United Nations Industrial Development Organization

Global Environment Facility

Bureau Of Energy Efficiency

Detailed Energy Audit Report

M/s Karim Bux Handtools Udyog
Nagaur Handtools Cluster

Under GEF-UNIDO-BEE project

Promoting energy efficiency and renewable energy in selected MSME clusters in India

January 2016

pwc

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List of abbreviations

APFC	Automatic Power Factor Controller
AVVNL	Ajmer Vidyut Vitran Nigam Limited
BEE	Bureau of Energy Efficiency
DISCOM	Distribution Company
GEF	Global Environment Facility
HP	Horsepower
kCal	Kilo Calories
kVA	Kilo Volt Ampere
kVAr	Kilo Volt Ampere reactive
kW	Kilo Watt
kWh	Kilo Watt Hour
MSME	Micro, Small and Medium Enterprises
MT	Metric Tonne
PMU	Project Management Unit
UNIDO	United Nations Industrial Development Organization

Acknowledgement

We sincerely thank GEF- UNIDO-BEE for associating PricewaterhouseCoopers Private Limited (PwC) in its prestigious project "Promoting energy efficiency and renewable energy in selected MSME clusters in India" which involves developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Nagaur handtools cluster is one of them.

We express our sincere gratitude to all following officials of GEF-UNIDO-BEE PMU for their valuable support and guidance during the project:-

- Mr. Milind Deore, Energy Economist, BEE
- Mr. Abhishek Nath, National Project Manager, UNIDO
- Mr. Niranjan Rao Deevela, National Technology Coordinator, UNIDO
- Mr. Ashish Sharma, Project Engineer, BEE

PwC is thankful to Nagaur Handtool Manufacturer's Association for extending support for this assignment. We are also thankful to Mr. Karim Bux, Owner, Karim Bux Handtools Udyog and his team for giving full support during the energy audit. We would like to thank Mr. Rajiv Singhal, Cluster Leader, GEF-UNIDO-BEE Project for providing on-field support during the energy audit.

Executive Summary

Karim Bux Handtools Udyog is located in Basni Industrial Area of Nagaur and is involved in manufacturing of pliers. It uses EN 8 as raw material which is sheared into appropriate size through a shearing machine. Thereafter, blanks are fed to reheating furnace for heating up to a temperature of around 1150 – 1200 °C. After which the heated blank is rolled and pressed to give the shape of plier. During the process, excess material is cut and finally end cutting is done so that the final product is of correct size.

During the energy audit, following energy efficiency opportunities were identified:

S.No.	Energy Efficiency measure	Investment (INR)	Savings (INR)	Payback period (months)
1	Installation of Automatic Power Factor Controller (APFC)	33,075	40571	10
2	Installation of electric billet heater	15,27,000	6,49,791	28
3	Installation of cogged belt on load side and poly-V belt on common shaft drive side	9,488	7743	15
4	Preheating arrangement for raw material	20,000	92,286	3
Total		**15,89,563**	**7,90,391**	**24**

The details about the unit, load profiles, efficiency of furnace and description of energy conservation measures are discussed in appropriate sections of the report.

Project Background

1.1. Background of the project

GEF-UNIDO-BEE is developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India which includes Nagaur handtools cluster also.

The overall motive of this assignment is to improve the productivity and competitiveness of units as well as to reduce overall carbon emissions and improve the local environment.

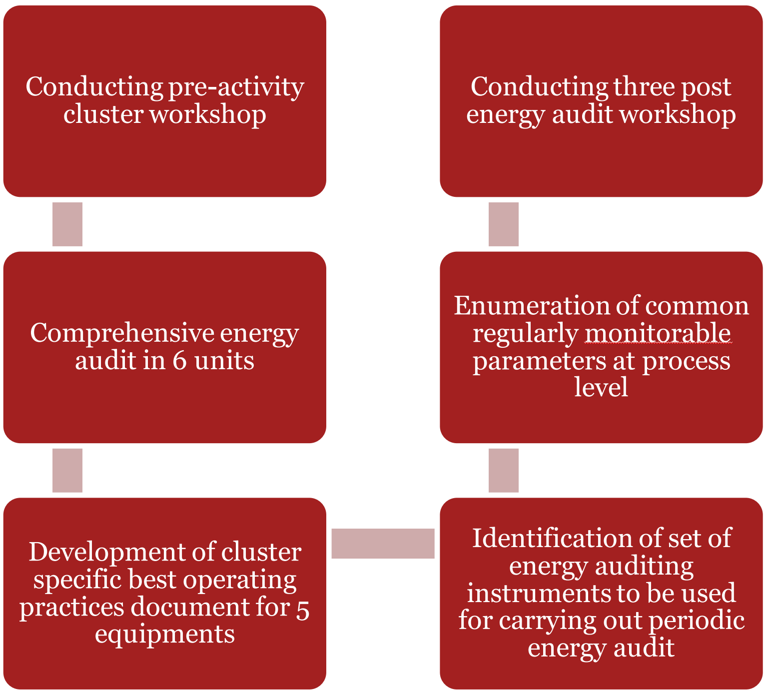
1.2. Introduction to assignment

Under GEF-UNIDO-BEE project 'Promoting energy efficiency and renewable energy in selected MSME clusters in India' India', PwC has been appointed for conducting activities of energy audit and dissemination in the Nagaur Handtools Cluster.

1.3. Scope of services

The activities being conducted by PwC under this assignment are shown at **Error! Not a valid bookmark self-reference.**.

Figure 1: Scope of services



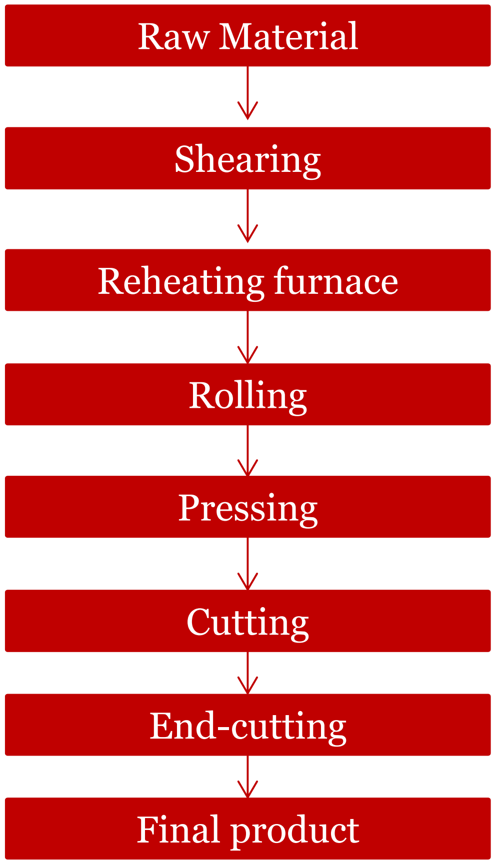
This current report has been prepared under the task 2 of above scope of services i.e. conducting comprehensive energy audits in 6 units in the cluster.

2. Energy Audit at Karim Bux Handtools

2.1. Process flow

The process flow at Karim Bux Handtools is shown at Figure 2 below. The raw material (EN 8) is sheared into appropriate size through a shearing machine. Thereafter, blanks are fed to reheating furnace for heating up to a temperature of around 1150 – 1200 °C. After which the heated blank is rolled and pressed to give the shape of plier. During the process, excess material is cut and finally end cutting is done so that the final product is of correct size. This is depicted in the following figure.

Figure 2: Process flow



The specialized instruments that were used during the energy audit included:

- Non-contact Infrared Thermometer (Testo-845 and Extech)
- Flue Gas Analyzer (KANE 900+)
- 3-phase Power Analyzer (Krykard ALM 30)
- 1-phase Power Analyzer (Krykard ALM 10)
- Vane Anemometer (Testo-416)
- Digital Tachometer (Extech-461995)

Details about the make of energy audit instruments are provided at **Annexure A.**

This report presents the field measurements, design and operational data and data analysis.

2.2. Baseline information of Karim Bux Handtools

In order to assess the present energy consumption levels and possible energy efficiency measures at 'Karim Bux Handtools' basic and general information was collected during the audit conducted on 4th and 5th May 2015.

The detail of energy audit of unit is provided below.

2.2.1. About the Unit

This unit is located in Basni Industrial Area of Nagaur. The baseline profile of the unit is presented in Table 1.

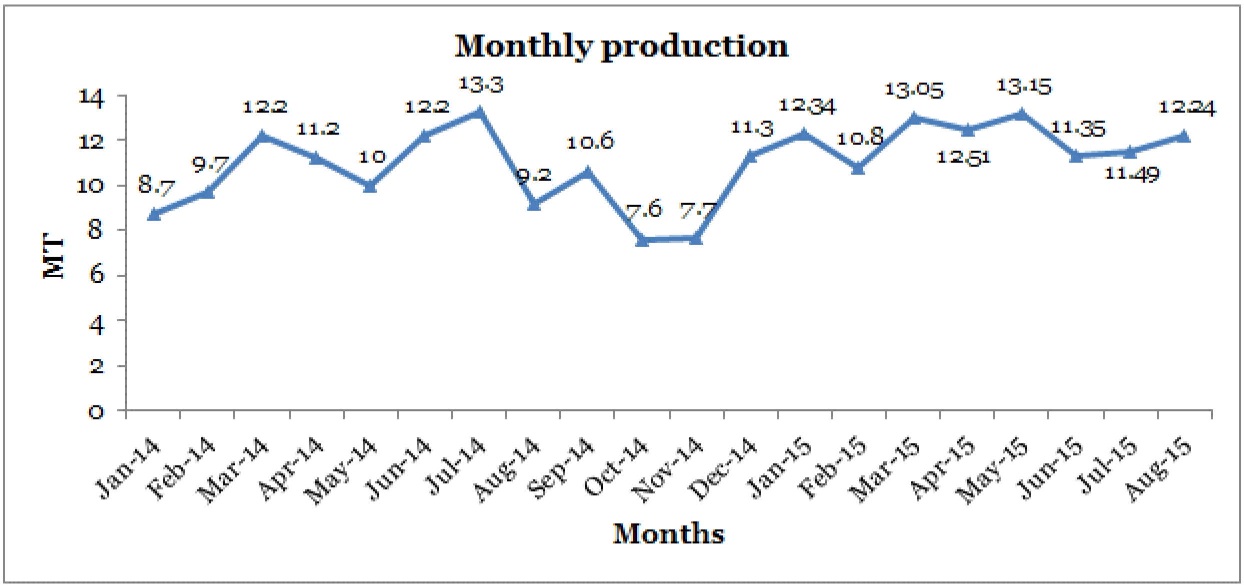
Table 1: Baseline profile

Parameters	Details
Name of the unit	Karim Bux Handtools
Address of the unit	52, Basni Industrial Area, Nagaur
Name & contact number of contact person	Mr. Karim Bux Mobile - 9414118197
Date of audit	4th and 5th May 2015
Raw material	EN-8
Final product	Plier 8"
Furnace	Box type
Dimension of furnace	31" X 19" X 19"
Fuel used	Furnace oil
Press hammer weight	500 kg
Daily production	1700 pieces
Operating hours/day	7 hours
Sanction load	58 hp

2.3. Monthly trend of production

The audit team has collected monthly production data from the unit and the same has been depicted in the following figure.

Figure 3: Monthly production data



2.4. Past electricity bill analysis

The electricity bills of unit are based on medium industry tariff (HT-3) specified by AVVNL. The details of this tariff category are:

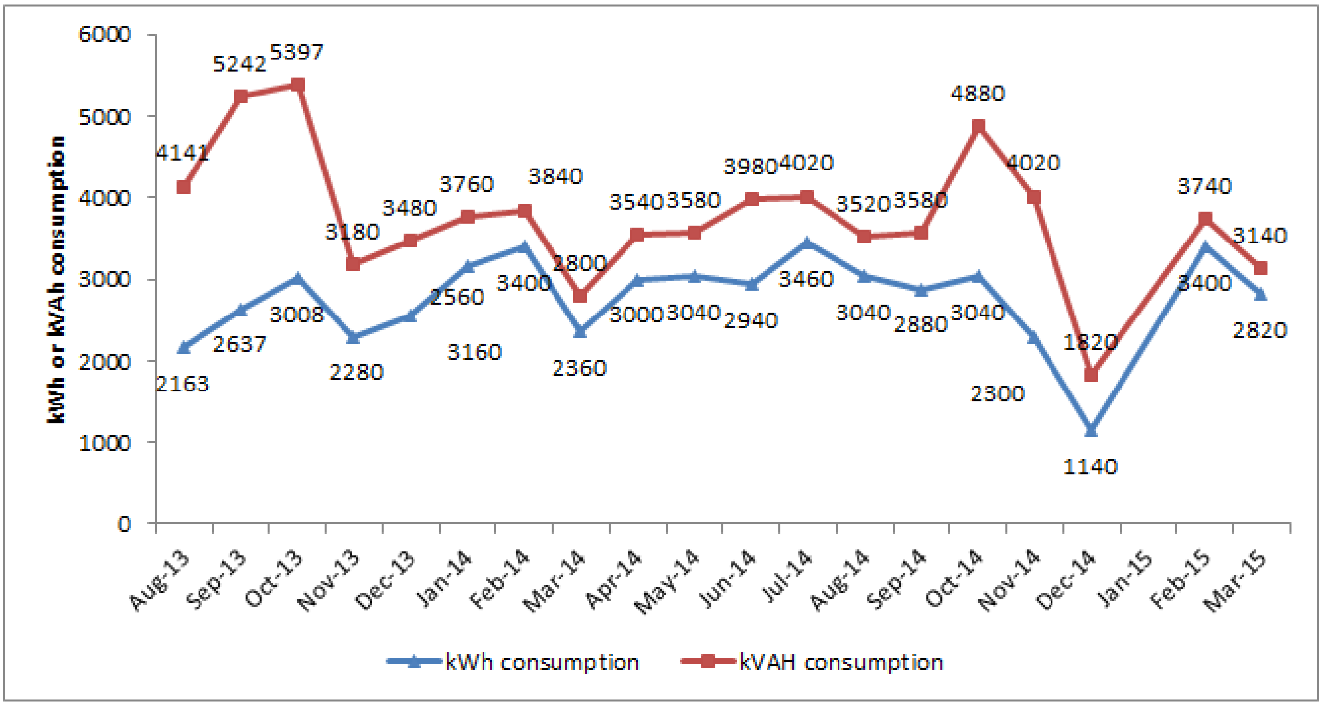
Table 2: Tariff description

Parameter	Specifications
Category description	Sanction load above 25 hp and not exceeding 150 hp or maximum demand of 125 kVA
Fixed charges	INR 125/ kVA
Energy charges	INR 5.25/ kWh*

* Electricity tariff has been revised to INR 6.25 from March 2015

The team has collected electricity bills from August 2013 to March 2015 for the purpose of analysis. A graph showing pattern of energy consumption is shown below.

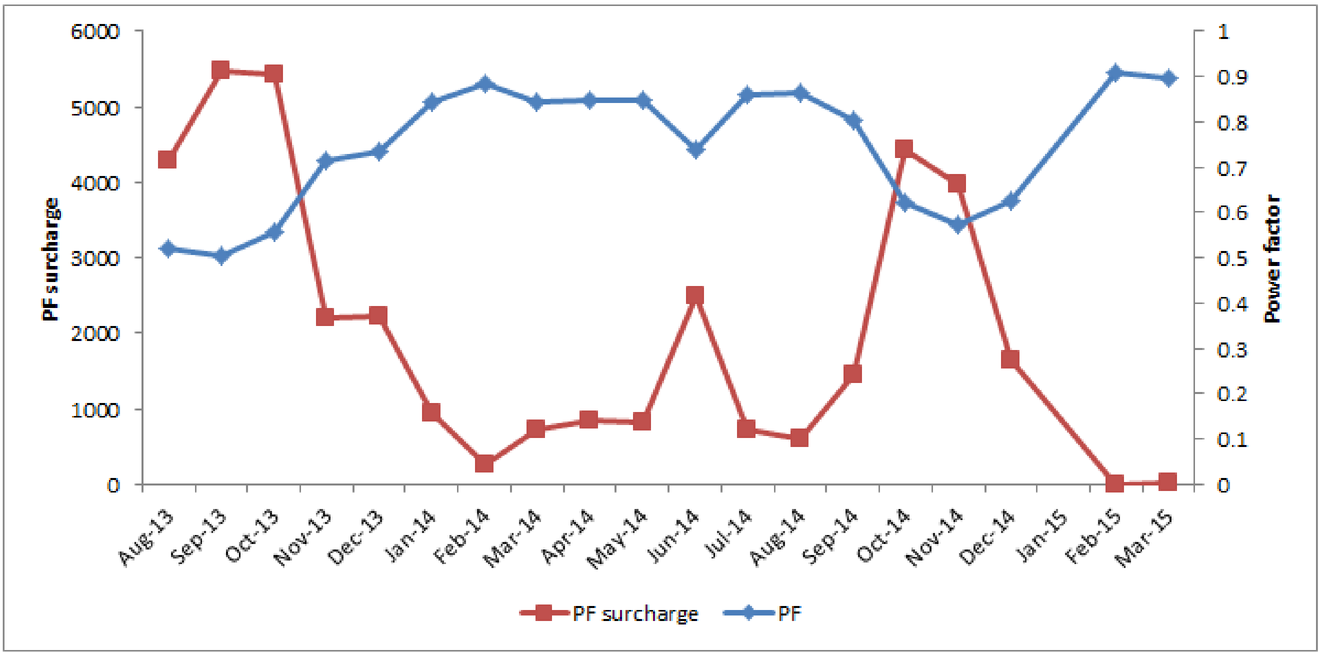
Figure 4: Energy consumption pattern



It can be inferred from above figure that the energy consumption peaks during months of February, July and October after which the consumption decreases in the month of March, August and November. Further, the average energy consumption, for the said period, is 2769 kWh/month.

Similarly, the power factor profile as well as power factor surcharge paid by the unit are shown in following figure.

Figure 5: Power factor profile and power factor surcharge



It can be seen that the unit has paid around INR 40000 due to low power factor surcharge from August 2013 to March 2015.

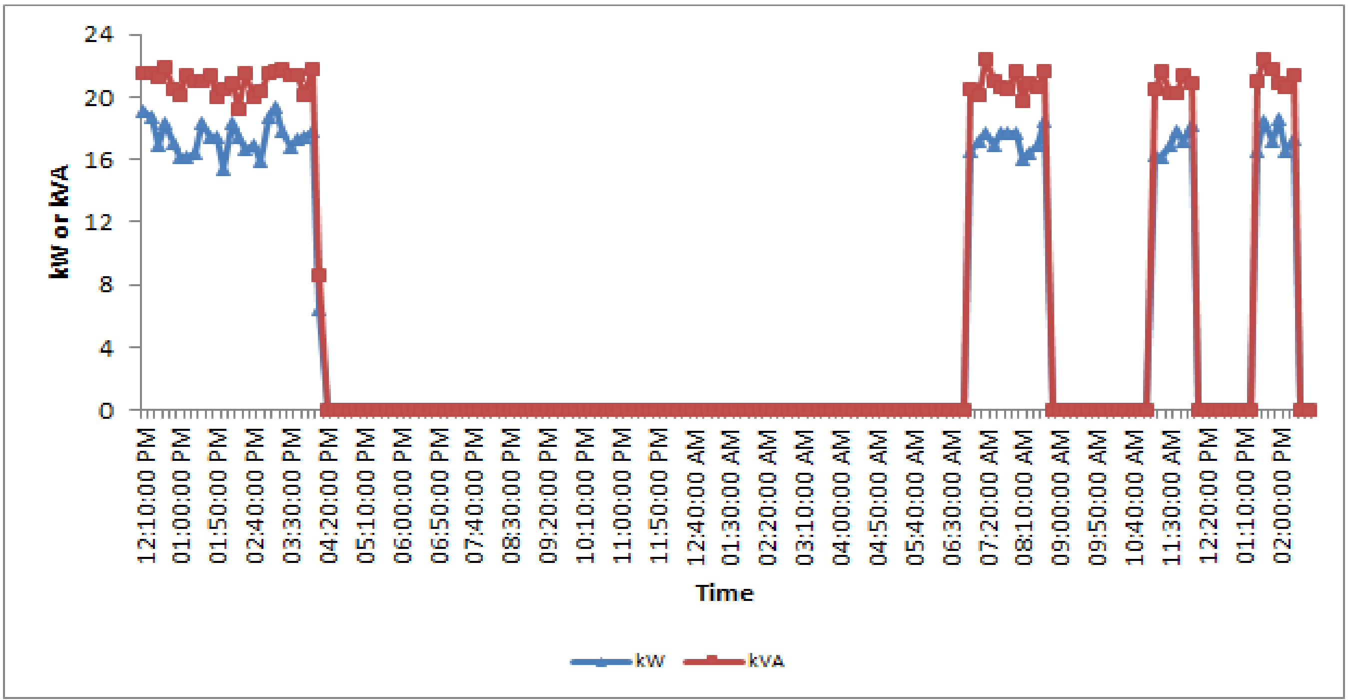
2.5. Load profile of Karim Bux Handtools

In order to derive the load profile of the unit, many electrical parameters were measured by using a sophisticated portable 3-phase power analyser (KRYKARD).

2.5.1. Load (kW) and apparent power (kVA) profile

Load profile and apparent power profile is a graph of the variation in the electrical load versus time. In any electrical system, the vector sum of the active power (kW) and reactive power (kVAr) make up the total (or apparent) power (kVA) used. This is the power generated by a generation station for the user to perform a given amount of work. Total power is measured in kVA (Kilo Volts-Amperes) and the load or active power is measured in kW (kilowatts) and they become equal as and when the power factor approaches unity. Total electricity charges (units and demand) are based on the load or active power (kW) and apparent power (kVA).

Figure 6: Active power (Load) and apparent power profile during audit



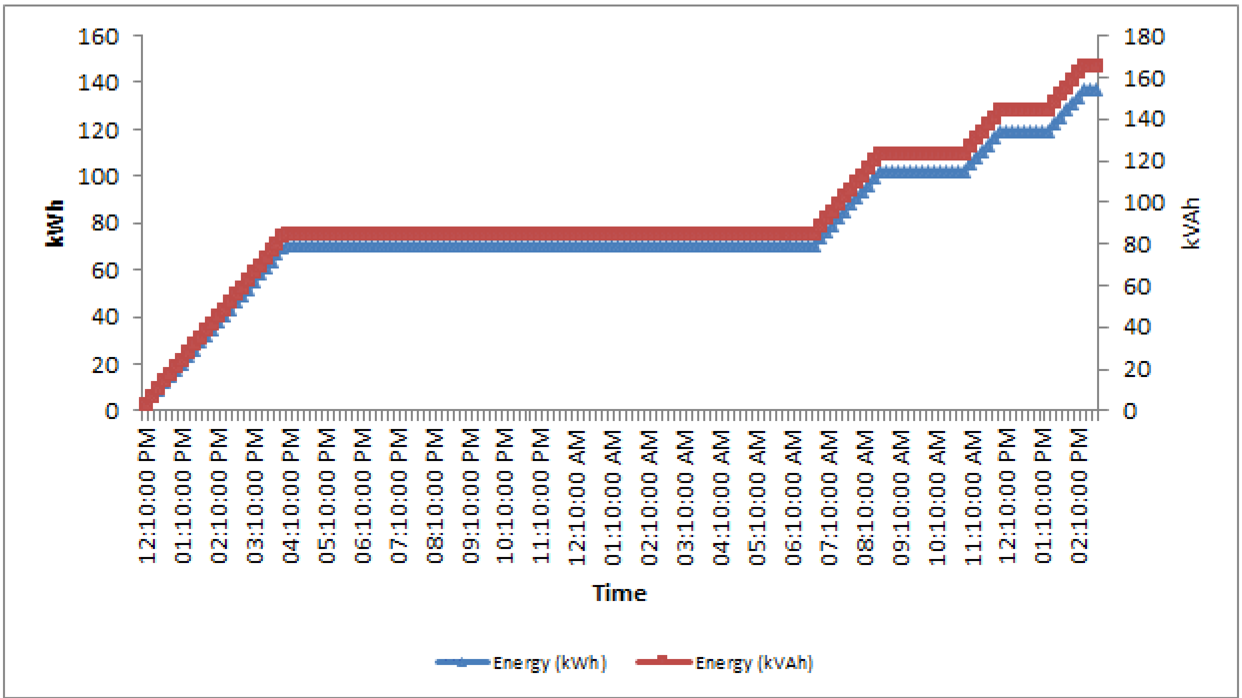
Observations made from the above graph:

- The maximum input power drawn by the unit is 19.3 kW. The graph shows that the unit stopped operation around 4:20 PM and then began its operation from 6:30 AM onwards.
- Apparent power curve (kVA) line is significantly above the active power (kW) line indicating that power factor is on lower side.

2.5.2. Electricity consumption (kWh) profile

Electricity consumption profile is the pattern of the consumption of electricity in the unit during the energy audit. The following graph captures the electricity consumption (kWh) profile of the unit:

Figure 7: Electricity consumption (kWh) and (kVAh) profile during audit



Observations made from the above graph:

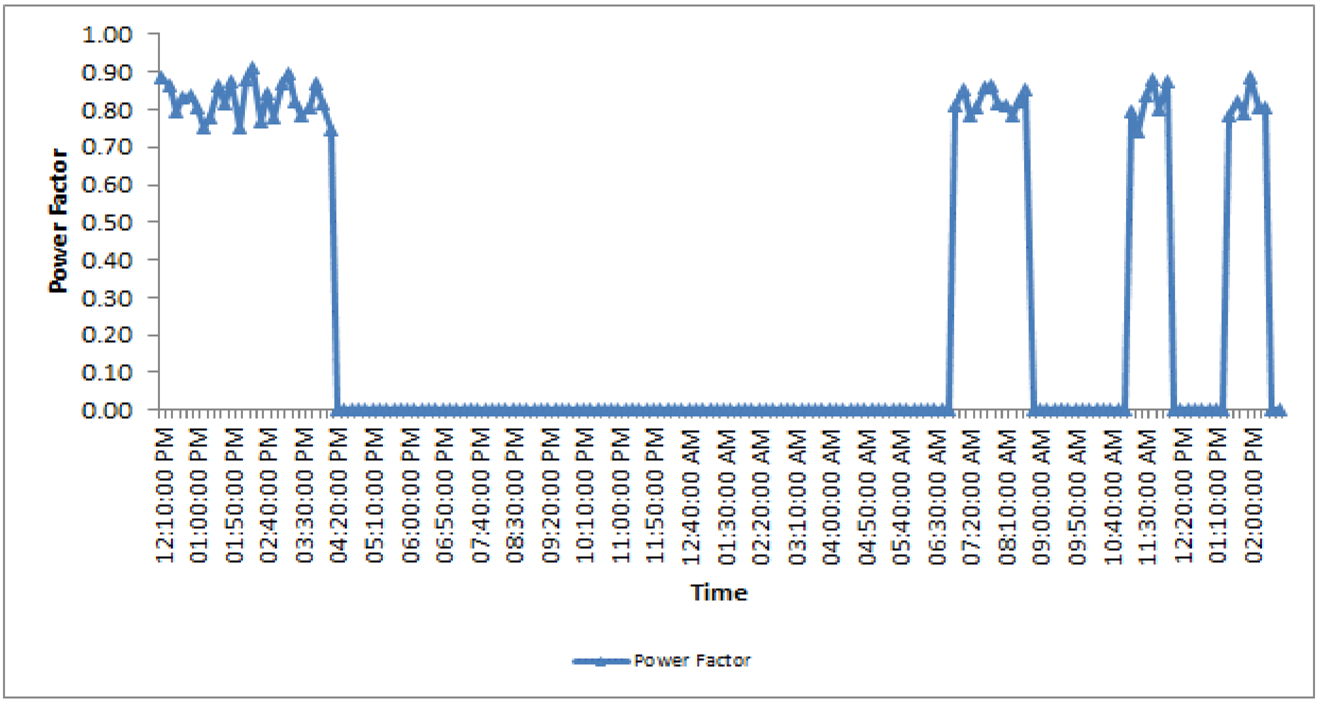
- The unit consumed nearly 140 kWh and around 170 kVAh during the recording period of almost 27 hours.

2.5.3. Power factor profile of the unit

Power factor is an important parameter for the unit since its billing is based on kVAh where in power factor plays a major role. Also, DISCOM's supplying power to the units impose power factor surcharge on the bills in case the power factor is below 0.90.

The following graph captures the power factor profile of the unit:

Figure 8: Power factor profile during audit



Observations made from the above graph:

- The power factor of the unit is on lower side with maximum power factor being at 0.91
- The unit may consider installing capacitor banks for improving the power factor so that they do not get charged with power factor surcharge.

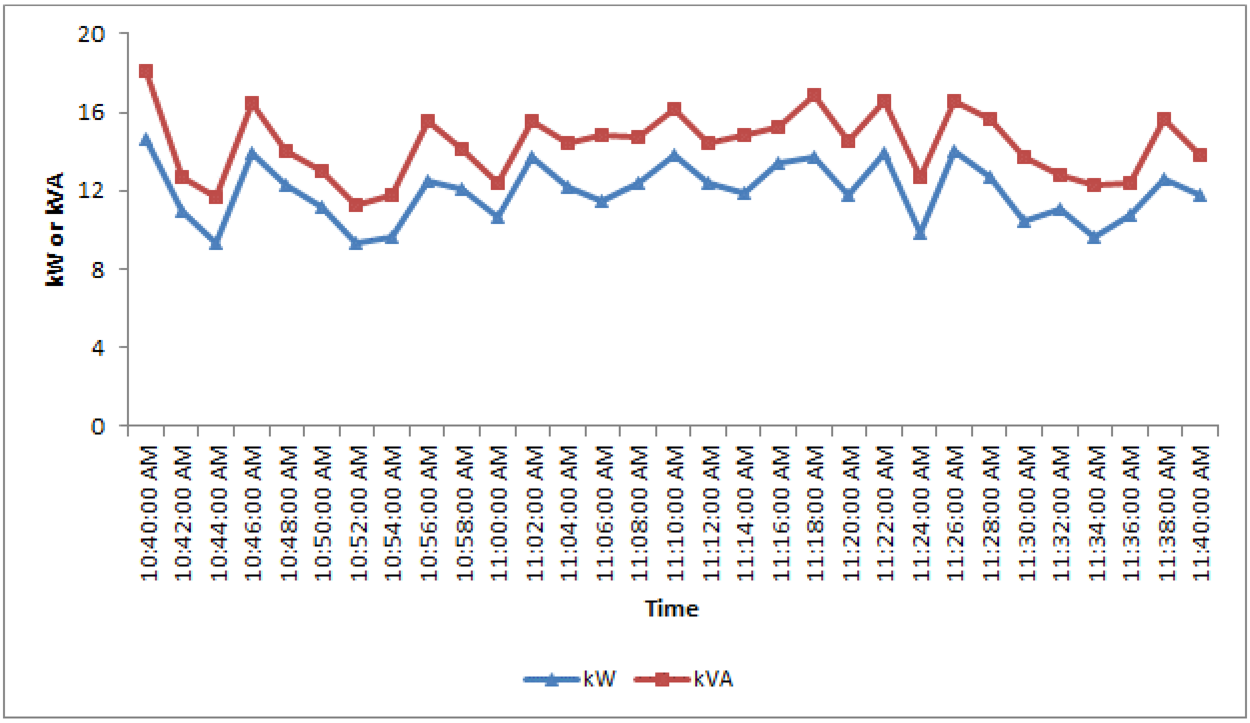
2.5.4. Load profile of key motors of the unit

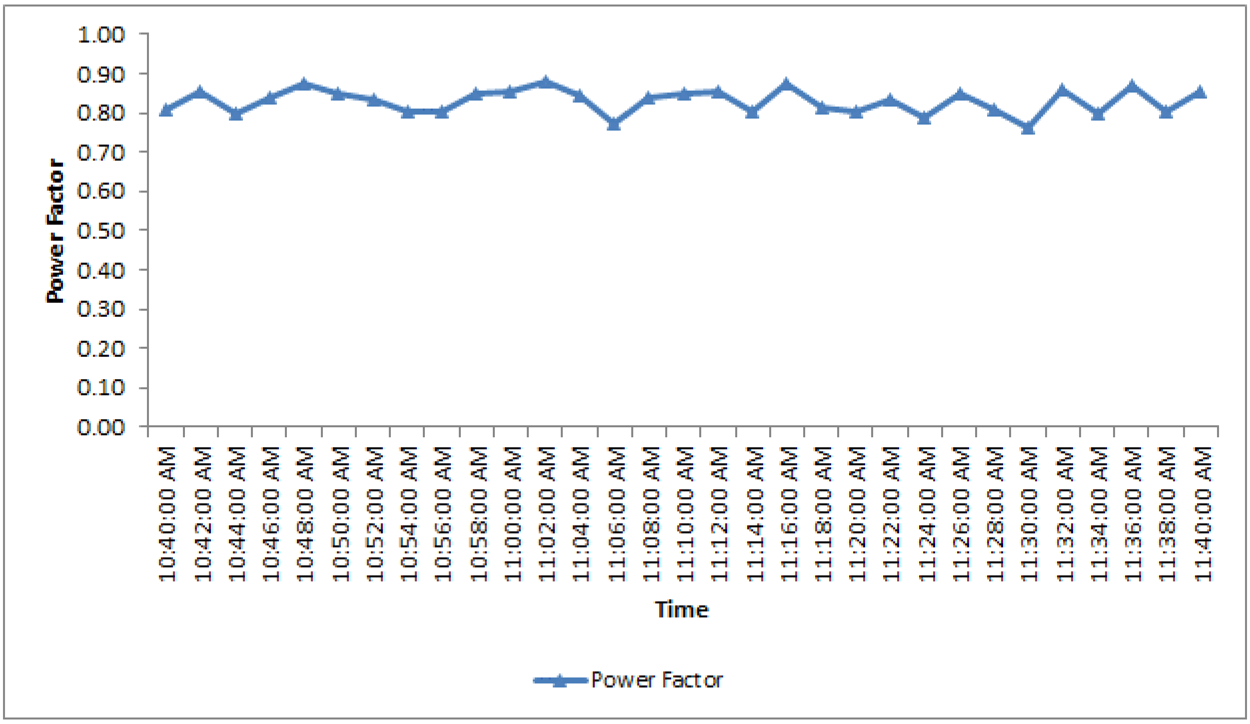
There are following two key motors in the unit:

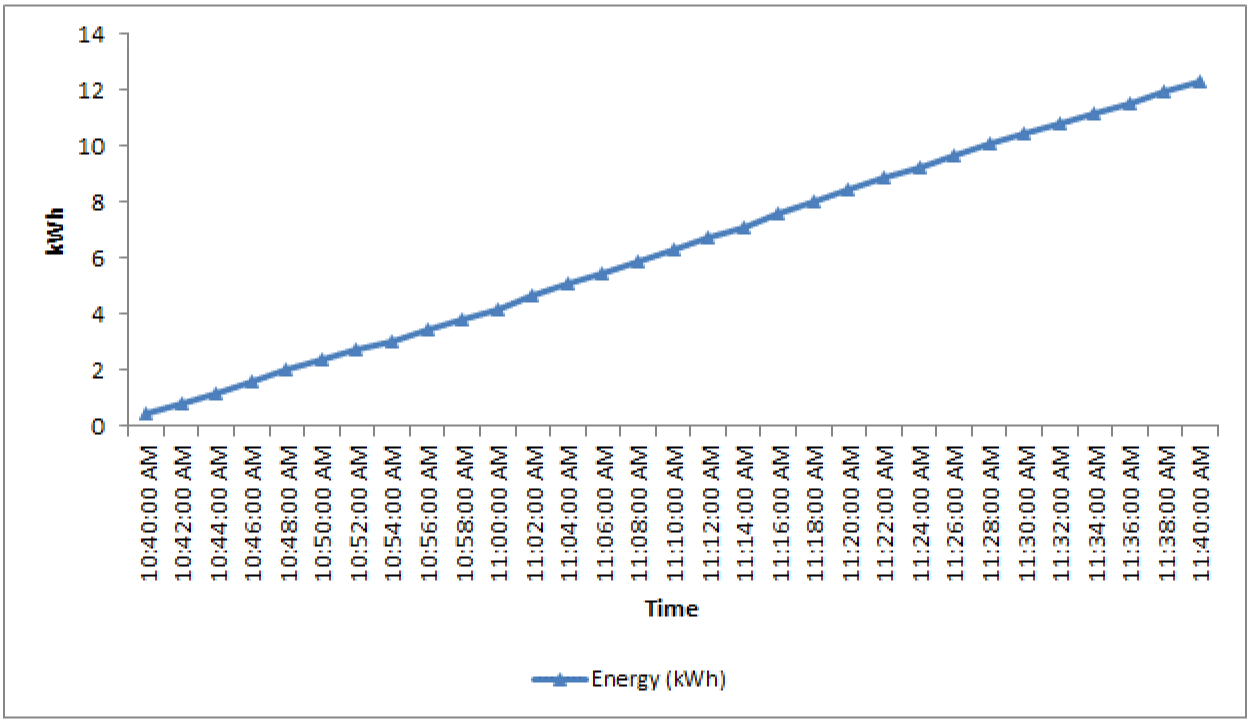
- Press motor
- Common drive motor

The load profile, power factor profile and cumulative kWh of press motor are shown below.

Figure 9: Load profile, power factor profile and cumulative kWh of press motor





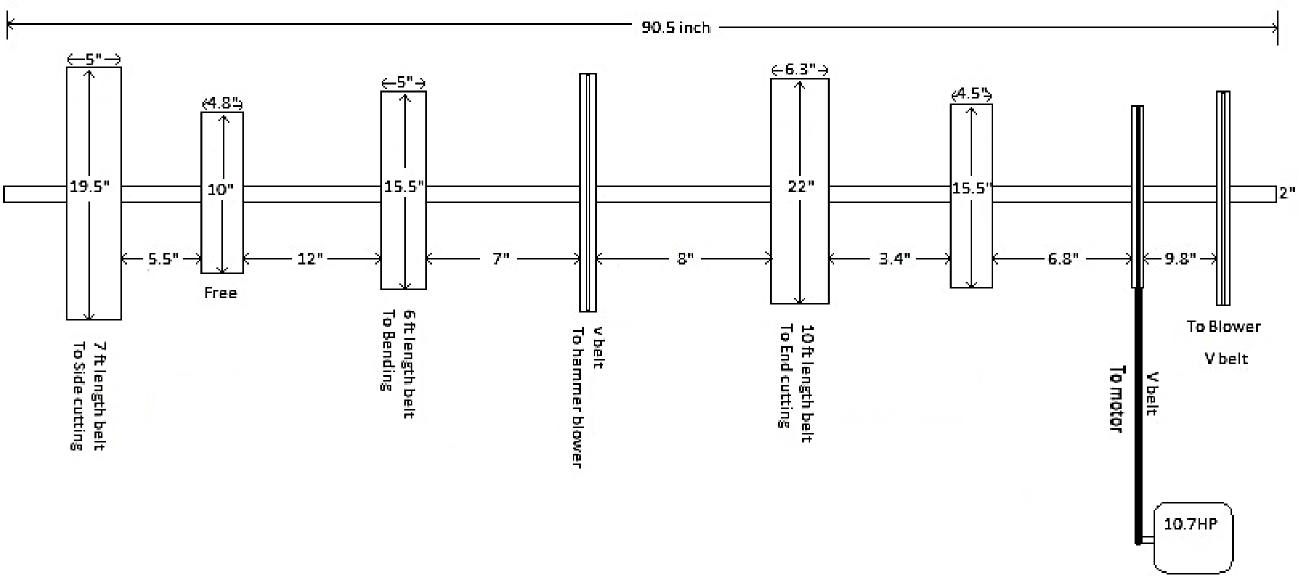


The profiles were recorded for a period of 1 hour and the key observations are listed below:

- Maximum power drawn during recording period was 14.63 kW
- The power factor of motor ranged from 0.76 to 0.88
- The motor consumed around 12 kWh during one hour of recording period
- The motor is operating at 65% loading

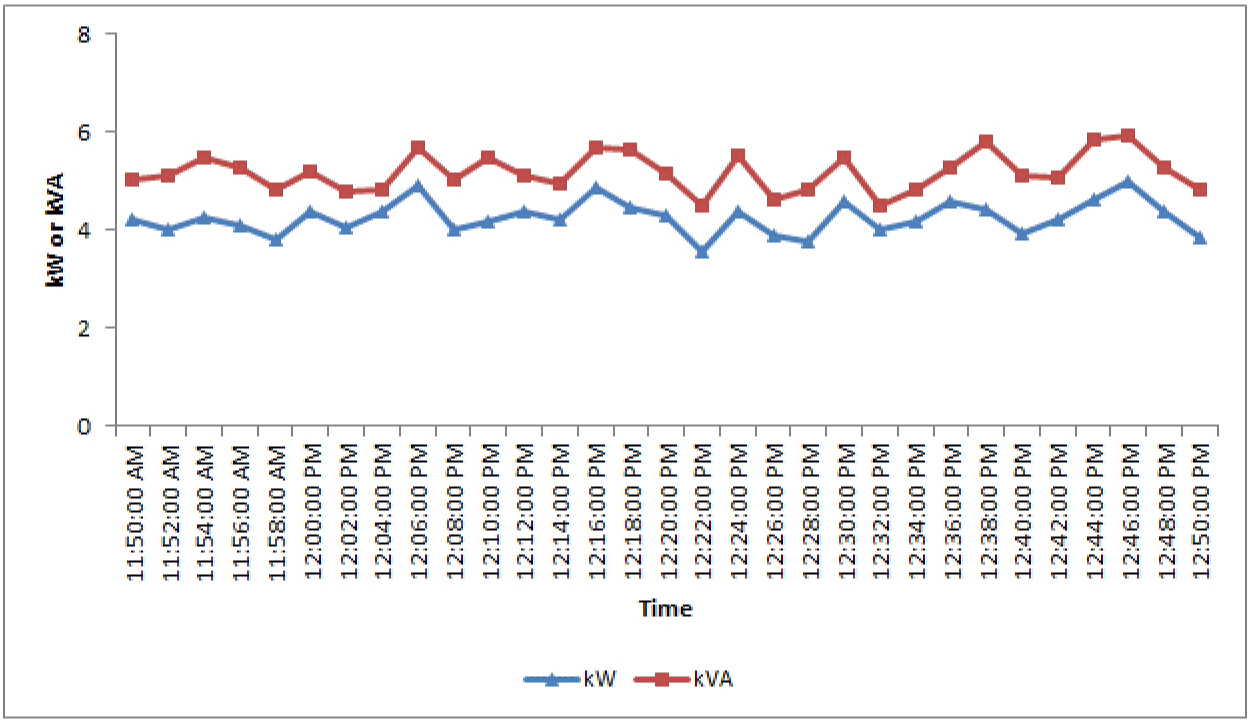
A common shaft is used in the unit for transmission of power from drive motor to other loads. The layout and positioning of various loads and centre distances are depicted in following figure.

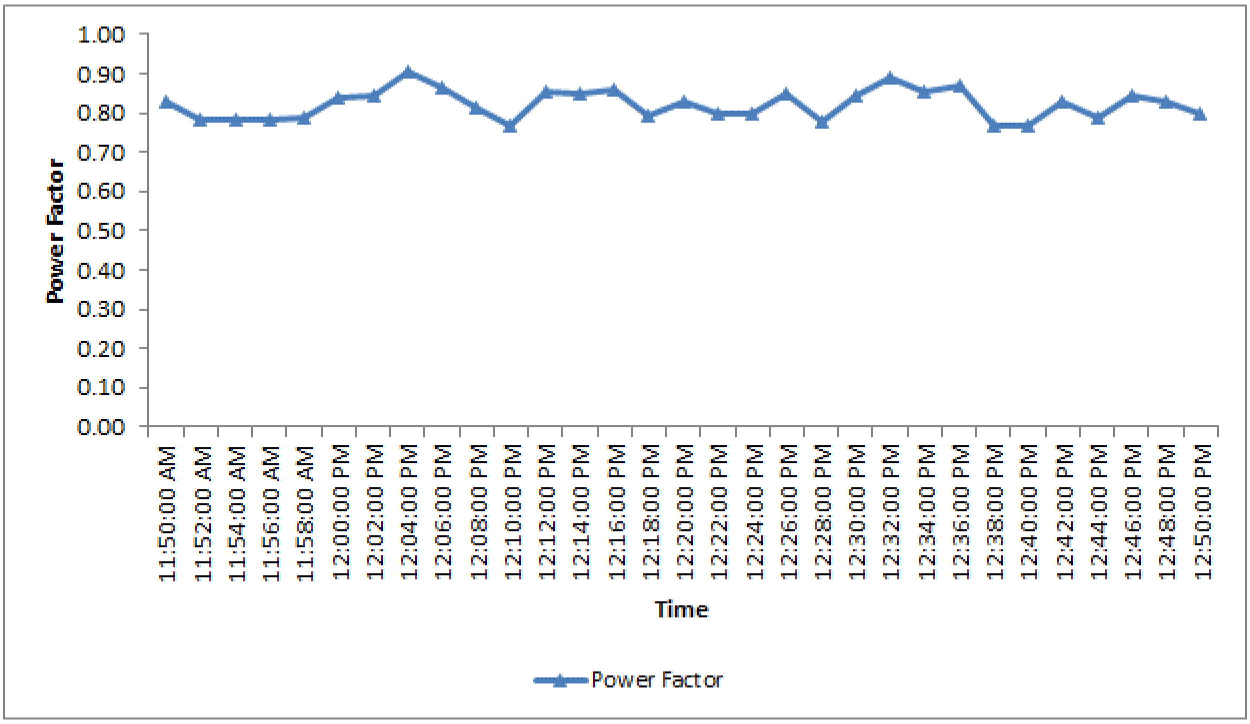
Figure 10: Different loads and centre distances of pulleys on common shaft

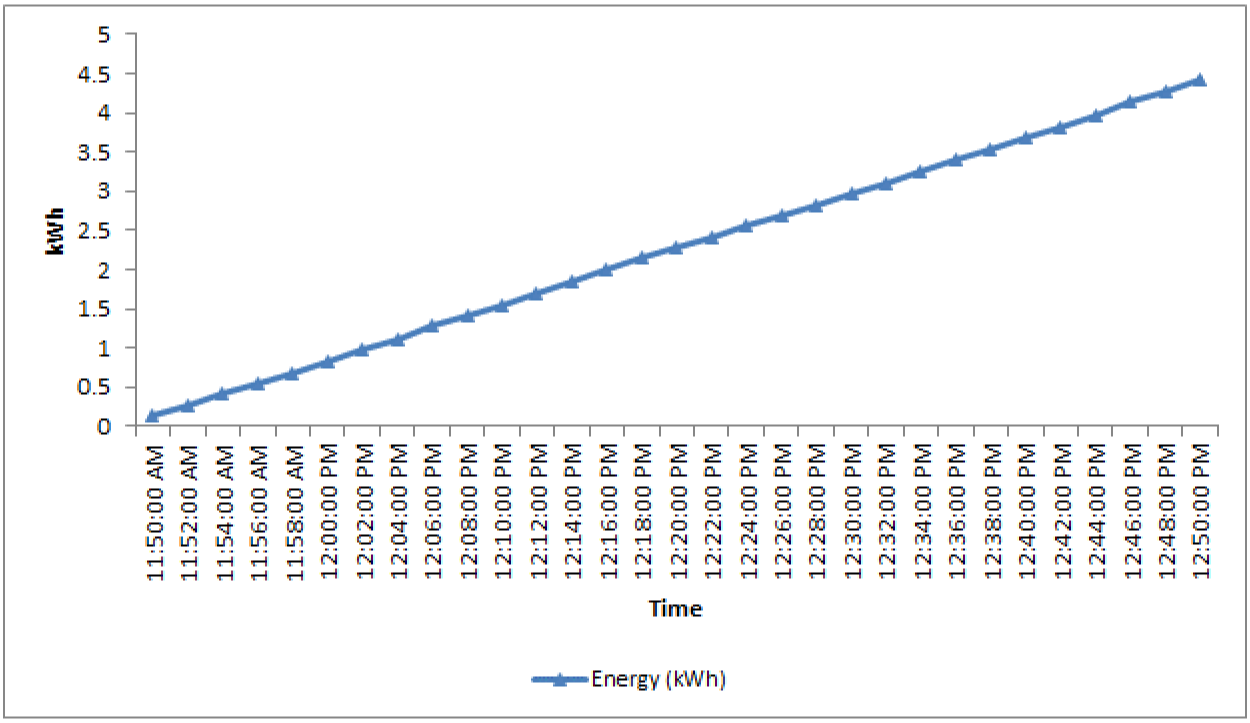


The load profile, power factor profile and cumulative kWh of common drive motor are shown below.

Figure 11: Load profile, power factor profile and cumulative kWh of common drive motor







The profiles were recorded for a period of 1 hour and the key observations are listed below:

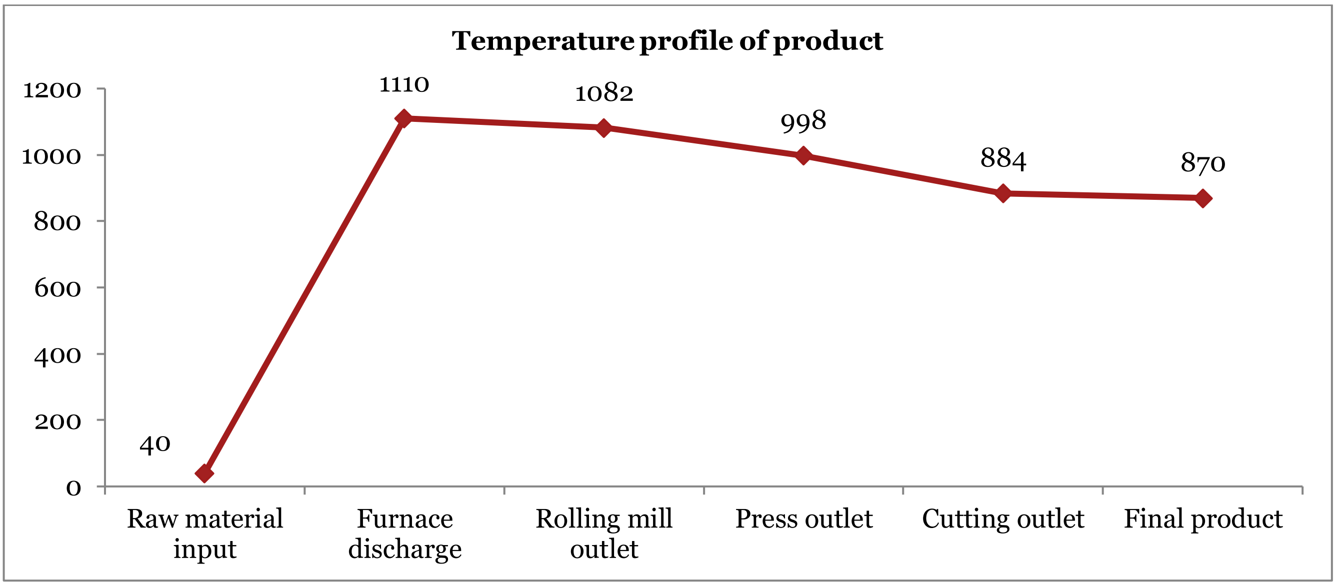
- Maximum power drawn during recording period was 5 kW
- The power factor of motor ranged from 0.77 to 0.90
- The motor consumed around 5 kWh during one hour of recording period
- The motor is operating at 67% loading

2.6. Temperature profile of process and furnace

2.6.1.1. Temperature profile

During the baseline energy audit, temperature was measured at various stages of the process such as raw material temperature, furnace discharge, rolling mill outlet, press outlet, cutting outlet and final product. The temperature profile is presented at following figure.

Figure 12: Temperature profile from raw material to final product



There is total temperature drop of around 240°C from furnace outlet till final product.

2.6.1.2. Skin temperature

The skin temperature of furnace was captured using infrared thermometer. The temperature profile is mentioned below:

Figure 13: Skin temperature of furnace

Discharge side		
245	330	290
190	320	340
286		
Burner side		
250	330	350
170	260	340
283		

Back Side	
240	290
190	195
229	

It can be observed that the skin temperature is very high indicating that refractory lining is not proper inside the furnace and it also indicates that surface insulation is not present.

2.7. Thermal efficiency of furnace – direct method

Furnace thermal efficiency calculation by direct method involves comparison of useful heat content in the stock with the total thermal energy input to the furnace. Thermal efficiency for the reheating furnace is calculated by direct method in table below.

Table 3: Thermal efficiency of furnace – direct method

Parameter	Unit	Value
Production on audit day	kg/day	904.28
Furnace throughput	kg/hr	129.18
Fuel consumption rate	kg/hr	11.57
Gross calorific value of fuel	kCal/kg	10,880.00
Specific heat of the material	kCal/kg °C	0.12
Material charging temperature	°C	40.00
Material discharge temperature	°C	1,110.00
Furnace efficiency by direct method	**%**	13.18

It can be seen from above table that furnace thermal efficiency is around 14% as calculated by direct method. However, using direct method, one cannot determine different heat losses associated with furnace operation. Hence, indirect method or heat loss method is employed to determine furnace thermal efficiency as well as heat losses due to various other factors. The same has been discussed in next.

2.8. Thermal efficiency of furnace – indirect method

Indirect Method helps to determine major heat loss from furnace which includes losses in flue gas and other heat loss parameters like surface radiation losses, CO formation loss, etc. All these losses are calculated in table below:

Table 4: Thermal efficiency of furnace – indirect method

Parameter	*Unit*	*Value*
Measured O_2 in flue gas	%	7.30
Measured CO in flue gas	ppm	125
Excess air used for combustion	%	53.28
Corresponding CO_2	%	11.38
Total air used for combustion	kg/kg of fuel	19.79
Sensible heat loss in flue gas	%	**65.36**
Heat loss due to moisture present in fuel	%	0.019
Heat loss due to evaporation of water formed due to hydrogen in fuel	%	**7.24**
Heat loss due to moisture present in air	%	1.82
Heat loss due to CO formation	%	0.05
Heat loss due to radiation and openings	%	**6.43**
Heat loss in scale generation	%	0.60
Heat content in the material	%	13.18
Unaccounted Heat Losses	%	5.30

The exit flue gas temperature of furnace is 1050 °C and it can be observed from above that heat loss due to flue gas is one of the major contributors to overall heat loss from the furnace followed by heat loss due to hydrogen in fuel and heat loss due to radiation & openings. Detailed calculation sheet is attached at Annexure B.

2.9. Material loss during production

As observed in the process flow, material loss happens in following forms:

- Burning loss
- Cuttings after pressing
- End cuttings after sizing of product

We have captured these parameters to assess the burning loss as well as other material loss during the production process.

The assessment is tabulated below:

Table 5: Material loss during production

Parameter	*Unit*	*Value*
Weight of raw material	kg/piece	0.3478
Weight of final product	kg/piece	0.2978
Weight of cuttings	kg/piece	0.0293
Weight of end-cuttings	kg/piece	0.0048
Material loss in cuttings & end-cuttings	kg/piece	0.0341

Total material loss	kg/piece	0.0499
Burning loss	kg/piece	0.0158
Burning loss	%	**4.56**
Total material loss	%	14.37

2.10. Specific energy consumption

Specific Energy Consumption for the product is calculated by aggregating individual specific energy consumption of fuel and electricity, as shown in table next.

Table 6: Specific energy consumption

Parameter	Unit	Value
Production	kg/day	904.28
Furnace oil consumption	L/day	88
Electricity consumption	kWh/day	66.11
Specific fuel consumption	L/Tonne	**97.31**
Specific electricity consumption	kWh/Tonne	**73.11**

3. Energy Conservation Measures

During the energy audit, we have identified following energy conservation measures:

- Installation of Automatic Power Factor Controller (APFC)
- Installation of electric billet heater
- Installation of cogged belt on load side and poly-V belt on common shaft drive side
- Preheating arrangement for raw material

We have analysed each of above mentioned measures next.

3.1. Measure 1: Installation of Automatic Power Factor Controller (APFC)

Recommendation

The average monthly power factor of the unit based on the electricity bills of the unit is 0.74 and it could be improved to 0.99 for load reduction and I^2R losses reduction. This will also help in reducing the maximum demand. By installing Automatic Power Factor Control (APFC) unit, the power factor can be improved to unity.

Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 7: Power factor improvement - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Cost parameters		
Particulars	Unit	Value
Tentative price of capacitor bank	INR/kVAr	900
Tentative price of capacitor bank of 35 kVAr	INR	31,500
Installation cost	% of capital cost	5
Energy and financial savings		
Average monthly power factor		0.74
Proposed power factor		0.99
Required capacitor bank capacity	kVAr	35
Total annual monetary savings through power factor incentives	INR	40,571
Total investment requirement (price of capacitor bank and installation cost)	INR	33,075
Simple payback period	Months	10

The implementation of this recommendation will help the Karim Bux Unit to save around INR 40,571 per year by installing capacitor bank of around 35 kVAr. The implementation cost required to install Automatic Power Factor Control (APFC) panel is approximately INR 33,075 and the simple payback period of this investment is around 10 months.

3.2. Measure 2: Installation of electric billet heater

Recommendation

The efficiency of reheating furnace used in the unit is pretty low and it generates lot of smoke making the environment not suitable for the workers. So, we recommend installation of electric billet heater in place of existing furnace oil fired reheating furnace. This will result in higher efficiency of billet heater and also better working environment for the workers.

Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 8: Installation of electric billet heater - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Present Scenario		
Particulars	Unit	Value
Existing burning loss	%	4.56
Specific fuel consumption	L/T	97.31
Hourly production	Kg/h	129.18
Proposed Scenario		
Size of billet heater	kW	60
Proposed burning loss	%	0.35
Specific electricity consumption	kWh/T	436
Cost components		
Cost of electric billet heater	INR	12,00,000
Cost of new transformer	INR	1,50,000
Miscellaneous expenses	INR	50,000
Impact of increased sanction demand @ 60 kVA	INR	1,27,000
Total cost	INR	15,27,000
Electricity consumption	kWh/annum	1,18,277
Electricity charges (in kWh/annum X INR 6.25/kWh)	INR	7,39,233
Benefits		
Material savings	T/annum	11.43
Fuel savings	L/annum	26,398
Material savings (in T/annum X INR 43000/T)	INR	4,91,490
Fuel savings (in L/annum X INR 34/L)	INR	8,97,534
Total benefits (Material savings + Fuel savings - Electricity charges)	INR	6,49,791
Simple payback period	Months	28

The implementation of this recommendation will help the Karim Bux Unit to save around INR 6,49,791 per year by installing electric billet heater of around 60 kW capacity. This will not result in change in existing tariff category. The simple payback period of this investment is around 28 months.

3.3. Measure 3: Installation of cogged belt on load side and poly-V belt on common shaft drive side

Recommendation

Since the drive system in the unit is based on common shaft and different belts give input to other loads in the unit. Presently, the unit is using V-belt in common shaft drive side and flat belts on load side. However, if we replace existing belts with V-belt on load side and poly-V belt on common shaft drive side then it will give significant savings in electricity consumption of common drive motor as well as lower slippage losses.

Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 9: Installation of cogged belt on load side and poly-V belt on common shaft drive side - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Assumptions		
Particulars	Unit	Value
Efficiency of V-belt	%	0.85
Efficiency of normal belt	%	0.8
Efficiency of poly V-belt	%	0.92
Efficiency of cogged belt	%	0.85
Hours of operation per day	Hours	7
Annual operation days	Days	300
Tariff	INR/kWh	6.25
Present Scenario		
kW consumed	kW	4.5
kW at drive shaft	kW	3.83
kW at load	kW	3.06
Proposed scenario		
kW consumed	kW	3.91
kW at drive shaft	kW	3.60
kW at load	kW	3.06
Cost elements		
Cost of 10 feet cogged belt type "C"	INR	1173
Cost of 7 feet cogged belt type "C"	INR	729
Cost of 6 feet cogged belt type "C"	INR	595
Cost of 5 feet poly-V belt (3 nos.)	INR	1780.5
Installation of pulleys of appropriate size	INR	1650
Total cost	INR	9488.50
Benefits		
Power savings	kW	0.59
Annual electricity savings	kWh/annum	1239
Monetary electricity savings	INR	7743.75
Simple payback period	Months	15

The implementation of this recommendation will help the Karim Bux Unit to save around INR 7743.75 per year by installing cogged and poly-V belts with an investment of INR 9488.50. The simple payback period of this investment is around 15 months.

3.4. Measure 4: Preheating arrangement for raw material

Recommendation

It was observed during the energy audit that exit flue gas temperature from furnace is as high as 1050 °C which is not being utilized. We have also observed that it takes approximately 90 minutes for processing a batch of 300 pieces. So, we propose installation of a preheating arrangement at exit of furnace wherein next batch of 300 pieces are kept. Thus, during that time next batch of 300 pieces can be preheated and then transferred into furnace for processing. This will result in significant savings in fuel without any changes in furnace efficiency.

Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 10: Installation of preheating arrangement for raw material - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Assumptions		
Particulars	Unit	Value
Furnace efficiency	%	13.18
Material discharge temperature	°C	1100
Production	kg/h	129.18
Gross calorific value	kCal/kg	10880
Hours of operation per day	Hours	7
Annual operation days	Days	300
Fuel cost	INR/L	34
Present Scenario		
Material charging temperature	°C	40
Fuel consumption	L/day	87.19
Proposed scenario		
Material charging temperature	°C	150
Fuel consumption	L/day	78.14
Cost elements		
Lump-sum cost for installation of preheating system	INR	20,000
Benefits		
Fuel savings	L/day	9.05
Annual fuel savings	L/annum	2714.29
Monetary savings due to fuel savings	INR	92,286
Simple payback period	Months	3

The implementation of this recommendation will help the Karim Bux Unit to save around INR 92,286 per year by installing preheating system for raw material with an investment of INR 20,000. The simple payback period of this investment is around 3 months.

Annexure A: List of Energy Audit Instruments

PwC has multiple energy audit instruments kits. All the instruments are of have high quality, precision and are periodically calibrated. The instruments are capable to cover all electrical and thermal measurements required in the plants. A list of instruments used by PwC during the audit are shown below:

S. No.	Name of the Instrument	Make	Quantity Used
Thermal Instruments			
1	Non-contact Infrared Thermometer (Testo-845 and Extech)	Testo (USA), Extech (USA)	2
2	Flue Gas Analyzer (KANE 900+)	Kane (UK)	1
Electrical Instruments			
3	3-phase Power Analyzer	Krykard, Circutor and Extech	3
4	1-phase Power Analyzer		2
Others			
5	Vane Anemometer (Testo-416)	Testo (USA)	2
6	Digital Tachometer (Extech-461995)	Extech (USA)	1

Annexure B: Calculation sheet of furnace efficiency by indirect method

		Data Sheet
General Details		
Name of unit	Karim bux	
No. of Energy Audit	1	
Product type	Plier	
Product size	200mm	
Raw material under process	EN8	
Production Capacity	0.904	TPD
Standard Temperature for operation	1110	°C
Average scale loss	4.56	%
Average plant operation	7	hrs./day
Annual plant operation	300	days/annum
Fuel Details		
Type of fuel	Furnace Oil	
Total carbon	88.9	% by mass
Hydrogen content	8	% by mass
Sulfur content	0.5	% by mass
Oxygen content	1.4	% by mass
Nitrogen content	0.5	% by mass
Moisture content	0.35	% by mass
Ash content	0.35	% by mass
Gross calorific value	10880	kcal/kg.
Bulk Density	920	kg/m^3
Fuel consumption per hour	11.56571429	kg/hr
Fuel consumption per day	80.96	kg/day
Fuel consumption per annum	24.288	TPA
Cost of fuel	31	Rs./kg
Measured Data		
Ambient air temperature : (DBT)	40	°C
Ambient air temperature : (WBT)	38	°C
Material Temperature at feeding	40	°C
Temp. of supply air for combustion	40	°C
Average Oxygen level	7.3	%
Average CO level	125	ppm
Exit flue gas temperature	1050	°C
Average surface temperature -main body	230	°C
Average surface temperature -front & back	284	°C
Average surface temperature - Top	250	°C
Temperature at Discharge opening	1110	°C
Temperature at Charge opening	350	°C
Surface area - main body	0.75999848	m^2
Surface area - front & back	0.46580552	m^2
Surface Area - Top	0.37999924	m^2
Area - Discharge opening	0.02516124	m^2
Area - Charge opening	0.03145155	m^2
Material temperature at furnace exit	1110	°C
Material Feeding Rate	129.18	kg/hr
Material Feeding Rate	904.26	kg/day
Standard Data		
Specific heat of water	1	kcal/kg °C
Specific Heat of steel	0.12	kcal/kg °C
Specific Heat of coal	0.25	kcal/kg °C
Specific heat of air	0.24	kcal/kg °C
specific heat of water vapour at flue gas tempe	0.52	kcal/kg °C
Enthalpy of steam at flue gas temperature	640	kcal/kg
Enthalpy of water at supply air temperature	40	kcal/kg
Specific Heat of flue gas	0.3319	kcal/kg °C
Moisture content of supply air	0.019	kg/kg of air

		Results Sheet
Efficiency Calculation of Furnace		
Name of unit	Karim bux	
No. of Furnaces	1	
Type of furnace	Plier	
Application of furnace	200mm	
Raw material under process	EN8	
Production Capacity	0.904	TPD
Material feeding rate	129.18	kg/hr
Fuel Consumption rate	11.57	kg/hr
Specific heat of the material	0.12	kcal/kg ^oC
Material temperature at furnace entry	40	^oC
Material temperature at furnace exit	1110	^oC
Furnace efficiency by direct method	**13.2**	**%**
Furnace efficiency by heat loss method		
Stoichiometric air required for combustion	12.913	kg/kg of fuel
Theoretical max. CO_2	17.44	%
Measured O_2 in flue gas	7.3	%
Measured CO in flue gas	125	ppm
Excess air used for combustion	53.28	%
Corresponding CO_2	11.38	%
Total air used for combustion	19.79	kg/kg of fuel
Heat loss due to dry flue gas	65.36	%
Heat loss due to moisture in fuel	0.019	%
Heat loss due to Hydrogen in fuel	7.24	%
Heat loss due to moisture in air	1.82	%
Heat loss due to CO formation	0.05	%
Heat loss due to radiation & openings	6.43	%
Heat loss in scale generation	0.60	%
Heat content in the material	13.18	%
Unaccounted loss	5.30	%

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