Energy Audit Report

Of **CASPRO METAL INDUSTRIES**, KOLHAPUR

March, 2012

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

CONTENTS

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.

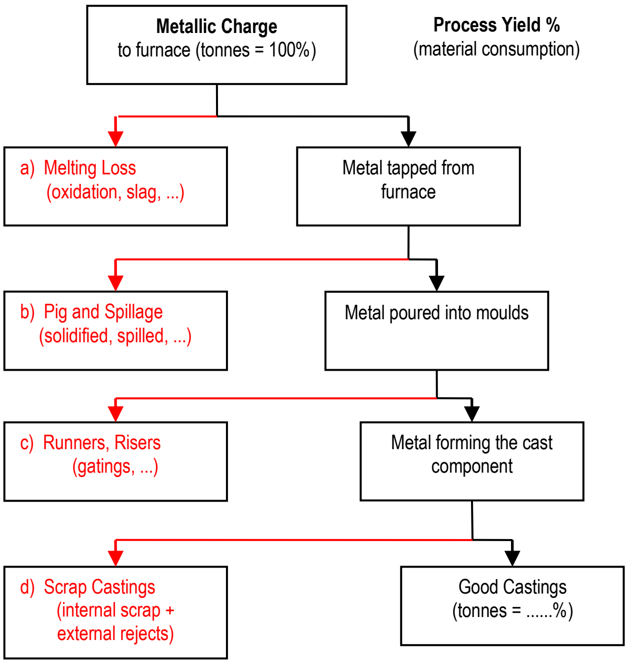
The analysis and the recommendations made in this report are based on the audit data provided by Shivaji University and the information provided by the foundries themselves and observations made during the field visits undertaken in November 2012.

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 (%)

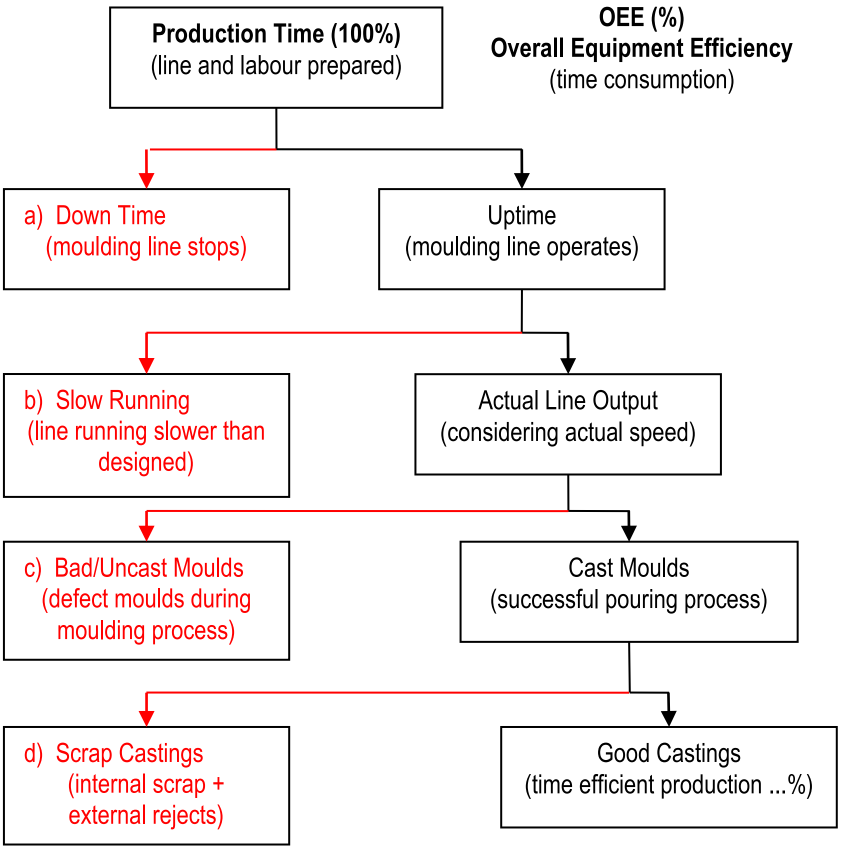
Formula:
KPI 1 = (1-a) x (1-b) x (1-c) x (1-d) x 100%

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 and 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 CASPRO METAL INDUSTRIES

2.1 Introduction

Insufficient data was collected by Shivaji University to allow a full audit report to be compiled. However, some data was collected and that, together with observations made during the audit visit, allows a qualitative assessment of the plant to be carried out and that assessment is contained below.

2.2 General Description

Annual Tonnage – 12,000 tonnes per annum.

Melting is carried out using three induction furnaces. Two of the furnaces have a capacity of 500 kg, the other (newly installed) being 1,000 kg.

Moulding is carried out using three pairs of jolt-squeeze machines. Moulds are then transferred onto a pouring and cooling track before shake-out. Core making facilities include cold box and shell.

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

2.3 Product Mix

The 12,000 tonnes per annum produced by Caspro Metal Industries can be considered to be a single production category of Grey Iron Machine Moulded General Engineering and Automotive Castings. Within that category the production split is as follows:

Automotive Castings	–	40%
General Engineering	–	60%

An explanation of the categories is given in Figure 1.

2.4 Audit Results

2.4.1 Process Yield

During the audit period some 5,326 kg of metallics was charged to the induction furnaces. The amount of liquid metal tapped from the furnaces was 5,048 kg, giving a melting loss of 278 kg or 5.2%. The liquid metal poured into the moulds was 4,857 kg, representing a loss to pig and spillage of 191 kg or 3.8%.

No box yield or scrap figures were recorded so the Process Yield cannot be fully calculated.

2.4.2 Effective Production and TEEP

No mould production figures were recorded so the Effective Production for the plant cannot be calculated. Similarly with the Effective Production figure it is not possible to calculate the TEEP or plant utilisation.

2.4.4 Energy

i) *Melting* – the induction furnaces consumed some 4,020 kWh to melt a total of 5,326 kg. Therefore the energy consumed during melting is equivalent to 755 kWh per tonne charged.

ii) *Overall Consumption* – no total energy consumption for the plant was recorded.

2.4.5 Sand

New sand consumption was 0.24 tonnes per tonne of good castings. Of this 0.15 tonnes was used for core making.

During the audit period, some 98.0% of the greensand produced and used was reclaimed.

2.4.6 Productivity

A total of 744,000 man hours was worked to produce some 12,000 tonnes of finished castings. This equates to a productivity level of 62.0 man hours per tonne of good castings. The ratio of direct to indirect workers is 5.0.

2.5 Comparison of Results

In order for Caspro Metal Industries to compare the results above, and for them to rank any future evaluations that they may carry out, MB Associates has compared their performance with other foundries below:

2.5.1 Kolhapur Cluster

In the table below the Caspro Metal Industries audit data is compared to the average of all of the Kolhapur audit results.

Caspro Metal Industries vs. Kolhapur Cluster		
	Caspro Metal Industries	**Kolhapur Cluster**
Melting Loss	5.2%	6.8%
Pig & Spillage	3.8%	4.6%
Runners & Feeders	N/R	19.7%
Scrap & Rejects	N/R	4.6%
Process Yield	N/R	68.1%
Downtime	N/R	Nil
Slow Running	N/R	50.0%
Bad Moulds	N/R	2.4%
Scrap & Rejects	N/R	4.6%
Effective Production	N/R	46.6%
TEEP	N/R	28.8%
Energy Consumption Per Tonne Melted	755 kWh	1057 kWh
Per Tonne Good Castings	N/R	1770 kWh
Sand Consumption New Sand/tonnes castings	0.23 t	0.50 t
Cores/tonnes castings	0.15 t	0.08 t
Sand Reclamation	98.0%	59.0%
Productivity Man hours/tonnes castings	62	48.9
Direct Ratio	5	4

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

2.5.2 Similar Foundries

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

Caspro Metal Industries Performance Comparison

		Developing Countries		Western Europe	
	Caspro Metal Industries	Average Performance	Best Practice	Average Performance	Best Practice
Melting Loss	5.2%	5.1%	2.8%	2.0%	1.0%
Pig & Spillage	3.8%	2.8%	1.0%	3.5%	2.6%
Runners & Feeders	N/R	30.3%	13.1%	30.0%	27.5%
Scrap & Rejects	N/R	8.4%	0.5%	5.0%	4.0%
Process Yield	N/R	58.9%	83.2%	62.9%	67.1%
Downtime	N/R	27.2%	4.3%	15.0%	13.4%
Slow Running	N/R	21.4%	0%	5.0%	4.5%
Bad Moulds	N/R	1.9%	0.5%	1.0%	0.9%
Scrap & Rejects	N/R	8.4%	0.5%	5.0%	4.0%
Effective Production	N/R	51.4%	94.7%	75.9%	78.7%
TEEP	N/R	28.2%	65.5%	46.7%	51.9%
Energy Consumption Per Tonne Melted	755 kWh	1285 kWh	543 kWh	600 kWh	580 kWh
Per Tonne Good Castings	N/R	2948 kWh	1521 kWh	1424 kWh	1235 kWh
Sand Consumption New Sand/t castings	0.23 t	1.18 t	0.37 t	0.19 t	0.16 t
Cores/t castings	0.15 t	N/R	N/R	N/R	N/R
Sand Reclamation	98.0%	92.7%	97.6%	95.0%	98.0%
Productivity Man hours/t castings	62	162.7	37.6	25	20
Direct Ratio	5	N/R	N/R	N/R	N/R

The data above applies to medium sized foundries with mechanical moulding facilities producing general engineering and automotive castings in grey 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.

2.6 Conclusions and General Comments

2.6.1 Process Yield

The melting loss in the induction furnaces is high at 5.2%. Although it is a lower figure than the average for the Kolhapur Cluster, other foundries in the cluster melt using cupolas which have a higher inherent melting loss. Figures for a similar plant in Western Europe would be 2.0%. There is some concern as to the condition of the drillings/chippings being used and the extent thereof – as much as 18–20% of the charge material. They appear to be dry but not cleaned. The surface area to weight ratio is very high with chippings such that in high power furnaces they oxidise very easily. In addition, it was observed that pour down material being charged to the furnaces was uncleaned and heavily contaminated with slag and sand. Such material may be okay for cupolas but it is not suitable charge material for induction furnaces.

Since materials account for 50% of the total operating costs of the plant, a 2.0% reduction in melting loss would add 1% to the operating margin of the foundry.

Excess metal was observed being returned in many of the ladles. This result in cold metal and potential scrap castings.

2.6.2 Other Parameters

The energy consumed during melting was 755 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 600 kWh/tonne.

The recorded level of productivity for the plant is poor at 62.0 man hours per tonne of finished castings. This compares to 48.9 man hours per tonne for the average of Kolhapur Cluster and 25.0 man hours per tonne for a similar foundry in Western Europe.

2.6.3 Running and Feeding Systems

It was observed that several types of moulds had strainer cores placed at the top of the downright immediately below the pouring bush. Placing the strainer cores there does nothing and is just a waste of money. The function of a strainer core or filter is to produce a lamellar metal flow. In this case by the time the metal hits the bottom of the downright it will be in complete turbulent flow and will be mixing into the metal all of the oxides and slag particles available. Strainer cores or filters should be placed at the bottom of the downright or in the runner bar.

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