TEHRMAL ENERGY EFFICIENCY

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THERMAL AUDIT
METHODOLOGY

Visit of NCB Team to cement plant.

Collection of relevant data through data collection format

Field measurement of process parameters

Detailed techno-economic analysis

Discussion with plant officials

Calculations based on field measurements

Report submission
IMPORTANT MEASUREMENT LOCATIONS IN K-5

- **SLC ID FAN**
  - Temp: 320 Deg C
  - Flow: 0.7 Nm3/kg cl
  - Temp: 297 Deg C

- **ILC ID FAN**
  - Temp: 420 Deg C
  - Flow: 1.1 Nm3/kg cl
  - Temp: 407 Deg C

- **To coal mill**
  - Flow: 0.17 Nm3/kg cl
  - Temp: 637 Deg C

- **Cooler vent**
  - Flow: 0.62 Nm3/kg cl
  - Temp: 400 Deg C

- **Clinker leaving cooler**
  - Temp: 170 Deg C

- **SLC string pre heater exit gas**
  - Flow: 0.7 Nm3/kg cl
  - Temp: 297 Deg C

- **ILC string pre heater exit gas**
  - Flow: 1.1 Nm3/kg cl
  - Temp: 407 Deg C

- **Cooling air**
  - Flow: 1.58 Nm3/kg cl
  - Temp: 170 Deg C
## Heat Balance

<table>
<thead>
<tr>
<th>Heat output</th>
<th>K-1</th>
<th>K-2</th>
<th>K-3</th>
<th>K-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat in Clinker leaving cooler (Kcal/kg clk)</td>
<td>31.7</td>
<td>35.4</td>
<td>30.0</td>
<td>49.0</td>
</tr>
<tr>
<td>Heat of reaction (Kcal/kg clk)</td>
<td>402.2</td>
<td>403.0</td>
<td>400.0</td>
<td>400.0</td>
</tr>
<tr>
<td>Heat in Return dust (Kcal/kg clk)</td>
<td>10.5</td>
<td>7.9</td>
<td>4.6</td>
<td>13.5</td>
</tr>
<tr>
<td>Heat in Evaporated Moisture (from Kiln feed &amp; Coal) at preheat exit (Kcal/kg clk)</td>
<td>0.8</td>
<td>2.5</td>
<td>7.3</td>
<td>7.9</td>
</tr>
<tr>
<td>Heat in Cooler exhaust air (Kcal/kg clk)</td>
<td>121.9</td>
<td>82.7</td>
<td>81.0</td>
<td>69.3</td>
</tr>
<tr>
<td>Heat in Preheater exit gases (Kcal/kg clk)</td>
<td>154.7</td>
<td>140.1</td>
<td>163.1</td>
<td>173.5</td>
</tr>
<tr>
<td>Heat in Evaporated water (in cooler), (Kcal/kg clk)</td>
<td>20.2</td>
<td>24.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Radiation &amp; Convection losses (Kcal/kg clk)</td>
<td>50.1</td>
<td>50.0</td>
<td>65.0</td>
<td>60.0</td>
</tr>
<tr>
<td><strong>Total Heat output</strong></td>
<td>792.1</td>
<td>746.4</td>
<td>751.0</td>
<td>773.2</td>
</tr>
<tr>
<td>Sensible heat input (Kcal/kg clk)</td>
<td>27.1</td>
<td>26.7</td>
<td>26.7</td>
<td>27.8</td>
</tr>
<tr>
<td>Heat through fuel (Specific heat combustion)</td>
<td>765.1</td>
<td>719.7</td>
<td>724.1</td>
<td>745.4</td>
</tr>
<tr>
<td><strong>Total Heat input</strong></td>
<td>792.1</td>
<td>746.4</td>
<td>751.0</td>
<td>773.2</td>
</tr>
<tr>
<td>Cooler Efficiency %</td>
<td>51</td>
<td>61</td>
<td>68</td>
<td>67</td>
</tr>
<tr>
<td>Clinker Production (TPD)</td>
<td>6700</td>
<td>7300</td>
<td>3000</td>
<td>3800</td>
</tr>
<tr>
<td>Thermal Potential (kcal/kg clk)</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>35</td>
</tr>
</tbody>
</table>
KILN & COOLER DETAILS

- K-1: 6 Stage ILC& SLC, FLS-Coolex clinker cooler
- K-2: 6 Stage ILC, FLS-SF Cross bar clinker cooler
- K-3: 6 Stage ILC, FLS-Cross bar clinker cooler
- K-4: 5 Stage ILC, grate cooler retrofitted with IKN
- K-5: 4 Stage-ILC & 5 Stage SLC, grate cooler retrofitted with IKN
KILN-1

- Kiln inlet oxygen was 6% which is higher than the normal level of 2-2.5% in ILC indicating high excess air to the kiln.
- False air from PC outlet to preheater fan inlet in ILC and SLC strings are 14% and 7% respectively. (recommended < 6%)
- Heat loss from PH exit gas is 154.7 kcal/kg clinker which is high for 6 stage PH and can be reduced to 146 kcal/kg clinker by maintaining the PH exit gas temperature at 290°C as against to existing temperatures 322°C & 306°C for ILC & SLC string respectively.
KILN-2

- The temperature at kiln inlet was found to be more than 1250 °C which is very high for calciner kilns. Limiting the temperature around 1000 °C will result in saving of fuel for kiln firing.
- False air from PC outlet to preheater fan inlet is 14.5 % and 11.1 % in string 1 and string 2 respectively. (recommended < 6%)
- Heat losses in cooler is 145.9 kcal/kg clinker which is reflected in low cooler heat recuperation efficiency of 61 % against recommended value of 75-80 % for modern coolers.
OBSERVATIONS & RECOMMENDATIONS

KILN-3

• Calciner outlet gas oxygen is around 7% which is high against the normal value of 3-4%.

• Heat losses through preheater exit gases at 163.1 kcal/kg clinker is high on account of high preheater exit gas temperature of 311 °C and high gas volume @ 1.58 Nm3/kg clinker.

• The total heat loss by radiation & convection is 65 kcal/kg clinker. It is recommended to maintain improved refractory practices which will result in reduction of heat losses from radiation & convection to the tune of 10 kcal/ kg clinker.
KILN-4

• Heat losses through preheater exit gases at 173.5 kcal/kg clinker is high on account of high preheater exit gas temperature of 360 Deg C against the recommended value of 330 Deg C for a 5 stage PH.

• Preheater top cyclones collection efficiency was 90 % against the expected value of 96-97 % for modern plants.
KILN-5

• Heat losses through preheater exit gases at 227.8 kcal/kg clinker is high on account of high preheater exit gas temperature of 426 °C for 4 stage ILC & 320 °C for 5 stage SLC.

• Heat losses in cooler is 147.8 kcal/kg clinker which is reflected in low cooler heat recuperation efficiency of 61 % against recommended value of 75-80 % for modern coolers.

• Tertiary air temperature at cooler take off is around 870 °C as against the normal value of 970 °C for modern plants.

• The combined preheater top cyclones collection efficiency of both ILC & SLC was 88 % against the expected value of 96-97 % for modern plants.
## PAT-EFFECT ON THERMAL EFFICIENCY FOR CEMENT KILNS

<table>
<thead>
<tr>
<th>Unit</th>
<th>Potential savings with marginal investment (Kcal/kg clinker)</th>
<th>Clinker Production (LTPA)</th>
<th>PAT Effect (TOE/annum)</th>
<th>Equivalent coal saving per annum (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-1</td>
<td>30</td>
<td>22.11</td>
<td>6633</td>
<td>13266</td>
</tr>
<tr>
<td>K-2</td>
<td>25</td>
<td>24.09</td>
<td>6022.5</td>
<td>12045</td>
</tr>
<tr>
<td>K-3</td>
<td>20</td>
<td>9.90</td>
<td>1980</td>
<td>3960</td>
</tr>
<tr>
<td>K-4</td>
<td>35</td>
<td>12.54</td>
<td>4389</td>
<td>8778</td>
</tr>
<tr>
<td>K-5</td>
<td>30</td>
<td>13.2</td>
<td>3960</td>
<td>7920</td>
</tr>
</tbody>
</table>
PYROPROCESSING OPTIMIZATION
FACTORS RESPONSIBLE FOR SUB-OPTIMAL KILN PERFORMANCE

Deficiency of combustion air

Low level of oxygen below 1% against normal value of 2% with CO formation limiting the kiln firing to 25% and reduction of clinker output besides deterioration in clinker quality.

High PH Exit Gas Temperature

- Old PH string (PH1) - 366°C
- New PH string (PH 2) - 380°C
- Normal 310-330°C for five stage Preheater

Factors behind high preheater exit temperature is high gas velocity of 19-21 m/s as against the maximum velocity of 15-17 m/s in preheater.
FACTORS RESPONSIBLE FOR SUB-OPTIMAL KILN PERFORMANCE

Low Flame Momentum
• Low Flame momentum at 1275%, m/sec against desirable level of 1500%, m/sec for efficient combustion of coal.

Kiln feed LSF variation
• High LSF variation for KF of 112-119 one of the reasons for high free lime in clinker
• LSF Variation should be controlled in the range of +2
FACTORS RESPONSIBLE FOR SUB-OPTIMAL KILN PERFORMANCE

Degree of calcinations

- High DOC of hot meal samples at 96-98% at kiln inlet against the normal range 92-95%
- High calciner outlet temperature of 870-890°C leading to high preheater exit gas temperature
FACTORS BEHIND THE HIGH HEAT CONSUMPTION OF 850 KCAL/KG CLINKER

- High velocity profile in preheater leading to high preheater losses of 218 Kcal/ kg clinker
- High heat losses of 172 Kcal/ kg clinker from cooler
- Low heat recuperation efficiency of 55% for grate cooler
SUGGESTIONS AND RECOMMENDATIONS

- O₂ content not less than 2% and CO content not more than 1000 ppm (0.1 %) at kiln inlet for efficient combustion of coal
- Limit the degree of calcinations to 92-95%
- Silo filling to be maintained above 75% to achieve higher blending
- Silo extraction mechanism changed from sequential to alternate segment with reduction in cycle time of extraction
- Restrict the existing LSF variation of 112 -119 for kiln feed to a suitable level so as to maintain variations within ± 2
- The kiln burner to be operated with a flame momentum of 1500 %m/sec for improved fuel combustion
CONCLUSION

• NCCBM rich experience is Available to Cement plants for improving Thermal Efficiency of Cement kilns
• Good Potential savings exists with marginal investment for a number of kilns
• Machinery suppliers have to come forward for improving thermal efficiency further to save fossil fuels and reduce CO$_2$ emissions
• There should be concerted efforts by cement plants, machinery suppliers, consultants and ESCO for improving the thermal efficiency of cement kilns