BEE's National Program
on
Energy Efficiency and Technology Up-gradation in SMEs

Ludhiana Forging Cluster

Post Implementation Audit Report
Bharat International




Submitted to

ENERGY IS LIFE
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Submitted by

InsPIRE

InsPIRE Network for Environment

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Preface

The project titled "BEE's National Program on Energy Efficiency and Technology Up-gradation in SMEs" supported by Bureau of Energy Efficiency (BEE), Ministry of MSME and Ludhiana Auto Parts Manufacturers Association aims to bring down the energy demand of MSME industries located at Ludhiana Forging cluster. The project aims to support the MSME units in Ludhiana cluster to implement Energy Efficient Technologies.

There are more than 1500 Small and Medium Enterprise (SME) forging units operating in the various industrial pockets in and around Ludhiana, manufacturing products suitable for automotive, industrial and agricultural sector. The project aims to initially diffuse energy efficient technologies in selected units in the cluster. These units will act as demonstration units for long term and sustainable penetration of energy efficient technologies in the entire cluster. InsPIRE Network for Environment, New Delhi has been appointed as the executing agency to carry out the following activities in the cluster:

- Conducting pre-activity cluster workshop in the cluster.
- Conducting initial walk through audits in 5 representative units of the cluster.
- Identify and proposes BEE on energy efficient process technologies, relevant to the cluster, with highest energy saving and replication potential, and their cost benefit analysis.
- Identify local technology/service providers (LSP) for the above technologies in the cluster
- Identify SME units willing to implement and demonstrate the energy efficient technologies
- Assist BEE to enter into a contract with each of the shortlisted SME units to enable implementation and showcasing of Energy Efficient technology.
- Conduct comprehensive Baseline Energy Audits in the shortlisted SME units wherein these technologies can be implemented and document the findings in the form of a report.
- Develop technology specific case studies (Audio-Visual and print) for each technology
- Prepare Best Operating Practices (BOP) document for the top 5 energy using equipment / process in the industry cluster
- Enumeration of common regularly monitorable parameter at the process level which have impact on energy performance, and listing of appropriate instrumentation for the same with options including make, supplier, indicative cost specifications and accuracy of measurements.
- Carry out post implementation energy audit in the implemented units to verify energy savings as a result of EE technology implementation.
- Verify and submit to BEE all the relevant documents of each participating unit owner indicating his complete credentials, proof of purchasing the equipment, evidence of implementation and commissioning of the EE technology in the unit.

Based on the confirmation on installation from a unit, a 5 member team consisting of Shri Tarun Dixit, Project Engineer, BEE; Shri Madhur Gupta, Financial Expert, Ludhiana Forging Cluster, Shri Arindam Mukherjee, Sr. Program Officer; Shri S. Vamsi Krishna, Program Officer and Shri Chaman Shukla, Sr. Program Associate from InsPIRE Network for Environment carried out a cross-verification of the implementation. As part of the activities under the energy efficiency program in Ludhiana Forging cluster, post implementation energy audits in 8 forging units under Ludhiana cluster was conducted in the month of June'2016. This specific audit report details the findings of the post implementation energy audit study carried out at ***Bharat International.***

Executive Summary

1. Unit Details

Unit Name	:	**Bharat International**
Address	:	C-27, Focal Point, Ludhiana – 141010, Punjab
Contact Person	:	Mr. Gurpreet Singh Kahlon (Cell No. 9914188832)
Products	:	Bolts, Nuts, Washers and Auto Parts
Production	:	1 – 2 Tons/day
DIC Number	:	030091200251 (Part-II)
Bank Details	:	State Bank of India; Miller Ganj Branch - Ludhiana Account Number, 10330878666, IFSC Code –SBIN0000731
TIN / PAN No.	:	PAN: AABFB09453; TAN: JLDB01169A
Contract demand	:	400 kVA

2. Energy Efficient Technologies implemented vis-à-vis baseline energy audit recommendation

Technology recommended as per baseline energy audit (as approved by steering committee)	Technology implementation and cross-verified during post implementation energy audit
Induction Heater (50 kW)	Induction Heater (50 kW)
SPM machine – Turning (2 Nos.)	SPM machine – Turning (2 Nos.)
SPM machine- Drilling	SPM machine- Drilling

3. Cost Economics Analysis: Projected (as per baseline) vs. Actual

Technology	Estimated Energy Savings (%)	Savings	Investment	Simple Payback period (years)
Installation of Induction Heater (50 KW)				
Baseline (Projected)	73	628,128	936,510	1.50 years
Post Implementation (Actual)	81	1,012,487	731,745	0.72 years
SPM machine – Turning (1)				
Baseline (Projected)	81	194,706	5,50,000	2.82 years
Post Implementation (Actual)	78	187,992	5,30,250	2.82 years
SPM machine – Turning (2)				
Baseline (Projected)	81	194,706	5,50,000	2.82 years
Post Implementation (Actual)	82	264,492	5,30,250	2.00 years
SPM machine- Drilling				
Baseline (Projected)	73	65,880	350,000	5.30 years
Post Implementation (Actual)	55	64,356	371,175	5.77 years

4. Project Impacts

Energy Efficient Technology implemented	Percentage Savings in specific energy consumption from baseline (%)	Annual Energy Savings (TOE)	Annual CO_2 emission reduction (tCO_2/year)
Induction Heater	81	25.16	27.16
SPM machine – Turning (1)	78	2.16	22.56
SPM machine – Turning (2)	82	3.03	31.74
SPM machine- Drilling	55	0.74	7.72

Assumptions / conversion factors:

- Calorific Value of FO has been considered as 10,200 kcal / kg
- 1 TOE (tonnes of oil equivalent) = 0.0148 TJ (Tera Joule)
- Emission factor LPG has been taken as 72.93 t CO 2 per TJ (IPCC Guideline)
- CO_2 emission reduction calculation has been done based on equivalent reduction in annual energy consumption.

Introduction

1.1 MSME SECTOR – AN OVERVIEW

The MSME sector is an important pillar of Indian economy as it contributes greatly to growth of Indian economy with a vast network of around 30 million units, creating employment of about 70 million, manufacturing more than 6000 products, contributing about 45% to manufacturing output and about 40% of exports, directly and indirectly. This sector even assumes greater importance now as the country moves towards a faster and inclusive growth agenda. Moreover, it is the MSME sector which can help realize the target of proposed National Manufacturing Policy of raising the share of manufacturing sector in GDP from 16% at present to 25% by the end of 2022. However, owing to the recent insecure market conditions and escalating energy expense, the economic scenario of MSME sector, is transpiring gloomier endangering the long term profitability, competitiveness and sustainability.

However, a significant portion of the MSME units are energy-intensive where the cost of energy is 20-40% of the production cost, which implies huge energy saving potential. A study by BEE appraises the total energy efficiency market in India as INR 74,603 crore out of which, the share for MSME sector has been estimated at INR 12100 crore. But, in spite of huge energy efficiency potential in MSME sector, it is hurdled largely by following major barriers:

- Obsolete technology and lack of access to modern technological solutions resulting in low productivity.
- Very few programs to support technology development.
- Lack of local service providers to sustain energy efficient technologies.
- Lack of knowledge, financing and dedicated personnel for identifying energy efficiency improvements & opportunities.
- 90% of units are proprietorship concerns, which are limited on their managerial skills as well as amenability to new ideas.
- Perceptions of Energy efficiency measures are financially unviable.
- MSME units are reluctant to change & seek external technical assistance.

In the wake of the need, Government of India has set ambitious target of energy saving of 44.85 BU at consumer side by the terminal year 2016-17 of 12th Five year Plan which is equivalent to 60.17 BU on Bus bar side translating into 12,350 MW avoided capacity. In addition, total thermal energy saving equivalent to 21.30 Mtoe is targeted.

1.2 BEE-SME PROJECT AT A GLANCE

Under the 12th Five Year Plan, the Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India, has taken an ambitious program on energy efficiency and technology upgradation in SME clusters in India. The program titled "BEE's National Program on Energy Efficiency and Technology Upgradation in SMEs" is being implemented by BEE with support from Ministry of MSME in five selected clusters in India. These clusters include Ludhiana, Punjab; Pali, Rajasthan; Kochi, Kerala; Indore, Madhya Pradesh and Varanasi, Uttar Pradesh. The project aims to set up demonstration units in these clusters, wherein energy efficient technologies will be implemented. Efforts will also be made to replicate the successful technologies and wider penetration of energy efficient technologies in the sector as a whole. The key components of the project include:

- Conducting pre-activity cluster workshop in the cluster.
- Conducting initial walk through audits in 5 representative units of the cluster.
- Approve energy efficient process technologies, relevant to the cluster, with highest energy saving and replication potential, and establish their cost benefit analysis.
- Identify local technology/service providers (LSP) for the above technologies in the cluster
- Identify SME units willing to implement and demonstrate the energy efficient technologies
- Enter into a contract with each of the shortlisted SME units to enable implementation and showcasing of Energy Efficient technology.
- Conduct comprehensive Baseline Energy Audits in the shortlisted SME units wherein these technologies can be implemented and document the findings in the form of a report.
- Support the units towards implementation of energy efficient technologies.
- Carry out post implementation energy audit in the implemented units to verify energy savings as a result of EE technology implementation.
- Develop technology specific case studies (Audio-Visual and print) for each technology
- Prepare Best Operating Practices (BOP) document for the top 5 energy using equipment / process in the industry cluster
- Enumeration of common regularly monitorable parameter at the process level which have impact on energy performance, and listing of appropriate instrumentation for the same with options including make, supplier, indicative cost specifications and accuracy of measurements.
- Release of financial incentive to units on submission of the relevant documents of each participating unit owner indicating his complete credentials, proof of purchasing the equipment, evidence of implementation and commissioning of the EE technology in the unit.

The forging cluster located at Ludhiana, Punjab is one of the selected clusters under the BEE-SME program.

1.3 LUDHIANA FORGING CLUSTER – AN INSIGHT

Ludhiana is one among the biggest forging cluster in India consisting of over 1500 units, manufacturing a wide range of products, suitable for the use of automotive, agricultural and other engineering industry. A significant portion of the manufactured goods are also exported from the cluster. The units usually get raw materials in the form of steel and other ferrous products from the local industries and process the same using forging, machining and finishing process. The finished product is directly dispatched for the use of the target industry. The units are located in clusters in areas such as Focal Point (Ludhiana), Industrial Area (Jalandhar City), Industrial Area (Phagwara) and Industrial Area (Moga). Electricity is the main source of energy in these units. Majority of the units uses free hammer to forge the heated steel. The temperature required for forging is around 1150 - 1200 ^{o}C.

Despite being in large numbers, most of the units in the clusters are un-organized, using obsolete and high energy consuming equipment. Also, the cluster has seen limited development in terms of technology up gradation and automation, over the years. Some of the important barriers towards accelerated adoption of energy efficient technologies have been lack of knowledge, lack of government scheme to support technology up gradation, lack of skill manpower and lack of financing options available with these units. Because of the lower penetration about the knowledge of energy efficient technologies in the cluster, the units has been using age old practices of manual lathes for machining and batch furnaces for heating operations.

Twenty (20) units were selected from the cluster with the purpose of conducting baseline audit. Out of these, eight (8) nos. of units has completed implementation, within the stipulated time period and as per the guidelines of implementation.

1.4 ABOUT THE UNIT

Bharat International was started it commercial production in 1996 and is engaged in manufacturing of different types of bolts, nuts, washers and auto fasteners in various sizes as per the requirements of various customer spread in Pan India basis. The manufacturing unit is located at C-27, Focal Point, Ludhiana – 141003, Punjab.

The raw material used by the unit for making bolts and other auto components include Mild Steel, EN8, and EN15.

The he daily production of the unit lies in the range of 1 to 2 tons per day. Bharat International is using energy in the form of electricity supply from Punjab State Electricity Board, for various process and utility applications in its premises. The average monthly FO consumption in the unit (during baseline study) was 673 liters. During baseline energy audit, it was observed that the average monthly electricity consumption was 46,900 kWh.

1.5 PROJECT IMPLEMENTATION METHODOLOGY

The BEE's National Program on Energy Efficiency and Technology Upgradation at Ludhiana Forging Cluster followed the following implementation methodology:

Figure 1.1: ***Project implementation methodology***

1.6 PRODUCTION PROCESS OF PLANT

The following figure shows the typical process employed at manufacturing of forged products at Bharat International, Ludhiana:

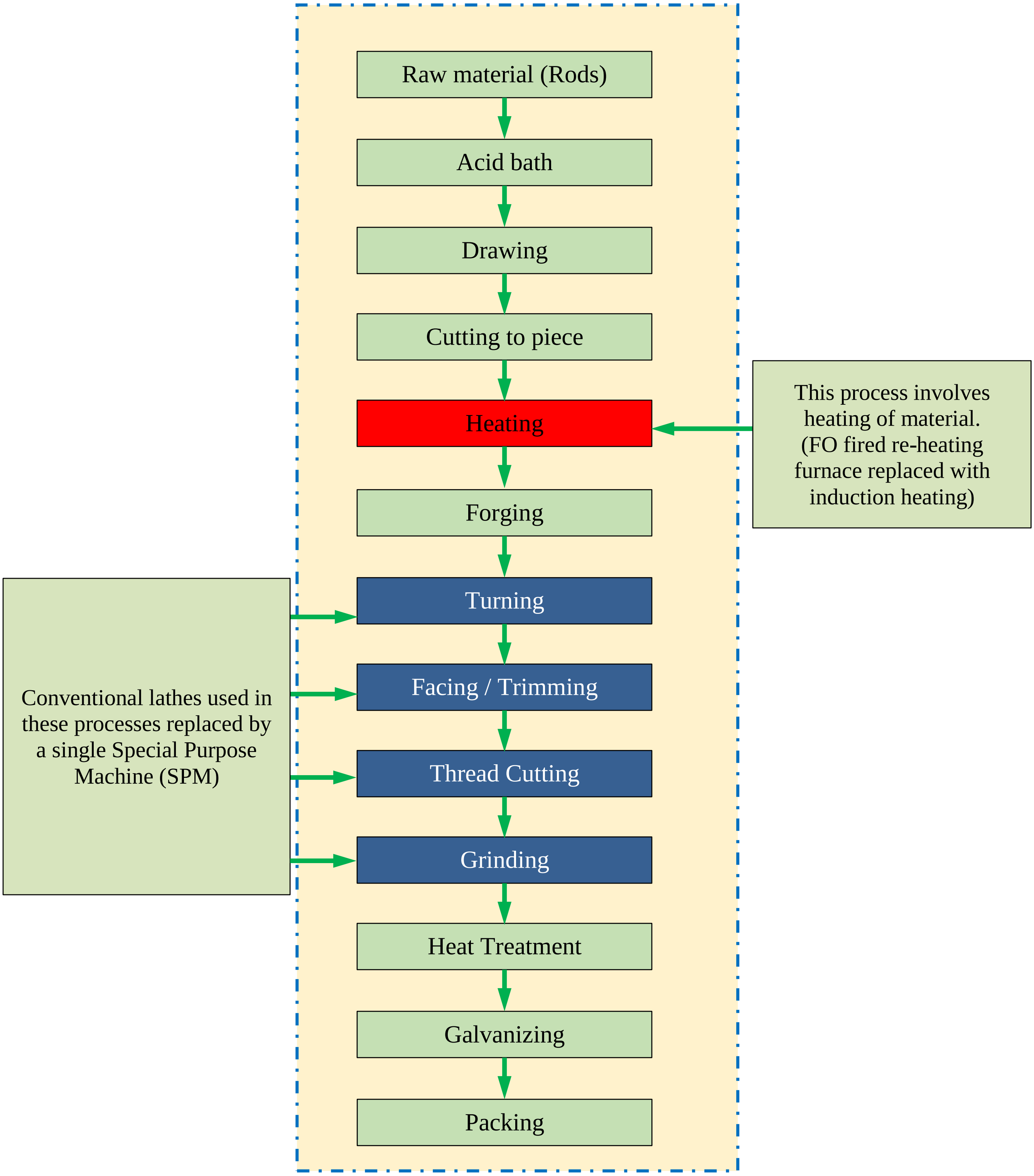


Figure 1.2: ***Production process***

1.7 ENERGY AUDIT METHODOLOGY

The primary objective of the baseline energy audit was to quantify the baseline energy consumption pattern and identify technologies which can lead to reduction in energy consumption. Based on the suggestions under the baseline audit, the units have implemented the technologies. The primary objective of the post implementation energy audit is cross-verify the implementation and document the impact. The key points targeted through energy audits were determination of specific energy consumption, both thermal and electrical, productivity etc. Pre – planned methodology was followed to conduct the energy audits. The energy audit methodology followed for baseline and post implementation energy audits is depicted in ***Figure 1.3*** below:

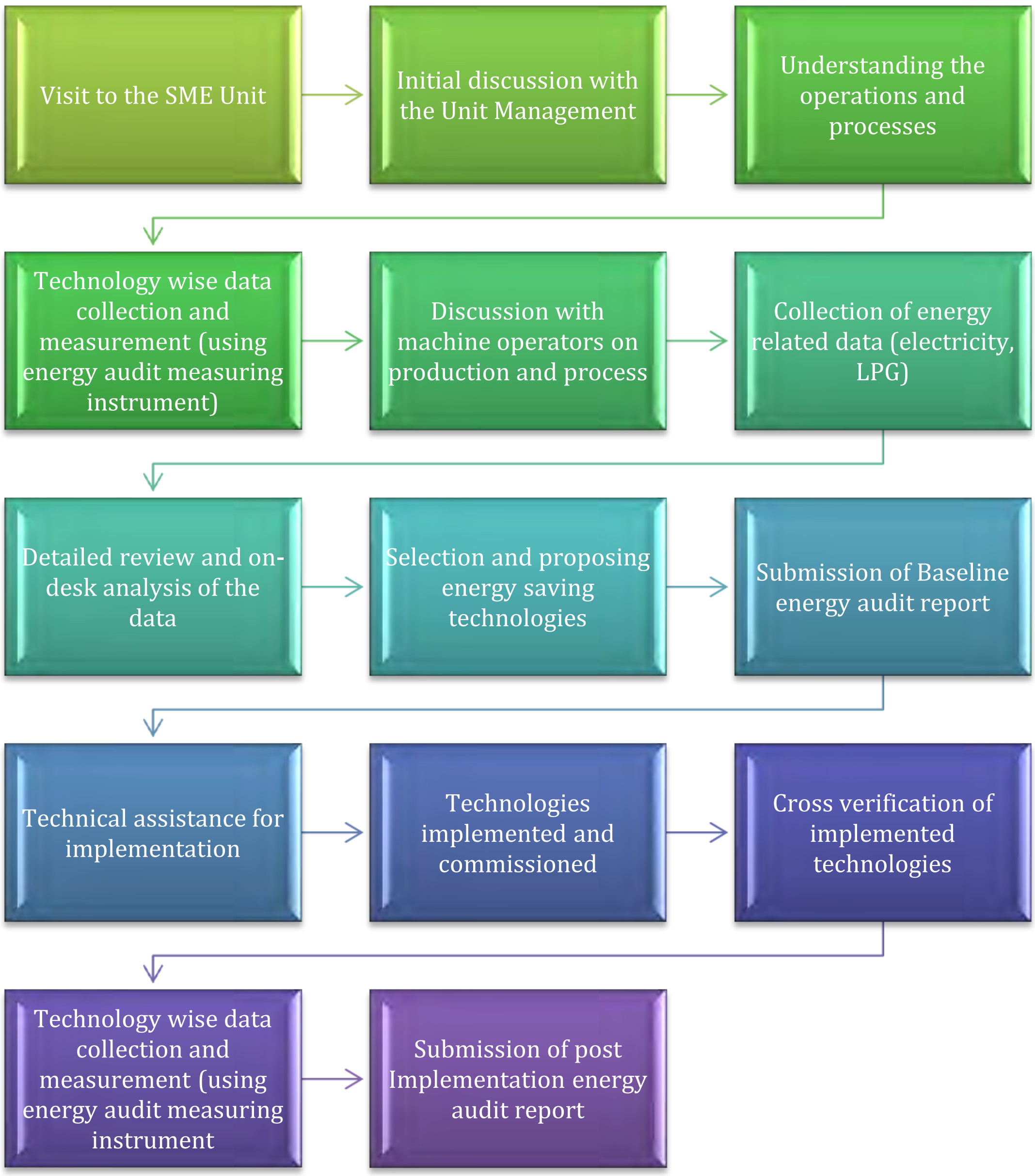


Figure 1.3: *Energy audit methodology*

CHAPTER 2:

Post Implementation Energy Audit Outcome and Results

2.1 INSTALLATION OF INDUCTION HEATER (50 KW)

2.1.1 Baseline Scenario

During the baseline energy audit, M/s Bharat International was using a Furnace Oil (FO) fired batch type re-heating furnace to heat the metal pieces for forging. In a batch type re-heating furnace, the metal pieces are kept inside the furnace and heated for a period of 30 – 45 mins, depending upon the size/shape of the metal piece and final product to be formed. The metal piece to be forged is heated to a temperature of 1150~1200 deg. C. After the heating process, the red hot metal piece is kept on the forging die (using a tong) having the cavity of the product to be formed. The hot metal piece is forged using a free hammer on the forging press and the metal piece attains the required shape of the die. The re-heating furnace, used by the unit, was old having conventional design with manual control option for fuel firing. A large quantity of heat was seen penetrating from the furnace opening. Thus, the efficiency of the furnace was low. Further, the flame of the furnace directly touched the surface of the metal leading to high burning loss and scale formation due to oxidation ultimately leading to material/ production loss. In addition, the atomic/grain structure of the metal is deteriorated by this process.

Figure 2.1: ***Oil fired re-heating furnace (Presently dismantled)***

2.1.2 Present Scenario

Based on the recommendation made as per the baseline energy audit, the conventional FO based re-heating furnace has been replaced by induction heating system of capacity 50 kW. As the Induction heater attains instant heating the metal can be able to reach the desired temperature within 6- 8 sec, thereby increasing the productivity by 3 to 4 times. The operating principle and benefits of using an induction heating system has been summarized below:

Induction heating is the process of heating an electrically conducting object by electromagnetic induction, where eddy currents are generated within the metal and resistance leads to Joule heating of the metal. So it is possible to heat a metal without direct contact and without open flames or other heat sources (like IR). An induction heater consists of an electromagnet (coil), through which a high-frequency alternating current (AC) is passed. The frequency of AC used depends on the object size, material type, coupling (between the work coil and the object to be heated) and the penetration depth. An induction heating system is composed by an inductor (to generate the magnetic field) and a converter (to supply the inductor with a time-varying electrical current).

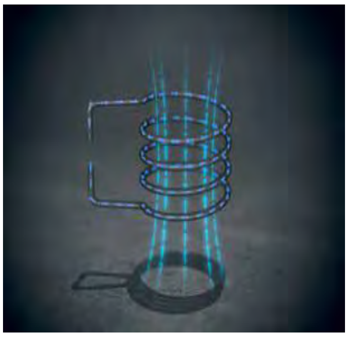
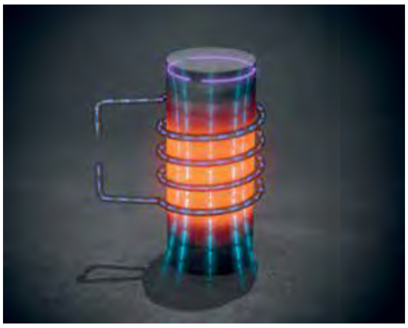


Figure 2.2: ***Induction heating coil***

- **Operating Principle:**

Alternating current flowing through an electro-magnetic coil generates a magnetic field. The strength of the field varies in relation to the strength of the current passing through the coil. The field is concentrated in the area enclosed by the coil;



Eddy currents are induced in any electrically conductive object—a metal bar, for example—placed inside the coil. The phenomenon of resistance generates heat in the area where the eddy currents are flowing. Increasing the strength of the magnetic field increases the heating effect. However, the total heating effect is also influenced by the magnetic properties of the object and the distance between it and the coil. In case of the forging process, the induction heating system is used to heat the metal bar to the forging temperature which is typically 1150-1200 0C depending on the material.

- **Use of Induction Heating in Forging Process:**

Forging is a process where metal is formed into shape using pressure applied by an impact hammer or press. It is one of the oldest known metal working processes. Metals can be forged cold, warm or hot. Cold forging is used for forming softer materials and smaller steel parts, but this process hardens the material making it brittle and difficult to process after forging.

Hot forging is a process where the part is heated above the material recrystallization temperature before forging, typically 1100°C (2012°F) for steel. Hot forging allows a part to be formed with less pressure, creating finished parts with reduced residual stress that are easier to machine or heat treat. Warm forging is forging a part below the recrystallization temperature, typically below 700°C (1292°F). As a superior alternative to furnace heating, induction heating provides faster, more efficient heat in forging applications. The process relies on electrical currents to produce heat within the part that remains confined to precisely targeted areas. High power density means extremely rapid heating, with exacting control over the heated area.

Recent advances in solid-state technology have made induction heating a remarkably simple and cost-effective heating method. Benefits of using Induction heating for forging are:

- Rapid heating for improved productivity and higher volumes
- Precise, even heating of all or only a portion of the part
- A clean, non-contact method of heating
- Safe and reliable – instant on, instant off heating
- Cost-effective, reduces energy consumption compared to other heating methods
- Easy to integrate into production cells
- Reduced scaling

2.1.3 Energy saving and Cost Economics Analysis (baseline vis-à-vis post implementation)

The table below summarizes the post implementation energy consumption figures of the unit vis-à-vis the baseline energy audit data at M/s Bharat International, Ludhiana:

Parameter	Unit	Value
Baseline Scenario		
Furnace oil consumption on re-heating furnace	Ltr/hr	7.00
Productivity in terms of Kg	Kg/hour	36.00
Specific energy consumption on FO based re-heating furnace	Ltr/Kg	0.1944
Specific fuel consumption in terms of kcal	kcal/kg	1983.33
Cost of energy consumption	Rs./Kg	9.72
Annual production (based on baseline productivity)	Kg/annum	86400
Post Implementation Scenario		
Power consumed by induction Heater (based on on-site measurement) Note: Induction Heater was observed to be running at 60 % loading	kWh	28.01
Productivity in terms of Kg	Kg/hr	65
Specific energy consumption on Induction Heater	kWh/Kg	0.43
Specific fuel consumption in terms of kcal	kcal/kg	370.59
Cost of energy consumption	Rs/kg	3.23
Annual production (based on post implementation productivity)	Kg/annum	156000
Savings		
Reduction in cost of energy	Rs/kg	6.5
Reduction in specific energy consumption in kcal	kcal/kg	1612.7
Annual Cost Savings (in terms of post implementation productivity)	Rs	1012487
Annual Cost Savings (in terms of baseline productivity)	Rs	561600
Annual Reduction in Energy Consumption (in terms of post implementation productivity)	toe	25.16
Annual Reduction in Energy Consumption (in terms of baseline productivity)	toe	13.93
Percentage reduction in energy consumption	%	81.31
Investment made Induction Heater (50 kW)	Rs	731745
Simple payback period (based on post implementation productivity)	years	0.72
Simple payback period (based on baseline productivity)	years	1.30
Annual CO_2 emission reduction (based on post implementation productivity)	t CO_2/year	27.16

Assumption / conversion factors:

- Specific gross calorific value of FO has been considered as 10,200 kcal /kg
- 1 TOE (tonnes of oil equivalent) = 0.0148 TJ (Tera Joule)
- Emission factor FO has been considered as 72.93 t CO_2 per TJ (as per IPCC guideline)
- CO_2 emission reduction calculation has been considered based on equivalent reduction in CO_2 emission

Inference:

The energy cost saved per kg of forged material is Rs. 6.5. The actual investment made to implement the energy efficient induction heater technology is Rs 7.31 lakhs with annual saving of Rs. 10.12 Lakhs. Thus, the investment made will be recovered within 0.72 years, if we consider the post implementation productivity.

2.1.4 Snap-shot of implementation (before and after)

A comparison of the snap-shots of FO based re-heating furnace used during the baseline vis-à-vis the induction heating system used in the post implementation study has been shown below:

Figure 2.3: *Snap shot of FO based re-heating furnace at Bharat International (presently dismantled)*

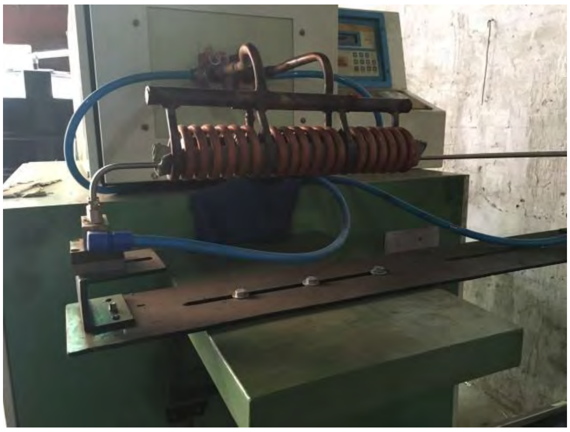


Figure 2.4: *Induction heater of capacity 50kW installed at Bharat International*

2.2 INSTALLATION OF SPECIAL PURPOSE MACHINE

2.2.1 Baseline Scenario

During the baseline energy audit studies, the unit was using manually operated conventional machines for various machining job work like facing, turning, grinding, drilling etc. These machine runs on electrical motors having the capacity varying from 2 HP to 10 HP with production/ machining of 1000~1500 pieces per day. Since these machines are manually operated, the process through which components are manufactured is very slow and time consuming. Apart from the slow process, it is also difficult to maintain the quality of the product in case of manual machining. It often observed that the machine operate ideally (without any component loaded on to the machines) and the operator is busy in doing some other work/activity. All these factors lead to valuable resource; energy, manpower, time and money. Conventional machines includes manually operated lathe, drilling, threading machines. A particular job work needs to be machined worked in two to three machines for completion. E.g. A metal piece is first fed into the lathe for turning and facing operation. After this, the job needs to be transferred to some other machine for threading operations and drilling needs to be done in a third machine. In some cases, the trimming operation is done in a separate machine. Thus, for a single job work, a number of machines are required which leads to lower productivity, higher energy consumption and lower efficiency due to manual intervention in each process.

Figure 2.5: ***Conventional Lathe Machine***

2.2.2 Present Scenario

The conventional lathe machine has been replaced by automatic special purpose machine (SPMs). These machines run on pre-installed programs, and are equipped to carry out multi-tasking at a single time. Thus, consumption of electricity only happens when there is a function or operation required on the component. In the ideal condition the machine remains in dead mode/ no operation mode. The machine also has an automatic feeder to automatically loads the component for machining. The cycle time of the each component is fixed in the business logic of the PLC / SPM, therefore each component will take specific time for processing or machining. The SPM machines results in 30-50% percent of the energy savings depending upon the type of component, operation, material, cycle time. The details and operating principle of SPM has been summarized below.

A **Special Purpose Machine (SPM)** is a kind of multi-tasking machine used for machining purpose. A special purpose machine is used as a replacement to conventional machines like lathe, drilling or trimming machine. A special purpose machine is designed based on the customized requirement of a unit and may be used for one or multiple task as per the design. For example, a conventional lathe machine takes 3 mins (say) to machine (turn) a metal piece. Thereafter it is transferred to another machine for facing and trimming operations. In some cases, a third machine is used for threading operations. A special purpose machine specifically designed can replace all the three machines with a single machine. The replaced special purpose machine can perform all the four activities i.e. turning, facing, trimming, and threading on sequential manner. The sequence of operation is pre-set using timers and sensors. The entire operation is maintained using pneumatic and mechanical control. For ease of operation, each special purpose machine is equipped with an automatic feeder. Replacement of conventional machines with special purpose machines usually increases machine productivity by 5 times, easing the life of the operators by avoiding manual intervention during each operation.

▸ Operating Principle

A special purpose machine (SPM) is usually customized based on the specific requirement of a unit. A SPM is used for multi-task operation, which are typically performed in more than one conventional machine. The sequence of operation in a SPM is pre-set using timers and sensors. Usually, a SPM is equipped with two or more machine tools fitted in different axis. The operations are carried out in sequential manner. The axial motion of the machine tool is usually powered by pneumatic controls, whereas positioning of the tool is done using sensors. A particular operation e.g. turning operation in a metal piece of 400 mm is pre-set using timers. Once the operation is over, the sensor directs the next sequence of operations, which are also pre-fed programs in the machine. Thus, manual intervention in each operation can be prevented. Also, two or more operational can

Figure 2.6.: ***Special Purpose Machine- Turning***

Similar is the case for SPM-drilling machine, where the time taken in conventional drilling machine which performs one drilling operation at a time, can be significant reduced by simultaneously performing two or more drilling operations at a time.

2.2.3 Energy saving and Cost Economics Analysis (baseline vis-à-vis post implementation)

The table below summarizes the post implementation energy consumption figures of the unit vis-à-vis the baseline energy audit data at M/s Bharat International

Parameter	Unit	Value
Baseline Scenario		
Power consumed by conventional turning machine (one machine of 2 hp)	kW	1.49
Productivity on conventional turning machine	Pcs/hr	50
Specific power consumption on conventional machine	kWh/Pcs	0.030
Specific fuel consumption in terms of kcal	kcal/pcs	25.662
Cost of energy consumption	Rs/pcs	0.224
Annual production (based on baseline productivity)	pcs/annum	120000
Post Implementation Scenario		
Power consumed by 1 nos. SPM turning machine (based on actual on-site measurement) Note: SPM machine was observed to be running at 80% loading)	kW	2.984
Productivity on SPM turning machine	Pcs/hr	450
Specific power consumption on SPM	kWh/Pcs	0.007
Specific fuel consumption in terms of kcal	kcal/pcs	5.703
Cost of energy consumption	Rs/pcs	0.050
Annual production (based on post implementation productivity)	pcs/annum	1080000
Savings		
Reduction in cost of energy	Rs/pcs	0.17
Reduction in specific energy consumption in kcal	kcal/pcs	20.0
Annual Cost Savings (in terms of post implementation	Rs	187992

Parameter	Unit	Value
production)		
Annual Reduction in Energy Consumption (in terms of post implementation production)	toe	2.16
Percentage reduction in energy consumption	%	77.78
Investment made on SPM turning machine	Rs	530250
Simple payback period	years	2.82
Annual CO_2 emission reduction (based on post implementation productivity)	t CO_2/year	22.56

Assumption / conversion factors:

- 1 toe = 0.0148 TJ
- Emission factor power is 0.9 tCO2 per MWh
- CO_2 emission reduction calculation has been considered based on equivalent reduction in energy consumption

The energy cost saved per piece of forged material is Rs. 0.17. The actual investment made to implement the energy efficient SPM technology is Rs 5.30 lakhs with annual saving of Rs. 1.87 Lakhs. Thus, the investment made will be recovered within 2.82 years.

2.2.4 Snap-shot of implementation (before and after)

A comparison of the snap-shots of conventional lathe machine used during the baseline vis-à-vis the Special Purpose Machine used in the post implementation study has been shown below:

Figure 2.7: *Snap shot of conventional lathe machine at Bharat International*

Figure 2.8: *Special Purpose Machine installed at Bharat International*

2.2.3 Energy saving and Cost Economics Analysis (baseline vis-à-vis post implementation)

The table below summarizes the post implementation energy consumption figures of the unit vis-à-vis the baseline energy audit data at M/s Bharat International

Parameter	Unit	Value
Baseline Scenario		
Power consumed by conventional turning machine (one machine of 2 hp)	kW	1.49
Productivity on conventional turning machine	Pcs/hr	50
Specific power consumption on conventional machine	kWh/Pcs	0.030
Specific fuel consumption in terms of kcal	kcal/pcs	25.662
Cost of energy consumption	Rs/pcs	0.224
Annual production (based on baseline productivity)	pcs/annum	120000
Post Implementation Scenario		
Power consumed by 1 nos. SPM turning machine (based on actual on-site measurement) Note: SPM machine was observed to be running at 80% loading)	kW	3.21
Productivity on SPM turning machine	Pcs/hr	600
Specific power consumption on SPM	kWh/Pcs	0.005
Specific fuel consumption in terms of kcal	kcal/pcs	4.601
Cost of energy consumption	Rs/pcs	0.040
Annual production (based on post implementation productivity)	Pcs/annum	1440000
Savings		
Reduction in cost of energy	Rs/pcs	0.18
Reduction in specific energy consumption in kcal	kcal/pcs	21.1
Annual Cost Savings (in terms of post implementation production)	Rs	264492
Annual Reduction in Energy Consumption (in terms of post implementation production)	toe	3.03
Percentage reduction in energy consumption	%	82.07
Investment made on SPM turning machine	Rs	530250
Simple payback period	years	2.00
Annual CO_2 emission reduction (based on post implementation productivity)	t CO_2/year	31.74

Assumption / conversion factors:

- 1 toe = 0.0148 TJ
- Emission factor power is 0.9 tCO2 per MWh
- CO_2 emission reduction calculation has been considered based on equivalent reduction in energy consumption

The energy cost saved per piece of forged material is Rs. 0.18. The actual investment made to implement the energy efficient SPM technology is Rs 5.30 lakhs with annual saving of Rs. 2.64 Lakhs. Thus, the investment made will be recovered within 2 years.

2.2.5 Snap-shot of implementation (before and after)

A comparison of the snap-shots of conventional lathe machine used during the baseline vis-à-vis the Special Purpose Machine used in the post implementation study has been shown below:

Figure 2.9: *Snap shot of conventional lathe machine at Bharat International*

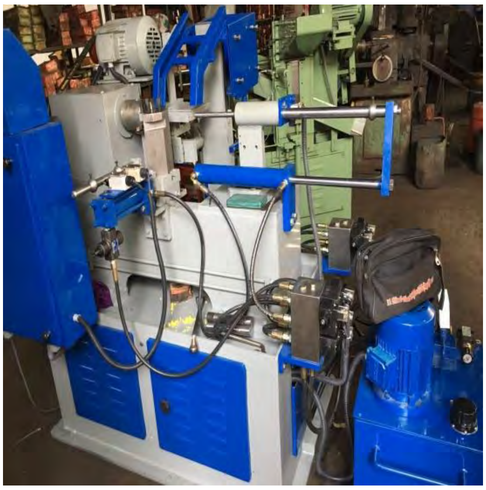


Figure 2.10: *Special Purpose Machine installed at Bharat International*

2.2.4 Energy saving and Cost Economics Analysis (baseline vis-à-vis post implementation)

The table below summarizes the post implementation energy consumption figures of the unit vis-à-vis the baseline energy audit data at M/s Bharat International

Parameter	Unit	Value
Baseline Scenario		
Power consumed by conventional drilling machine (one machine of 2 hp)	kW	1.49
Productivity on conventional drilling machine	Pcs/hr	90
Specific power consumption on conventional machine	kWh/Pcs	0.017
Specific fuel consumption in terms of kcal	kcal/pcs	14.257
Cost of energy consumption	Rs/pcs	0.124
Annual production (based on baseline productivity)	Pcs/annum	216000
Post Implementation Scenario		
Power consumed by SPM drilling machine (based on actual on-site measurement) Note: SPM machine was observed to be running at 80% loading)	kW	2.89
Productivity on SPM turning machine	Pcs/hr	390
Specific power consumption on SPM	kWh/Pcs	0.007
Specific fuel consumption in terms of kcal	kcal/pcs	6.373
Cost of energy consumption	Pcs/kg	0.056
Annual production (based on post implementation productivity)	Pcs/annum	936000
Savings		
Reduction in cost of energy	Rs/pcs	0.07
Reduction in specific energy consumption in kcal	kcal/pcs	7.9
Annual Cost Savings (in terms of post implementation production)	Rs	64356
Annual Reduction in Energy Consumption (in terms of post implementation production)	toe	0.74
Percentage reduction in energy consumption	%	55.30

Parameter	Unit	Value
Investment made on SPM drilling machine	Rs	371175
Simple payback period	years	5.77
Annual CO_2 emission reduction (based on post implementation productivity)	t CO_2/year	7.72

Assumption / conversion factors:

- 1 toe = 0.0148 TJ
- Emission factor power is 0.9 tCO2 per MWh
- CO_2 emission reduction calculation has been considered based on equivalent reduction in energy consumption

The energy cost saved per piece of forged material is Rs. 0.07. The actual investment made to implement the energy efficient SPM technology is Rs 3.71 lakhs with annual saving of Rs. 0.64 Lakhs. Thus, the investment made will be recovered within 5.77 years.

2.2.4 Snap-shot of implementation (before and after)

A comparison of the snap-shots of conventional lathe machine used during the baseline vis-à-vis the Special Purpose Machine used in the post implementation study has been shown below:

Figure 2.11: *Snap shot of conventional drilling machine at Bharat International*

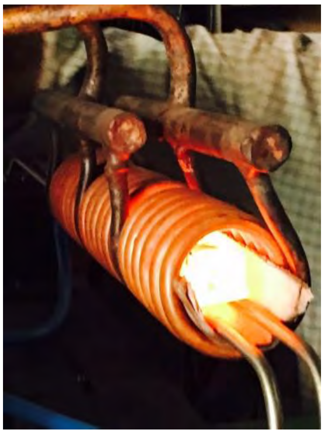
Figure 2.12: *Special Purpose Machine (drilling) installed at Bharat International*

Unit Photographs

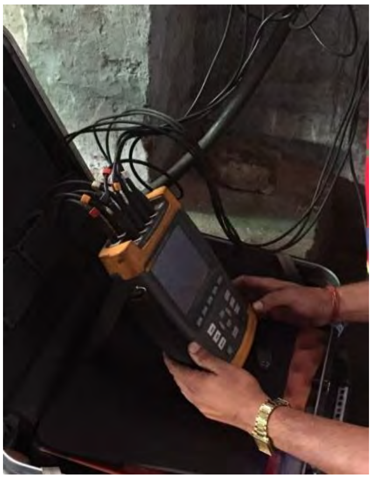
Caption: Special Purpose Machine for Turning Operations at Bharat International

Caption: Conventional Re-heating furnace at Bharat International (Dismantled presently)

Caption: Induction heater coil at Bharat International



Caption: Induction heating process at Bharat International



Caption: Energy audit at Bharat International

Caption: Forging operation at Bharat International

Base Executive Summary

Executive Summary

1. Unit Details

Unit Name	:	**Bharat International**
Address	:	C-27, Focal Point, Ludhiana – 141010, Punjab
Contact Person	:	Mr. Gurpreet Singh Kahlon (Cell No: 9914188832)
Products	:	Bolts, Nuts, Washers and Auto parts
Production	:	1 - 2 Tons/ day
DIC Number	:	030091200251 (Part-II)
Bank Details	:	State Bank of India, Miller Ganj Branch – Ludhiana Account No.: 10330878666, IFSC Code – SBIN0000731
TAN / PAN No.	:	PAN: AABFB09453; TAN: JLDB01169A
Contract demand	:	400 kVA

2. Existing Major Energy Consuming Technology

FO Based re-heating technology

- Conventional Technology with higher losses
- Prevailing energy consumption is 0.194 liters of FO per kg of the production

Lathe Machine

- Manually operated lathe machines for machining job work including threading, turning, grinding, drilling etc.
- Electrical motor rating of 2-3 HP with production of 40- 90 pieces per hour per set of lathe machine.

3. Proposed Energy Saving Technologies with Cost Economics

Proposed Energy Saving Measures

- Replacement of FO fired re-heating furnace with 50 kW induction re-heating furnace
- Replacement of manual lathe machines by three numbers of CNC based Special Purpose Machine (SPM), two for turning and one for drilling operation

Table 1: *Cost Economic Analysis*

Proposed Technology	Estimated Energy Savings (%)	Savings (in Rs.)	Investment (in Rs.)	Simple Payback period (Years)
Induction re-heating furnace (50 kW)	73	628,128	936,510	1.5
SPM machine - Turning (2 Nos)	81	389,412	1,100,000	2.8
SPM machine - Drilling	73	65,880	350,000	5.3
Total		**1,083,420**	**2,386,510**	

Clearance by CA

MADHUR GUPTA
CHARTERED ACCOUNTANT
687 PREM NAGAR
CIVIL LINES, LUDHIANA
+99155-12967, 0161-5053340

To
M/s Bharat International
C-27, Focal Point
Ludhiana

Subject:- Recommendation to place an order for procurement of Machinery.

Sir

This is in reference to your request for clearance to place an order with least amount quoted supplier to purchase energy efficiency equipment.

The details of quotations submitted by you are mentioned in below table:-

Suggested Technology Measures	Summary of Quotation (L-1)	Summary of Quotation (L-2)	Summary of Quotation (L-3)
Special Purpose Machine (SPM)	Special Purpose Machine (SPM) for turning and facing 4 sleeves with PLC Control-2 in No. amounting to Rs.10.00 lacs (+) Special Purpose Machine (SPM) for drilling with PLC control amounting to Rs.3.50 lacs	Special Purpose Machine (SPM) for turning and facing 4 sleeves with PLC Control-2 in No. amounting to Rs.11.00 lacs (+) Special Purpose Machine (SPM) for drilling with PLC control amounting to Rs.3.80 lacs	Special Purpose Machine (SPM) for turning and facing 4 sleeves with PLC Control-2 in No. amounting to Rs.10.80 lacs (+) Special Purpose Machine (SPM) for drilling with PLC control amounting to Rs.3.75 lacs
Total Cost	Rs.13.50 Lacs	Rs.14.80 Lacs	Rs.14.55 Lacs
Name of Service Provider	M/s Harkaram Enterprises	Harjit Turner	Bhambar Enginers (Regd)

MADHUR GUPTA
CHARTERED ACCOUNTANT
687 PREM NAGAR
CIVIL LINES, LUDHIANA
+99155-12967, 0161-5053340

Suggested Technology Measures	Summary of Quotation (L-1)	Summary of Quotation (L-2)	Summary of Quotation (L-3)
Induction Heating Equipment (50 KW)	50 KW Induction Heating Machine, scanner with pusher, along with cooling system amounting to Rs.7.30 Lacs	50 KW Induction Heater with collant pumps and coolant system with installation amounting to Rs.7.35 Lacs	Induction Heating Machine 50 KVA amounting to Rs.7.50 Lacs
Name of Service Provider	M/s Akal Induction Pvt Ltd	G.R.D Induction	Sohal Electric Works

Note:- The above said prices are ex-works prices and taxes are not included in it. However taxes are levied on as is basis i.e.rate prevailing at time of dispatch of machine. Thus comparison of quotations has been done on bases of tax excluded prices

Accordingly we recommend to place and order of Induction Heating Equipment 50 KW with M/s Akal Induction Pvt Ltd and SPM with M/s Harkaram Enterprises, being lowest among all.

It is appreciating fact that earlier M/s Akal Induction Pvt Ltd had quoted higher price and after due negotiation, unit is able to reduce the prices.

You are requested to intimate us once the procurement and installation process is complete

Thanking You

Madhur Gupta

Chartered Accountant

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BHARAT INTERNATIONAL

★ STAR EXPORT HOUSE (RECOGNISED BY GOVT. OF INDIA)

Dated: 16.2.2016

Sh. Madhur Gupta,
Chartered Accountant,
Nominated Financial Expert for BEE,
Civil Lines, Ludhiana.

Subject:- Implementation of demonstration projects in Ludhiana (Forging) Cluster –reg.

Dear Sir,

With reference to above it is to inform you that we have received quotations from the following parties against the proposed EE equipments. The same are enclosed for your perusal please.

1. M/s Harkaram Enterprises, Ludhiana.
2. M/s Harjit Turners, Ludhiana.
3. M/s Bhamber Engineers (Regd.), Ludhiana.
4. M/s Sohal Electric Works, Ludhiana.
5. M/s Akal Induction Pvt. Ltd., Phagwara.
6. M/s GRD Induction, Jalandhar.

We are willing to place order to the supplier quoted least amount. Please do the needful and give us clearance, so that needful further action may be taken accordingly.

Thanking you,

Yours faithfully,
For Bharat International,

Partner.

Encl: Quotations.

Subject to Ludhiana Jurisdiction only

BHAMBAR ENGINEERS (Regd.)

Registered Trade Mark No. 689498

1208, G.T. Road, Dhandari Khurd, Ludhiana-141010 (Pb.) INDIA Tel : +91-161-2510183
Telefax : +91-161-2510002 E-mail : info@bhambar.in Visit us at : www.bhambar.in

Mfrs. & Exporters : All Geared CE Universal, Vertical, Ram Turret & Special Purpose Milling Machines

Dated: 12.2.2016

M/s Bharat International,
C-27, Focal Point, Phase-II,
Ludhiana.

Dear Sirs,

With reference to your enquiry, we are pleased to quote our minimum possible rates as under:-

Description of machine	Qty.	Rate per machine	Amount
Special Purpose Machine (SPM) for turning and facing 4 sleeves with PLC Control.	2 Nos.	5,40,000/-	10,80,000/-
Special Purpose Machine(SPM) for drilling with PLC Control.	1 No.	3,75,000/-	3,75,000/-

Terms & conditions:

1. FOR ex-works at Ludhiana.
2. VAT will be charged extra as applicable.
3. Delivery within 45 days after receipt of confirmed order with 40% advance payment.
4. Rates are valid up to 3 months only.

Thanking you and awaiting your valued order accordingly,

Yours faithfully,
For Bhambar Engineers (Regd.),

Authorized Signatory

VAT No. 03531060990

97797-31313
93179-91313

HARJIT TURNERS

J. B. Industrial Estate, Near Sunny Kharay Dharam Kanda,
Jaspal Bangar Road, Ludhiana.
E-mail : harjitturners@gmail.com, Web. www.harjitturners.com

Dated: 11.2.2016

Ref. No. .... Dated ....

QUOTATION

Quotation.

M/s Bharat International,
C-27, Focal Point, Phase-II,
Ludhiana.

Dear Sirs,

We are pleased to quote our lowest possible rates as under, as per your telephonic request.

Details of machine & specifications	***Qty.***	***Rate per machine***	***Amount***
Special Purpose Machine (SPM) for turning and facing 4 sleeves with PLC Control.	*2 Nos.*	*5,50,000/-*	*11,00,000/-*
Special Purpose Machine(SPM) for drilling with PLC Control.	*1 No.*	*3,80,000/-*	*3,80,000/-*

Terms & conditions:

1. *FOR ex-works at Ludhiana.*
2. *VAT and other taxes, as applicable, will be charged extra.*
3. *Delivery within 40 days after receipt of confirmed order with 35% advance payment.*
4. *The above rates are valid up to 50 days only.*

We hope that you will find our rates quite reasonable and competitive. Please favour us with your valued order, so that the machines may be supplied accordingly.

Thanking you,

Yours faithfully,
For Harjit Turners,

Manager

InsPIRE

VAT No. : 03481034391
C.ST.No. 46518919, Dt. 17-6-95

HE-TRACE®

Tele Fax : 0161-5027178
Ph. : 0161-5076178
(M) : 93169 - 17985

HARKARAM ENTERPRISES

Specialist In : Hydraulic Copying Attachment And Auto Lathes

Mfrs. & Suppliers of :TURNNING MACHINERY, SPECIAL PURPOSE MACHINERY & COPY MILLING MACHINES

10529, St. No: 10, Partap Nagar, Bhagwan Chowk, Industrial Area-B, Ludhiana-141003.
Head Off. St. No. 15, Plot No.7166, New Janta Nagar, Daba Road, LUDHIANA-141003.

Ref. No. .... Dated..................

DATE:- 04 FEB 2016

QUATATION

M/S. BHARAT INTERNATIONAL.
C-27, FOCAL POINT,PHASE-II
LUDHIANA.

DISCRIPTION OF MACHINE	QTY.	RATE PER MACHINE	TOTAL
1. SPECIAL PURPOSE MACHINE (SPM) FOR TURNING AND FACING 4 SLEEVES WITH PLC CONTROL.	2NOS.	5,00,000/-	10,00,000/-
2. SPECIAL PURPOSE MACHINE (SPM) FOR DRILLING WITH PLC CONTROL.	1 NO.	3,50,000/-	3,50,000/-

TERMS AND CONITIONS.

1. ADVANCE 35% AND BALANCE BEFORE DELIVERY.
2. **VAT 6.05% WILL BE EXTRA.**
3. DELIVERY IN 45 DAYS.
4. OIL AND TOOLING WILL BE EXTRA.

HARKARAM ENTERPRISES
Indervir Singh
AUTH SIGN.

Completion Letter

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BHARAT INTERNATIONAL

STAR EXPORT HOUSE (RECOGNISED BY GOVT. OF INDIA)

C-27, Focal Point, Ludhiana, 141010 (INDIA)
Tel. +91-161-2670269 / 2674502 / 2675859
Fax. +91-161-2670285
E-mail: litlite@litlite.com / gskahlon150@gmail.com
Website: www.litlite.com, www.lit-lite.com

Dated: 27.5.2016

The Energy Economist,
Bureau of Energy Efficiency,
4th Floor, Sewa Bhawan, R.K. Puram,
New Delhi – 110 066

Subject:- Implementation of demonstration projects in Ludhiana Forging Cluster.

Dear Sir,

We are pleased to inform you that the recommended technologies under BEE-SME Programme have been successfully implemented and commissioned in our unit.

You are requested to do the needful action in this regard.

Thanking you,

Yours faithfully,
For Bharat International,

Partner.

DNV
(An ISO 9001:2008 Certified Co.)
(100% Export Oriented Unit)

LIT-LITE

Annexure 4 (a):

Energy Saving Calculation for Induction Heating

Parameter	Unit	Value
Baseline Scenario		
Furnace oil consumption on re-heating furnace	ltr/hr	7.00
Productivity in terms of Kg	kg/hour	36.00
Specific energy consumption on FO based re-heating furnace	ltr/Kg	0.1944
Specific fuel consumption in terms of kcal	kcal/kg	1983.33
Cost of energy consumption	Rs./Kg	9.72
Annual production (based on baseline productivity)	Kg/annum	86400
Post Implementation Scenario		
Power consumed by induction furnace (based on on-site measurement)	kWh	28.01
Note: Induction furnace was observed to be running at 60 % loading		
Productivity in terms of Kg	Kg/hr	65
Specific energy consumption on induction reheating furnace	kWh/Kg	0.43
Specific fuel consumption in terms of kcal	kcal/kg	370.59
Cost of energy consumption	Rs/kg	3.23
Annual production (based on post implementation productivity)	Kg/annum	156000
Savings		
Reduction in cost of energy	Rs/kg	6.5
Reduction in specific energy consumption in kcal	kcal/kg	1612.7
Annual Cost Savings (in terms of post implementation productivity)	Rs	1012487
Annual Reduction in Energy Consumption (in terms of post implementation productivity)	toe	25.16
Percentage reduction in energy consumption	%	81.31
Investment made Induction furnace (50 kW)	Rs	731745
Simple payback period	years	0.72
Annual CO_2 emissions reduction	tCO_2/year	27.16

Annexure 4 (b):

Energy Saving Calculation SPM Turning Machine -1

Parameter	Unit	Value
Baseline Scenario		
Power consumed by conventional turning machine (one machine of 2 hp)	kW	1.49
Productivity on conventional turning machine	Pcs/hr	50
Specific power consumption on conventional machine	kWh/Pcs	0.030
Specific fuel consumption in terms of kcal	kcal/pcs	25.662
Cost of energy consumption	Rs/pcs	0.224
Annual production (based on baseline productivity)	pcs/annum	120000
Post Implementation Scenario		
Power consumed by 1 nos. SPM turning machine (based on actual on-site measurement) Note: SPM machine was observed to be running at 80% loading)	kW	2.984
Productivity on SPM turning machine	Pcs/hr	450
Specific power consumption on SPM	kWh/Pcs	0.007
Specific fuel consumption in terms of kcal	kcal/pcs	5.703
Cost of energy consumption	Rs/pcs	0.050
Annual production (based on post implementation productivity)	pcs/annum	1080000
Savings		
Reduction in cost of energy	Rs/pcs	0.17
Reduction in specific energy consumption in kcal	kcal/pcs	20.0
Annual Cost Savings (in terms of post implementation production)	Rs	187992
Annual Reduction in Energy Consumption (in terns of post implementation production)	toe	2.16
Percentage reduction in energy consumption	%	77.78
Investment made on SPM turning machine	Rs	530250
Simple payback period	years	2.82
Annual CO_2 emissions reduction	t CO_2/year	22.56

Annexure 4 (c):

Energy Saving Calculation SPM Turning Machine -2

Parameter	Unit	Value
Baseline Scenario		
Power consumed by conventional turning machine (one machine of 2 hp)	kW	1.49
Productivity on conventional turning machine	Pcs/hr	50
Specific power consumption on conventional machine	kWh/Pcs	0.030
Specific fuel consumption in terms of kcal	kcal/pcs	25.662
Cost of energy consumption	Rs/pcs	0.224
Annual production (based on baseline productivity)	pcs/annum	120000
Post Implementation Scenario		
Power consumed by SPM turning machine (based on actual on-site measurement) Note: SPM machine was observed to be running at 80% loading)	kW	3.21
Productivity on SPM turning machine	Pcs/hr	600
Specific power consumption on SPM	kWh/Pcs	0.005
Specific fuel consumption in terms of kcal	kcal/pcs	4.601
Cost of energy consumption	Rs/pcs	0.040
Annual production (based on post implementation productivity)	Pcs/annum	1440000
Savings		
Reduction in cost of energy	Rs/pcs	0.18
Reduction in specific energy consumption in kcal	kcal/pcs	21.1
Annual Cost Savings (in terms of post implementation production)	Rs	264492
Annual Reduction in Energy Consumption (in terms of post implementation production)	toe	3.03
Percentage reduction in energy consumption	%	82.07
Investment made on SPM turning machine	Rs	530250
Simple payback period	years	2.00
Annual CO_2 emissions reduction	t CO_2/year	31.74

Annexure 4 (d):

Energy Saving Calculation SPM Drilling

Parameter	Unit	Value
Baseline Scenario		
Power consumed by conventional drilling machine (one machine of 2 hp)	kW	1.49
Productivity on conventional drilling machine	Pcs/hr	90
Specific power consumption on conventional machine	kWh/Pcs	0.017
Specific fuel consumption in terms of kcal	kcal/pcs	14.257
Cost of energy consumption	Rs/pcs	0.124
Annual production (based on baseline productivity)	Pcs/annum	216000
Post Implementation Scenario		
Power consumed by SPM drilling machine (based on actual on-site measurement)		
Note: SPM machine was observed to be running at 80% loading)	kW	2.89
Productivity on SPM turning machine	Pcs/hr	390
Specific power consumption on SPM	kWh/Pcs	0.007
Specific fuel consumption in terms of kcal	kcal/pcs	6.373
Cost of energy consumption	Pcs/kg	0.056
Annual production (based on post implementation productivity)	Pcs/annum	936000
Savings		
Reduction in cost of energy	Rs/pcs	0.07
Reduction in specific energy consumption in kcal	kcal/pcs	7.9
Annual Cost Savings (in terms of post implementation production)	Rs	64356
Annual Reduction in Energy Consumption (in terms of post implementation production)	toe	0.74
Percentage reduction in energy consumption	%	55.30
Investment made on SPM drilling machine	Rs	371175
Simple payback period	years	5.77
Annual CO_2 emissions reduction	t CO_2/year	7.72

Annexure 5

GHG Emission Factor

Emission Factors for Greenhouse Gas Inventories

Last Modified: 4 April 2014

Red text indicates an update from the 2011 version of this document.

Typically, greenhouse gas emissions are reported in units of carbon dioxide equivalent (CO_2e). Gases are converted to CO_2e by multiplying by their global warming potential (GWP). The emission factors listed in this document have not been converted to CO_2e. To do so, multiply the emissions by the corresponding GWP listed in the table below.

Gas	100-year GWP
CH_4	25
N_2O	298

Source: Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007. See the source note to Table 9 for further explanation.

Table 1 Stationary Combustion Emission Factors

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per short ton	g CH_4 per short ton	g N_2O per short ton	
Coal and Coke								
Anthracite Coal	25.09	103.69	11	1.6	2,602	276	40	short tons
Bituminous Coal	24.93	93.28	11	1.6	2,325	274	40	short tons
Sub-bituminous Coal	17.25	97.17	11	1.6	1,676	190	28	short tons
Lignite Coal	14.21	97.72	11	1.6	1,389	156	23	short tons
Mixed (Commercial Sector)	21.39	94.27	11	1.6	2,016	235	34	short tons
Mixed (Electric Power Sector)	19.73	95.52	11	1.6	1,885	217	32	short tons
Mixed (Industrial Coking)	26.28	93.90	11	1.6	2,468	289	42	short tons
Mixed (Industrial Sector)	22.35	94.67	11	1.6	2,116	246	36	short tons
Coal Coke	24.80	113.67	11	1.6	2,819	273	40	short tons
Fossil Fuel-derived Fuels (Solid)								
Municipal Solid Waste	9.95	90.70	32	4.2	902	318	42	short tons
Petroleum Coke (Solid)	30.00	102.41	32	4.2	3,072	960	126	short tons
Plastics	38.00	75.00	32	4.2	2,850	1,216	160	short tons
Tires	28.00	85.97	32	4.2	2,407	896	118	short tons
Biomass Fuels (Solid)								
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35	short tons
Peat	8.00	111.84	32	4.2	895	256	34	short tons
Solid Byproducts	10.39	105.51	32	4.2	1,096	332	44	short tons
Wood and Wood Residuals	17.48	93.80	7.2	3.6	1,640	126	63	short tons
	mmBtu per scf	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf	
Natural Gas								
Natural Gas (per scf)	0.001026	53.06	1.0	0.10	0.05444	0.00103	0.00010	scf
Fossil-derived Fuels (Gaseous)								
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.02524	0.000002	0.000009	scf
Coke Oven Gas	0.000599	46.85	0.48	0.10	0.02806	0.000288	0.000060	scf
Fuel Gas	0.001388	59.00	3.0	0.60	0.08189	0.004164	0.000833	scf
Propane Gas	0.002516	61.46	0.022	0.10	0.15463	0.000055	0.000252	scf
Biomass Fuels (Gaseous)								
Landfill Gas	0.000485	52.07	3.2	0.63	0.025254	0.001552	0.000306	scf
Other Biomass Gases	0.000655	52.07	3.2	0.63	0.034106	0.002096	0.000413	scf
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon	
Petroleum Products								
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09	gallon
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07	gallon
Butane	0.103	64.77	3.0	0.60	6.67	0.31	0.06	gallon
Butylene	0.105	68.72	3.0	0.60	7.22	0.32	0.06	gallon
Crude Oil	0.138	74.54	3.0	0.60	10.29	0.41	0.08	gallon
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08	gallon
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08	gallon
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09	gallon
Ethane	0.068	59.60	3.0	0.60	4.05	0.20	0.04	gallon
Ethylene	0.058	65.96	3.0	0.60	3.83	0.17	0.03	gallon
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09	gallon
Isobutane	0.099	64.94	3.0	0.60	6.43	0.30	0.06	gallon
Isobutylene	0.103	68.86	3.0	0.60	7.09	0.31	0.06	gallon
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08	gallon
Kerosene-type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08	gallon
Liquefied Petroleum Gases (LPG)	0.092	61.71	3.0	0.60	5.68	0.28	0.06	gallon
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09	gallon
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08	gallon
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08	gallon
Natural Gasoline	0.110	66.88	3.0	0.60	7.36	0.33	0.07	gallon
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08	gallon
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07	gallon
Petrochemical Feedstocks	0.125	71.02	3.0	0.60	8.88	0.38	0.08	gallon
Petroleum Coke	0.143	102.41	3.0	0.60	14.64	0.43	0.09	gallon
Propane	0.091	62.87	3.0	0.60	5.72	0.27	0.05	gallon
Propylene	0.091	65.95	3.0	0.60	6.00	0.27	0.05	gallon
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08	gallon
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09	gallon
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08	gallon
Still Gas	0.143	66.72	3.0	0.60	9.54	0.43	0.09	gallon
Unfinished Oils	0.139	74.54	3.0	0.60	10.36	0.42	0.08	gallon
Used Oil	0.138	74.00	3.0	0.60	10.21	0.41	0.08	gallon
Biomass Fuels (Liquid)								
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01	gallon
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01	gallon
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01	gallon
Vegetable Oil	0.120	81.55	1.1	0.11	9.79	0.13	0.01	gallon
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu				
Steam and Hot Water								
Steam and Hot Water		66.33	1.250	0.125				mmBtu

Source:

Solid, gaseous, liquid and biomass fuels: Federal Register (2009) EPA; *40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule*, 30Oct09, 261 pp. Tables C-1 and C-2 at FR pp. 56409-56410. Revised emission factors for selected fuels: Federal Register (2010) EPA; 40 CFR Part 98; Mandatory Reporting of Greenhouse Gases; Final Rule, 17Dec10, 81 pp. With Amendments from Memo: Table of Final 2013 Revisions to the Greenhouse Gas Reporting Rule (PDF) to 40 CFR part 98, subpart C: Table C–1 to Subpart C—Default CO2 Emission Factors and High Heat Values for Various Types of Fuel and Table C–2 to Subpart C—Default CH4 and N2O Emission Factors for Various Types of Fuel.

Steam and Hot Water: EPA (2008) *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance - Indirect Emissions from Purchases/Sales of Electricity and Steam*. Assumption: 80% boiler efficiency and fuel type assumed natural gas. Factors are per mmBtu of steam or hot water purchased.

http://www.epa.gov/ghgreporting/documents/pdf/2013/documents/memo-2013-technical-revisions.pdf

http://www.epa.gov/ghgreporting/reporters/subpart/c.html