MELTING EFFICIENCY – F2B

Energy eco-efficiency opportunities in Queensland Foundries

Furnace efficiency

The metal casting industry is one of Queensland's most energy-intensive manufacturing sectors. Most of the energy use is in the furnaces with energy loss a result of conduction, radiation and convection heat losses from the furnace, stack loss (flue gases), and metal loss. The extent of the losses will depend heavily on the furnace design, level of process control, the type of fuel used and operator practice.

There are two fact sheets in this series discussing melting efficiency:

- Melting efficiency – F2A: Charge preparation, energy management and metal reduction; and
- Melting efficiency – F2B: Furnace efficiency

This fact sheet (F2B) will discuss some eco-efficiency opportunities that may help to reduce energy losses and improve productivity through improved furnace efficiency. The fact sheet on Charge preparation, energy management and metal reduction (F2A) provides some tips on how to reduce energy consumption by improving charge preparation and energy management and reducing metal content of products and runners.

Loading the charge

Furnaces are typically loaded using automated handling and weighing equipment. Equipment includes cranes, magnets and claws to pick up the metal and put it into buckets or conveyors for loading into the furnace.

Furnaces are either

- **loaded cold** which means the entire furnace mass must be heated as well as the metal; or
- **continuously operated** so the furnace stays hot and only the metal needs to be heated.

Continuously operated furnaces can use less energy as energy is not required to reheat the furnace for every load. However, savings can often be negated by heat loss from lids or doors opened for loading. The charging rates (the rate of loading charge into the furnace) can often be 20 per cent below optimum.[1] This adds to heat loss as lids and doors are left open for longer. To reduce these losses, foundries should ensure that the charging rate is not unnecessarily slow.

For more information on efficiency gains through better charge preparation refer to the Charge preparation, energy management and metal reduction fact sheet (F2A) of this series.

1 Natural Resources Canada, 2003, Guide to Energy Efficiency Opportunities in Canadian Foundries oee.nrcan.gc.ca/cipec/ieep/newscentre/foundry/2/2_3_3.cfm

Choosing a furnace

Although high energy expenses are a significant concern for metal casters many foundries are using melting technologies with poor energy efficiency as Table 1 demonstrates. Of the amount of heat put into the furnace, the thermal efficiency refers to the percentage of that heat that actually melts the metal. The remaining heat is lost, through for example, inefficient combustion, the furnace's housing and flue.

Table 1: Differences in furnace efficiency[2]

Type of furnace	Capacity (tonnes)	Metal types	Metal loss (%)	Thermal efficiencies (%)
Induction	0.001 – 50	Aluminium	0.75-1.25	59-76
		Copper base	2-3	50-70
		Magnesium	2-3	59-76
		Iron	1-2	50-70
		Steel	2-3	50-70
Direct Arc	1.5-100	Steel	5-8	35-45
Cupola	0.05 - 20 per hour	Iron	3-12	40-50
Crucible (gas)	0.007 – 100	Aluminium	4-6	7-19
		Magnesium	4-6	7-19
		Copper base	2-3	7-15
Rotary	N/A	Aluminium	N/A	35
Stack Meters (gas)	1-10 per hour	Aluminium	1-2	40-45
Reverberatory (electric)	0.5-125	Aluminium	1-2	59-76
		Zinc	2-3	59-76
Reverberatory (gas)	0.5-125	Aluminium	3-5	30-45
		Zinc	4-7	32-40
Immersion (low temp)	0.7per hour	Zinc	N/A	63-67

Electrical induction furnace efficiencies

Most of Queensland's major foundries replaced their coal-fired cupola furnaces with electric induction furnaces during the nineties because the induction furnaces were cleaner burning and more energy efficient than most other combustion processes. Compared with the cupola furnaces, electric induction furnaces can offer greater flexibility for batching, better metal homogeneity from induction stirring, a quieter working environment and closer process control. Recent industry focus has been on improving furnace efficiency through greater process control, fault diagnoses, reducing power use and charges and increased automation of maintenance tasks. Induction furnaces also produce less CO, SO_2, NO_x, dioxin and slag onsite than many other furnace options. However offsite emissions from the required electricity production should also be included when considering total emissions from this type of furnace.

For efficiency tips on energy management in foundries refer to the Charge preparation, energy management and metal reduction fact sheet (F2A) of this series.

2 BCS, 2005, Advanced Melting Technologies
www1.eere.energy.gov/industry/metalcasting/pdfs/advancedmeltingtechnologies.pdf

NEW FURNACE SAVES TIME AND ENERGY

Tyco Water at Currumbin was undertaking its melting operations using two old medium frequency electric induction furnaces (50Hz). The site was melting in its large furnace which, because of its slow melt rate and large volume, was always kept half full with raw charge being added to this pool. A pool of metal was even kept in the furnace, with the power on, over weekends when the site was not operating as this was more cost effective than emptying the furnace on Friday night and then refilling and melting all day Sunday for production on Monday morning.

The molten metal was then transferred in one tonne batches to the site's smaller furnace for holding. The result was a continuous melting and transfer regime to try and keep up with the site's production rate.

With the installation of a new high frequency induction furnace (250Hz) with a higher melt rate the site can now undertake a number of batch melts in a shorter period of time meaning the site can melt and fill the large furnace (now only used for holding) in normal production hours. The furnace has many other advantages including:

- the ability to accept swarf that the existing furnaces could not accept. Charging wet swarf into a molten bath of metal was a significant safety concern with the existing furnace charge method.
- a single board computer control system with a user friendly interface that can provide the operator with real time information about the furnace's power consumption, cooling water temperature, metal temperature and faults.
- a three phase 6 pulse wave rectifier that can convert mains power from 3 phase 50Hz to DC providing a high constant power factor of 0.95. For more information on power factor see fact sheet Motors, pumps and fan efficiency (F4) of this series.
- the furnace's filter network can also result in the lowest possible harmonics generation that can be detrimental to the power supplier and any sensitive electrical equipment connected to the same system.
- less frequent liner replacement; previously when the large furnace was used for melting, the lining needed to be replaced every 6 weeks. As a holding furnace, this lining will now only need to be replaced approximately every 12 weeks.

It is estimated that the new furnace will save the site $130 000 annually through reduced melting time and more efficient melting based on current electricity prices. The payback period will be approximately 2 years.

Furnace insulation

Well insulated furnace covers, designed to be removed in sections, can reduce heat loss. Hydraulic swivel options can be used in situations where lids are cumbersome, heavy or hot.[3] Lids should be tight fitting and not damaged or warped. Around 75 per cent of the heat loss in an induction furnace occurs when the lid is open.[4]

Refractory lining

Refractory lining monitoring uses optical fibre to accurately determine the temperature in real time over the entire crucible irrespective of refractory type. Such monitoring ensures maximum furnace utilisation between relining while minimising the risks associated with thin lining. As the new technology uses non-electrical measurement it eliminates false signals from magnetic interference.[5]

Hydraulic lining push-out systems consist of a large moveable plug that pushes out the lining in minutes. Traditionally, worn furnace lining is removed manually which can be labour intensive and poor practices can lead to damaged back-up lining. Hydraulic lining push-out systems reduce time leading to quicker melt cycles which in turn indirectly save energy.[6]

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3 Modern Casting, 2006, 10 Ways to Improve Melting **www.thefreelibrary.com/10+ways+to+improve+melting:+achieving+perfection+may+be+too+much+to...-a0152259924**

4 Modern Casting, 2006, 10 Ways to Improve Melting **www.thefreelibrary.com/10+ways+to+improve+melting:+achieving+perfection+may+be+too+much+to...-a0152259924**

5 W. Schmitz, F. Donsbach and H. Henrik, 2006, Development and Use of a New Optical Sensor System for Induction Furnace Crucible Monitoring. World Foundry Congress **www.lios-support.com/LIOS_Paper_World_Foundry_Congress.pdf**

6 C. Fink, 2005, Modern Induction Melting, Foundry Management and Technology.

BENEFITS OF AUTOMATED LINING PUSH-OUT SYSTEM

Tyco Water in Currumbin has installed automatic lining push-out systems on all its furnaces to allow the refractory lining to be removed more efficiently and safely. Previously, manual methods using jack hammers consumed many man-hours and created a lot of dust. The lining is now pushed into a large covered bin that contains all of the dust and the bin is then taken away via forklift greatly reducing the manual labour involved.

New refractory linings are continually being developed with improved thermal shock resistance, greater corrosion resistance, and improved emissivity (ability to radiate absorbed energy) resulting in a longer life span and greater energy efficiency. Checking with refractory suppliers about lining developments may help to improve furnace energy efficiency.

For example the iron foundry, Elyria in Ohio, USA agreed to investigate a new refractory system for its induction furnaces. The new lining had 3 dry vibratable materials to help address slag attack, abrasion and mechanical abuse. The supplier engineered refractory resulted in an additional 3 months in production time due to a 50 per cent reduction in down time (only four lining and inductor changes per year versus eight previously) and a more reliable melt.[7]

Robots can be used to improve worker safety and energy efficiency on the melt floor.[9]

Robotics

Robotics on the melt floor can now be used to:

- insert thermocouple lance through a port to measure the molten metal's temperature without opening the furnace cover (reduced heat loss)
- take samples for metal analysis
- add trim alloys as required
- evenly spread the correct amount of slag coagulant and remove slag.[8]

The complete melting process from charge makeup, charging, melting, analysis correction and even operation of auxiliary units can now be fully monitored and controlled from the safety of an air conditioned control room. Such automation not only improves worker safety but also increases consistency, productivity and energy efficiency.

Fuel furnace efficiencies

While waste gas heat losses are unavoidable in fuel fired melt, holding and metal treatment furnaces, there are a number of opportunities to reduce emissions and energy losses.

Correct fuel to air ratios (high efficiency combustion) can help reduce heat lost through the exhaust flue. For every fuel there is a chemically correct amount of air required to burn it which provides the greatest thermal efficiencies. Not providing enough air results in incomplete combustion that causes poor thermal efficiency and toxic by-products (carbon monoxide and unburned hydrocarbons). Providing excessive amounts of air carries the heat away from the process and up the flue increasing the temperature of the flue. Installing flue and air control meters, such as a stack gas oxygen analyser can continuously monitor and adjust the fuel-to-air ratio for optimum efficiency.

Hot furnace gases are less dense than ambient air and rise creating a differential pressure between the top and the bottom of the furnace causing a draft or negative pressure. The draft can draw in cold air from door, lid or port openings or from leaks in furnace seals and joints which must then be heated to maintain the furnace temperature wasting fuel, creating cold spots and quality problems. **Positive pressure** can prevent this draft by making sure the furnace is air tight and installing a pressure controller that can regulate the airflow by either varying the speed of draft fans or by changing damper settings for the incoming combustion air or the exiting flue gas.

7 Modern Casting, 2001, Iron Foundry Cuts Melting Costs with Furnace Refractory
www.thefreelibrary.com/Iron+Foundry+Cuts+Melting+Costs+with+Furnace+Refractory-a074887331

8 J. Belsh, 2009, Better Control, Safer Operation for Melting, Foundry Management and Technology
www.foundrymag.com/zone/melting/news/83623/better_control_safer_operation_for_melting

9 J. Belsh, 2009, Better Control, Safer Operation for Melting, Foundry Management and Technology

Oxygen enriched combustion is where 100 per cent oxygen or a component of oxygen is added to ambient air. It can reduce flue gas heat losses as less nitrogen is available to carry heat. Lower emissions (lower levels of nitrogen oxide, carbon monoxide and hydrocarbons), temperature stability and heat transfer (more stable combustion) are also improved. There are a number of ways to implement oxygen enrichment including mixing it with the combustion air stream, injecting it through lances into the furnace or through burners designed for higher oxygen concentrations.

Recover hot flue gas for preheating combustion air can typically reduce energy consumption from 5 per cent to 30 per cent.[10] A gas-to-gas heat exchanger called a recuperator is most commonly used. Alternatively incoming cold combustion air is passed through a regenerator, which is filled with metal or ceramic shapes that absorb the heat from the hot flue gas, preheating the combustion air. If a boiler is operating at the same time as the furnaces the heat from flue gases can also be used to preheat boiler makeup water.

Optimise air flow through fume hoods
Excessive air flow through fume hoods can draw heat off the top of the furnace. Make sure the amount of air flow through the hood is only sufficient to effectively remove fumes.

Tapping

Ladle heaters can consume a lot of fuel with the average burner efficiency in iron foundries being 53 per cent and even lower in steel and non-ferrous foundries.[11] A blue flame indicates carbon monoxide burning and efficiencies below 58 per cent. Maintaining **proper air ratios** as discussed previously can improve the combustion efficiency up to the 62–65 per cent range.[12] A **heat shield reflector** can be used to reflect heat back into the ladle.[13]

Radiation losses from a ladle holding molten metal can also be very significant. Many foundries compensate for radiation heat loss by superheating the metal in the melting or holding furnace. If metal that could have been poured at 1510 °C (2,750°F) for example are allowed to rise to 1649 °C (3,000°F) (less than 10 per cent) then additional energy will be used by the furnace while the heat losses are boosted by 33 per cent.[14]

Ways to reduce heat losses include **covering the ladle with a lid or lightweight ceramic-fibre cover** during transfers which can enable the dropping of tap temperatures by as much as 50°C.[15]

Consider if tapping practice could be completed more quickly by using larger ladles or transfer launders (transfer channels) to **reduce the number of taps**. As the furnace is not being used for melting during the tapping process these practices could not only reduce heat loss but increase productivity.

A large USA jobbing foundry, for example, increased its melt furnace utilisation by 30 per cent by simply increasing the width of the trough in the transfer launders from the melters to its holding furnaces.[16]

Again foundries should investigate improving the insulation properties of the wall and bottom ladle lining to prevent heat losses.

This series of fact sheets provides examples and suggestions to the modern foundry operator on how to achieve both economic and environmental benefits from eco-efficiency. Visit the project website www.ecoefficiency.com.au for more ideas and case studies.

10 USA Department of Energy, 2005, Energy Tips - Process Heating, Install Waste Heat Recovery Systems for Fuel-Fired Furnaces www1.eere.energy.gov/industry/bestpractices/pdfs/install_waste_heat_process_htgts8.pdf
11 Natural Resources Canada, 2003, Guide to Energy Efficiency Opportunities in Canadian Foundries.
12 Natural Resources Canada, 2003, Guide to Energy Efficiency Opportunities in Canadian Foundries.
13 Natural Resources Canada, 2003, Guide to Energy Efficiency Opportunities in Canadian Foundries.
14 M. Eckert, 2007, Reduce Power Consumption Without Sacrificing Production Foundry Management and Technology.
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