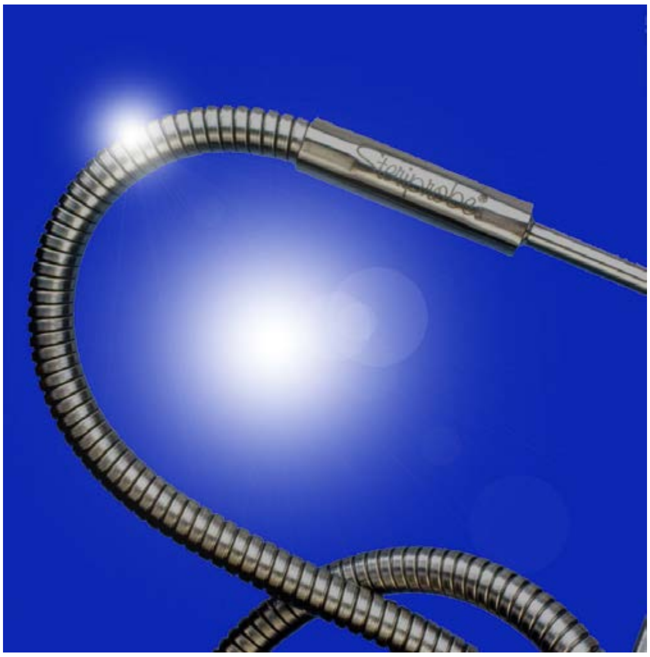

DESIGN CONSIDERATIONS FOR ACCURATE TEMPERATURE MEASUREMENT USING PT100 DETECTORS

ABSTRACT

Thermal Detection has over 30 years experience manufacturing PT100 temperature probes. The following paper outlines the key design considerations for successful temperature measurement.

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Introduction

Highly accurate and stable temperature measurement is possible with a PT100 temperature probe between -200 and +850°C, which makes it a popular choice in many industrial applications. In particular, the high degree of accuracy across the -50 to 150ºC range means that it is the preferred choice for temperature measurement in Pharmaceutical applications, such as in sterilisation processes.

The following guidelines will help the user to specify the correct configuration.

They are written with Pharmaceutical and Healthcare applications in mind although the concepts apply across all industry sectors.

Thermal Detection has over 30 years' experience in specifying and manufacturing PT100 temperature probes, and can help you to navigate through the complex choices that need to be made for optimum temperature measurement.

Please view our range of RTD temperature products on our website, and use the product enquiry forms on the product pages to let us know your requirements.

Keywords

PT100 Temperature probe, tolerance, resistance measurement, pharmaceutical autoclave, 3 wire compensation, 4 wire compensation.

Principle of Measurement

The PT100 detector is a popular example of a resistance temperature detector (RTD). It is based on the principle observed in metals whereby a change in temperature will cause a change in the resistance of the material. Platinum exibits a positive temperature coefficient i.e it shows an increasing resistance with increasing temperature, and so is the most common material used to construct RTD's.

The PT100 detector is designed to have a resistance of exactly 100Ω at 0.0°C, and a resistance increase of 0.385Ω per 1°C increase between 0 and 100°C according to ISO 60751: 2008

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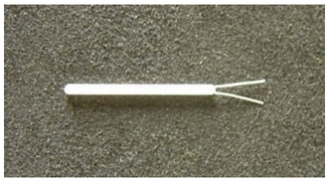
Detector Types and Construction

PT100 detectors are commonly constructed using two methods:

1. Wire wound sensors.

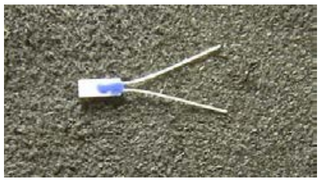
Platinum wire wound detectors consist of a thin platinum wire loosely wrapped around, or threaded within, a ceramic core.



Wire wound detectors can be used over a wide range of temperatures, however they can be susceptible to mechanical shock, which induces measurement drift.

2. Thin film PT100.

Thin film detectors are based upon a ceramic substrate with a deposition of high purity platinum, laser etched to give 100Ω at 0.0°C. This is then sealed within a glass adhesive.



These detectors are cheaper than wire wound detectors, and are less sensitive to impact damage. However they operate within a smaller temperature range than wire wound detectors.

Detector Tolerance

Detectors are commercially available to several different tolerance levels, according to BS EN 60751:2008, as class B, A and AA in order of increasing precision. In addition 1/10 DIN detectors are available which are picked to ensure a tolerance band 1/10th that of a Class B detector.

The table shows the detector tolerance at different temperatures, for different classes and also shows temperature limits for thin film and wire wound detectors.

PT100 Temperature Tolerance (+/- °C)

Temperature °C	EN 60751 1996 Class B / EN 60751 2008 Class B	EN 60751 1996 Class A / EN 60751 2008 Class A	1/3 DIN / EN 60751 2008 Class AA	1/10 DIN (not in standard)
-196	1.28			
-100	0.80	0.35		
-80	0.70	0.31		
-50	0.55	0.25	0.19	
-25	0.43	0.20	0.14	
0	0.30	0.15	0.10	0.03
25	0.43	0.20	0.14	0.04
50	0.55	0.25	0.19	0.06
75	0.68	0.30	0.23	0.07
100	0.80	0.35	0.27	0.08
125	0.93	0.40	0.31	
150	1.05	0.45	0.36	
175	1.18	0.50	0.40	
200	1.30	0.55	0.44	
225	1.43	0.60	0.48	
250	1.55	0.65	0.53	
275	1.68	0.70		
300	1.80	0.75		
325	1.93	0.80		
350	2.05	0.85		
375	2.18	0.90		
400	2.30	0.95		
425	2.43	1.00		
450	2.55	1.05		
475	2.68			
500	2.80			
550	3.05			
600	3.30			

Wire Wound Detector (red)
Thin Film Detector (blue)

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Selecting the Right PT100 Detector

Selecting the right PT100 detector is usually a balance of competing factors. For example, selecting a PT100 detector for use in a pharmaceutical autoclave chamber, it is a balance between the optimum tolerance of the temperature measurement and the resilience of the detector to frequent handling by process operators. It is for that reason that Thermal Detection recommends the use of thin film detectors with a minimum tolerance of class 'A' for pharmaceutical applications.

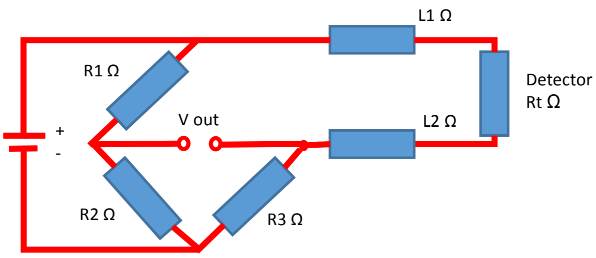
For other applications, such as chemical or manufacturing sectors, Class 'B' is often a sufficient level of tolerance. Maximum service temperature may also dictate a ceramic detector in preference to a thin film.

Impact of Probe Lead Length on PT100 Measurement Accuracy

PT100 detectors are connected to the measuring instrumentation using any one of three different connection principles:

- Two wire, with no lead wire compensation
- Three wire with partial compensation
- Four wire with full compensation.

Two wire connection is the simplest wiring method. Since the variable output of a PT100 detector is resistance, it follows that the resistance of the connecting leads (L1 and L2) between detector and instrument will also have an impact on the final measurement, and therefore the temperature inferred at the detector.



Where the lead lengths are short, and where they are exposed to the same temperature as the detector, then in theory this can be accounted for.

However in, for example, a Pharmaceutical autoclave chamber, where the lead length between probe and instrument can be very long, a two wire connection would lead to significant measurement error.

A high proportion of the leads will be inside the chamber during the sterilising cycle, and therefore at the same elevated temperature as the detector. The remaining lead length will be outside the chamber and at ambient temperature. These temperature differences will cause resistance change in the lead wire conductors.

To illustrate this by way of an example let's consider an autoclave with a temperature probe with a simple two wire connection of overall length 4.7M, with 1.7M inside the chamber, at the cycle temperature of 120°C, and 3M outside the chamber, at 22°C.

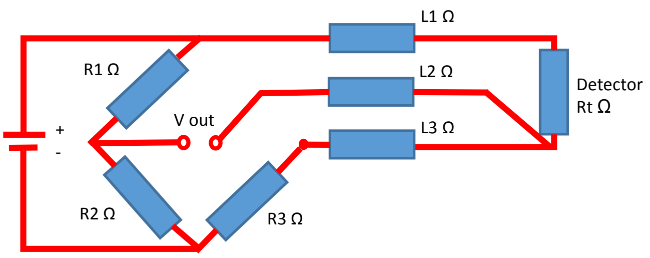
A typical PTFE insulated lead with a 7/0.16mm stranded copper wire has the following resistance:

At 120°C:	0.168 Ω/M
At 22°C:	0.130 Ω/M
Difference:	0.038 Ω/M

1.7M x 2 wires inside chamber: 3.4 x 0.038 = 0.129Ω additional resistance

This is equivalent to an error of 0.34°C compared to the expected tolerance of a Class A detector at 120°C of ±0.35°C

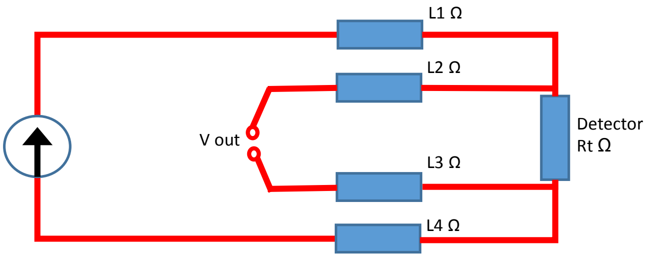
So clearly a 2 wire connection in such an application is not compatible with accurate measurement, and so the 3 wire compensation method was adopted using a modified Wheatstone bridge.



In this configuration the detector lead wires L1 and L3 are connected to the opposite sides of the bridge, effectively compensating for each other, with the third wire L2 supplying power to the bridge.

However this will produce a thermal gradient along the leads themselves. Although the effect of Joule heating is reduced, it cannot be eliminated altogether because the heat transfer conditions at the detector will be different from those of the matching 100Ω resistor in the bridge circuit. In fact there will only be one situation when this effect is eliminated entirely and that is when both the 100Ω resistor and the PT100 detector are at the same temperature.

To enable more accurate measurements to be made, particularly when the connecting lead wires are relatively long and passing through varying ambient temperatures, a 4 wire system was developed which is a true 4 wire compensation system.



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One pair of lead wires takes the constant current power source to the detector and the other pair is used to measure the actual voltage drop across the detector. Therefore by using a constant current source and being able to simply measure the change in voltage across the PT100 detector rather than a change in resistance (Ohms Law), any fixed or varying lead wire resistance is totally eliminated.

It is worth noting that when calibrating either a 3 or 4 wire PT100 probe in an oil bath or hot block, the difference in readings between these two connection types may appear to largely disappear. This is due to there being no temperature effect on the leads of the 3 wire connection.

The realistic choice for a PT100 probe is therefore between a 3 and 4 wire system, and the user may be constrained by the limitations of existing instrumentation that may already be in place.

Thermal Detection would recommend using a 4 wire system where possible, to ensure the most accurate reading. The use of a 3 or 4 wire PT100 temperature transmitter is a further option to reduce the overall lead length and convert the probe reading to a 4-20mA signal which will be easily integrated into process instrumentation.

Single or Duplex Detectors

It is possible in most probes to incorporate two detectors, each with separate leads, to ensure continuity in the case of a detector failure, or to cross check readings for added security.

This may constrain the minimum probe diameter so it is generally not an option on probes with a diameter of 3mm or less.

Conclusions

Highly accurate temperature measurements are possible with PT100 detectors however care must be taken to specify the correct detector type, detector tolerance and wiring method.

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