POST TAPHOLE PRACTICES ADDING VALUE

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ABSTRACT

Whereas in the past, ladles were simply a means of transferring molten products from furnace tapholes to points of discharge be they casting pans or waste dumps, the ladle is now becoming a more integral and versatile piece of equipment in the pyrometallurgical plant. The drive behind this development is the need for continuous improvement in performance where better, faster and cheaper means remaining competitive in the global market.

This paper will explore the technologies available for the rendering of a costly and otherwise cumbersome piece of pyrometallurgical equipment more efficient and versatile in adding value to the final product. Essentially it all revolves around heat and more importantly the loss of it when tapping. The common practice is to move the molten product to its point of discharge quickly with the minimum of interruption to prevent skulling and hence the cost associated with clearing it. The advances in Oxy-fuel burners, AC or DC ladle furnaces, converters, gas purging and high velocity, bath injection systems has increased the versatility of processes and enhanced the potential for adding value to intermediate products through down stream practices such as granulation and atomisation.

1. INTRODUCTION

As a result of the recent broadening of market opportunities, the smelting industry in South Africa has quite suddenly found itself competing diametrically with international rivals and in order to remain competitive in the global market, it has become ever more important to optimise process operations. The drive for continuous cost-effective improvement must therefore be in all facets of the metallurgical operation. In the pyrometallurgical process, ladles may be simply looked at, as a means of transferring molten product from furnace tap hole to points of discharge, be they casting pans or waste dumps. However, with the high cost associated with maintaining this equipment and in order to achieve cost-effective optimisation, the ladle has to now become a more integral and versatile apparatus in the pyrometallurgical plant.

This paper will explore the technologies available for the rendering of this costly and otherwise cumbersome piece of pyrometallurgical equipment more efficient and versatile. Essentially it all revolves around energy in the form of heat and more importantly the loss of it when tapping. The common practice is to move the molten product to its point of discharge quickly and with the minimum of interruption to prevent skulling and hence the cost associated with cleaning of the ladle and re-melting of the reverts. The delivery requirements by down stream processes are now putting greater demands on this otherwise simple modus operandi. It is not the molten product alone that is the value basis but the form in which it is solidified and the losses associated with solidification and subsequent resizing, be this casting and crushing, granulating or atomising. Even waste products such as slag are being processed by these methods in order to render them safe to stockpile and easy to reprocess should it become cost effective some time in the future. The necessity to control the amount of super heat or heat in excess of the liquidus required by the down stream process makes it necessary to consider designs that allow for energy input after the tapping operation. This requirement for energy input step at this point is normally driven by a process requirement such as refining or de-carbonisation. The opportunity to re-melt reverts at this point rather than returning it to the smelter is an added advantage.

Oxy-fuel burners, AC or DC ladle furnaces, converters, gas purging and high velocity, bath injection systems are all technologies that increase the versatility of this process requirement and enhanced the possibility of adding value to down stream practices such as granulation and atomisation by making them more efficient. In this paper we shall endeavour to investigate the pro's and con's associated with these configurations to better understand the application and the benefits and pit falls associated with down stream processes.

2. LADLE HEATING AND SKULL FORMATION

Let us consider an empty ladle where the first requirement for heat in the operating life of this ladle is the drying and firing of the refractory lining. A common practice is to first air dry the lining, after which a wood fire is lit to initiate the removal of any water of crystallisation. The refractory supplier will have a specific drying and firing cycle for the installed lining and in order to do justice to the cost thereof one should consider the proper equipment necessary for this purpose.

For the initial drying and firing of the refractory lining as well as subsequent heating, electric ladle heaters generally give better temperature control at lower temperature ranges than gas burners and hence make for safer discharge of entrained water. The down side however tends to be the rather less than robust heating element arrangement which invariably gets damaged when the unit is lowered into position by the overhead crane. A properly designed drying operation with an automated lifting and lowering device needs to be considered if this option is selected.

Gas burners attached to ladle lids with quick couplings are a more robust portable option, should that degree of flexibility be required. A typical temperature, which can be achieved by gas burners, is around 800°C. This temperature range is well above the thermal shock level for most commercial refractory linings available today but it may not however be high enough to limit the formation of skulls, which are the most common contributor to losses associated with poor ladle performance. In a recent study undertaken on a ferrosilicon ladle process where skulling of the ladle is more problematic, it was determined that the energy losses at the top of the ladle wall were approximately twice that of the bottom. This is a common scenario and with the radiant losses makes the top third of the ladle most susceptible to skull formation.

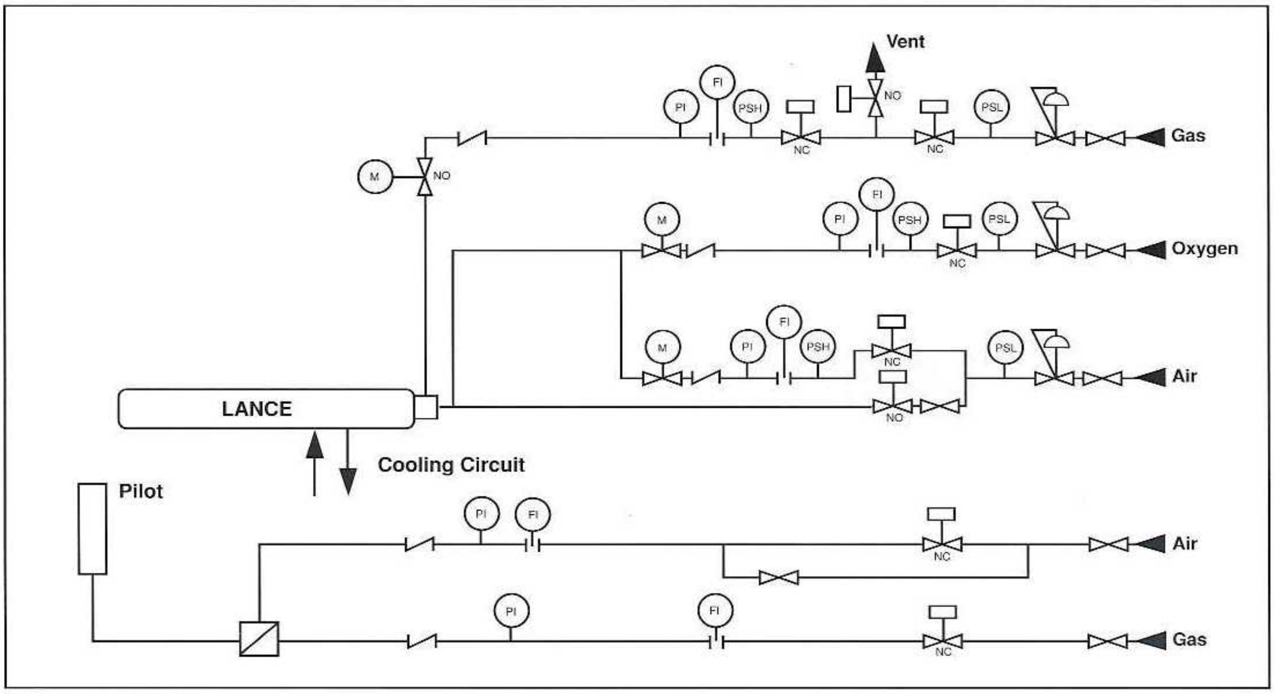

Figure 1. Typical schematic of an Oxy-fuel lance system.

Limiting the skulling effect in the aforementioned study would require the ladle to be kept at an operating temperature of 1600°C, which is somewhat out of the rage of the Venturi nozzle and fan aspirated burners but not the Oxy-fuel devices. The configuration is well described as a, water-cooled lance as opposed to a gas burner and is a more recent development for high temperature gas fired applications. These systems are designed for specific high temperature applications and can achieve a temperature that not only caters for the limitation of skull formations but also allow for the re-melting of spillage's and other losses. In the case of the ferrosilicon study it was determined that a firing rate of around 900MJ/hr would be required to hold the temperature at 1600°C. A 2.5GJ/hr (approx. 700 kW) duty would be required to reheat a colder ladle of around 1450°C to 1600°C and that this would require a recovery time of some 48 minutes. The hood design would therefore have to be altered to accommodate the increased exhaust gas volume. The above figures are modelled for SASOL gas as opposed to LP gas and 100% oxygen input would be required. A typical schematic for the system is given in figure 1.

The 100% oxygen requirement is not common for these systems but is a function of the fuel source and the energy required, figure 2 gives the effect of oxygen enrichment on temperature with a corresponding air volume.

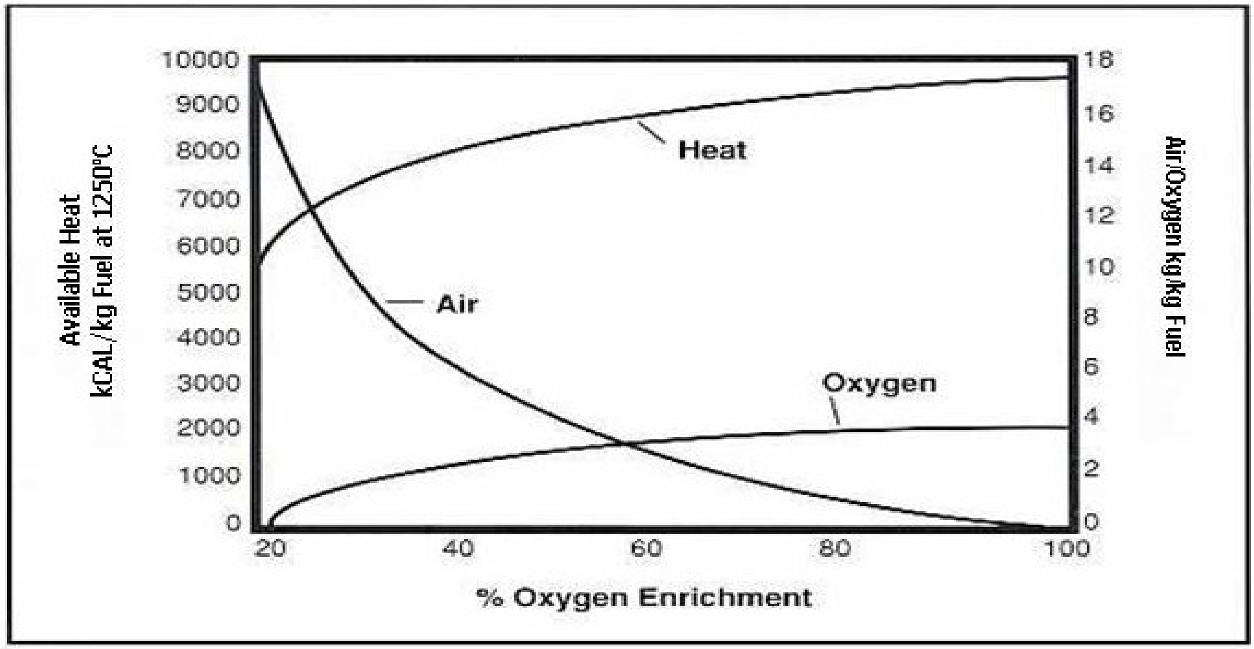

Figure 2. Impact of oxygen.

The Oxy-fuel combustion systems are most effective in Rotary Furnace (see figure 3) installations and can be adapted to accommodate the feeding of fine material to the bath. In the case of ladle heating the application has its own unique exertions. Ladles by their very design are deep open bath vessels, being a most practical design for the transfer of molten material. The ladle design is not however suited to effective heat transfer. The heat source impinges on the surface of the molten product and heat transfer is not as effective due to the depth of the ladle and the radiant losses to the roof section. The top surface of the ladle contents tends to overheat as well as the side walls of the ladle which leads to refractory lining wear and the formation of slag, which is an unwanted contaminant to the down stream process.

Similar problems were encountered by Electrotherm and covered in a paper, the details of which are given in SECTION 7.1 below. Purging with inert gas through a porous plug in the bottom of the ladle to create a stirring effect remedies the problem to an extent but the trade off is the amount of agitation required for effective heat transfer versus the cooling effect of the gas. This is true for all ladle-heating applications be they gas or electrical. Most ladles tend to be just too deep for efficient heat transfer at higher temperatures. It is generally felt that for higher temperature applications, smaller ladles of say 5 to 10 tons are suited for Oxy-fuel lance systems.

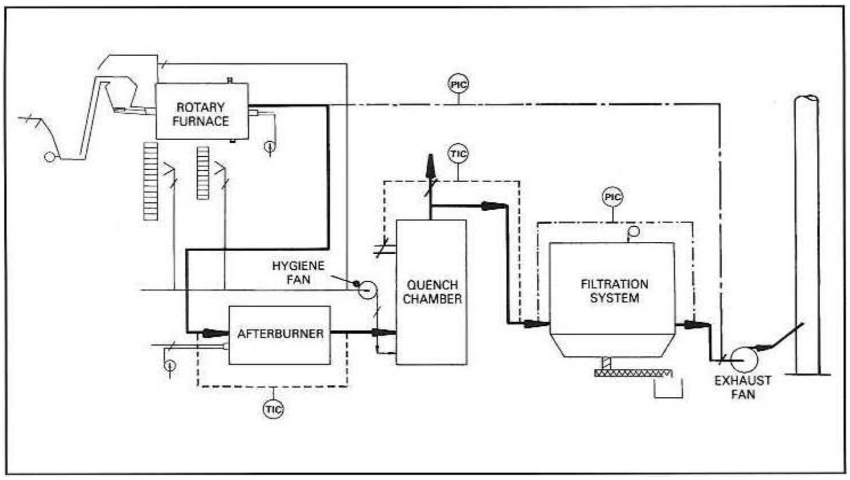

Figure 3. Schematic of a typical Rotary Furnace application.

Selecting an Oxy-fuel gas re-heating system therefore depends on a number of considerations, the cost and availability of the gaseous fuel and oxygen is certainly one of the most important. The requirement to re-melt fines may also be a consideration where an alternative power source such as electricity may be difficult to utilise. The optimal temperatures required and size of the ladle, are also to be considered. The metal product may be sensitive to carbon pickup and hence a ladle heating system that does not incorporate the use of graphite electrodes would be beneficial.

3. ALTERNATIVE LADLE HEATING PRACTICES

The only other alternative for high temperature ladle processes is electricity, which can be categorised into AC, DC and induction heating configurations. A detailed description of the three types of ladle heating systems is given in the aforementioned paper by authors M. Bhandari, D. Norval. It is interesting to note that the AC three-electrode, system was not successful on a smaller scale due to overheating of the side walls resulting in refractory erosion. The 8 ton, 1450 kW Single Electrode DC configuration had also presented its difficulties. The inconvenience experienced by operations personnel to connect the bottom electrode to the power supply and the heat transfer efficiency was also poor (about 10 %) are cited as reasons for further development to the two electrode DC System (see figure 4).

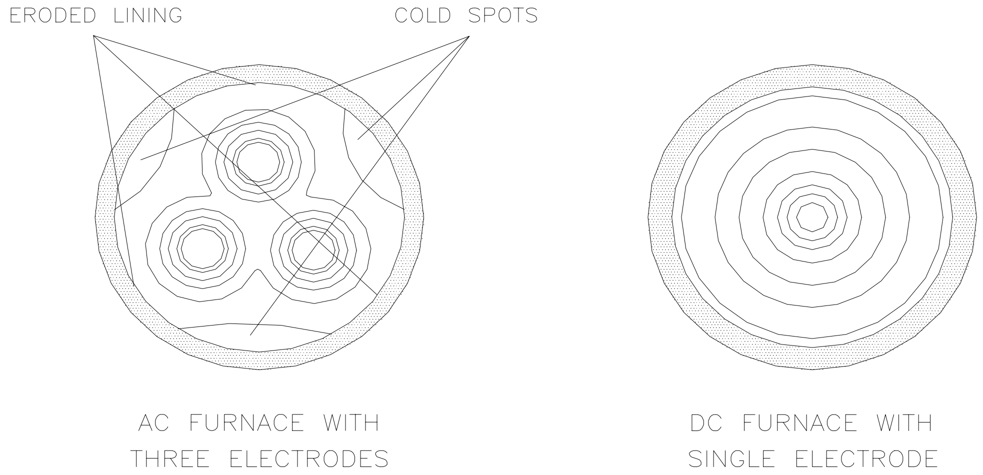

Figure 4. Schematic plan view of ladle heating.

A 20 ton / 2500 kW Double electrode DC Arc Ladle Refining Furnace (see figure 5) has been operated successfully and an interesting observation made was that the anode connection on the two electrode system tended to consume more quickly than that of the cathode. This problem was simply remedied by reversing the connections to balance out the electrode consumption.

Figure 5. The two electrode DC Ladle Refining Furnace in action.

These ladle-heating options are best suited to processes that are not sensitive to carbon pick up and tend to be more user friendly at a larger scale (15ton capacity and larger) and are rated with a 20% thermal efficiency. Successful designs do however exist to cater for smaller operation at around 8 ton capacity but what about operations where carbon contamination is problematic?

Induction heating is well suited to processes where carbon from the electrodes is problematic to the process. In the past the technology was not seen as practicable but developments in the design of these systems have made it a viable option. The INDUREF system (see figure 6) as described in the aforementioned paper by authors M. Bhandari, D. Norval was operated successfully at 250kW with a 60% thermal efficiency at a 1.5ton capacity. A 15 tonne, 1500kW unit is being operated and has a 40% thermal efficiency. The unit gives a cost saving of R44.25/ton when compared to the more conventional electrode systems. This is a versatile option for ladle heating with improved thermal efficiency and numerous advantages over the more conventional systems as listed below.

- Lower installation, operation and maintenance cost.
- Easy to operate and maintain.
- Reduced refractory consumption.
- Higher thermal and electrical efficiency.
- No line-flicker and can be operated with a weak grid as well.
- It has a good Power Factor and is a balanced load.
- No skull formation in the bottom of the ladle.
- No carbon pick-up.
- Higher yield of Fe-alloys.
- Can be operated on Diesel Generator sets.

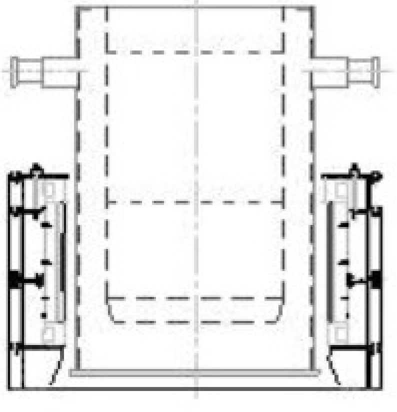

Figure 6. Schematic of the Induction Heated Ladle Configuration.

4. DOWN STREAM PROCESSES – GRANULATION AND ATOMISATION

The need for ladle furnaces and heating systems is governed by the process requirements such as refining and additive additions. The option to be able to re-melt refined metal skulls and spillage's without having to recycle it through the primary smelter is also an advantage. The cost of such facilities is much lower than that of a conventional smelter and the smaller capacities are easier to control and reduce the margins for error.

There is however another important consideration, which impacts on down stream processes such as granulation and atomising. This has to do with the delivery of the molten metal to the granulation/atomisation process. These systems are designed with a specific feed rate requirement, which is normally controlled by a ladle tilter and tundish with a fixed nozzle. The apparatus thus controls the rate at which the molten metal is fed and good operation is very important to preclude hazardous conditions that will result in an uncontrolled release of energy. Molten metal, which is too cold, will 'freeze up' in the hot runner/tundish causing a blockage that will halt the process and possibly result in the spillage of molten material. Excessive heat can be even more destructive causing refractory lining failure resulting in a feed rate well in excess of the design specification. The ability to control and optimise individual melts by ladle heating and monitoring is a definite advantage to these two processes and the lack thereof can render the downstream process difficult if not dangerous to operate.

5. CONCLUSION

Table 1 and 2 below give a comparison for the heating a four tonne ladle containing ferrosilicon. Although the Hydrocarbon Fuel gas will achieve the desired temperature increase, it somewhat slower and more costly and the combusted gas extraction system will add significantly to the total cost. An estimate of the capital cost for the two processes established the price for an oxy-fuel system at R11 000 000.00 while the cost of the induction heating system that would achieve a somewhat better performance amounted to R14 000 000.00. There is a significant increase in capital cost for the induction heating system but an off gas handling and ventilation system was not included in the price for the oxy-fuel system. Operating costs and specifically the cost of electricity as apposed liquid petroleum gas or equivalent will make the induction heated ladle system a very attractive option. Tariffs for the two commodities namely gas and electricity are too variable and as such none have been included.

Table 1. Gas heating a 4 tonne Ladle with temperature rise from
1450ºC to 1600ºC containing ferrosilicon.

Heating time	48 minutes
Power consumption per tonne of alloy	138.8kWh/t
Hydrocarbon Fuel gas consumption (at 30.72MJ/kg)	65.1kg
Stoichiometric oxygen	100%
Heat rate	3ºC/minute

Table 2. Induction Heating a 4 tonne Ladle with temperature rise from
1400ºC to 1600ºC containing ferrosilicon.

Heating time	40 minutes
Power consumption per tonne of alloy	150kWh/t
Hydrocarbon Fuel gas consumption (at 30.72MJ/kg)	N/A
Frequency	80-100Hz
Generator efficiency	95%
Heat rate	5ºC/minute

The options available for ladle processes are numerous and advantage is better process control and productivity. The selection of one over the other will depend on the specific circumstances as each process has its own unique requirements and challenges. The need to remain competitive will no doubt be the drive behind future innovation in optimising metallurgical processes.

6. ACKNOWLEDGEMENTS

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The author would like to acknowledge the assistance and inputs of Mr. D Norval in a paper titled: SOLIDIFICATION AND FURTHER PROCESSING OF FERRO ALLOYS AND SLAGS TO GRANULATE OR NOT TO GRANULATE by author D. Norval

The author would like to acknowledge the assistance and inputs of Mr J. J. Dunkley and Mr. D Norval in a paper titled: ATOMISATION OF FERROALLOYS by authors J. J. Dunkley and D. Norval

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