Application Note AN0101:
Typical Causes when Customers claim Inaccurate Temperature Reading

1.) General Informations

From time to time we are receiving reports of deviations in temperature acquisition. The customer reports that the temperature displayed on the controller does not fit to the actual kiln temperature.

Our controllers are designed with a self-validation system. If the signal acquisition circuits fails the controller recognizes by itself and display an error message (e.g. „F9 3“). In other words, if the controller does not show an error message you can definitely <u>exclude</u> a controller problem. But what else can be the cause?

2.) Typical Causes

Please find below the most typical causes of inaccurate temperature reading:

- Type of thermocouple does not fit: The controller is set to a specific type of thermocouple (see type label). Since the mV signal of the different kind of thermocouples are totally different, a mis-match of type of thermocouple and controller will cause huge deviation. See examples below (true kiln temperature 1000°C (table to the left) and 200°C (table to the right), about values):

Kiln t/c	type S unit reads	type R unit reads	type K unit reads
S	1000°C	930°C	250°C
R	1070°C	1000°C	270°C
K	„F3“	„F3“	1000°C

kiln t/c	type S unit reads	type R unit reads	Type K unit reads
S	200°C	190°C	60°C
R	210°C	200°C	65°C
K	900°C	840°C	200°C

- Tip of the thermocouple is not shifted far enough in the kiln. It should be at least 40mm in the kiln (varies on kiln insulation and type of thermocouple). The required distance increases on type K thermocouples and on kilns with thin insulations. On thermocouple with ceramic cover also make sure that the thermocouple itself (the wire inside the cover) really is shifted to the tip of the ceramic cover. Disregarding these rules may cause low readings of up to several hundreds degrees

- Wrong compensating wire used or polarized bad on both ends: Make sure that all the electrical link between thermocouple and controller is done using compensation wire fitting to the type of thermocouple. Note that compensating wire is totally different for type K and type S / R thermocouples (for S and R it is the same). Using ordinary copper cable causes too low readings. Also make sure that + and – couple if the compensating wire is really connected to the right pole of the thermocouple! If you switch polarization on both sides the firing starts well but will have too low reading, it is even worse than using copper cable. Disregarding these rules causes less readings of 20°C up to 400°C (example. kiln 1000°C, controller reads 800°C only)

- Thermocouple has an internal short circuit behind the tip: The tips of the couple are welded togather and measuring the temperature at this point. If the two couples have an electrical short circuit behind the tip (e.g. on their way in the ceramic cover) the controller will also read too low (but there is still a reading!) If there is a strong short cicuit the bentrup controllers are capable of recognizing this and interrupting the firing showing an error message (e.g. „F1")

3.) Further Considerations

Note that most problems will cause *the kiln to fire too high*. This is because the controller has no other way to gather the temperature than reading the thermocouple signal. The real kiln temperature might be much higher but the controller can not know, still continues to heat up because it did not find the thermocouple signal to be accordingly.

4.) Verifying the Kiln Temperature using Seger Cones

Seger cones are still commonly used to check the kiln resp. the controller. In many cases the operator finds the seger cone not confirming the temperature as expected. This result is confusing especially for those users who are used to work with seger cones and therefore initially rely on these indications more than on a controllers reading.

It is very important to understand what exactly a seger cone indicates: A seger cone does NOT indicate a certain temperature, a seger cone indicates heatwork, ie. temperature during a time. Assuming a firing at exactly 1070°C, a seger cone for 1070°C will look like new on a fast firing, but the same kind of seger cone will be totally melted down if you do a slow firing with a 30 minutes dwell at 1070°C! Check the specification sheets from the manufacturers of the seger cones. The temperatures always refer to a certain increase in temperature and dwell (ie. 150°K/h and no dwell).

Seger cones are known to be accurate. This is actually true as long as they are fired exactly according to these specifications. However, accuracy of commonly used seger cones is limited to 5 – 8°K. Compared to the high accuracy of bentrup controllers (e.g. 0.5°K on a TC500 series controller) it is odd to check the controller accuracy with a seger cone. Keep in mind that commonly used thermocouples (so called "non calibrated thermocouples) do have an accuracy of about 3°K in ceramic applications (0.3% according to IEC). But still controller and thermocouple imply a much higher accuracy than a seger cone.

There are other non-electronic principles to measure temperatures in kilns. Philips PTMRs are little rings which shrink accurately according to the highest temperature reached. Compared to seger cones they are quite costly and also require accurate equipment to measure the diameter.

5.) Temperature Gradients in Kilns

Assuming that you have complied to all requirements to setup an accurate environment to measure temperatures in your kiln. Even then you might find a difference in temperature of 10 or 20°K in your kiln. Why?

Having a closer look to the temperatures in a kiln, you will find 1500°C or even more right on the surfaces of the heating elements versus the outside shelf of the kiln at 50°C. The difference in temperature (gradient) is 1450°C in our example. This gradient distributes according to the insulation materials used. It is desirable most of the gradient will be built up in the insulation. At the heating elements there will be a drop of temperature because circulating air can not pickup 100% of the temperature. Keeping this in mind it is obvious that a 10 or 20°K deviation in temperature in a kiln is to be considered as very good. Air convection makes sure that temperatures equalize. However, direct heat radiation is also an issue causing high absorbing materials to gain higher temperatures.

A multizone kiln controlled by a bentrup multizone controller can be used to minimize these effects of temperature deviations. For details see Applications Note AN0602.

Conclusion: Even if you are measuring with properly installed equipment, you WILL probably find deviations because you are never measuring at exactly the same location in the kiln. These effects of course can be minimized considering impact of air convection, radiation and isolation.

6.) Modifying the Controller Calibration?

Recalibrating the controller does not make sense at all. The controllers are accurately calibrated in a laboratory environment using ISO9002 approved instruments. Any change in calibration would make them inaccurate.

Sometimes users ask for an option to fine tune the controller to compensate for deviations in their setup/kiln environment. For this purpose TC-S1/M2 controllers do have an option of +/- 2.5% full scale and offset trim. However, usually a deviation in the setup/kiln environment is not linear, ie. the trim option can never compensate properly. Example: A too short thermocouple will initially give an reading of 10°K less than the real temperature at 1000°C. After 30 minutes dwell the insulation has heated up and therefore thermocouple reading now deviates only 3°K, after another 60 minutes it reads properly. What trim would you like to enter in the TC-S1/M2?

Inaccuracy should always be compensated at its origin. The controller should not be used to compensate.

Initial Issue	January 10th 2001		Be
Updated	November 12th 2002	added seger cone rules	Be