# A new concept in molten metal handling for ferrous foundries

## Introduction

**The Impact of molten metal handling on production, quality and costs**

60-70% of the energy consumed in foundries is in metal melting and holding operations (1). A finite quantity of energy is required to melt and superheat the metal to the required temperature for casting, however all other energy inputs and losses are within the control of the foundry. In many cases, excess energy is used in melting and holding the metal to compensate for inadequacies in the molten metal handling and distribution systems. This excess energy can amount to 10% of the total energy consumption of the foundry.

A highly insulating system to maintain heat energy within vessels containing molten metal will give many benefits including;

- Lower furnace-tapping temperatures resulting in energy savings, reduced furnace refractory wear and faster furnace turnround.
- Improved pouring temperature control resulting in consistency in casting production and longer casting time from a ladle within the pouring temperature specification.
- Reduced scrap or rectification from mis-run castings and lap defects due to low pouring temperatures.
- Reduced scrap or rectification from shrinkage cavities and inaccurate castings due to excessively high pouring temperatures.
- Lower tapping and holding temperature resulting in reduced fade of alloying elements. Less alloying material is required and improved metallurgical consistency is achieved.

Conventionally ladles are lined with a castable or plastic refractory, these materials have a relatively high density and while offering adequate mechanical and chemical resistance to the molten metal provide poor insulation. The materials are messy in application, require skilled labour to install, and have a time consuming application method requiring energy intensive drying and firing operations often taking days to complete.

The long ladle downtime and high labour and energy costs associated with relining a ladle results in the ladles life being extended beyond acceptable limits. This gives many problems:

- The linings become worn and slag builds up causing inconsistent capacities and insulation characteristics
- The ladles become "dirty" and therefore affect the cleanliness and integrity of the castings
- The linings require regular repair which is a costly, unpleasant and relatively dangerous operation.

## KALTEK ISO

Through working closely with Iron and Steel Foundrymen to understand the limitations of currently available Molten Metal Transfer Systems and to clearly define their requirements KALTEK ISO has been developed and Patented.

KALTEK ISO is a low-density dry powder ladle lining system providing

- A high level of insulation.
- Simple, clean and fast application to the ladle.
- Resistance to chemical attack and physical erosion of the molten metal.

**Ladle Installation Procedure for KALTEK ISO**

To apply a lining, the following simple equipment is required, KALTEK ISO powder (see Figure 1), an empty ladle, a suitable former, a hammer, a gas torch and a crowbar or lifting equipment.

*Figure 1: KALTEK ISO supplied in sacks and used as a dry powder*

**An outline of the process is as follows (2):**

1. The former is necessary to provide the internal shape, with suitable capacity for the ladle. The former needs to allow for the formation of the required lining thickness, 50-60mm is recommended for a 400kg ladle. Many 4mm holes throughout the former are required. The formers can be a simple one-piece system for a lip pour ladle; a three-part system is required for a ladle incorporating a dam board (see Figure 2).
2. The base of the ladle is filled to the correct depth with the dry powder, no mixing is required. The former in then located centrally in the ladle shell.
3. Further dry powder is poured between the ladle former and the ladle shell. The ladle needs to be occasionally tamped with the hammer to aid packing of the powder (see Figures 3 and 4).
4. A gas flame is directed into the former to initiate the exothermic reaction of the powder, this takes approximately two minutes, the gas flame is then removed. The exothermic reaction continues for approximately 15 minutes during which time hydrogen gas is liberated, this is released through the top of the ladle and the holes in the former as gas flames (see Figures 5 and 6).
5. When there are no more flames evident the reaction is complete. The former can then be removed from the ladle either manually or with the assistance of a crane for larger ladles.
6. Following any necessary shaping of the pouring spout and capping if required the ladle is ready for use.
7. An initial preheat to approximately 1000°C is recommended but not essential. This aids the bonding process of the lining system, improving the refractoriness of the ladle in use. Due to the high level of insulation and low thermal mass red heat is quickly achieved (see Figure 7).

*Figure 2: A former for the production of a T-Pot ladle, this is stripped from the ladle in 3 parts*

*Figure 3: The dry KALTEK ISO powder is poured between the ladle shell and the former*

*Figure 4: The void between the ladle and the shell has been filled with KALTEK ISO*

*Figure 5: A gas flame is applied to initiate the exothermic reaction*

*Figure 6: The reaction continues for approximately 15 minutes*

*Figure 7: A short preheat prior to initial use is beneficial*

**KALTEK ISO Bonding System**
The KALTEK ISO system is based on carefully selected graded mullite to provide optimum packing, high levels of insulation, while maintaining resistance to abrasion and attack from the molten iron.

The density of a KALTEK ISO lining ready for use is 1.6 g/cm$^3$, approximately 60% less than the alternative castable and rammable refractories used.

There are three main bonding mechanisms responsible for the development of the required properties in the mullite based system. The first reaction is the exotherm instigated by the gas flame and is based on the following equation;

$$Na_2SiO_3 + 5H_2O(l)] + 2Al \text{ -------->} SiO_2(s) + 2NaAlO_2(s) + 2H_2O(l) + 3H_2(g)$$

This reaction develops a low temperature bonding system which is sufficiently strong to allow the metal former to be removed and the ladle to be handled.

Preheating of the ladle facilitates the formation of a vitreous bond. Solid state sintering of the system is developed quickly when metal is tapped into the ladle. The development of the bonding system is shown in Figure 8.

**Use of a Kaltek ISO lined ladle**
After the recommended initial preheating, prior to the first tap of metal into the ladle, no further preheating is required. The low density system is highly insulating and non chilling so superheating of the metal in the furnace can be minimised. Laboratory tests have been performed which compare the heat conductivity between a conventional castable system and KALTEK ISO by placing a 50 mm thick plate of the test material against an increasing heat source and measuring the radiant heat from the cold face. The results of this experiment are shown in Figure 9.

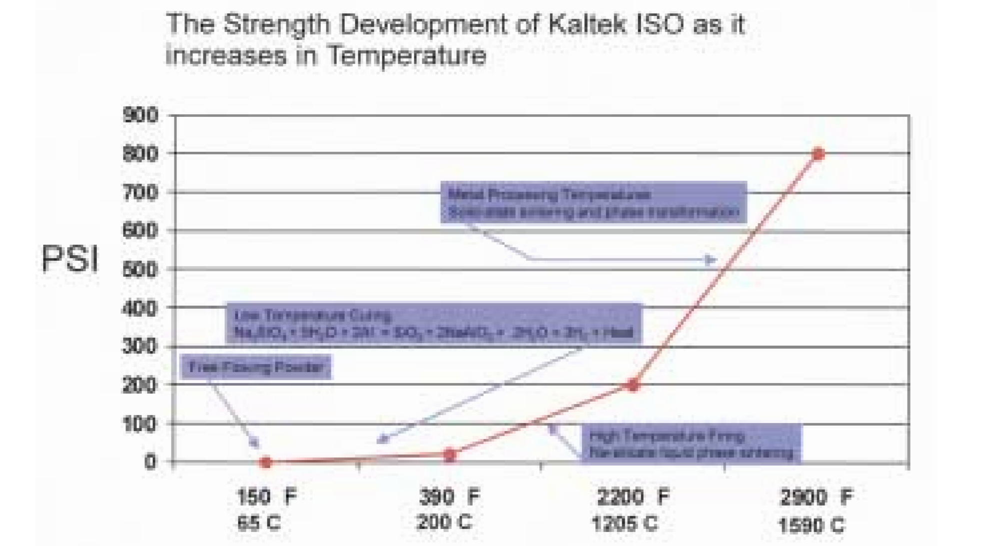


*Figure 8:*

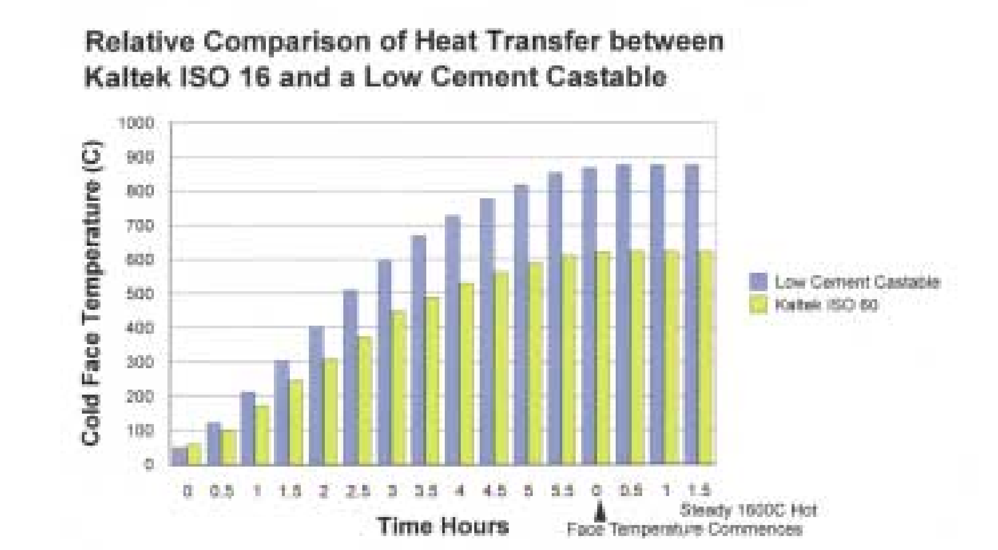


*Figure 9:*

The KALTEK ISO is a low wetting refractory system, so the build up of slag is less than with a conventional system (see Figure 10).

- ❑ requirement to clean the ladle is therefore reduced but when necessary can be achieved by scraping or prising with a steel bar
- ❑ minor repairs to the KALTEK ISO lining can be performed if required
- ❑ the KALTEK ISO system can offer a similar life in terms of tonnes of molten metal as conventional linings.

Knock out of an expended lining is quick and simple. Removal of the lining from the ladle can normally be achieved in 5 minutes with a steel bar; there is no need for the use of pneumatic hammers. Coventional ladles often continue to be used when realistically the lining has reached the end of its effective life. The refractory is worn away and replaced by slag, resulting in poor temperature control and inconsistent capacity, the ladles are essentially dirty giving the potential for inclusions in the castings. This abuse often originates from the expense and extensive downtime normally associated with relining a ladle.

KALTEK ISO allows the ladle to be taken out of commission when it needs to be, the ladle can be knocked out, relined and back in service within one hour with a brand new premium quality lining.

70% Alumina rammable

KALTEK ISO

*Figure 10: A comparison of a ladle lined with KALTEK ISO and a 70% alumina rammable. Both ladles have been used to pour the same quantity of SG Iron over a 24 hour period.*

A comparison between the labour time associated with lining the same ladle with rammable, castable and KALTEK ISO is shown in Figure 11.

| FUNCTION | KALTEK ISO Time Minutes | CONVENTIONAL RAMMABLE Time Minutes | CONVENTIONAL CASTABLE Time Minutes |
|---|---|---|---|
| Installing Former | 3 | N/A | 3 |
| Lining Ladle | 10 | 60 | 45 |
| Exotherm | 15 | N/A | N/A |
| Strip Former | 3 | N/A | 3 |
| Drying / Fritting | 20 (Optional) | 600 minimum | 1200 minimum |
| **TOTAL** | **51 maximum** | **660 minimum** | **1251 minimum** |

Other Considerations

| | | | |
|---|---|---|---|
| Preheat | N/A | 60 minimum | 60 minimum |
| Repair / Maintenance / Clean Down | 30 | 60 | 60 |
| Used Lining Removal | 5 | 45 | 60 |

*Figure 11: A comparison between the time taken to reline an equivalent ladle with rammable, Castable and KALTEK ISO*

## Summary of the major features and benefits of the KALTEK ISO system

- Simple, clean and quick ladle turnaround
  A ladle can have the old lining removed and a new lining installed ready for use within one hour.

- A highly insulating refractory
  Lower tapping temperatures reduce furnace wear and improve furnace turnround time. Control of the metal pouring temperature allows for consistent casting production and a reduction in temperature related casting defects and scrap.

- A non wetting refractory system
  A reduced build up of slag in the ladle and less erosion of the refectory lining reduces the need for lining maintenance and provides clean metal to the mould.

## References

(1) Metal distribution and handling in Iron Foundries – ETSU, Harwell, Didcot, Oxfordshire, United Kingdom

(2) KALTEK ISO - The next Generation of Ladle Lining Technology - Harry Clark