

# An end to the uncertainty

## DIN EN 60751:2009 legitimises the use of platinum resistance thermometers in industrial applications

Dietmar Saecker

DIN EN 60751, the standard for industrial platinum resistance thermometers, was recently re-issued after more than a decade (2009 Edition). The primary reason for this update was that several aspects that had already been successfully established in practice were not yet mentioned in the 1996 standard. The two most important examples are the use of thin-film resistors and the so-called 1/3 DIN accuracy class.

Many users were unsure about whether they were actually allowed to use the new, but non-standardised, technologies at all. Now this uncertainty has come to an end: the new DIN EN 60751 standard describes these points in detail and defines new, realistic limits of use for sensor types and accuracy classes. Unfortunately, however, the new standard abandons its usual clarity when it comes to specifying the vibration resistance of thermometers, leaving itself open to a wide range of interpretations. This article comments on the most important changes and helps understand the new standard.

### Measuring resistor designs

The electrical resistance of a resistance thermometer's sensor changes with temperature. Since the resistance increases as the temperature rises, the device is said to have a PTC (Positive Temperature Coefficient). Pt100 measuring resistors are normally used for industrial applications. In the predecessor version of IEC 60751 (1996 Edition), there is no mention of the design of the sensors used. In the old days, there were only wire-wound measuring resistances (W). However, during the last decade, thin-film resistors (also referred to as

flat-film resistors, F) have become widely accepted.

Since thin-film measuring resistors were omitted from the old standard, many users were of the erroneous opinion that standardised thermometer configurations still made exclusive use of wire-wound resistors. In fact, the usage limitations vary, depending on the sensor configuration. The dominant types in industry are described below.

### Wire-wound resistors (W)

With this design, a very thin platinum wire is encased within a round, protective body. This design has been well-established for decades and is common worldwide. Two sub-types are available that differ in the choice of insulating material, namely glass or ceramic resistors.

The bifilar wire of a glass resistor is fused within a glass body. Since this prevents the wire from moving, this type demonstrates high vibration resistance. Unfortunately, some properties of glass change at high temperatures, causing its electrical conductivity to increase. Owing to its decreasing insulation resistance, the sensor loses its accuracy and should therefore only be employed in the temperature range from -196 to +400 °C. The production of this sensor type is complicated and the resulting price is comparatively high.

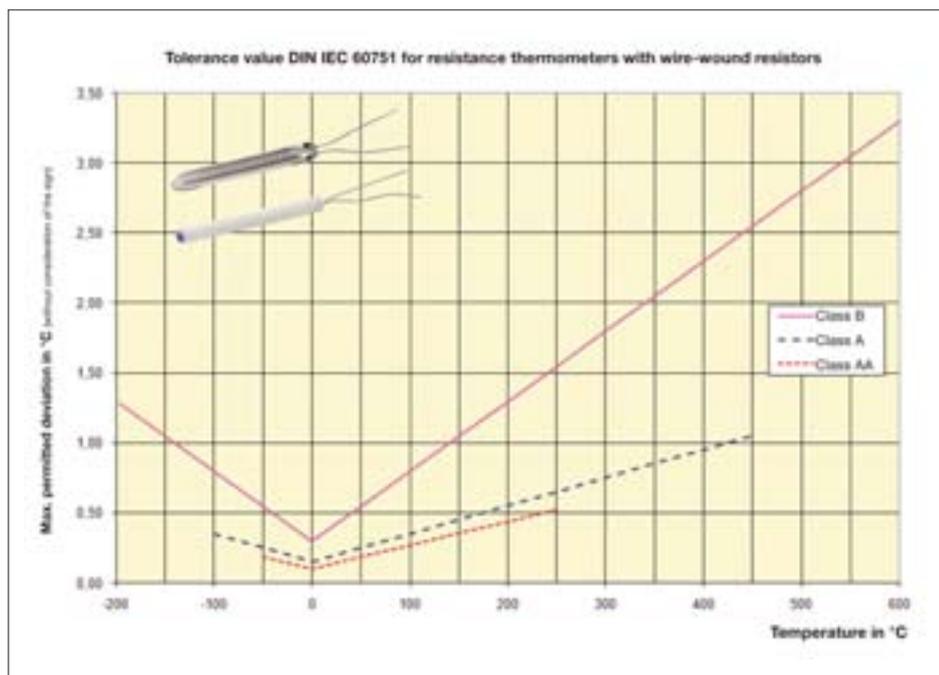
The platinum wire of a ceramic resistor is spiral-wound and located in a cylindrical cavity in the protective body. With high vibrations, the lack of support may mean the windings of the coil touch one another and alter the resistance. Under extreme vibration, the freely oscillating wires may even break. This is why this sensor design can only be used if the vibration stress is low. However, these sensors provide the widest temperature range and are suitable from -196 to +600 °C.

### Thin-film resistors (F)

With thin-film resistors, a very thin platinum film is applied to a ceramic carrier plate. Connecting wires are then attached. Finally, the platinum film and the connecting wire junctions are sealed against external effects by a layer of glass. Thin-film resistors typically have a very small size and high vibration resistance. Due to the combination of different materials, the temperature range is limited to between -50 and +500 °C.

Since thin-film resistors are also used in large quantities in consumer appliances, sensors of this type are, in most cases, very cheap to produce.

The new standard proposes identifying the sensor type on the product label of the thermometer by adding (W) or (F).



The new DIN EN 60751:2009 standard changes the use of platinum resistance thermometers in industrial applications

## Operating limits

A new feature in the 2009 version of the standard is that the operating limits for the thermometer configurations vary according to the sensor design, resulting in metrological differences (table).

In class B, the complete measuring range can only be covered using wire-wound ceramic resistors. Thin-film resistors, in reality, are limited by the standard. Glass resistors can only be used up to +400 °C, because the increasing electrical conductivity of the glass body causes a measuring error. In order to be more realistic, accuracy Class A now only applies from -100 to +450 °C. It had become evident that all thermometers makes frequently drift away from the old Class A in continuous use at extreme temperatures. Thus, the Class A specification basically only applied in the as-delivered state and not during operation. The new standard informs the user that "only" Class B is applicable at extreme temperatures. Another way of specifying accuracy, referred to as 1/3 DIN, was proven in practice but not yet standardised. Without standardisation, this could be interpreted by providers in different ways. The only standard feature was that a tolerance of 0.1 °C

### Facts & Figures

## Temperature and resistance relationship

There is exactly one resistance value for each temperature. This clear relationship can be described by mathematical formulae. The formulae shown below apply within the operating temperature limits and do not depend on the design of the measuring resistor.

The following applies in the temperature range from -200 to 0 °C:

$$R_t = R_0 [1 + At + Bt^2 + C(t - 100\text{ °C})^3]$$

The following applies in the temperature range from 0 to +600 °C:

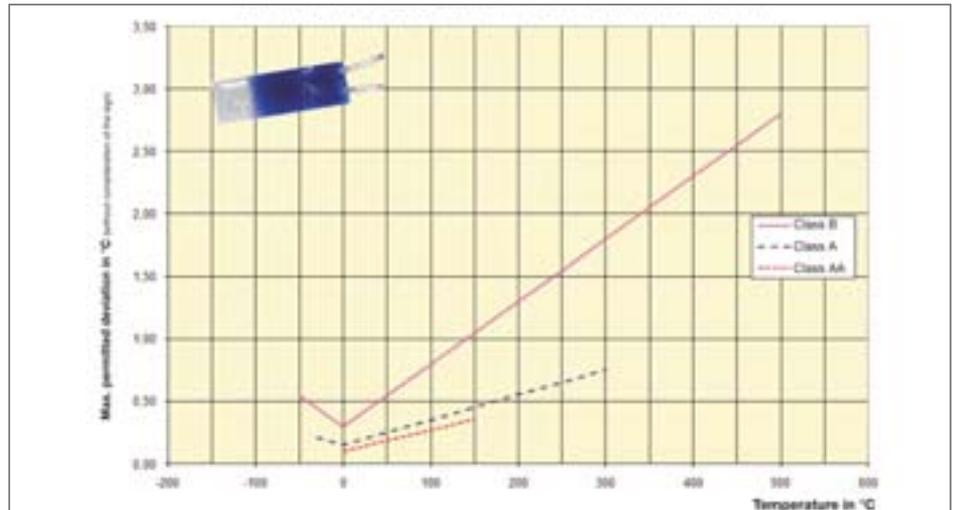
$$R_t = R_0 [1 + At + Bt^2]$$

where

$t$  = Temperature in °C  
 $R_t$  = Resistance in ohms at the measured temperature  
 $R_0$  = Resistance in ohms at  $t = 0\text{ °C}$  (e.g. 100 ohms)

The following constants apply for the purpose of the calculation:

$A = 3.9083 \cdot 10^{-3} (\text{°C}^{-1})$   
 $B = -5.7750 \cdot 10^{-7} (\text{°C}^{-2})$   
 $C = -4.1830 \cdot 10^{-12} (\text{°C}^{-4})$



Graph of the tolerance values according to DIN EN 60751 for resistance thermometers with wire-wound resistors (left) or thin-film resistors (right)

(that is, one third of Class B) had to be observed at the calibration point (0 °C). The new standard takes this into account by turning it into a true accuracy class, in which a temperature range is combined with a calculation of the permissible sensor limiting error. This new accuracy class, which is in fact slightly better than 1/3 DIN, is called Class AA.

Practical considerations likewise dictated the replacement of the lowest calibration point, i.e. -200 °C, with -196 °C, which is much easier to represent. Under real conditions, -200 °C could never be achieved while -196 °C can be reached very easily by boiling nitrogen at standard pressure.

## Lack of clarity on vibration resistance

In accordance with DIN EN 60751, any resistance thermometer conforming to the standard can be exposed to vibration-induced accelerations of up to 30 m/s<sup>2</sup> that occur in a frequency range from 10 to 500 Hz. Unfortunately, the new standard's text is ambiguous here. The 1996 edition clearly refers to "peak-to-peak". This information has been missing from the 2009 edition since it was revised by the IEC (International Electrotechnical Commission). This opens up a wide range of interpretations. Most other standards (e.g. IEC 60068 Environmental Tests) concerned with vibration tests use the term amplitude exclusively. This means that other measuring instruments, such as manometers, are tested for stability at a given vibration with a given amplitude.

Based on the new wording of DIN EN 60751, it must be assumed that this standard also refers to the amplitude, since this is the customary term in vibration engineering.

However, according to the above-mentioned curve, this would double the specifications for thermometers. Consultations with various members of the DKE Standards Committee have confirmed that this increased severity was not the aim. What they actually meant was "everything stays the same", except that this was formulated without the words "peak-to-peak". Apparently, this extra information was deleted by the IEC. We will therefore have to live with this uncertainty until the next edition of the standard is published. This explains why some manufacturers of industrial thermometers have decided to refine the vibration resistance data in their documentation by adding "amplitude" or "peak-to-peak".

If the frequency is known and constant, the amplitudes of acceleration, speed and deflection can be converted to one another. The vibration frequency can be used to calculate the so-called angular frequency  $\omega$  ( $\omega = 2\pi f$ ). At a given amplitude of acceleration  $A$ , the maximum velocity  $V_{max}$  is specified as  $V_{max} = A/\omega$ . This can be used to determine the deflection from the zero line  $x_{max} = V_{max}/\omega$ . The space required for the vibration, i.e. the difference between the deflections, can be represented as the peak-to-peak value of the deflection  $x_{s2s}$ . The new standard brings the written description of Pt100 resistance thermometers and their actual usage closer together. Users are clearly informed about the new technical possibilities and their limitations. Unfortunately, the statement on vibration resistance remains ambiguous, so that this parameter requires particular attention when comparing data from different manufacturers.

Hall 7, Booth B21

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