A SYSTEM COMPARISON OF CONTINUOUS TEMPERATURE SYSTEMS IN CONCAST OPERATIONS

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Temperature control in continuous casting comes in basically 2 different ways: Either by disposable temperature sensor or continuous. Modern casters of all types are today widely automated and have replaced manual measurement action by automated on demand or continuous techniques. Semi-permanent continuous sensors are the industrial standard in continuous casting. Most common is the thermocouple-based measurement, with over 95%. Thermocouple reliability and accuracy are still unmatched and require almost zero maintenance. But optical systems are on the move as well showing a promising potential of good precision and cost effectiveness. This paper gives a system comparison of today's industrial systems in respect to cost and technical performance.

KEYWORDS: continuous casting, temperature, continuous temperature, thermocouple

INTRODUCTION

Since Charles Darwin's 'On the origin of Species' we know that the strongest, the fastest, the most resistant etc survives in the chain of evolution. If this is true for the cleverest as well, the Homo erectus, we do not know yet, and we may have our doubts when looking at the recent rapid change of the world climate threatening mankind with storms, flooding, expansion of deserts etc. And what about this in the metallurgical world? I remember Hans-Ulrich Lindenberg from Thyssen-Krupp saying 'The most stupid metallurgists got the biggest inclusions' in analogy to 'The most stupid farmers harvest the biggest potatoes'. Today this is no longer true or if still, then in a different sense. Till the early 60's, the eye of the experienced foreman read the temperature of the liquid steel from the color of the steel flames and the carbon content from the sample sparks. This species of metallurgist has (almost) faded away from our steel shops. Their brilliant knowledge is not needed any more; time swept them away and replaced them with a new graven image, a new idol named sensing technology. In Concast operations, continuous sensors have taken over leaving human experts and disposable thermocouples by far in the shade in terms of precision and cost effectiveness. Let us a look at various systems for making better steel. Without changing mind and accepting the new trend, the old saying 'In the furnace gold, silver in the ladle, but scrap in the mould' might still have its truth.

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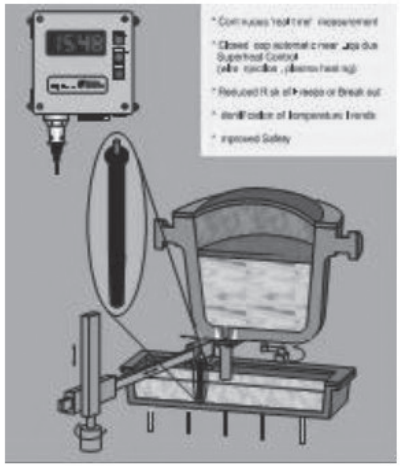
THERMOMETRIC SYSTEMS

Top immersion type

This version of continuous measuring thermocouple combines cost, fit and function in a way that makes it today's standard. Broadly independent from Concast operations it features precision and good flexibility. Its reusability for the next sequence of casting ladles and a long service life of typically 24hrs makes it very economic for most caster applications. Thermal shock is no issue with the black refractory protector tubes used, and thus the sensor may be immersed directly without preheating.
Fig. 1 shows a typical application and the schematic diagram of the sensor construction.
It is common to use tundish pantographs or pre- fixed arrangements to immerse and park the sensor.

The 'Contilance' type

A recent innovation for continuous temperature measurement is a reduced weight continuous sensor system, which enables a truly mobile system for the first time. There are a few aspects that make a Contilance attractive:
- Familiarity. The method for applying the lance is virtually the same as for traditional spot measurements.



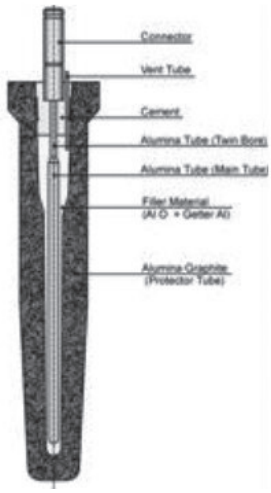
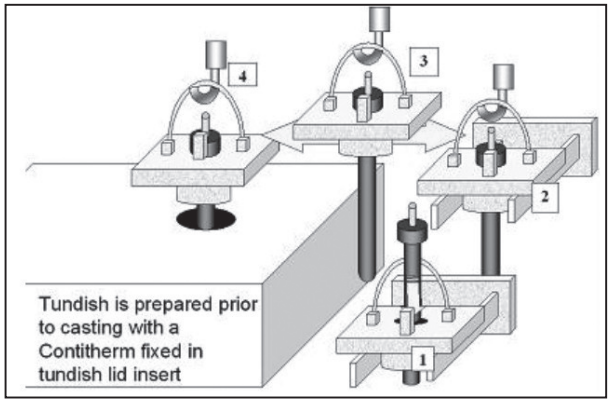


Fig. 1

Sensor, application sketch and inner construction.

Sonda, applicazione e costruzione interna.

a



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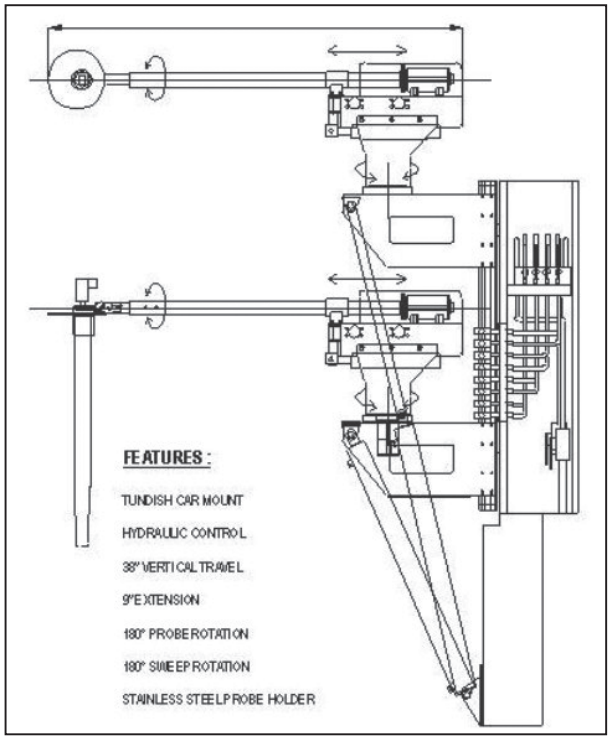


Fig. 2

a: Pre-fixed arrangement, b: Pantograph.

a: Sistema premontato, b: Manipolatore.

- Mobility. Move the continuous measurement from here to there.
- Easy access. A lance is most flexible and may reach a measurement place that is difficult to access by a fix installation.
- Fast thermal response.
- Low investment cost
- Easy and low cost maintenance
- Improved operator safety compared to spot measurements and heavier continuous sensor types

This system is most attractive for short sequence casters. The air-cooled lance is self-positioning and keeps the sensor floating even with changing steel level in the tundish. This ensures an optimised constant immersion depth, and avoids shallow immersion or even immersion loss with erratic reading.

The lance rest system is adjustable in position, and adapta-

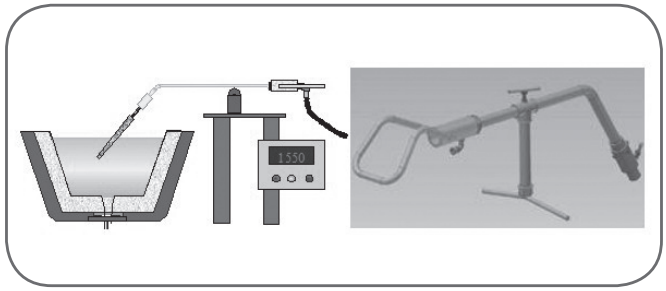


Fig. 3

Contilance lance scheme.

Schema lancia Contilance.

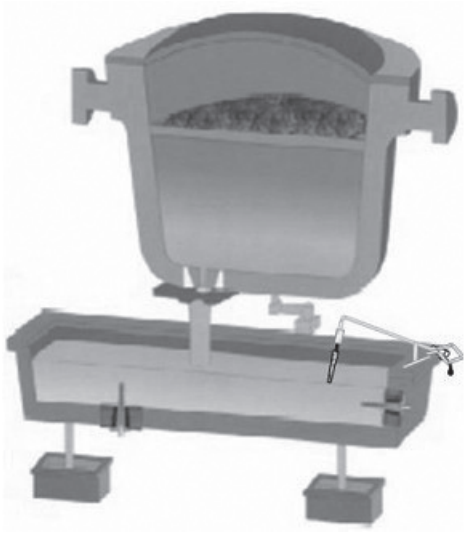


Fig. 4
Contilance application scheme.
Applicazione della Contilance.

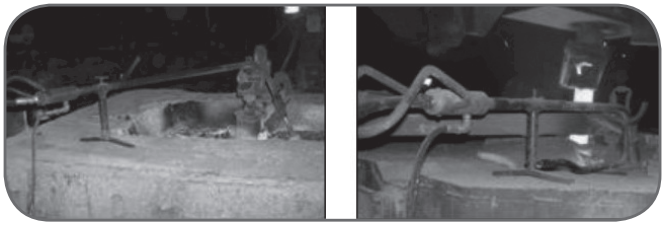


Fig. 5
Contilance in covered and open tundish applications.
Applicazione della Contilance in paniera coperta e scoperta.

ble, enabling plant specific solutions to be decided locally.

Through the wall system

A continuous thermocouple installed through the wall or the bottom of the tundish is already an old concept but offers, if engineered in the right way, an enormous potential and customer benefits. Fig. 6 shows the arrangement. This chapter describes the industrial implementation of a new approach, a very accurate real time continuous temperature measurement of the steel close to the tundish outlet nozzle.

The measuring system consists of a disposable sensor which is replaced every tundish sequence and a reusable well block which is permanently mounted in the tundish lasting the lining campaign; plus instrumentation hardware. So the measured temperature relates to the steel that is exiting the tundish. Fig 7 shows the temperatures as measured through the refractory lining cross-section during a typical tundish sequence. The CasTemp and its Well Block are manufactured from materials which can be termed "technical refractories" and as such are much more refractory than the surrounding standard tundish lining materials.

Experience with the CasTemp system at Corus, IJmuiden

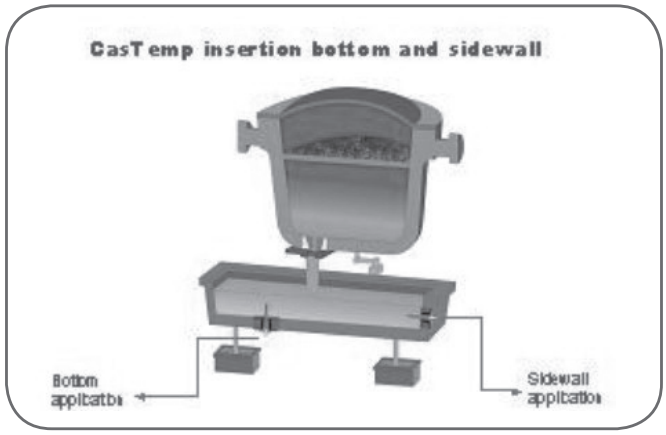


Fig. 6
The location of the through the wall sensor (CasTemp) in relation to the outlet ports, the sensor and the ladle shroud.
Posizionamento del sensore CasTemp in relazione agli scaricatori e alla siviera.

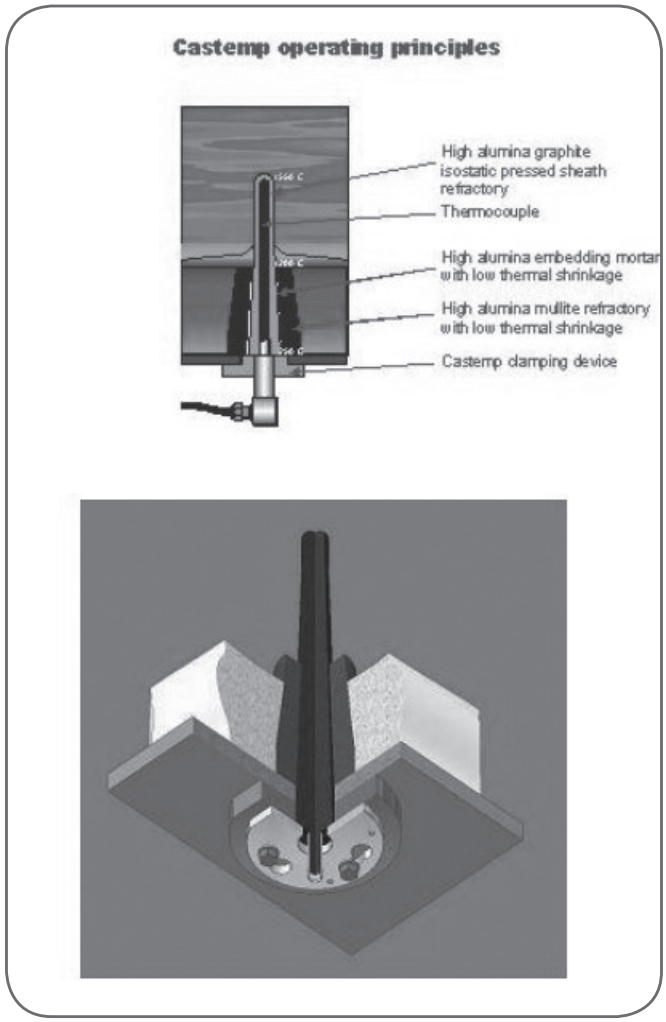


Fig. 7
The CasTemp sensor mounted through the tundish ling.
Il sensore CasTemp montato attraverso il rivestimento refrattario.

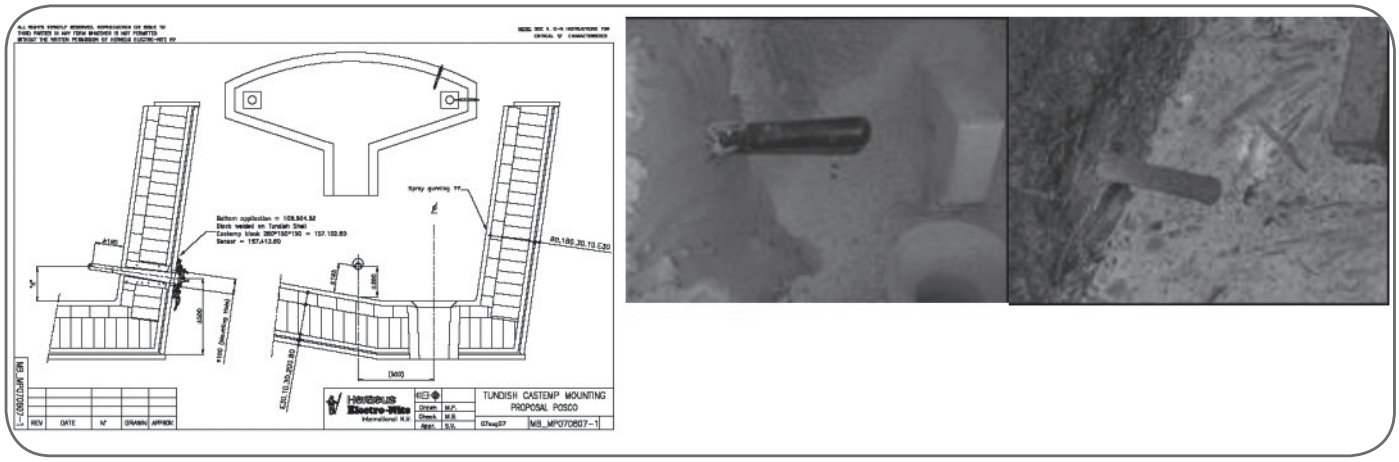


Fig. 8

Positioning the 'through the wall' sensor. Right: sensor prior to and after 12h sequence casting. Interesting is the very low sensor erosion and absolutely zero erosion around the sensor at the tundish wall spray gunning layer.
Posizionamento del sensore attraverso la parete. A destra il sensore prima e dopo una sequenza di 12h. Interessante è la bassa erosione del sensore e la assoluta mancanza di erosione del rivestimento paniera in prossimità della sonda.

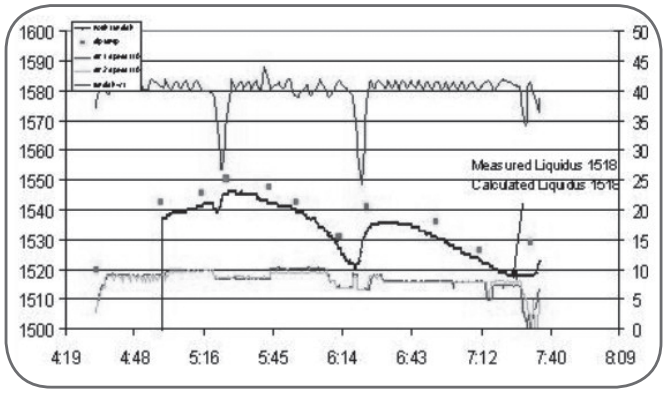


Fig. 9

CasTemp and dip measurements.
Misura della sonda CasTemp e delle termocoppie classiche ad immersione.

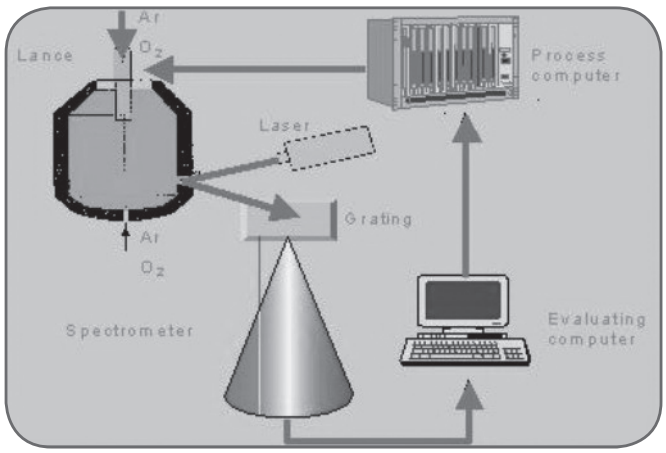
has shown that the developed system allowed the plant to achieve the desired measurement as well as bringing the following advantages:
- A tundish temperature measuring system where the sensor measures close to the tundish outlet nozzles.
- A sensor, which measures the tundish pre-heat temperatures.
- A temperature measuring system, which requires minimal casting plant operator involvement saving manpower and ensuring safety.
- An applied measuring system requiring minimal changes to the existing plant.
- An accurate temperature signal within 90 seconds of opening the ladle
- A temperature measuring system where the connection cables are located in a cool well protected area ensuring minimum damage and resulting in extended life.

The sensor measuring point should be as close as possible at the tundish outlet nozzle, so that the measured temperature relates to the steel that is exiting the tundish.
CasTemp is not a new temperature measurement. Under ideal circumstances it nicely coincides with the top immersed continuous and dip measurements. The overall advantage is that it eliminates human mistakes and corrects the assumption that the tundish temperature is homogenous over its 3D dimensions. The 'through the wall' system is foolproof and allows immediate, unquestioned accuracy, even during preheating, casting start-up and ladle changeover periods. In the upper chart the continuous trend of the CasTemp sensor indicates a potential risk of freezing already 30 minutes prior to ladle change, see

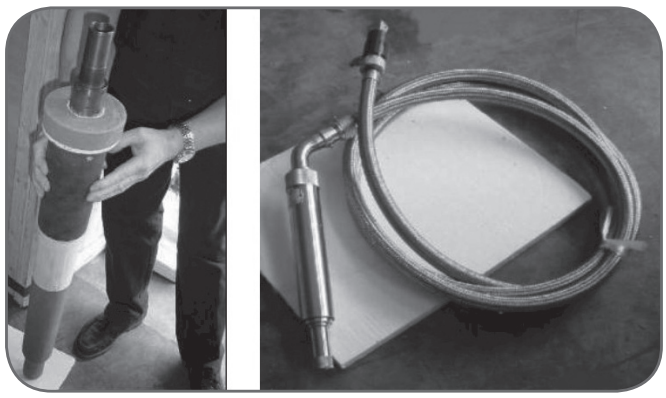
System Type	Response time from RT to 1550 degrees	Accuracy	Investment cost	Operational cost per t of steel cast
Contitherm	*4.5 min*	*2°*	*3.000 - 30.000 €*	*0,05 €*
Contilance	*1.5 min*	*2°*	*2.000 €*	*0,06 €*
CasTemp	*1.5 min*	*1°*	*1.000 €*	*0,09 €*

Tab. 1

Data comparison of thermocouple-based continuous measuring systems. The wide range of investment cost for Contitherm is due to cost variation for installed immersion system (manual, automated).
Confronto dei dati dei sistemi di misura basati su termocoppia in continuo. L'ampiezza della variazione dell'investimento relativo alla Contitherm deriva dal tipo di sitema di posizionamento della sonda (manuale, automatico).



▲ Fig. 10 ***Optical emission system in BOF application.***
Sistema ad emissione ottica in un'applicazione per BOF.



▲ Fig. 11 ***Continuous black body tube, spectrometer and cable for continuous temperature measurement in tundish application.***
Tubo a corpo nero, spettrometro e cavo per la misura in continuo della temperatura in paniera.

middle blue line, whereas the dip measurement trend is less pronounced (pink squares). Liquidus temperature is shown (plateau) at the steel's freezing point at end of casting, see Fig. 9. No handling, manipulation and exchange problems.
These characteristics make the through the wall system for many caster applications especially interesting particularly where there is high-speed casting, and casting different strand sizes from one tundish. Whenever it comes to 'mixed' casting with different mould sizes or higher casting speed (e.g. thin slab), the tundish may no longer be regarded as a homogenous vessel where an identical temperature prevails. The faster flow from ladle shroud through the lower tundish level to the moulds with high casting speed, and in case of 'mixed' casting the preferential flow of fresh steel to the higher consuming, bigger mould creates a temperature difference either in respect to tundish level or tundish section. The through the wall measurement can play its advantage here, as it measures the temperature where it counts, i.e. at the tundish nozzle. This up to now widely unknown (or at least unmeasured) effect gives chance to avoid mould breakouts, and on the other side enables caster speed optimization. A major integrated steel shop of the ArcelorMittal group in the USA calculated an extra caster output of plus 100,000t per year with this new technology.
A general view to this system comparison shows the Pro's and Con's of each one, see Tab. 1. Highest technical standard has its price. However the savings of each individual caster may by far justify this. The data assumes a scenario with casting sequence of 10x200t-ladles. The cost reflects the relevant sensor prices and service lives.

Non-thermocouple based systems

For decades researchers have been trying to replace thermocouples by optical methods, either via contacting light guides or non-contacting emission systems (e. g. infrared).
Fig.10 shows an optical emission system applied in a BOF converter. The initial side installation via a porous plug was replaced by a bottom system (through tuyere). Features are acceptable accuracy for primary steelmaking, high investment cost (approx. 150.000€), unknown maintenance and recalibration intervals.
For tundish application Infrared systems are already existing but still the exception or just used for R&D purposes.

SUMMARY

Modern thermocouple-based continuous temperature measurement systems are still the industrial standard of today combining accuracy and economy. Reaching from a highly economic reusable, through most flexible to top accurate systems, continuous temperature measurement has found its way to many cc-machines. They fulfill all the modern demands on automation, safety and maximized caster output. Continuous control for a continuous process, whereas the batch processes of primary and secondary steelmaking do not have a problem with a spot measurement on demand. Optical systems continue to be on the move, but still suffer from the one or the other drawback to be solved.

ABSTRACT

UN CONFRONTO TRA I SISTEMI DI MISURA DELLA TEMPERATURA IN CONTINUO IN COLATA CONTINUA

Parole chiave: Colata continua, temperature, temperature in continuo, termocoppia

Nella gestione della colata continua, la misura in continuo della temperatura sta sostituendo le termocoppie classiche in un'ottica di precisione della misura e di riduzione dei costi e permettendo nel contempo di superare le sempre più frequenti carenze di professionalità ed esperienza degli operatori.

SISTEMI TERMOMETRICI

Modello "Top immersion"

Questo tipo di termocoppia combina comodità d'uso e costi. La sua riutilizzabilità su più sequenze unite ad una vita utile tipicamente intorno alle 24 ore, ne fa uno strumento economicamente vantaggioso nella la maggior delle applicazioni. La sonda non e' sensibile agli shock termici e può essere utilizzata senza preriscaldo.

Modello "Contilance"

Un innovazione recentemente introdotta è rappresentata da sensori di misura in continuo leggeri che rendono il sistema realmente mobile. Ci sono alcuni aspetti che rendono il modello "Contilance" interessante:

- Familiarità: la lancia usata è simile a quella della misura tradizionale spot.
- Mobilità: si può spostare facilmente da un punto di misura all'altro
- Accesso alla paniera: la lancia è un sistema molto più flessibile per raggiungere punti altrimenti difficili per installazioni fisse (manipolatori)
- Risposta termica rapida
- Basso investimento
- Manutenzione facile ed economica
- Maggior sicurezza degli operatori in confronto con il sistema di misura a spot o con sistemi più pesanti

Il sistema è molto interessante per colate continue con bassi indici di sequenza. La lancia raffreddata ad aria è auto posizionante e mantiene in posizione di galleggiamento il sensore anche in caso di significative variazioni di livello in paniera.
Questo garantisce una profondità di immersione costante ed ottimale evitando errori di misura dovuti all'insufficiente profondità di misura.

Sistemi attraverso la parete della paniera

Una termocoppia continua inserita attraverso la parete laterale o attraverso il fondo della paniera offre un enorme potenziale di benefici per l'utilizzatore. La Fig. 6 mostra il sistema. Si tratta infatti dell'applicazione di un nuovo approccio per la misura in continuo della temperatura dell'acciaio in prossimità della busetta di scarico in lingottiera. In questo modo la temperatura misurata e' direttamente correlata a quella dell'acciaio che passa in lingottiera. Il sistema di misura consiste in un sensore monouso che viene sostituto ad ogni paniera e un blocco porta sonda riutilizzabile montato fisso sulla paniera in grado di resistere per tutta la campagna della paniera. Al sensore si aggiungono l'hardware di campo e la strumentazione di misura. La Fig. 7 mostra le temperature misurate lungo la sezione del rivestimento refrattario durante il colaggio.
Esperienze condotte col Castemp presso Corus Ijmuiden hanno mostrato che il sistema permette all'impianto di raggiungere gli obiettivi di misura ottenendo i seguenti benefici:
- La misura di temperatura di colaggio in continuo vicino agli scaricatori della paniera
- La misura della temperatura durante il preriscaldo della paniera
- La minimizzazione delle operazioni manuali riducendo i costi e aumentando la sicurezza degli operatori
- Applicazione del sistema con minime modifiche impiantistiche
- Una misura precisa di temperatura già dopo 90 secondi dall'apertura siviera
- Un sistema di misura in cui cavi e connessioni fossero in un area protetta e sufficientemente fredda assicurando un'elevata precisione e ridotti rischi di danneggiamento

Il punto di misura deve essere il più possibile vicino agli scaricatori in modo che la temperatura misurata sia direttamente in relazione con quella dell'acciaio che cola in lingottiera.
In particolari e ideali condizioni, la misura del Castemp coincide con quella della normale termocoppia ad immersione. Il grosso vantaggio è l'eliminazione del fattore umano e la correzione dell'assunto che la temperatura dell'acciaio in paniera sia omogenea nelle tre dimensioni. Il sistema di misura attraverso la parete e' a prova di stupido e garantisce misure estremamente precise anche durante il preriscaldo, durante la fase di avviamento e durante i cambi siviera.
Nella Fig. 9 l'andamento della misura del Castemp indica un potenziale rischio di "freezing" già 30 minuti prima del cambio siviera (cfr. linea blu), quando invece la misura discontinua fornisce solo una debole indicazione (punti rosa). Alla fine della colata, il grafico mostra la temperatura di liquidus (plateau).
Queste caratteristiche fanno del sistema di misura attraverso la parete uno strumento interessante per diverse applicazioni in colata continua, specialmente in macchine che colano ad alta velocità o che colano diverse sezioni contemporaneamente.
Con questo sistema viene misurata la temperatura dove serve (i.e. vicino agli scaricatori); ad oggi questa temperatura non viene misurata e la sua conoscenza può dare grossi vantaggi in termini di eliminazione di break-out e di ottimizzazione della velocità di colaggio. Un importante stabilimento americano del gruppo ArcelorMittal ha calcolato in 100.000 tonnellate anno l'incremento di produttività associato all'uso di questa nuova tecnologia.

Sistemi ottici

Per decenni i ricercatori hanno cercato di sostituire le termocoppie con sensori ottici sia con guide di luce a contatto che per emissione non a contatto. Ad oggi tali sistemi sono solo per scopi di R&D e non hanno applicazioni su scala industriale

In conclusione, i moderni sistemi di misura in continuo della temperatura in paniera, stanno diventando lo standard, combinando precisione ed economicità.