NOVEL SENSING TECHNIQUES IN HOT METAL PRODUCTION, STEELMAKING AND CASTING - SUSTAINED EPOCHAL ADVANCEMENT IN STEEL INDUSTRY (SEAISI)

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Synopsis:

The new Hot Metal probe measures instantaneously sulfur prior to, during and after HM desulphurisation treatment. The system enables direct treatment decisions, saves expensive magnesium in desulfurisation and helps to match HM ladles to the steelmaking program. In a variant the sensor gives the HM silicon content prior to BOF charging.

Ladle slags can now be controlled on-line. A precision sensor applied like a standard disposable probe reads on-line oxidation potential and corresponding FeO-content of ferrous slags. In electric steelmaking foamy slag practice is enhanced, in ladle metallurgy the sensor minimizes aluminium fade and nonmetallic particle formation.

A novel route for continuous temperature measurement is presented. Operator independent and zero handling combined to up-to-now unknown accuracy make the system the number one choice in continuous casting control.

Key words: Hot Metal sensors, Slag sensors, continuous temperature measurement

1. INTRODUCTION

The recent boom for steel products made companies invest in new ironmaking, steelmaking and casting facilities to meet the ever growing demand for steel. Others being more careful, as there have been countless ups and downs in this market sector over the decades, and are therefore trying to squeeze more production out of their existing facilities. And they can, using all technical and logistic means available. Everywhere these days the following tenor is heard: 'We want to make more steel this year'. This paper shows 3 examples using novel sensing techniques to optimize production but keeping up good quality standards.

2. SULFUR AND SILICON CONTROL IN HOT METAL

Sulphur and silicon are the most important elements in Hot Metal. For downstream BOF processing sulphur is decisive to match certain Hot Metal transfer ladles to the steel grade production program. Silicon alters the chemical heat input and allows for a higher vessel scrap charge rate. Both sensors offer good comparison to sample analysis Figs. 1a and 1b. They save both, time to decide for material flow (silicon &sulfur sensors) and desulfurisation agents (sulfur sensor), Fig. 2 and Table 1.

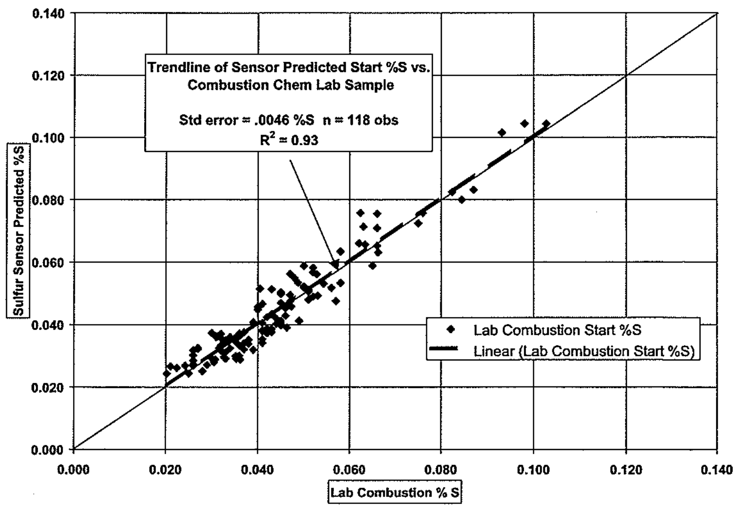

Fig. 1a: Sensors comparison to sample analysis

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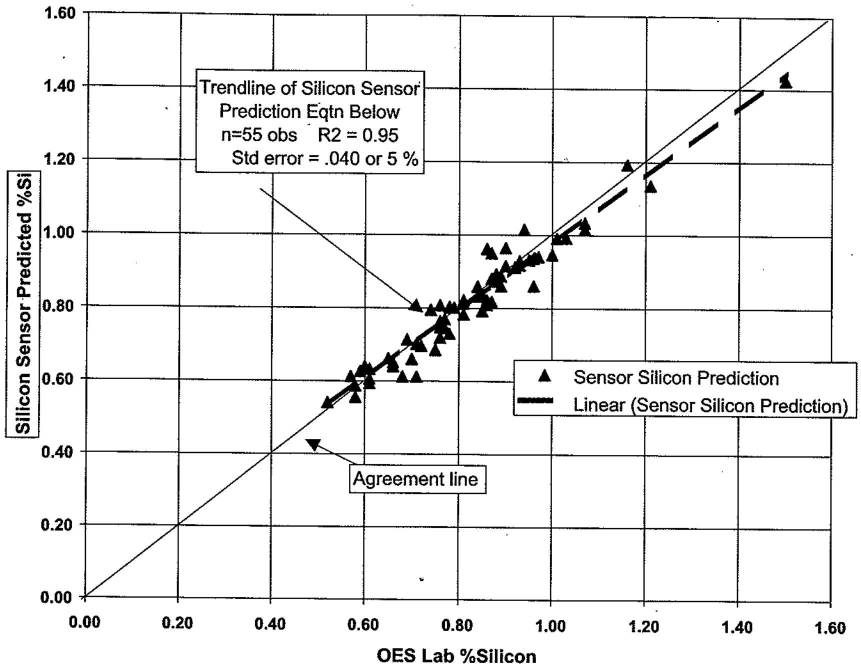

Fig. 1b: *Sensors comparison to sample analysis*

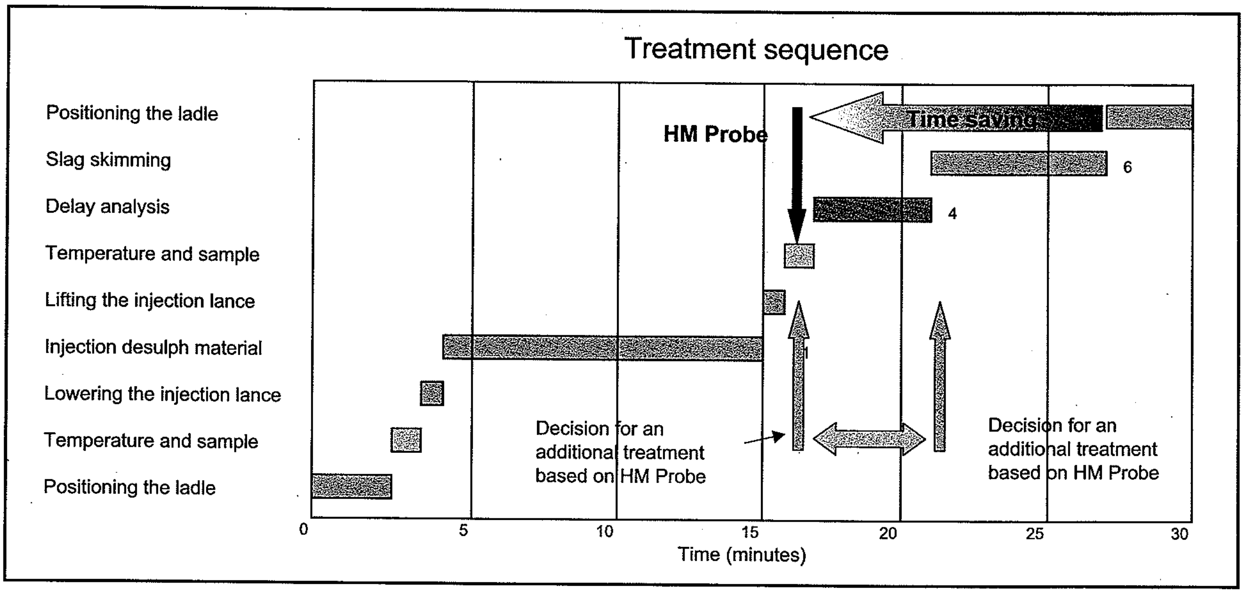

Fig. 2: Time saving with Hot Metal sulfur sensor

Table 1: Time and hot metal temperature savings through sulfur sensor application

Table I. Comparisons of Effects of Test Methods on Cycle Time and Hot Metal Temperature

Process Step	Information Req'd	Conventional Technology Time (Results, minutes)	Conventional Technology Temperature (Loss, °F)	Sensor Technology Time (Results, minutes)	Sensor Technology Temperature (Loss, °F)	Sensor Technology Advantages Time (Saving,minutes)	Sensor Technology Advantages Temperature (Saving, °F)
At Hot Metal Transfer Hole							
Fill Ladle (to Bogey)	Si, S; Temp	6~10	8	1~3	2	6	6
At Desulf Station							
End Desulf Blow	S	5	5	1	1	4	4
End Raking	S	5	8	1	2	4	6
Totals at BOF Shop							
To End Desulf Blow		13	13	3	3	10	10
To End Raking		18	22	4	5	14	17
To End Ladle Re-injection	S, T	~5	~8	1	2	~4	~6
Totals to End of Re-Treatment		23	23	5	7	18	16

The upper time sequence shows that at least 4 minutes per treatment cycle can be cut through sensor application compared to sampling and analysis. In a US steel shop, lower table, even 18 minutes and 7 degrees in temperature loss had been savable.

Furthermore material savings of desulfurising magnesium are possible, especially when deep-desulphurising Fig. 3. As a rule of thumb for low sulfur steel grades, approx. 25% magnesium is usually added in access just to make sure that the max. specification of sulfur is met.

Conclusion for hot metal sulfur and silicon sensors: new sensing technology offers substantial savings of time and material in hot metal treatment.

3. INSTANT CONTROL OF METALLURGICAL SLAGS IN LADLE METALLURGY USING AN ELECTROCHEMICAL SENSOR

Metal–slag reactions are of key importance during metallurgical operations, e.g. during secondary metallurgy influencing chemical composition and steel cleanliness. Whereas liquid steel temperature and chemical analysis can be kept under control using special sensors and samplers, on-line slag control was not possible until now. A new method is presented in this paper to measure slag oxygen activity on-line within seconds Figs 4a and 4b. The new method enables immediate met-

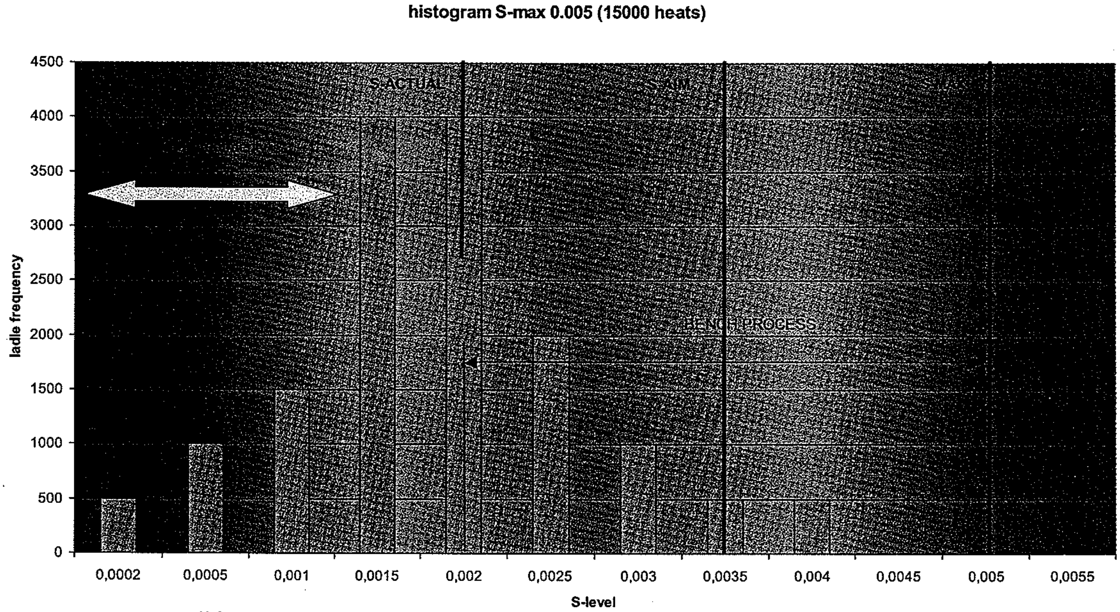

Fig. 3: Potential over-treatment in hot metal deep desulfurisation

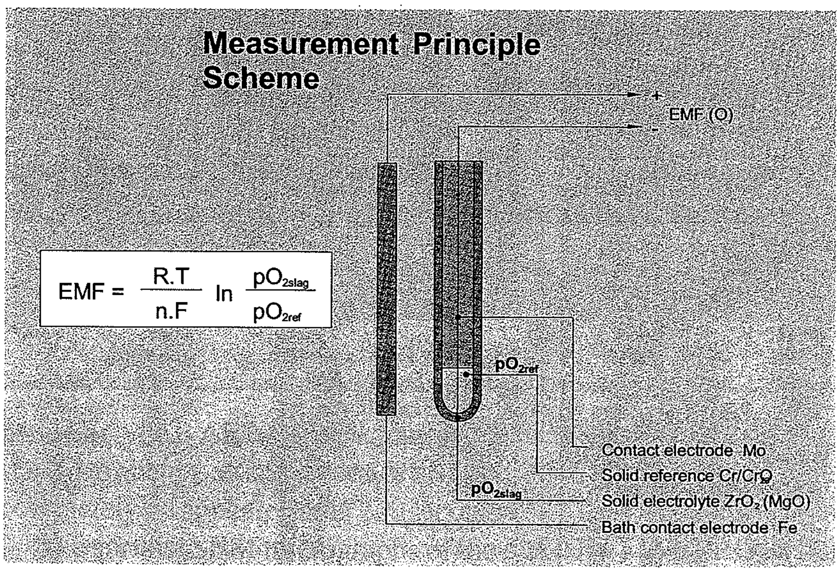

Fig. 4a:
The electrochemical sensor and the measurement practice

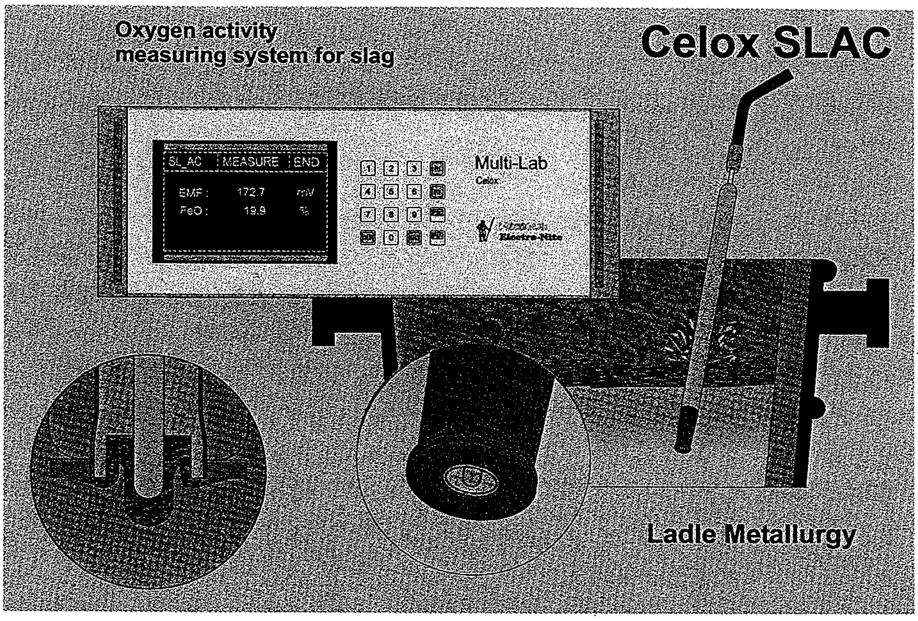

Fig. 4b: The electrochemical sensor and the measurement practice

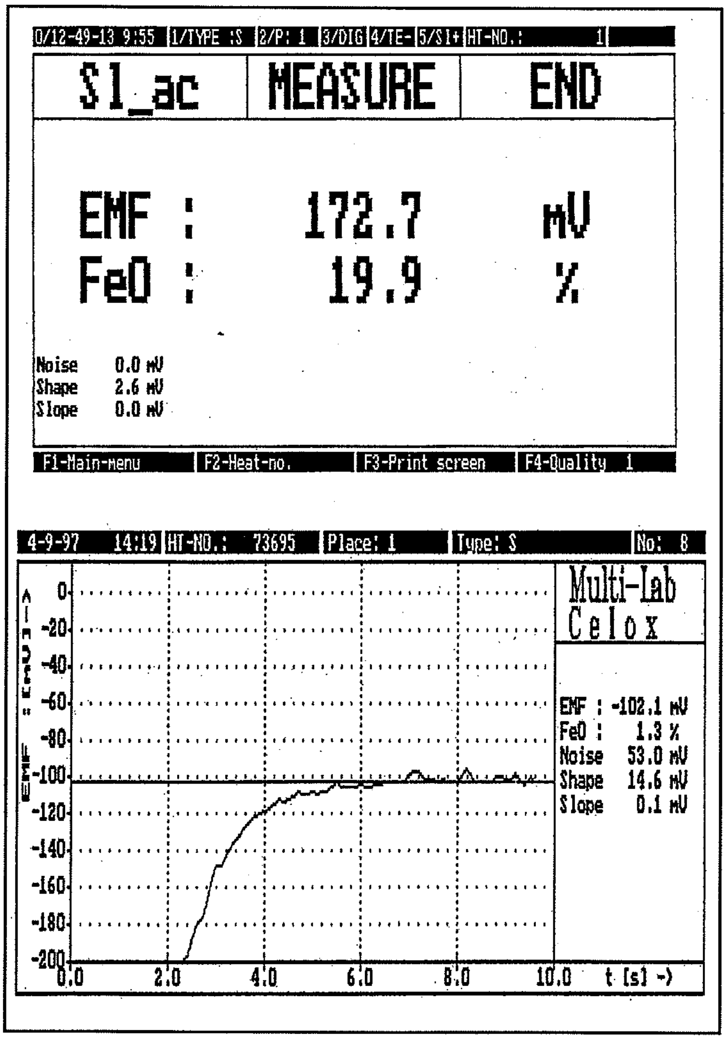

***Fig. 5**: Typical reading and display*

allurgical corrections to ladle slags. Ladle slag modifiers after tap or during various treatment stages can be optimized. Based upon the slag's measured FeO-content, further direct decisions can be taken on desulphurisation practice, fade of deoxidants and castability. Using this method to control the slag's reoxidation potential significant improvement on steel cleanliness can be expected.

Similar to the well-known probe for oxygen activity measurements in liquid steel, the slag sensor is based on a galvanic cell where the EMF generated is proportional to slag oxygen activity. The measurement procedure follows the standard practice of probe immersion into liquid steel. A typical reading is shown in Fig. 5.

Due to magnetic metallic particle separation problem the lab mostly reports too high FeO values in the low FeO-range. The FeO sensor is both, faster and more precise compared to slag sample-analyzing methods Fig. 6 and Fig. 7. In the high FeO-range, sensor and lab results coincide very well just leaving the speed advantage to the sensor.

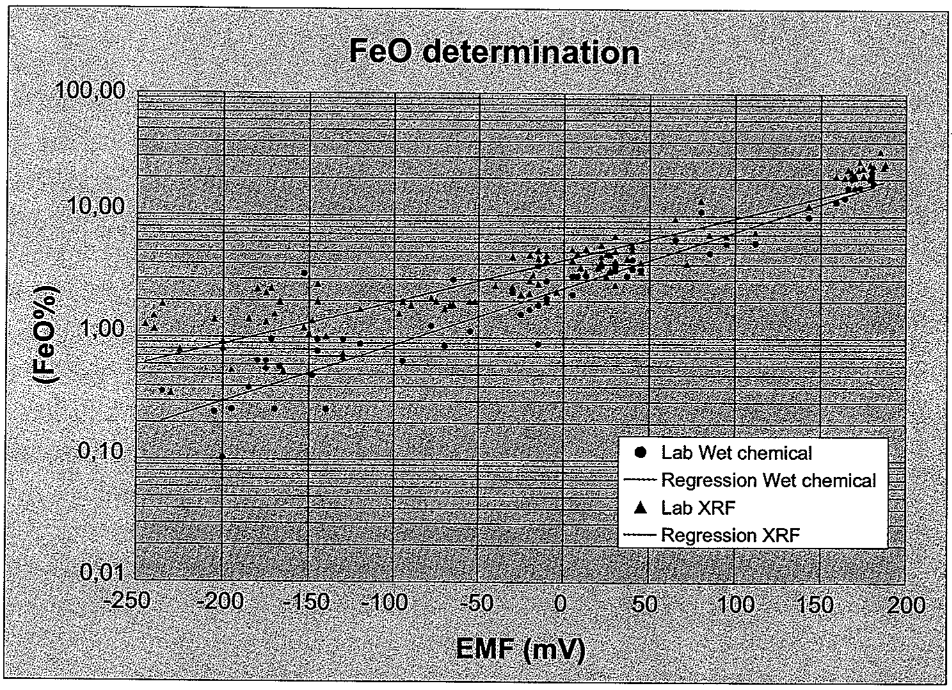

Fig. 6:
Correlation measured EMF to %FeO

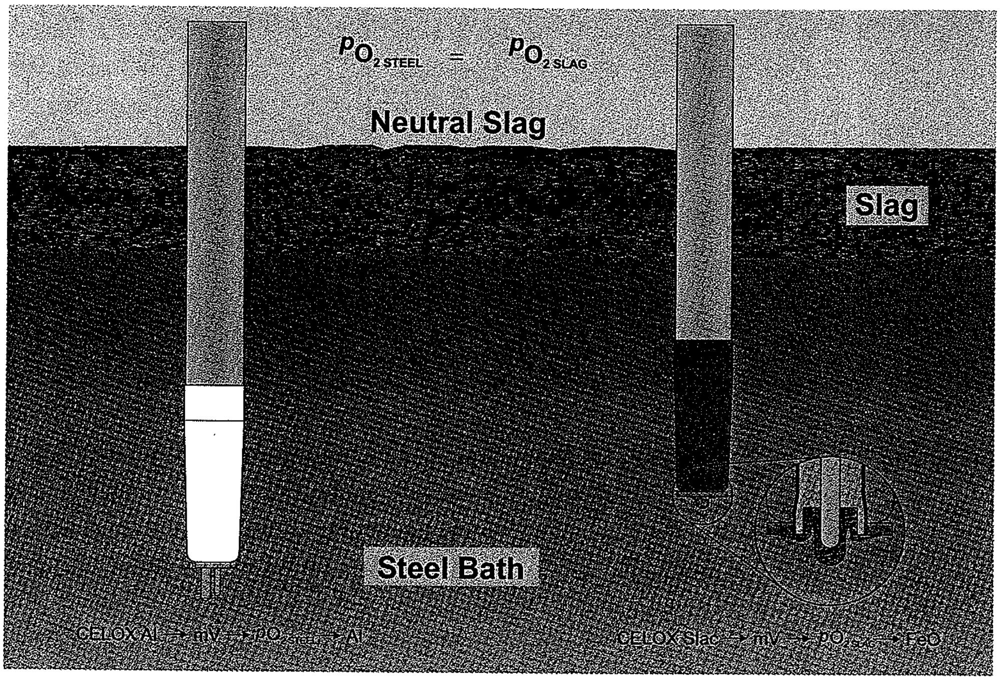

Fig. 7:
Schematic showing relationship of steel oxygen activity measurement vs. slag.

Oxidizing and re-oxidizing metal-slag reactions have to be slow or at least predictable within a high degree of confidence. With excessive oxygen unbalance in steel and slag (e.g. Al-killed steel, high FeO containing slag) any metallurgical action lacks precise prediction. Especially the issues of alloy and deoxidizer additions, desulphurisation treatment, Ca-treatment and rinsing for liquid steel cleanliness.

Even with today's methods using slag stoppers, EBT, or slag detecting devices, slag carry-over continues to be a concern, as unknown quantity and oxygen potential of primary steelmaking slag added to ladle slag formers influence said metallurgical ladle operations.

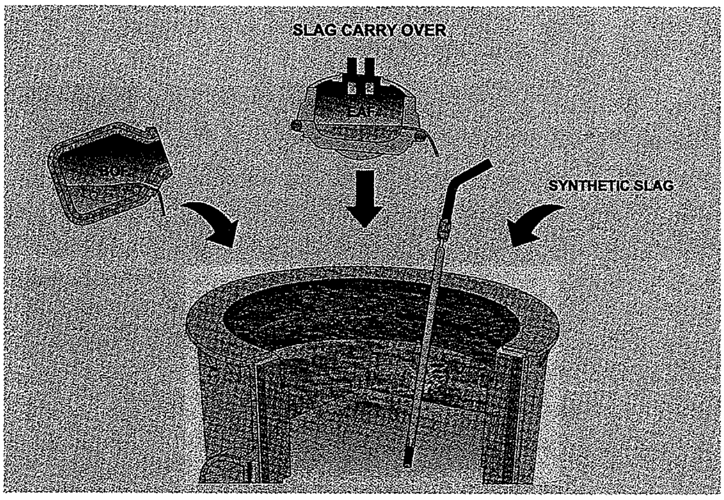

***Fig. 8:** Primary steelmaking slag added to ladle slag formers influence metallurgical ladle operations.*

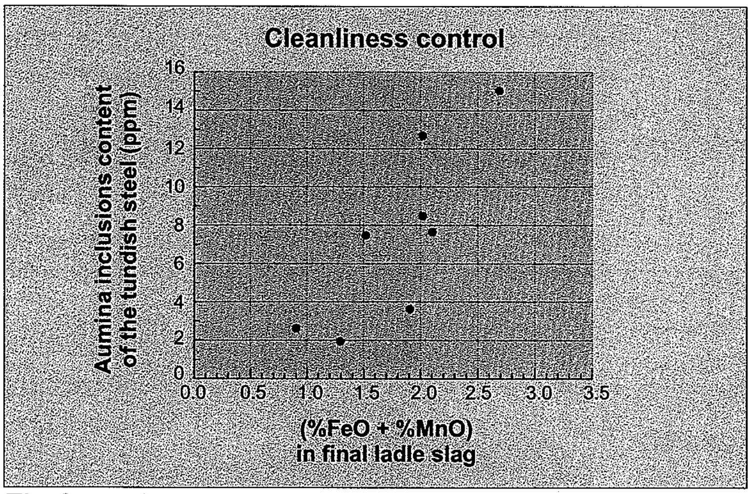

***Fig. 9:** Total oxygen increases with rising oxygen activity in slag*

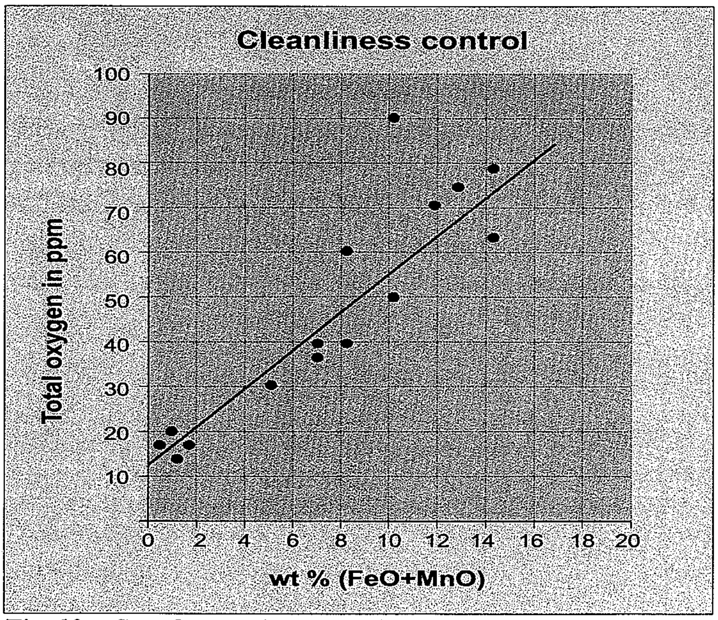

***Fig. 10:** Correlation alumina inclusions and slag oxygen activity in aluminium-killed steels*

A Sensor measurement after tapping should be the basis for decisions on:

- Ladle slag skimming
- Ladle top slag treatment by adding slag modifiers, such as aluminum, calcium carbide or
- Additional slag formers to dilute FeO down to an acceptable level, Fig. 8

In all cases where the oxygen activity in slag is not same as in steel, there will be influences to especially aluminium and sulfur. High oxygen levels in slag mean aluminium fade and poor sulfur capacity and vise versa. To generally comment about the correlation of steel reoxidation from ladle slags to total oxygen content in steel and related castability issues is of same importance, as if a rice bag drops down in China Fig. 9. Everybody is in general familiar with that but struggles what to do in practice and how to get a means to control these issues. And there are different religions "what's best?" for different steel grades and different casters.

The slab caster casting LCAK steel grades for D&I can applications might want lowest total oxygen to avoid any can leakage from exhibiting surface non-metallic inclusions in extremely thin rolled and deep drawn D&I cans (Canning producers specify a max. leakage of 1pc within 80Mio cans). The thin slab caster in a similar way struggles with elevated total oxygen and related inclusion levels as well, as its narrow internal refractory subentry nozzles are not forgiving to clogging. Even with a low FeO-range in ladle slags, there is already a significant link to non-metallic inclusion formation in steel, Fig. 10.

The slag sensor is the means to control, and thus to prevent these specific problems enabling both, statistical means to improve cleanliness/castability and an on-line means to e.g. clean the heat by additional gas rinsing treatment.

Billet casters casting Al-killed re-

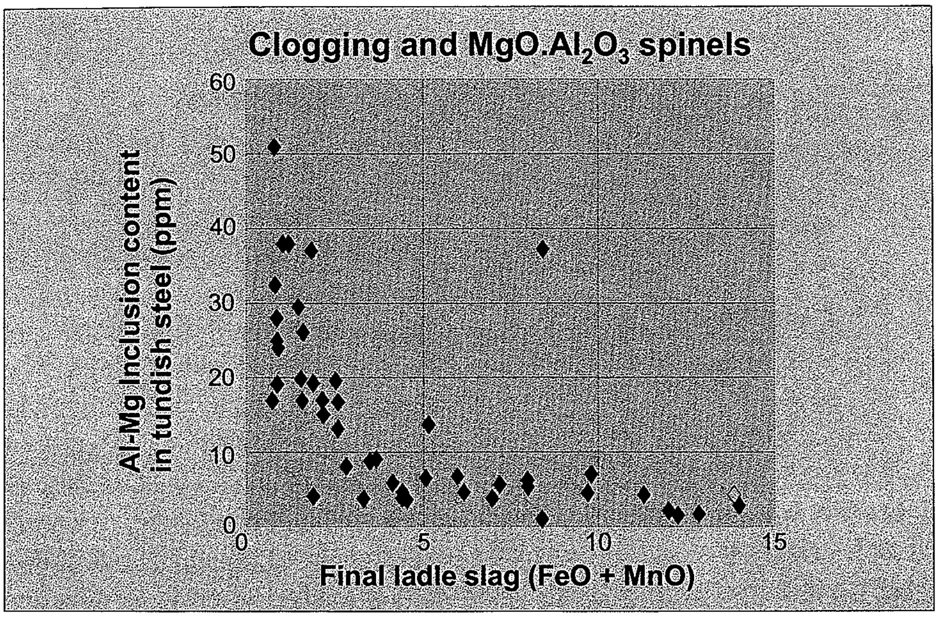

Fig. 11: *Slag oxygen activity and spinal inclusion formation in billet casters*

quire a certain FeO-window in ladle slag to guarantee simultaneously a proper castability (keep spinals quantity low) and a clean as-cast billet, Fig. 11.

Conclusion for the slag sensor: The real time nature of the slag activity measurement affords the opportunity to open the "sealed book" of direct ladle slag chemistry. For decades precision sensors in liquid steelmaking have been used for online control to produce steel in the required grade, cleanliness and at competitive cost. Precise and reliable sensors make the difference in modern steelmaking, as a basis for on-line decision-making, either through experienced metallurgists or an expert system. The slag sensor has opened a new chapter in metallurgical control to the benefit of advanced steel shops.

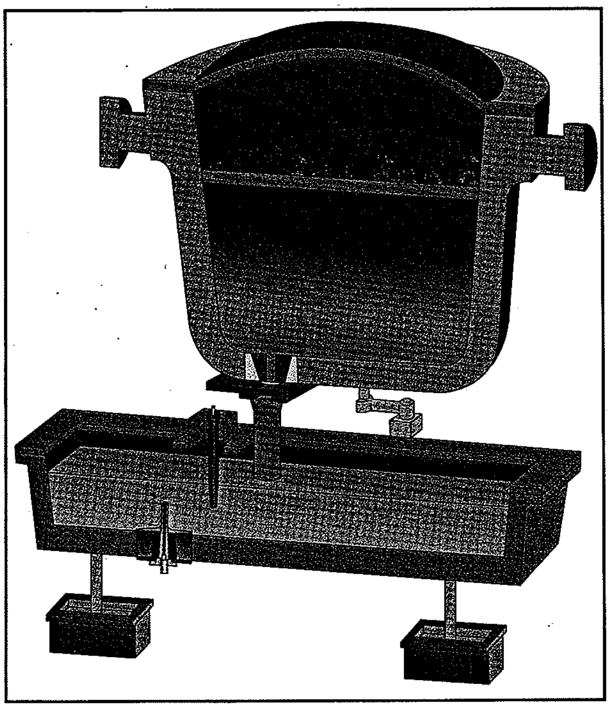

Fig. 12: The location of the CasTemp sensor in relation to the outlet ports, the Contitherm sensor and the ladle shroud

4. CASTEMP – END OF THE RAINBOW FOR CONTINUOUS TEMPERATURE MEASUREMENT

This paper 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 at Corus, IJmuiden, The Netherlands Fig. 12. The Corus shops cast 6.6 Mt per year of packaging, TiSULC and AKLC steel through 2 conventional slab and one thin slab continuous casting machines. Over the years the plant has progressed to a very highly developed level of automation to the point that the two conventional casters are almost man-less for the period between cast initiation and cast completion. Tundish temperature is recognized as a very important parameter due to the requirement for high production throughput on the 3 casters. It is critical to optimize the casting speed relative to temperature to maximize the throughput without subjecting the plant to risk of "breakouts" as well as "freezings".

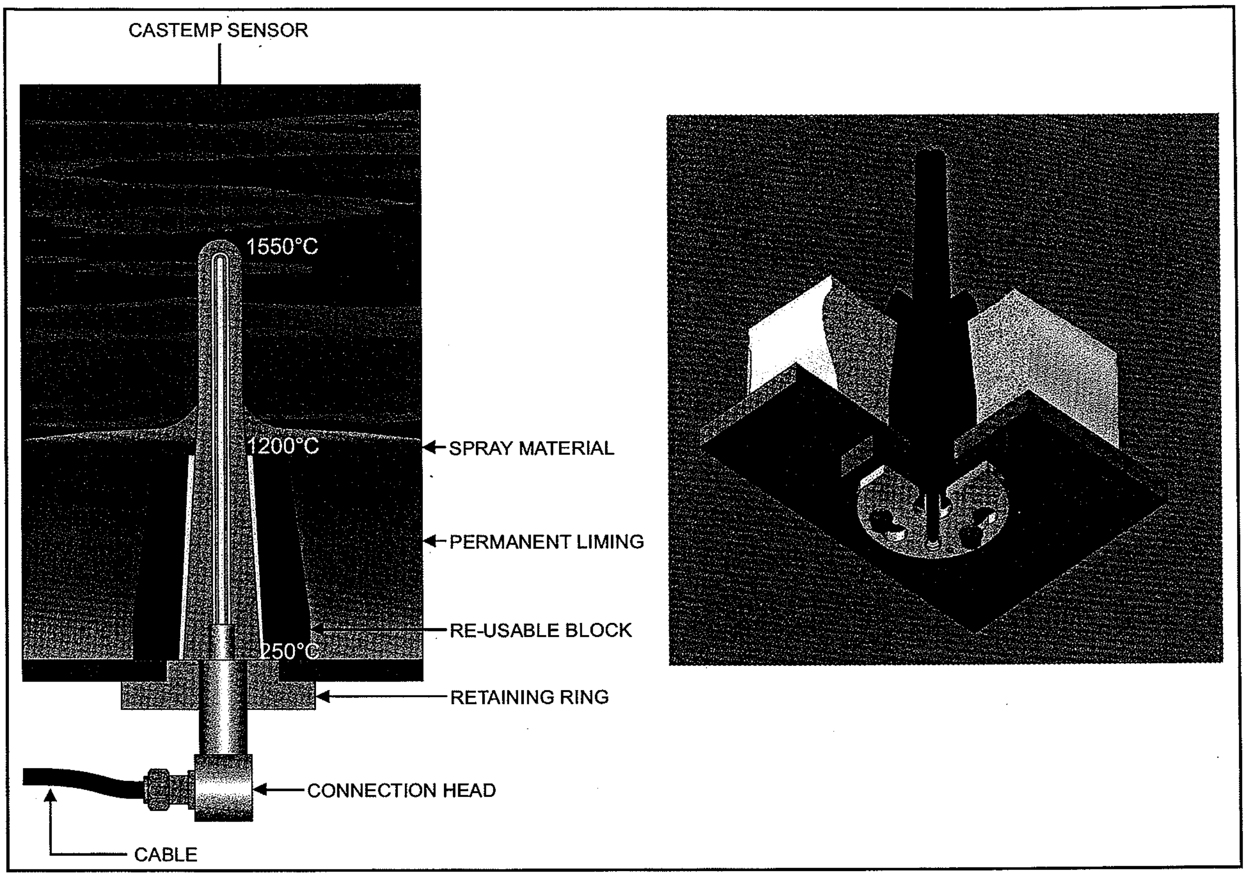

Fig. 13: The CasTemp sensor mounted in the bottom of a tundish.

The CasTemp 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; in the Corus, IJmuiden application the sensor is located close to the tundish outlet nozzle so the measured temperature relates to the steel that is exiting the tundish. Fig. 13 also 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 has shown that the developed system allowed the plant to achieved 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 preheat 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 graph shows a typical comparison of the 2 continuous temperature measurement systems, CasTemp and Contitherm to the Positherm disposable immersion sensors. It can be seen that during normal full tundish casting conditions that the three systems all give a very similar output. CasTemp is not a new temperature measurement system; under ideal circumstances it nicely coincides with continuous Contitherm and Positherm dip measurements. The overall advantage is that is eliminates human mistakes and corrects the assumption that the tundish temperature is homogenous over its 3D dimensions, see Fig. 14.

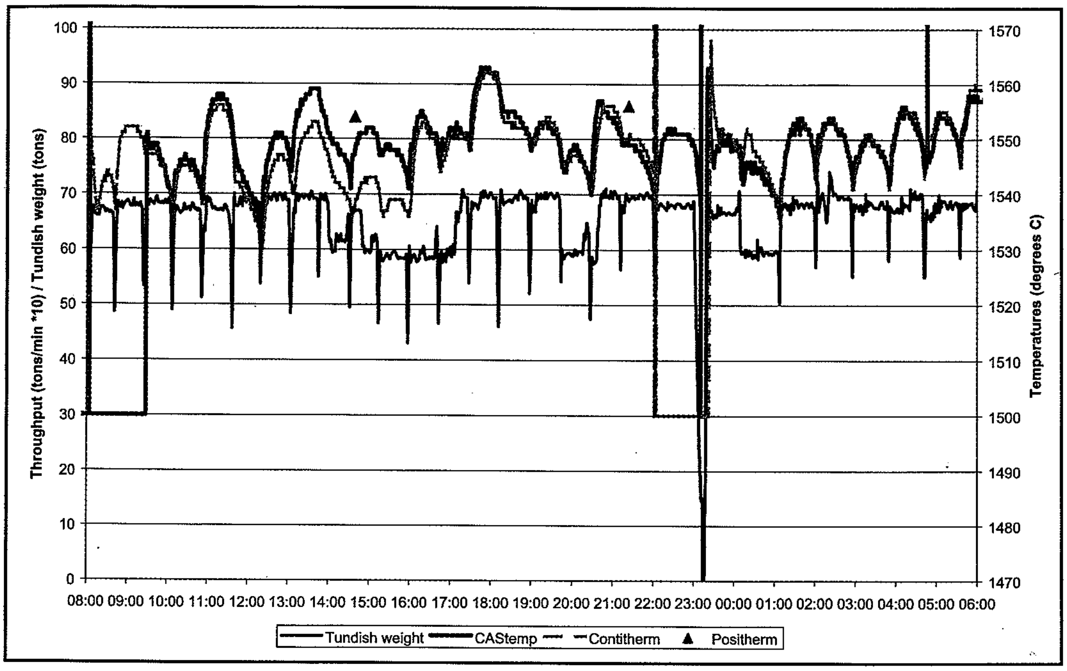

Fig. 14: Comparison of temperature measuring systems.

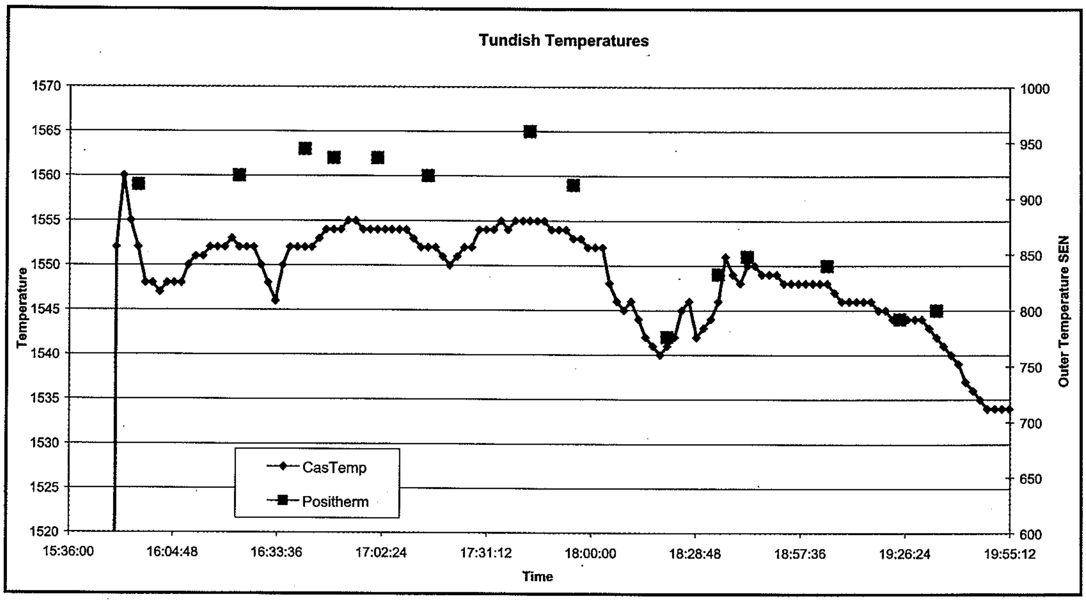

Fig. 15: CasTemp and dip measurements. Corrected immersion lance position.

The 'through the wall' CasTemp system is foolproof and allows immediate, unquestioned accuracy, even during preheating, casting start-up and ladle changeover periods. Liquidus temperature is shown (plateau) at the steel's freezing point at end of casting, see Fig. 15. No handling, manipulation and exchange problems. CasTemp arrives where all other temperature control systems end.

5. PAPER SUMMARY

Here and there you will meet metallurgists and technologists in today's steel shops being overloaded with problems and certain "absolute priorities". I believe they are mostly just poorly organized. The religion should be to get rid of daily headaches where a viable solution is offered. Taking the chances of new techniques and concentrate on the job to make more and better steel. That is what is needed in a boom period. Novel sensors will assist on this way. Successful enterprises say "let us have a look and we give it a try" rather than "we have it always done like this".