.

Thermocouples Part 1:

Eight established types to choose from. What type do I need?

Arthur Holland, Holland Technical Skills

Of all the temperature sensors used in industry and research, the thermocouple is the sensor of choice on grounds of temperature range, speed of response, ruggedness and cost.

Industrial Thermocouple with Thermowell and Signal Converter

Though there are other important sensors I will limit this article to the eight most commonly used thermocouples known as Types **J, K, T, E, N, S, R and B**. These letter designations, now used world wide, follow the recommendations of the **IEC** (International Electrotechnical Commission), the **ISA** (Instrumentation, Systems and Automation Society), the **ASTM** (American Society for Testing and Materials) and the **ANSI** (American National Standards Institute)**.**

Type J is useable up to 720°C . It is not very susceptible to aging up to about 540°C. It is very cost effective and is the thermocouple of choice in the plastics processing industry where temperatures rarely exceed 400 °C. The iron conductor is subject to oxidation at higher temperatures and when unprotected.

Type K is useable up to 1150°C in an oxidising atmosphere. Metallurgical changes can cause a calibration drift of 1 to 2°C in a few hours, increasing to 5 °C over time. A special grade of Type K is available that can maintain special limit accuracy up to ten times longer than the regular grade.

Type E – Chromel/Constantan is useable up to 820 °C. It has the highest mV output of all the thermocouples and has similar calibration drift to that of Type K so the same precautions are recommended.

Type N - Nicrosil/Nisil is useable up to1260°C. It was developed to overcome several problems inherent in Type K thermocouples. Aging in the 300 to 600 °C range is considerably less. Also Type N has also been found to be more stable than Type K in nuclear environments, where Type K has been the sensor of choice.

Type T – Copper/Constantan. . Oxidisation of the copper limits the useable temperature to about 370 °C. It has been the thermocouple of choice for applications down to – 200 °C.

Types R – (Platinum 13% Rhodium. Platinum) and S (Platinum10% Rhodium/Platinum) are usable up to 1480°C. They are extremely stable but reducing atmospheres are particularly damaging. This type should be protected with a gas-tight ceramic tube and a secondary tube of porcelain, silicon carbide or metal outer tube, as conditions require. Type R delivers some 15% more mV than type S.

Type B Platinum-13% Rhodium/Platinum 6% Rhodium)is usable up to 1700 °C,). Also easily contaminated, and damaged by reducing atmospheres. The same protective measures for R and S shown above apply to type B thermocouples.

Wire Size and Atmosphere. The upper temperature limits and life expectancy of all thermocouples are very dependent on atmosphere and wire size. Don't count on going to the above limits in most applications. For longer life and higher temperature use, choose the larger size wires. For speed of response choose the smaller sizes; but note that a protection tube will dominate response time. With the platinum alloys the high cost and the long life of the materials usually dictate small wire sizes, typically 0.35mm.

Construction Basic:.Take two wires, join them at the hot end, measure the mV at the other end; who needs more? Often nothing wrong with that. Poke it in a duct or a non-aggressive liquid, or clamp it to the process under a screw and washer or a hose clip. .

For protection from damage, abrasion and corrosion I'll give a few choices here. But for the hundreds of real workable answers **look in the many excellent supplier catalogs and web sites**. Here are just a few design examples:

1.Twin or quad bore alumina with the wires inside. The junction may be exposed, given a non-aggressive environment. Otherwise it may be fitted in metal or ceramic outer tube to protect from atmosphere or damage.

2. Fiberglass or ceramic-fiber insulated wire inside a stainless steel tube; hot junction welded to the closed end. This is a very common on plastics machinery and good for fast heat transfer.

3. The metal clad MgO (magnesium oxide) compacted design is very rugged, easily bent and good for protection from aggressive media. There is a wide choice of sizes and metal sheath grades for different media.

4. The thermowell is a tough handy fitting for giving access to the contents of a vessel or pipe. You can slip your thermocouple inside it and still get to it for service or replacement without draining the contents. The hot junction stops short of the closed end of the well. To aid heat transfer you might use a blob of electrically insulating, thermally conducting material at the tip. Thermowell assemblies can be big, strong and slow so can mess up your control system response. Keep them small as possible.

Response Times of thermocouples. Time constants go from 0.1S (e.g. exposed tip in a fast stream) to some 15S (e.g. a thermowell in a tank). Time constant is the time taken to reach 63% of the final value. Watch that you don't hurt the control response by putting a slow thermocouple on a lively process.

Thermocouples Part 2: Traps and Hazards

And why we don't need Types J, K, T, E and S

How do you pick up all of the temperature?

Keep in mind that you are processing material so try to get to it rather than a pipe or vessel surface. If it's a liquid or a gas stream you need an immersion depth at least four times the probe diameter. Heavy metal-sheathed probes can conduct heat outwards cooling the tip and giving a lower than true reading. Thin wall or non-metallic probes mitigate this effect. Plastic processing machinery calls for deep holes drilled in barrels, molds and dies, ending just short of the polymer. You then insert a spring-loaded bayonet-mounted thermocouple that has a grounded hot junction in contact with the blind end of the hole. On a work-piece in an oven or furnace an attached thermocouple is advisable in addition to one in the space. In a vacuum furnace you have to wonder what a thermocouple in the space is representing.

Surface measurements. These may be acceptable but you need a low mass thermocouple in intimate contact with the surface and under a thermally insulating pad. Otherwise the reading will be a compromise between the true surface temperature and the surrounding air temperature.

For a clean or reasonably conducting metal surface you can use a **foundry probe**. This is a spring-loaded pair of sharp spikes of different thermocouple materials e.g. one of chromel, the other of alumel. These are connected by the appropriate thermocouple extension cable out to your instrument. The metal that you a prodding completes the hot junction but makes no thermoelectric interference with the measurement. This probe is usually used for spot measurements of billets and castings rather than for control.

Don't ground thermocouple wiring. Many thermocouples are grounded already at the hot end during manufacture for reasons of fast response. Any more grounds, at the protection tube or anywhere at all along the wiring route will more often than not reduce the temperature signal, tell lies to the controller and overheat the process.

Millivolts Vs Degrees curves are different for every type of thermocouple. The top end of the useable range is around 12mV for Type B and some 60mV for type E. Modern dc amplifiers are so stable that the magnitude of the signal is not a big issue when choosing a thermocouple. These curves and tables are widely available from suppliers and on the internet so are not shown here.

The Hazards of Variety. Wider the choice greater the risk. Mismatching controllers and thermocouples during installation and maintenance has long been a threat, not just to product yield and quality but also to people and plant. You cannot depend on round the clock vigilance of operators, installers and maintenance technicians. Do all you can to reduce the variety of thermocouples in your plant Decide whether you want a °F or a °C shop and stick to it. Label your indicators, controllers, thermocouples and zones with the thermocouple type.

The continued use of six different territorial extension cable color codes multiplied by eight different thermocouple types in an importing and exporting industrial market cannot be justified. The color codes have **since 1989** been harmonised and standards agreed world wide by representatives of the major industrial countries through the IEC committees. Their adoption in North America has not yet begun at year **2002.**

Standards Committee work is needed, aimed at minimising the variety of thermocouple types in process plants. Four of the eight most common, J, K, T and E can be replaced by Type N which has been around and proven for 30 or more years. This would eliminate the short and long-term instability problems associated with these four. Type T is well established for low temperatures in the food industry and has the advantage of about 40% bigger signal than Type N. The useable range of Type N (-250 to 1230 °C) brackets all four. Also there is no need to keep both Type R and Type S. Either one could go and not be missed. For many years controllers, indicators and recording systems, being microprocessor based, have been field configurable to match any of the eight standard thermocouples so changing a thermocouple type does not present a problem. A bigger challenge would be replacement of the thermocouple extension cables in the plant.

Name Confusion. Some common thermocouple alloys are given registered trade names that differ from the commonly used names or defined alloy composition names. Some have caught on and are almost generic and are even used here to avoid being pedantic. . Other trade names may not be recognisable and could add to identification problems.