Traps and Colour Confusion in Thermocouple Wiring

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This article concerns inaccuracies and instabilities caused by misuse of thermocouple extension cable on temperature control systems. The jungle of different cable colour codes is a major source of such problems.

A newly wired furnace suffered burnout of all six of its silicon carbide elements at a cost of some $9000. The controllers were in good order and showed normal working temperature though the furnace was clearly much hotter. The type R thermocouples were good and located properly but somehow the controllers were being deceived.

Cause. The extension cables were type J and should have been type R. The red was connected as + and white as – (i.e. wires crossed at both ends).

Red as positive sounds logical being a common worldwide convention but not on North American thermocouple wires. This is an understandable but costly error.

Treacherous too because for a while after the furnace came up to temperature there was no problem. But as the thermocouple head heated up in relation to the controller terminals, the type J extension cable injected a large negative signal into the controller. This made it read low by as much as 5 times the thermocouple head-to-controller temperature difference causing it to severely overheat the furnace. Knowledge of extension cables and their colour codes could have prevented this damage.

Typical Symptom

You suspect that your processing temperature is high even though the correct temperature shows on the controller. The process appears to overheat gradually over the first few hours after start up. This usually occurs on an imported or newly installed process or one where the thermocouple has been rewired or worked on.

You have verified that you are using the right thermocouple for the temperature and atmosphere; it is located where it sees the work temperature and it is calibrated correctly. Your controller is accurate, calibrated for the thermocouple in use and is tuned for good control stability.

How the Controller receives Signals from the Process

The circuit below shows the signal route from the hot tip of the thermocouple to the temperature controller. Degrees C are used in this

example.

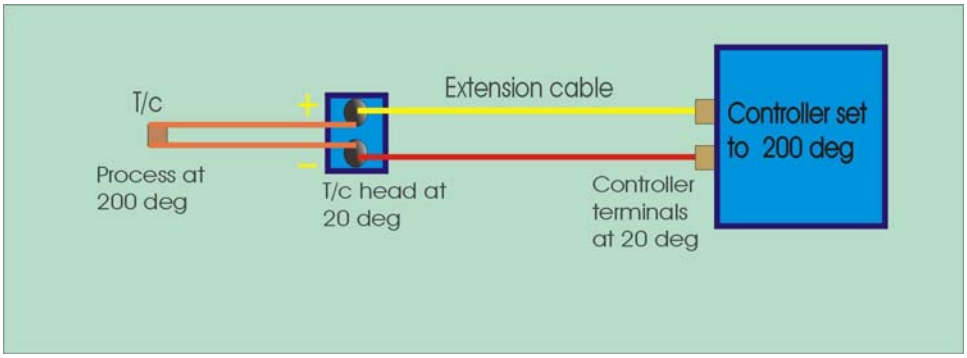


Fig 1.Thermocouple wiring

There are three contributions to the millivolt signal that the controller receives and acts upon, totalling 200 deg worth in this case

Those generated between the hot junction and head of the thermocouple (180 deg worth in this case, being proportional to temperature difference).

Those generated by the extension cable between the thermocouple head and the controller (0 deg worth at this point because there is no temperature difference)

Those generated by the controller, representing its own (ambient) temperature, 20 deg in this example. It has to contribute this so as not to be short by an amount equal to its own ambient temperature. This is called cold junction compensation.

After start up, the outside of the process begins to warm up and let's say the temperature of the thermocouple head rises to 40 deg. The thermocouple now delivers 160 deg of signal and the correct extension cable will generate the 20 deg representing the 20 deg end to end difference. The controller will still see 200 deg.

Trap 1. You use copper instead of extension cable

The copper fails to generate the 20 deg of signal in the above example and the controller faces the prospect of seeing 180 deg instead of the true 200 deg. However it will get to work as soon as any shortfall appears and will already be turning the process up towards 220 deg in order to be satisfied. This will raise no suspicion because the controller will be indicating the

desired temperature 200 deg all the time the temperature is slowly climbing. Ignoring thermocouple non-linearities the temperature will settle out too high by an amount about equal to the head-to-controller temperature difference.

Trap 2. You use the correct extension cable but cross the pair of wires at both ends

This is even worse than using copper. The temperature will settle out higher than indicated by about twice the head-to-controller temperature difference.

This error can vary during the day from not noticeable to some 100 deg too hot, depending on how near the thermocouple head is to the hot process and how long the process has been running.

This double reversal wiring error is common and understandable since the negative wire is color coded red on all North American extension cables and can be mistaken for positive. Red positive is indeed used by Japan and Germany (see the table below).

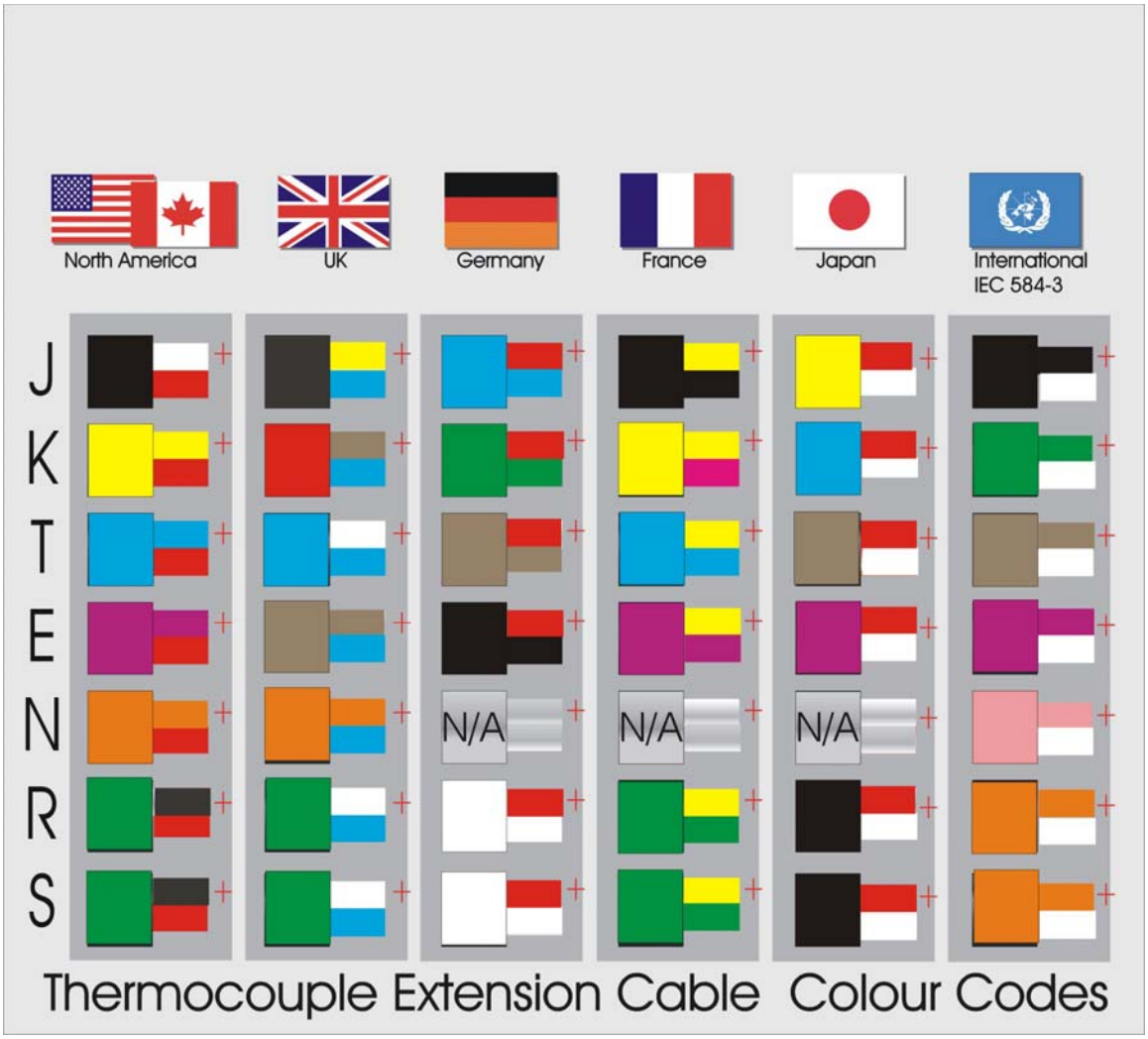
Trap 3. You use the wrong extension cable.

Remember that extension cable makes its contribution to the millivolt signal which is interpreted as temperature by the controller. The proper cable will match the thermocouple in respect of its microvolts per degree. Wrong cable can make the controller indicate too high or too low depending on how much its microvolts per degree differs from that of the thermocouple.

In the burnout case noted above, the type J extension cable delivered some 5 times the output of the correct type R cable, and injected errors of some hundreds of degrees. There are even worse combinations than this one.

Extension cable colour codes

The table below covers the six most commonly used thermocouple types. It shows five varieties of cable colour codes used in various countries, plus the IEC codes. The IEC codes represent a single world standard and are beginning to show up on European equipment. They will eventually replace the currently used codes.



Tips for cable identification

Look at the colours of the cable all the way from the thermocouple head to the controller.

Check for wires crossed at both ends.

If you don't trust or cannot see the colours, perform a heat test for polarity, i.e. disconnect the extension cable from the thermocouple head and twist or clamp the extension cable bare wire ends together. The controller should now show room temperature at that location and the indication should increase when you heat this junction.

A magnet test is useful with types J and K wire. On type J the positive conductor is iron and therefore magnetic. On Type K wire the negative conductor is Ni/Al and slightly magnetic.
Note too that thermocouple connectors are colour coded to agree with the corresponding cable jacket.