GUIDELINES FOR GOOD THERMOCOUPLE PRACTICE

Each unique thermal process dictates the selection and operation of thermocouples, and while many factors contribute to thermocouple life expectancy, which can vary from just a few hours to many years, following some simple guidelines can help you get the most out of these sensors.

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Thermocouples are dependable temperature measuring devices that will provide trouble-free service and long life. However, occasionally, difficulties may be encountered resulting from improper application or operation. The information presented in this article can serve as a brief guide to help thermocouple users obtain optimal accuracy and economy for which the thermocouple alloys are known. The following 13 guidelines can help in the selection and operation to maximize your investment.

1 **Selection of Thermocouple Type** – Metals combinations used to form thermocouple pairs vary greatly in service temperature and initial accuracy. For low temperature, high accuracy requirements, a type "T" thermocouple might be used, whereas in high temperature metals processing and heat treatment, a platinum metals type "S" might be used. The most commonly used combinations are "J" and "K." Letter of the alphabet and color codes are used to differentiate these metal combinations, and they are referred to as calibration. Color coding may be used with wire and connectors as defined by ASTM and IEC standards (Fig. 1). Choose a type that matches your operational temperature.

2 **Protect Thermocouples in Service** – Evaporation, diffusion, oxidation, corrosion, and contamination induce EMF drift due to their effect on the composition of thermocouple alloys. Because these environmental factors are destructive to all common thermocouple materials, it is essential that proper protection be provided when adverse conditions are encountered. In many applications, this requirement can be met by the use of sheathed unit construction. If bare wire thermocouples are used, the thermoelements must be properly installed in suitable protection tubes. When the interiors of such tubes are clean and free of sulfur-bearing oils, refractories, etc., and when they consist of the proper diameter-to-length ratios to permit adequate ventilation inside, they serve very well in overcoming the harmful effects of corrosive atmosphere.

3 **Use Largest Practical Size** – It is generally true that heavy-gage thermocouples are more stable at high temperatures than their finer gage counterparts. However, in many applications a heavy gage thermocouple will not satisfy requirements for flexibility, rapid response, equipment geometry, and the like. This requires a compromise between long-term stability of heavy sizes and greater versatility of smaller thermocouples. Where high temperature stability is a substantial consideration, use the largest practical size consistent with the other requirements of the job.

4 **Install Thermocouple in Proper Location** – The location selected for installation of the thermocouple should

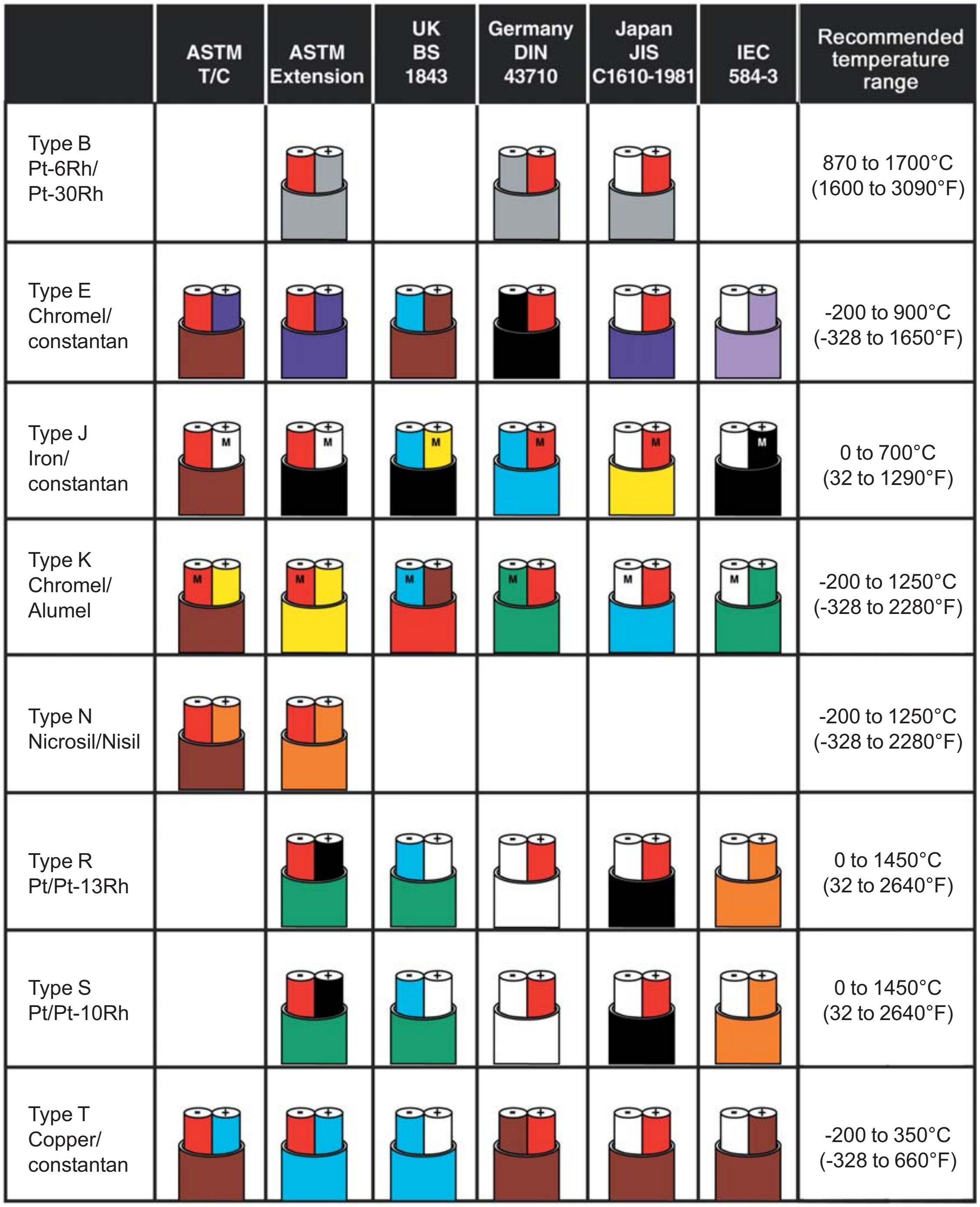

Fig. 1 — Color coding for thermocouples and extension wires for different country thermocouple standards.

ensure that the temperatures being measured are representative of the equipment or medium. Direct flame impingement on the thermocouple, for example, does not provide a representative temperature. Placement of the sensor in relationship to the workload and heat source can compensate for various types of energy demands from the workload. Sensor placement can limit the effects of thermal lags in the heat transfer process. The controller can only respond to the temperature changes it "sees" through feedback from the sensor location. Thus, sensor placement influences the ability of the controller to regulate the temperature around a desired set point. Be aware that sensor placement cannot compensate for inefficiencies in the system caused by long delays in thermal transfer. Within most thermal systems, temperature varies from point to point.

Sensor in a static system (Fig. 2) – A system is static when there is slow thermal response from the heat source, slow thermal transfer, and minimal changes in the workload. Placing the sensor closer to the heat source in a static system keeps the

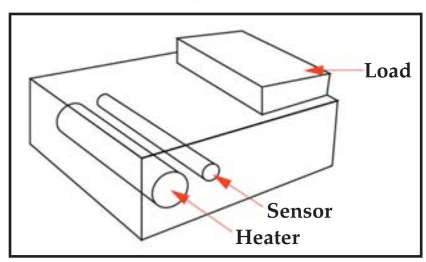

Fig. 2 — Sensor in a static system; placing the sensor closer to the heat source in a static system keeps the heat fairly constant throughout the process.

heat fairly constant throughout the process. In this type of system, the distance between the heat source and the sensor is small (minimal thermal lag); therefore, the heat source cycles frequently, reducing the potential for overshoot and undershoot at the workload. With the sensor placed at or near the heat source, it can quickly sense temperature changes, thus maintaining tight control.

Sensor in a dynamic system (Fig. 3) – A system is dynamic when there is rapid thermal response from the heat source, rapid thermal transfer, and frequent changes in the workload. Placing the sensor closer to the workload enables the sensor to see the load temperature change faster, and allows the controller to take the appropriate output action more quickly. However, in this type of system, the distance between the heat source and the sensor is notable, causing thermal lag or delay. Therefore, the heat source cycles are longer, causing a wider swing between the maximum (overshoot) and minimum (undershoot) temperatures at the workload. The electronic controller selected for this situation should include the PID features (anticipation and offset ability) to compensate for these conditions. A sensor at or near the work load can quickly sense increases and decreases in temperature.

Sensor in a combination static/dynamic system (Fig. 4) – When the heat demand fluctuates and creates a system between a static and dynamic one, place the sensor halfway between the heat source and workload to divide the heat transfer lag times equally. Because the system can produce some over shoot and/or under shoot, the electronic controller selected for this situation should include the PID features (anticipation and offset ability) to compensate for these conditions. This sensor location is most the practical in the majority of thermal systems.

5 Provide for Sufficient Immersion Depth – Because heat conducted away from the hot junction causes the thermocouple to indicate a lower temperature, provide for sufficient depth of immersion of the thermocouple into the medium being measured to minimize heat transfer along the protection tube. A general rule is to use a minimum immersion depth ten times the outside diameter of the protection tube.

6 Avoid Changing Depth of Immersion – Under certain conditions, inhomogeneities can gradually develop in a pair of thermocouple wires due to oxidation, corrosion, evaporation, contamination, and metallurgical changes. A change in depth of immersion, which shifts such inhomogeneous wire into a steep temperature gradient zone, can alter the thermocouple output and produce erroneous readings. Therefore, avoid changing the depth of immersion of a thermocouple after it has been in service. Thermocouples should be checked in place if possible. If it is necessary to remove the thermocouple, it should be reinserted to the same depth or deeper to avoid errors arising from placing an inhomogeneous segment of wire in a steep temperature gradient.

7 Recognize Effect of Heating Cycles – For maximum accuracy, a thermocouple should be used to control a single temperature or successively higher temperatures only. However, this is not always possible for various reasons. In many installations, thermocouples continually traverse a broad range of temperatures with adequate results. Errors that arise out of cyclic heating are analogous to those generated by changes in immersion depth, and may range from 2 to 3°F for thermocouples in good condition, to many degrees for badly corroded thermocouples. Thus, the type of heating cycle and condition of the thermocouple mutually affect the accuracy obtainable in a specific location. Where cyclic heating cannot be avoided, use thermocouples in top condition for maximum accuracy.

8 Establish a Preventive Maintenance Program – Thermocouples, protection tubes, and extension-wire circuits should be checked regularly. Experience largely determines the frequency of inspection, but once a month is usually sufficient.

9 Match Wire Type to the Thermocouple – The extension wire and connector wire are specific to the thermocouple type being used. Using the incorrect wiring components between control and process thermocouple can result in erroneous readings. Connectors and extension wire are often visually identified to thermocouple calibration type by color code. However, this is not an absolute identifier with different color coding standards used around the world (See Fig. 1). For example, IEC color for type "K" is green, whereas the green is the ASTM color for type "S."

10 Periodic Visual Examination – To prevent future problems, both ceramic and metal protection tubes should be examined for excessive corrosion, wear, oxidation and physical damage. Protection tubes exhibiting damage and/or excessive corrosion should be replaced. Wiring should be examined for damaged insulation and tight connection points.

11 Determine if You Want Accuracy or Repeatability – Each user must determine what is most important, being able to repeat the process day after day (for example, repeatedly measuring the outside of a pipe and using it as an indicator of liquid flowing on the inside), or knowing the specific temperature obtained by the material being processed (for example, knowing accurately the metal temperature during heat treating to achieve specific properties).

12 Provide Safe System Operation Using Limit Sensing – All systems should be examined for potential thermocouple failure. How will the system react if the thermocouple circuit opens or forms a secondary junction? Limit sensors provide safe operation. These sensors and controls should be separate from the system control.

13 Avoid Electrical Noise – The sensor input and power output lines, as well as the power source line, all have the potential to couple or link the control circuit to a noise source. Depending on its intensity, noise can be coupled to the sensor circuit by any one or combination of the following ways:

• Common impedance coupling occurs when two circuits share a common conductor or impedance (even common power sources).

• Magnetic inductive coupling generally appears where wires are running parallel to or are in close vicinity to each other. This happens when the wires from several different circuits are bundled together to make the system wiring appear neat.

• Electrostatic capacitive coupling appears where wires run parallel to each other, similar to magnetic coupling. However, that is where the similarities end, because electrostatic, or capacitive, coupling is a function of the distance the wires run parallel to each other, the distance between the wires, and the wire diameters.

• Electromagnetic radiation coupling occurs when the sensor is very close to a high energy source like television or radio broadcasting towers.

Thermocouple life expectancy varies greatly from just a few hours to many years. Many factors including calibration type, environment, temperature, sensor design, and thermal cycling will determine life expectancy. Experience with your unique process will dictate the check and replacement intervals of thermocouples.

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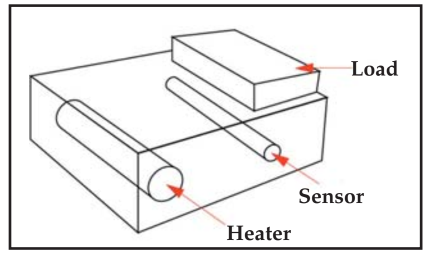

Fig. 3 — Sensor in a dynamic system; placing the sensor closer to the workload enables the sensor to see the load temperature change faster, and allows the controller to take the appropriate output action more quickly.

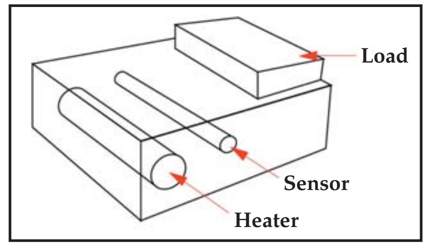

Fig. 4 — Sensor in a combination static/dynamic system; place the sensor halfway between the heat source and workload to divide the heat transfer lag times equally.