DANGEROUS WITH REVERSED-POLARITY CABLING TO A FURNACE REGULATOR

There are measurement engineers with personal experience of how double reversed-polarity cabling between a thermocouple and a furnace regulator can cause a catastrophe at high temperatures. This article explains the conditions and consequences as well as what preventive measures you can take.

Figure 1 shows a correctly connected measuring circuit. A thermocouple is connected by extension cables from the connectors inside its terminal head to the sensor inputs on the instrument's terminals. Because the digital voltmeter (DVM) senses the voltage difference between the thermocouple's measuring junction, T_{Meas} and the connection terminal on the instrument T_{Ref} which is normally at room temperature, we must add the voltage between room temperature and zero so that the reading can be translated into degrees Celsius. This is why the instrument measures the terminal's temperature T'_{Ref} and adds the corresponding voltage to the measurement result.

The voltage E in DVM is comprised of the terms in equation (1). Here we have assumed that the splicing cables have the same sensitivity, S'_{AB} as the thermocouple and the instrument's compensation for the "cool junction", T'_{Ref}

$$E_{DVM} = S_{AB}\,(T_{Meas} - T_{Splice}) + S_{AB}\,(T_{Splice} - T_{Ref}) + S_{AB}\,(T_{Ref} - 0) \quad (1)$$

$$E_{DVM} = S_{AB}\,T_{Meas} \Rightarrow T_{Meas} = E_{DVM} / S_{AB} \quad (2)$$

Double reverse polarity

Because the colour coding of splicing cables was originally standardised in different countries, there is a multitude of colour codes. For example, DIN has standardised the type K cable as green, with red as the positive conductor whereas the Americans have chosen red as the negative conductor. It is easy for an uninitiated person to make a mistake.

In the case of double reversed polarity, the following case occurs. See Figure 2. Equation (1) gives:

$$E_{DVM} = S_{AB}\,(T_{Meas} - T_{Splice}) + S_{BA}\,(T_{Splice} - T_{Ref}) + S_{AB}\,(T_{Ref} - 0) \quad (3)$$

The sensitivity – the relative Seebeck coefficient – of the cables is also "reversed" to S_{BA} see (3), which complicates a simple transition to an equation similar to (2). In fact, S_{BA} is the same as the difference between the absolute Seebeck coefficients for the connectors B and A. We can therefore reformulate the equation:

$$S_{BA} = S_B - S_A = -(S_A - S_B) = -S_{AB} \quad (4)$$

(4) inserted into equation (3) gives

$$E_{DVM} = S_{AB}\,(T_{Meas} - T_{Splice}) - S_{AB}\,(T_{Splice} - T_{Ref}) + S_{AB}\,(T_{Ref} - 0)$$

$$E_{DVM} = S_{AB}\,[T_{Meas} - 2\,(T_{Splice} - T_{Ref})] \quad (5)$$

The result (5) means that when there is a double reversed polarity of the splicing cables, we are measuring the measuring junction's temperature reduced by twice the difference between the temperatures of the terminal head and the reference junction. Should $T_{Splice} = T_{Ref}$ we will regain the result in equation (2) but this situation is not likely at high furnace temperatures.

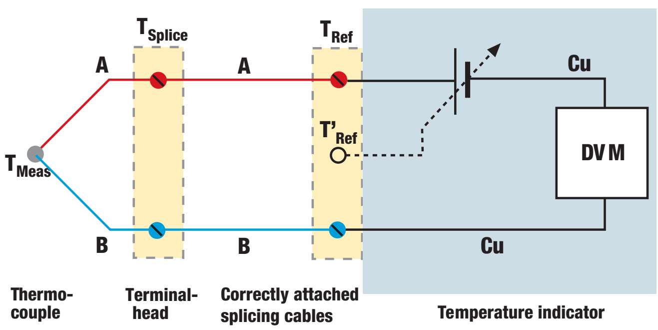


Figure 1. The correct installation of extension or compensation cabling for the thermocouple A/B.

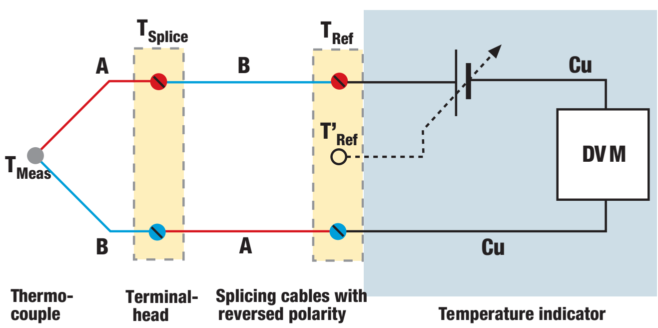


Figure 2. An incorrect connection with the polarity of the splicing cables reversed at both ends, B/A.

Furnace disaster

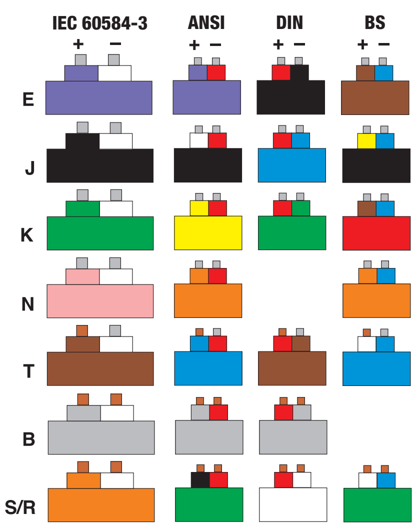
In a control situation, this can be dangerous. Let us assume that we want to regulate a furnace at 1000 °C, the terminal head has a temperature of 60 °C due to heat leakage from the furnace and the reference temperature of the regulator is 25 °C. These values inserted in (5) give an actual temperature of 1000 - 70 = 930 °C. The regulator strives to keep the actual value and the set value the same, and therefore increases the power so that the sensor supplies the corresponding 1000 + 70 = 1070 °C while the actual and set values indicate 1000 °C. An incorrectly connected separate alarm is misled in the same way. At high temperatures the margins are small, and both product components and furnace components can melt when the thermocouple cabling has a double reverse polarity.

Prevent reversed polarity

What can you do to prevent reversed polarity?

- Only use cables with a standard colour coding, normally IEC 60584-3.
- Install the sensor so that the terminal head is heated as little as possible.

You can also double check during the installation process by first attaching the sensor cables at the regulator end and then short circuiting the wires at the other end and heating it. If the actual value increases, it is correctly installed. You then attach the cable to the terminal head and heat the probe tip. The actual value should then increase, indicating that the installation is correct.



THE IEC's international colour codes plus ANSI's (USA). The IEC's has replaced DIN (Germany) and BS (United Kingdom).