# Promoting EE & RE in Selected MSME Clusters in India – Morbi Cluster

## DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

## UNIT CODE WT-40: AIRSON CERAMICS INDUSTRIES

Submitted to

GEF-UNIDO-BEE Project Management Unit

**BUREAU OF ENERGY EFFICIENCY**

Submitted by

DESL

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**Disclaimer**

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- Mr. Kennit Suresh
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- Mr. Vamsi Krishna
- Mr. Vijay Mishra

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- Mr. Balkrishna K. Ambani, Partner

It is well worthy to mention that the efforts being taken and the enthusiasm shown by all the personnel towards energy conservation are really admirable.

We also acknowledge the support from Morbi Ceramics Association throughout the study.

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**ABBREVIATIONS**

| Abbreviations | Expansions |
|---|---|
| APFC | Automatic power factor controller |
| BEE | Bureau of Energy Efficiency |
| BIS | Bureau of Indian Standards |
| BOP | Best operating practice |
| CGCRI | Central Glass and Ceramic Research Institute |
| CMP | Common monitorable parameters |
| DESL | Development Environergy Services Limited |
| ECM | Energy conservation measure |
| EE | Energy efficiency |
| FI | Financial institutions |
| FT | Floor tile |
| GEF | Global Environmental Facility |
| GPCB | Gujarat State Pollution Control Board |
| IRR | Internal rate of return |
| LPG | Liquefied petroleum gas |
| MCA | Morbi Ceramic Association |
| MSME | Micro, small and medium enterprises |
| NPV | Net present value |
| PG | Producer gas |
| PMU | Project management unit |
| PV | Photovoltaic |
| SEC | Specific energy consumption |
| SP | Sanitary ware products |
| RE | Renewable energy |
| UNIDO | United Nations Industrial Development Organization |
| VFD | Variable frequency drive |
| VT | Vitrified tile |
| WH | Waste heat |
| WHR | Waste heat recovery |
| WT | Wall tile |

## UNITS AND MEASURES

| Parameters | UOM |
|---|---|
| Calorific value | CV |
| Degree centigrade | $^0C$ |
| Horse power | hp |
| Hour(s) | h |
| Hours per year | h/y |
| Indian rupee | INR/Rs. |
| Kilo calorie | kcal |
| Kilogram | kg |
| Kilo volt | kV |
| Kilo volt ampere | kVA |
| Kilo watt | kW |
| Kilo watt hour | kWh |
| Litre | L |
| Meter | m |
| Meter square | $m^2$ |
| Metric ton | MT |
| Oil equivalent | OE |
| Standard cubic meter | scm |
| Ton | t |
| Tons of oil equivalent | TOE |
| Ton of $CO_2$ | $tCO_2$ |
| Ton per hour | t/h |
| Ton per year | t/y |
| Voltage | V |
| Watt | W |
| Year(s) | y |

## CONVERSION FACTORS

| TOE Conversion | Value | UOM | Value | UOM |
|---|---|---|---|---|
| Electricity | 1 | kWh | 0.000086 | TOE/kWh |
| Coal | 1 | MT | 0.45 | TOE/MT |
| Natural gas | 1 | scm | 0.00089 | TOE/scm |
| Emissions | | | | |
| Electricity | 1 | kWh | 0.00082 | $tCO_2$/kWh |
| Coal | 1 | MT | 2.116 | $tCO_2$/t |
| Natural gas | 1 | scm | 0.001923 | $tCO_2$/scm |

# EXECUTIVE SUMMARY

The Bureau of Energy Efficiency (BEE) in collaboration with United Nations Industrial Development Organization (UNIDO) is working on the Global Environment Facility (GEF) funded project titled - 'Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India', which aims to give impetus to the energy efficiency initiatives in the small and medium enterprises (SMEs) sector in India. The objective of the program is development and promotion of energy efficiency and enhanced use of renewable energy in 12 selected energy-intensive MSME clusters, identified on the basis of their total energy utilization and energy-intensity levels. The project will provide solutions to certain technological as well as policy level barriers in implementation of energy efficient technologies in the MSME sector. Development Environergy Services Ltd. (DESL) has been engaged to lend project development support for the Morbi Ceramic Cluster in Gujarat.

The assignment targets ceramic industries in four (4) major product categories viz. sanitary products, floor tiles, wall tiles and vitrified tiles. Based on walk through audit and questionnaire survey of several ceramic manufacturing industries, 20 units have been shortlisted by BEE and UNIDO in consultation and discussion with the Morbi Ceramic Association (MCA) to conduct detailed energy audits.

Airson Ceramics Industries has been selected as one of the 20 units for detailed energy audit. Airson Ceramic Industries is a wall & floor tiles manufacturing unit. This report has been prepared as an outcome of energy audit activities carried out in the unit.

## ➨ INTRODUCTION OF THE UNITOF THE UNIT

| | |
|---|---|
| Name of the Unit | Airson Ceramics Industries |
| Year of Establishment | 2008 |
| Address | 8-A National Highway, Opp G.E.B feeder, Lalpar. |
| Products Manufactured | Wall & Floor Tiles |
| Name(s) of the Promoters / Directors | Mr. Balkrishna K. Ambani |

## ➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

- **Stage 1:** Walk through energy audit of the plant to understand process, energy drivers, assessment of the measurement system, assessment of scope, measurability, formulation of audit plan and obtaining required information
- **Stage 2:** Detailed energy audit-testing & measurement for identification of saving potential, technology assessment and understanding of project constraints
- **Stage 3**: Data analysis, initial configuration of projects, savings quantification, vendor consultation, interaction with unit and freezing of projects for implementation and preparation of comprehensive energy audit report.

## ➨ PRODUCTION PROCESS OF THE UNIT

A brief description of the manufacturing process is given below:

The main energy utilizing equipment is kiln in which the fuel used is natural gas. The temperature maintained in biscuits kiln is approximately 800°C – 1,150°C and glaze kiln is 700°C- 1,085°C (in heating zone).

- **Clay ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio as per requirement along with water to form a slip.
- **Agitator:** The slip after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Spray dryer:** The hot air is introduced through the top of the drying chamber and the moisture slip sprayed through the nozzle, So ID fans present outside suck the moisture.
- **Hydraulic press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Dryer:** Biscuits are sent to dryer for pre drying before it passed in kiln.
- **Glaze ball mill:** For producing glazing material used on wall tiles.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slip, air cleaning, glazing etc.
- **Kiln:** Biscuits are baked in kiln at 1,100-1,150°C and again baked after glazing.
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The detailed energy audit covered all equipment which was operational during the field study. The main energy consuming areas are kilns which account for more than 70% of the total energy used.

## ➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in kiln: Coal gas is used as fuel in this kiln and oxygen content in flue gas was found to be 7.5 % against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation in recuperator pipelines: In kiln, the recuperator pipes were found to be un-insulated with surface temperature of 107°C which should be maintained at 80 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the recuperator pipes with insulation material for reducing surface heat losses.
- Insulation in pipe line in indirect cooling zone: In kiln, the indirect cooling zone pipes were found to be un-insulated with surface temperature of 179°C which should be maintained at 80 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the 90 pipes with insulation material for reducing surface heat losses.
- Optimized resource consumption in clay section: TDS of water used in clay section was found to be 900 ppm against desired level of 400 ppm. It is recommended to install water softener plant which will blend RO water with raw water.
- Replacement of existing compressor with screw compressor: In unit, there are two reciprocating compressor of 11 kW each. It is recommended to replace both compressors with 22 kW screw compressor with variable frequency drive.

- Replacement of inefficient pumps with EE pumps: Gasifier CT pump-1 & 2 (pump 1 – 16.4% & pump 2 – 21.6%) were running at lower efficiency against desired efficiency of 65%. It is recommended to replace the existing pumps with energy efficient pumps.
- Replacement of inefficient light with EE lights: Conventional lights like Fluorescent Tube lights and Compact fluorescent light were present in unit which results in higher electrical consumption. It is recommended to replace the conventional lights with energy efficient LED lamps.
- Voltage optimization at main incomer: The present voltage at main incomer was found to be 430V against desired voltage of 410V. It is recommended to install separate servo stabilizer of 600kVA rating for main incomer.
- Installation of harmonic filter: Harmonics levels were found to be higher than the prescribed limits as per IEEE guidelines. It is recommended to install harmonic filter at main incomer.
- Cable loss minimization: In Sizing section, Section 1 and 2 were having poor power factor around 0.53 and 0.69 respectively against desired value of 0.99. It is recommended to install power factor improvement capacitors for sizing section.
- Replacement of V belt to REC belt: All of blowers used in both kilns are V belt driven. These belts were consuming more power. So it is recommended to replace V belt to raw edge cogged belt which result in 3.6 % of energy saving.
- Installation of energy management system: Online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption and there were no proper fuel monitoring system installed at hot air generator, five layers dryer and kiln. It is recommended to install online electrical energy management systems (smart energy meters) on the main incomer and on the various electricity distribution panels and fuel monitoring system.

**Table 1 : Summary of energy conservation measures**

| Sl. No. | Energy Conservation Measures | Annual Energy Savings | | | Monetary Savings | Investment | Payback Period | Emission Reduction |
|---|---|---|---|---|---|---|---|---|
| | | Electricity kWh/y | Coal t/y | Total TOE/y | Lakh Rs/y | Lakh Rs | Months | $tCO_2/y$ |
| 1 | Excess air control in kiln | 5,836 | 122 | 67 | 7.73 | 18.48 | 29 | 263 |
| 2 | Insulation in recuperator pipe lines | | 11 | 6 | 0.67 | 1.06 | 19 | 24 |
| 3 | Insulation in pipe line in indirect cooling zone | | 9 | 5 | 0.56 | 0.20 | 4 | 20 |
| 4 | Optimized resource consumption in clay section | 15,143 | 821 | 453 | 54.03 | 39.60 | 9 | 1,751 |
| 5 | Replacement of existing compressor with screw compressor with VFD | 26,734 | | 2 | 1.97 | 5.94 | 36 | 24 |
| 6 | Replacement of pumps with EE pumps | 90,844 | | 8 | 6.68 | 0.84 | 2 | 81 |
| 7 | Replacement of inefficient light with EE lights | 119,249 | | 10 | 8.77 | 5.62 | 8 | 106 |
| 8 | Main LT voltage optimization | 128,861 | | 11 | 9.48 | 7.92 | 10 | 115 |
| 9 | Installation of harmonic filter | 29,342 | | 3 | 2.16 | 4.75 | 26 | 26 |
| 10 | Cable loss minimization | 13,974 | | 1 | 0.14 | 0.28 | 24 | 12 |
| 11 | Replacement of V belt from REC (Raw edged cogged) belt | 4,917 | | 0.42 | 0.36 | 0.92 | 31 | 4 |
| 12 | Energy management system | 51,728 | | 4 | 13.71 | 5.62 | 5 | 46 |
| | **Total** | **486,626** | **963** | **571** | **106** | **91** | **10** | **2,472** |

The recommendations, when implemented, will enable the following improvements:

- Reduction in energy cost by 10.3 %
- Reduction in electricity consumption by 18.5 %
- Reduction in thermal consumption by 9.4 %
- Reduction in greenhouse gas emissions by 10.6 %

## FINANCIAL ANALYSIS

Summary of financial indicators of the each recommendation is summarized in the table below. The IRR and discounted payback period has been calculated considering a five-year period.

Table 2: Financial indicators

| # | Energy Conservation Measures | Investment<br>Lakh Rs | Internal Rate of Return<br>% | Discounted Payback Period<br>Months |
|---|---|---|---|---|
| 1 | Excess air control in kiln | 18.48 | 21% | 10.46 |
| 2 | Insulation in recuperator pipe lines | 1.06 | 43% | 7.08 |
| 3 | Insulation in pipe line in indirect cooling zone | 0.20 | 211% | 1.69 |
| 4 | Optimized resource consumption in clay section | 39.60 | 101% | 3.44 |
| 5 | Screw compressor with VFD | 5.94 | 13% | 12.68 |
| 6 | Replacement of pumps with EE pumps | 0.84 | 585% | 0.61 |
| 7 | Replacement of inefficient light with EE lights | 5.62 | 117% | 3.01 |
| 8 | Main LT voltage optimization | 7.92 | 88% | 3.90 |
| 9 | Installation of harmonic filter | 4.75 | 24% | 9.82 |
| 10 | Cable loss minimization | 0.28 | 30% | 8.77 |
| 11 | Replacement of V belt from REC (Raw edged cogged) belt | 0.92 | 18% | 11.27 |
| 12 | Energy management system | 5.62 | 187% | 1.93 |

# 1 CHAPTER – 1 INTRODUCTION

## 1.1 BACKGROUND AND PROJECT OBJECTIVE

The Bureau of Energy Efficiency (BEE) in collaboration with United Nations Industrial Development Organization (UNIDO) is working on the Global Environment Facility (GEF) funded project titled - 'Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India', which aims to give impetus to the energy efficiency initiatives in the small and medium enterprises (SMEs) sector in India. The objective of the program is development and promotion of energy efficiency and enhanced use of renewable energy in 12 selected energy-intensive MSME clusters, identified on the basis of their total energy utilization and energy-intensity levels. The project will provide solutions to certain technological as well as policy level barriers in implementation of energy efficient technologies in the MSME sector.

The objective of the project includes:

- Increased capacity of suppliers of energy efficiency (EE) and renewable energy (RE) based products, service providers and financing institutions.
- Increasing the levels of end-use demand and implementation of EE and RE technologies and practices by SMEs.
- Scaling up of the project to a national level.
- Strengthening policy, Institutional and decision-making frameworks.

## 1.2 ABOUT THE UNIT

General details of the unit are given below:

**Table 3: Overview of the unit**

| Description | Details | | |
|---|---|---|---|
| Name of the plant | Airson Ceramic Industries | | |
| Plant address | 8-A National Highway, Opp G.E.B Feeder Lalpar, Morbi , Gujarat - 363642 | | |
| Constitution | Partnership | | |
| Name of promoters | Mr. Balkrishna Kacharbhai Ambani | | |
| Contact person | Name | Mr. Jagdish Bhai | |
| | Designation | MD | |
| | Tel | 9825121562 | |
| | Fax | | |
| | Email | info@airsoncera.com | |
| Year of commissioning of plant | 2008 | | |
| List of products manufactured | Wall tile, 300 x 450 mm<br>Wall tile, 250 x 380 mm<br>Floor tile, 300 x 300 mm | | |
| Installed plant capacity | 6,000 boxes/day | | |
| Financial information (Lakh Rs) | 2014-15 | 2015-16 | 2016-17 |
| Turnover | 2,072.7 | 1,633.3 | 1,342.2 |

| Description | Details | | |
|---|---|---|---|
| Net profit | 30.1 | 25.1 | 20.6 |
| No of operational days in a year | Days/Year | 330 | |
| | Hours/Day | 24 | |
| | Shifts /Day | 2 | |
| Number of employees | Staff | 10 | |
| | Worker | 20 | |
| | Casual labor | 80 | |
| Details of energy consumption | Source | Yes/No | Areas of Use |
| | Electricity (kWh) | Yes | Entire Process and Utility |
| | Coal (kg) | Yes | Spray Dryer & Kiln through coal gasifier |
| | Diesel (litres) | Yes | DG – Rarely used |
| | Natural Gas (scm) | Yes | Only in kiln |
| | Other (specify) | No | |
| Have you conducted any previous energy audit? | No | | |

## 1.3 METHODOLOGY AND APPROACH

The study was conducted in 3 stages:

- **Stage 1:** Walk through energy audit of the plant to understand process, energy drivers, assessment of the measurement system, assessment of scope, measurability, formulation of audit plan and obtaining required information
- **Stage 2:** Detailed energy audit-testing & measurement for identification of saving potential, technology assessment and understanding of project constraints
- **Stage 3**: Desk work for data analysis, initial configuration of projects, savings quantification, vendor consultation, interaction with unit and freezing of projects for implementation and preparation of energy audit report

The following flow chart illustrates the methodology followed for Stage-2 and Stage-3.

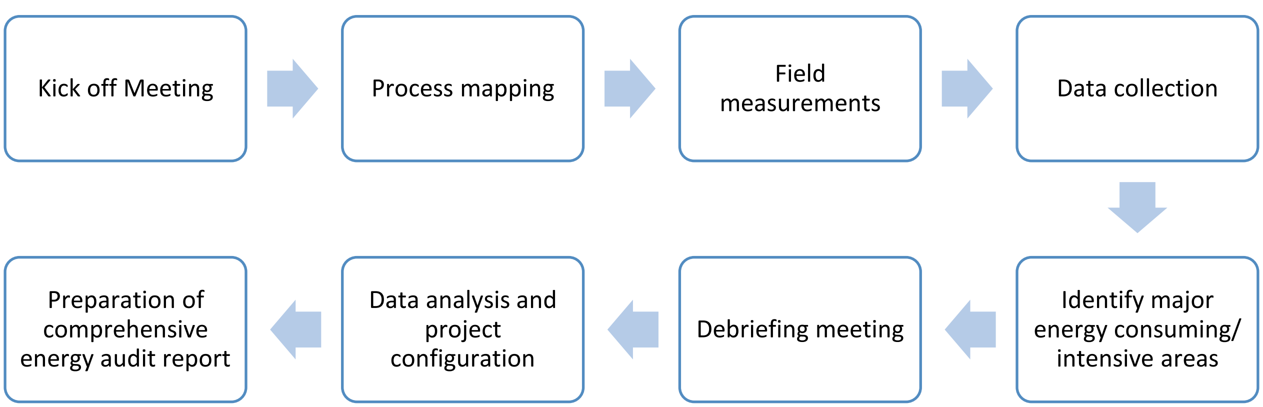



Figure 1: General methodology

The field work was carried out during 3rd – 5th December, 2018.

**Stage-2**: A kick off meeting was conducted to explain to the unit the methodology of field assessment and map major areas of concern/expectation of the unit. This was followed by a process mapping to understand the manufacturing process based on which field measurement was planned in all major energy consuming areas. Field measurements were conducted as per this plan using calibrated portable measurement instruments. The audit covered all the energy intensive systems and equipment which were working during the field study. Simultaneously, process flow diagram, single line diagram, and data collection were done. At the end of the field study, a debriefing meeting was conducted to discuss initial findings and project ideas.

**Stage-3**: Post audit off-site work carried out included data compilation, data analysis, calculations for arriving at the savings potential, investment estimate through information available with DESL vendor database and carrying out vendor interactions as required, configuring the individual energy performance improvement actions and preparation of comprehensive energy audit report. The identified energy conservation measurements (ECM's) normally fall under short, medium and long-term measures.

## 1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit, are following:

Table 4: Energy audit instruments

| Sl. No. | Instruments | Parameters Measured |
|---|---|---|
| 1 | Power analyzer – 3 phase (for un balanced Load) with 3 CT and 3 PT | AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval |
| 2 | Power analyzer – 3 phase (for balance load) with 1 CT and 2 PT | AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval |
| 3 | Digital multi meter | AC Amp, AC-DC Voltage, Resistance, Capacitance |
| 4 | Digital clamp on power meter – 3 Phase and 1 Phase | AC Amp, AC-DC Volt, Hz, Power Factor, Power |
| 5 | Flue gas analyzer | $O_2$%, $CO_2$%, CO in ppm and Flue gas temperature, Ambient temperature |
| 6 | Digital temperature and Humidity logger | Temperature and Humidity data logging |
| 7 | Digital Temperature & Humidity meter | Temperature & Humidity |
| 8 | Digital anemometer | Air velocity |
| 9 | Vane type anemometer | Air velocity |
| 10 | Digital infrared temperature gun | Distant surface temperature |
| 11 | Contact type temperature meter | Liquid and Surface temperature |
| 12 | High touch probe temperature meter | Temperature upto 1,300°$C$ |
| 13 | Lux meter | Lumens |

| Sl. No. | Instruments | Parameters Measured |
|---|---|---|
| 14 | Manometer | Differential air pressure in duct |
| 15 | Pressure gauge | Water pressure 0 to 40 kg |

## 1.5 STRUCTURE OF THE REPORT

This detailed energy audit report has been organized and presented sequentially in the following order:

- Executive summary of the report covers the summary list of projects along with estimated investment & energy and financial saving figures for individual projects.
- Chapter 1 (this chapter) of the report provides a brief background of the project, the scope of work and unit details and the methodology and approach for detailed energy audit.
- Chapter 2 of the report provides a description of the manufacturing process, analysis of historical energy consumption and establishment of baseline.
- Chapter 3 and 4 cover the performance evaluation of major energy consuming equipment and sections, thermal and electrical.
- Chapter 5 covers information on energy monitoring practices and best monitoring practices.
- Chapter 6 covers information on renewable energy assessment in the unit.

# 2 CHAPTER – 2 PRODUCTION AND ENERGY CONSUMPTION

## 2.1 MANUFACTURING PROCESS WITH MAJOR EQUIPMENT INSTALLED (FLOW DIAGRAM)

A simple block diagram of the process flow is shown in the figure below:

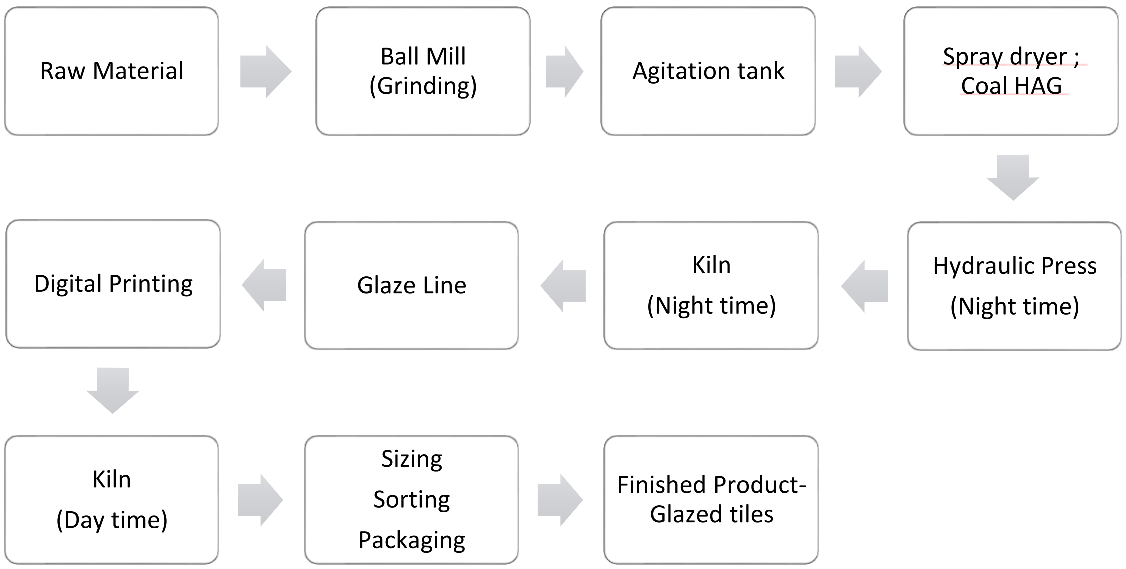



**Figure 2: Process Flow Diagram**

The process description is as follows:

- The raw materials such as china clay, talc, calcite, dolomite, silicate, feldspar and scrap are mixed together with water in the ball mill for a period of 120 minutes depending upon residue percentage in slip.
- It is then transferred into the agitator tank for thorough mixing.
- Slip containing moisture is taken into underground tanks fitted with agitator motor in each tank to maintain uniformity of mixture.
- The slip containing about 30-40% moisture and required density is then pumped through hydraulic pump at a pressure of 12-13 bar into spray dryer using nozzles. At the top of spray dryer, hot air is passed at a temperature of 550-650°C. This hot air is generated by using hot air generator (HAG) using coal as a fuel. Material is dried in spray dryer, thus the moisture added in grinding process in clay ball mill gets removed from spray dryer. At the outlet of spray dryer, clay in powdered form is collected having moisture of 5-6%. Final products from spray dryer are collected in silos.
- The product from spray dryer is then sent to hydraulic press where the required sizes of biscuit tiles (green tiles) are formed.
- After drying, the biscuit tiles are sent to the kiln for baking. The baking temperature is around 1100°C to 1200°C to get the required strength.
- This is followed by glazing,
- After glazing, the glazed tiles are sent for final firing in the same kiln. Glazed tiles are fired at a temperature of 1,050°C-1,100°C in the kiln.

- Tiles coming out of kiln are sent for sizing and calibration; the tiles are cut to proper sizes so that all the tiles are of same dimension.

The major energy consuming equipment in the plant is:

- **Clay ball mill:** Here the raw materials like clay, feldspar and quartz are mixed along with water to form a slip.
- **Hot air generator:** Coal is being used as fuel to produce hot air at temperature 540°C to 712°C.
- **Spray dryer:** Slip flows from agitator tanks to spray nozzles and sprayed in the upward direction from the nozzles and hot air coming from hot air generator will pass from top of the spray dryer and slip convert into powder. The moisture content is around 5% to 6% (The powder is carried through conveyors and stored in silos.)
- **Hydraulic press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit (green tile).
- **Kiln:** Biscuits are baked in kiln at 1,100-1,150°C at night and baked again in the same kiln in day time after glazing process.
- **Glaze ball mill:** For producing glazing material used on tiles.
- **Air compressor:** Compressed air is used at several locations in a unit viz. Slip pumping, Sizing, press bed cleaning, glazing, digital printing, etc.

A detailed mass balance diagram for the unit is included as **Annexure 1**. A detailed list of equipment is included as **Annexure 2**.

## 2.2 Production Details

The unit is currently manufacturing wall tiles of the following specifications:

**Table 5: Product specifications**

| Product | Size /Piece | Weight per box | Area per box | Pieces per box |
|---|---|---|---|---|
| | mm x mm | kg | $m^2$ | # |
| Wall tiles | 300 x 450 | 87,000 | 4,860 | 6 |
| Wall tiles | 250 x 380 | 54,000 | 4,560 | 8 |
| Floor tiles | 300 x 300 | 78,000 | 5,400 | 9 |

The products are mainly exported to foreign market. The month wise production details of various products are given below:

Table 6: Month wise production

| Month | Production (No. of boxes) | | | Corresponding area (m²) | | | Production (MT) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 300 x 450 | 250 x 380 | 300 x 300 | 300 x 450 | 250 x 380 | 300 x 300 | 300 x 450 | 250 x 380 | 300 x 300 |
| Oct-17 | - | - | - | - | - | - | - | - | - |
| Nov-17 | - | - | - | - | - | - | - | - | - |
| Dec-17 | 64,891 | 77,252 | 12,360 | 52,562 | 12,051 | 10,012 | 934 | 695 | 133 |
| Jan-18 | 64,657 | 76,973 | 12,315 | 52,372 | 12,008 | 9,975 | 931 | 693 | 133 |
| Feb-18 | 58,800 | 70,000 | 11,200 | 47,628 | 10,920 | 9,072 | 847 | 630 | 121 |
| Mar-18 | 66,388 | 79,034 | 12,645 | 53,774 | 12,329 | 10,242 | 956 | 711 | 137 |
| Apr-18 | 64,499 | 76,785 | 12,285 | 52,244 | 11,978 | 9,951 | 929 | 691 | 133 |
| May-18 | 64,748 | 77,081 | 12,333 | 52,446 | 12,025 | 9,990 | 932 | 694 | 133 |
| Jun-18 | 64,348 | 76,605 | 12,256 | 52,122 | 11,950 | 9,927 | 927 | 689 | 132 |
| Jul-18 | 66,154 | 78,755 | 12,600 | 53,585 | 12,286 | 10,206 | 953 | 709 | 136 |
| Aug-18 | 66,935 | 79,685 | 12,749 | 54,217 | 12,431 | 10,327 | 964 | 717 | 138 |
| Sep-18 | 62,710 | 74,655 | 11,945 | 50,795 | 11,646 | 9,675 | 903 | 672 | 129 |
| **Total** | **644,130** | **766,825** | **122,688** | **627,959** | **143,977** | **119,608** | **9,275** | **6,901** | **1,325** |

The production data for Oct-17 & Nov-17 is not available as unit was in shut down condition.

## 2.3 ENERGY SCENARIO

Both electricity and thermal energy is used in different manufacturing processes. The overall energy use pattern in the unit is as follows:

- Electricity is supplied from two different sources:
  - From the Utility, Paschim Gujarat Vij Company Ltd. (PGVCL)
  - Captive backup DG sets for whole plant
- Thermal energy is used for following applications :
  - Coal for hot air generator
  - Coal gas for kiln
  - Earlier NG was being used in kilns but now coal gas used as a primary fuel in kiln.

Total energy consumption pattern for the period Oct-17 to Sept-18, from different sources are as follows:

**Table 7: Energy use and cost distribution**

| Particular | Energy cost | | Energy use | |
|---|---|---|---|---|
| | Rs Lakhs | % of total | TOE | % of total |
| Grid – Electricity | 189.89 | 18.5 | 222 | 4.2 |
| Thermal - Coal | 693.00 | 67.5 | 4,616 | 88.1 |
| Thermal – NG | 143.54 | 14.0 | 402 | 7.7 |
| Total | 1,026.42 | 100 | 5,240 | 100 |

From Jan -18 to May -18, NG was used as a fuel in kiln and now unit is using coal gas generated from coal gasifier as a primary fuel.

This is shown graphically in the figures below:

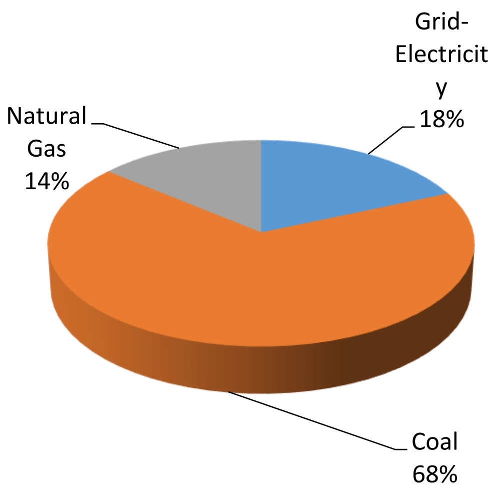



Figure 3: Energy cost share

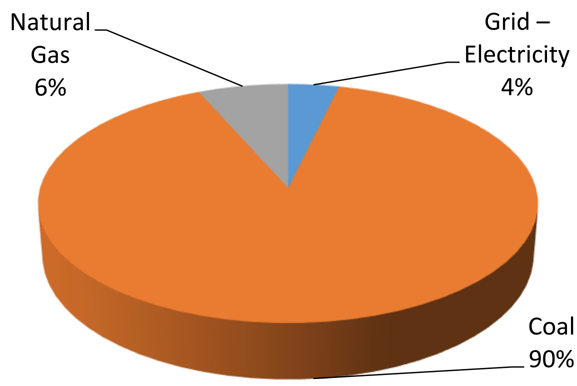



Figure 4: Energy use share

The major observations are as under:

- The unit uses both thermal and electrical energy for the manufacturing operations.

- Electricity is sourced from the grid as well as self-generated in DG sets when the grid power is not available. However, blackouts are infrequent, due to which the diesel consumption is minimal and records are not maintained.
- Electricity used in the utility and process accounts for the 18% of the energy cost and 4 % of the overall energy consumption.
- Source of thermal energy is from combustion of coal in HAG, coal gas & natural gas is used in kiln account for 68% & 14% of the total energy cost respectively and 88% & 8% of overall energy consumption respectively.

### 2.2.1 Analysis of electricity consumption

#### *2.2.1.1 Supply from utility*

Electricity is supplied by the Paschim Gujarat Vij Company Ltd. (PGVCL). The unit has one electricity connections, details of which are given below:

**Table 8 : Details of electricity connection**

| Particulars | Description |
|---|---|
| Consumer number | 26516 |
| Tariff category | HTP-I |
| Contract demand, kVA | 750 |
| Supply voltage, kV | 11 |

The tariff structure is as follows:

**Table 9: Tariff structure**

| Particulars | Tariff structure for category HTP-1 |
|---|---|
| Demand charges (Rs./kVA) | |
| 1st 500 kVA | 150 |
| 2nd 500 kVA | 260 |
| Next 297 | 475 |
| Energy charges (Rs./kWh) | |
| Normal hours | 4.2 |
| Peak hours | 0.85 |
| Night time | 0.4 |
| Fuel surcharge (Rs./kWh) | 1.63 |
| Electricity duty (% of total energy charges) | 15% |
| Meter charges (Rs./Month) | 0.00 |

#### ***2.2.1.2 Month wise electricity consumption and cost***

Month wise total electrical energy consumption is shown as under:

**Table 10 : Electricity consumption & cost**

| Month | Units consumed | Total electricity cost | Average unit Cost |
|---|---|---|---|
| | kWh | Rs | Rs/kWh |
| Oct-17 | 158,328 | 1,233,648 | 7.79 |
| Nov-17 | 182,264 | 1,383,993 | 7.59 |
| Dec-17 | 191,912 | 1,443,320 | 7.52 |

| Month | Units consumed kWh | Total electricity cost Rs | Average unit Cost Rs/kWh |
|---|---|---|---|
| Jan-18 | 187,184 | 1,410,249 | 7.53 |
| Feb-18 | 307,100 | 2,207,854 | 7.19 |
| Mar-18 | 297,696 | 2,148,083 | 7.22 |
| Apr-18 | 252,768 | 1,847,979 | 7.31 |
| May-18 | 163,700 | 1,087,283 | 6.64 |
| June-18 | 231,336 | 1,687,494 | 7.29 |
| July-18 | 203,152 | 1,506,275 | 7.41 |
| Aug-18 | 222,592 | 1,632,477 | 7.33 |
| Sep-18 | 188,344 | 1,399,846 | 7.43 |

Average electricity consumption is 2,15,531 kWh/month and cost is Rs 15.8 Lakhs per month. The average cost of electricity is Rs. 7.36 /kWh.

#### *2.2.1.3 Analysis of month-wise electricity consumption and cost*

The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

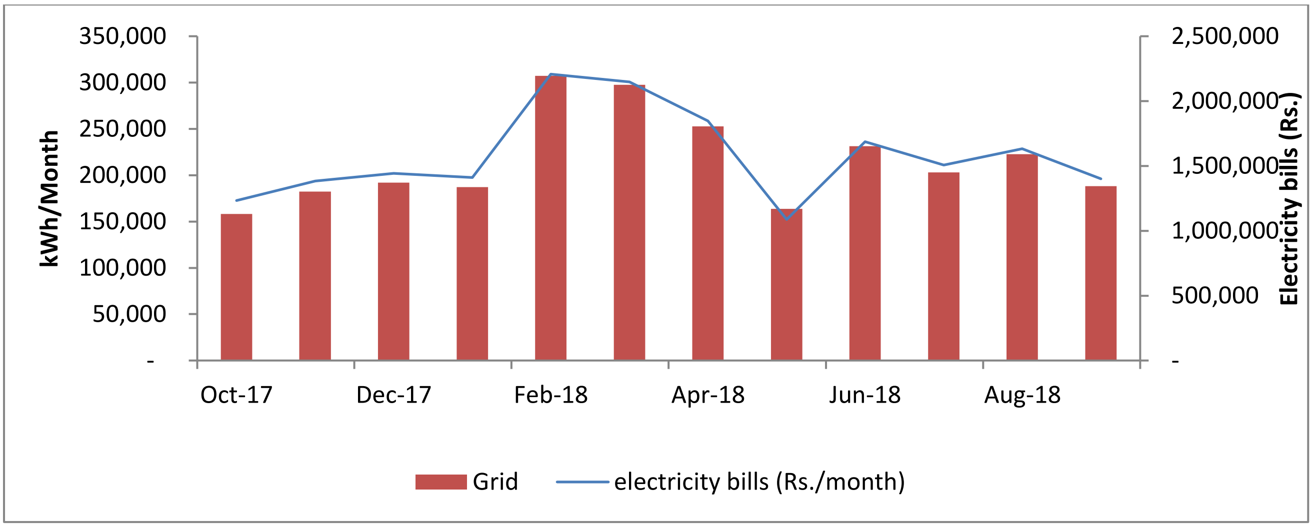



Figure 5: Month wise Variation in Electricity Consumption

**Power factor**: Power factor as per electricity bills is shown below:

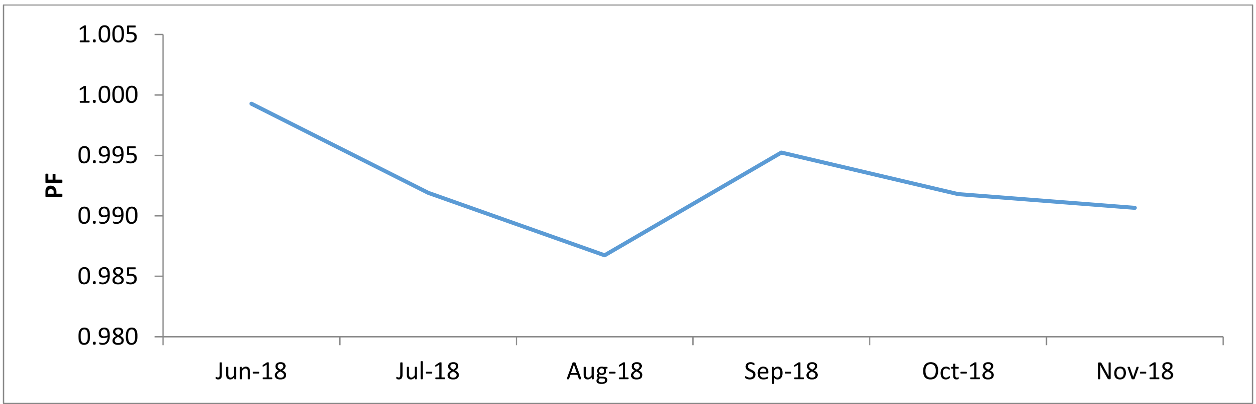



Figure 6 : Month wise variation in Power Factor

The utility bills reflect the power factor. A study was conducted by logging the electrical parameters of the main incomer using a power analyzer. The average power factor was found to be 0.993 with the minimum being 0.987 and the maximum being 0.999.

**Maximum demand**: Maximum demand as reflected in the utility bill is 577 kVA from the bill analysis.

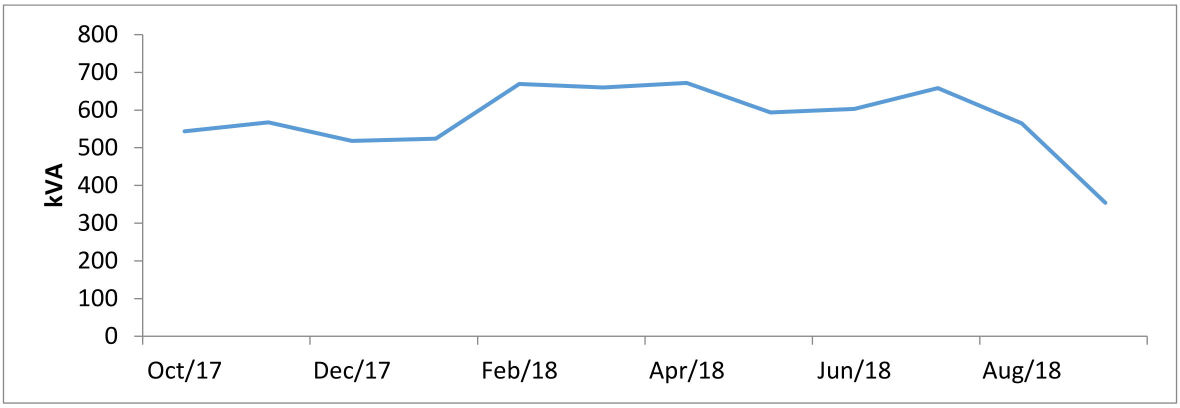



Figure 7 : Month wise variation in Maximum Demand

### *2.2.1.4 Single line diagram*

Single line diagram of plant is shown in below figure:

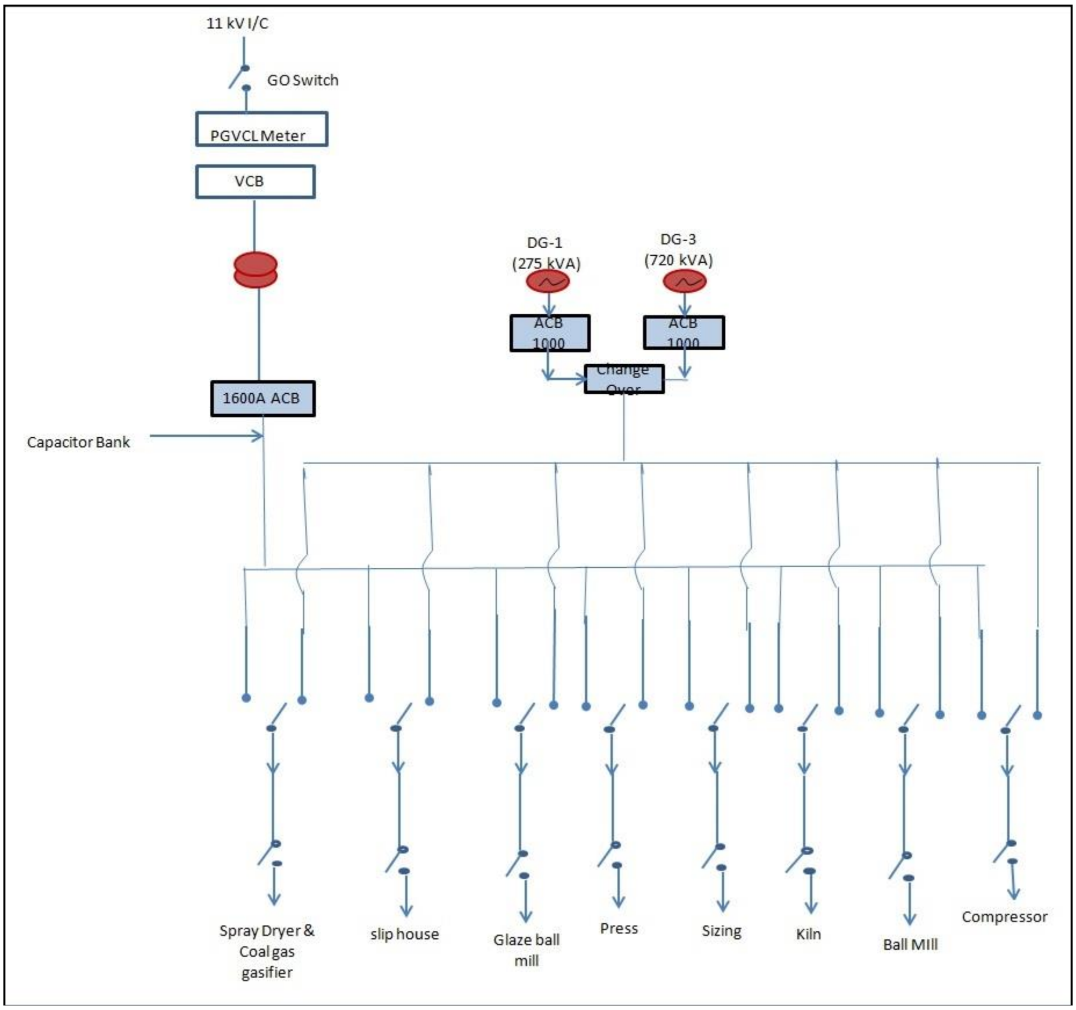



Figure 8: SLD of electrical load

### *2.2.1.5 Electricity consumption areas*

The plant total connected load is 1,135 kW, which includes:

- The plant and machinery load is 1,040 kW
- The utility load (fan and lighting) is about 54 kW including the single phase load.

Table 11 : Equipment wise connected load

| Sl. No. | Equipment | Total capacity(kW) |
|---|---|---|
| 1 | Compressors | 22 |
| 2 | Hydraulic presses | 110 |
| 3 | Kiln | 172 |
| 4 | Dryer | 66 |
| 5 | Sizing machine | 166 |
| 6 | Glaze ball mill | 75 |
| 7 | Glaze line | 31 |
| 8 | Agitator | 37 |
| 9 | Clay ball mill | 215 |
| 10 | HAG | 39 |
| 11 | Spray dryer | 110 |
| 12 | Coal gasifier | 43 |
| 11 | Lighting | 41 |
|  | Total | 1,135 |

A pie chart of the entire connected load is shown in the figure below:

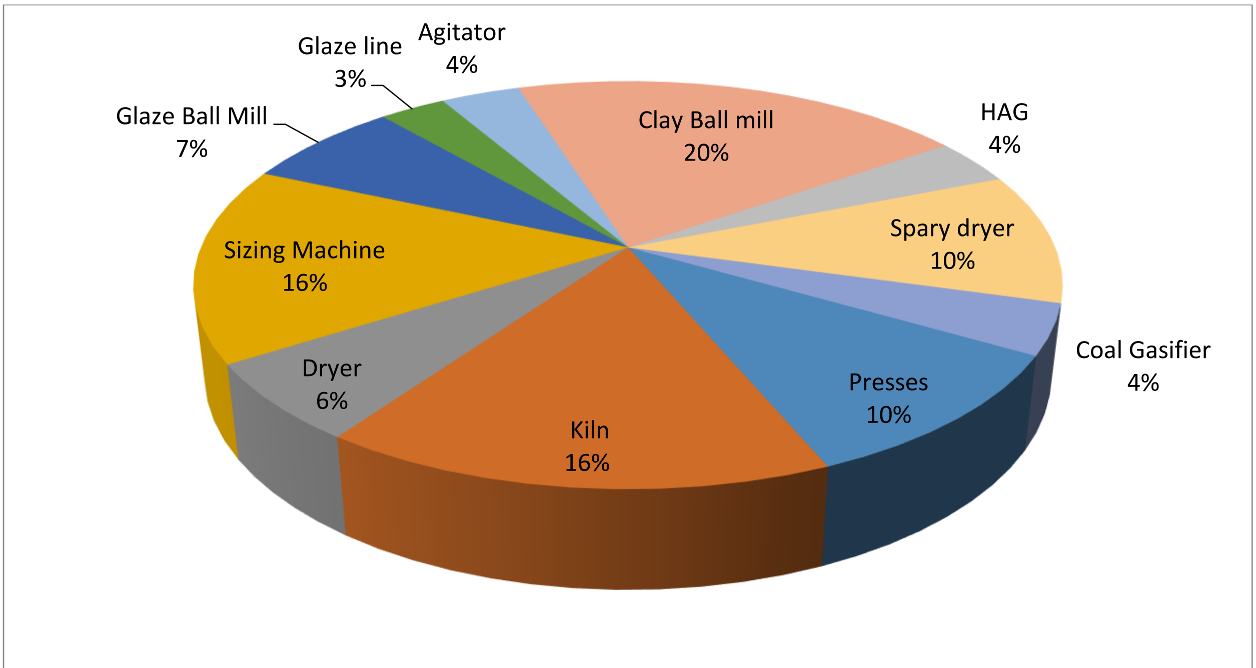



Figure 9 : Details of connected load

As shown in the figure, the maximum share of connected electrical load is for the Clay Ball mill – 20 %, followed by kiln & sizing machine– 16% , spray dryer & hydraulic press – 10%, Glaze ball mill –7%, dryer- 6%, hot air generator & agitator each-4% and rest remaining loads.

#### 2.2.1.6 Specific electricity consumption

The month wise variation of specific electricity consumption (kWh/m$^2$ of production) is shown in the figure below:

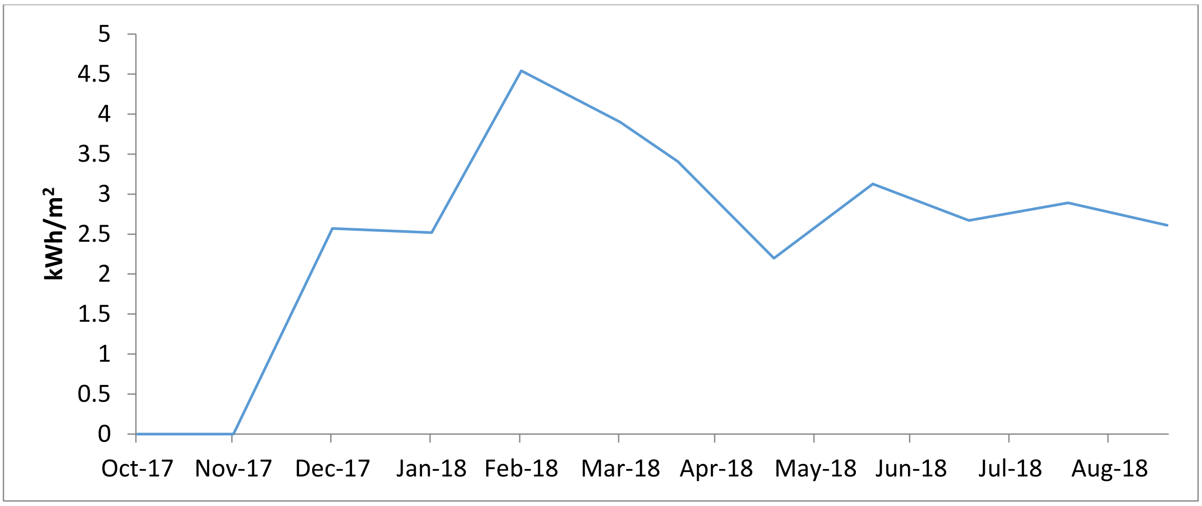



**Figure 10: Month wise variation in Specific Electricity Consumption**

In Oct -17 and Nov-17, plant was in shut down. Thus, SEC has zero value. Apart from these months, month May-18 and Oct-18 are outliers. Excluding this month, the maximum and minimum values are within ±20% of the average SEC of 3.04 kWh/m$^2$ indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in clay ball mill section, spray dryer section, hydraulic press section, kiln, utility like compressor, pumps etc.

### 2.2.2 Analysis of thermal energy consumption

#### 2.2.2.1 Month wise fuel consumption and cost

The thermal consumption areas are the hot air generator and the kiln. Coal is used as fuel for the hot air generator while coal gas produced by gasifier is used as fuel in the kiln. Coal is purchased from local coal suppliers who in turn import coal from Indonesia. Annual fuel consumption and cost are summarized below:

**Table 12 : Monthly fuel consumption**

| Month | Coal used MT | Coal cost Rs/MT |
|---|---|---|
| Oct-17 | - | - |
| Nov-17 | - | - |
| Dec-17 | 450 | 3,150,000 |
| Jan-18 | 450 | 3,150,000 |
| Feb-18 | 450 | 3,150,000 |
| Mar-18 | 450 | 3,150,000 |
| Apr-18 | 450 | 3,150,000 |
| May-18 | 450 | 3,150,000 |
| Jun-18 | 1,200 | 8,400,000 |
| Jul-18 | 1,200 | 8,400,000 |
| Aug-18 | 1,200 | 8,400,000 |

| Month | Coal used MT | Coal cost Rs/MT |
|---|---|---|
| Sep-18 | 1,200 | 8,400,000 |
| Average | 700 | 49,00,000 |

Observation:

- Average monthly coal consumption is 700 tons/month and average cost is Rs 49 lakhs/month.

#### *2.2.2.2 Specific fuel consumption*

The month wise variation of specific fuel consumption (SFC- GJ/$m^2$ of production) is shown in the figure below:

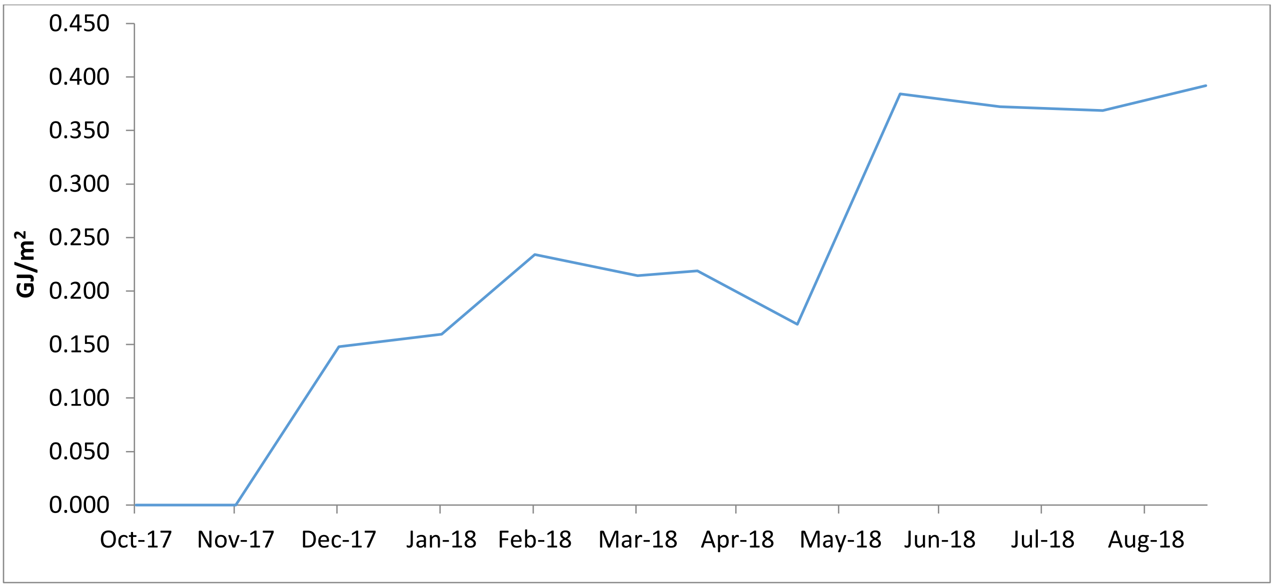



**Figure 11 : Month wise variation in Specific Fuel Consumption**

In Oct -17 and Nov-17, plant was in shut down. Thus, SFC has zero value. The average SFC is 0.284 GJ/$m^2$. Since Dec-17 the SFC is continuously increasing and is maximum in the month of Aug-18 which is 0.392 GJ/$m^2$ and is low in the month of Dec-17 which is 0.148 GJ/$m^2$. For better quality information, sub-metering /data logging is required at hot air generator (HAG) and dryer for monitoring thermal energy consumption.

### 2.2.3 Specific energy consumption

#### *2.2.3.1 Based on data collected during EA*

Specific energy on the basis of data collected during energy audit is shown in below table:

**Table 13: Specific energy consumption**

| Particulars | UoM | Value |
|---|---|---|
| Average production | $m^2$/h | 303.75 |
| Power consumption | kW | 319 |
| Coal consumption | kg/h | 1,041.6 |
| Energy consumption | TOE/h | 0.600 |
| SEC of plant | TOE/$m^2$ | 0.002 |

#### 2.2.3.2 *Section wise energy consumption*

Specific electricity consumption section wise (major areas) based on DEA is as follows. This is determined on weight basis, since mass data could be collected at each stage. Hydraulic press is shut down in day time, so SEC of hydraulic press could not measure.

Table 14: Section wise specific energy consumption (per unit production)

| Particulars | Coal | Electricity |
|---|---|---|
| | kg/t | kW/t |
| Clay ball mill | | 7.50 |
| Agitator | | 0.55 |
| HAG (Bubbling Bed) | 163.0 | 6.44 |
| Spray dryer (New) | | 3.60 |
| kiln | 100.28 | 3.19 |
| Sizing unit | | 9.46 |

The detailed mass balance diagram based on which above has been arrived at is included as Annexure - 1.

#### 2.2.3.3 *Based on yearly data furnished by unit*

Based on the available information, various specific energy consumption (SEC) parameters have been estimated as shown in the following table:

Table 15: Overall: specific energy consumption

| Parameters | UOM | Value |
|---|---|---|
| Annual grid electricity consumption | kWh/y | 2,621,852 |
| Self-generation from DG Set | kWh/y | 0 |
| Annual total electricity consumption | kWh/y | 2,621,852 |
| Annual thermal energy consumption (Imported Coal) | t/y | 9,900 |
| Annual thermal energy consumption (NG) | scm/y | 451,427 |
| Annual energy consumption | TOE | 5,067 |
| Annual energy cost | Rs. Lakh | 1,026 |
| Annual production | $m^2$ | 891,544 |
| | t | 17,502 |
| SEC; Electrical | $kWh/m^2$ | 2.94 |
| | kWh/t | 149.80 |
| SEC; Thermal | $GJ/m^2$ | 0.27 |
| | GJ/t | 13.97 |
| SEC; Overall | $TOE/m^2$ | 0.28 |
| | TOE/t | 0.35 |
| SEC; Cost based | $Rs./m^2$ | 115.13 |
| | Rs./t | 5,865 |

Basis for estimation of energy consumption in terms of tons of oil equivalent are as follows:

- Conversion factors
  - Electricity from the Grid : 860 kcal/kWh
- GCV of NG : 8900 kCal/scm
- GCV of imported coal : 5,495 kcal/kg
- $CO_2$ conversion factor

- Grid : 0.89 kg/kWh
- Imported coal : 2.116 t/t
- NG : 0.001923 $tCO_2$/SCM

#### *2.2.3.4 Baseline parameters*

The following are the general baseline parameters, which have been considered for the techno-economic evaluation of various identified energy cost reduction projects as well as for the purpose of comparison post implementation of the projects. The costs shown are landed costs.

**Table 16: Baseline parameters**

| Parameters | UoM | Value |
|---|---|---|
| Cost of electricity | Rs./ kWh | 7.36 |
| Cost of NG | Rs./scm | 30.69 |
| Cost of coal | Rs./MT | 6,000 |
| Annual operating days | d/y | 330 |
| Operating hours per day | h/d | 24 |
| Annual production | $m^2$ | 891,544 |

## 2.4 WATER USAGE & DISTRIBUTION

Water usage and pumping efficiencies (including water receipt, storage, distribution, utilization etc.) pump specs, breakdown maintenance etc.

Water requirement is met by own bore-well from where it is extracted and stored in storage tank. From this storage water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 150-200 m3/day as informed by unit.

Water distribution diagram is shown below.

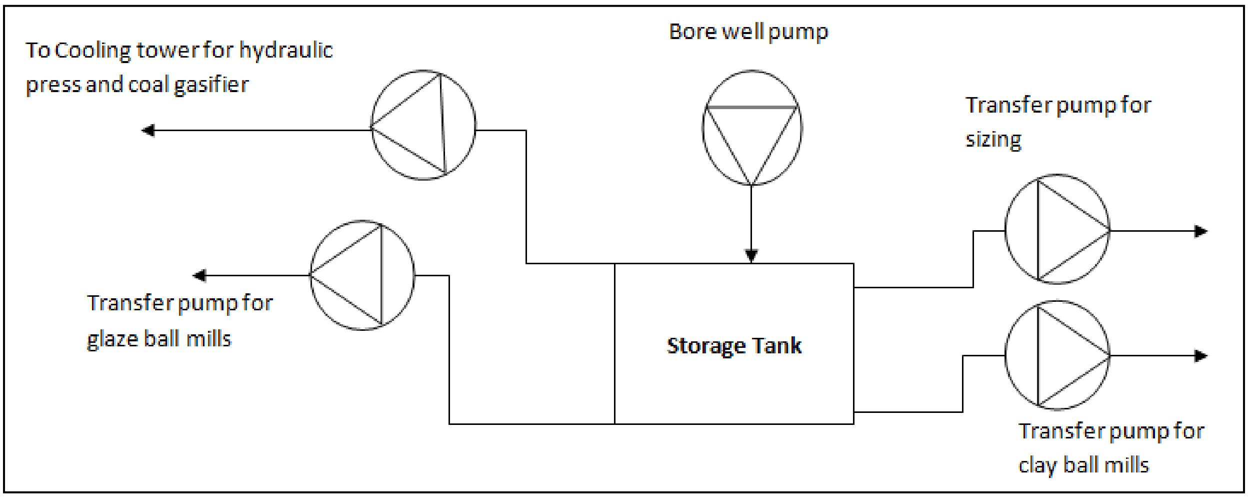



**Figure 12: Water Distribution Diagram**

Unit has own bore-well from where water is extracted and used in clay ball mills and glaze ball mills. Flow measurements could not be done for any of the pumps due to poor condition of pipe lines. Rating of cooling tower circulation pumps are given below:

Table 17: Press cooling water circulation pump details

| Parameters | UoM | Cooling water pumps |
|---|---|---|
| Make | - | - |
| Motor rating | kW | 4 |
| RPM | rpm | 2,900 |
| Quantity | number | 2 |

Water is extracted from own bore-well and have TDS of > 1100ppm and major water consuming areas like clay ball mills and glaze ball mills are being monitored.

# 3 CHAPTER-3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

## 3.1 KILN

### 3.1.1 Specifications

Coal gas is used as a fuel in kiln to heat the ceramic tiles to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan). During day time, the kiln is used for heating of glazed tiles and during night time, kiln is used for baking of biscuits (green tiles) produced from hydraulic press.

Cooling blower and rapid cooling blowers are used for cooling the tiles after combustion zone to get required tile quality and at the starting point, a smoke blower is installed which preheats the tiles before combustion zone of kiln.

Kiln also consists of dryer section before preheating. It includes smoke blower of 15 hp and hot air blower of 20 hp. Dryer is only be used when kiln acts as a biscuit kiln at night. In day time, dryer is shut down. Only kiln used to baked glazed tiles in day time.

Kiln consists of 230 hp electrical loads which include 50 hp smoke blower, 25 hp (2 nos.) combustion blowers, 25 hp for rapid cooling, 50 hp for Hot air blower, 40 hp for final cooling blower and 15 hp for indirect cooling blower.

**Table 18: Kiln details**

| Sl. No | Parameters | UoM | Value |
|---|---|---|---|
| | Make | | Modema |
| 1 | Kiln operating time | h | 24 |
| 2 | Fuel consumption | scm/h | 2,417 |
| 3 | Number of burner to left | - | 68 |
| 4 | Number of burner to right | - | 68 |
| 5 | Cycle time | Minutes | 45 |
| 6 | Pressure in firing zone | mm WC | 28 |
| 7 | Maximum temperature | °C | 1,003 |
| 8 | Waste heat recovery option | | No |
| 9 | Kiln dimensions (Length x Width x Height) | | |
| | Preheating zone | M | 36 x 3 x 1 |
| | Firing zone | M | 29 x 3 x 1 |
| | Rapid cooling zone | M | 13 x 3 x 1 |
| | Indirect cooling zone | M | 21 x 3 x 1 |
| | Final cooling zone | M | 16 x 3 x 1 |

### 3.1.2 Field measurement and analysis

During DEA, measurement of power consumption for all blowers, surface temperature of the kiln, flue gas analysis, air flow measurement of blowers and section wise temperature profile of both the kilns were done. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 19: FGA study of kilns

| Parameter | Kiln |
|---|---|
| Oxygen Level measured in Flue Gas | 7.53 % |
| Ambient Air Temperature | 40.2 °C |
| Exhaust Temperature of Flue Gas | 130 °C |

From the above table, it is clear that the oxygen level measured in flue gas was high in kiln. The inlet temperature of raw material in kiln was in the range of 40.2°C. Surface temperature was high, throughout the surface of the kiln as shown in the table below:

Table 20: Surface temperature of kilns

| Surface Temperatures | Value (°C) |
|---|---|
| Ambient Temperature | 39 |
| Pre-heating zone average surface temperature | 51 |
| Heating zone average surface temperature | 65 |
| Rapid cooling zone average surface temperature | 55 |
| Indirect cooling zone average surface temperature | 60 |
| Final cooling zone average surface temperature | 55 |

The temperature profile of the kilns is shown below:

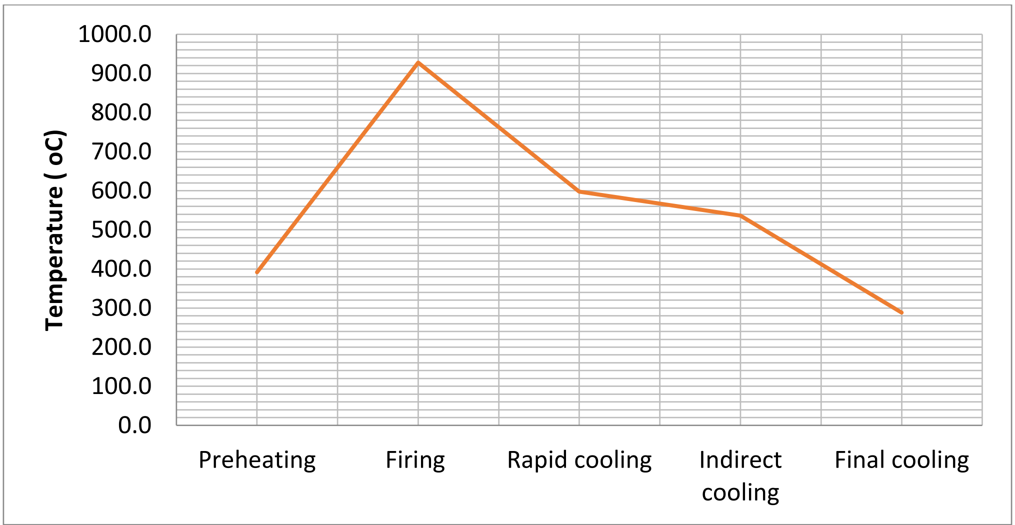



Figure 13: Temperature Profile of Kiln

Measured data of power for all blowers is given in below table, details are provided in Annex-4: Electrical Measurements.

Table 21: Power measurements of all blowers

| Equipment | Kiln | |
|---|---|---|
| | Average Power (kW) | PF |
| Combustion blower | 1.83 | 0.93 |
| Smoke blower | 4.93 | 0.92 |
| Hot air blower | 2.27 | 0.98 |
| Indirect cooling blower | 1.87 | 1 |
| Rapid cooling blower | 1.81 | 0.96 |
| Final cooling blower | 4.53 | 0.89 |

### 3.1.3 Observations and performance assessment

Kiln heat utilization has been calculated based on the flue gas analysis study conducted during visit. Overall heat utilization of the kiln is 40.5%. Summary of all losses is shown in below figure:

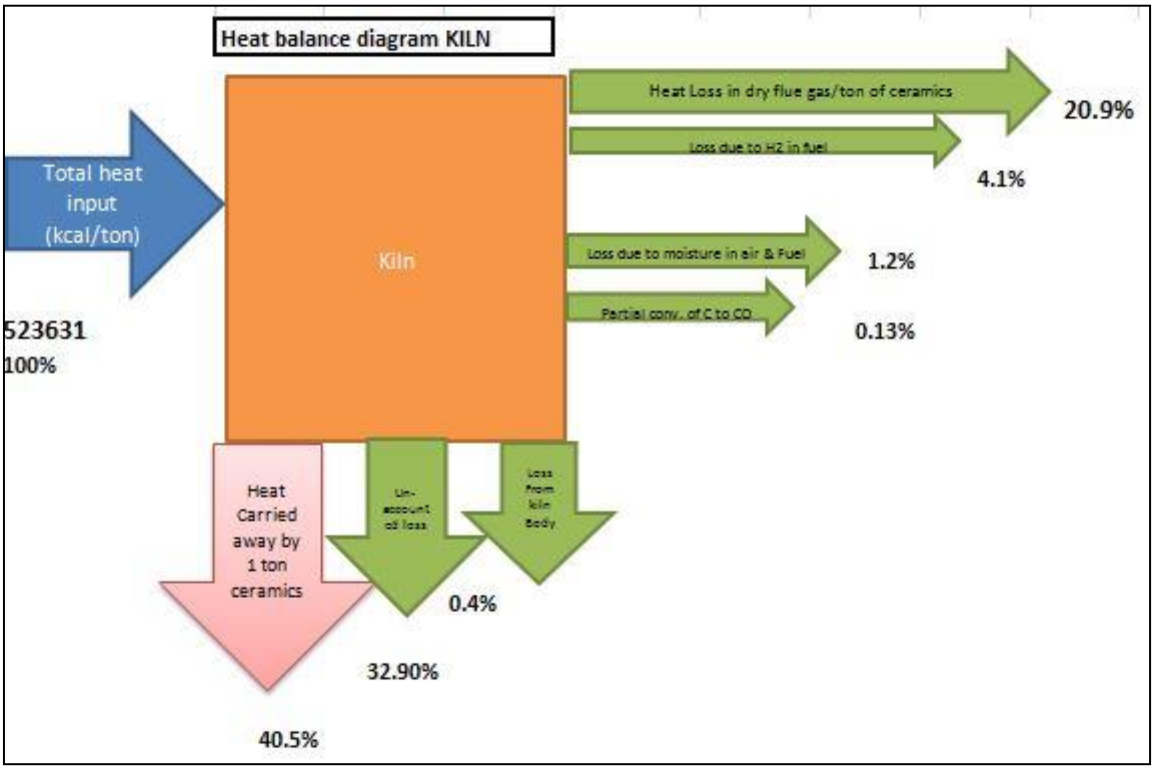



**Figure 14: Heat Balance Diagram of Kiln**

The unaccounted loss occurred in kiln includes heat gained by rollers, small openings at side of kiln causes loss in heat and Fan body are at higher temperature causing loss in heat Detailed calculation is included in Annexure - 5.

### 3.1.4 Energy Conservation Measures (ECM)

Energy conservation measures are described below:

#### *3.1.4.1 Energy conservation measures - ECM #1: Excess air control in kiln*

***Technology description***

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of fuel. The excess air levels are calculated based on oxygen content in the flue gases. The theoretical air required for combustion of any fuel can be known from the ultimate analysis of the fuel. All combustion process requires certain amount of excess air in addition to the theoretical air supplied. Excess air supplied needs to be maintained at optimum levels, as, too much excess air results in excessive heat loss through the flue gases whereas too little excess air results in in-complete combustion of fuel and formation of black colored smoke in flue gases.

In general, in most of the kilns, fuel is fired with too much excess air. This results in the formation of excess flue gases, taking away the heat produced from the combustion and increasing the fuel consumption. This also results in the formation of excess GHG emissions.

A PID controller, if installed, measures the oxygen levels in the flue gases at the exit of the kiln and based on that the combustion air flow from FD fan (blower) is regulated and subsequently proper temperature and optimum excess air for combustion is attained in the kiln.

### *Study and investigation*

At present, there is no proper automation and control system installed in the kiln to monitor and maintain optimum excess air levels. Fuel was fired from the existing burner system and no air flow control mechanism was in place for maintaining proper combustion of the fuel. The combustion air and cooling air (through air curtains) were being supplied from the same FD fan. The pressures required for combustion and for cooling air were different and supplying both the air from one common FD fan was not a good practice.

### *Recommended action*

Separate blowers for Biscuit Kiln and Glaze Kiln have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. For Kiln oxygen level is 7.5 % which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

**Table 22: Cost benefit analysis for Kiln (ECM-1)**

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Oxygen level in flue gas just before firing zone | % | 7.5 | 5.0 |
| Excess air percentage in flue gas | % | 55.8 | 31.3 |
| Dry flue gas loss | % | 21% | |
| Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption | kg of fuel/ton of tile | 426 | 415 |
| Average production in Kiln | t/h | 5.4 | 5.4 |
| Saving in specific fuel consumption | kg/h | | 56.90 |
| Operating hours per day | h/d | | 330 |
| Annual operating days | d/y | | 24 |
| Annual fuel saving | t/y | | 451 |
| Coal gas to coal ratio | kg/kg | 3.70 | 3.70 |
| Coal saving in gasifier | t/y | | 122 |
| Fuel cost | Rs/t | | 6,000 |
| Annual fuel cost saving | Lakh Rs/y | | 7.3 |
| Power saving in combustion blower | | | |
| Mass flow rate of air | t/h | 27.85 | 23.45 |
| Density of air | kg/m$^3$ | 1.23 | 1.23 |
| Mass flow rate of air | m$^3$/s | 6.3 | 5.3 |
| Measured power of blower | kW | 1.83 | 1.09 |
| Total power saving | kW | | 0.74 |
| Operating days per year | d/y | | 24 |
| Operating hours per day | h/d | | 330 |
| Annual energy saving | kWh/y | 5,836 | |
| Weighted electricity cost | Rs/kWh | 7.36 | 7.36 |
| Annual energy cost saving | Lakh Rs/y | | 0.43 |
| Overall energy cost saving | Lakh Rs/y | | 7.73 |
| Estimated investment | Lakh Rs | | 18.48 |

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Payback period | Months | | 28.67 |
| IRR | % | | 21 |
| Discounted payback period | Months | | 10.46 |

#### *3.1.4.2 Energy conservation measures - ECM #2: Insulation in recuperator pipes of kiln*

### ***Technology description***

A significant portion of the losses in a kiln occurs as radiation and convection loss from the combustion air carrying pipes. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of insulation should be provided on these pipes to maintain the skin temperature of the furnace at around 80°C, so as to avoid heat loss due to radiation and convection.

Thermal insulations are used for reduction in heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact or in range of radiative influence.

Recuperator pipes is made by combination of insulation layers and cladding, with the objective of retaining the desired temperature of air inside the pipes and avoids losses from pipe walls

### ***Study and investigation***

There are 24 un-insulated pipes in recuperator in rapid cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 177°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

### ***Recommended action***

Recommended surface temperature of the pipe surface has to be reduced to within 80°C to reduce the heat loss due to radiation and convection and utilize the useful heat. The amount of heat lost through radiation and convection in each zone is given in the table below.

**Table 23: Cost benefit analysis (ECM-2)**

| Parameter | UoM | Present | Proposed |
|---|---|---|---|
| No of un-insulated pipe in recuperator | # | 24 | 24 |
| Recuperator pipe size | Mm | 96 | 96 |
| Pipe length | M | 2 | 2 |
| Total surface area | $m^2$ | 15.84 | 15.84 |
| Average surface temperature | °C | 107 | 80 |
| Ambient air temperature | °C | 35 | 35 |
| Heat loss | kcal/h.$m^2$ | 973 | 551 |
| Total heat loss | kcal/h | 15,421 | 8,732 |
| GCV of fuel | kcal/scm | 1,231 | 1,231 |
| Heat loss in terms of fuel | kg /h | 3.2 | 1.8 |
| Fuel saving | kg/h | | 1.4 |
| Operating hours per day | h/d | 24 | 24 |
| Annual operating days | d/y | 330 | 330 |

| Parameter | UoM | Present | Proposed |
|---|---|---|---|
| Annual fuel saving | t/y | 11 | |
| Fuel cost | Rs/t | 6,000 | |
| Annual fuel cost saving | Rs Lakh/y | 0.67 | |
| Estimated investment | Rs Lakh | 1.06 | |
| Payback period | Months | 18.98 | |
| IRR | % | 43 | |
| Discounted Payback period | Months | 7.08 | |

#### *3.1.4.3 Energy Conservation Measures - ECM #3: Insulation in pipes of indirect cooling zone*

##### ***Technology description***

A significant portion of the losses in a kiln occurs as radiation and convection loss from the combustion air carrying pipes. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of insulation should be provided on these pipes to maintain the skin temperature of the furnace at around 80°C, so as to avoid heat loss due to radiation and convection.

Thermal insulations are used for reduction in heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact or in range of radiative influence.

Recuperator pipes is made by combination of insulation layers and cladding, with the objective of retaining the desired temperature of air inside the pipes and avoids losses from pipe walls

##### ***Study and investigation***

There are 90 un-insulated pipes in indirect cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 177°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

##### ***Recommended action***

Recommended surface temperature of the pipe surface has to be reduced to within 80°C to reduce the heat loss due to radiation and convection and utilize the useful heat. The amount of heat lost through radiation and convection in each zone is given in the table below.

**Table 24: Cost benefit analysis for insulation in pipes of indirect cooling zone (ECM-3)**

| Parameter | UoM | Present | Proposed |
|---|---|---|---|
| No of un-insulated pipe in indirect cooling zone | # | 90 | 90 |
| Recuperator pipe size | mm | 26 | 26 |
| Pipe length | m | 0.40 | 0.40 |
| Total surface area | $m^2$ | 2.88 | 2.88 |
| Average surface temperature | °C | 179 | 80 |
| Ambient air temperature | °C | 35 | 35 |
| Heat loss | kcal/h/$m^2$ | 2,485 | 551 |
| Total heat loss | kcal/h | 7,167 | 1,590 |
| GCV of coal gas | kcal/$sm^3$ | 1,231 | 1,231 |
| Heat loss in terms of fuel (coal gas) in Kiln | $sm^3$/h | 5.8 | 1.3 |

| Parameter | UoM | Present | Proposed |
|---|---|---|---|
| Gas to coal ratio of gasifier | $sm^3/kg$ | 3.9 | 3.9 |
| Heat loss in terms of coal in gasifier | kg/h | 1.5 | 0.3 |
| Fuel saving | kg/h | | 1.2 |
| Operating hours per day | h/d | 24 | 24 |
| Annual operating days | d/y | 330 | 330 |
| Annual fuel saving | t/y | | 9 |
| Fuel cost | Rs/t | | 6,000 |
| Annual fuel cost saving | Rs Lakh/y | | 0.56 |
| Estimated investment | Rs Lakh | | 0.20 |
| Payback period | Months | | 4.27 |
| IRR | % | | 211% |
| Discounted payback period | Months | | 2 |

## 3.2 Coal Gasifier

### 3.2.1 Specifications

Coal gasifier produces coal gas from coal at controlled combustion by partial combustion using coal and water vapor. Coal gas is used. The specification of coal gasifier is given below:

**Table 25: Specifications of coal gasifier**

| Particular | UOM | Value |
|---|---|---|
| Make | | Radhey |
| Coal consumption | t/d | 15 |
| Water consumption | l/d | 2,000 |
| FD Blower | hp | 1 x 18 |
| Cooling water pump | hp | 2 x 12 |

### 3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Coal input to gasifier
- Volume of gas produced by gasifier
- Power measurement of FD blower
- Power and flow measurement of CT pumps

The coal input to the gasifier was 625 kg/h. Volume of gas produced in gasifier is 2,418 scm/h. The power consumption for FD blower was 2.16 kW, for CT pump-1 & 2 was 9.39 & 6.87 kW.

### 3.2.3 Observations and performance assessment

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, the specific energy consumption of coal gasifier was 0.25 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm of coal gas generation in plant which is 0.0076 kWh/scm.

## 3.3 Hot Air Generator& Spray Dryer

### 3.3.1 Specifications

Bubbling bed type hot air generator is used for evaporating water from slip which is coming from ball mill. Spray dryer is the heat exchanging unit for power generation from slip by taking heat from hot air of HAG. Specifications of HAG are given below:

**Table 26: Specifications of Hot air generator (HAG)**

| Particular | UoM | Bubbling bed |
|---|---|---|
| Fuel type | | Coal |
| Air handling capacity | $m^3/h$ | - |
| Fuel consumption | t/d | 260 |
| Flue gas temperature | °C | 560 |
| FD blower | kW | 1 x 22 |
| PA fan | kW | 1 x 5.6 |

The specification of spray dryer is given below:

**Table 27: Specifications of spray dryer**

| Particular | UOM | Value |
|---|---|---|
| Powder generation capacity | t/d | 200 |
| Inlet slip moisture | % | 40 |
| Outlet powder moisture | % | 5 |
| Slip hydraulic pump | kW | 2 |

### 3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Hot air generators & Spray dryer
  - Power consumption of FD and ID fan
  - Air flow measurement of FD fan
  - Details of measurements on HAG are given below:

**Table 28: Field measurement at site**

| Particular | UoM | Bubbling bed |
|---|---|---|
| Air velocity at FD fan suction | m/s | 13.7 |
| Suction area | $m^2$ | 0.314 |
| Exit temperature of air | °C | 590 |
| Surface temperature | °C | 90 |
| Average power consumption-FD Blower | kW | 24.7 |
| Average power consumption-ID Fan | kW | 38.6 |

All blowers are operating with VFDs.

### 3.3.3 Observations and performance assessment

Mass and energy balance of HAG and spray dryer determined based on data collected is as follows:

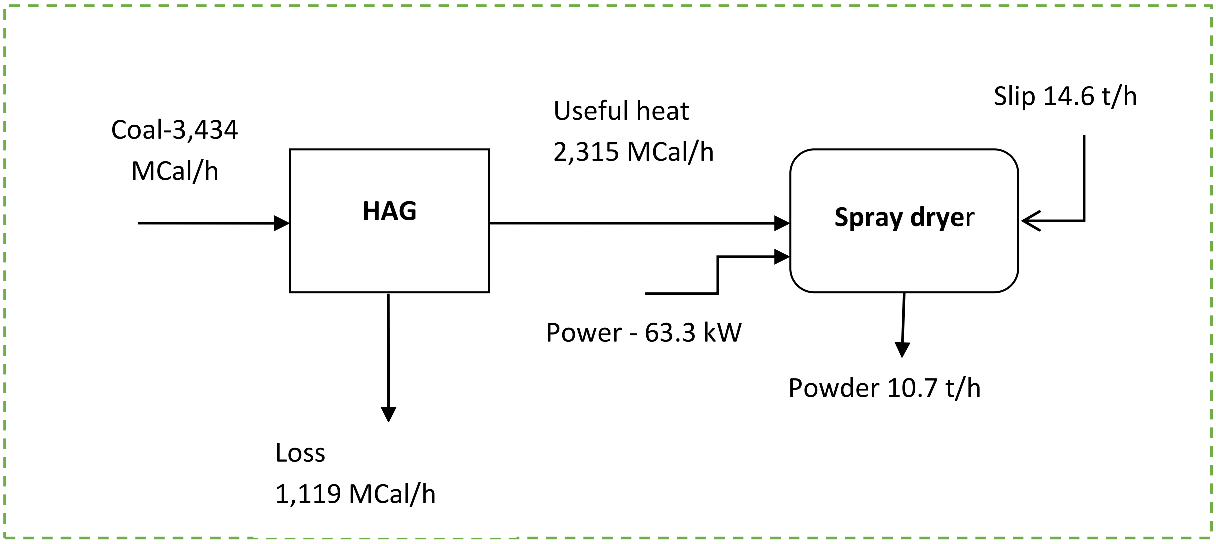



Figure 15: Energy and mass balance of Chain stoker HAG and New spray dryer

Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for evaporating one kg water from slip) and specific thermal energy measure (fuel used for evaporating 1 kg of water in slip). Based on observations during DEA, the bubbling bed HAG corresponding values are 6.44 kW/ton and 163.0 kg of coal/ton.

Performance of spray dryer measures in terms of specific electricity consumption (electrical energy used for delivering one kg of powder). Based on observations during DEA, the specific electricity consumption of spray dryer was 3.60kW/ton. Since blowers are VFD controlled and operation is optimized.

# 4 CHAPTER -4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

## 4.1 CLAY BALL MILLS

### 4.1.1 Specifications

Clay ball mills produce slip by mixing clay, water and chemicals SMS and STPP. Clay ball mills take 2-3 hrs for slip preparation. The specifications of clay ball mills and its accessories are given below:

**Table 29: Specifications of clay ball mills**

| Particular | UoM | Value |
|---|---|---|
| Numbers of clay ball mill | # | 1 |
| Capacity of clay ball mill | t/batch | 58 |
| Water consumption in each ball mill | t/batch | 40 |
| SMS (chemical consumption) | kg/batch | 50 |
| STPP (chemical consumption) | kg/batch | 10 |
| Water TDS | Ppm | 900 |
| Nos. of batch per day | # | 6 |

### 4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of clay ball mill
- Mass consumption as per Table 29.

All power profile is included in **Annexure-4**. Average power consumption and power factor are given in below table:

**Table 30: Average power consumption and PF of clay ball mills**

| Equipment | Average Power (kW) | PF |
|---|---|---|
| Clay ball mill | 218.5 | 1 |

### 4.1.3 Observations and performance assessment

Mass balance of clay ball mill based on measurements for clay ball mill is given below:

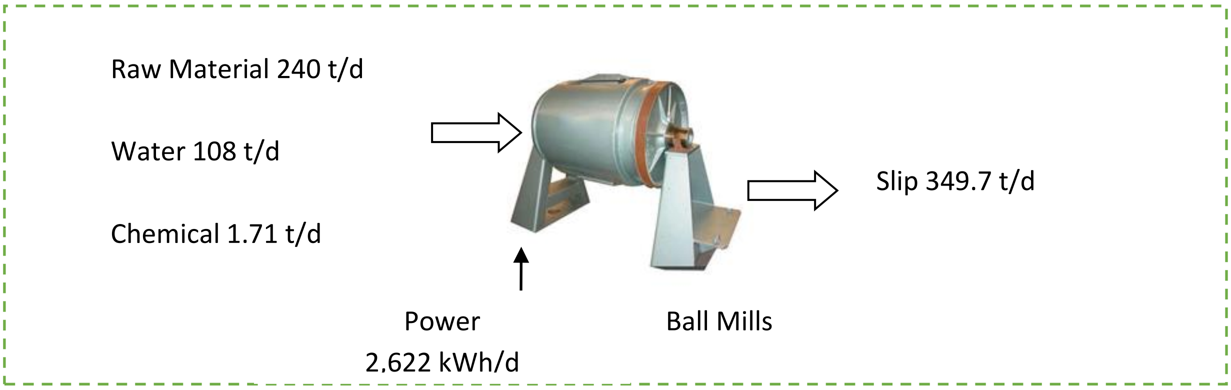



**Figure 16: Energy and mass balance of Ball Mills**

Performance of ball mills measure in terms of specific energy consumption (power consumed for preparation of 1 ton of slip). Based on observations during DEA, the specific energy consumption of ball mills was 7.5 kW/ton. TDS of bore well water is very high; this should be controlled by installing water softener plant which will enable resource savings.

### 4.1.4 Energy Conservation Measures (ECM)

Energy conservation measures are described below:

#### *4.1.4.1 Energy conservation measures - ECM #4: Using soft water in clay ball mill*

***Technology description***

It was observed that the TDS of water used in clay section is 900 ppm, which results in higher consumption of water, chemicals and electricity per batch of slip preparation and later higher coal consumption for spray dryer.

***Study and investigation***

All the details of the composition of raw materials per batch, water consumption per batch and electricity consumption per batch were collected for analysis and proposed solution for resource conservation.

***Recommended action***

It is recommended to install brackish water plant which will blend RO water with raw water to get desired TDS of water(less than 400ppm) to be used in ball mill. Resource saving has been considered for water, chemicals, coal and power consumption to arrive at techno economics of the proposed energy conservation measure. Coal consumption will be reduced due to reduced quantity of water to be evaporated in spray dryer.

Estimated cost benefit is given in the table below:

**Table 31: Saving and cost benefit by using improved water quality [ECM-4]**

| Particulars | UoM | Present | Proposed |
|---|---|---|---|
| TDS of water | ppm | 900 | 400 |
| Assumption : Water saving | | | 15% |
| Assumption : Electricity saving | | | 3% |
| Assumption : Fuel saving | | | 30% |
| Assumption : Chemical saving | | | 30% |
| Water used per batch | $m^3$ | 18.00 | 15.30 |
| Water saving | $m^3$ | | 2.70 |
| Electricity used per batch | kWh | 218.51 | 212.0 |
| Temperature of water | °C | 25 | 25 |
| Boiling temp. of water | °C | 100 | 100 |
| GCV of coal | kCal/kg | 5,495 | 5,495 |
| Eff. of HAG | % | 85 | 85 |
| Coal saving per batch | kg | | 356 |
| Chemical saving per batch | | | |
| SMS | kg | 50 | 35 |
| STPP | | 10 | 7 |
| Per unit cost | | | |
| Water | Rs./$m^3$ | 5.00 | 5.00 |
| Electricity | Rs/kWh | 7.36 | 7.36 |

| Particulars | UoM | Present | Proposed |
|---|---|---|---|
| Coal | Rs/kg | 6.00 | 6.00 |
| Chemical | | | |
| SMS | Rs/kg | 15.00 | 15.00 |
| STPP | Rs/kg | 75.00 | 75.00 |
| Cost savings per batch | Rs | | 2,645 |
| Total batches per day | # | 7 | 7 |
| Annual operating days | d/y | 330 | 330 |
| Annual resource savings | | | |
| Water | $m^3/y$ | | 6,237.0 |
| Electricity | kWh/y | | 15,142.60 |
| Coal | t/y | | 821.23 |
| Chemical | kg/y | | 41,580.00 |
| Annual cost savings | Lakh Rs/y | | 61.09 |
| Operating cost- Water treatment | $Rs/m^3$ | | 20.00 |
| | Lakh Rs/y | | 7.00 |
| Net monetary savings | Lakh Rs/y | | 54.03 |
| Estimated investment | Lakh Rs | | 39.60 |
| Payback period | Months | | 8.80 |
| IRR | % | 101 | |
| Discounted payback period | Months | 3.44 | |

## 4.2 Hydraulic presses

### 4.2.1 Specifications

There are 2 hydraulic presses. Hydraulic presses give shape for powder that is coming from spray dryer in tiles form by pressing powder with high pressure (15.5MPa). Hydraulic press is being is being operated in night time. The power rating of hydraulic press 980 and press 1600 are given below:

Table 32: Specifications of hydraulic press

| Particular | UoM | Press 980 | Press 1600 |
|---|---|---|---|
| Power rating | kW | 55 | 55 |
| Water circulation pump | # | 1 | 1 |

### 4.2.2 Field measurement and analysis

During DEA, as hydraulic press operate only in night when kiln acts as a biscuit kiln, the field measurement done only in power profile. The following measurements were done:

- Power consumption of hydraulic press and water circulation pumps

Average power consumption of Press 1600 was 48 kW (PF 0.74) during DEA. Water circulation pumps were consuming power of 4.07 KW (PF 0.83).

### 4.2.3 Observation and performance assessment

Both circulation pumps operates 24 hours in a day while press has frequent shut down, however it is not advisable to regulate pump based on oil temperature as the temperature will suddenly rise if circulation pump is stopped.

Performances of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). As hydraulic press is operated at night, SEC cannot be measured.

## 4.3 Agitator

### 4.3.1 Specifications

Slip is stored in the agitation tank after preparation in ball mils where agitator motors (stirrer) were rotating continuously. Stirrer prevents the settling of slip. The specifications of agitator motors are given below:

Table 33: Specifications of agitators

| Particular | UOM | Value |
|---|---|---|
| Numbers of agitators in tank | # | 9 |
| Capacity of each agitator motor | kW | 1.77 |
| Number of motors | # | 9 |

### 4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

Power consumption and P.F. of all agitator motors (stirrer) are given in below table:

Table 34: Power consumption and P.F. of agitator motors

| Equipment | kW | PF |
|---|---|---|
| Agitator motor-1 | 1.78 | 0.82 |
| Agitator motor-2 | 1.76 | 0.89 |
| Agitator motor-3 | 1.78 | 0.83 |
| Agitator motor-4 | 1.76 | 0.83 |
| Agitator motor-5 | 1.77 | 0.84 |
| Agitator motor-6 | 1.77 | 0.84 |
| Agitator motor-7 | 1.76 | 0.85 |
| Agitator motor-8 | 1.78 | 0.85 |
| Agitator motor-9 | 1.77 | 0.85 |

### 4.3.3 Observations and performance assessment

Based on measurement it can be seen that power factor of agitator motor is in the range of 0.80-0.85. There is timer controller installed for each motor having time interval of 40 minutes.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slip). Based on observations during DEA, the specific energy consumption of agitator motors were 0.55 kW/ton of slip.

## 4.4 Glazing

### 4.4.1 Specifications

Ceramic glaze is an impervious layer or coating of a vitreous substance which is fused to a ceramic body through firing. Glaze can serve to color, decorate or waterproof an item. It also gives a tougher surface. Glaze is also used on stoneware and porcelain. In addition to their functionality, glazes can form a variety of surface finishes, including degrees of glossy or matte finish and color. Glazes may also enhance the underlying design or texture unmodified or inscribed, carved or painted.

Glazes need to include a ceramic flux which functions by promoting partial liquefaction in the clay bodies and the other glaze materials. Fluxes lower the high melting point of the glass formers silica, and sometimes boron trioxide. These glass formers may be included in the glaze materials, or may be drawn from the clay beneath.

Raw materials of ceramic glazes generally include silica, which will be the main glass former. Various metal oxides, such as sodium, potassium, and calcium, act as flux and therefore lower the melting temperature. Alumina, often derived from clay, stiffens the molten glaze to prevent it from running off the piece. Colorants, such as iron oxide, copper carbonate, or cobalt carbonate and sometimes opacifiers like tin oxide or zirconium oxide, are used to modify the visual appearance of the fired glaze.

The specifications of glazing mills are given below:

**Table 35: Specifications of glaze ball mill**

| Particular | UoM | Glaze mill |
|---|---|---|
| Numbers of glazing mills | Nos. | 5 |
| Capacity of glaze mill 1 | Ton/batch | 1.0 |
| Capacity of glaze mill 2 | Ton/batch | 1.0 |
| Capacity of glaze mill 3 | Ton/batch | 1.0 |
| Capacity of glaze mill 4 | Ton/batch | 1.5 |
| Capacity of glaze mill 5 | Ton/batch | 1.5 |
| Connected load of glaze ball mill 1 | kW | 15 |
| Connected load of glaze ball mill 2 | kW | 15 |
| Connected load of glaze ball mill 3 | kW | 15 |
| Connected load of glaze ball mill 4 | kW | 15 |
| Connected load of glaze ball mill 5 | kW | 15 |

### 4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of two glaze ball mill which were in operation.
- Mass consumption of material input to glaze ball mill as per Table 35.

Power consumption and P.F. of all glaze mills are given in below table:

**Table 36: Power consumption and P.F. of glaze mills**

| Equipment | kW | PF |
|---|---|---|
| Glaze ball mill-1 | 10.8 | 0.8 |
| Glaze ball mill -2 | 10.8 | 0.78 |

### 4.4.3 Observations and performance assessment

Performance of glaze ball mill can be measured in terms of specific energy consumption (power consumed for glazing 1 ton of tiles). Based on observations during DEA, the specific energy consumption of glaze ball mill was 3.97kW/ton.

## 4.5 Sizing

### 4.5.1 Specifications

There were 2 sizing lines; each holding two sizing machines each comprising many grinders along with dust collector blower. The specifications of sizing machines are given below:

**Table 37: Specifications of sizing machine**

| Particular | UoM | Value |
|---|---|---|
| Numbers of sizing machines | Nos. | 2 |
| Sizing Machine 1 | kW | 9.2 |
| Sizing Machine 2 | kW | 9.2 |
| Sizing line – Conveyors | kW | 1.12 |

### 4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of each sizing machines
- Tile production in sizing section 5.4 t/h.

Average power consumption and power factor (PF) from sizing machines are tabulated below:

**Table 38 : Measured Parameters of sizing machine**

| Equipment | UoM | Value | PF |
|---|---|---|---|
| Average power (M/c#1) | kW | 26.3 | 0.53 |
| Average power (M/c#2) | kW | 24.8 | 0.69 |

### 4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were:

**Table 39 : SEC of sizing machine**

| Equipment | UOM | Value |
|---|---|---|
| Sizing unit | kW/t | 9.46 |

## 4.6 Air Compressors

### 4.6.1 Specifications

Two air compressors are installed in plant. Both compressor is reciprocating type. The specifications of compressors are given below:

**Table 40: Specifications of compressors**

| Particular | Units | Compressor 1 | Compressor 2 |
|---|---|---|---|
| Power rating | kW | 11 | 11 |
| Maximum pressure | Bar (a) | 10.5 | 10.5 |
| Rated Capacity | $m^3$/min | - | - |

All compressors have a common receiver.

### 4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all compressor
- Loading and unloading time

Average power consumption and loading/unloading of the compressors is given below:

Table 41: Measured parameters of compressors

| Equipment | Average power (kW) | PF | % of time on load |
|---|---|---|---|
| Compressor 1 | 10.44 | 0.81 | 52.8 |
| Compressor 2 | 12.05 | 0.84 | 50.9 |

FAD of compressors could not be conducted as there was only one receiver for whole plant.

### 4.6.3 Observation and performance assessment

Based on observations during DEA, it was observed that operating pressure was higher in both the compressors which can be reduced as per requirement. VFD installation is recommended for Kaeser compressor to avoid power consumption during unloading.

### 4.6.4 Energy conservation measures (ECM)

Energy conservation measures are described below:

#### *4.6.4.1 Energy conservation measures - ECM #5: Replacement of reciprocating compressor with screw compressor*

***Technology description***

Replacement of reciprocating compressor with screw capacity compressor.

***Study and investigation***

During measurements, it was found that the reciprocating compressor was consuming more power when compared with new EE screw compressor.

***Recommended action***

It is recommended to replace the existing reciprocating compressor with EE screw compressor with VFD. The cost benefit analysis of the energy conservation measure is given below:

Table 42: Cost benefit analysis screw compressor (ECM – 5)

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Compressor motor rating | kW | 22 | 22 |
| Average power consumption | kW | 22.50 | 19.13 |
| Operating hours per day | h/d | 24 | 24 |
| Operating days per year | d/y | 330 | 330 |
| Annual energy consumption | kWh/y | 178,226 | 151,492 |
| Annual energy saving | kWh/y | | 26,734 |
| Unit cost of electricity | Rs/kWh | | 7.36 |
| Annual monetary savings | Lakh Rs/y | | 1.97 |
| Estimated Investment | Lakh Rs | | 5.94 |
| Payback period | Months | | 36 |
| IRR | % | | 12 |
| Discounted payback period | Months | | 12.93 |

## 4.7 Water Pumping System

### 4.7.1 Specifications

Pumping system comprises four transfer pumps as shown in Figure 12.

### 4.7.2 Field measurement and analysis

During DEA, the following measurements were done for the following pumps:

- Power consumption of hydraulic press oil cooling tower pumps by running pumps for a while for measurement, as hydraulic press section is under shut during day time.
- Power and flow measurement of coal gasifier cooling tower pumps.
- Other pumps are having smaller size and internal corrosion problems.
- Flow could not be measured due to internal corrosion problems.

Power measured for pumps are given in below table:

Table 43: Operating details of pump

| Particulars | UoM | Press Pump 1 | Press Pump 2 | Coal gasifier Pump 1 | Coal gasifier Pump 2 |
|---|---|---|---|---|---|
| Actual power consumption | kW | 4.07 | 4.55 | 9.39 | 6.87 |
| Power factor | | 0.83 | 0.72 | 0.99 | 0.93 |
| Flow | $m^3/h$ | 24.5 | 31.8 | 40 | 38.5 |

### 4.7.3 Observation and performance assessment

Based on observations during DEA, it was observed that the coal gasifier cooling tower pump is less efficient. The pipe carrying water is rusted and scale is formed on it.

### 4.7.4 Energy conservation measures

The energy conservation measures recommended are:

#### *4.7.4.1 Energy conservation measures (ECM) - ECM #6: Replacement of inefficient pump with efficient pumps in Coal gasifier cooling tower*

***Technology description***

Presently, there are energy efficient pumps available having pump efficiency of 65% which leads to reduced energy consumption.

***Study and investigation***

The unit is having two cooling tower pumps. Efficiency of existing pumps is 18.4% and 21.6% respectively.

***Recommended action***

It is recommended to replace inefficient pumps with energy efficient pumps. New pumps shall have efficiency up to 65%. The cost benefit analysis is given below:

Table 44: Cost benefit analysis (ECM-6)

| Particulars | UoM | Value | | Value | |
|---|---|---|---|---|---|
| | | CT Pump-1 (Coal gasifier | | CT Pump-2 (coal gasifier) | |
| Pump efficiency | | | 65 | | 65 |

| Particulars | UoM | Value | | Value | |
|---|---|---|---|---|---|
| Motor I/P power | kW | 5.59 | 3.10 | 5.59 | 2.65 |
| Motor efficiency | % | 85 | 87.7 | 85.00 | 87.7 |
| Measured parameters | | **Present** | **Proposed** | **Present** | **Proposed** |
| Flow rate | $m^3/h$ | 45.0 | 45.0 | 38.5 | 38.5 |
| Suction pressure | $kg/cm^2$ | 0.0 | 0.0 | 0.00 | 0.0 |
| Discharge pressure | $kg/cm^2$ | 1.20 | 1.2 | 1.2 | 1.2 |
| Motor input power | kW | 9.4 | | 6.9 | 2.21 |
| Saving assessment | | **Present** | **Proposed** | **Present** | **Proposed** |
| Flow rate | $m^3/s$ | 0.01250 | 0.01250 | 0.01069 | 0.01069 |
| Total head developed | m | 12.0 | 12.0 | 12.0 | 12.0 |
| Liquid horse power | kW | 1.5 | 1.5 | 1.3 | 1.3 |
| Motor Input power | kW | 9.4 | 2.58 | 6.9 | 2.21 |
| Nearest standard pump size | kW | | 3.0 | | 3.00 |
| Motor loading | % | 167.9 | 103.3 | 122.8 | 88.3 |
| Overall system efficiency | % | 15.7 | 57.0 | 18.3 | 57.0 |
| Pump efficiency | % | 18.4 | 65.0 | 21.6 | 65.0 |
| Average working hours | h/d | 24 | 24.0 | 24.0 | 24.0 |
| Annual working days | d/y | 330 | 330.0 | 330.0 | 330.0 |
| Annual energy consumption | kWh/y | 74,369 | 20,444 | 54,410 | 17,491 |
| Annual energy saving | kWh/y | - | 53,924 | - | 36,919 |
| Weighted average cost | Rs/kWh | 7.4 | 7.4 | 7.4 | 7.4 |
| Annual energy cost saving | Rs Lakh/y | - | 3.97 | - | 2.72 |
| Percentage of energy saving | % | - | 72.5 | - | 67.9 |
| Estimated investment | Rs Lakh | - | 0.422 | - | 0.422 |
| Total annual energy saving | kWh/y | 90,844 | | | |
| Total annual monetary saving | Rs Lakh/y | 6.68 | | | |
| Total investment | Rs Lakh | 0.84 | | | |
| Payback period | Month | 2 | | | |
| IRR | % | 589% | | | |
| Discounted Payback period | Months | 1 | | | |

## 4.8 Lighting System

### 4.8.1 Specifications

The plant's lighting system includes:

Table 45: Specifications of lighting load

| Particular | Units | T-8 | T-12 | CFL | CFL | CFL | MH | MH | AC | FANS |
|---|---|---|---|---|---|---|---|---|---|---|
| Power consumption per fixture | W | 36 | 40 | 65 | 75 | 36 | 150 | 400 | | 75 |
| Numbers of fixtures | # | 285 | 35 | 258 | 1 | 17 | 2 | 4 | 10 | 68 |

### 4.8.2 Field measurement and analysis

During DEA, the following measurements were done by :

- Recording Inventory
- Recording Lux Levels

Measured values are summarized below:

**Table 46: Lux measurement at site**

| Particular | Measured Value Lumen/$m^2$ | Particular | Measured Value Lumen/$m^2$ |
|---|---|---|---|
| Office | 180 | Clay ball mill and agitators | 83 |
| Kiln control room | 110 | HAG and spray dryer | 80 |
| Kiln area | 90 | Glaze line | 112 |
| Press | 110 | Sizing Machine | 90 |
| Inventory | 90 | Glaze ball mill | 85 |

### 4.8.3 Observations and performance assessment

Adequate day lighting is used wherever possible. There is scope to replace luminaries with more energy efficient types which are currently available.

### 4.8.4 Energy conservation measures (ECM)

Energy conservation measures are described below:

#### *4.8.4.1 Energy conservation measures (ECM) - ECM #7: Replacement of inefficient light with EE lights*

***Technology description***

Replacing conventional lamps with LED lights helps in reducing the power consumption and also results in higher illumination (lux) levels for the same power consumption.

***Study and investigation***

Most of the installed luminaries are of conventional type.

***Recommended action***

It is recommended to replace the above mentioned light fixtures with energy efficient LED lamps which shall help reduce present lighting energy consumption. The cost benefit analysis is given below:

Table 47: cost benefit analysis (ECM 7)

| Parameter | UOM | Present | Proposed | Present | Proposed | Present | Proposed | Present | Proposed | Present | Proposed | Present | Proposed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of fixture | | FTL T8 | LED tube | FTL T12 | LED tube | CFL (65 W) | LED | CFL (36 W) | LED (18 W bulb) | MH flood light (150 W) | LED | MH flood light (400 W) | LED |
| Type of choke if applicable | | Magnetic | Driver | Magnetic | Driver | | | | | Magnetic | Driver | Magnetic | Driver |
| Number of fixtures | # | 285 | 285 | 35 | 35 | 258 | 258 | 17 | 17 | 2 | 2 | 4 | 4 |
| Rated power of fixture | W/Unit | 36 | 20 | 40 | 20 | 65 | 36 | 36 | 18 | 150 | 60 | 400 | 200 |
| Consumption of choke | W | 12 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 35 | 0 |
| Operating power | W/fixture | 48 | 20 | 52 | 20 | 65 | 36 | 36 | 18 | 180 | 60 | 435 | 200 |
| Operating hours/day | h/d | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Operating days/year | d/y | 330 | 330 | 330 | 330 | 330 | 330 | 330 | 330 | 330 | 330 | 330 | 330 |
| Annual energy consumption | kWh/y | 90,288 | 37,620 | 12,012 | 4,620 | 110,682 | 61,301 | 4,039 | 2,020 | 2,376 | 792 | 11,484 | 5,280 |
| Annual energy saving | kWh/y | | 52,668 | | 7,392 | | 49,381 | | 2,020 | | 1,584 | | 6,204 |
| Total annual energy savings | kWh/y | 119,249 | | | | | | | | | | | |
| Unit cost of electricity | Rs/kWh | 7.36 | | | | | | | | | | | |
| Annual monetary savings | Lakh Rs/y | 8.77 | | | | | | | | | | | |
| Estimated investment | Lakh Rs | 5.62 | | | | | | | | | | | |
| Payback period | Months | 8 | | | | | | | | | | | |
| IRR | % | 117 | | | | | | | | | | | |
| Discounted payback period | Months | 3.01 | | | | | | | | | | | |

## 4.9 Electrical Distribution System

### 4.10.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415 V) by step down transformer (1.00 MVA). Automatic power factor correction system is installed in parallel to main supply. There were two DGs (capacity of 1 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeders which are shown in single line diagram in Figure 20.

### 4.10.2 Field measurement and analysis

During DEA, the following measurements were done:

- Whole plant load measurement by installing power analyzer at main incomer feeder.

### 4.10.3 Observations and performance assessment

After analyzing feeder power profiling, it was observed that the maximum kVA recorded during study period was **514 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **430 V.** Maximum voltage was **442 V** and minimum was **409 V**.

Average total voltage and current harmonics distortion found **7.70% and 19.02%** respectively during power profile recording.

There is only one electricity meter in the plant at the main incomer, with no sub-metering.

It was observed that some of the outgoing feeders to sizing and press section has low poor power factor. Poor power factor leads to cable losses ($I^2R$) in the electrical distribution system. However since cable length is very less no recommendation is given.

### 4.10.4 Energy conservation measures (ECM)

Energy conservation measures are described below:

#### *4.10.4.1 Energy conservation measures (ECM) - ECM #8: Main LT voltage optimization*

***Technology description***

A Servo Stabilizer is a Servo motor controlled stabilization system that performs optimum voltage supply using a Buck\Boost transformer booster that captures voltage fluctuations from input and regulates current to the correct output. An AC synchronous motor adjusts voltage in clockwise or anticlockwise direction and manages the output voltage with components like control card, dimmer, comparator, transistors, MOCS, etc.

***Study and investigation***

During field measurements, it was found that the present voltage was higher than the standard voltage which is 415V. According to the main LT Power Profiling, maximum voltage was 443 & average voltage is 430 V found.

### *Recommended action*

A 0.7MVA servo stabilizer is suggested to install on main LT panel to optimize voltage. Servo stabilizer rating is suggested according to Electricity monthly billing demand. The cost benefit analysis for this project is given below:

**Table 48: Cost benefit analysis of Main LT voltage optimization (ECM – 8)**

| Parameter | UoM | Present | Proposed |
|---|---|---|---|
| Maximum load (Measured) | kW | 508 | 508 |
| | kVA | 515 | 515 |
| Maximum demand as per electricity bill | kVA | 750 | 750 |
| Maximum voltage | | 443 | 415 |
| Average voltage | V | 430 | 410 |
| Reduction in voltage | % | | 4.5% |
| % reduction in energy consumption | % | | 8.88% |
| Average power factor of system | PF | 0.97 | 0.97 |
| Annual electricity consumption | kWh/y | 2,586,376 | 2,586,376 |
| Savings estimate from other EPIAs | kWh/y | | 296,386 |
| Actual energy considered for voltage regulation | kWh/y | | 2,289,990 |
| Actual energy consumption after voltage regulation | kWh/y | | 2,086,526 |
| Efficiency of servo stabilizer | % | | 95% |
| Period for which voltage regulation is required | Months/y | | 8 |
| Net saving from voltage regulation | kWh/y | | 128,861 |
| Unit cost of electricity | Rs/kWh | | 7.36 |
| Annual monetary saving | Lakh Rs/y | | 9.48 |
| Sizing of servo stabilizer | kVA | | 557 |
| Rating of servo stabilizer | kVA | | 600 |
| Estimated investment | Lakh Rs | | 7.92 |
| Payback period | Months | | 10.03 |
| IRR | % | | 91% |
| Discounted payback period | Months | | 4 |

#### *4.10.4.2 Energy conservation measures (ECM) - ECM #9: Installation of harmonics filter*

### *Technology description*

During the field visit, it was found that harmonics levels are higher than the prescribed limits as per IEEE guidelines.

Some of the effects of harmonics are mentioned hereunder.

- Increased line losses.
- Reduced efficiency and increased losses in rotating machines.

- Overstressing of capacitors.
- Cable insulation failure.
- Increased losses and stress on insulation of transformers.
- Mal operation of relays.
- Errors in metering equipment.
- Telephone interference.

### *Study and investigation*

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 3.7 kW.

**Table 49: Measured harmonics at main incomer**

| Name & Sr. No. | Phase | | Voltage | Amp. | THD V (%) | THD I (%) | Individual Current Harmonics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A3% | A5% | A7% | A9% | A11% |
| **Main Incomer** | R | Average | 431 | 426 | 7.57 | 20.2 | 1.14 | 14.8 | 12.9 | 0.82 | 2.0 |
| | | Minimum | 411 | 259 | 5.20 | 8.6 | 0.10 | 5.4 | 3.70 | 0.10 | 0.10 |
| | | Maximum | 443 | 673 | 10.50 | 40.2 | 2.60 | 27.4 | 29.2 | 1.90 | 3.9 |
| | Y | Average | 429 | 457 | 7.69 | 17.9 | 1.03 | 13.7 | 10.7 | 0.60 | 1.5 |
| | | Minimum | 410 | 301 | 5.40 | 6.9 | 0.10 | 5.3 | 3.10 | 0.10 | 0.10 |
| | | Maximum | 442 | 711 | 10.70 | 35.1 | 2.50 | 23.5 | 26.2 | 1.70 | 3.3 |
| | B | Average | 428 | 439 | 7.84 | 19.0 | 0.79 | 15.2 | 10.6 | 0.43 | 1.85 |
| | | Minimum | 409 | 289 | 5.30 | 7.7 | 0.10 | 5.6 | 2.70 | 0.00 | 0.00 |
| | | Maximum | 441 | 679 | 11.10 | 36.9 | 2.40 | 29.6 | 22.4 | 1.50 | 3.9 |

Voltage and ampere THD profile for main incomer is shown in below figure:

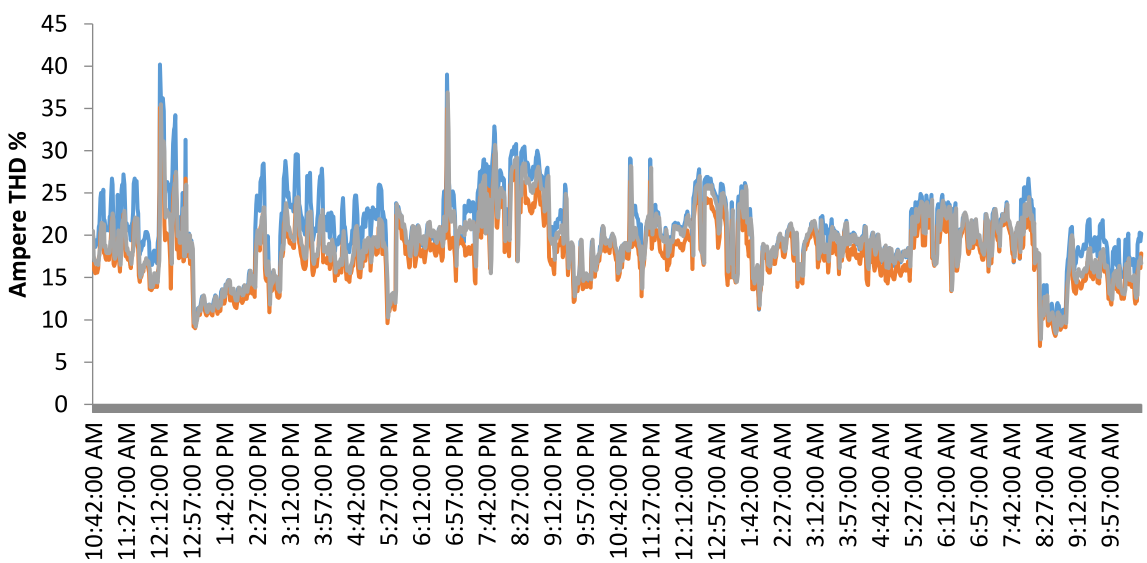


Figure 17: Ampere THD profile

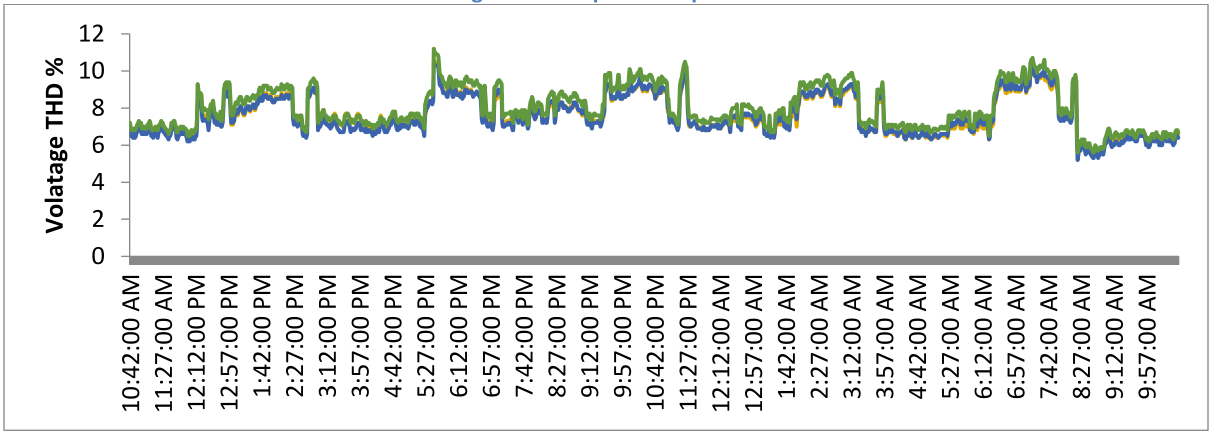



Figure 18: Voltage THD profile

### *Recommended action*

It is recommended to install active harmonics filters (AHF) at main incomer; further study can be conducted to find out exact source of harmonics generation. **Ampere ratings of harmonics filters to be installed are 60A**. Estimation of ratings for AHF is done on the basis of power cycles captured during field visit.

- It is a known fact that if harmonics are present in any system, then power factor improvement capacitors will further amplify the existing harmonics.
- It is strongly recommended to install active harmonic filter at locations where THD is exceeding the prescribed limits.
- The active harmonic filter will take care of harmonics in the system and maintain the desired power factor as per requirement.
- Active harmonic filters can also take care of unbalanced load problems
- It is further recommended that all VFDs, UPS should be procured only with 12-pulse or 18-pulse rectifier circuit.
- All electronic ballasts to be procured in future shall be specified for less than 10% THD (Current).

The cost benefit analysis for this project is given below:

Table 50 : Cost benefit analysis of harmonic filter (ECM - 9)

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Estimated losses due to harmonics | kW | 3.7 | 0 |
| Saving potential by installation of active harmonics filter | kW | | 3.7 |
| Operating hours per day | h/d | | 24 |
| Operating days per year | d/y | | 330 |
| Annual electricity savings | kWh/y | | 29,342 |
| Cost of electricity | Rs/kWh | | 7.36 |
| Annual electricity cost saving | Lakh Rs /y | | 2.16 |
| Estimated rating of active harmonics filter (Ampere) | A | | 60 |

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Estimated investment | Lakh Rs | | 4.75 |
| Payback period | months | | 26.42 |
| IRR | % | | 24 |
| Discounted IRR | Months | | 9.82 |

#### *4.10.4.3 Energy conservation measures (ECM) - ECM #10: Cable loss minimization*

***Technology description***

It was observed that some of the outgoing feeders to sizing and press section has very poor factor.

***Study and investigation***

Electrical parameters were logged in these feeders and it was noted that in sizing section power factor was between 0.59-0.75.

***Recommended action***

It is recommended to install power factor improvement capacitors for sizing whereas for press section automatic power factor controller is recommended.

The cost benefit analysis for this project is given below:

**Table 51 : Cost benefit analysis of cable loss minimization (ECM -10)**

| Particulars | UoM | Sizing Machine-1 (Section 1) | Sizing Machine-2 (Section 2) |
|---|---|---|---|
| Existing power factor | PF | 0.53 | 0.69 |
| Proposed power factor | PF | 0.99 | 0.99 |
| Existing load | kW | 26.3 | 24.8 |
| Cable losses present | W | 254.9 | 138.8 |
| Cable losses proposed | W | 73.9 | 67.7 |
| Capacitor required | kVAr | 21 | 18 |
| Annual energy saving | kWh/y | 1,443 | 563 |
| Total annual energy savings | kWh/y | 1,996 | |
| Unit cost of electricity | Rs./kWh | 7.36 | |
| Savings estimated | Rs Lakh/y | 0.14 | |
| Estimate investment | Rs Lakh | 0.28 | |
| Payback period | Months | 23 | |
| IRR | % | 33 | |
| Discounted payback period | Months | 8.38 | |

## 4.11 Belt Operated Drives

### 4.11.1 Specifications

There are 7 drives operated with V Belt of total capacity of 172 kW. Locations include:

- Kiln (7)

### 4.11.2 Field measurement and analysis

During DEA, power consumption of all v belt driven equipment was measured.

### 4.11.3 Observations and performance assessment

Maximum belts in plant are v belt which are not energy efficient.

### 4.11.4 Energy conservation measures (ECM) - ECM #11: V Belt replacement with REC belt

#### *Technology description*

Replacing V-belts with energy efficient belt REC (raw edged cogged) belt. REC belts transmit more power as compared to V-belts, hence deliver rated RPM and more air supplied.
Benefits of Cogged belts & Pulley over V belts:

- The cogged belts by design, is having 30% power carrying capacity for the same V belt.
- The cogged belts run cooler, 50% more longer hours, and occupy less space in pulley.
- The narrow and cogged belts operate higher speed ratios using smaller diameter pulleys.
- Hence the existing pulley needs to be replaced with 20% lighter weight pulley.

#### *Study and investigation*

The unit is having about 7 belt driven blowers in plant

#### *Recommended action*

It is recommended to replace the above conventional belt with REC belt for energy savings. Cost benefit is given below:

**Table 52: Replacement of conventional belt with REC belt [ECM-11]**

| Particulars | UoM | AS IS | TO BE |
|---|---|---|---|
| Number of belt driven blower | # | 7 | 7 |
| Measured power of all belt driven blowers | kW | 17.25 | 16.63[1] |
| Running hours of blowers | h/d | 24 | 24 |
| Annual operating days | d/y | 330 | 330 |
| Annual power consumption | kWh/y | 136,591 | 131,673 |
| Annual energy saving | kWh/y | | 4,917 |
| Electricity cost | Rs./kWh | 7.36 | |
| Annual energy cost saving | Rs. Lakh | 0.36 | |
| Estimated investment | Rs. Lakh | 0.92 | |
| Payback Period | Months | 31 | |
| IRR | % | 18% | |
| Discounted pay back period | Months | 12 | |

[1] 3.6% energy saving is claimed as per latest suppliers

# 5 CHAPTER -5 ENERGY CONSUMPTION MONITORING

## 5.1 Energy Consumption Monitoring

In order to monitor the overall energy performance, the installation of a basic energy monitoring system has been proposed for the unit.

### 5.1.1 Energy conservation measures (ECM) - ECM#12: Energy management system

***Technology description***

Installation of energy management system on a unit will monitor the energy consumed by various machines. From this, the energy consumption benchmark can be set with respect to production for the machines. If an increase in energy consumption is noticed for any machine, then the reasons for the increased consumption can be diagnosed and proper remedial actions can be taken.

***Study and investigation***

It was observed during the audit that online data measurement is not being done on various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed in kilns like on-line flow-meters.

***Recommended action***

It is recommended to install online electrical energy monitoring systems (smart energy meters) on the main incomer and on the various electricity distribution panels. This measure will help in reduction in energy consumption by approximately 2% from its present levels. The cost benefit analysis for this project is given below:

**Table 53: Cost benefit analysis for energy management system (ECM-12)**

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Energy monitoring saving for electrical system | % | 2.00 | |
| Energy consumption of major machines per year | kWh/y | 2,586,376 | 2,534,648 |
| Annual electricity saving per year | kWh/y | | 51,728 |
| Cost of electricity | Rs/kWh | | 7.36 |
| Annual monetary savings | Lakh Rs/y | | 3.81 |
| Number of equipments/system | # | 30 | 30 |
| No. of energy meters | # | 0 | 30 |
| Estimated investment | Lakh Rs | | 2.98 |
| Thermal energy monitoring system | % | 2.00 | |
| Current coal consumption in HAG | kg/y | 8,250,000 | 8,085,000 |
| Annual coal saving per year | kg/y | | 165,000 |
| Cost of coal | Rs/kg | | 6.00 |
| Annual NG consumption in kiln | scm/y | | |
| Annual fuel saving | scm/y | | |
| Average NG cost | Rs/scm | | |

| Parameters | UoM | Present | Proposed |
|---|---|---|---|
| Total annual monetary savings | Lakh Rs/y | | 9.90 |
| Number of equipments/system | # | 2 | 2 |
| Number of coal weighing machines | | | 2 |
| Number of NG meters | | | 0 |
| Estimated investment | Lakh Rs | | 2.64 |
| Annual monetary savings (Electrical + Thermal) | Lakh Rs/y | | 13.71 |
| Estimated (Electrical + Thermal) | Lakh Rs | | 5.62 |
| Payback period | Months | | 5 |
| IRR | % | | 183 |
| Discounted payback period | Months | | 2 |

## 5.2 Best Operating Practices

Unique operating practices which were observed in the unit include the following:

**Table 54: Unique Operating practices**

| Sl. No. | Equipment/System | Unique operating practices |
|---|---|---|
| 1 | Transformer | APFC installed to maintain power factor |
| 2 | Clay ball mill | VFD for energy saving. Timer control system. |
| 3 | Spray dryer and HAG | Cyclone separator and Wet scrubber for reducing pollution |
| 3 | Hydraulic press | None |
| 5 | HT Dryer | Waste heat from kiln is used in VD with supplementary firing but horizontal dryer is still running on fresh air with coal gas |
| 6 | Glaze ball mill | Timer control in each ball mill. |
| 7 | Kiln | VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone. |
| 8 | Sizing | Fully automatic system. Dust collected system installed. |
| 9 | Printing | Automated digital printing with fully auto control system |
| 10 | Lighting | LED lights |

## 5.3 New/Emerging Technologies

Evaluation of the techno-economic viability of the following emerging and new technology options, are suggested here:

### 5.3.1 Dry Clay Grinding Technology: “Magical Grinding System “Technology description

“Magical Grinding System”, a technology offered by Boffin - China, is a high-efficiency energy-saving ceramic raw material grinding process, which overcomes the drawbacks of traditional milling process in ceramic production, viz. high energy consumption and high cost of mill materials and consumables[2]. The main technical specifications are as follows:

**Table 55 : Specifications of dry clay grinding technology**

| Parameter | UOM | Scenario-1 | Scenario-2 | Scenario-3 |
|---|---|---|---|---|
| Moisture content of | % | 5-7% | 7-8% | 8-10% |

[2] The information in this section has been obtained from : http://www.guangdong-boffin.com/en/

| | | | | |
|---|---|---|---|---|
| input material | | | | |
| Production output | t/h | ≥60 | ≤50 | ≤15 |
| Power consumption | kWh/t | ≤7.5 | ≤8.5 | ≤11 |
| Remarks | | Low dust emission, steady output | | When the moisture is higher than 8%, the output drops. The cost increases accordingly. |

When water content of input materials ≤8% and size of materials <60mm, the overall equipment has a capacity up to 50 t/h, and unit energy consumption is lower than 8.5 kWh/t. Savings include reduction in power consumption by over 25% and reduction in consumables by over 25%.

The working principle is as follows:

- Grinding equipment are used to crush large pieces of different sizes into even, small-size materials (≤10-mesh sieve) – equivalent to rough grinding stage in ball mill. As against the conventional method of grinding by impact, in the dry grinding process, the size reduction is achieved by “squeezing method”, where in the squeezing of the two working faces – grinding roller and grinding plate results in the force being fully applied on the materials with lower energy loss (and hence lower power consumption).
- Further, the grinding process optimizes the ball media grading of the ball mill, so as to increase contact of ball media and materials and increase grinding efficiency. Since this process features very small grain sizes of materials, it can directly enter fine grinding stage, without the need of rough grinding of large-size ball media.

Case Study New Pearl Ceramics and Beisite Ceramics Co., Ltd[3]:

After the implementation of dry grinding, the benefits accrued are:

a) Reduction in thermal energy consumption -70%
b) Reduction in water consumption- 75.4%
c) Reduction in power consumption -1%
d) Reduction in use of chemical additives – 100%
e) Overall reduction in manufacturing costs – 44%
f) Reduction in abrasion
g) Reduction in ball milling time
h) Reduction in floor area required

[3] Case Study presented by Mr. Chaitanya Patel – Regional Manager-Guangdong Boffin at the Knowledge Dissemination Workshop for WT & FT units on 8th Feb- 19, under this project

### 5.3.2 Waste Heat Recovery from Kiln: SACMI Double heat recovery technology description

Heat recovery from roller kiln is most important feature to operate the kiln at optimum efficiency and reduce fuel consumption. The working principle of the heat recovery system with double heat recovery is as follows:

Cooling air may have temperature ranging from 120°C to 250 °C (depending on whether cooling is with a single chimney or with double cooling circuit). Air is drawn from the fan and sent to a filter before being made available to the combustion air fan passing through heat recovery system to raise the combustion air temperature up to 250°C. Final cooling air is also retrieved for use as combustion air, where the air is filtered and sent to combustion air fan before being heated via a heat exchanger in the fast cooling zone reaching temperature up to 250 °C depending upon the product and kiln temperature.

**Figure 19 : Heat recovery system for combustion air**

The estimated benefits of double heat recovery include[4]:

- Fuel savings upto 10%
- Combustion air temperature up to 250 °C at burner
- Easy installation

A working installation of double heat recovery system is available at a vitrified tile unit in Morbi cluster.

### 5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

The roller kiln is major energy consuming system in ceramic tile unit. Over a period of time, the losses from kiln increases for various reasons like operating practices, insulation deterioration, poor

[4] SACMI Kiln Revamping catalogue for roller kilns

maintenance, high breakdown level etc. It is beneficial to upgrade the kiln performance by total kiln revamping including following systems[5]:

1. **Upgrading burners** with better technology and higher combustion efficiency with several benefits like:
    a. Broad working range
    b. Most stable flame detection
    c. Better flame speed
    d. Compatibility with burner block types
    e. Easy head cleaning procedure
2. **Heat recovery systems** – Sin**gle and double heat r**ecovery for combustion air.
3. **NG fuel Consumption monitoring kit** : Real time monitoring of gas consumption on operator panel and on kiln.
    a. Retrofittable and can be installed on dryers and kilns
    b. Real-time gas consumption monitoring on operator panel
    c. Instantaneous pressure and temperature readings
    d. Easy calibration

**Figure 20: NG consumption monitoring kit**

4. **Combustion air control:** The combustion system is divided in to 3 macro zones, each of which supplies a specific kiln zone namely: Pre-heating, Pre-firing and Firing zone. The operator panel can be used to adjust the air flow to burners in specific zones according to raw material recipe used in body clay, product and kiln conditions. Maximum efficiency is obtained by combining this modification with Oxygen Analyzer to optimize the amount of combustion air under all conditions and consequently, optimize product quality and fuel consumption both.

[5] SACMI Kiln Revamping catalogue for roller kilns

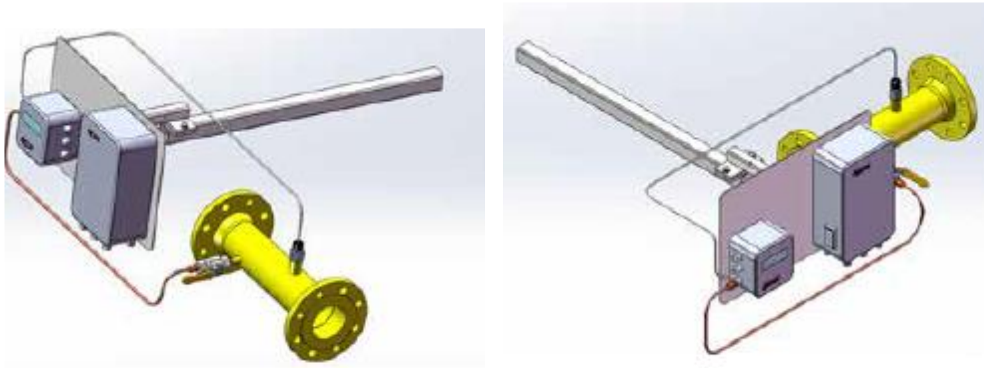


**Figure 21: Combustion air control for burner**

The combustion air circuit is modified to create three fuel feed macro-zones. Each macro-zone is, in turn, sub-divided into an upper branch and a lower one and each branch has a motorized valve connected to a pressure transducer. The system is completed by installation of an inverter on the fan and a pressure transducer on the main duct to keep circuit pressure stable under all operating conditions. The system is managed via a control panel, ensuring repeatability of settings and letting the user differentiate opening in the different zones according to production requirements. In the event of a gap in production valve aperture can be adjusted to a pre-defined setting. The advantages include:

- Flexibility – Air volume can be set according to the product
- Fuel consumption optimisation
- Reduced consumption if there is gap in production
- 3 independent macro zones can be controlled separately

5. **Heat recovery from Kiln to Dryer:** The air is drawn from the final cooling chimney by a fan and sent via an insulated duct to the dryers. The booster fan is equipped with an inverter getting feedback from the pressure transducer mounted on the duct downstream from the fan helps to control the air transfer flow. The control panel is independent and can be installed /retrofitted on any machine. System parameters are constantly monitored by software to maximize the saving without changing the production cycle. The advantages of the system include:
    - Immediate savings
    - Control system to optimize the economic advantages
    - Complete integration with existing plant
    - Suitable for all kilns and dryers – horizontal and vertical
    - Quick return on investment

Figure 22: Heat recovery from kiln to dryer

6. **Fast Cooling Management:** This retrofit intervention involves modification of the fast cooling duct by separating the upper and lower circuit with motorized control valve which can be controlled from operator panel. Further modification to the duct can allow the creation of two separate fast cooling zones. Each zone has a general motorized valve which is controlled by a thermocouple; it also has a motorized valve with position control for both upper and lower channel separately. To complete the system, an inverter is fitted on fan drive motor and a pressure transducer is fitted on the main duct. All regulators and valves are controlled via operator panel. The advantages of the system include:
    - Complete control
    - Parameters can be changed / set as per RM recipe
    - Volume control in case of gap in production
    - Flow control via fan inverter
    - Adjustment flexibility in upper and lower roller bed

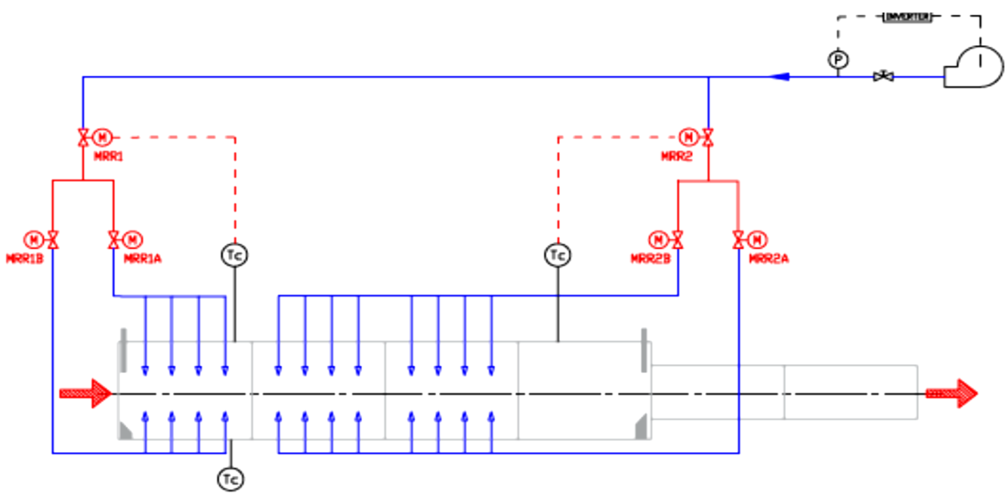



Figure 23: Fast cooling air management

7. **Industry 4.0 system for easiness in operation and real-time information:** Industry 4.0 system provides opportunity to make full use of data control and management system. These systems are modern, compatible with the most widely used data platforms and ensure machines can be used flexibly with excellent usability of collected data. The technical features of such a system includes:
    - Network connected PLC system for automation and operator/machine safety
    - Simple user-friendly man-machine interface that can be used by operators in any situation
    - Continuous monitoring of process parameters and working conditions using suitable sensors
    - Adaptive - behavior system control in the event of any process drift
    - Remote tele-assistance service allows modification of process parameters and updating the software
    - PC/SCADA system allows monitoring, control and supervision of the machine using connection network
    - Complete consumption and production database available to corporate network and to management software using internet or database SQL protocols.

Figure 24: Real time information system 4.0

The advantages of the system are:

- Production and consumption data can be shared with company management system
- Coordinated automation to plan production
- Remote/Tele-assistance system
- Productivity and plant problem analysis

### 5.3.4 High Alumina Pebbles for Ball Mills:

Ball mills performance is greatly affected by quantity and quality of grinding balls / Pebbles used. There are different qualities of pebbles used in Morbi cluster:

a. Local pebbles from river
b. Imported pebbles from China
c. High Alumina Pebbles from EU

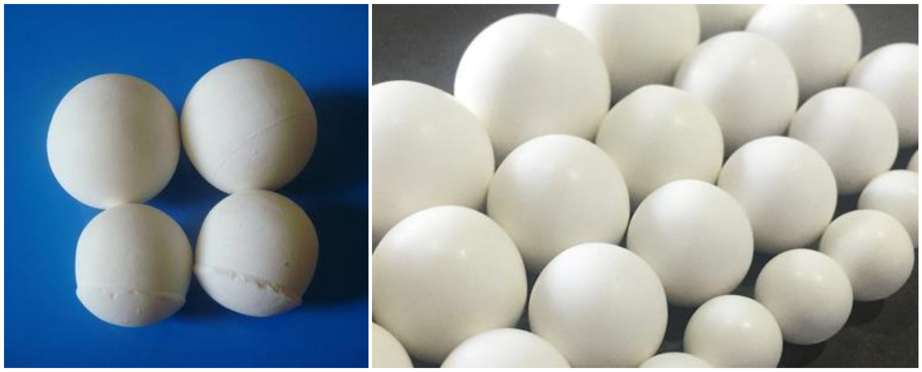


Figure 25: - High Alumina pebbles for Ball mill

The cost and quality of each pebble is different and has major impact on energy consumption of ball mill as described below:

a. Local pebbles: The local river pebbles are used mainly for economic reasons as they are cheap but its sizes vary irregularly and wears out very fast resulting in longer grinding time which increases the energy consumption.
b. Imported Pebbles: Chinese pebbles are available in different quality and variable working life span. These quality is also widely used by ceramic units which gives better performance as compared to local pebbles.
c. High Alumina Pebbles: The third quality is High alumina pebbles from Spain/ EU origin which are having very high Alumina percentage ranging from 80-92 % which gives very long life. As per one feedback from unit during audit, it was learnt from production team that local pebbles are worn out in 8-10 grinding batches where as high alumina pebbles last 8-10 times longer (90-100 batches) which reduces energy consumption and running time of ball mill. The fineness and residue percentage of RM used are also affected with local /poor quality pebbles which is not the case in high alumina pebbles. The cost is relatively high which restricts the use of high alumina pebbles, but if the running cost, productivity and energy consumption is taken in to account, the high alumina pebbles are proven better.
d. Replacement of pebbles is a coniferous process as this is consumable. Only a few units in Morbi cluster are already following this practice, there is a scope for wider adaption of the recommended practice.

#### 5.3.5 Use of Organic deflocculant in Ball Mill grinding process of Ceramic tiles:

In the tile manufacturing process different raw materials which include one or more clays are mixed in specific Ratio (Clay Body). Clay body is subjected to wet grinding in a ball mill to get required density and viscosity. For efficient grinding, inorganic dispersants like STPP, SHMP or sodium silicate are used. These can be replaced either partially or fully by organic deflocculant (Brand name FLOSPERSE[6]) to save fuel cost during spray drying. Slip is stored in tanks which will be sieved for sending to spray drying.

[6] Product brochure of M/s SNF (India) Pvt. Ltd. Vizag

Purpose of using deflocculants is to avoid increase in the viscosity of the slurry due to thixotropy. Lower viscosity during wet-grinding makes the grinding operation faster, thus reducing power consumption. Lower viscosity also prevents choking of pipelines & spray drier nozzles, thus ensuring proper granulometry of spray dried dust/clay, which is essential for achieving green tile strength. Deflocculants allows for achieving higher slurry density (more solids loading per litre of slurry) without increasing viscosity. For spray drying operation, achieving higher slurry density is important since more solids in slurry, less water to be evaporated in spray drier and less fuel consumption , making the operation viable commercially.

In water, the deflocculant ionizes to cation and anion. The anion absorbs on the particle imparting it a negative surface charge. Thus the electric double layer on the particle surface is expanded (as opposed to coagulation, where the double layer is compressed) leading to increased repulsion and lower viscosity.

Estimated savings from use of deflocculants for **Partial Replacement of STPP/Sodium Silicate include**

- STPP dosage is reduced by more than 50%
- For the same treatment cost as STPP alone, by using FLOSPERSE in combination, a higher density slip can be achieved at the same viscosity thus saving much more in terms of fuel cost in spray dryer

Since this is a new product, a small scale pilot is recommended to ascertain the cost and benefits.

### 5.3.6 Use of Organic Binder in Porcelain/Granite Tiles Manufacture:

In ceramic bodies where highly plastic clays are used, sufficient green and dry strength is achieved due to the inherent binding ability of the clays hence the use of external binders is not necessary. However, in the manufacturing process of vitrified/granite tiles, almost 75 % of raw materials are non-plastic in nature which contribute very less to green and dry strength. Special white firing clays which are not highly plastic are used in small quantity and do not impart sufficient strength. Organic binders like FLOBIND[7] can be used very effectively to increase the green and dry strength as well as edge strength of the tiles. The working principle of the binder is as follows:

- During wet grinding, the binder gets uniformly mixed through the body and inter-particulate bonds are formed which remain intact even after physically combined water is removed during the drying stage. Thus, green and dry strength is imparted.
- Conversely, during each process stage, if water is absorbed, there is loss of strength. Organic binders ensures that sufficient strength is maintained to withstand all the process stages thus reducing rejections due to cracks, damaged edges and breakages.

Advantages of using Binder for Vitrified tiles include:

- Lower dosage or effective binder cost.

[7] Source: Product brochure of M/s SNF (India( Pvt. Ltd., Vizag, India

- The product is non-fouling which is not susceptible to bacteriological contamination during slip storage, hence no need to use biocides.
- Minimum or no adverse effect on the rheological properties of slip (The rheological behavior of non-Newtonian fluids such as cement paste, mortar, or concrete is often characterized by two parameters, yield stress, $\tau 0$, and plastic viscosity, $\mu$, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.
- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost

Since this is a new product, a small scale pilot is recommended to ascertain the cost and benefits.

### 5.3.7 Use of Direct blower fans instead of belt drive:

There are a numbers of fans used in tile manufacturing, most of which are using belt drive system. The major application of blower fans in kiln is for combustion heating, cooling, recovery of hot air, exhaust / flue air etc. There are also other applications viz. FD and ID fans on Hot Air Generators. In most of these applications, the air temperature is high and overall system is working in handling high temperature air with whole mechanical structure including fan and shaft are at higher temperature compared to atmospheric air temperature. The fans are working with heavy inertia load of fan impeller and air flow which continuously create stress on V-belts resulting in belt elongation and slippage. In order to avoid energy loss in belt drive slippage, direct mounted fans on motor shaft eliminates the slippage issue and depending upon size and application, @ 3-5 % of energy loss can be reduced using direct motor mounted fans along with Inverter drive for speed control.

A few units in Morbi cluster are using direct drive fans.

**Figure 26: Direct drive blower fan**

# 6 CHAPTER - 6 RENEWABLE ENERGY APPLICATIONS

The roof top PV potential is estimated as 418 kW. Cost benefit analysis is given below:

## 6.1 Energy conservation measures (ECM) - ECM#13: Installation of Solar PV system

### *Technology description*

Solar Photovoltaic system is one of the renewable energy sources which use PV modules to convert sunlight into electricity. The electricity generated can be stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy sources.

### *Study and investigation*

It was observed during energy audit that 2,610 $m^2$ of area is available on the roof top for installation of solar PV panels.

### *Recommended action*

The average electricity generation is estimated at 640,181 kWh/y using 418 kW panels. The cost benefit analysis is given below:

**Table 56: Solar PV installation**

| Parameters | UOM | Present | Proposed |
|---|---|---|---|
| Available area on roof | $m^2$ | 4,350 | 4,350 |
| Estimated total solar PV panel area | $m^2$ | 2,610 | 2,610 |
| Number of panels (1m x 2m) of 320 Wp | # | | 1,305 |
| Estimated installed capacity of solar panel | kW | | 418 |
| Electricity generation per kW of panel | kWh/d | | 4.2 |
| Energy generation from solar panel | kWh/d | | 1,754 |
| Solar radiation days per year | d/y | | 365 |
| Average electricity generation per year | kWh/y | | 640,181 |
| Cost of Electricity | Rs/kWh | | 6.87 |
| Annual monetary savings | Lakh Rs/y | | 7 |
| Estimated Investment | Lakh Rs | | 47 |
| Payback Period | Months | | 230 |
| IRR | % | | -4% |
| Discounted payback period | Months | | 20.04 |

There is a generation of 2.5 $W_p$ of electricity per kW of installed panel instead of 4.2 $W_p$ due to orientation of the building. The project IRR is negative and hence the project is not considered feasible. The reasons are as follows:

a) Increase in capital expenditure on account of
   a. Requirement for strengthening the structure for accommodating the solar panels.
   b. Requirement for construction of walkways for cleaning of solar panels.
b) Degradation of generation considered on account of heavy dust accumulation on the panels.
c) Increase in operating costs on account of cleaning frequency and use of DM water for cleaning.

# 7 ANNEXES

## ANNEX-1: PROCESS FLOW DIAGRAM

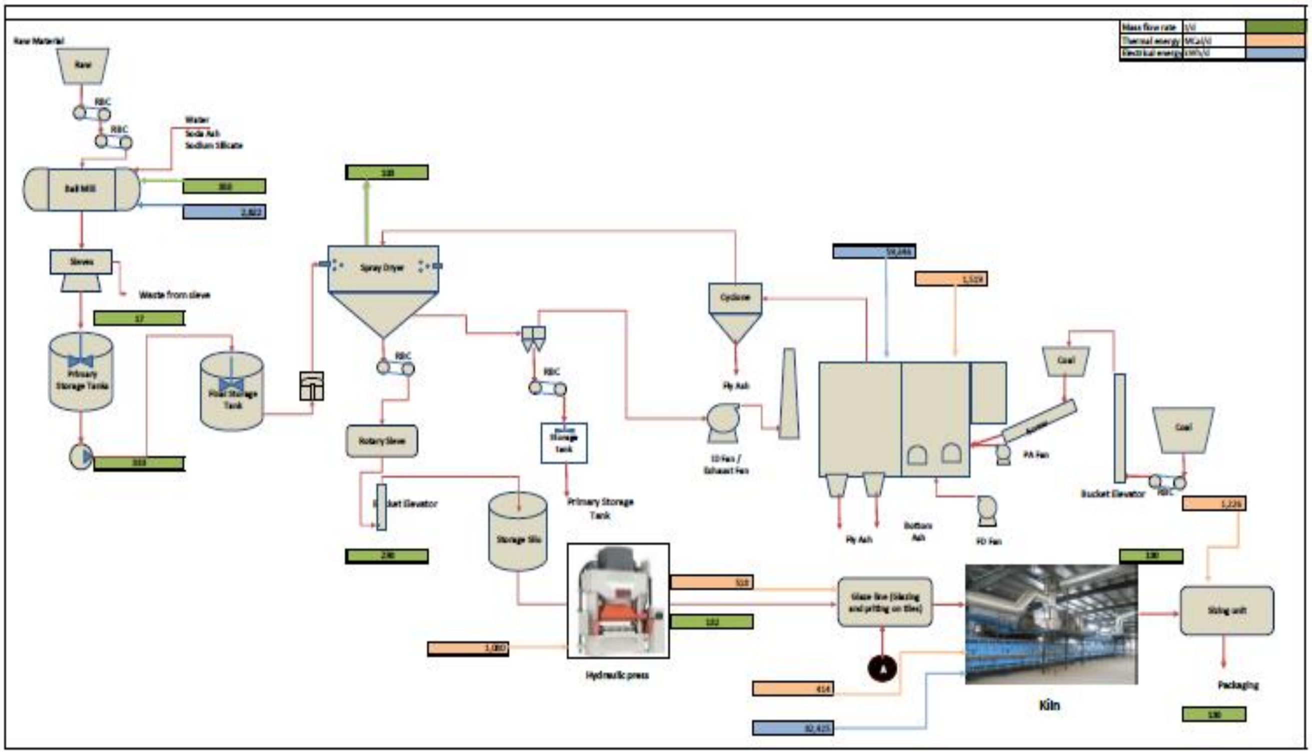



**Figure 27: Process Flow Diagram of Plant**

## ANNEX-2: DETAILED INVENTORY

| Equipment | Connected load | Rating (kW) |
|---|---|---|
| Clay ball Mill | Clay ball mill 1 | 215 |
| Agitator tank | Stirrer-1 | 1.5 |
| | Stirrer-2 | 1.5 |
| | Stirrer-3 | 1.5 |
| | Stirrer-4 | 1.5 |
| | Stirrer-5 | 1.5 |
| | Stirrer-6 | 1.5 |
| | Stirrer-7 | 1.5 |
| | Stirrer-8 | 1.5 |
| | Stirrer-9 | 1.5 |
| Spray dryer | Hydraulic pump-1 | 18.5 |
| | Hydraulic pump-1 (S/B) | 18.5 |
| | ID fan | 75 |
| | FD fan | 22 |
| | Cyclone | 0.7 |
| | Conveyer | 9.7 |
| Hot Air Generator | PA Fan | 5.5 |
| | FD Fan | 22 |
| | Varam | 3.7 |
| | Coal conveyer | 3.7 |
| | Coal elevator | 3.7 |
| Hydraulic press | Press-1 | 55 |
| | Press-2 | 55 |
| Cooling tower | Pump | 8 |
| Coal gasifier | ID fan | 18.5 |
| | CT pumps | 24 |
| HZ dryer connected with kiln | Smoke blower | 12 |
| | Hot air blower | 15 |
| | Conveyer | 32 |
| Printing | Printing | 2.2 |
| Kiln | Kiln | 171.5 |
| Sizing line | sizing machine 1 | 81 |
| | sizing machine 2 | 81 |
| | sizing line 1 | 3.7 |
| Glaze line | Stirrer | 2.98 |
| | Vibrator | 3.72 |
| Glaze ball mill | Glaze ball mill 1 (1 ton) | 15 |
| | Glaze ball mill 2 (1 ton) | 15 |
| | Glaze ball mill 3 (1 ton) | 15 |
| | Glaze ball mill 4 (1.5 ton) | 15 |
| | Glaze ball mill 5 (1.5 ton) | 15 |
| Lighting | | 41.174 |

## Annex-3: Single Line Diagram

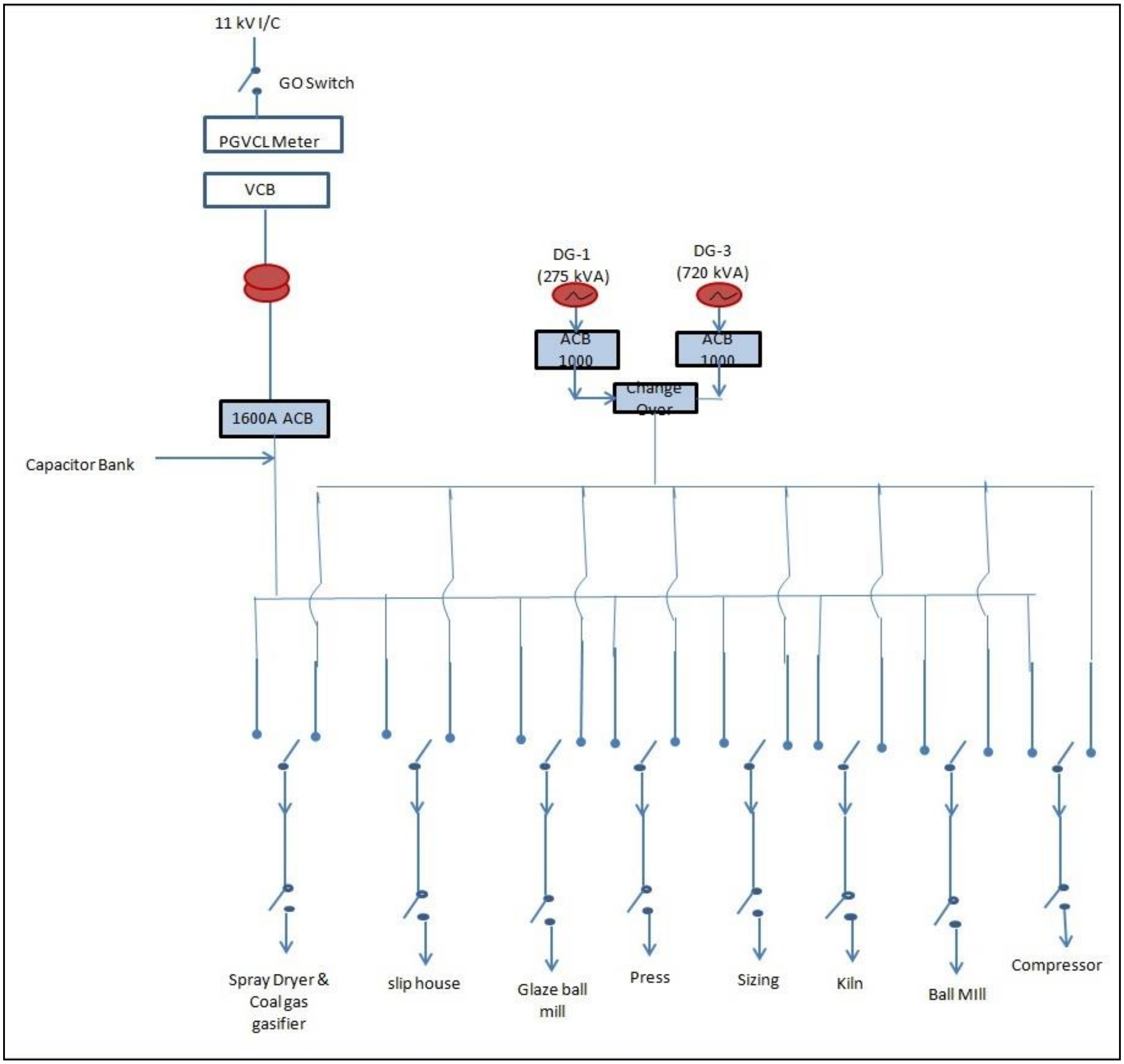
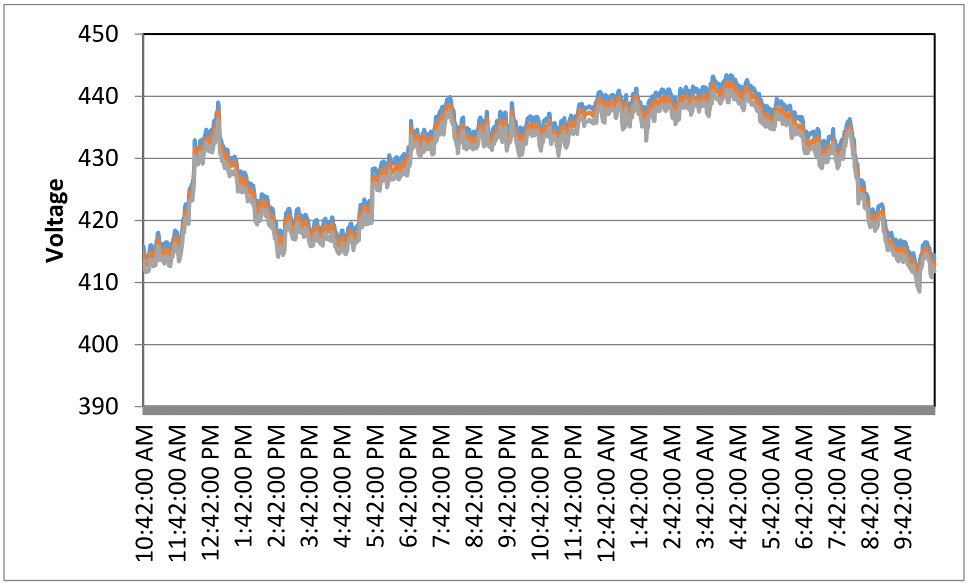



**Figure 28: Single Line Diagram (SLD)**

## ANNEX-4: ELECTRICAL MEASUREMENTS



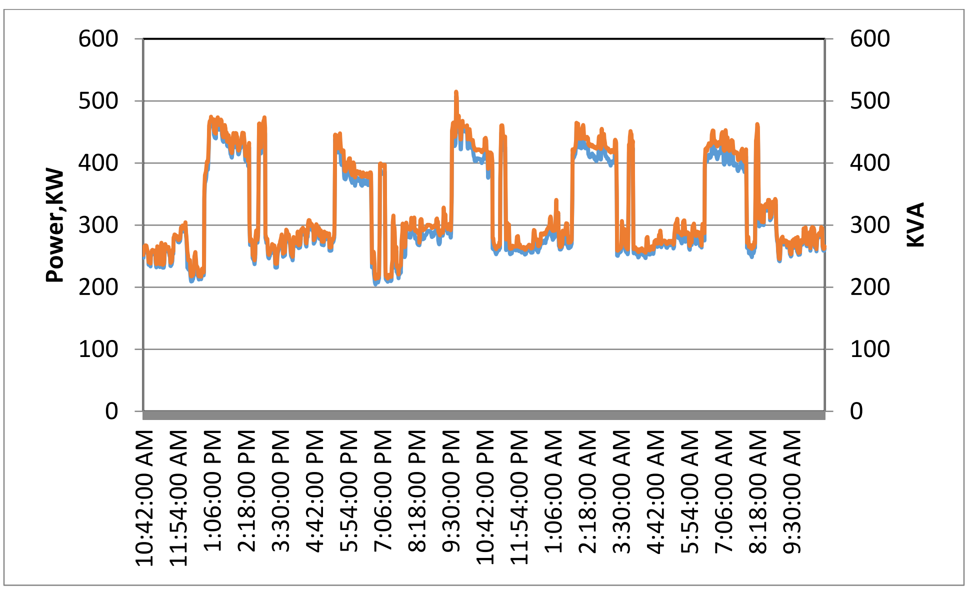




**Figure 29: Power and voltage profile of Main Incomer**

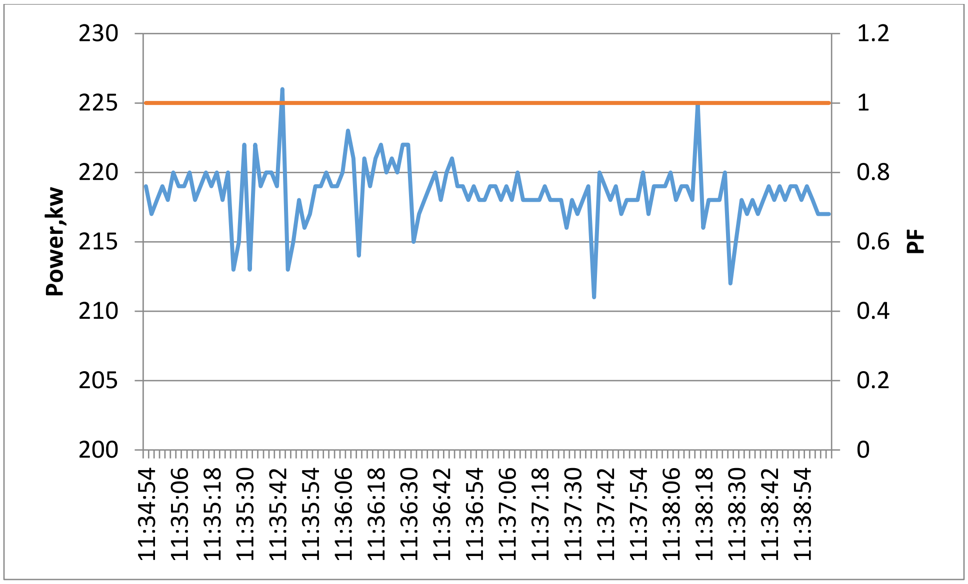



Figure 30: Power and PF profile of Clay ball Mill

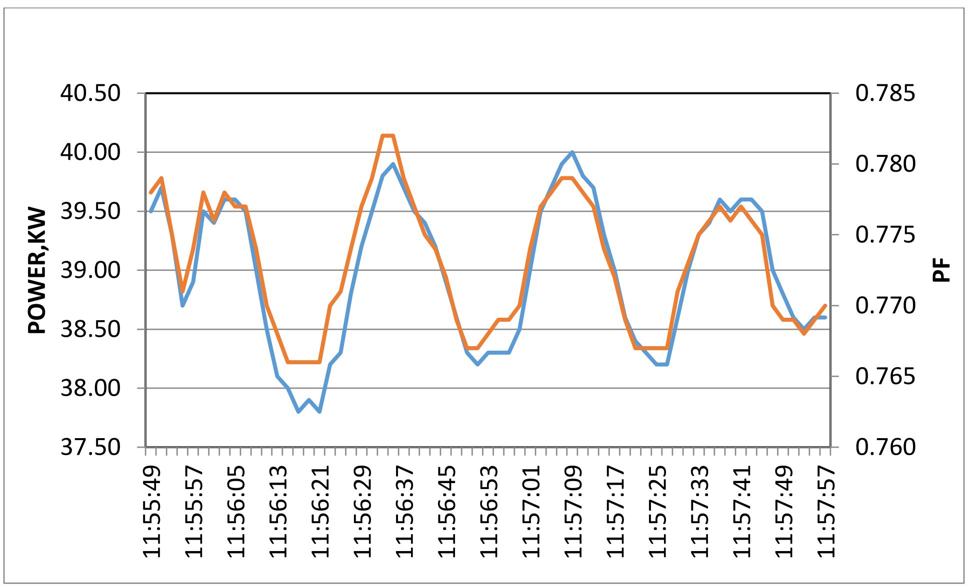



Figure 31 : Power and PF profile of spray dryer - ID fan

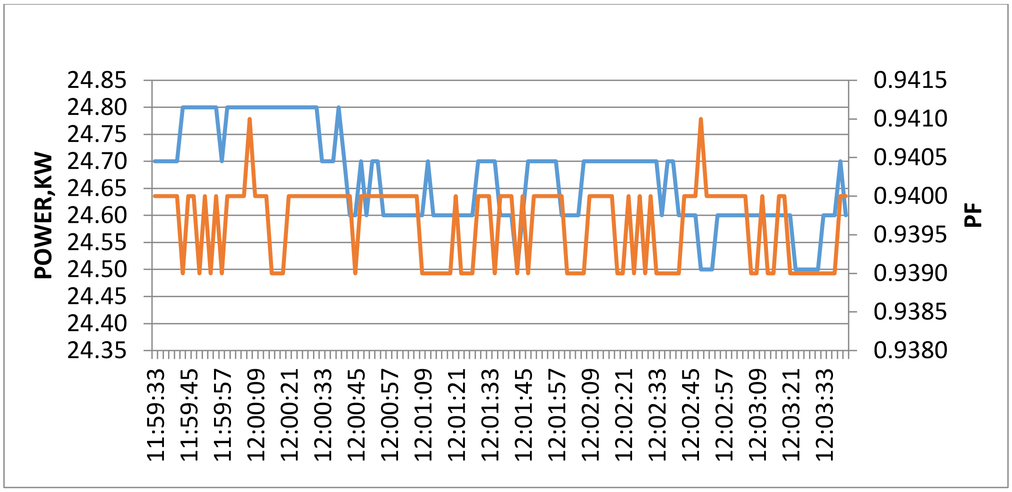
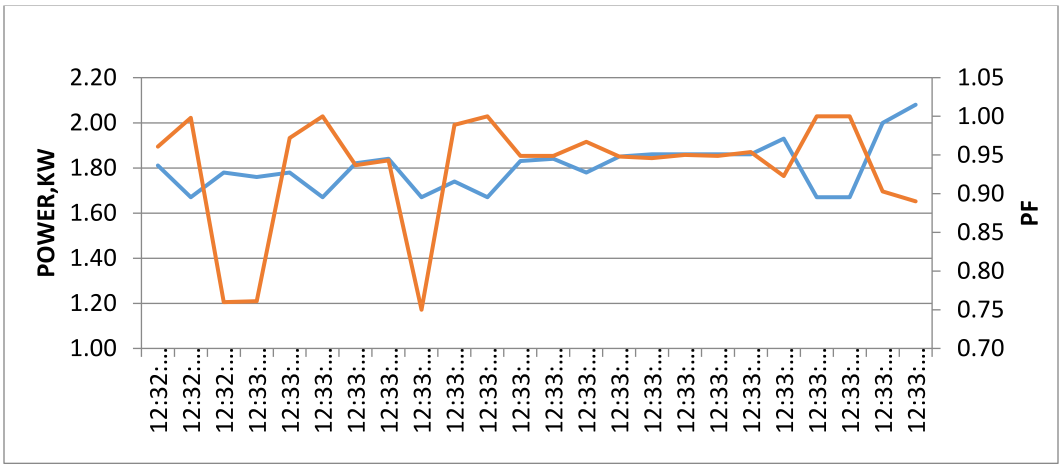



Figure 32 : Power and PF profile of spray dryer - FD fan



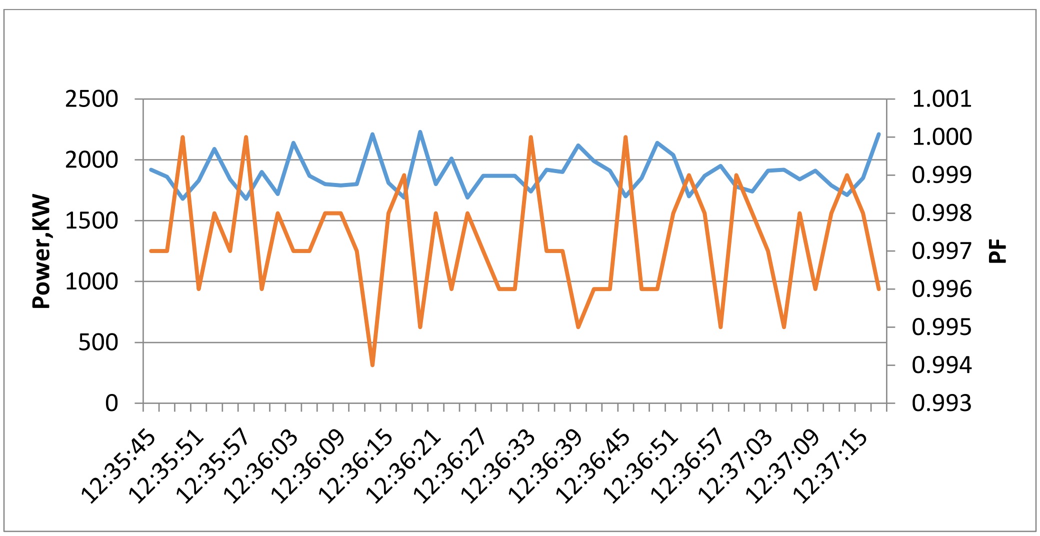




Figure 33: Power and PF profile of all blowers of Kiln

## ANNEX-5: THERMAL MEASUREMENTS

### *1. Kiln heat utilization calculations*

**Input parameters**

| Input data sheet | | |
|---|---|---|
| Type of fuel | Coal Gas | |
| Source of fuel | Coal Gasifier | |
| Particulars | **Value** | **UoM** |
| Kiln operating temperature (Heating zone) | 1003.2 | *Deg C* |
| Initial temperature of kiln tiles | 40.2 | *Deg C* |
| Avg. fuel consumption | 2,314 | *kg/h* |
| Density of coal gas | 0.58 | *kg/sm3* |
| Avg. fuel consumption | 3,989 | *sm3/h* |
| **Flue gas details** | | |
| Flue gas temp at smog blower | 130 | *deg C* |
| Preheated air temp./Ambient | 40 | *deg C* |
| O2 in flue gas | 7.53 | *%* |
| CO2 in flue gas | 7.535 | *%* |
| CO in flue gas | 89.7 | *ppm* |
| **Atmospheric air** | | |
| Ambient temp. | 40.2 | *Deg C* |
| Relative humidity | 45 | *%* |
| Humidity in ambient air | 0.03 | *kg/kgdry air* |
| **Fuel analysis** | | |
| C | *24.35* | % |
| H | *12.17* | % |
| N | *46.09* | % |
| O | *0.00* | % |
| S | *15.22* | % |
| Moisture | *2.17* | % |
| Ash | *0.00* | % |
| GCV of fuel | 1231 | *kcal/scm* |
| **Ash analysis** | | |
| Un-burnt in bottom ash | *0.00* | % |
| Un-burnt in fly ash | *0.00* | % |
| GCV of bottom ash | *0* | kcal/kg |
| GCV of fly ash | *0* | kcal/kg |
| **Material and flue gas data** | | |
| Weight of Kiln car material | 0 | *kg/h* |
| Weight of ceramic material being heated in Kiln | 5,438 | *kg/h* |
| Weight of stock | 5,438 | *kg/h* |
| Specific heat of clay material | 0.22 | *kcal/kg-oC* |
| Avg. specific heat of fuel | 0.51 | *kcal/kg-oC* |
| Fuel temp | 40.2 | *deg C* |
| Specific heat of flue gas | 0.24 | *kcal/kg-oC* |
| Specific heat of superheated vapour | 0.45 | *kcal/kg-oC* |
| **Heat loss from surfaces of various zone** | | |

| Input data sheet | | |
|---|---|---|
| Radiation and convection from preheating zone surface | 3,681 | *kcal/h* |
| Radiation and convection from heating zone surface | 6,883 | *kcal/h* |
| Heat loss from all zones | **10,564** | *kcal/h* |
| **For radiation loss in kiln** | | |
| Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln | 0.82 | *h* |
| Area of entry opening | 1.2 | *m2* |
| Coefficient based on profile of kiln opening | 0.7 | |
| Average operating temp. of kiln | 343 | *deg K* |

**Efficiency calculations**

| Calculations | Kiln | UoM |
|---|---|---|
| Theoretical air required | 7.72 | *kg/kg of fuel* |
| Excess air supplied | 55.84 | *%* |
| Actual mass of supplied air | 12.04 | *kg/kg of fuel* |
| Mass of dry flue gas | 11.92 | *kg/kg of fuel* |
| Amount of wet flue gas | 13.04 | *Kg of flue gas/kg of fuel* |
| Amount of water vapour in flue gas | 1.12 | *Kg of H2O/kg of fuel* |
| Amount of dry flue gas | 11.92 | *kg/kg of fuel* |
| Specific fuel consumption | 425.50 | *kg of fuel/ton of tile* |
| **Heat Input Calculations** | | |
| Combustion heat of fuel | 523,631 | *kcal/ton of tiles* |
| Total heat input | 523,631 | *kcal/ton of tile* |
| **Heat Output Calculation** | | |
| Heat carried away by 1 ton of tile | 211,853 | *kcal/ton of tile* |
| Heat loss in dry flue gas | 109,295 | *kcal/ton of tile* |
| Loss due to H2 in fuel | 21,274 | *kcal/ton of tile* |
| Loss due to moisture in combustion air | 486.36 | *kcal/ton of tile* |
| Loss due to partial conversion of C to CO | 696.23 | *kcal/ton of tile* |
| Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln) | 25.97 | *kcal/ton of tile* |
| Loss Due to Evaporation of Moisture Present in Fuel | 5,776 | *kcal/ton of tile* |
| Total heat loss from kiln (surface) body | 1,943 | *kcal/ton of tile* |
| Heat loss due to un-burnt in Fly ash | - | *kcal/ton of tile* |
| Heat loss due to un-burnt in bottom ash | - | *kcal/ton of tile* |
| Heat loss due to kiln car | - | *kcal/ton of tile* |
| Unaccounted heat lossess | 172,282 | *kcal/ton of tile* |
| **Heat Loss from kiln Body and Other Sections** | | |
| Total heat loss from kiln | 1,943 | *Kcal/ton* |
| Kiln efficiency | 40.46 | *%* |

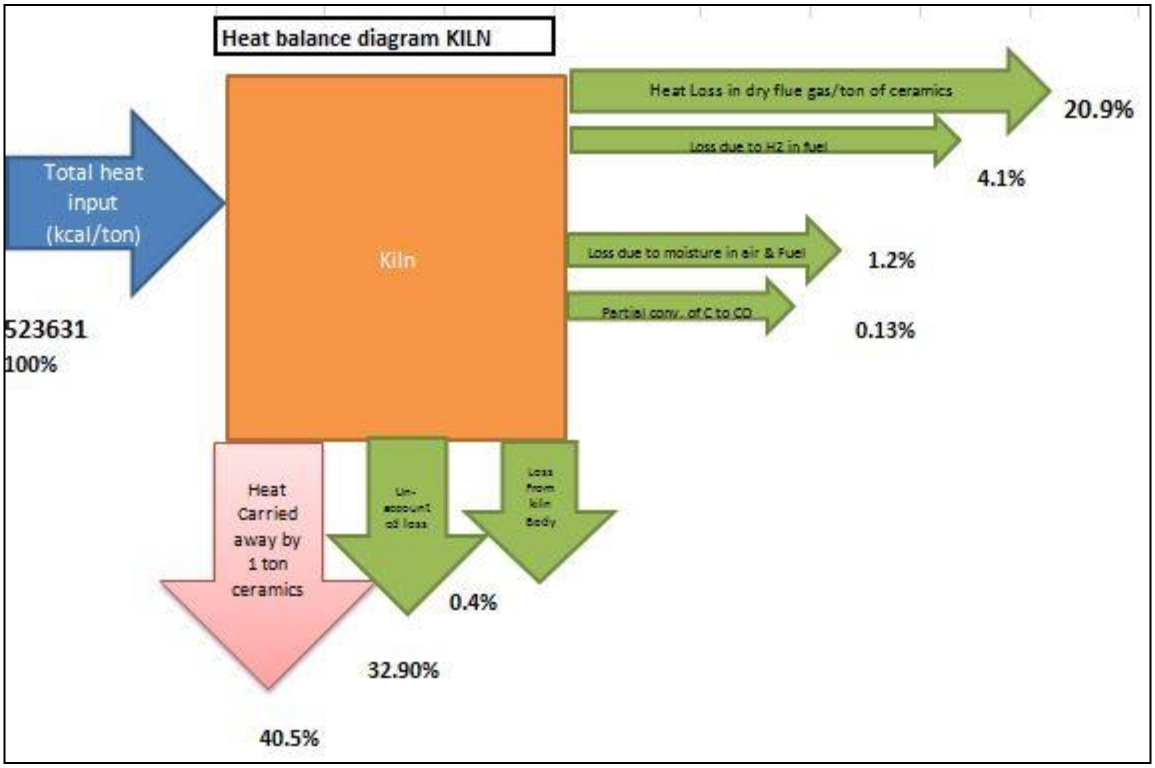



Figure 34: Heat Balance diagram of Kiln

## ANNEX-6: LIST OF VENDORS

**ECM-1: Excess air control in kiln 1**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Nevco Engineers | 90-A (2nd floor), Amrit Puri B, Main Road, East of Kailash, New Delhi – 110065 | Tel : 011 – 26285196/197<br>Fax: 011 – 26285202 | Nevco_delhi@yahoo.co.in |
| 2 | High-tech controls for ABB Oxygen Analysers | A 5, Vrindavan Tenament, Gorwa Behind SBI Bank, Near Sahyog Garden, Vadodara - 390016, Gujarat, India | Mr. Bhavik Parikh<br>M: 8071640984 | NA |
| 3 | Knack well Engineers | C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India | Darshan Thanawala, Ravi Thanawala ( Proprietor ) 8079452278, 9428597582, 9327013773 | www.knackwellengineers.com<br><br>darshan@kanckwell.com, ravi@kanckwell.com |

**ECM 2: Radiation and convection loss in recuperator pipes**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Morgan Advanced Materials - Thermal Ceramics | P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA | T 91 44 2530 6888<br>F 91 44 2534 5985<br>M 919840334836 | munuswamy.kadhirvelu@morganplc.com<br><br>mmtcl.india@morganplc.com |
| 2 | M/s LLOYD Insulations (India) Limited, | 2,Kalka ji Industrial Area, New Delhi-110019 | Phone: +91-11-30882874 / 75<br>Mr. Rajneesh<br>Phone : 0161-2819388<br>Mobile : 9417004025 | **Email: kk.mitra@lloydinsulation.com** |
| **3** | **Shivay Insulation** | **20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009** | **Mobile- 9712030444** | **shivayinsulation@gmail.com** |

**ECM 3: Radiation and convection loss reduction in indirect cooling zone**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| **1** | Morgan Advanced Materials - Thermal | P.O. Box 1570, Dare House Complex, Old No. 234, New | T 91 44 2530 6888 | **munuswamy.kadhirvel** |

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| | Ceramics | No. 2, NSC Bose Rd, Chennai - 600001, INDIA | F 91 44 2534 5985<br>M 919840334836 | **u@morganplc.com**<br>**mmtcl.india@morganplc.com** |
| **2** | M/s LLOYD Insulations (India) Limited, | 2,Kalka ji Industrial Area, New Delhi-110019 | Phone: +91-11-30882874 / 7**5**<br>Mr. Rajneesh<br>Phone : 0161-2819388<br>Mobile : 9417004025 | Email: kk.mitra@lloydinsulation.com |
| 3 | Shivay Insulation | 20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009 | Mobile- 9712030444 | shivayinsulation@gmail.com |

**ECM-4: Optimized Resource Consumption in Clay Section**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Aqualux Water India | A/2, Pawan Apartment, Nr. Ahmedabad Homiopathic Medical College, Bopal - Ghuma Road, Ghuma, Ahmedabad, Gujarat 380058 | Mob: 9924312411 | sales@aqualuxwater.com |
| 2 | Aquatechplus Pvt. Ltd. | Shree Khodiyar Park, behind Ruda Transportnagar,Rajkot-Amdavad Highway, Rajkot-363670 | Mr. Bhavesh Dabhi 9512301122 | www.aquatechro.com<br>bhavesh@aquatechro.com |
| 3 | Raj Water Technology (Gujarat) Pvt Ltd | Plot-27, Survey-47, Jivraj Industrial Area Near Falcon Pump, Gondal Rd, Vavdi, Rajkot, Gujarat 360004 | 70439 55777 | marketing@rajwater.com<br>www.rajwater.com |

**ECM-5: Retrofit of VFD in compressor**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Samhita Technologies Pvt. Ltd | 309, Vardhman Grand Plaza, Distt Center, Mangalam Place, Plot No. 7, Outer ring road, Sec 3, Rohini, Delhi – 110085 | Mob: +91 9711320759<br>Tel: +91 11 45565088 | sales@samhitatech.com |

| | | | | |
|---|---|---|---|---|
| **2** | Amtech Electronics (India) Ltd | E-6 GIDC Electronics Zone, Gandhinagar | Mr. Sachin Patel 079-23289101/102 | mktg2@amtechelectronics.com |
| **3** | Hitachi Hi-Rel Power Electronics Pvt. Ltd | B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044 | Mr. V. Jaikumar 079 2328 7180 - 81 | v_jaikumar@hitachi-hirel. com |

**ECM-6: Replacement of inefficient pump with EE pumps**

| Sl. no. | Name of company | Address | Phone no. | E-mail / Website |
|---|---|---|---|---|
| 1 | Trivium Power Engineers Pvt. Ltd. | F 73, SECTOR 11, ace honda showroom, Noida, Uttar Pradesh, 201301, India | Mob: +91 9999684606<br><br>Fax: 0120 4269637 | |
| 2 | Kirloskar Brothers Ltd | 1st floor, Kalapi Avenue, Opp. Vaccine Institute, Old Padra Road, Vadodara | Mr. Sanjeev Jadhav 0265-2338723/2338735 | aksur@bdq.kbl.co.in |
| 3 | KSB Pumps Ltd | Neel Kamal, Ashram Road, Opposite Sales India, Ashram Road, Ahmedabad, Gujarat 382410 | Mr. Jayesh Shah 098794 83210 | https://www.ksb.com/ksb-in/ksb-in-india/ |

**ECM-7: Replacement of inefficient lighting systems**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Osram Electricals Contact Person: Mr. Vinay Bharti | OSRAM India Private Limited,Signature Towers, 11th Floor,Tower B, South City - 1,122001 Gurgaon, Haryana | Phone: 011-30416390 Mob: 9560215888 | vinay.bharti@osram.com |
| 2 | Philips Electronics Contact Person: Mr. R. Nanda kishore | 1st Floor Watika Atrium, DLF Golf Course Road, Sector 53, Sector 53 Gurgaon, Haryana 122002 | 9810997486, 9818712322(Yogesh-Area Manager), 9810495473(Sandeep-Faridabad) | r.nandakishore@phillips.com<br><br>sandeep.raina@phillips.com |
| **3** | Bajaj Electricals Contact Person: Mr. Kushgra Kishore | Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002 | 9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341 | kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com; sanjay.adlakha@bajajele |

| | | | | |
|---|---|---|---|---|
| | | | (Mr. Rahul Khare), | ctricals.com |

**ECM-8: Main LT Voltage optimization**

| Sl. No. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Dynamic Energy Solutions | Plot Number 6, Nangla Ind. Area, Nangla Gazipur Road, Faridabad- 121004 | 9873565940 | dynamicenergysolutions@gmail.com |
| 2 | Recons Power Equipment Pvt. Ltd | Plot Number 38, Sector-25, Faridabad-121004 | 0129-4062114-116 9811095526 | mail@reconsindia.com |
| **3** | SERVOMAX INDUSTRIES LIMITED | Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033 | +91 9111234567 | customercare@servomax.in<br><br>www.wervomax.in |

**ECM-9: Installation of Harmonic filter**

| Sl. no. | Name of company | Address | Phone no. | E-mail / Website |
|---|---|---|---|---|
| 1 | Infinity Enterprise Private Limited | 13, Crystal Avenue & Industrial Park, near Odhav Ring road circle, Odhav, Ahmedabad – 382415, Gujarat, India | Mob: +91 8048412433 | info@infinityenterprise.net |
| **2** | Amtech Electronics (India) Ltd | E-6 GIDC Electronics Zone, Gandhinagar | Mr. Sachin Patel 079-23289101/102 | mktg2@amtechelectronics.com |
| **3** | Hitachi Hi-Rel Power Electronics Pvt. Ltd | B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044 | Mr. V.Jaikumar 079 2328 7180 - 81 | v_jaikumar@hitachi-hirel.com |

**ECM-10: Cable loss minimization**

| Sl. no. | Name of company | Address | Phone no. | E-mail / Website |
|---|---|---|---|---|
| 1 | Cummins Power Generation<br>Contact Person: Rishi Gulati<br>Senior Manager- Power Electronics | Cummins India Limited<br>Power Generation Business Unit<br>35/A/1/2, Erandawana, Pune 411 038, India | Phone: (91) 020-3024 8600 , +91 124 3910908 | cpgindia@cummins.com<br><br>rishi.s.gulati@cummins.com |
| 2 | Krishna Automation System | ESTERN CHAWLA COLONY, NEAR KAUSHIK VATIKA, GURGAON CANAL | Mob: 9015877030, 9582325232 | krishnaautomationsystems@gmail.com |

| Sl. no. | Name of company | Address | Phone no. | E-mail / Website |
|---|---|---|---|---|
| | Contact Person: Vikram Singh Bhati | BALLBGARH FARIDABAD 121004 | | |
| 3 | Next Gen Power controls | 8, Rashmi Growth Hub Estate, Near Shree Sai Palace Hotel Odhav, Ahmedabad- 382415, Gujarat, India | Mob: 08048110759 | |

**ECM-11: V Belt with REC belt replacement**

| Sl. No. | Name of Company | Address | Phone No. | E-mail |
|---|---|---|---|---|
| 1 | Shree Ram Marketing Co. | 67, Sharhanand Marg, G.B. Road, Shardanand Marg, Delhi – 110006 | 08048022651 | NA |
| **2.** | Mangal singh Bros. Pvt Ltd | 24-B, Raju Gardens, Near Krishnasamy nagar, Sowripalayamp Post, Coimbatore-641028 | Ramiz Parker +91 77381 86851 | mangalsinghcbe@gmail.com |
| **3** | Shreeji Traders | Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001 | +91 94281 01565 | NA |

**ECM-12: Energy Management system**

| Sl. no. | Name of company | Address | Phone no. | E-mail |
|---|---|---|---|---|
| 1 | Iadept Marketing Contact Person: Mr. Brijesh Kumar Director | S- 7, 2nd Floor, Manish Global Mall, Sector 22 Dwarka, Shahabad Mohammadpur, New Delhi, DL 110075 | Tel.: 011-65151223 | iadept@vsnl.net, info@iadeptmarketing.com |
| 2 | Aimil Limited Contact Person: Mr. Manjul Pandey | Naimex House A-8, Mohan Co-op Industrial Estate, Mathura Road, New Delhi - 110 044 | Office: 011-30810229, Mobile: +91-981817181 | manjulpandey@aimil.com |
| 3 | Panasonic India Contact Person: Neeraj Vashisht | Panasonic India Pvt Ltd Industrial Device Division ABW Tower,7th Floor, Sector 25, IFFCO Chowk, MG Road, Gurgaon - 122001, | 9650015288 | neeraj.vashisht@in.panasonic.com |

## ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

**Table 57: Assumptions for Financial Analysis**

| Particulars | UoM | Value |
|---|---|---|
| Debt equity ratio for bank loan | | 2.00 : 1.00 |
| Interest rate on bank loan | % | 13.50% |
| Project implementation period | y | 0.50 |
| Moratorium period | y | 0.50 |
| Loan repayment period | y | 5.00 |
| Depreciation rate (IT Act) | % | 80.00% |
| Depreciation rate (Co's Act) | % | 15.00% |
| Effective income tax rate | % | 26.750% |
| Effective MAT rate | % | 21.644% |
| Discount factor | % | 15.000% |