ESTAD2017 – Diss Tec seminar
Measuring of liquid steel temperature in secondary metallurgy

Torsten Lamp, Marek Cichonski, Harald Fischer

MINKON German Technology

1. Introduction

Knowing the precise liquid steel temperature is most important for the whole steel making process

- **Too low temperature causes:**
- Re blow operation at converter
- Recycled heats at ladles furnace
- Problems at continuous casting
- etc.
- **Too high temperature causes:**
- Higher energy consumption
- Higher refractory wear
- Additionally waiting time for cooling
- Break through at CC
- Surface failures at casted product

1. Introduction

Accuracy, precision, and availability of liquid steel temperature measurement have direct influence on quality of the final product and on the productivity of the steel shop.

For the last decades very reliable results were given by thermoelectric measurements using thermocouples

MINKON German Technology

2. History

Before roughly 200 years everything started!

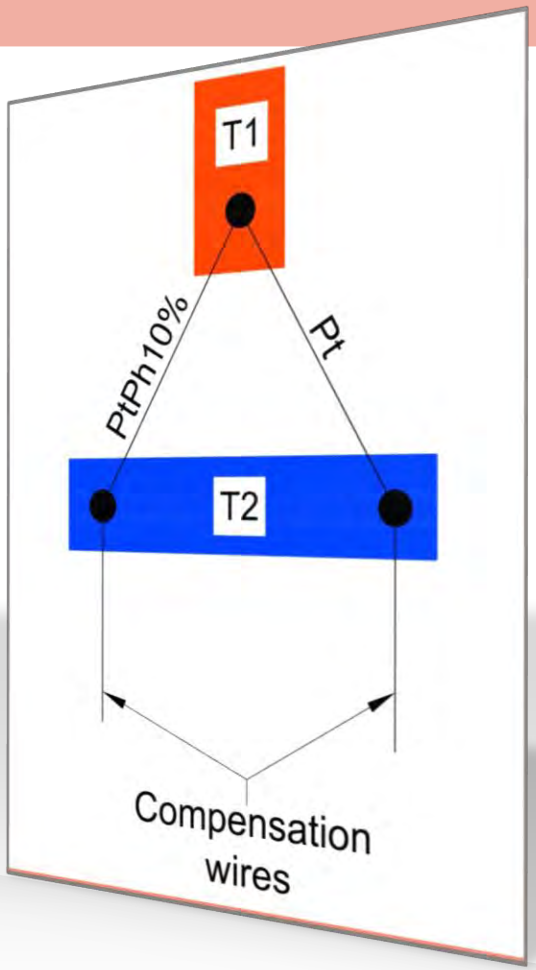
- 1821 T J Seebeck used the thermoelectric effect to construct a thermocouple
- Consisting of 2 different metals which were heated at their junction.

- 1885 Henri Le Chartellier persented a Platinum/Platinum-Rhodium thermocouple for the use in steel industry.
- The positive wire contained 90% Platinum and 10% Rhodium, the negative wire was pure Platinum.
- This combination is still widely used.

3. Measuring principle

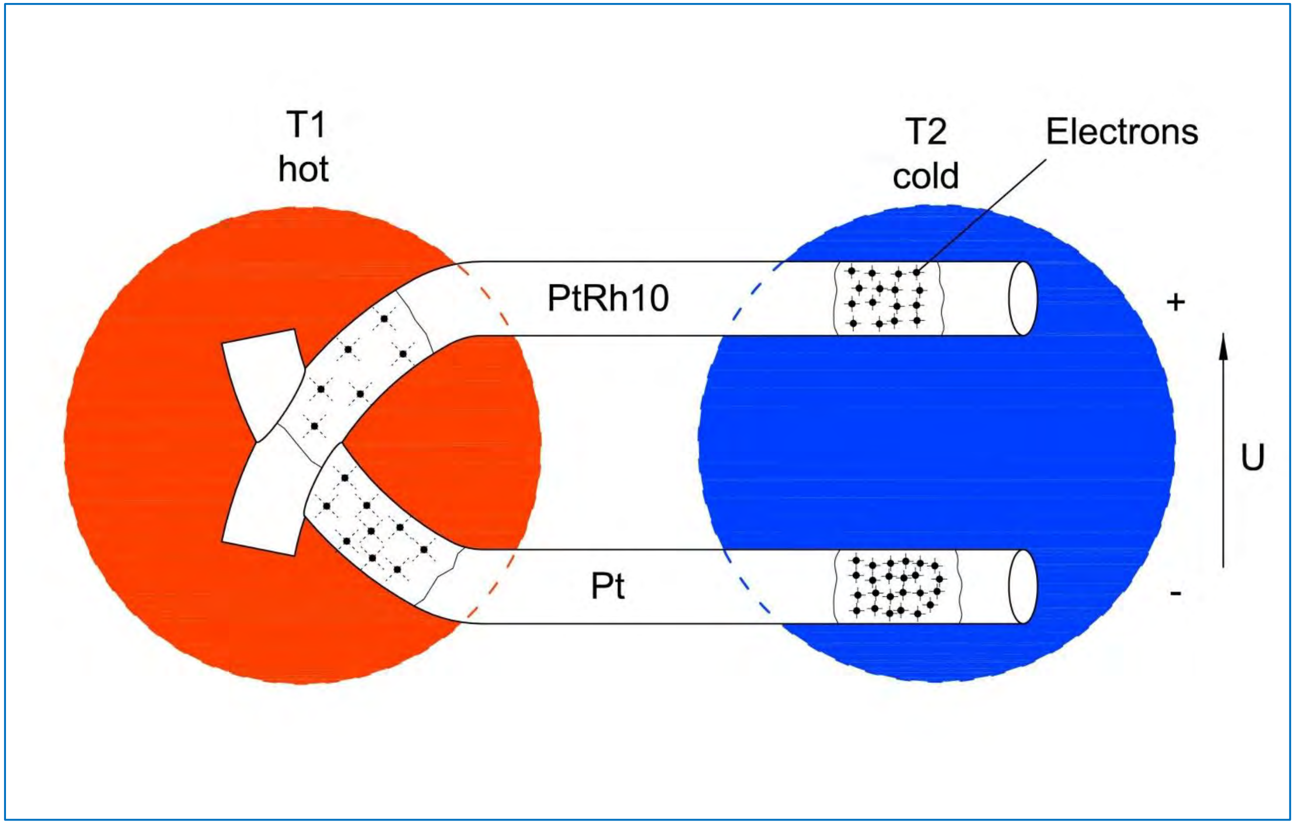
The Seebeck Effekt

- The discovery by Seebeck allows to convert a temperature difference into a proportional electrical voltage.
- 2 different metal wires connected at one end with temperature T1, generate at the open end with temperature T2 an electrical voltage.
- The electrical voltage is only dependent on the composition of the metal wires and the temperature difference between T1 and T2.
- The voltage is independent of diameter and length of the wires.
- T1 = Hot Junction / T2 = Cold Junction
- The measured voltage is proportional to the temperature difference T1-T2



3. Measuring principle

The Seebeck Effect – thermal electron diffusion

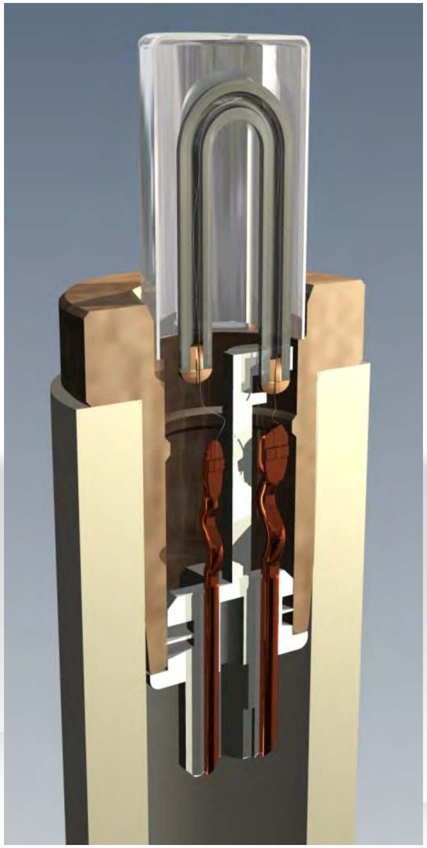


measuring temperature difference T1-T2

4. The senor construction

MINKON MMT – thermocouple probe

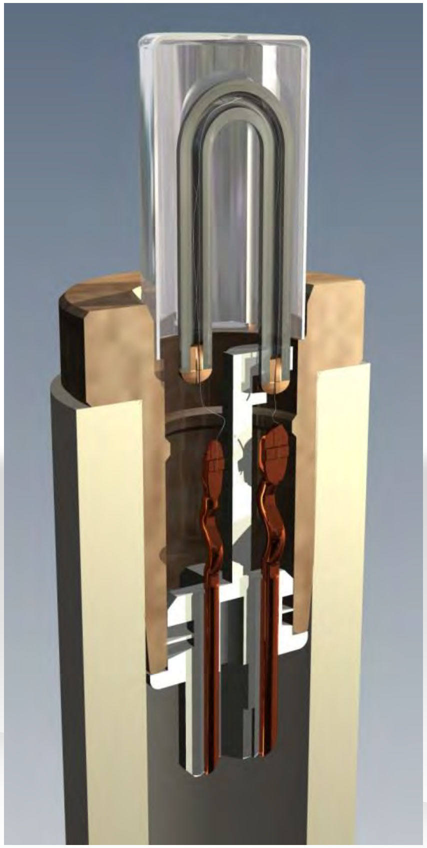
- Special selected thermocouple wire pairs with a allowable tolerance at the Palladium melting point (1554°C) of +/- 1,5°C
- A small quartz glass tube shields and positions the wire pair
- A contact plug of compensation material gives reliable contact to the lance
- Ceramic housing
- Refractory cement (not displayed)
- Metal cap for slag protection at immersion into the liquid steel
- Card board tube shields the contact plug, the lance and compensation wires inside



4. The sensor construction

Thermocouple pairs

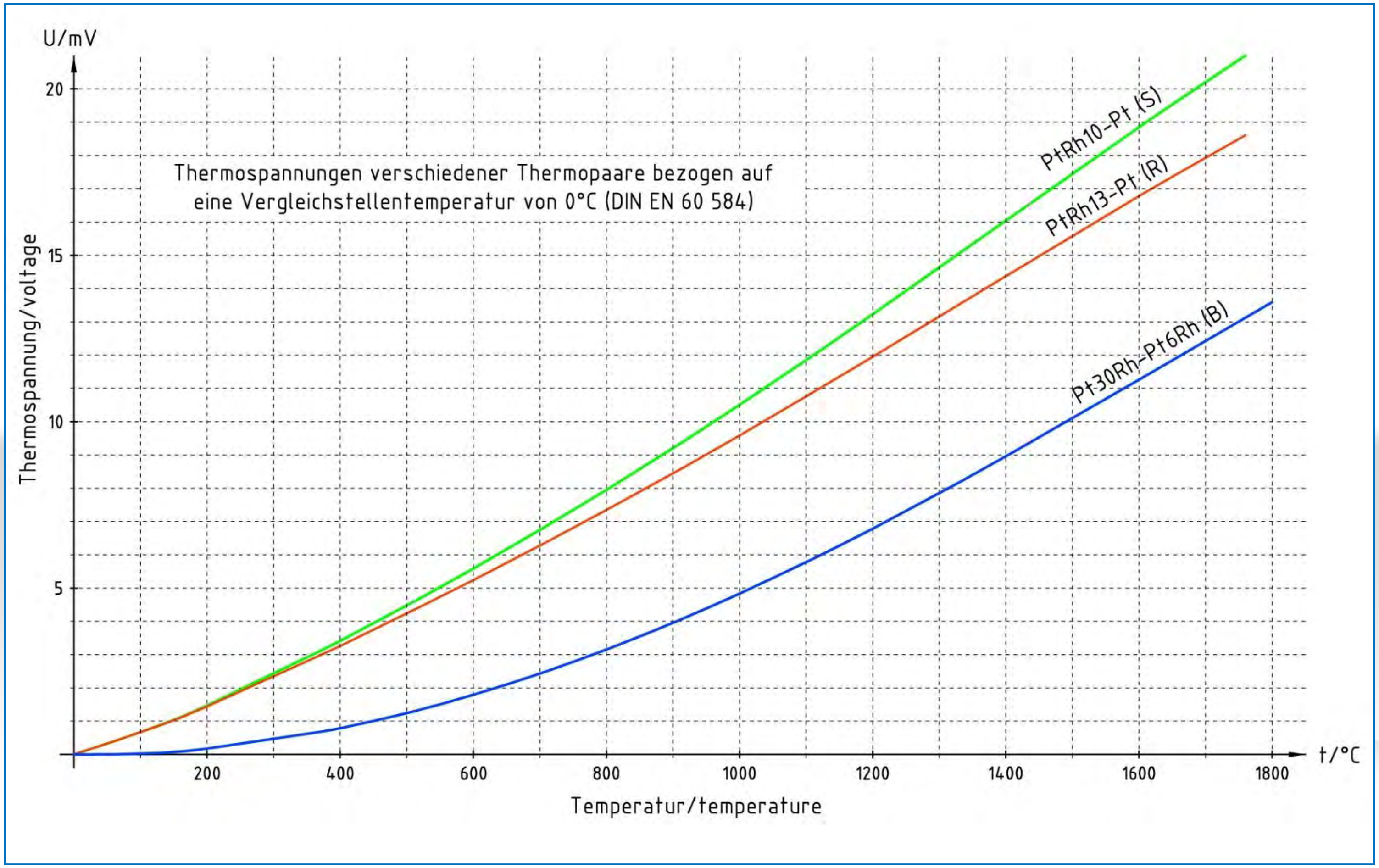
- **Type S**
  - PT-10%Rh/PT
  - up to 1750°C usable
  - compensation wires needed for connection
  - mostly used
- **Type R**
  - PT-13%Rh/PT
  - up to 1750°C usable
  - compensation wires needed for connection
  - higher precision
- **Type B**
  - PT-30%Rh/PT-6%RH
  - up to 1820°C usable
  - no compensation wire needed



MINKON German Technology

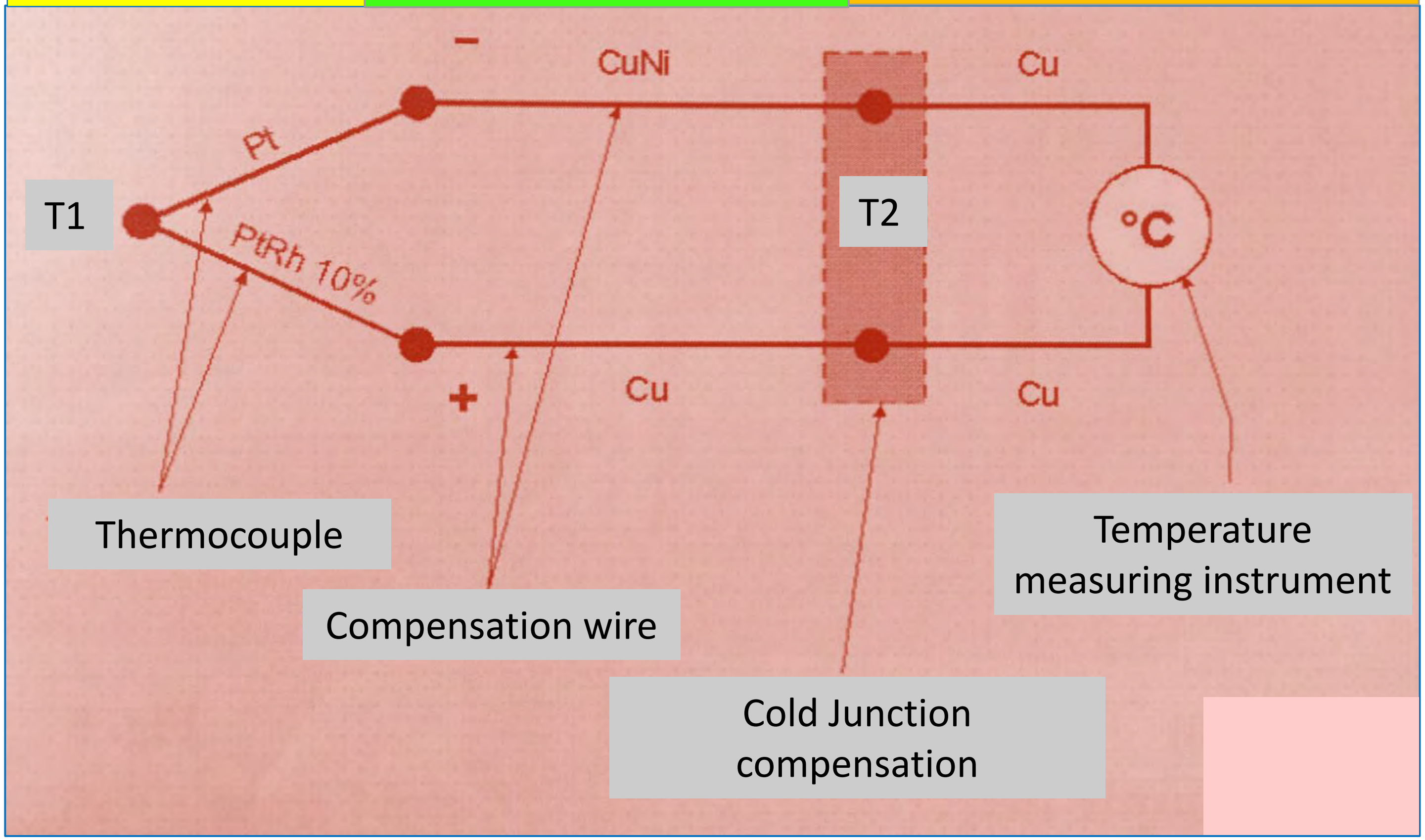
4. The sensor construction

Thermocouple voltage in DIN EN 60 584



5. The measurement chain

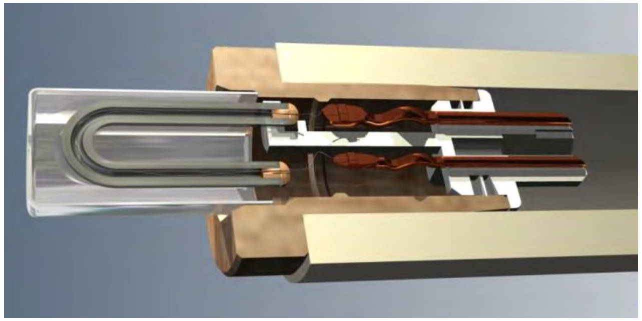
Sensor tip 1300-1800°C	**Compensation wire < 100°C**	**Measuring instrument < 50°C**



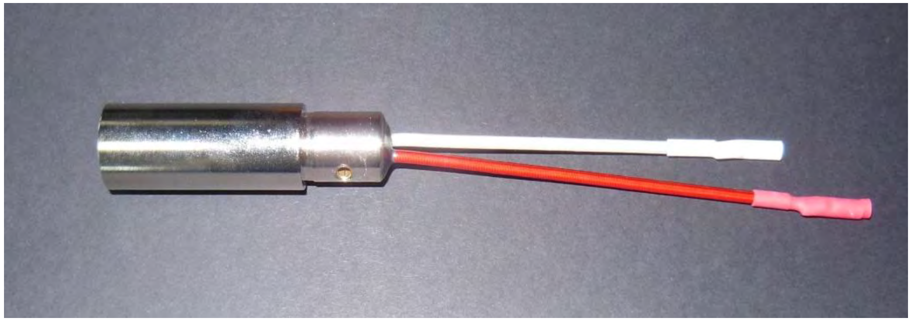
MINKON German Technology

5. Components of the measuring chain

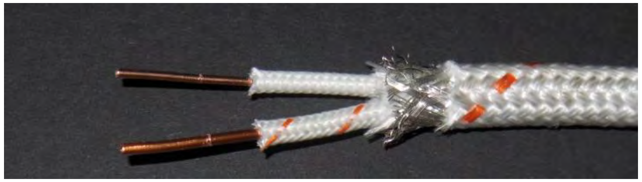
Temperature Sensor



Contact block at Lance tip

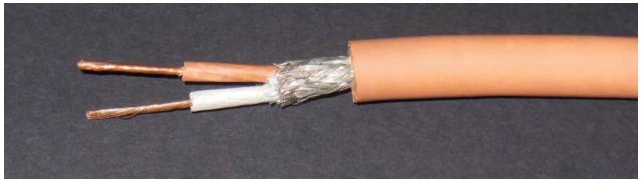


Internal compensation wire



Lance tip

External compensation wire



Temperature measuring instrument

6. Possible measuring errors

Defined errors (comonent tolerances)

- Instrument +/- 0,5°C
- Thermocouple wire +/-1,5°C
- Compensation wire +/-1,7°C
- ***Total error +/- 2,3°C***

Estimation of possible errors

- Corrosion/dirt at lance connection +/- 1,1°C
- Too high temperature; Temp.-difference in meas.-chain +/-1,1°C
- Temperature stratification in the melt +/-1,7°C
- Accuracy of calibration tools +/-1,1°C
- ***Total error +/- 2,6°C***

Defined & estimated errors
Together result in +/- 3,5 °C

MINKON German Technology

7. Quality assurance

Wire

- *Calibration of thermocouple wire pair at Palladium melting point (1554°C)*
- *Allowable tolerance +/- 1,5°C (+/-0,1%!!)*
- *Minimum five Palladium point measurements with every wire batch are made by supplier and confirmed by 3.1 certification (DIN EN 10204)*
- *Up to 100.000 thermocouples are manufactured from one wire batch*
- *Smaller tolerance of premium sensors by selection (0°C to +1°C)*

Thermocouple

- *In-Situ function check using induction furnace*
- *Representative sample of each production batch (20.000 Stk)*
- *Precision: allowable standard error 1,5°C; for premium Sensors 1°C*

MINKON German Technology

8. Continuous measurement

Thermocouples

- Thick refractory protection in direct contact with melt
- Adapting time from 60 seconds up to 5 minutes
- Special maintenance needed
- Usage of standard instruments possible

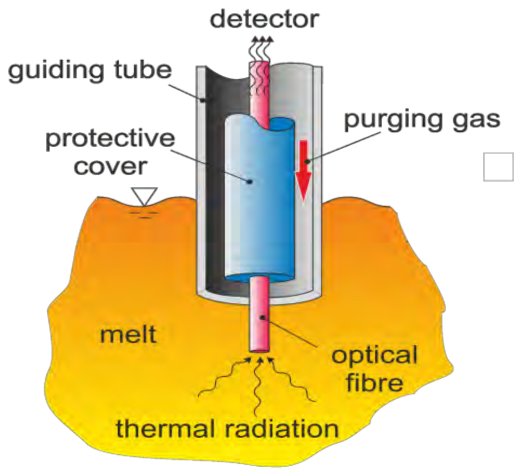
Pyrometric methods

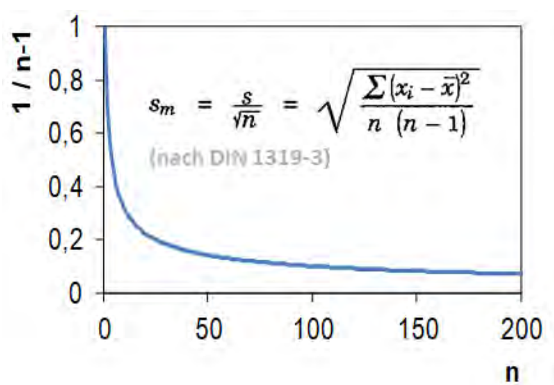
- Contactless measurement
- Free field of view is needed
- Only surface temperature can be measured
- Exact surface emissivity unknown → big errors possible

MINKON German Technology

8. Continuous measurement

Liquid steel temperature measurement using fibre optical system DynTemp®





- Consumable optical fibre continuously fed into melt by gas purged metallurgical nozzles
- Thermal melt radiation guided to detector
- No influence of slag / or surface emissivity (ε=1)
- Accuracy of single spot measurements +/- 2°C
- Improvement of accuracy by continuous measurement
- High measurement dynamics
- In process measurement for direct process control

MINKON German Technology

8. Continuous measurement

Impact of using Dyntemp

Upon introduction of this technology in the European market, considerable potential technological, economic and environmental benefits for the European Steel industry identified from the research to date include (H2020 – RECOBA):

- Reduced energy consumption of 600 GWh/year
- Reduction of CO_2 emissions of 360 kton/year
- Increase in metal yield of about 1%
- Reduced refractory consumption of 5%
- 1 to 5% reduction of none renewable primary raw materials

MINKON German Technology

Conclusion #1

1 Thermocouple measurements are quick, precise, and inexpensive

2 Over 120 years experience in steel industry with permanent improvement

3 Max. thermo wire tolerance only +/-1,5°C (0,1 %) at Palladium point

4 Tolerance of total measuring chain +/- 3,5°C

5 Higher accuracy only achievable by improved maintenance of measuring infrastructure

Thermocouples will remain essential for steel making in future

MINKON German Technology

Conclusion #2

1 Process control by thermocouples restricted due to long adapting time

2 Accuracy of pyrometric measurement not sufficient for process control

3 DynTemp® offers high potential to more precise process control

4 High energy savings, yield increase and less refractory wear by in process temperature measurement

Thermocouples will remain essential for steel making
but in future they will be complemented by continuous measuring using DynTemp®

MINKON German Technology

Thank You for your attention.

Do you have questions?

Contact

Minkon GmbH
Heinrich-Hertz-Str. 30-32
D-40699 Erkrath

Dr. Torsten Lamp

Phone: +49 (0)211 209908-56
Telefax: +49 (0)211 209908-90

Torsten.Lamp@minkon.de

www.minkon-international.de

MINKON
German Technology