The Metal-clad Thermocouple

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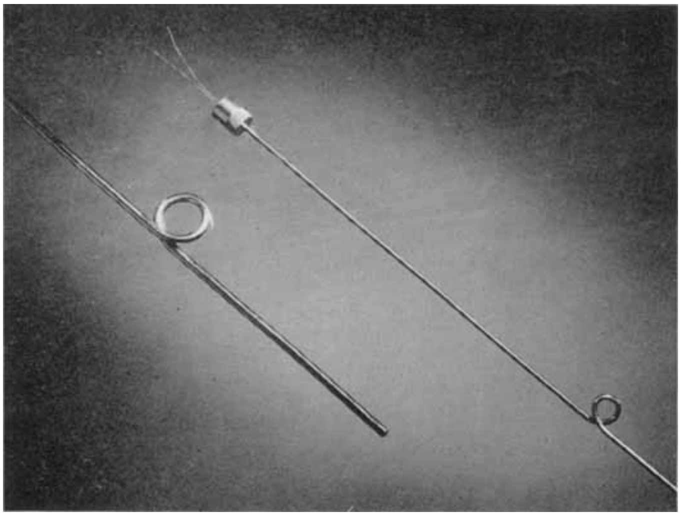
A new type of metal-sheathed mineral-insulated platinum thermocouple has been developed by Johnson Matthey to provide flexibility with resistance to thermal shock and corrosion. Applications are outlined in the steel, glass, engineering and nuclear energy industries.

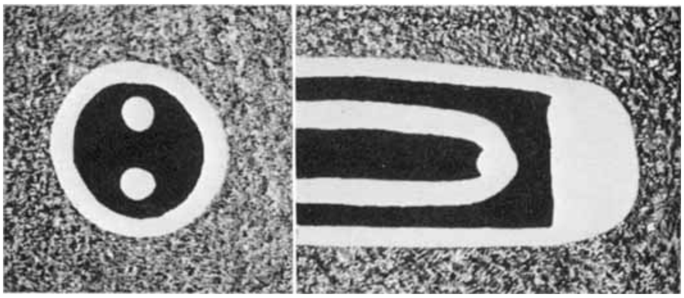
Platinum and rhodium-platinum alloys are now universally accepted as standard thermocouple materials and their accuracy and reliability over a wide temperature range are well known. The life of any thermocouple is, however, greatly influenced by the effectiveness of its sheath. If metallic vapours or other volatile substances are able to diffuse through the sheath, rapid attack of the wires can ensue followed by a drift from calibrated values. In such cases the wires eventually become embrittled and mechanical failure occurs. Fortunately modern sheathing techniques are such that the incidence of failure is low, and noble metal couples can be used in all normal industrial atmospheres up to 1800°C or above.

There are occasions where standard ceramic sheaths are for one or more reasons unsuitable. The limitations of this type of sheath include its rigidity, the high thermal mass resulting in long response times, and the low resistance to thermal and mechanical shock.

In answer to the growing demand for a more flexible construction Johnson Matthey have recently introduced a metal-sheathed, mineral-insulated assembly known as the "Metal-Clad Couple". This type of assembly, illustrated below, consists essentially of a flexible metallic sheath containing the two thermocouple wires separated from each other and from the sheath by a high-grade refractory oxide. It is available in two standard sizes, 0.065 inch and 0.125 inch total outside diameters. The sheath may consist of 10 per cent rhodium-platinum, of 10 per cent rhodium-platinum joined at a specified point to a cheaper base metal, or completely of base metal. The base metals may be either pure nickel or stainless steel.



This photograph of the two standard sizes of the Johnson Matthey metal-sheathed mineral-insulated thermocouple shows both the flexibility of assembly and the special end cap provided for the cold junction



Photomicrographs of the cross-section and longitudinal section of the hot junction show that the thermocouple wires are completely insulated from each other and from the sheath

to ensure that the insulation is sound and that the sheath is pin-hole free. The thermocouple wires are in the fully annealed condition but the sheath may be either in the cold-worked or in the annealed state. In the former condition it is spring-like and rigid but in the latter it can be readily bent and twisted.

As can be seen from the photomicrographs above the thermocouple wires are completely insulated from each other along their length and also from the sheath. The hot junction is also completely insulated from the sheath, and if necessary the sheath may be earthed. The thermocouple wires may be any of the standard combinations, platinum against 10 per cent or 13 per cent rhodium-platinum; 5 per cent rhodium-platinum against 20 per cent rhodium-platinum; 20 per cent rhodium-platinum against 40 per cent rhodium-platinum, or the Pallador combination 10 per cent iridium-platinum with 40 per cent palladium-gold. In every case the couples are guaranteed to operate in accordance with the appropriate calibration table.

Each couple is made to order and so it is possible to arrange any combination of wires and sheath. It is, however, recommended that when a composite sheath is required the noble metal portion be not less than six inches long to ensure that the noble metal/base metal joint does not operate continuously at too high a temperature.

As can be seen from the illustration the cold end of the assembly terminates in a permanently attached end cap through which protrude the insulated thermocouple wires. This cap has been specially designed to prevent chafing and shorting of the wires, and normally three inches of wire extends. It is presumed that this wire will be connected to a terminal block, and the circuit to the instrument completed with the normal compensating cable. Each assembly is rigorously tested

It is advisable when bending the assembly to use a simple mandrel such as a pencil or screwdriver to avoid fracturing the sheath.

The metal-sheathed assembly has many advantages over the standard ceramic sheathed couples. The flexibility and ability to bend round small radii enable the couple to be located in places that could not be reached by an inflexible ceramic sheath. The smaller overall diameter is also an advantage in this respect. The metal sheath has extremely good resistance to thermal shock and so rapidly fluctuating temperatures can be recorded without harming the couple. The mechanical shock resistance is also good and so vibrations or buffetting do no damage to the couple. Because of the manner of construction it is not possible to strain the thermocouple wires and so one common cause of failure is eliminated. The sheathing takes all the strain and long lengths of couple can be suspended vertically without ill effect.

As mentioned above, one common cause for failure of thermocouples is contamination, this either leading to drift from calibration, embrittlement or both. In the higher temperature ranges where platinum : rhodium-platinum couples are most commonly used the diffusion processes which give rise to this type of failure readily occur. The non-porous nature of the metal sheath overcomes this problem and so long operating lives are obtained in environments which would normally produce rapid failure with the standard assembly. The metal-sheathed couple can be used in either oxidising or reducing conditions and in many other corrosive atmospheres where a ceramic sheath would be attacked. For example, a couple sheathed with rhodium-platinum can be continuously immersed in molten glass without any ill effect. There are many other locations, especially in the chemical engineering industry, where the high corrosion resistance coupled with the known accuracy of the noble metal combination will make the metal-clad couple most useful.

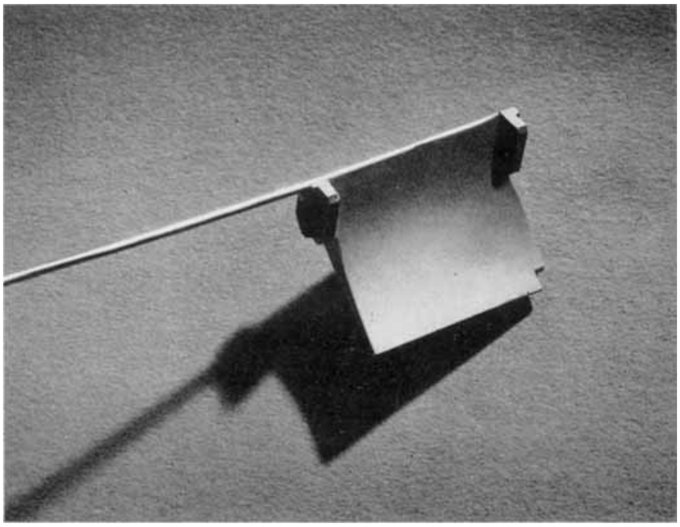
In some applications response time is of prime importance; the fastest response will obviously be obtained from a completely unsheathed couple but this is generally impracticable. The metal-clad assembly is extremely sensitive in relation to the protection provided and responds quickly to changes in temperature. The thermal capacity of the whole assembly is small and in some cases it is possible to braze or weld the metal sheath to the work-piece so as to get extremely good thermal conductivity.

In the steel industry applications are found in soaking pits, in reheating and annealing furnaces and in locations where corrosive conditions are intense, such as the domes of blast furnace stoves or in arc furnace roofs.

In the glass industry the advantages of a rhodium-platinum thermocouple sheath are well known. For many years couples reading temperatures below the glass level have been protected with a loose sheath, and this new assembly is now undergoing trials. It has also been tried as a permanently installed couple for reading the melting furnace roof temperature.

The aero-engineering industry has also expressed interest and the illustration shows one typical application. The metal-clad couple, as can be seen, has been incorporated in the leading edge of the turbine blade, and this particular application illustrates many of the advantages of the metal-clad assembly. The sheath has been attached to the blade by a platinum solder and hence thermal conductivity is excellent and response time low. The position of the hot junction is precisely known and many valuable facts about the variation of temperatures on stator blades can be ascertained.

The atomic energy industry has also expressed interest since as their technology advances and reactor temperatures increase there is a growing requirement for couples which are reliable for very long periods at the higher temperatures. The use of metal-sheathed base metal couples is well established, and this new development will allow the noble metal combination to be used in the hotter regions.



The attachment of a metal-clad thermocouple to a turbine nozzle blade provides a means of obtaining valuable information on variations in the temperature of the blade. This technique has been adopted by D. Napier & Son Limited in studying the performance of the Eland aero-engine