

## True Life-cycle Cost of a Resistance Temperature Detector

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#### Introduction

When selecting a resistance temperature detector (RTD), it is important to understand the downstream costs that can be avoided or minimized by aligning the RTD capability with the process conditions. In this paper we will examine RTD selection criteria for accuracy and operating performance that best aligns with the process conditions, expectations, and installation, for lowest life-cycle cost.

#### Cost Factors

The cost associated with measuring temperature in any process can range far beyond the initial purchase price of the RTD. Costs such as wasted energy, downtime, troubleshooting and evaluation, product loss / product quality costs, as well as various overhead and inventory costs should be considered. Many of these downstream costs can be minimized or avoided, resulting in the lowest life-cycle cost for the measurement by appropriate RTD selection. Important selection considerations include; Durability, Accuracy, and insuring that the sensor operating performance meets or exceeds the process conditions.

#### Durability / Reliability:

Selecting a RTD with a proven track record of reliability is valuable to process confidence. An instrument with documented results from long term testing and proof testing will ensure confidence. If a problem is suspected with the process system, time is often wasted troubleshooting the source of the issue. If a particular sensor is determined to be cause or contributor to the issue, the sensor will need to be recalibrated or replaced. Replacement, often times, requires shutting down the process causing unplanned production downtime. A process that has not been in control or is operating inconsistently, increases the risk of product quality concerns or product loss.

Premature sensor replacement may require spares to be kept in inventory as well as system verification costs. The more frequently change outs take place, the larger the inventory is needed for critical spares. This typically involves various overhead functions including the purchasing department to manage and procure the inventory as well as recalibration services and process verification. These costs are very real yet often are hidden and difficult to capture and measure.

#### Accuracy:

The accuracy of the selected RTD is an important consideration for several reasons. It is important to match the sensor accuracy with the real needs of the process. General good practice would suggest that the sensor accuracy should be about 4 times better than the needed measurement accuracy. The value of this approach relates to process control confidence but also energy savings. For energy intensive processes, wasted thermal energy can add a significant amount of cost over time.

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## An example calculation

Let's assume the processing fluid, water for this example, flows at a rate of 100 gallons per minute (GPM) for one year. This fluid is to be controlled at 100 °F, but due to the monitoring sensors' in-accuracy, the fluid is actually being controlled at 101 °F.

## How much will this cost the company in wasted energy?

Basically, we are asking how much heat is used to raise the temperature of a year's worth of fluid by one °F and how much does that heat cost?

$$Q = c_p m \Delta T$$

Where:

Q = heat transferred (BTU)

$c_p$  = specific heat at constant pressure (BTU/lbm-°F)

m = mass (lbm)

$\Delta T$  = temperature change (°F)

In this example, the only unknown is Q.

Q = unknown

$c_p$  = 1 BTU/lbm-°F

$m = (8.33 \text{ lbm/gal})(100 \text{ gal/min})(525600 \text{ min/yr}) = 437,824,800 \text{ lbm/yr}$

$\Delta T = 1 \text{ °F}$

Substituting:  $Q = (1 \text{ BTU/lbm-°F})(437,824,800 \text{ lbm})(1 \text{ °F})$

Solving:  $Q = 437,824,800 \text{ BTU}$

Converting: 1 KW-hour = 3413 BTU

Result:  $Q = 128,282 \text{ KW-hour}$

For electrically heated systems: Assuming the cost of electricity is 7 cents per KW-hour.

Cost =  $(128,282 \text{ KW-hour})(.07 \text{ dollars/KW-hour})$

**= \$8,980**

This example shows the savings that can be achieved by using an accurate sensor over the course of a year that provides the 1°F (0.56 °C) improved measurement capability. This measurement accuracy capability can be achieved with an understanding of the various sources of error. Five of the most common error sources are briefly described here:

## Interchangeability

Interchangeability, also referred to as resistance tolerance, is the "closeness of agreement" in the R vs. T relationship of a PRT to a pre-defined nominal R vs. T relationship. The interchangeability of a PRT may be a significant source of the total error when measuring temperature.

## Insulation Resistance

Insulation resistance refers to the electrical resistance between the sensing circuit and metallic sheath of a PRT. Errors in temperature measurement occur because the resistance of the sensing element cannot be accurately determined due to a portion of the sensing current leaking out of the circuit. IR decreases as temperature increases and the overall result is an increase in the error due to IR as the temperature increases.

## Stability

Stability is described as the ability of a PRT to maintain its R vs. T relationship over time as a result of thermal exposure. The most prominent source of instability is contamination of the platinum sensing element which can come from the materials, build processes, and foreign substances introduced during manufacture.

## Repeatability

Repeatability is described as the ability of a PRT to maintain its R vs. T relationship after experiencing thermal cycling

throughout a specified temperature range. The most prominent source of non-repeatability is strain in the sensing element caused by thermal expansion and contraction.

## **Stem Conduction**

Stem conduction is the error that results from the PRT sheath conducting heat into and out of the process. Stem conduction error is primarily caused by poor installation techniques or inadequate immersion length.

For a deeper analysis of sources of error, as well as how matching the RTD with a transmitter can improve measurement accuracy by a factor of 7, visit the Technical papers page on the Burns Web site.

## **RTD selection for the process environment**

Proper RTD selection begins by fully understanding a sensor's environment. Understanding environmental factors will allow one to intelligently select, design, and install a RTD for lowest life-cycle cost.

The RTD must be capable of withstanding the operating temperatures. By not exposing the RTD above its maximum temperature rating or unnecessarily exposing it to elevated temperatures beyond the important operating range, stability errors can be minimized. Also, temperature cycling well beyond the operating range and thermal shocks can increase repeatability errors. Operating within the RTDs temperature range and minimizing temperature cycling will put less strain on the sensing element and extend the performance life of the RTD.

If the RTD is going to be used in the presence of vibration or mechanical shock, a robust sensor must be used. The RTD must be designed such that the element is sufficiently supported to effectively protect the sensing element from damage or stress. The design must also incorporate a robust lead termination seal. If the seal is compromised, moisture will enter the probe and cause insulation resistance related errors.

## **Conclusion**

When selecting a RTD or RTD-Transmitter system, be aware that the purchase price is only one component of the cost of the measurement. For the lowest life-cycle cost an acknowledgment of the downstream and hidden costs is required. Invest in an instrument that meets or exceeds the measurement accuracy needs of the process, has a proven track record of reliability, and is designed for the process environment. The value of the RTD can be measured by the real savings achieved in your process and the confidence the measurement provides for product quality and safety.