Energy Audit Report

Of **SHRIRAM FOUNDRY,**
KOLHAPUR

March, 2012

Metal tapped from furnace

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Under the Joint Initiative of WB-GEF (BEE) and Institute for Industrial Productivity

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1.0 INTRODUCTION

In November 2011 MB Associates assisted a series of audits of operation – with a view to reducing energy consumption – in the Kolhapur foundry cluster. The audits were carried out by Shivaji University personnel as part of a World Bank-GEF-BEE initiative. MB Associates' role was to assist the Institute for Industrial Productivity (IIP) to provide industry specific technical guidance before and during the audits.

The objective of the project was to develop an understanding of the overall performance of the Kolhapur Cluster, carry out a comparison of that performance and provide guidance as to the methods required for improvement. This should enable the foundries to check and improve their efficiency and consumption of resources and energy.

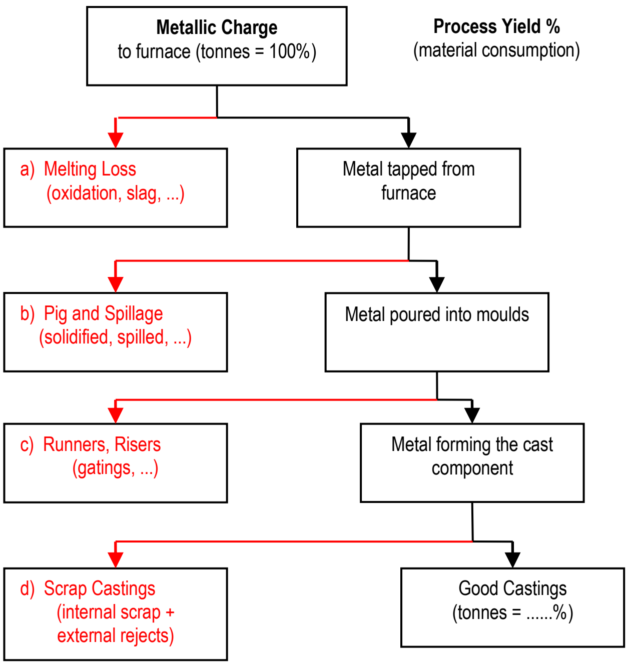
The analysis and the recommendations made in this report are based on the audit data provided by Shivaji University and the information provided by the foundries themselves and observations made during the field visits undertaken in November 2012.

In order for the individual units to better understand the energy audit results and the recommendations made thereof, a brief explanation is provided about Key Performance Indicators (KPIs) in a foundry.

1.1 Key Performance Indicators (KPIs)

1.1.1 Process Yield

This KPI monitors how much of the material processed ends up as good saleable castings. As most of the material which does not end up as good castings is recycled, the loss of material is of minor importance. Much more important is the loss of energy, labour time, and capacity for processing material which does not end up as a saleable product. See below:



Performance:
Tonnes of Good Castings divided by tonnes of liquid melt processed;

This KPI is comprised from 4 sub-indicators

a) KPI 1.1 – Melting loss (%)
b) KPI 1.2 – Pig and spillage (%)
c) KPI 1.3 – Runners and risers (%)
d) KPI 1.4 – Scrap castings (%)

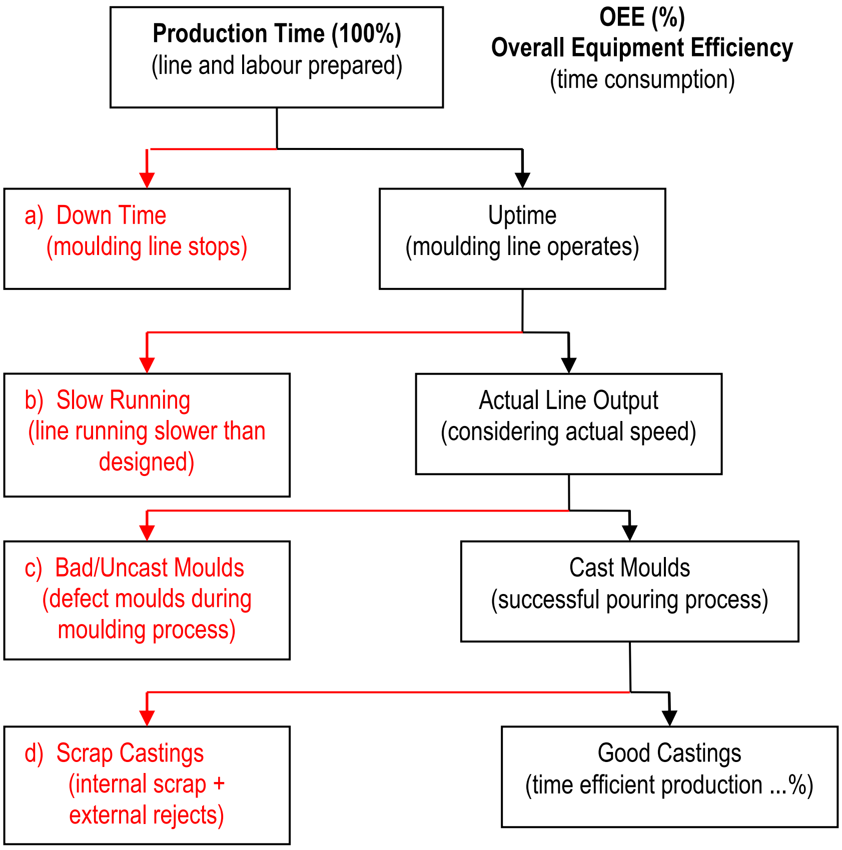
Formula:
KPI 1 = (1-a) x (1-b) x (1-c) x (1-d) x 100%

No	KPI	Definition
1	Process Yield (%)	Material consumption based performance. The weight of net good castings produced as a percentage of the metallic material charged to the melting furnaces; comprised from 4 performance indicators.
1.1	Melting Loss (%)	The material lost during melting (either by oxidation or incorporation into the slag) expressed as a percentage of the metallic material charged to the melting furnaces.
1.2	Pig and Spillage (%)	The amount of liquid metal tapped from the furnace which does not get poured into moulds expressed as a percentage of the liquid metal tapped.
1.3	Runners and Risers (%)	The weight of liquid metal poured into the mould which does not form a casting expressed as a percentage of the liquid metal poured into that mould.
1.4	Scrap Castings and Rejects (%)	The weight of scrap castings (including customer returns) expressed as a percentage of the weight of gross castings produced.

1.1.2 Effective Production (OEE)

Time consumption based performance also known as Overall Equipment Effectiveness indicates the gap between actual and ideal performance.

The time during which the plant produces good saleable castings expressed as a percentage of the time that the plant was available for production. See below:



This KPI is comprised from 4 sub-indicators

a) KPI 2.1 – Down Time (Moulding) (%)
b) KPI 2.2 – Slow Running (%)
c) KPI 2.3 – Bad Moulds (%)
d) KPI 2.4 – Scrap and Rejects (%)

Formula:

KPI 2 = (1-a) x (1-b) x (1-c) x (1-d) x 100%

No	KPI	Definition
2	OEE (%) – Overall Equipment Efficiency	Time consumption based performance. The time during which the plant produces good saleable castings expressed as percentage of the time that the plant was available for production; comprised from 4 performance indicators.
2.1	Downtime (Moulding) (%)	The time that a moulding facility is not operating due to breakdowns or operational reasons expressed as a percentage of the total time available for production (often called the net operating time).
2.2	Slow Running (%)	The production time lost by operating a moulding facility at a speed below the design capacity or calculated output expressed as an equivalent percentage of the net operating time.
2.3	Bad Moulds (%)	The number of moulds that are not poured expressed as a percentage of the total number of moulds produced.
2.4	Scrap and Rejects (%) (internal scrap and external rejects)	The weight of scrap castings (including customer returns) expressed as a percentage of the weight of gross castings produced.

1.1.3 TEEP (Total Effective Equipment Performance)

No	KPI	Definition
3	TEEP (%) – Total Effective Equipment Performance	Time based capacity utilisation. Total effective equipment performance (TEEP) measures OEE effectiveness against calendar hours, i.e. 24 hours per day, 365 days per year. Total Effective Production per annum expressed as a percentage of the total plant capacity if operating for 24 hours per day, 365 days per year.

1.1.4 Energy Consumption

The KPIs referring to energy consumption are monitored for two levels as some 75% of total energy consumption is usually consumed already only in the melting plant and measures for improvement can be concentrated on this department:

- KPI 4.1 – energy consumption in melting
- KPI 4.2 – energy consumption in foundry

The energy consumption includes all types of energy such as electric power, coke (i.e. when combustion melting in cupola furnaces), gas and oil. The energy consumption is expressed in kWh.

No	KPI	Definition
4	Energy Consumption	Energy is one of the most important cost factors apart from raw material and in melting the energy supply often is a limiting capacity factor.
4.1	Energy Consumption in Melting (Melting Efficiency) (kWh/tonne melt)	Furnace power consumption (kWh) divided by the tonnage of metallic material charged to the furnaces *(the melting consumes some 75% of the total foundry energy demand; a good performance of the melt shop saves money and capacity).*
4.2	Energy Consumption in Foundry (kWh/tonne good castings)	Total power consumption (kWh) in the foundry departments divided by the tonnage of net good castings produced *(the cost impact of energy consumption is a competitive mark).*

1.1.5 Sand Consumption

The performance of sand consumption is monitored with 2 KPIs:

- new (fresh) sand consumption per tonne of good castings (indicates design of casting process)
- rate of sand regeneration (indicates how much sand must be dumped)

No	KPI	Definition
5	Sand Consumption	The sand utilised for making the moulds is supposed to be recycled and regenerated as much as possible. A perfect designed and operated sand regeneration plant will reduce costs for sand purchase and also improve quality of castings.
5.1	Fresh Sand Consumption (tonnes sand/tonnes good castings)	The weight of new (fresh) sand used divided by the tonnage of net good castings produced. This indicator includes sand for moulding as well as sand for core making.
5.2	Rate of Sand Regeneration (%)	The percentage of sand that is re-used at each moulding cycle (as an average of all moulding cycles included in the sampling period).

1.1.6 Labour Productivity

No	KPI	Definition
6	Labour productivity (man hours/tonnes good castings)	Apart from the overall productivity a lean organisation and a high grade of automation have the impact on labour productivity. The total number of man hours worked (excluding management and supervisory hours) divided by the tonnage of net good castings produced.

2.0 SHRIRAM FOUNDRY

2.1 General Description

Annual Tonnage – 16,200 tonnes per annum.

Melting is carried out using four induction furnaces of 750 kg capacity. Two of the furnaces are rated at 750 kW, the other two at 550 kW.

Moulding is carried out using three pairs of jolt-squeeze machines with pin-lift facilities. Moulds are then transferred on to a pouring and cooling track before shake-out.

Core making facilities include cold box, shell and chemically bonded no-bake technologies.

The plant operates continually 24 hours per day for 6 days per week.

2.2 Product Mix

The 16,200 tonnes per annum produced by Shriram Foundry can be divided into four production categories as follows:

GMAG (Grey Iron Mechanised Moulding Agricultural Castings)	–	1,620 tonnes (10.0%)
GMGE (Grey Iron Mechanised Moulding General Engineering and Automotive Castings)	–	1,620 tonnes (10.0%)
DMAU (Ductile Iron Mechanised Moulding Automotive)	–	6,480 tonnes (40%)
DMGE (Ductile Iron Mechanised Moulding General Engineering and Agricultural Castings)	–	6,480 tonnes (40%)

An explanation of the categories is given in Figure 1.

2.3 Audit Results

2.3.1 Process Yield

During the audit period some 8,484 kg of metallics was charged to the induction furnaces.

The amount of liquid metal tapped from the furnaces was 8,020 kg, giving a melting loss of 464 kg or 5.5%. The liquid metal poured into the moulds was 7,434 kg, representing a loss to pig and spillage of 586 kg or 7.3%.

Of the 7,434 kg of metal in the mould, 2,163 kg was runners and feeders, giving a box yield of 70.9% and 5,271 kg of gross castings.

The average scrap rate of 3.5% results in a net good saleable casting weight of 5,087 kg. Thus some 59.9% of the weight of the material charged to the induction furnaces resulted in castings that could be sold. A representation of the calculation of the Process Yield is given below:

Process Yield Calculation

Material Charged	8,484	100%	100%
Metal Loss	464	5.5%	
Liquid Metal	8,020	94.5%	94.5%
Pig and Spillage	586	7.3%	
Metal in Moulds	7,434	92.7%	87.6%
Runners & Feeders	2,163	29.1%	
Gross Castings	5,271	70.9%	62.1%
Scrap & Rejects	184	3.5%	
Net Good Castings	5,087	96.5%	59.9%

Process Yield – 59.9%

2.3.2 Effective Production

No downtime stoppages were recorded.

A pair of jolt-squeeze machines should easily be capable of producing 50 moulds per hour. During the audit period of four hours therefore, with 3 pairs of machines, a total of 600 moulds should have been produced. During the audit, a total of 150 moulds were produced. This represents only 25% of the potential available.

Bad moulds were reported at 1.3% and the scrap level was 3.5% – see above.

Therefore the Effective Production for the plant was 23.8%. This means that the plant produced saleable castings for only 23.8% of the available moulding capacity operating time. The calculation of Effective Production is given below:

Effective Production Calculation

Production Time	600	100%	100%
Downtime	0	0%	
Operating Time	600	100%	100%
Slow Running	450	75.0%	
Moulding Output	150	25.0%	25.0%
Bad Moulds	2	1.3%	
Good Moulds	148	98.7%	24.7%
Scrap Castings	5	3.5%	
Good Production	143	96.5%	23.8%

Effective production – 23.8%

2.3.3 TEEP

The plant operates 24 hours per day for 310 days per year. This equates to 7,440 hours or a plant utilisation of 84.9%. However, when the plant is operating the Effective Production is only 23.8%. Thus the real plant utilisation or TEEP (Total Equipment Effective Production) is only 20.2% (84.9% x 23.8%). This means that the plant operates in such a way that it only uses 20.2% of its total capacity.

2.3.4 Energy

i) *Melting* – the induction furnaces consumed some 6,435 kWh to melt a total of 8,484 kg. Therefore the energy consumed during melting is equivalent to 758 kWh per tonne charged

ii) *Overall Consumption* – during the time of the audit 5.087 tonnes of net good castings were produced, giving a total energy consumption of 1,265 kWh per tonne of good castings.

2.3.5 Sand

New sand consumption was 0.09 tonnes per tonne of good castings. Of this, 0.01 tonnes was used for core making.

During the audit period some 99.0% of the greensand produced and used was reclaimed.

2.3.6 Productivity

A total of 223,200 man hours was worked to produce some 16,200 tonnes of finished castings. This equates to a productivity level of 13.8 man hours per tonne of good castings.

2.4 Comparison of Results

In order for Shriram Foundry to obtain the maximum benefit from the audit, their data will be compared below to other foundries.

2.4.1 Kolhapur Cluster

In the table below Shriram Foundry audit data is compared to the average of all of the Kolhapur audit results.

Shriram Foundry vs. Kolhapur Cluster		
	Shriram Foundry	**Kolhapur Cluster**
Melting Loss	5.5%	6.8%
Pig & Spillage	7.3%	4.6%
Runners & Feeders	29.1%	19.7%
Scrap & Rejects	3.5%	4.6%
Process Yield	59.9%	68.1%
Downtime	Nil	Nil
Slow Running	75.0%	50.0%
Bad Moulds	1.3%	2.4%
Scrap & Rejects	3.5%	4.6%
Effective Production	23.8%	46.6%
TEEP	20.2%	28.8%
Energy Consumption		
Per Tonne Melted	758 kWh	1057 kWh
Per Tonne Good Castings	1265 kWh	1770 kWh
Sand Consumption		
New Sand/tonnes castings	0.09 t	0.50 t
Cores/tonnes castings	0.01 t	0.08 t
Sand Reclamation	99.0%	59.0%
Productivity		
Man hours/tonnes castings	13.8	48.9
Direct Ratio	1.5	4

However, the above table compares the Shriram Foundry performance with other foundries in the area which have different products and production methods. To gain a more realistic guide to the Shriram Foundry performance it must be compared to that of similar foundries.

2.4.2 Similar Foundries

In the table below the Shriram Foundry performance data is compared to that of similar foundries in other parts of the developing world (both average and best practice) and Western Europe.

Shriram Foundry Performance Comparison

		Developing Countries		Western Europe	
	Shriram Foundry	Average Performance	Best Practice	Average Performance	Best Practice
Melting Loss	5.5%	3.9%	1.7%	2.0%	1.0%
Pig & Spillage	7.3%	2.8%	2.4%	3.0%	2.4%
Runners & Feeders	29.1%	47.7%	41.2%	38.0%	35.7%
Scrap & Rejects	3.5%	6.9%	2.0%	3.0%	2.1%
Process Yield	59.9%	45.5%	55.3%	57.6%	60.8%
Downtime	Nil	13.1%	13.2%	15.0%	13.7%
Slow Running	75.0%	18.8%	4.0%	5.0%	4.5%
Bad Moulds	1.3%	6.1%	0.9%	1.0%	0.9%
Scrap & Rejects	3.5%	6.9%	2.0%	3.0%	2.1%
Effective Production	23.8%	48.9%	80.9%	77.5%	80.0%
TEEP	20.2%	21.2%	43.5%	47.7%	52.8%
Energy Consumption Per Tonne Melted	758 kWh	1151 kWh	841 kWh	620 kWh	596 kWh
Per Tonne Good Castings	1265 kWh	4121 kWh	3861 kWh	1675 kWh	1405 kWh
Sand Consumption New Sand/t castings	0.09 t	0.63 t	0.18 t	0.23 t	0.20 t
Cores/t castings	0.01 t	N/R	N/R	N/R	N/R
Sand Reclamation	99.0%	91.7%	100.0%	94.7%	97.8%
Productivity Man hours/t castings	13.8	65.1	34.7	22.8	15.4
Direct Ratio	1.5	N/R	N/R	N/R	N/R

The data above applies to medium sized foundries with mechanised moulding facilities producing automotive and tractor castings in both grey and ductile iron. The term "Developing Countries" applies to countries such as Brazil, Russia and Mexico.

It should be noted that scrap levels are quoted in terms of the quality standards prevailing in the country of the foundry concerned. For instance what is a good casting in Kolhapur may not be a good casting in the UK or Germany.

2.5 Conclusions and General Comments

2.5.1 Process Yield

The melting loss in the induction furnaces is high at 5.5%. There is some concern as to the condition of the borings/chippings being used. They appear to be dry but not cleaned – thick black smoke was produced when charging ductile chips. The surface area to weight ratio is very high with chippings such that in high power furnaces they oxidise very easily – especially if they are not dry and clean. Shriram Foundry should try to ensure that, if it intends to use chippings, which they are in good condition. Figures for melting loss for similar plants in other parts of the world would be 3.9% for developing countries and 2.0% for Western Europe.

There is also a high pig and spillage figure. This is metal that is tapped from the furnace but does not find its way into the mould. This figure compares to an average of 4.6% in the Kolhapur Cluster as a whole and 3.0% in Western Europe and represents a substantial opportunity for Shriram Foundry to reduce operating costs.

The overall process yield figure for Shriram Foundry of 59.9% compares favourably with similar foundries in other developing countries (45.5%) and with Western Europe (57.6%).

2.5.2 Effective Production

No downtime was recorded for the plant. The moulding machines are only operating at 25.0% of their capacity with a "slow running" time of 75.0%. This compares to 50.0% for the average of the Kolhapur Cluster, only 18.8% for other developing countries and as low as only 5.0% for Western Europe.

The moulding machines concerned are all of the "pin-lift" type which means that half moulds have to be lifted off the machine and then transported away. During this time the moulding machines cannot be operated. These machines should be converted to "roller lift" whereby the half moulds could be rolled off the moulding machine onto a small section of roller track and handled elsewhere. This would allow the moulding machine to continue operating within its own cycle time.

Taking into account the scrap level and bad moulds, the Effective Production level of the plant is 23.8% which is lower than other foundries in the Kolhapur Cluster (average 46.6%) and similar foundries in other developing countries (48.9%) and of those in Western Europe (77.5%).

2.5.3 Other Parameters

The energy consumed during melting was 758 kWh/tonne which compares well with the Kolhapur average of 1,057 kWh/tonne. However, a similar foundry in Western Europe would operate at an average of 620 kWh/tonne.

The overall energy consumption per tonne of finished castings is very good at 1,265 kWh/tonne.

The recorded level of productivity for the plant is also good at 13.8 man hours per tonne of finished castings.

Overall plant utilisation (TEEP – 20.2%) is quite low for this type of installation and has a potential for improvement.

2.6 Potential Improvements

Improving the melting loss and reducing the pig and spillage figure could and should save at least 3.5% of the charged material. Since material represents 51.5% of the total operating costs of the foundry such a reduction in material loss represents a reduction in total operating costs of 1.8%.

For a foundry of this type this probably increases the profit margin by as much as 50%.

2.7 Additional Observations

During the audit visit a number of observations were made by MB Associates as follows:

2.7.1 Process Technology Issues

- The ductile iron being produced had a high aluminium content (0.011%). This can cause pinhole defects and N_2/H_2 problems. The source of the aluminium should be identified and removed.
- Castings on the shake-out were knocked out very hot – above red heat.
- For the greensand both compactability and moisture levels in the sand appeared to be low for the type of moulding machines being used. The sand properties were more suited to use for very high pressure moulding machines not with jolt-squeeze.

2.7.2 Facilities and Systems

The plant exhibited facilities and systems not normally associated with Indian foundries:

- very good quality assurance and process control systems
- almost all castings machined
- advanced pattern design and inspection systems
- real-time x-ray system for scanning castings
- ability to produce compacted graphite irons.

Shriram Foundry is a good, well controlled foundry with staff and facilities of a high standard. With some improvements in plant utilisation they could easily compete with Western Foundries.

Figure 1 Product and Manufacturing Method Classification

Grey iron product categories

Automatic moulding

GABH = automotive engine blocks and cylinder heads
GAAO = automotive other
GAAG = agriculture
GAMI = mining

Mechanised moulding

GMBH = medium sized engine blocks and heads (energy generation)
GMAG = agriculture
GMMI = mining
GMGE = general engineering

Manual (hand) moulding

GHBH = large size engine blocks and heads (energy generation)
GHMI = mining
GHGE = general engineering

Ductile iron product categories

Automatic moulding

DAAU = automotive other
DAGE = general engineering

Mechanised moulding

DMAU = automotive
DMGE = general engineering

Manual (hand) moulding

DHEN = energy generation components
DHCO = compressor components
DHGE = general engineering

Steel product categories

Automatic moulding

SARC = railway components (c)
SAMM = mining components (m)
SAAC = commercial vehicles (c)
SAGC = general engineering

Mechanised moulding

SMRC = railway components (c)
SMMM = mining components (m)
SMPC = pumps and valves (c)
SMPS = pumps and valves (s)
SMGC = general engineering (c)
SMAC = commercial vehicles (c)

Manual (hand) moulding

SHMM = mining components (c)
SHPC = pumps and valves (c)
SHEA = energy components (a)
SHGC = general engineering (c)

c = carbon steel, s = stainless steel
m = manganese steel, a = high alloy steel