Foundry Energy Optimization

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Introduction:

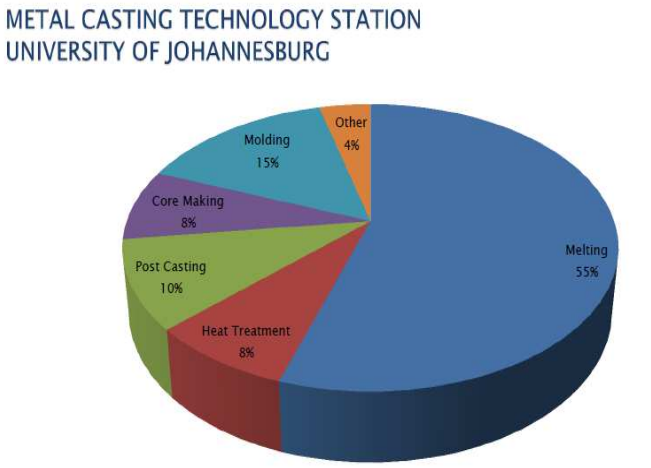
It is estimated that more than 48,300 foundries are registered globally. [1] The metal casting industry is one of the most energy-intensive manufacturing sectors with the melting process accounting for over half of its energy consumption. Although its high energy expenses have been a significant concern for metal casters, the industry continues to use melting technologies with poor energy efficiency. [2] Pakistan is facing energy crisis. The availability of the energy is far less than the demand. Striving to reduce energy consumption in melting metals shows a promising path to lowering operating costs in foundries and, in turn, cutting down the production costs for the entire manufacturing sector. The industry, especially foundry sector, needs to adopt smart energy consumption methods to handle the situation. The betterment can be expected through improvements in equipment design, process control and management techniques.

The Energy Sources:

A melting furnace derives its heat from solid fuels (coke and breeze), natural gas, electricity, or other sources of energy. To be smart user of energy we need find the ways to maximize the output by minimum input of the energy in each respect. Coreless Induction Furnace and Cupola Furnaces are more popular than other types of furnaces for cast iron production.

The Energy Consumption:

As per study of Metal casting technology station University of Johannesburg, the highest electrical energy in the foundry is consumed by the melting unit. [9]



Energy consumption in the metal casting facility
Source MODERN CASTING APRIL 2011

The runner ups in energy consuming equipments in a foundry is utility of compressors that supply high pressure air to other departments.

The Equipment and Machinery:

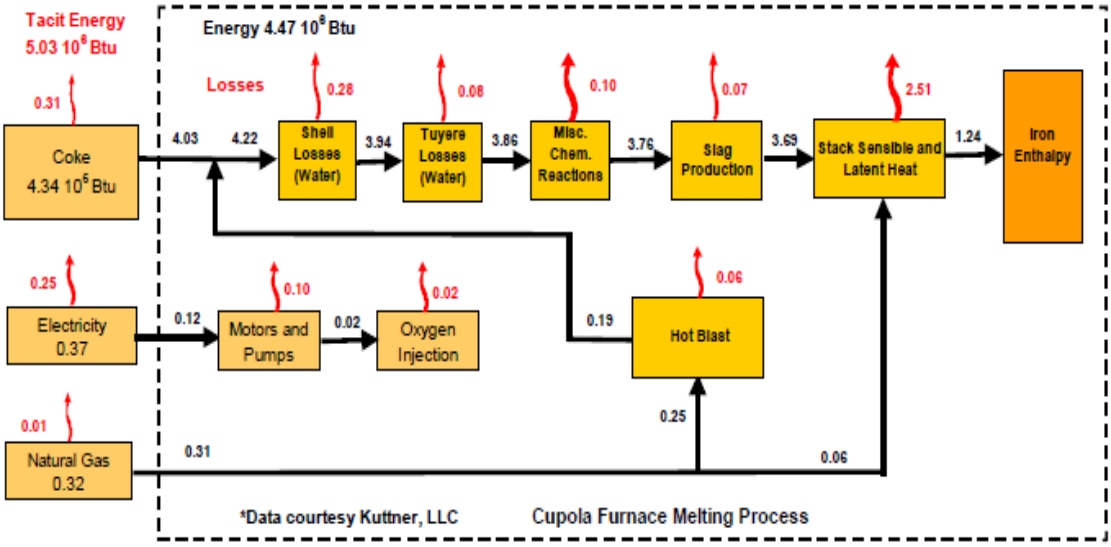
The energy can be saved through investing in energy efficient equipment over standard efficiency equipment. Cupola furnaces are most common furnace for cast iron melting. The most energy-efficient cupola, found by Teri, use 13.6% charge coke (coke:metal ratio of 1:7.5). The figure for the least energy-efficient cupola was found to be as high as 26.5% (coke:metal ratio of 1:4). [3]

Energy efficient designs have been developed that include oxygen enriched blast cupola, divided blast cupola, hot blast cupola, long campaign cupola, plasma fired cupola, and coke-less cupola (gas cupola). Different designs claim 12 to 40% reduction in coke consumption as compared to conventional single tuyers cold blast cupola.

The new possibility of sparing managing the energy by melting cast iron includes a Brasilian cupola type FAR. A dramatically reduction of the coke: metal ratio, namely to the level 6~7 kg/100 kg of metal is expected with this design.

Computer-aided control of the cupola process may also lead to the best calculated output of the energy input.[4] Recently, computer models have become available, including neural network models, to provide rapid estimates of process variables for use in automated control schemes. Computer control of the cupola process lowers material and processing costs, reduces scrap and improves quality.[5]

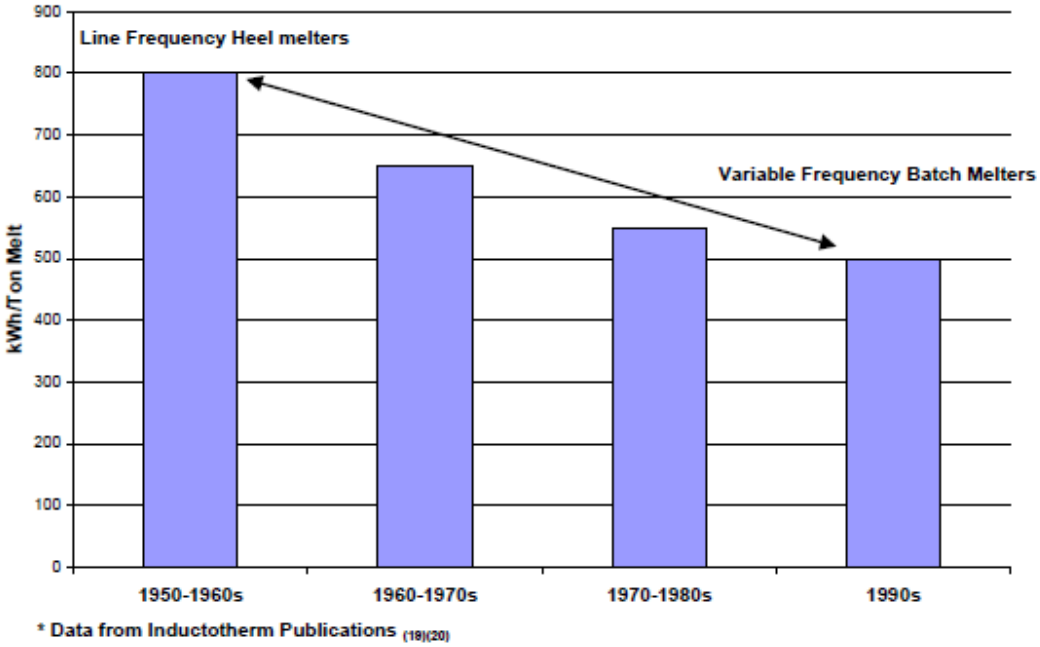
Low-Efficiency Cupola Melting Process Energy Balance (10^6 Btu/Ton Iron Melt)* (Water-Cooled Bare Shell) [6]



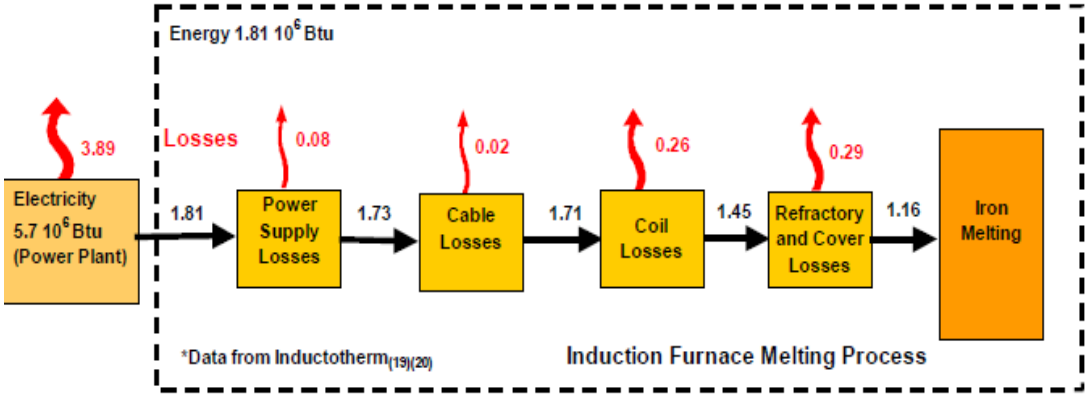
A 10 ton coreless induction furnace operating at 60 Hz can melt its capacity in two hours. At 275 Hz, the same furnace can melt the full 10 ton charge in 26 minutes, or four times faster. [5]

Better harmonics control can lead to the better efficiency of the coreless induction furnace. Harmonics problem, or feedback of electrical equipment on the power source, can be caused by the high power of the furnace power supplies. These power interface problems include low-power factor, high-frequency harmonics, line voltage notching, and inter-harmonic distortions. Special technologies and equipments have been developed to minimize the negative influence of induction furnaces on the power supply. Computerized controls and diagnostic systems are available to provide close control of the melting operation and reduce the chances of accidental overheating. A typical control system uses information from load cells for the weight of the furnace charge and thermocouple readings for melt control optimization. Multiple-Output Power Supplies have also been developed. Dual-output or “butterfly” operations utilize a single power supply and two furnaces with mechanized or electronic switching. This results in continuous and completely controllable power to two furnaces at the same time. Recently, multiple-output power units with three or more outputs have been developed. These new systems are designed with capacitive furnace isolation and include one or two AC rectifiers. Such systems are capable of achieving the high volumes of metal production previously possible only with cupolas. [5]

Historical Induction Melting Furnace Energy* (Delivered) [6]



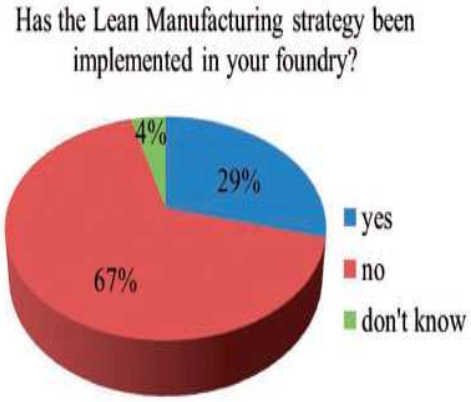
Comparison of Practical Minimum, Theoretical Minimum and Best Practice Minimums for Selected Processes (Delivered kWh/Ton Melt) [6]					
Selected Processes	**Theoretical Minimum**	**Industry Average**	**% Difference**	**Practice Minimum**	**% Difference**
Iron Induction Melting	351.5	796.3	56%	538.1	35%



Modern Induction Melting Process Energy Balance (10^6 Btu/Ton Melt)* [6]

Lean Manufacturing Techniques:

The verbal meaning of “lean” is “thin”. The Rockford Consulting USA defines it as, “Lean Manufacturing is an operational strategy oriented towards achieving the shortest possible cycle time by eliminating waste”. It is the philosophy of continually reducing waste in all areas and in all forms.
Also known as Toyota Production System (TPS), presently, Lean manufacturing techniques are not widely adopted in foundry sector. In 2013 J.Jezierski and K. Janerka of Poland conducted a survey.[8] Three hundred (300) Polish foundries responded the questionnaire. The results showed that the lean was not implemented widely and properly in the foundry sector.



Implementation of Lean in foundries



Reasons to not implement lean tools

Types of Waste:

The soul of lean manufacturing is to eliminate waste in the process through various tools. Anything that adds cost to the product without adding value is defined as waste. After the value stream mapping it is important to know the waste. Lean defines eight types of Waste:

1. D efects

2. O ver production

3. W aiting time

4. N on-utilized people

5. T ransportation

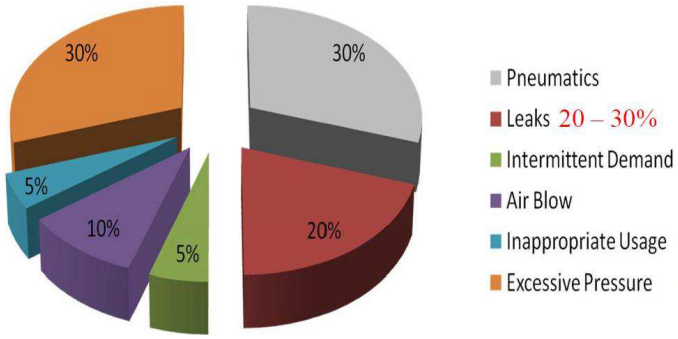
6. I nventory

7. M otion

8. E xcess processing

If we join first letter of each type, we get the word 'downtime'!

Among all the eight some types of waste are frequently observed in the foundries that ultimately cause the waste of energy. The defective castings or rejections simply mean that all the energy in any form we consumed to manufacture a rejection, gone in vain. The over-production leads to spend energy only to build up finished stock inventory which is not only the over-production waste but also the inventory waste. Controlling the defects and over production will reduce the energy consumption per ton shipped to the customer. Among all other waiting times, the most drastic in the foundry is furnace waiting. Each minute of holding the furnace, for any reason, will cost units of energy for which the customer will not pay for. The over heating of the melt is an example of excess processing that consumes energy. Sometimes the metal is even cooled down before pouring at the desired temperature. This excess processing is a waste of energy adding cost to the end product. The heat is dissipated through radiation from the induction furnaces without lids hence wasting the energy. It is estimated that only 30% of the compressed air is utilized for production, rest of the valuable air is wasted due to leakages, artificial over demands, and poor distribution designs. [10]



The 1989 British survey of cupola foundries showed the average specific coke consumption (SCC) of 158 kg/t liquid iron. A U.K. cupola foundry lowered the SCC of their cold-blast cupolas to 113 kg/t, a savings of 28%. They achieved this through improved production planning to reduce variations in composition, temperature and melted metal demand, accurate weighing of coke and charge, and other process improvements. [7]

The following are some general recommendations that apply to both ferrous and nonferrous melting: [6]

1. Use clean scrap – one pound of sand charged means two pounds of iron or steel not melted and increases the slag generated. Do not waste energy to heat the sand!
2. Maintain minimum tapping temperatures that ensure quality castings. Streamline temperature measurement – automated furnace temperature and power controls

prevent overshooting temperature settings. Do not waste energy for extra processing!

3. Optimized scheduling – minimizes excessive holding power. Do not waste energy in wait!
4. Refractory – maintain refractory thickness to factory recommendations. There should not be over thickness. Do not waste energy to heat extra refractory!
5. Reduce the time the lid is open for all purposes while melting or holding iron. A 12-ton capacity furnace (storage tons) loses 14 kWh for each minute the lid is open. Do not waste energy to heat the surroundings!

The Energy Audits:

Energy audits indicate the ways in which different forms of energy are being used and quantify energy use according to discrete functions. An energy audit does not provide the final answer to the problem; it identifies where the potential for improvement lies, and therefore, where energy management efforts must be directed. [7]

The entire audit exercise can be divided into three steps. Step one identifies the quantity and cost of the various energy forms used in the plant. Step two identifies energy consumption at the department/process level. The study involves detailed mass and energy balance of major energy consuming equipments. Step three relates energy input to production (output), thereby highlighting energy wastage in major equipment/processes. The system efficiencies are evaluated and measures are identified for improving the end-use energy efficiency.

The energy audits can be performed internally by a competent individual with suitable technical training and good overall knowledge of the foundry's operations and also externally by the energy audit firms.

Incentives on Energy Savings:

Energy management is a cost reduction strategy that can have an immediate impact on profitability. Successful energy management is more than just turning off the lights.[11] It takes a champion, a commitment, and a holistic, comprehensive program. It is not a quick fix, but a long term commitment with a program. It does not necessarily require capital investment but a change in company culture. Any individual or collective effort to minimize the energy consumption should be highlighted and praised with appreciation certificates, awards and cash prizes. The energy saving competition among the various departments in terms of %age reduction in input for more output can be held on monthly basis. The incentives offered to the direct consumers may make them think to find more effective ways to further saving of energy than standard usage.

References:

1. Enhancing Competitiveness of Small and Medium Size Foundries- Scope, Challenges and Way Forward, Foundation for MSME Cluster, Shri Mukesh Gulati, Ms. Neetu Goel

2. “Advanced Melting Technologies: Energy Saving Concepts and Opportunities for the Metal Casting Industry”, BCS Columbia, Incorporated November 2005

3. http://www.indianfoundry.org/source/Teri/energy.htm

4. “Tendencies to the Improvement of the Cupola Process”, A. Jopkiewicz a,*, C. Podrzucki b, ARCHIVES o f FOUNDRY ENGINEERING, ISSN (1897-3310) Volume 7 Issue 3/2007 61 – 70., Polish Academy of Sciences, Poland

5. "Induction Furnace - A Review", Vivek R. Gandhewar, Satish V. Bansod2, Atul B.Borade, International Journal of Engineering and Technology Vol.3 (4), 2011, 277-284

6. “ Theoretical/Best Practice Energy Use In Metalcasting Operations”, J. F. Schifo, J.T. Radia, KERAMIDA Environmental, Inc. Indianapolis, May 2004

7. “Guide to Energy Efficiency Opportunities in Canadian Foundries”, Canadian Foundry Association and Natural Resources Canada, 2003

8. “The lean manufacturing tools in Polish foundries”, J. Jezierski, K. Janerka, Archive of Metallurgy and Materials, Volume 58 2013 Issue 3, DOI: 10.2478/amm-2013-0105,

9. “A collective approach towards green foundries in South Africa”3rd Foundry Industry Colloquium 2011 October 27 and 28, Johansberg, South Africa

10. “Moving towards green foundries in South Africa”, Lessons from the US Experience, M Jones Papo, University of Johannesburg, Colloquium, 27-28th October 2011

11. “Effective Energy Management”, Steve Robison, American Foundry Society – EHS Conference, Aug 23-25, 2010 – Nashville TN