</tr>
<tr>
<td>8</td>
<td>1,552,260</td>
<td>4.46</td>
<td>6.10</td>
<td>5.0</td>
<td>+1.10</td>
</tr>
<tr>
<td>9</td>
<td>143,341</td>
<td>0.41</td>
<td>0.56</td>
<td>0.5</td>
<td>O.K.</td>
</tr>
<tr>
<td>10</td>
<td>138,947</td>
<td>0.40</td>
<td>0.55</td>
<td>0.50</td>
<td>O.K.</td>
</tr>
<tr>
<td>11</td>
<td>44,724</td>
<td>0.13</td>
<td>0.18</td>
<td>0.10</td>
<td>+0.80</td>
</tr>
<tr>
<td>12</td>
<td>120,670</td>
<td>0.35</td>
<td>0.47</td>
<td>0.25</td>
<td>+0.22</td>
</tr>
<tr>
<td>13</td>
<td>253,521</td>
<td>0.76</td>
<td>1.03</td>
<td>1.00</td>
<td>+0.03</td>
</tr>
<tr>
<td>14</td>
<td>525,931</td>
<td>—</td>
<td>2.07</td>
<td>2.0</td>
<td>+0.07</td>
</tr>
<tr>
<td>(a)</td>
<td>672,982</td>
<td>—</td>
<td>2.64</td>
<td>2.0</td>
<td>+0.64</td>
</tr>
<tr>
<td>(b)</td>
<td>61,431</td>
<td>—</td>
<td>0.24</td>
<td>0.20</td>
<td>+0.04</td>
</tr>
<tr>
<td>(c)</td>
<td>36,928,422</td>
<td>103.89</td>
<td>144.98</td>
<td>116.00</td>
<td>+28.82</td>
</tr>
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</table>