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Revision Memo

12/00	Added section on grounded vs. ungrounded thermowell junctions. Added a section on Economic Considerations. Deleted reference to separate, second thermowell to align DP with current version of IP 15-2-1. Deleted reference to temperature criteria for flanged versus threaded thermowells. Deleted Figures 2 and 3 in favor of referencing appropriate Industry Standards.
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SCOPE

This section covers aspects of temperature measurement and control that are of importance in process design and operation and that are considered and decided upon in preparing a Design Specification.

REFERENCES

INTERNATIONAL PRACTICES

IP 3-6-1	Piping for Instruments
IP 15-2-1	Temperature Instruments
IP 15-2-2	Digital Temperature Indicating System
IP 15-6-1	Electronic and Pneumatic Instruments

BACKGROUND

Unlike flow, pressure, and level measurement, the most common temperature instruments operate on principles of electricity. The usual primary temperature measuring element is the thermocouple. Others include Resistance Thermometers (RTDs), filled systems, and pyrometers.

In thermocouples, an electrical voltage is created directly at the point of temperature measurement. In RTDs, a resistance that varies with temperature is created inside the detector. Either of these devices' signals are usually suitable for termination directly on a system input (such as a Distributed Control System, Digital Variable Indicating system, indicator, or recorder.) In some cases, a transmitter is also required. Non-electrical types of temperature instruments are used infrequently - either because the situation is unusual (e.g., optical pyrometers in sulfur unit combustors) or the instrument is not critical or is local only (e.g., filled element heat tracing controllers.)

TEMPERATURE MEASUREMENT - SENSING ELEMENTS

THERMOCOUPLES

Principles of Measurement with Thermocouples

The thermocouple is used for temperature measurement in all but a small percentage of process control applications, because of these characteristics:

- Low cost
- Wide operating temperature range
- Relatively fast response time
- Relatively good stability and precision
- Acceptable accuracy
- Ease of check instrument installation
- Ease of replacement

Most plant temperature measurements are made with one of two thermocouple types: Type "K" or Type "T." **Table 1** outlines temperature limits, accuracy of matching the standard calibration curve, and some of their limitations. The choice of thermocouple type is covered in detail in [IP 15-2-1](#).



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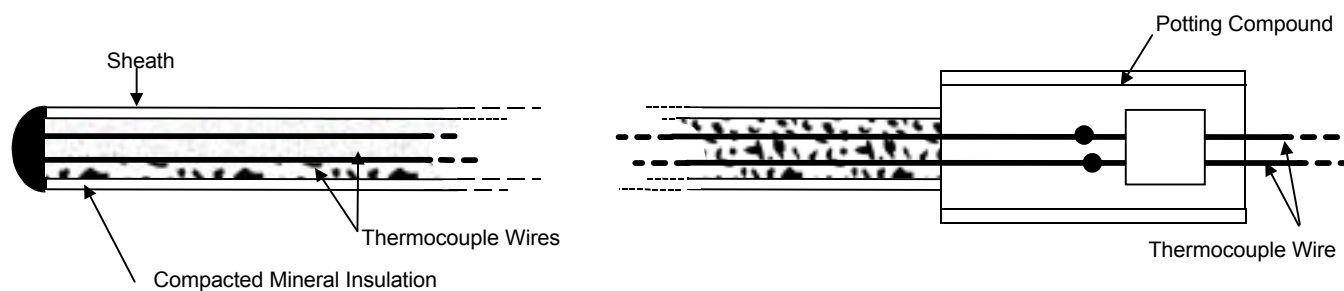
TEMPERATURE MEASUREMENT - SENSING ELEMENTS (Cont)

TABLE 1
TYPICAL CHARACTERISTICS, APPLICATIONS, AND LIMITATIONS OF STANDARD THERMOCOUPLES

THERMOCOUPLE	LOWER TEMPERATURE LIMIT °F (°C)	UPPER TEMPERATURE LIMIT °F (°C)	MAXIMUM ERROR	OTHER NOTES
"K" Chromel (+) Alumel (-)	0 (-20)	2000 (1090)	+/- 4°F up to 530°F 3/4% above 530°F	Most commonly used
"T" Copper (+) Constantan (-)	-300 (-195)	200 (95)	2% below -75°F 1-1/2°F -75 to 200°F 3/4% above 200°F	Better option when accuracy or low-temperature range is required

Figure 1 details the most common thermocouple device construction. The two types of wire are welded, creating the point of measurement. Both wires are then sheathed in stainless steel, with any interior space filled with mineral insulation, typically Magnesium Oxide. This mineral insulation gives the common name "MI cable," which means that the "cable" is actually a set of conductors inside a sheath, filled with mineral insulation.

FIGURE 1
SHEATHED TYPE THERMOCOUPLE



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Thermocouple Installation

Figures 2 and 3 show the most common methods of thermocouple installation. In general, thermocouples are to be used inside of thermowells, which isolate the thermocouple and outside hardware from the process fluid inside the pipe or vessel. Any thermocouple mounted in any thermowell, can be replaced on-line, except for the rare case where the thermowell has catastrophically eroded or failed, exposing the thermocouple to the process fluid. The "flanged" and "threaded" thermowells are the most common methods of thermocouple installation.

Single-Point Thermocouple

A single-point thermocouple has no thermowell, rendering it non-replaceable on-line. The sheathed thermocouple is inserted into the flange, and its compression fitting is directly screwed to the flange. This thermocouple cannot be removed from the line without leaking process fluid. For this reason, [IP 15-2-1](#) requires that most thermocouple installations be inserted into thermowells for safety reasons (see "Flanged Thermowell" below for further description).

Flanged Thermowell

The thermowell is welded to a flange. Flanged thermowell assembly should be fabricated as per ASME PTC 19.3 and/or API 551 (**Figure 26**). The assembly may then be conveniently removed for maintenance during turnaround. The sheathed thermocouple may be replaced at anytime, even while the unit is running.

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TEMPERATURE MEASUREMENT - SENSING ELEMENTS (Cont)

Skin Thermocouples

The thermocouple is welded to the outside surface of a vessel wall. While not directly measuring the process fluid, any inordinately hot areas can be identified.

Temporary Thermocouples

Temporary thermocouples are commonly used when drying out refractory, which requires slow, controlled heating of the firing chamber, at temperatures which are usually lower than the designed primary temperature sensor can measure. The temporary thermocouple is typically inserted through a fitting installed in the port where the normal temperature sensor would be mounted. Therefore, even if normal operation does not require thermocouples, temporary thermocouples would have to have been engineered, if required for heater startup. A pyrometer (see **Page 8**) is often useful for spot measurements.

Multi-point Thermocouple Assemblies

Two choices exist for reactor temperature profile measurement. They are "bundle" and "radial" types. The choice of technique depends upon the profiles and speed of response desired. This decision is best made in consultation with the instrument specialist, who can provide cost and installation details.

Regardless of which technique is chosen, containment of process fluid, secondary to the thermowells, must be provided. The secondary containment enclosure is fitted with a pressure gauge, which signals a presence of pressure [loss of the primary containment (thermowell)]. Secondary containment is required because of vibration, corrosion, bed movement, and thermal expansions and contractions, which all may contribute to a breach of primary containment (thermowell).

Thermowells feed through to the junction box compartment, which is to be vented to atmosphere.

Multipoint Bundle

Figure 3 shows a typical vertical multipoint thermocouple installation. The thermocouples are brought into the vessel inside a large sheath, typically a pipe. Each mineral insulated (MI) thermocouple is typically of different length, carefully designed to measure different points along the main bundle's sheath.

These assemblies can also be installed horizontally in tall vertical reactors (side-entry) to reduce the length of assembly required.

The thermocouples are removable on-line, without any loss of primary containment of the process fluid. Loss of secondary containment protection for the duration of the thermocouple replacement is typically acceptable.