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A NOVEL APPROACH TO CONTINUOUS TUNDISH TEMPERATURE MEASUREMENT[1]

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Abstract

The current state-of-the art in continuous tundish temperature measurement involves the sensor inserted through the tundish wall to positioning in the optimal position to measure the steel inside the tundish. This paper describes a new continuous temperature measurement system, which gives an excellent accurate and a real time temperature during the entire casting process as well as tundish pre-heating. Through the tundish wall, sensor is implemented and guarantees a permanent temperature available from the beginning of tundish preheating up to the end of casting and steel solidifying.

Key words: Continuous temperature; Tundish; Side wall.

UMA NOVA ABORDAGEM PARA MEDIÇÃO DE TEMPERATURA CONTINUA EM DISTRIBUIDOR

Resumo

O estado-da-arte atual em medição de temperatura contínua em distribuidor, envolve o sensor inserido através da parede do distribuidor ao melhor posicionamento para medir o aço no distribuidor. Este artigo descreve um novo sistema de medição contínua de temperatura, o que dá uma precisão excelente, mede temperatura em tempo real durante o processo de lingotamento inteiro, bem durante o pré-aquecimento do distribuidor. A através da parede do distribuidor, o sensor é colocado e e garante uma leitura de temperatura constante a partir do início de pré-aquecimento do distribuidor até o final do lingotamento.

Palavras-chave: Temperatura contínua; Distribuidor; Parede.

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1 INTRODUCTION

Since continuous casting technology is a tight part of steel production, many developments to improve the casting process regarding output and availability of the caster as well as strand quality, were carried out.
Continuous casting steel is a process, where solidification of steel is the principle of the process. A well-controlled steel solidification is the precondition for high quality products. Therefore tundish temperature is recognised as a very important factor due to strand quality and casting speed in connection with the cast steel grade.
The current state-of-the-art in tundish temperature measurement involves immersing a sensor through the slag steel interface to measure the temperature of the molten steel in the tundish. This is mostly done by dip measurement for a discontinuously temperatur measurement
A big step forward was the development of a continuous temperature measurement device, so called "Contitherm" which allows a continuous temperatur measurement during casting. Contitherm is a measuring system, which is also immersed into the liquid steel through the slag and tundish covering powder and enables a continuous temperatur measurement from the beginning of immersing till the probe is taken out of the liquid steel, which is mostly done before the end of casting. Dropping steel level in the tundish during ladle change interrupts the measurement and tough slag could break the probe. A continuous- temperatur- measurement is not ensured.
Temperatures taken with both systems very accurate but the measuring positions are far away from the interesting temperatur close to the outlet nozzle, the dip and sensor positions are not always even to get reproducible temperatures, according Glitscher.(1)

2 MEASURING TEMPERATURE IN THE TUNDISH

According the Lagerberg et al.,(2) traditionally, measuring temperature in the tundish has been done by using a series of disposable immersion (dip) thermocouples, taken at the tundish entry position of the ladle pouring stream (Figure 1).

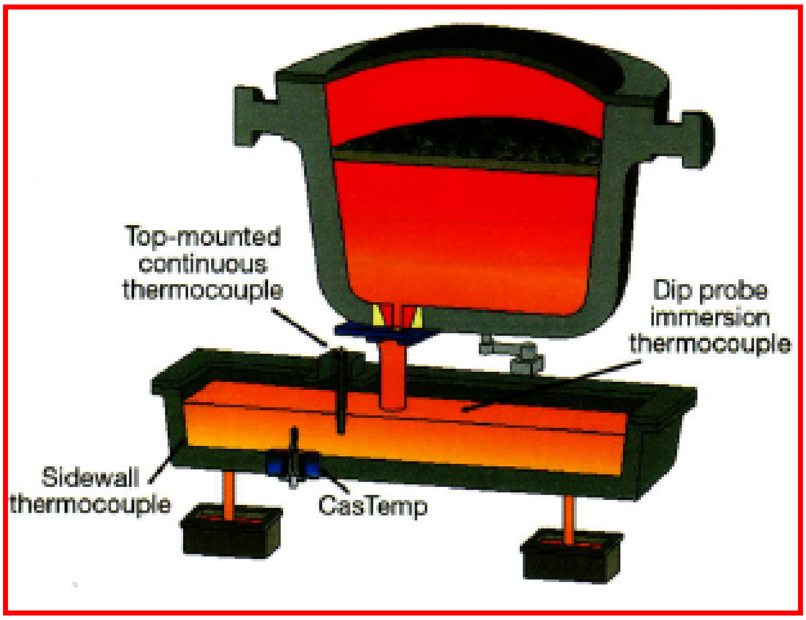

Figure 1. Measuring temperature in the tundish.

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Disposable dip thermocouples give only spot measurements (non-continuous) and are dependent on the operator dipping the sensor to the same depth in the same position to maintain a repeatable measurement. These thermocouples cannot usually be taken during the first minutes of tundish fill or after a ladle change because the tundish level is too low and splashing steel makes a dip impossible or too danger for the operator.
As continuous thermocouples have gained acceptance in and commercial use, continuous top thermocouple measurement of the tundish bath or tundish sidewall thermocouples have replaced dip probes for many casters. The factors that limit the use and accuracy of top mounted measuring systems can be summarized as follows:

- Top mounted sensors measures a significant distance away from the steel flowing out of the tundish through the casting nozzle. These sensors are limited to only measuring steel in the upper part of the tundish;
- top mounted sensors have a large refractory mass for slag protection, which cause a lag in response time;
- top mounted sensors are usually inserted after a new tundish has been filled and will not register any temperatures until the tundish level reaches a minimum height. Handling and insertion of preheated sensors present a challenge t prevent breakage and can pose a safety risk to operators;
- during ladle changes top mount sensors are limited if the steel drops below the sensor and suffer a time lag for accurate measurement when the steel re-immerses the sensors;
- viscous, aggressive tundish slag's can severely reduce the life of top mounted thermocouples;
- with multi-strand casters there is not enough data from a single sensor to understand unbalanced flow effects on temperatures entering each strand;
- while multiple sidewall thermocouples can be more easily used for each strand(with the probe tip at the interface between working lining and spray lining, they can be re-used on the same tundish), there are several factors that limit the use and accuracy of sidewall measuring systems, as summarized as follows: Sidewall sensors measures a significant distance away from the steel flowing out of the tundish through the casting nozzle, so abnormal flow patterns are not clearly detected. There is a thermal lag due to heat extraction from the tundish outer wall and the tundish brick in front of the thermocouple so that unsteady-state temperatures at tundish fill and ladle exchange will not be accurately measured.

3 HERAEUS ELECTRO-NITE CASTEMP SYSTEM

Heraeus Electro-Nite developed a through wall temperatur measurement system, so called CasTemp, which is a sensor inserted through the tundish wall being flexible for all measuring applications e.g. through the tundish bottom as well as side-wall to be closed to the outlet nozzle (Figure 2).

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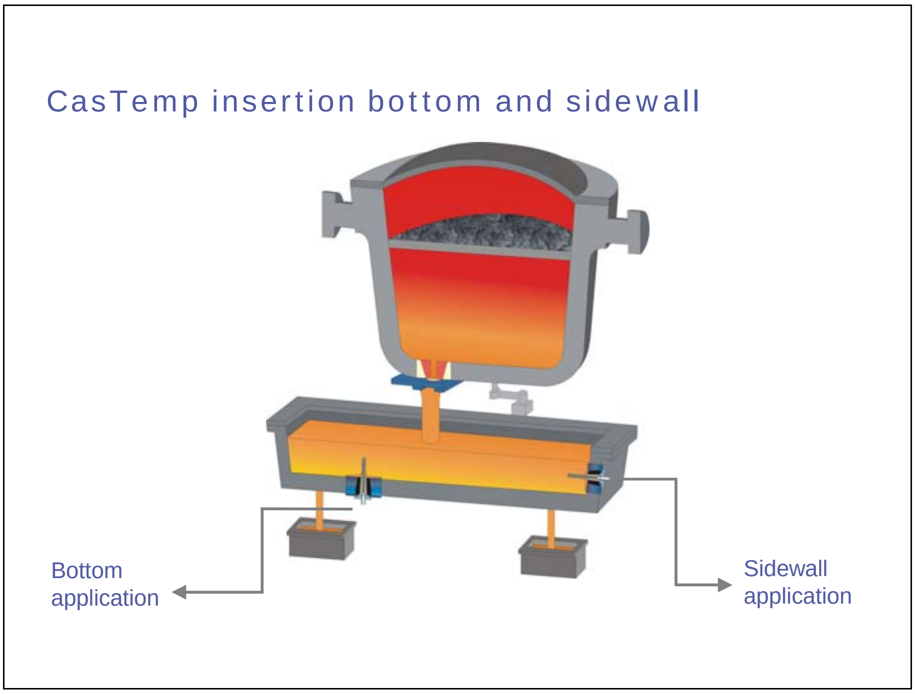

Figure 2. CasTemp mounting positions.

Advantages of CasTemp Vs Conventional Temperature Measurement:

- Measurement position can be very close to the tundish outlet nozzle;
- sensor is unaffected by tundish slag;
- sensor measures from tundish pre-heat through to tundish drain down, 100% availability for an entire casting sequence;
- a temperatur measuring system which requires minimal casting plant operator involvement saving manpower and ensuring safety;
- an accurate real time temperatur measurement within 3 minutes of opening the ladle;
- a temperatur measuring system where the connection cables are located in a cool well protected area ensuring minimum damage and resulting in extended life;
- a temperatur measuring system which measures the solidification temperatur and calibrates itself.

4 CASTEMP OPERATION PRINCIPLE

The CasTemp system consists of a disposable sensor, which is replaced every cast sequence and fixed in a reusable well block, placed in the tundish lining.
Figure 3 shows the castemp sensor mounted in the base of tundish, which also shows the temperatures as measured through the refractory lining during a typical tundish sequence. It should be clear from the construction and the measured temperatures that the system ensures the maximum amount of safety.

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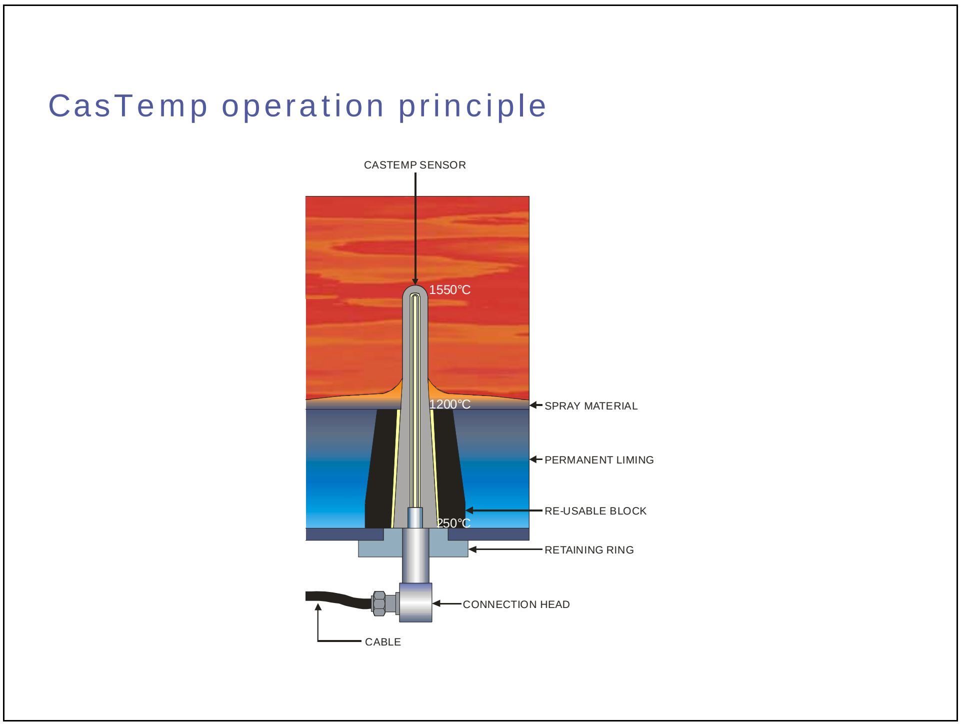

Figure 3. CasTemp operation principle.

The sensor is fixed into the well block with a non-adhering embedding mortar. This ensures that the join between the sensor and block is of high integrity yet allows the sensor to be easily removed once the steel scull has been removed from the tundish without damaging the well block.

The sensor once is mounted in the well block is secured in place by a thick steel retaining ring plate, screwed against the base plate which is welded on to or in to the tundish steel shell (Figure 4).

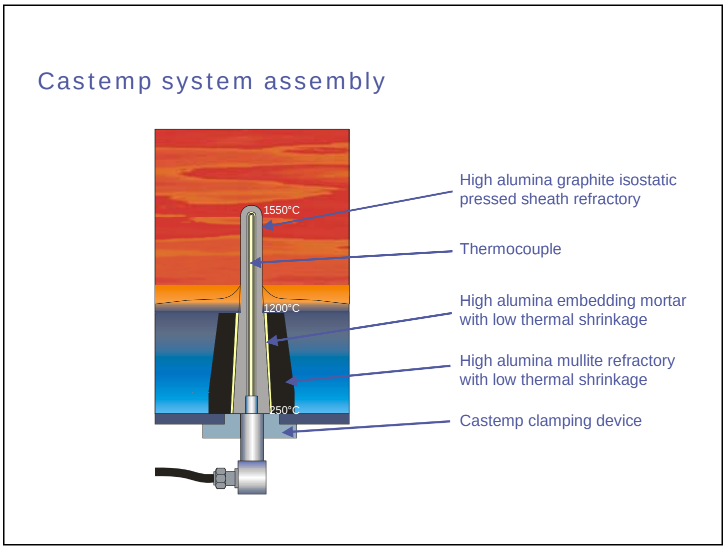

Figure 4. CasTemp system assembly.

5 CASTEMP SYSTEM PARAMETERS

All CasTemp sensors use specially selected Platinum/Rhodium thermocouple wire with an accuracy of ± 1,0°C at 1554°C. The Aluminum-graphite probe sheath is

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isostatic pressed and the heat conduction is related to the refractory heat conductivity and refractory mass. The sheath wall thickness at the level of the thermocouple hot junction is kept thin to ensure a high response time, which takes around 3 minutes to measure the true steel temperature in a pre-heated tundish (Figure 5).

Figure 5. CasTemp sensors.

The castemp probe positioning in the tundish is a major issue to get an accurate and reproducible steel temperatur. The sensor measuring point should be close to the tundish outlet nozzle to record a real time steel temperatur. The sensor measuring point is placed best in a distance of min 200 mm above the tundish wall and tundish bottom. This ensures the real time liquid steel temperature.

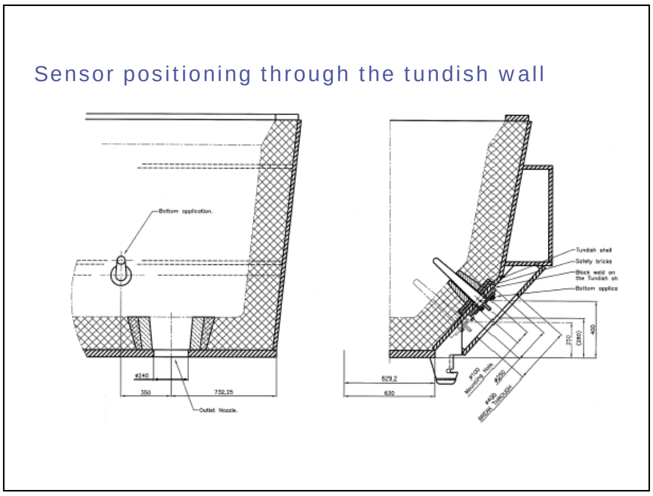

Figure 6. Sensor positioning through the tundish wall.

Figure 6 shows a mounting example of a slab caster, where the Castemp sensor is placed into the tundish sidewall, just 350 mm far away from the tundish outlet nozzle (middle axis to middle axis). This position guaranties a real time steel temperature measurement of the liquid steel, which is exiting the nozzle.
Figure 7 shows a CasTemp system in operation. The left hand picture shows the outside clamping device with the hot zone connection cable. The right hand picture shows the measuring part of the sensor, which sticks out of the tundish refractory lining inside into the tundish about 200 mm above the spray coating.

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Figure 7. CasTemp in operation.

6 RESULTS AND DISCUSSION

Figure 8 shows two typical sequences where the standard "from top" Contitherm has been compared to the CasTemp sensor. The graph shows a typical comparison of CasTemp, the standard Contitherm and the Positherm immersion sensors. It can be seen that during normal full tundish casting conditions that the three systems all give very similar output.
During the first sequence, where the tundish was operated at a low level after "low tundish weight" ladle change the Contitherm sensor is coated with tundish slag and not immersed deep in the steel causing it to measure low. In comparison the CasTemp is unaffected by these conditions and measures a similar temperatur to the disposable sensor.

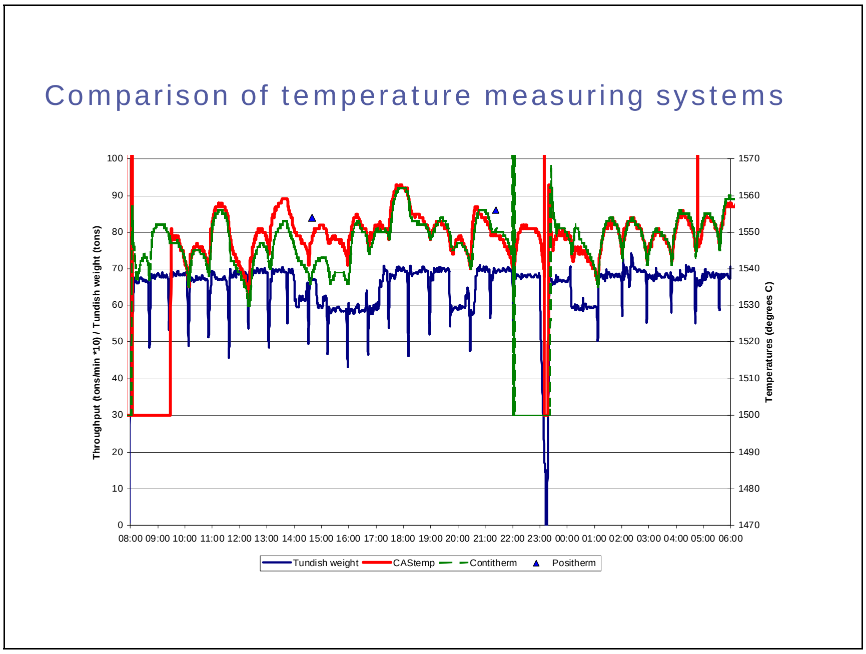

Figure 8. Comparison of temperature measuring systems.

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The CasTemp sensor measures the liquidus temperature of the steel when the steel freezes in the tundish .

Figure 9 shows the thermal arrest of the steel during cooling as measured by CasTemp. Interestingly this is within 1°C of the calculated liquidus temperature.

The CasTemp sensor measures between 2°C and 6°C lower than the Contitherm because of its position in the tundish.

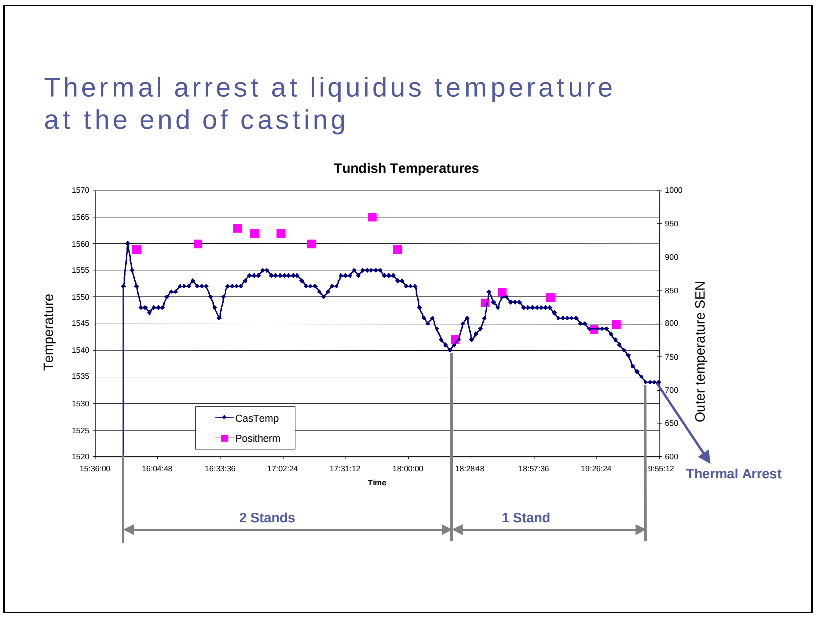

Figure 9. Thermal arrest at liquidus temperature at the end of casting.

7 SENSOR ACCURACY

Figure 10 shows a cast termination due to an unexpectedly cold ladle. The CastTemp data shows plant operators that the steel is starting to freeze in the tundish approximately 30 min before the final event, while the square points from the dip probes do not provide a very clear descriptionof the problem. This result was obtained during the first trials at a European twin strand slab caster, thus preventative measures to freeze-off were not in place. Possible actions with this new accurate data would be:

- Feed the data directly in real time to the ladle treatment facility so the operators are fully aware of the problems at the caster;
- increase casting speed to maximize yield and heat flow;
- minimize tundish weight at the ladle change, (to allow new hot steel to flush through the tundish), giving the best possible change of successful ladle exchange, in the worst case to minimize the tundish skull if freezing cannot be avoided;
- prepare the next tundish if possible to continue the strand also if freezing cannot be avoided.

The CasTemp system not only avoids many of the problems suffered by top mount sensors it also proves its own accuracy by measuring the liquidus arrest temperature as the steel freezes in the tundish at the end of the sequence. On a properly maintained system the arrest temperature always corresponds to the liquidus calculated from the steel chemistry, proving the absolute accuracy of the CasTemp system within ± 1°C. The new sensor has given the plant the confidence to use the

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reliable data to investigate actions to improve the plant productivity with respect to tundish temperature.

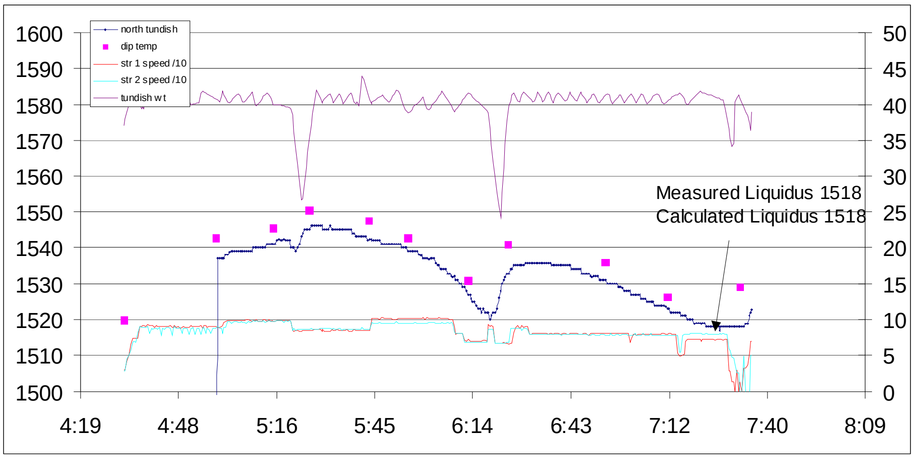

Figure 10. Cast termination due to low temperature.

Lifetime of the CasTemp sensor is one cast sequence, whereby the free oxygen level in the cast steel limits the sensor lifetime. Already reached casting time on billet casters up 90 hours confirms the performance of the CasTemp system (Figure 11).

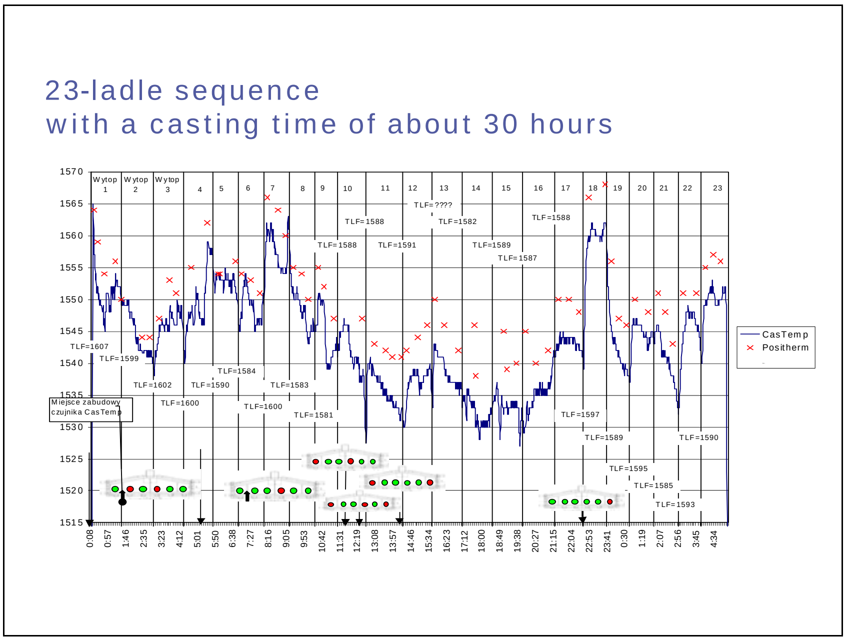

Figure 11. Example of a 23-ladle sequence with a casting time of about 30 hours.

Figure 12 shows a 6 ladle sequence recorded with CasTemp, where the temperature drop of the 2nd ladle almost hit the liquidus temperature. The superheat can be followed easily over the sequence and the trace gives and precise overview about the cast.

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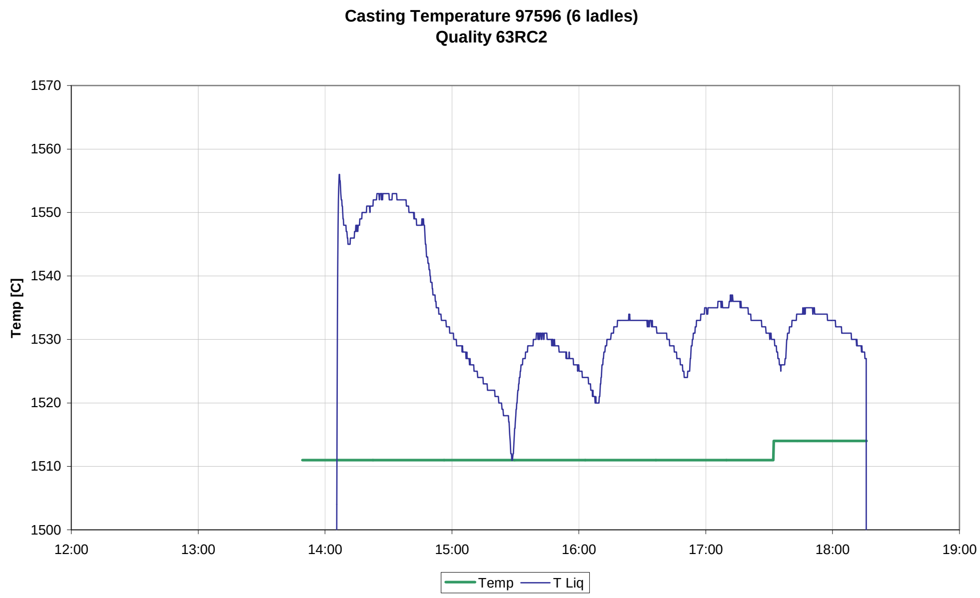

Figure 12. CasTemp trace showing the superheat and the temperature trend.

Figure 13 shows the superheat of a sequence in relation to the frequency in average 23°C.

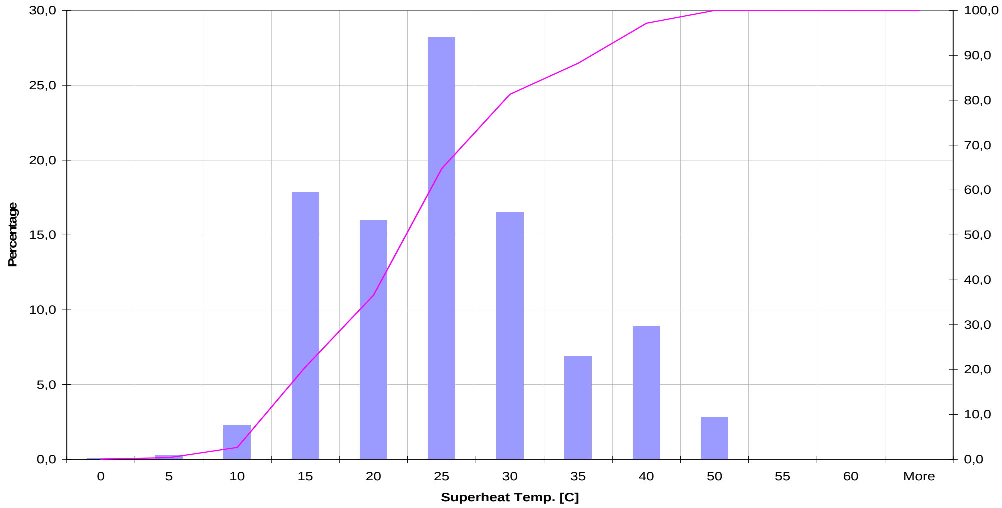

Figure 13. Temperature Histogram.

8 CASTEMP BENEFITS

The CasTemp system brings many benefits to the user.
With the real time steel temperature closed to the tundish outlet nozzle available at any time provides a precise overview about the temperature tendency during casting with the possibility to react immediately.
This allows:

- Breakouts, caused by too high temperature can be prevented or minimized;
- casting speed can be adapted and optimised to the temperature;
- caster output can be increased due to higher casting speed related to the temperature and steel grade;
- strand surface quality as well as internal steel quality can be improved;

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- strand freezing can be prevented;
- ladle rejection caused by frozen strands can be minimized, an aimed cast stop is possible;
- tundish pre-heating time can be optimized;
- increase of sequence ratio;
- less manpower;
- no steel splashing during casting, higher safety;
- system setting before start of cast, plug and forget.

More benefits are individual surely possible.

9 INSTRUMENTATION AND RECORDING

Conti-Lab E two channel instrument computes data of the continuous CasTemp signals as well as non continuous temperature measurements and serve as professional link to peripherical equipment and plant PC and large signal (Figure 14).

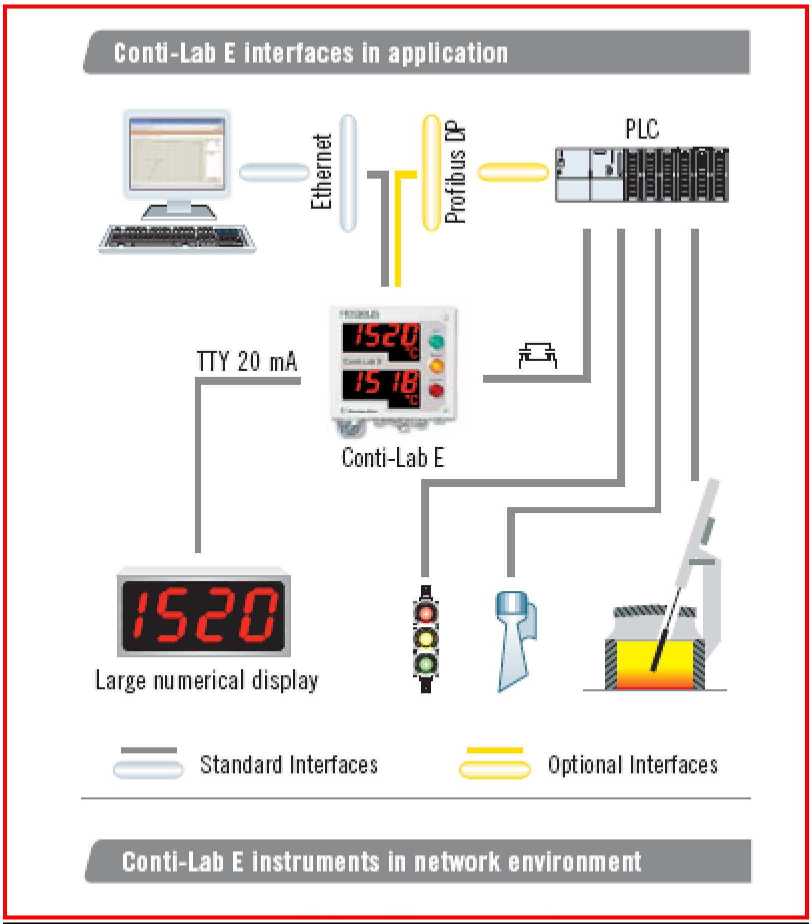

Figure 14. Conti-Lab E interfaces in application.

10 CONCLUSIONS

The CasTemp system offers uncounted possibilities to optimize the casting process and improves the cast strand quality. Many CasTemp systems have been successfully introduced and the huge market interest confirms the development of CasTemp. With the high flexibility of castemp sensor positions and accurate

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temperatur as well as real time temperatur measurement at the tundish outlet nozzle, castemp is a further milestone to improve the continuous casting process.

REFERENCES

1 Wolfgang Glitscher,Sonderdruck “Stahl und Eisen”Heft 4, Seite 45-48
2 J.L. Lagerberg, W.W. Oldenburg, R.S. Huisman, J. Yardy, M. Kendall. Experience with a novel approach to continuous tundish temperature measurement.