INSTALLATION AND MAINTENANCE
OF INDUSTRIAL ELECTRIC THERMOMETERS

GUIDELINE

POSSIBLE CAUSES OF TROUBLE
AS WELL AS THEIR ELIMINATION

SPECIAL CABLES
SAB BRÖCKSKES

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TRADITIONAL FAMILY BUSINESS SINCE 1947

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FAMILY BUSINESS IN THE THIRD GENERATION

75 years of experience in cable and wire manufacturing as well as in temperature measurement technology turned a one-man business into a company with more than 550 employees. We prove our strength every year with more than 1500 special products according to customers' requirements. Each product is a new challenge for our creative technical team. We at SAB see ourselves as a manufacturer and a service provider – in the sense of true partnership and the greatest possible customer orientation.

Today, the quality of our products is known and appreciated in more than 100 countries around the world. In all product ranges, we are certified according to DIN EN ISO 9001. Furthermore, we have implemented an environmental management system for our company according to DIN EN ISO 14001, an occupational health and safety management system according to NLF/ILO-OSH and DIN ISO 45001, and an energy management system according to DIN EN ISO 50001.

And also for the future, our slogan is: "WE GO FORWARD!"

FOUNDED:	1947 by Peter Bröckskes sen. an independent, medium-sized company.
CEO:	Peter Bröckskes and Sabine Bröckskes-Wetten
PLANT/LOCATION:	In Viersen (Lower Rhine) 110.000 m² company site. Own manufacturing from copper conductor to outer sheath. VDE approved burnchamber and laboratory within the company.
EMPLOYEES/WORKERS:	Approx. 430 at the plant in Viersen, 550 worldwide
YEARLY SALES:	Approx. 134 Mio. € worldwide
PRODUCTS:	Special Cables Measurement Technology Cable Harnessing
CERTIFICATES AND APPROVALS:	Quality management system acc. to DIN EN ISO 9001 for every manufacturing field Environmental management system acc. to DIN EN ISO 14001 Occupational health and safety management acc. to NLF/ILO-OSH and DIN ISO 45001 Energy management system acc. to DIN EN ISO 50001

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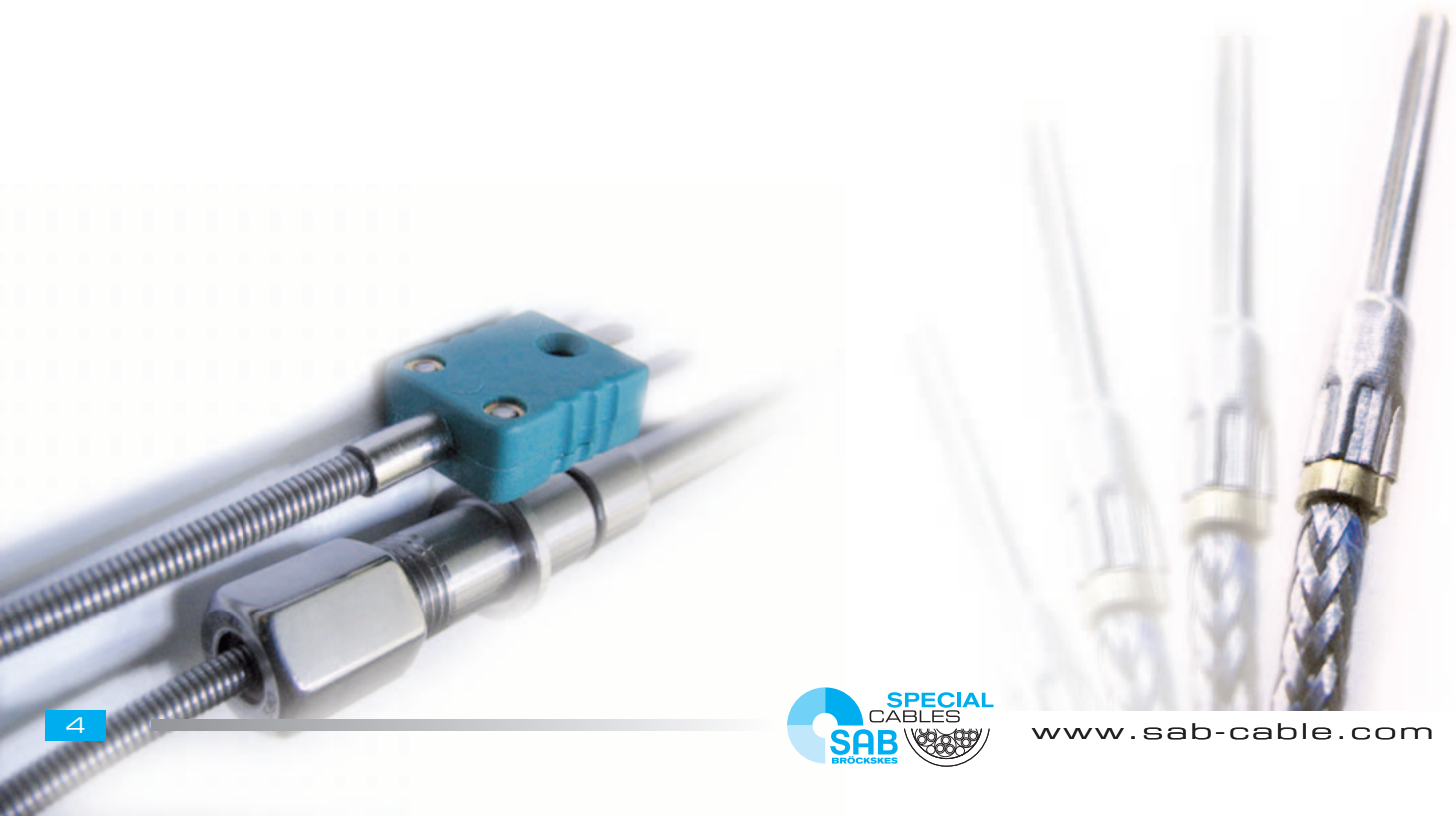
ELECTRIC THERMOMETERS
INSTALLATION, MAINTENANCE AND TROUBLE FINDING



1 General

Electric thermometers transfer the physical temperature value into a temperature dependent signal. They are closed constructive components delivering output signals for further treatment. In most cases auxiliary energy sources are necessary dependent on on the sensor type. The good transmission of those electrical signals over far distances offer a great advantage. The reception of the measured value and the reading place of the temperature can be far away from each other. The measuring signals can easily be integrated and treated in control or process control systems with small effort.

2 Principle of function of electric thermometers

2.1 Resistance thermometers

The most different construction types of platinum resistance thermometers are applied in industrial measuring techniques. Pt 100 resistance thermometers and measuring resistances are standardized according to DIN EN 60751. Their resistance value is 100 ohm at 0°C. Within a temperature range of -200°C up to + 850°C, the Pt 100 resistance thermometer corresponds to a fixed characteristic line. Deviations from this line, called basic values, are approved according to two tolerance classes, A and B. Within the tolerance class B measuring deviations of +/- 0.3 K up to +/- 4.6 K may occur. The positive temperature range, limited to + 650°C, allows +/- 0.15 K up to +/-1.45 K within tolerance class A. Technical PT resistance thermometers that are applied in many industrial manufacturing processes consist of standardized component parts, protecting tube, connection head and Pt 100 gauge slides. A survey on the standardized construction types is shown under DIN 43770. The characteristic lines and electric properties are standardized according to DIN EN 60751.

2.2 Thermocouples

Compared with resistance thermometers, thermocouples show higher inaccuracies in temperature measurement. Nevertheless, they can be used in much higher temperature ranges and are less sensitive to mechanical stress. Thermocouples with base thermocouples show measuring deviations from +/- 1 K up to +/- 9 K within a temperature range of -200°C up to + 1200°C , dependent on element type and temperature. In the range of 0°C up to +1200°C, thermocouples made of precious metals have +/-1.5 K up to 3 K and furthermore, up to max. + 1700°C +/- 4.3 K. Those deviations correspond to the limit deviations for thermocouples according to DIN EN 60584 within tolerance class 2. The basic values of the most important thermocouples are determined in this standard as well as under DIN 43710 (withdrawn in April1996) . As a reliable temperature measurement requires a precise adaptation to the corresponding process, thermocouples offer a wide range of construction types. Analogous to the resistance thermometers, there are industrially standardized types that are called technical thermocouples.

3 Installation and first initiation of thermometers

3.1 Spacial arrangement of thermometers

In general, electrical thermometers work independently of their position. The preferred mounting position is „vertically suspended" that means connection head on the top and protecting tube below.

3.2 Installation of thermometers

Usual installation methods are:

- screwed thread (cylindric and conical outer thread)
- swivel nut with inner thread
- adjustable flanges and counter flanges, only tight with small gas pressures
- welded flanges
- adjustable clamped screwings
- welded into tubes/ connection pieces, walls
- bayonet nipples, not liquid or gas tight

In case that the protecting tube must be welded, the neck pipe with connection head and gauge sildes have to be dismounted. Before mounting again, it has to be assured that the bore of the protecting tube does not show any grease or impurities.

Ceramic protecting tubes

Ceramic protecting tubes have to be protected against mechanical stress (stroke) and temperature shocks. If they are mounted or exchanged with running processes, they have to be slowly pushed in.
Standard values are the following:
10-20 cm/min at + 1200°C
1-2 cm/min at + 1600°C
or the protecting tubes have to be adequately preheated.

Horizontal and unsupported lengths of more than 500 mm at temperatures of more than + 1200 °C have to be avoided as well as direct contact with flames.

3.3 Positioning

In order to place the cable, the connection head with cable screwing can be turned. Therefore, the screwing of the neck pipe at the connection head respectively in the neck pipe is loosened, the connection head turned into the required direction and the screwing fastened again.

3.4 Operational conditions

It is of great importance for all mentioned mounting methods, that the connections with the process are tight, fix and secure according to the accepted technical rules and the local prescriptions. Furthermore, it has to be assured that the thermometers have a sufficient „surface for heat exchange" with the medium to be measured and that faults due to heat elimination by the protecting tube are kept small. This can be achieved for technical applications, if the following immersion lengths are chosen:

for measurements in liquids	EL + 5x protecting tube diameter
for measurements in gases	EL + 10x protecting tube diameter

(EL = effective length of the probe)

The generally applied measuring probes respectively resistance thermometers have an effective length of 5 up to 30 mm depending on the design and construction type.

The temperature sensitive length of thermocouples can generally be ignored. In pipelines with small diameters the required immersion length can only be achieved, if the protecting tube is mounted in the pipe bend against flow direction. In case of a too small immersion length, big faults can occur compared with the standard tolerances.

Attention: In general the **fitting length** is larger than the **immersion length** and only the latter is of great importance.

3.5 Surrounding conditions at connection head

The ambient temperatures shall range from -25 °C up to + 80 °C. If silicone gaskets are used, temperatures up to + 150°C are possible. The stress on gaskets, cable insulation, on the material of the connection heads, etc. has to be considered!
If electronic transmitters are mounted in the connection head, their temperature limits have to be taken into account! The admissible temperature of the weakest component part is important!
The protecting type of the connection heads has to be chosen according to the expected ambient conditions.

4 Measuring cables

4.1 General

The cables have to be chosen that they are appropriate for the corresponding environment that means resistant against thermal, mechanical and chemical influences. All cable connections have to be well done. Measuring cables shall be laid separately and > 0.5 m away from supply cables and cross the latter rectangular. All measuring circuits shall be operated ungrounded; if necessary a one point grounding is recommended. In order to avoid electrostatic or magnetic interference the cables shall be screened respectively have twisted cores.

Valid standards and prescriptions have to be taken into account.

4.2 Cables for thermocouples

Between thermometer and measuring device the correct compensating or extension cable suitable for the thermocouple has to be laid and connected in correct polarity. The colour code of the compensating or extension cable corresponds to the applied standard for the thermocouples. All connection points are bare metal and shall be free of intermittent contacts so that they have negligible transition resistances.

4.3 Cables for resistance thermometers

Between thermometer and measuring device copper cables have to be laid. In order to keep cable resistances and their temperature dependent fluctuations as small as possible, an appropriate cable section has to be chosen. Resistance thermometers can have a 2-, 3-, or 4- wire circuit depending on the requirements on accuracy. The 2-wire circuit causes the highest measuring fault. For the 2- and 3- wire circuit the so called line balancing is recommended, if the topped instruments are appropriate; thus feeding faults can be reduced or almost completely suppressed.

4.4 Cable connection in the connection head

After the connections at the socket have been done, it has to be assured that the connection head is closed thoroughly and the cable screwing is tight. This is the only way to assure the IP protection class of the device.

5 Maintenance

5.1 Returning inspections

Thermometers and their measuring circuits shall be controlled regularly (1 to 12 months) with regard to:
- mechanical, thermal, chemical damage of the protecting tubes
- corrosion and bad contacts at cable connections
- tightness of connection heads
- function of the measuring circuits (drifts, insulation resistance)

5.2 Control of measuring circuits

Loosen cable connections in connection head and check instruments with regard to the operating temperature for
- thermocouples with mV signal
- for resistance thermometers with test resistance

Thus one can find out if the thermometer or the instruments are the cause of trouble.
During operation the following values of a gauge slide can be checked:
- the transmission
- the loop resistance of all conductors
- insulation resistance
- electromagnetic force of thermocouples
- resistance of Pt sensors
- wrong polarity of thermocouples

The insulation resistance of the complete ungrounded measuring circuit, cables and thermometer shall be bigger than 1 MΩ measured with 10 V DC. Process temperature and material of the cable insulation have to be considered!

5.3 Control of removed gauge slides

Rapid control of removed thermocouples and resistance thermometers and of the corresponding measuring circuits.
Necessary instruments:
- mV - meter
- Ohm - meter or resistance balance
- insulation measuring device with 10 - 100 V DC test voltage

All measurements are executed at room temperature. By „tapping" wire breaks and interruptions can be found out. The transmission and insulation control is done at room temperature. A thermocouple can be considered to be okay, if R < 20 Ω (value depends on wire section and length). For insulated thermocouples the insulation resistance shall be 100 MΩ.

The warming of the measuring point to a temperature from + 200°C up to + 400°C (without temperature control) allow further conclusions with regard to wrong polarity, breaks or too low insulation resistances, etc.

5.4 Control of protecting tubes

Protecting tubes are wearing parts! At measuring points with particularly strong mechanic, abrasive or chemical attacks, every machine stop shall be used to check the condition of the protecting tubes. If necessary, they have to be exchanged in order to prevent unplanned operational interruptions.

Within this brochure only some of the most frequent failures and their elimination can be described. The enumeration does not claim to be complete. The indications only refer to thermometers. The subject of the topped instrumentation is not treated herei.

6 Operational defects and their elimination

6.1 Possible operational defects for nearly all electrical thermometers

Defects	Possible reason	Remedy
Faulty measuring signals (measuring signal is floating, drifting, too high or too low)	- electric/ magnetic interference - connections	- check cable installation min. 0.5 m distance between measuring and supply cables - electrostatic screening; grounding at **one** point - use cables with twisted cores - cross disturbing supply cables right-angled
	- ground circuits by multiple contact - by insulation defects in grounded measuring circuits	- preferably floating measuring circuit - only one grounding point in measuring circuit
	- insulation fault by humidity	- dry gauge slide apply new sealing
	- thermal stress	- choose appropriate sensor
Wrong temperature indications in contrast to comparable measuring points	- protecting tube in „flow shadow”	- choose installation place with undisturbed flow. The medium must be able to transfer the temperature undisturbed to the thermometer
	- immersion depth too small	- choose longer protecting tube or more favourable installation place
	- influence of an additional heat source	- choose other installation place
Extremely inert time behaviour	- sediments on protecting tube	- clean protecting tube during inspection
	- protecting tube „too thick”	- choose smallest possible protecting tube with respect to process - choose different protecting tube construction, for example tapered versions
	- too small immersion depth	- change immersion depth a) for measurements in liquids EL + 5 x protecting tube diameter b) for measurements in gases EL + 10 x protecting tube diameter (EL = effective length of measuring sensor)
	- gauge slide without sufficient contact to protecting tube	- gauge slide must be in contact with the protecting tube ground and if possible shall touch the protecting tube wall
	- too high heat dissipation	- use contact medium: liquids, heat conducting paste, metal foils, - sleeves
Interruption of measuring circuit	- vibrations caused by machine parts or flowing	- possibly choose different mounting place - dampen equipment - use more rigid protecting tube - use gauge slides with strengthened springs - special constructions of gauge slide and protecting tube
Protecting tube strongly corroded or damaged by abrasion	- medium does not correspond to original specification	- check operational conditions - check control medium
	- wrong material chosen - composition of medium has been changed	- choose more appropriate protecting tube material - choose appropriate construction - provide appropriate surface protection
Protecting tube broken	- too high flow velocity - solid particles in the medium - swirls of the medium	- reduce immersion length - choose different protecting tube construction - choose different installation place

6.2 Specific defects of thermocouples

Defects	Possible reason	Remedy
Temperature indication too low in case of thinner thermo wires or sectional reduction due to consumption	- resistance of the measuring circuit too high - incoming or inner resistance of instrument too low	- choose instrument with high incoming resistance (≥ 1MΩ)
Faulty reading gets higher with rising temperature (reading too low)	- decreasing insulation resistance at with rising temperature (has the effect of a shunt and reduces the electromagnetic force)	- dry gauge slides and seal tightly against humidity
	- impurities or corrosion and humidity at cable connections and clamps	- clean contact points and protect against humidity
Temperature reading deviates strongly from table values	- parasitic tensions - wrong material combination - bad electrical contacts	- check thermoelectric voltage - examine compensating or extension cable and exchange if necessary
	- right compensating cable connected with wrong polarity - wrong compensating cable connected - too high ambient temperatures	- control type and polarity of compensating cable, if necessary exchange cable - relay connection points
Temperature reading deviates in time	- thermal ageing causes structural transformation	- oxygen, sulphur, silicium, hydrogen, etc.changes the chemical and metallurgic structure of the thermoelectric material. Best known „green decay" (selective oxidation of the alloyed thermoelectric leg). In this case the immersion length shall not be reduced. The tightness and material appropriateness of protecting tubes must be controlled. The diameter of the thermo wires has to be chosen as large as possible
	- impact of harmful substances	- „rinse" the protecting tube by air or operate under overpressure in order to avoid the diffusion of harmful substances
	- defect in short range order	- use preliminary annealed thermo wires - use thermocouple type N
Unsteady temperature reading within a correct measuring circuit	- unsteady temperature at cold junction	- temperature at cold junction must be kept steady

6.3 Specific defects of resistance thermometers

Defects	Possible reason	Remedy
Process temperature is too low with correct indication of the electrical thermometer	- high conductor resistance - impact of circuit, especially in case of 2-wire circuit	- choose cable with bigger section - shorten feeding line - choose 3-or 4-wire circuit, possibly only from connection socket of gauge slide
	- self-heating by a too high measuring current	- control measuring current and reduce if necessary
Variable temperature reading	- feeding in the field of unsteady temperatures with 2-wire circuit	- choose 3-wire circuit in order to avoid environmental temperature impacts
	- unsteady current supply (full influence on measurement)	- use appropriate supply unit
Measuring fault gets bigger with rising temperature (reading too low)	- decreasing insulation resistance has the effect of a shunt to the measuring resistance (doubles the tolerance at temperatures of more than 600 °C)	- control gauge slides/sensor units, respectively dry and apply new sealing against humidity
Questionable measuring values	- impurities or corrosion and humidity at cable connections and clamps	- clean contact points and protect against penetrating humidity - eliminate causes of impurities
	- thermoelectric voltages at the connection points by temperature gradients	- take care of a steady temperature
The indicated temperature decreases in time (process temperature rises)	- ageing of the sensor by thermal or chemical influences	- ensure a reliable measurement at important measuring points by short maintenance intervals or by exchange of the gauge slides - ensure that the thermometer operates within the allowed temperature range

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