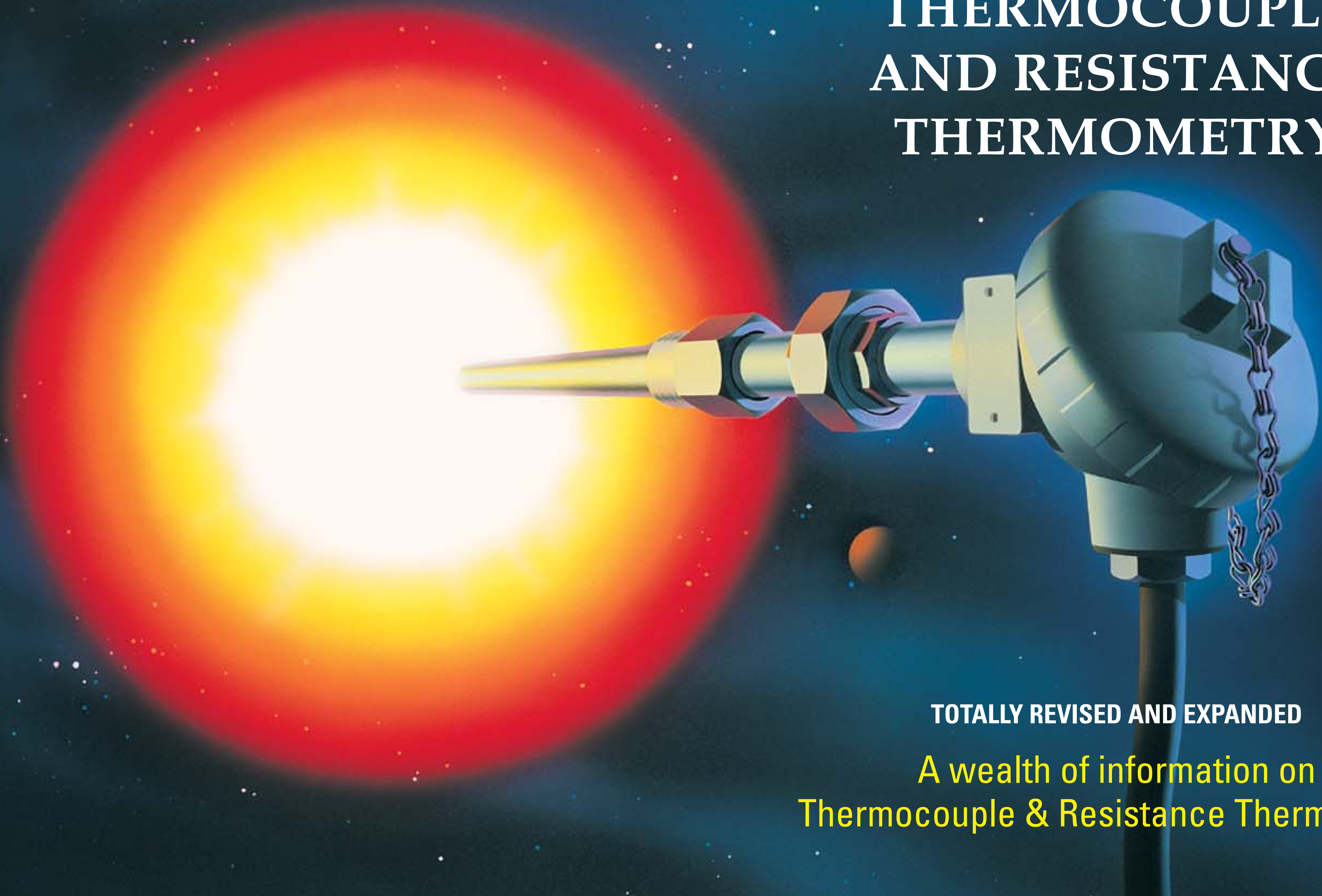
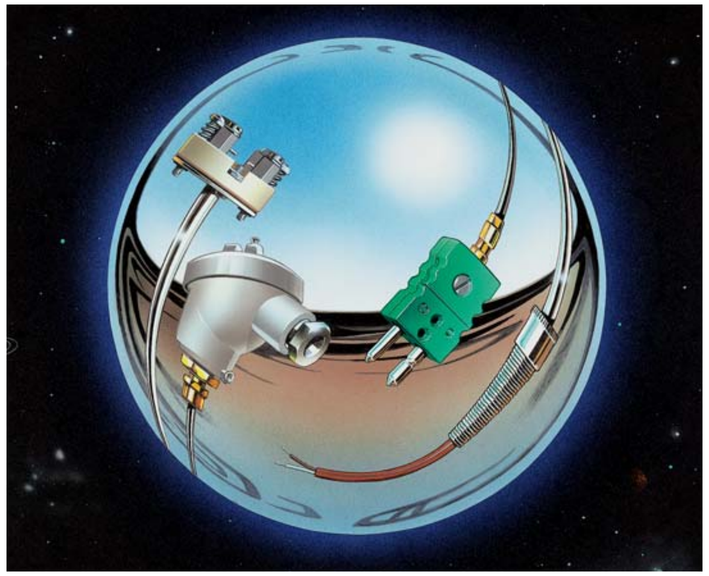
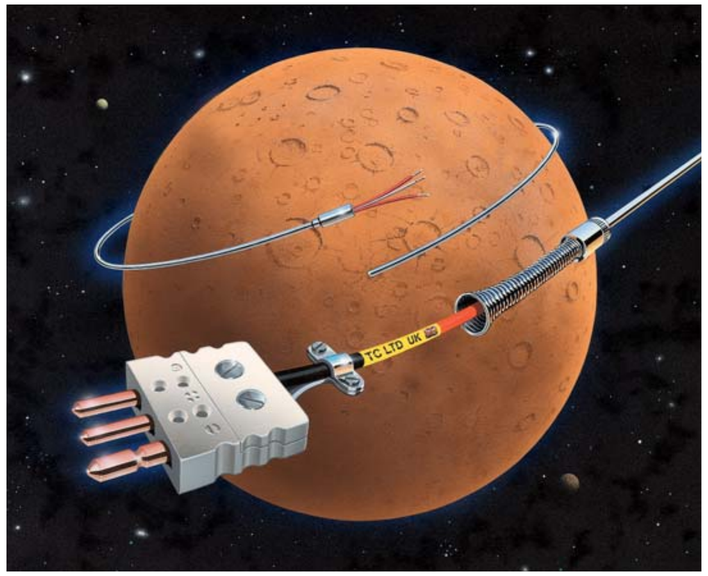
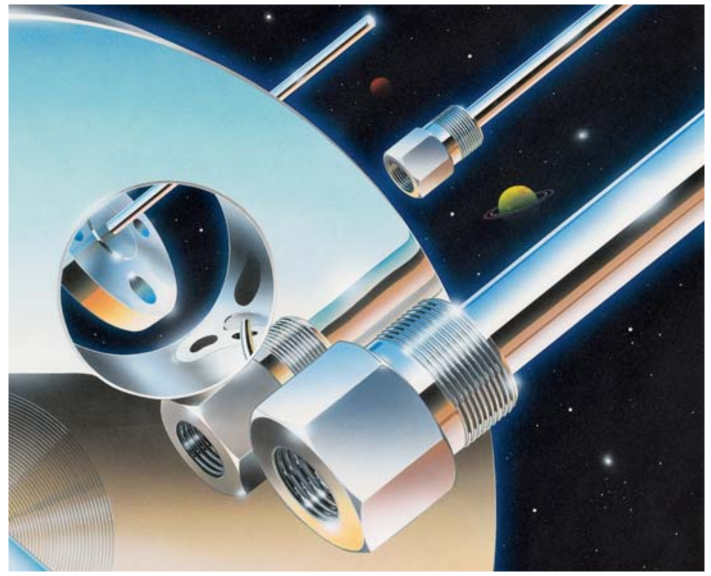
Issue 6.1

GUIDE TO THERMOCOUPLE AND RESISTANCE THERMOMETRY



TOTALLY REVISED AND EXPANDED

A wealth of information on
Thermocouple & Resistance Thermometry

A GUIDE TO THERMOCOUPLE AND RESISTANCE THERMOMETRY

Your personal copy of our latest edition of the Thermocouple and Resistance Thermometry Wallchart has been completely revised and expanded to provide more technical reference and guideline information.

If you wish to receive more copies of the wallchart, for your colleagues or for training purposes, then telephone us or complete the reply card on the front page and return it to us.

The sections of the wallchart describing our products contain many additional items. The descriptions are presented so that hardware is easy to select, and is available on a value-for-money basis that is second to none. Next time you have an application for temperature measurement products, or need information or assistance, please contact us. Our applications engineers will be pleased to answer questions, and advise the best way of meeting your requirements.

Standard products in our range are available on a same day despatch basis: custom built assemblies obviously take a little longer, but usually 3/4 days or faster if required. All it takes is a telephone call and your order is on its way. Account facilities can, in most cases, be established immediately or alternatively you may wish to pay by Visa or Mastercard.

To assist our customers in avoiding delays and plant shut downs, we operate a round-the clock service to ensure prompt attention to emergency orders. You are able to contact us on 01895 252222 between 0830hrs and 1800hrs Monday to Friday. Outside these hours call the same number and our voicemail system will page one of our engineers to contact you by return.

We know the only way to keep our business successful is to provide our customers with the best service possible in every respect. To this end we are continuously reviewing and improving our production facilities, despatch procedures and customer services.

We are registered to ISO 9001 : 2000 Quality Standard as well as having our own UKAS Calibration Laboratory which consolidates our dedication and commitment to offering products of the highest standard.

0564

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We look forward to hearing from you.

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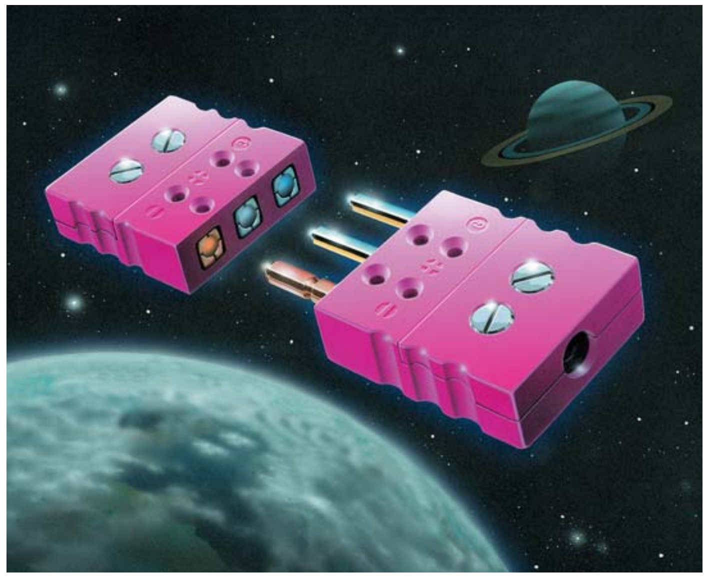

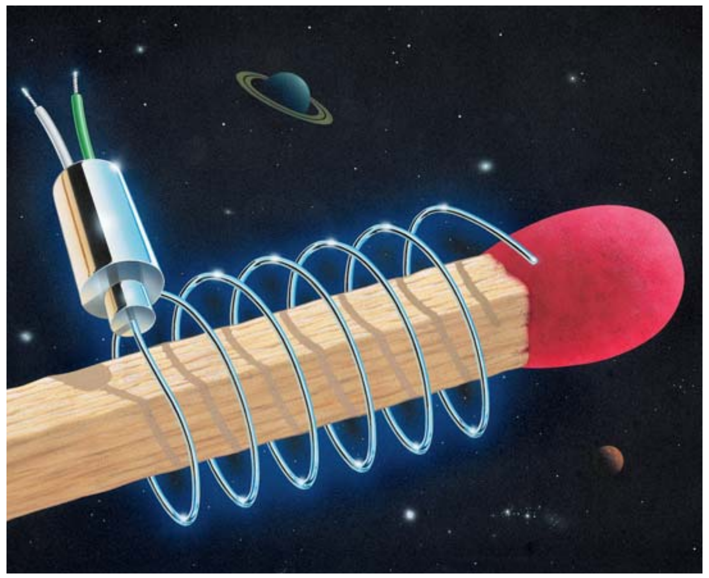


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*AN **INDEX** FOR THIS GUIDE IS DETAILED ON THE OUTSIDE BACK COVER OF THIS PUBLICATION.*

A GUIDE TO THERMOCOUPLE AND RESISTANCE THERMOMETRY

*SEE BACK COVER FOR **INDEX**.*

PREFACE

Temperature is one of the most measured of the physical quantities. As such, measuring it correctly is of vital importance.

Critical factors such as process and reaction rates, raw material usage, and product specification, yield and quality, can all be affected by the precision and frequency with which temperature is measured. Additionally temperature strongly influences such diverse factors as process and fuel efficiency, the effective recovery and use of solvents, and the life of plant and equipment.

Common to all these areas of industry is the need to provide reliable inputs to a whole range of temperature related control mechanisms – closed loop temperature control, safety and functional interlocking, process optimization and plant condition monitoring. The need for better accuracy and repeatability in all these areas is driving many users to consider more carefully the temperature measurements they are making.

There are many users who will be content to operate supplied temperature measuring systems without requiring a detailed understanding of their workings. However, for those who do want to know more about the theory and practice of temperature sensing, this guide is intended to provide a general, yet thorough, understanding of the two main temperature measuring technologies in use today, namely those based on thermocouples and resistance thermometers.

Between them, these two technologies fulfill most temperature measurement requirements. There are various types of thermocouple sensor available which in combination cover the range -250°C to +3,000°C. Resistance thermometer technology handles a more restricted range of -200°C to 1000°C. Thermocouples are generally characterized as rugged and versatile, whilst resistance thermometers permit better measurement accuracy and stability.

An important characteristic of both sensor technologies, and the main reason for their particular value to industry and science, is that their outputs are in the form of electrical signals. Such signals can be readily transmitted, switched, displayed, recorded and further processed by other equipment.

Whilst neither sensor technology has changed substantially in recent years, continued improvements have been made. These include the introduction of a new thermocouple type (Type N) and advances such as thin and thick film technology which enables resistance thermometers to be fabricated more cost effectively and with better stability.

New materials are continually being introduced, both for the sensors themselves and their protective sheathing. Additionally the electronics associated with the temperature sensors continue to advance delivering, the ability to sense temperature with greater stability and precision, the increased use of smart transmitters and the prospect of smart sensors designed to detect and measure their own degradation and failure.

This guide is divided into three main parts and an Epilogue: Theory and Standards; Sensors, Equipment and Practice; and Further Practical Points. It has been written to provide a simple yet authoritative guide to thermocouple and resistance thermometry.

Part One deals with the theory behind both thermocouples and resistance thermometers, and details their advantages and disadvantages. It covers the background to the International Temperature Scale, types of thermocouple and resistance thermometer detector (RTD) and the standards that apply to these. Signal conversion methods, linearizing functions and transmitter technology are also dealt with.

Part Two looks into the practical aspects of the sensors and associated equipment available. It covers thermocouples and their associated cables (including extension leads and compensating cables), sheath and insulation materials, colour codes, connectors, reference junctions, plus the equivalent components for RTD's. It then goes on to look at the equipment common to both sensors – end seals, protective sheaths, thermowells and accessories including transmitter styles and smart transmitters.

Part Three provides useful hints on the practicalities of choosing sensor and transmitter types and where to site sensors. System installation details and good engineering practice notes are also provided together with guidance on methods of linking sensors to the region of interest and a consideration of heat transfer and stagnation effects. There are also suggestions on calibration, signal averaging and response times. Some application notes are also included, along with information on trouble shooting.

The Epilogue deals mainly with the subject of future trends in electronic thermometry. It also includes a full Glossary of Terms, along with Further Reading References. This Guide can be read in sequence or, if the reader is already familiar with the basics, then the index can be used to select the appropriate section. There are plenty of cross references to assist the reader and it is hoped that the Guide will prove an invaluable aid to those involved in thermocouple and resistance thermometry.

PART 1: THEORY AND STANDARDS

1.0 Temperature Scales

The concept of a temperature scale may appear a little basic to begin a review of thermocouple and resistance thermometry but it can highlight many of the fundamental assumptions and misconceptions in our understanding of what temperature is all about. These colour our approach to temperature measurement in the real world.

Firstly, as with any measurement of a physical quantity, we need a system of units to which we can refer and thus make valued comparisons. Temperature, as the National Physical Laboratory maintains, is one of the seven base quantities in the `Système International d'Unités' – (the SI system). Arguably, however, it is among the most difficult to define and quantify.

Defining a temperature scale (based on thermodynamic theory) is not as easy as is the case with scales for distance, mass or even pressure. This is because there is no reproducible continuum of measurable points up and down a scale. Instead, interpolation between agreed "fixed" points is employed, using the best available sensor technology as appropriate to the different bands of the temperature spectrum. The temperature scale has to be defined in terms of `equations of state' of physical systems which accurately and reproducibly follow and infer temperature in terms of other `variables of state'. These include pressure, density, volume, resistance, and voltage. The laws of physics which have been harnessed in the definition of temperature are too numerous to mention. The definition of temperature owes its existence to a long line of famous scientists Planck, Nyquist, Stefan-Boltzmann, Carnot, and Kelvin.

Temperature is defined principally in terms of the Kelvin. One Kelvin unit is 1/273.16 of the thermodynamic temperature of the triple point of water. Most of us, however, prefer to think in terms of degrees Celsius. And, since the incremental units are the same, but with an offset of -273.15 degrees, the triple point of water in degrees Celsius is 0.01°C. From a practical point of view, the ice point is 0°C, and the steam point 100°C – an ideal metric interval.

It is however, worth stepping for a moment into the thermometry laboratory to appreciate what the above really means. The ice point is the exact temperature of a mixture of air-saturated water and ice at a pressure of 101,325Pa. The water triple point, however, is the temperature of the equilibrium between the three water phases – ice, water and water vapour – in the absence of air. The difference between the two happens to be the magic 0.01°C mentioned earlier.

At the other end of this water based scale [spectrum], however, recent experiments to accurately determine the steam point have shown some variance from the original figure. In the academic community there have been requests to get away from water altogether for defining temperature, and move to the triple point of gallium – near 30°C – since it is arguably much better defined.

1.1 ITS-90 versus IPTS-68

Resistance thermometry itself had its origins about 100 years ago. The first internationally recognised temperature scale was the International Temperature Scale of 1927 – ITS-27. Its purpose was to define procedures by which specified, high quality yet practical thermometry systems could be calibrated such that the values of temperature obtained from them would be concise and consistent instrument-to-instrument and sensor-to-sensor – while simultaneously approximating to the appropriate thermodynamic values within the limits of the technology available. This goal remains intact today.

ITS-27 extended from just below the boiling point of oxygen, -200°C, to beyond the freezing point of gold, 1,065°C. Interpolation formulae were specified for platinum resistance thermometers calibrated at 0°C and at the boiling points of oxygen, water and sulphur (445°C).

Above 660°C, the Pt-10%Rh vs Pt thermocouple was specified for measurement. Above the gold point optical pyrometry was employed and the values of the fixed points were based on the best available gas thermometry data of the day. ITS-27 was revised somewhat in 1948, and then more substantially in 1968 – with the adoption of the International Practical Temperature Scale, IPTS-68. 1975 saw a realignment with thermodynamic temperature through some numerical changes, and 1976 witnessed the introduction of the provisional 0.5 to 30K temperature scale – EPT-76.

The current scale, ITS-90, was adopted on 1st January 1990. ITS-90 replaced the platinum-rhodium thermocouple (type S) as a defining sensor with the more precise PRT. Type S and the related platinum-rhodium types R and B are now used only as secondary standards.

Continued on page 4

Equilibrium State	t_{90}/K	t_{90}/°C
Triple point of hydrogen	13.8033	-259.3467
Boiling point of hydrogen at a pressure of 33321.3 Pa	17.035	-256.115
Boiling point of hydrogen at a pressure of 101292 Pa	20.27	-252.88
Triple point of neon	24.5561	-248.5939
Triple point of oxygen	54.3584	-218.7916
Triple point of argon	83.8058	-189.3442
Triple point of mercury	234.3156	-38.8344
Triple point of water	273.16	0.01
Melting point of gallium	302.9146	29.7646
Freezing point of indium	429.7485	156.5985
Freezing point of tin	505.078	231.928
Freezing point of zinc	692.677	419.527
Freezing point of aluminium	933.473	660.323
Freezing point of silver	1234.93	961.78
Freezing point of gold	1337.33	1064.18
Freezing point of copper	1357.77	1084.62

Table 1.1: *The Fixed Points adopted in the ITS-90.*

Basically, the temperature range covered by the platinum resistance thermometer was extended right up to the freezing point of silver, 961.78°C, to take out some irregularities resulting from using the Pt-10%Rh vs Pt thermocouple above 630°C (see Figure 1.1). This overcomes the errors of interpolation that used to exist with IPTS-68, and the discontinuity in the first derivative at that temperature. Essentially, by present day standards the lowly thermocouple is not deemed sufficiently reproducible for use as a defining instrument – being capable only of ±0.2°C at best. Platinum resistance thermometers, on the other hand, can be an order of magnitude more precise.

Other changes included: the adoption of more accurate values for the fixed points themselves; the revision of the primary fixed points now excluding the boiling points of neon, oxygen and water; the extension of the range to very low temperatures (right down to 0.65K); and the revision of the formulae for interpolating temperature values between the fixed points.

Beyond this, so called sub-ranges were introduced, allowing platinum resistance thermometers to be calibrated over limited parts of their range such that definitive calibrations can be obtained without exposing the measuring device concerned to unnecessary extremes of temperature.

Essentially, ITS-90 now defines a scale of temperature in five overlapping ranges. These are: 0.65 to 5K using vapour pressures of Helium; 3 to 24.5561K via an interpolating constant volume gas thermometer; and 13.8033 to 273.16K (0.01°C) using ratioed resistances of qualified platinum resistance thermometers calibrated against various triple points. Then from 0 to 961.78°C PRTs are again used calibrated at fixed freezing and melting points. Finally, above the freezing point of silver, the Planck law of radiation is harnessed.

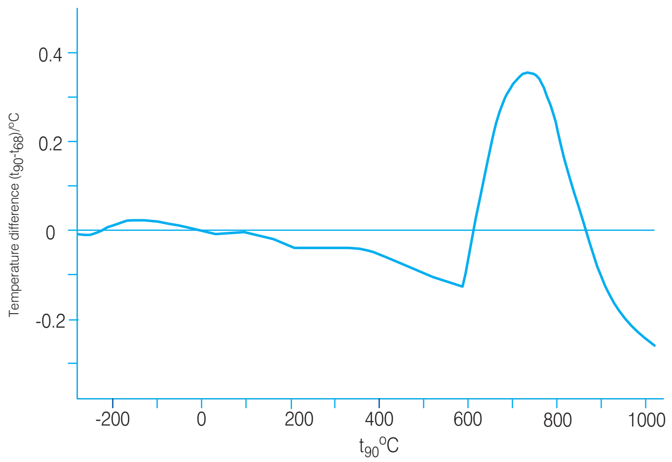


Figure 1.1: *Differences between ITS-90 and IPTS-68.*

ITS-90 marked the culmination of a huge amount of effort (theoretical and practical) at the National Physical Laboratory and elsewhere. It is not regarded as perfect, but is a close enough approximation to the real world of thermodynamic temperature, and is set to last us for at least 20 years.

The goal of an international temperature scale is to provide an exact definition of a measurable and traceable continuum of the physical state we call temperature. This goal is fundamental to the academic and scientific world but probably less so to the practising engineer.

The influence on thermometry of ITS-90, however, should not be understated.

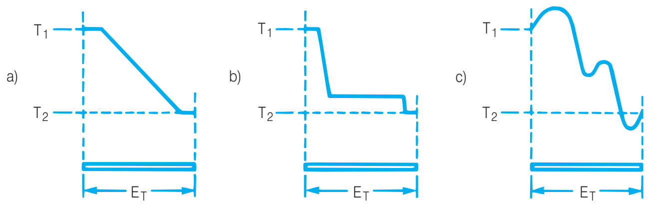
2.0 Thermocouples

If there is a temperature gradient in an electrical conductor, the energy (heat) flow is associated with an electron flow along the conductor, and an electromotive force (emf) is then generated in that region. Both the size and direction of the emf are dependent on the size and direction of the temperature gradient itself - and on the material forming the conductor. The voltage is a function of the temperature difference along the conductor length. For the historians among you, this effect was discovered by TJ Seebeck in 1822.

The voltage appearing across the ends of the conductor is the sum of all the emfs generated along it. So, for a given overall temperature difference, T1-T2, the gradient distributions shown diagrammatically in Figures 2.1 a, b and c produce the same total voltage, E - as long, that is, as the conductor has uniform thermoelectric characteristics throughout its length.

The output voltage of a single conductor, as shown, is not, however, normally measurable since the sum of the internal emfs around a completed circuit in any temperature situation is zero. So, in a practical thermocouple temperature sensor, the trick is to join two materials having different thermoelectric emf/temperature characteristics in order to produce a usable net electron flow and a detectable net output voltage.

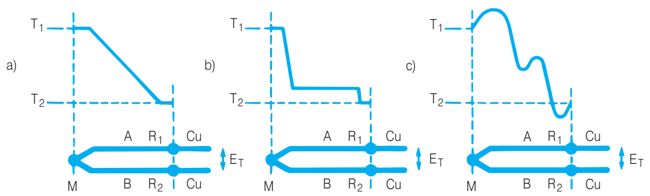
Thus, two connected dissimilar conductors, A and B, exposed to the same temperature gradients given in figure 2.1 generate outputs as shown in figure 2.2. Basically, there is a net electron flow across the junction caused by the different thermoelectric emfs, in turn resulting from the interaction of the gradient with the two different conductors. And, hence the term, `thermocouple'.



Figures 2.1 a,b,c: *Temperature Distributions Resulting in Same Thermoelectric Emf*

It is worth noting, however, that the thermoelectric emf is generated in the region of the temperature gradient, and not at the junction as such. This is an important point to understand since there are practical implications for thermocouple thermometry. These include ensuring that thermocouple conductors are physically and chemically homogenous if they are in a temperature gradient. Equally, the junctions themselves must be in isothermal areas. If either of these conditions is not satisfied, additional, unwanted emfs will result.

Incidentally, any number of conductors can be added into a thermoelectric circuit without affecting the output, so long as both ends are at the same temperature and, yet again, that homogeneity is ensured. This leads to the concept of extension leads and compensating cables - enabling probe conductor lengths to be increased. See Part 2, Section 3.



Figures 2.2 a,b,c: *Thermocouple Emfs Generated by Temperature Gradients*

Returning to Figure 2.2, in fact the output, ET, is the same for any temperature gradient distribution over the temperature difference T1 and T2, provided that the conductors again exhibit uniform thermoelectric characteristics throughout their lengths. Since the junctions, M, R1 and R2 represent the limits of the emf-generating conductors, and since the remaining conductors linking the measuring device are uniform copper wire, the output of the thermocouple is effectively a function only of the two main junctions' temperatures. And this, in essence, is the basis of practical thermocouple thermometry.

The relevant junctions are the so-called measuring junction (M) and the junction of the dissimilar wires to the copper output connections (usually, a pair of junctions), called the reference junction (R), as in Figure 2.2. So long as the reference junction (R) is maintained at a constant, known temperature, the temperature of the measuring junction (M) can be deduced from the thermocouple output voltage. Thermocouples can thus be considered as differential temperature measuring devices - not absolute temperature sensors.

Important points to note at this stage are four-fold. Firstly, thermocouples only generate an output in the regions where the temperature gradients exist - not beyond. Secondly, accuracy and stability can only be assured if the thermoelectric characteristics of the thermocouple conductors are uniform throughout. Thirdly, only a circuit comprising dissimilar materials in a temperature gradient generates an output. And, fourthly, although the thermoelectric effects are seen at junctions, they are not due to any magic property of the junction itself.

2.1 Calibration Tables

Beyond these, another crucial point to be aware of is that the thermoelectric sensitivity of most materials over a range of temperatures is non-linear. This is rarely an ideal world, and thermocouple thermometry no more ideal than any other. So, the temperature-related voltage output is not a linear function of temperature. Variable interpolation is required, as opposed to direct voltage reading (unless the temperature range to be measured is very narrow and the highest of accuracies is not a prerequisite).

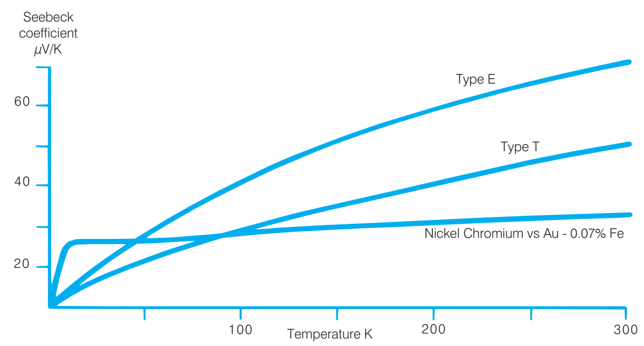


Figure 2.3: *Seebeck Coefficients for Types E, T and Nickel Chromium vs. Au - 0.07% Fe Thermocouples*

So, there are calibration tables for each thermocouple combination (Part 1, Section 3), relating output voltage to the temperature of the measuring junction. Throughout thermocouple thermometry it is clearly necessary to refer sensor voltage output to these in some way to ascertain true temperature.

2.2 Cold Junction Compensation

But, further, and most important, different net voltage outputs are produced for a given temperature difference between the measuring and reference junctions if the reference junction temperature itself is allowed to vary. So, the calibration tables mentioned above always expressly assume that the reference junction is held at 0°C.

This can be achieved by inserting the copper junction(s) into melting ice, via insulating glass tubes, or into a temperature controlled chamber, like an isothermal block with suitable temperature sensors. Today, however, for industrial measurement, this kind of function is normally performed by temperature correcting electronics - while linearising electronics (usually digital), harnessing curve fitting techniques, look after the inherent non-linearities as per the calibration tables - more in Part 1, Section 5.

Essentially, reference temperature variations are sensed by a device such as a thermistor as close as possible to the reference junction. An emf is then induced which varies with temperature such as to compensate for the temperature movements seen at the reference terminals.

2.3 Material Types

Most conducting materials can produce a thermoelectric output. However, when considerations, like width of the temperature range, actual useful signal output, linearity and repeatability (the unambiguous relationship of output to temperature), are taken into account, there is a somewhat restricted sensible choice. Material selections have been the subject of considerable work over several decades - on the part of

Continued on page 6

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Thermocouple Extension and Compensating Cables

Codes · Conductor Combinations · National and International Specifications

Thermocouple Conductor Combination Type	Extension and Compensating Cable Type: Extension Cable	Compensating Cable	International Colour Code To IEC 60584.3:2007 BS EN 60584.3:2008	International Colour Code To IEC 60584.3:2007 BS EN 60584.3:2008 for Intrinsically Safe Circuits	Redundant national colour coding for insulation of thermocouple extension and compensating cable: BRITISH To BS 1843	AMERICAN To ANSI/MC96.1	GERMAN To DIN 43714	FRENCH To NFC 42324	JAPANESE To JIS C 1610-1981	Tolerance values to IEC 60584.3:2007 (BS EN 60584.3:2008) for extension and compensating cables when used at temperatures within the cable temperature range column shown below. Tolerance Class 1	Tolerance Class 2	Cable Temperature Range °C	Measuring Junction Temperature	Notes
K	KX									±60 µV (±1.5°C)	±100 µV (±2.5°C)	−25°C TO +200°C	900°C	Type KX Thermocouple extension cable conductors are made from the same constituent elements as the Type K thermocouple combination and therefore minimises potential errors when connecting to a sensor.
		KCA									±100 µV (±2.5°C)	0°C TO +150°C	900°C	This compensating cable conductor combination is little known and generally not available. It should not be confused with the more popular Type KCB as shown below.
		KCB									±100 µV (±2.5°C)	0°C TO +100°C	900°C	This popular compensating cable conductor combination (previously known as Type V) is made with Copper vs Copper-Nickel conductors, and should only be used when the ambient temperature of the interconnection point between the cable and its Type K sensor is below 100°C. If suitable to your requirements it can save money where long runs are necessary.
T	TX									±30 µV (±0.5°C)	±60 µV (±1.0°C)	−25°C TO +100°C	300°C	Type TX extension cable conductors are made from the same constituent elements as Type T thermocouples. There is no compensating cable available for Type T, however the extension cable is relatively inexpensive.
J	JX									±85 µV (±1.5°C)	±140 µV (±2.5°C)	−25°C TO +200°C	500°C	Type JX extension cable conductors are made from the same constituent elements as Type J thermocouples. There is no compensating cable available for Type J, however the extension cable is relatively inexpensive.
N	NX									±60 µV (±1.5°C)	±100 µV (±2.5°C)	−25°C TO +200°C	900°C	Type NX extension cable conductors are made from the same constituent elements as Type N thermocouples. Although there is a designated compensating cable for Type N, it is not at present readily available.
		NC									±100 µV (±2.5°C)	0°C TO +150°C	900°C	Type NC compensating cable is not at present readily available. It can be assumed that as Type N thermocouples become more popular the compensating cable will start to be produced.
E	EX									±120 µV (±1.5°C)	±200 µV (±2.5°C)	−25°C TO +200°C	500°C	Type EX extension cable conductors are made from the same constituent elements as Type E thermocouples. There is no compensating cable available for Type E.
R		RCA									±30 µV (±2.5°C)	0°C TO +100°C	1000°C	Type RCA compensating cable is suitable for connecting to Type R thermocouples where the ambient temperature of the interconnection point between the cable and its Type R sensor is below 100°C.
		RCB									±60 µV (±5.0°C)	0°C TO +200°C	1000°C	Type RCB compensating cable is suitable for connecting to Type R thermocouples where the ambient temperature of the interconnection point between the cable and its Type R sensor is below 200°C, however this increased range is achieved with a lesser degree of accuracy than Type RCA as shown above.
S		SCA									±30 µV (±2.5°C)	0°C TO +100°C	1000°C	Type SCA compensating cable is suitable for connecting to Type S thermocouples where the ambient temperature of the interconnection point between the cable and its Type S sensor is below 100°C. SCA is in fact the same material as Type RCA.
		SCB									±60 µV (±5.0°C)	0°C TO +200°C	1000°C	Type SCB compensating cable is suitable for connecting to Type S thermocouples where the ambient temperature of the interconnection point between the cable and its Type S sensor is below 200°C, however this increased range is achieved with a lesser degree of accuracy than Type SCA as shown above. SCB is in fact the same material as Type RCB.
B		BC												This compensating cable is made from Copper vs Copper conductors. The expected maximum additional deviation when the ambient interconnection point is between 0 and 100°C would be approximately 3.5°C when the measuring junction is at 1400°C.
G (Formerly Code W)		GC	*											This compensating cable is made from Alloy 200* vs Alloy 226* and is suitable for use with Type G (Formerly W) Thermocouples.
C (Formerly Code W5)		CC	*											This compensating cable is made from Alloy 405* vs Alloy 426* and is suitable for use with Type C (Formerly W5) Thermocouples.
D (Formerly Code W3)		DC	*											This compensating cable is made from Alloy 203* vs Alloy 225* and is suitable for use with Type D (Formerly W3) Thermocouples.

Extension and compensating cables are used for the electrical connection between the open ends of a thermocouple and the reference junction in those installations where the conductors of the thermocouple are not directly connected to the reference junction.

* Codes G, C and D and the cable colours shown, are not officially recognised symbols.

* Trade Names

Extension Cables
Extension cables are manufactured from conductors having the same nominal composition as those of the corresponding thermocouple. They are designated by a letter "X" following the designation of the thermocouple, for example "JX".

Compensating Cables
Compensating cables are manufactured from conductors having a composition different from the corresponding thermocouple. They are designated by a letter "C" following the designation of the thermocouple, for example "KC". Different alloys may be used for the same thermocouple type and are distinguished by additional letters, for example, "KCA" or "KCB".

FOR FURTHER INFORMATION ON CONDUCTOR COMBINATIONS SEE PAGE 7

suppliers, the main calibration and qualifying laboratories and academia. So, the range of temperatures covered by usable metals and alloys, in both wire and complete sensor form, now extends from -270°C to 2,600°C.

Naturally, the full range cannot be covered by just one thermocouple junction combination. There are internationally recognised type designations, each claiming some special virtue. The British standard BS EN 60584.1 (formerly BS 4937), and the International standard IEC 60584 refer to the standardised thermocouples, and these are described by letter designation - the system originally proposed by the Instrument Society of America (see Part 1, Section 3).

In general, these are divided into two main categories - rare metal types (typically, platinum vs platinum rhodium) and base metal types (such as nickel chromium vs nickel aluminium and iron vs copper nickel (Constantan)). Platinum-based thermocouples tend to be the most stable, but they're also the most expensive. They have a useful temperature range from ambient to around 2,000°C - and, short term, much greater (-270°C to 3,000°C). The range for the base metal types is more restricted, typically from 0 to 1,200°C, although again wider for non-continuous exposure. However, signal outputs for rare metal types are small compared with those from base metal types.

Another issue here is the inherent thermoelectric instability of the workhorse base metal thermocouple, Type K, with both time and temperature - although Types E, J and T have also come in for some criticism (see Part 1, Section 3). And, hence the interest in Type N thermocouples (Nicrosil vs Nisil), with their promise of the best of the rare metal characteristics - at base metal prices, with base metal signal levels and a slightly extended base metal temperature range.

2.4 Type N

Instabilities come in a number of forms. Firstly, there is long term drift with exposure to high temperatures, mainly due to compositional changes caused by oxidation - or neutron bombardment in nuclear applications. In the former case, above 800°C oxidation effects on Type K thermocouples in air, for example, can cause changes in conductor homogeneity, leading to errors of several percent. Then again, where the devices are mounted in sheaths with limited air volume, the `green rot' phenomenon can be encountered - due to preferential oxidation of the chromium content. Meanwhile, with nuclear bombardment there is the problem of transmutation - leading to similar effects.

Secondly, there are short term cyclic changes in the thermal emfs (hysteresis) generated on heating and cooling base metal thermocouples, again notably Type K in the 250°C to 600°C range, causes being both magnetic and structural inhomogeneities. Errors of about 5°C and more are common in this temperature range, peaking at around 400°C. Thirdly, with mineral insulated thermocouple assemblies (see Part 2, Section 2.3) there can be time-related emf variations due to composition-dependent and magnetic effects in temperature ranges depending on the materials themselves. This is due essentially to transmutation of the high vapour pressure elements (mainly manganese and aluminium) from the K negative wire through the magnesium oxide insulant to the K positive wire. Again, the compositional change results in a shifting thermal emf.

Type N materials obviate or dramatically reduce these instabilities because of the detailed structure of the alloys engineered for this novel thermocouple. This applies to time, temperature cycling hysteresis, magnetic and nuclear effects. Basically, oxidation resistance is superior because of the combination of a higher level of chromium and silicon in the NP (Nicrosil) conductor, and a higher level of silicon and magnesium in the NN (Nisil) conductor, forming a diffusion barrier. Hence, there is much better long term drift resistance.

Then again, the absence of manganese, aluminium and copper in the NN conductor increases the stability of Type N against its base metal competitors in nuclear applications. As for the transmutation problem in mineral insulated assemblies, this too is virtually eliminated since the two Type N conductors both contain only traces of manganese and aluminium.

Looking at the temperature cycling hysteresis instabilities, these are also dramatically reduced due to the high level of chromium in the NP conductor and silicon in the NN conductor. In fact, the cycling spread is between 200°C and 1,000°C with a peak around 750°C - and figures of around 2°C to 3°C maximum excursion are quoted.

2.5 Thermocouple Selection

As for selection of a particular thermocouple type for a sensing application, physical conditions, duration of exposure, sensor lifetime and accuracy all have to be considered. Additionally, in the case of base metal types, there are the further criteria of sensitivity and compatibility with existing measuring equipment. More details on types and selection criteria are provided in: Part 1, Section 3, and Part 3, Section 1.

3.0 Thermocouple Types, Standards and Reference Tables

Many combinations of materials have been used to produce acceptable thermocouples, each with its own particular application spectrum. However, the value of interchangeability and the economics of mass production have led to standardisation, with a few specific types now being easily available, and covering by far the majority of the temperature and environmental applications.

These thermocouples are made to conform to an emf/temperature relationship specified in the form of tabulated values of emfs resolved normally to 1µV against temperature in 1°C intervals, and vice versa. Internationally, these reference tables are published as IEC 60584.1 (BS EN 60584.1). It is worth noting here, however, that the standards do not address the construction, or insulation of the cables themselves or other performance criteria. With the diversity to be found, manufacturers' own standards must be relied upon in this respect.

The standards cover the eight specified and most commonly used thermocouples, referring to their internationally recognised alpha character type designations and providing the full reference tables for each. See the reference tables published in this guide. At this point, it's worth looking at each in turn, assessing its value, its properties and its applicational spread. Note that the positive element is always referred to first. Note also that, especially for base metal thermocouples, the maximum operating temperature specified is not the be all and end all. In the real world, it has to be related to the wire diameter - as well as the anticipated environment and the thermocouple life requirements.

As a brief summary, thermocouple temperature ranges and material combinations are given in tables 3.1 and 3.2. The former comprise rare metal, platinum-based devices; the latter are base metal types.

International Type Designation	Conductor Material		Temperature range (°C)
R	Pt-13%Rh	(+)	0 to +1600
	Pt	(–)	
S	Pt-10%Rh	(+)	0 to +1500
	Pt	(–)	
B	Pt-30%Rh	(+)	+100 to +1600
	Pt-6%Rh	(–)	

Table 3.1: *Commonly Used Platinum Metal Thermocouples*

International Type Designation	Conductor Material		Temperature range (°C)
K	Ni-Cr	(+)	0 to +1100
	Ni-Al	(–)	
T	Cu	(+)	-185 to +300
	Cu-Ni	(–)	
J	Fe	(+)	+20 to +700
	Cu-Ni	(–)	
E	Ni-Cr	(+)	0 to +800
	Cu-Ni	(–)	
N	Ni-Cr-Si	(+)	0 to +1250
	Ni-Si	(–)	

Table 3.2: *Commonly Used Base Metal Thermocouples*

3.1 IEC 60584.1 Part 1: Type S - Platinum-10% Rhodium vs Platinum.

This thermocouple, also defined as BS EN 60584.1 Part 1, can be used in oxidising or inert atmospheres continuously at temperatures up to 1600°C and for brief periods up to 1700°C. For high temperature work, insulators and sheaths made from high purity recrystallised alumina are used. In fact, in all but the cleanest of applications, the device needs protection in the form of an impervious sheath since small quantities of metallic vapour can cause deterioration and a reduction in the emf generated.

Continuous use at high temperatures also causes degradation, and there is the possibility of diffusion of rhodium into the pure platinum conductor - again leading to a reduction in output.

3.2 IEC 60584.1 Part 2: Type R - Platinum-13% Rhodium vs Platinum

Similar to the Type S combination, this thermocouple (also defined as BS EN 60584.1 Part 2) has the advantage of slightly higher output and improved stability. In general Type R thermocouples are preferred over Type S, and applications covered are broadly identical.

3.3 IEC 60584.1 Part 3: Type J - Iron vs Copper-Nickel

Commonly referred to as Iron/Constantan (and defined in BS EN 60584.1 Part 3), this is one of the few thermocouples that can be used safely in reducing atmospheres. However, in oxidising atmospheres above 550°C, degradation is rapid. Maximum continuous operating temperature is around 800°C, although for short term use, temperatures up to 1,000°C can be handled. Minimum temperature is -210°C, but beware of condensation at temperatures below ambient - rusting of the iron arm can result, as well as low temperature embrittlement.

3.4 IEC 60584.1 Part 4: Type K - Nickel-Chromium vs Nickel-Aluminium

Generally referred to as Chromel-Alumel it is still the most common thermocouple in industrial use today. Also defined in BS EN 60584.1 Part 4, it is designed primarily for oxidising atmospheres. In fact, great care must be taken to protect the sensor in anything else! Maximum continuous temperature is about 1,100°C, although above 800°C oxidation increasingly causes drift and decalibration. For short term exposure, however, there is a small extension to 1,200°C. The device is also suitable for cryogenic applications down to -250°C.

Although Type K is widely used because of its range and cheapness, it is not as stable as other base metal sensors in common use. At temperatures between 250°C and 600°C, but especially 300°C and 550°C, temperature cycling hysteresis can result in errors of several degrees. Again, although Type K is popular for nuclear applications because of its relative radiation hardness, Type N is now a far better bet.

3.5 IEC 60584.1 Part 5: Type T - Copper vs Copper-Nickel

Copper-Constantan (BS EN 60584.1 Part 5), its original name, has found quite a niche for itself in laboratory temperature measurement over the range -250°C to 400°C - although above this the copper arm rapidly oxidises. Repeatability is excellent in the range -200°C to 200°C (±0.1°C). Points to watch out for include the high thermal conductivity of the copper arm, and the fact that the copper/nickel alloy used in the negative arm is not the same as that in Type J - so they're not interchangeable.

3.6 IEC 60584.1 Part 6: Type E - Nickel-Chromium vs Copper-Nickel

Also known as Chromel-Constantan (BS EN 60584.1 Part 6), this thermocouple's claim to fame is its high output - the highest of the commonly used devices, although this is less significant in these days of ultra stable solid state amplifiers. The usable temperature range extends from about -250°C (cryogenic) to 900°C in oxidising or inert atmospheres. Recognised as more stable than Type K, it is therefore more suitable for accurate measurement. However, Type N still scores higher marks because of its stability and range.

3.7 IEC 60584.1 Part 7: Type B - Platinum-30% Rhodium vs Platinum-6% Rhodium

Type B is of a more recent vintage (1950's, and defined in BS EN 60584.1 Part 7), and can be used continuously up to 1,600°C and intermittently up to around 1,800°C. In other respects the device resembles the other rare metal based thermocouples, Types S and R, although the output is lower, and therefore it is not normally used below 600°C. An interesting practical advantage is that since the output is negligible over the range 0°C to 50°C, cold junction compensation is not normally required.

3.8 IEC 60584.1 Part 8: Type N - Nickel-Chromium-Silicon vs Nickel-Silicon

Billed as the revolutionary replacement for the Type K thermocouple (the most common in industrial use), but without its drawbacks - Type N (Nicrosil-Nisil) exhibits a much greater resistance to oxidation-related drift at high temperatures than its rival, and to the other common instabilities of Type K in particular, but also the other base metal thermocouples to a

Continued on page 8

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Thermocouples Types · Conductor Combinations · Characteristics · National and International Standards

Code	Conductor Combinations		National Standards for Output of Thermocouple Conductors	Approximate Generated EMF Change per Degree Celsius Change with Reference Junction at 0°C µV/°C at			Approximate Working Temperature Range of Measuring Junction. *NB. Not related to wire diameters and conductor insulating materials* °C		Thermocouple Output Tolerances IEC 60584.2:1993, (BS EN 60584.2:1993) Note BS EN 60584.2:1993 replaced BS 4937 Pt 20:1991 *see note A below*				Notes
	+Leg	−Leg	Those Standards noted in this column all conform with each other and are based upon IEC60584.1:1995 & ITS-90	100°C	500°C	1000°C	CONTINUOUS	SHORT TERM	TYPE	Tolerance Class 1	Tolerance Class 2	Tolerance Class 3	
K	**NICKEL - CHROMIUM** Also known as: Chromel*, Thermokanthal KP*, NiCr, T1*, Tophel*	**NICKEL - ALUMINIUM** (MAGNETIC) Also known as: Ni-Al, Alumel*, Thermokanthal KN*, T2*, NiAl*	BS EN 60584.1 Pt4:1996 (Replaces BS 4937 Pt 4) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	42	43	39	0 to +1100	−180 to +1350	Temperature Range Tolerance Value Temperature Range Tolerance Value	−40°C to +375°C ±1.5°C 375°C to 1000°C ±0.004 · |t|	−40°C to +333°C ±2.5°C 333°C to 1200°C ±0.0075 · |t|	−167°C to +40°C ±2.5°C −200°C to −167°C ±0.015 · |t|	Most suited to oxidising atmospheres, it has a wide temperature range and is the most commonly used.
T	**COPPER**	**COPPER - NICKEL** Also known as: Constantan, Advance*, Cupron*	BS EN 60584.1 Pt5:1996 (Replaces BS 4937 Pt 5) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	46	–	–	−185 to +300	−250 to +400	Temperature Range Tolerance Value Temperature Range Tolerance Value	−40°C to +125°C ±0.5°C 125°C to 350°C ±0.004 · |t|	−40°C to +133°C ±1.0°C 133°C to 350°C ±0.0075 · |t|	−67°C to +40°C ±1.0°C −200°C to −67°C ±0.015 · |t|	Excellent for low temperature and cryogenic applications. Good for when moisture may be present.
J	**IRON** (MAGNETIC) Also known as: Fe	**COPPER - NICKEL** Also known as: Nickel-Copper, Constantan, Advance*, Cupron*	BS EN 60584.1 Pt3:1996 (Replaces BS 4937 Pt 3) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	54	56	59	+20 to +700	−180 to +750	Temperature Range Tolerance Value Temperature Range Tolerance Value	−40°C to +375°C ±1.5°C 375°C to 750°C ±0.004 · |t|	−40°C to +333°C ±2.5°C 333°C to 750°C ±0.0075 · |t|	– – – –	Commonly used in the plastics moulding industry. Used in reducing atmospheres as an unprotected thermocouple sensor. NB. Iron oxidises at low (rusts) and at high temperatures.
N	**NICKEL - CHROMIUM - SILICON** Also known as: Nicrosil	**NICKEL - SILICON - MAGNESIUM** Also known as: Nisil	BS EN 60584.1 Pt8:1996 (Replaces BS 4937 Pt 8) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	30	38	39	0 to +1150	−270 to +1300	Temperature Range Tolerance Value Temperature Range Tolerance Value	−40°C to +375°C ±1.5°C 375°C to 1000°C ±0.004 · |t|	−40°C to +333°C ±2.5°C 333°C to 1200°C ±0.0075 · |t|	−167°C to +40°C ±2.5°C −200°C to −167°C ±0.015 · |t|	Very stable output at high temperatures it can be used up to 1300°C. Good oxidation resistance. Type N stands up to temperature cycling extremely well.
E	**NICKEL - CHROMIUM** Also known as: Chromel*, Tophel*, Chromium, Nickel	**COPPER - NICKEL** Also known as: Nickel-Copper, Constantan, Advance*, Cupron*	BS EN 60584.1 Pt6:1996 (Replaces BS 4937 Pt 6) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	68	81	–	0 to +800	−40 to +900	Temperature Range Tolerance Value Temperature Range Tolerance Value	−40°C to +375°C ±1.5°C 375°C to 800°C ±0.004 · |t|	−40°C to +333°C ±2.5°C 333°C to 900°C ±0.0075 · |t|	−167°C to +40°C ±2.5°C −200°C to −167°C ±0.015 · |t|	Has the highest thermal EMF output change per °C. Suitable for use in a vacuum or mildly oxidising atmosphere as an unprotected thermocouple sensor.
R	**PLATINUM - 13% RHODIUM**	**PLATINUM**	BS EN 60584.1 Pt2:1996 (Replaces BS 4937 Pt 2) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	8	10	13	0 to +1600	-50 to +1700	Temperature Range Tolerance Value Temperature Range Tolerance Value	0°C to +1100°C ±1.0°C 1100°C to 1600°C ±(1 +0.003 (t · 1100)°C	0°C to +600°C ±1.5°C 600°C to 1600°C ±0.0025 · |t|	– – – –	Used for very high temperature applications. Used in the UK in preference to Type S for historical reasons. Has a high resistance to oxidation and corrosion. Easily contaminated, it normally requires protection.
S	**PLATINUM - 10% RHODIUM**	**PLATINUM**	BS EN 60584.1 Pt1:1996 (Replaces BS 4937 Pt 1) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	8	9	11	0 to +1550	-50 to +1750	Temperature Range Tolerance Value Temperature Range Tolerance Value	0°C to +1100°C ±1.0°C 1100°C to 1600°C ±(1 +0.003 (t · 1100)°C	0°C to +600°C ±1.5°C 600°C to 1600°C ±0.0025 · |t|	– – – –	Type S has similar characteristics to Type R as shown directly above.
B	**PLATINUM - 30% RHODIUM**	**PLATINUM - 6% RHODIUM**	BS EN 60584.1 Pt7:1996 (Replaces BS 4937 Pt 7) ANSI/MC96.1 DIN EN 60584.1: 1996 NF EN 60 584.1:1996 JISC 1602	1	5	9	+100 to +1600	+100 to +1820	Temperature Range Tolerance Value Temperature Range Tolerance Value	– – – –	– – 600°C to 1700°C ± 0.0025 · |t|	600°C to +800°C ±4.0°C 800°C to 1700°C ±0.005 · |t|	Type B has similar characteristics to Types R and S but is not so popular. Generally used in the glass industry.
G* (Formerly Code W)	**TUNGSTEN**	**TUNGSTEN 26% RHENIUM**	There are no officially recognised standards for Type G	5	16	21	+20 to +2320	0 to +2600	Temperature Range Tolerance Value Temperature Range Tolerance Value	– – – –	0°C to +425°C * ±4.5°C 425°C to 2320°C ±1.0%	– – – –	Formerly known as Code W. Tungsten Rhenium alloy combinations offer reasonably high and relatively linear EMF outputs for high temperature measurement up to 2600°C and good chemical stability at high temperatures in hydrogen, inert gas and vacuum atmospheres. They are not practicable for use below 400°C. Not recommended for use in oxidising conditions.
C* (Formerly Code W5)	**TUNGSTEN 5% RHENIUM**	**TUNGSTEN 26% RHENIUM**	There are no officially recognised standards for Type C	15	18	18	+50 to +1820	+20 to +2300	Temperature Range Tolerance Value Temperature Range Tolerance Value	– – – –	0°C to +425°C * ±4.4°C 425°C to 2320°C ±1.0%	– – – –	Formerly known as Code W5. See technical notes for Type G directly above.
D* (Formerly Code W3)	**TUNGSTEN 3% RHENIUM**	**TUNGSTEN 25% RHENIUM**	There are no officially recognised standards for Type D	13	20	20	0 to +2100	0 to +2600	Temperature Range Tolerance Value Temperature Range Tolerance Value	– – – –	0°C to +400°C * ±4.5°C 400°C to 2320°C ±1.0%	– – – –	Formerly known as Code W3. See technical notes for Type G directly above.

* Codes G, C and D and the tolerance values shown above are not officially recognised symbols or standards.
* Trade names.

Note A
1. The tolerance is expressed either as a deviation in degrees Celsius or as a function of the actual temperature.
2. Thermocouple materials are normally supplied to meet the tolerances specified in the table for temperatures above −40 deg C. These materials however, may not fall within the tolerances for low temperatures given under Class 3 for Types T, E and K thermocouples. If thermocouples are required to meet limits of Class 3, as well as those of Class 1 and/or Class 2, the purchaser should state this, as selection of materials is usually required.

FOR THERMOCOUPLE EXTENSION AND COMPENSATING CABLE COLOURS SEE PAGE 5

degree (see Part 1, Section 2.4). It can thus handle higher temperatures than Type K (1,280°C, and higher for short periods). It is also defined in BS EN 60584.1 Part 8.

Basically, oxidation resistance is superior because of the combination of a higher level of chromium and silicon in the positive Nicrosil conductor. Similarly, a higher level of silicon and magnesium in the negative Nisil conductor form a protective diffusion barrier. The device also shows much improved repeatability in the 300°C to 500°C range where Type K's stability is somewhat lacking (due to hysteresis induced by magnetic and/or structural inhomogeneities). High levels of chromium in the NP conductor, and silicon in the NN conductor provide improved magnetic stability. Beyond this, it does not suffer other long term drift problems associated with transmutation of the high vapour pressure elements in mineral insulated thermocouple assemblies (mainly manganese and aluminium from the KN wire through the magnesium oxide insulant to the KP wire). Transmutation is virtually eliminated since the conductors contain only traces of manganese and aluminium. Finally, since manganese, aluminium and copper are not used in the NN conductor, stability against nuclear bombardment is much better.

Standardised in 1986 as BS EN 60584.1 Part 8, and subsequently published in IEC 60584, this relative newcomer to thermocouple thermometry has even been said to make all other base metal thermocouples (E, J, K and T) obsolete. Another claim by the more enthusiastic manufacturers and distributors is that it provides many of the rare metal thermocouple characteristics, but at base metal costs. In fact, up to a maximum continuous temperature of 1,280°C, depending on service conditions, it can be used in place of Type R and S thermocouples - devices which are between 10 and 20 times the price.

In fact, although adoption of this sensor was slower than many anticipated, now that Nicrobell and similar alloys have been developed, tried and tested for sheathing mineral insulated and metal sheathed Type N thermocouples for higher temperatures, it is seeing ever greater use - and this can only grow. There is now no doubt that it is indeed a fundamentally better thermocouple than its base metal rivals

3.9 Non-Standard Thermocouples

Although there have been many, many thermocouple combinations developed over the years, almost all are no longer available or in use - except for very specialised applications, or for historical reasons. There are, however, four main non-standard types which continue to have their place in thermocouple thermometry.

3.10 Tungsten - Rhenium

There are three primary combinations of this thermocouple. These are: Type G (tungsten vs tungsten-26% rhenium); Type C (tungsten-5% rhenium vs tungsten-26% rhenium); and D (tungsten-3% rhenium vs tungsten-25% rhenium). Of these, the first is certainly the cheapest, but embrittlement can be a problem in the tungsten arm. All can be used up to 2,300°C, and for short periods up to 2,750°C in vacuum, pure hydrogen, or pure inert gases. Above 1,800°C, however, there can be problems with rhenium vaporisation. As for insulators, beryllia and thoria are generally recommended, although again problems can occur at the upper end of the temperature spectrum, with wires and insulators potentially reacting.

3.11 Iridium-40% Rhodium vs Iridium

With a claim to fame of being the only rare metal thermocouple that can be used in air without protection up to 2,000°C (short term only), these devices can also be used in vacuum and inert atmospheres. However, there are no standard reference tables, and users must depend upon the manufacturer for batch calibrations. Also, watch out for embrittlement after use at high temperatures.

3.12 Platinum-40% Rhodium vs Platinum-20% Rhodium

Recommended for use instead of Type B where slightly higher temperature coverage is required, this sensor can be used continuously at up to 1,700°C, and for short term exposure up to 1,850°C. Beyond this, the application rules as described for Type S apply. There are no standard reference tables, but normally batch calibrations are available from the manufacturer.

3.13 Nickel-Chromium vs Gold-0.07% Iron

This is probably the ultimate thermocouple specifically for cryogenics, being designed to measure below 1K, although it fares better at 4K and above. Reference tables have been published by the National Bureau of Standards, but in Europe the negative leg alloy is more commonly gold-0.03% iron.

3.14 IEC 60584.2: Thermocouple Output Tolerances

In practice, thermocouples can't always be made to conform exactly to the published tables. So thermocouple output tolerances for both noble and base metal thermocouples are published as IEC 60584.2, and BS EN 60584.2, and manufacturers provide the sensors to these agreed limits (Table 3.3).

The tolerance values are for thermocouples manufactured from wires normally in the diameter range 0.1 to 3mm, and do not allow for calibration drift during use. Thermocouples other than those listed in these standards are usually supplied with manufacturers' batch tables.

3.15 IEC 60584.3: (BS EN 60584.3) Colour Codes and Tolerances - Extension and Compensating Cable

IEC 60584.3: Extension and compensating cables - Tolerances and Identification Systems provides a common international system for thermocouple wire identification and manufacture, based essentially on thermoelectric emf as opposed to a datum of the emfs of the thermoelements against platinum. Tolerances are defined as the maximum additional deviation in µV caused by the introduction of the extension or compensating cable into a circuit.

Firstly, the scheme does not differentiate between extension and compensating cable on colour. Instead, the letter `X' after the thermocouple type indicates extension cable, while `C' denotes compensating cable. Further, it does not distinguish between the classes of conductor used in extension cable, so specifiers need to be aware of this nicety when making their precise requirements known. Normally, JX Class 1 indicates the tighter tolerance material for a Type J thermocouple, for example, whereas JX Class 2 is more likely to be supplied as standard. For example, Class 1 tolerance for Type K extension cable, KX, is ±60µV, and the cable is restricted to the range -25°C to +200°C. This is equivalent to about ±1.5°C at temperatures above 0°C.

Similarly, with compensating cable, the different alloys used are notified by the final letter - KCA and KCB, for example, indicate Type K thermocouple compensating cable using version A and version B alloys respectively. However, the standard does not define the alloy differences here. KCB is in fact the copper vs constantan combination previously designated `VX'; KCA is the iron vs constantan combination known for so long as WX. Clearly, care needs to be taken lest an old specification like this leads to the mistaken conclusion that the specifier is actually after extension cable (X), not compensating cable. In general, the standard suggests additional information, like the above (and numbers of pairs, conductor cross section, temperature range, manufacturer, etc) to be embossed or printed on cables and cable drums.

Although the IEC specification makes it simpler to understand that these alloys are for the compensation of Type K, the fact that they are not identified more comprehensively can lead to confusion. For example, without the details in Table 3.4, RCA, RCB, SCA and SCB (the compensating cables for Type R and S thermocouples respectively) might appear to be different grades of the same alloy. In fact, RCA/SCA is the older copper vs copper-nickel combination, which is limited to use below 100°C and has a tolerance of ±30µV - equivalent to ±2.5°C with measurements of 1,000°C. RCB/SCB is the modified alloy with more nickel plus manganese, and an extended range to 200°C (the resistivity change is not a problem with potentiometric instruments (see Part 3, Section 2.2)) and tolerance of ±60µV - equivalent to ±5°C at 1,000°C. RCB/SCB has largely replaced the earlier combination; only one alloy is required for Type R and S compensating cables.

The table on page 5 of this publication shows the colour identification scheme adopted. Important points to note are that all the negative legs are white, the insulation of the positive legs are as per the chart, and the sheath (if any) is the same colour as the positive leg - except where intrinsically safe circuits are concerned, where it is always blue.

Type	IEC 60584.3:2007		ANSI MC 96.1 1975		Alloy Combination	Cable Temperature (in °C)
	Class1	Class 2	Class 1	Class2		
JX	±1.5	±2.5	±1.1	±2.2	Iron/Constantan	-25 to 200
TX	±0.5	±1.0	±0.5	±1.0	Copper/Constantan	-25 to 200
EX	±1.5	±2.5	±0.85	±1.7	Nickel Chromium/Constantan	-25 to 200
KX	±1.5	±2.5	±1.1	±2.2	Nickel Chromium/Nickel Aluminium	-25 to 200
NX	±1.5	±2.5	–	–	Nicrosil/Nisil	-25 to 200
KCA (W)	–	±2.5	–	±2.2	Iron/Constantan	0 to 150
KCB (V)	–	±2.5	–	±2.2	Copper/Constantan	0 to 100
NC	–	±2.5	–	±2.2	Copper Nickel Mg/Copper Nickel Mg	0 to 150
RCA (U)	–	±2.5	–	–	Copper/Copper Low Value Nickel	0 to 100
RCB	–	±5.0	–	±5.0	Copper/Copper Nickel Mo	0 to 200
SCA (U)	–	±2.5	–	–	Copper/Copper Low Value Nickel	0 to 100
SCB	–	±5.0	–	±5.0	Copper/Copper Nickel Mo	0 to 200

IMPORTANT NOTE: The cable temperature range refers to conductors only. The usable range may be restricted by the insulation used. Specifiers and users are advised to seek advice from the cable manufacturer. Dashes indicate 'not specified in the standard'.

Table 3.4: *Tolerances IEC 60584.3 vs ANSI MC 96.2 (1975) and (omitted by IEC 60584.3) a Guide to Alloy Combinations*

Types	Tolerance class 1	Tolerance class 2	Tolerance class 3[1)]
Type T			
Temperature range	-40°C to +125 °C	-40°C to +133°C	-67°C to +40 °C
Tolerance value	±0,5°C	±1°C	±1°C
Temperature range	+125°C to +350 °C	+133°C to +350°C	-200°C to -67 °C
Tolerance value	±0,004 · |t|	±0,0075 · |t|	±0,015 · |t|
Type E			
Temperature range	-40°C to +375 °C	-40°C to +333°C	-167°C to +40 °C
Tolerance value	±1,5°C	±2,5°C	±2,5°C
Temperature range	+375°C to +800 °C	+333°C to +900°C	-200°C to -167 °C
Tolerance value	±0,004 · |t|	±0,0075 · |t|	±0,015 · |t|
Type J			
Temperature range	-40°C to +375 °C	-40°C to +333°C	-
Tolerance value	±1,5°C	±2,5°C	-
Temperature range	+375°C to +750 °C	+333°C to +750°C	-
Tolerance value	±0,004 · |t|	±0,0075 · |t|	-
Type K, Type N			
Temperature range	-40°C to +375 °C	-40°C to +333°C	-167°C to +40 °C
Tolerance value	±1,5°C	±2,5°C	±2,5°C
Temperature range	+375°C to +1000 °C	+333°C to +1200°C	-200°C to -167 °C
Tolerance value	±0,004 · |t|	±0,0075 · |t|	±0,015 · |t|
Type R, Type S			
Temperature range	0°C to +1100 °C	0°C to +600°C	-
Tolerance value	±1°C	±1,5°C	-
Temperature range	+1100°C to +1600 °C	+600°C to +1600°C	-
Tolerance value	±[1 + 0,003 (t -1100)] °C	±0,0025 · |t|	-
Type B			
Temperature range	-	-	+600°C to +800 °C
Tolerance value	-	-	+4°C
Temperature range	-	+600°C to +1700°C	+800°C to +1700 °C
Tolerance value	-	±0,0025 · |t|	±0,005 · |t|

1) Thermocouple materials are normally supplied to meet the manufacturing tolerances specified in the table for temperatures above –40°C. These materials, however, may not fall within the manufacturing tolerances for low temperatures given under Class 3 for Types T, E, K and N. If thermocouples are required to meet limits of class 3, as well as those of Class 1 or 2 the purchaser shall state this, as selection of materials is usually required.

Table 3.3: *Thermocouple Tolerances According to BS EN 60584.2 (reference junction at 0°C)*

Continued on page 9

3.16 Power Series Expansions and Polynomials

In several thermocouple applications involving the use of microprocessor-based instrumentation of all sorts, reference tables cease to be a practical data source. And, in these cases, with the kind of computing power readily available, computer models of the emf/temperature relationship are often used - being preferable to the look-up table alternative approach (Table 3.5).

BS EN 60584.1 does give the polynomial functions from which the table data was derived, but these contain between four and fourteen terms, with constants given to eleven significant figures which cannot be sensibly truncated. Fortunately, the National Physical Laboratory has prepared reports giving simplified forward and inverse functions to the standard reference tables which are accurate to approximately 0.1°C. These are available from the National Physical Laboratory as reports QU36 and QU46.

Power Series Expansions and Polynomials:

For computer applications the following expressions are given for the commonly used thermocouple conductor combinations.
Resultant errors from their use will be less than the last significant digit as per the thermocouple reference tables included in this publication.

K	T	J	N	E	R	S	B
Temperature Range **-270°C to 0°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 3.945 012 802 5 x 10^{1} a_2 = 2,362 237 359 8 x 10^{-2} a_3 = –3.285 890 678 4 x 10^{-4} a_4 = –4.990 482 877 7 x 10^{-6} a_5 = –6.750 905 917 3 x 10^{-8} a_6 = –5.741 032 742 8 x 10^{-10} a_7 = –3.108 887 289 4 x 10^{-12} a_8 = –1.045 160 936 5 x 10^{-14} a_9 = –1.988 926 687 8 x 10^{-17} a_{10} = –1.632 269 748 6 x 10^{-20} **0°C to 1372°C** $E = b_0 + \sum_{i=1}^{n} b_i (t_{90})^i + c_0 \exp[c_1 (t_{90} - 126.9686)^2]$ µV **where** b_0 = –1.760 041 368 6 x 10^{1} b_1 = 3.892 120 497 5 x 10^{1} b_2 = 1.855 877 003 2 x 10^{-2} b_3 = –9.945 759 287 4 x 10^{-5} b_4 = 3.184 094 571 9 x 10^{-7} b_5 = –5.607 284 488 9 x 10^{-10} b_6 = 5.607 505 905 9 x 10^{-13} b_7 = –3.202 072 000 3 x 10^{-16} b_8 = 9.715 114 715 2 x 10^{-20} b_9 = –1.210 472 127 5 x 10^{-23} c_0 = 1.185 976 x 10^{2} c_1 = –1.183 432 x 10^{-4}	**Temperature Range** **-270°C to 0°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 3.874 810 636 4 x 10^{1} a_2 = 4.419 443 434 7 x 10^{-2} a_3 = 1.184 432 310 5 x 10^{-4} a_4 = 2.003 297 355 4 x 10^{-5} a_5 = 9.013 801 955 9 x 10^{-7} a_6 = 2.265 115 659 3 x 10^{-8} a_7 = 3.607 115 420 5 x 10^{-10} a_8 = 3.849 393 988 3 x 10^{-12} a_9 = 2.821 352 192 5 x 10^{-14} a_{10} = 1.425 159 477 9 x 10^{-16} a_{11} = 4.876 866 228 6 x 10^{-19} a_{12} = 1.079 553 927 0 x 10^{-21} a_{13} = 1.394 502 706 2 x 10^{-24} a_{14} = 7.979 515 392 7 x 10^{-28} **0°C to 400°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 3.874 810 636 4 x 10^{1} a_2 = 3.329 222 788 0 x 10^{-2} a_3 = 2.061 824 340 4 x 10^{-4} a_4 = –2.188 225 684 6 x 10^{-6} a_5 = 1.099 688 092 8 x 10^{-8} a_6 = –3.081 575 877 2 x 10^{-11} a_7 = 4.547 913 529 0 x 10^{-14} a_8 = –2.751 290 167 3 x 10^{-17}	**Temperature Range** **-210°C to 760°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 5.038 118 781 5 x 10^{1} a_2 = 3.047 583 693 0 x 10^{-2} a_3 = –8.568 106 572 0 x 10^{-5} a_4 = 1.322 819 529 5 x 10^{-7} a_5 = –1.705 295 833 7 x 10^{-10} a_6 = 2.094 809 069 7 x 10^{-13} a_7 = –1.253 839 533 6 x 10^{-16} a_8 = 1.563 172 569 7 x 10^{-20} **760°C to 1200°C** $E = \sum_{i=0}^{n} a_i (t_{90})^i$ µV **where** a_0 = 2.964 562 568 1 x 10^{5} a_1 = –1.497 612 778 6 x 10^{3} a_2 = 3.178 710 392 4 a_3 = –3.184 768 670 1 x 10^{-3} a_4 = 1.572 081 900 4 x 10^{-6} a_5 = –3.069 136 905 6 x 10^{-10}	**Temperature Range** **-270°C to 0°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 2.615 910 596 2 x 10^{1} a_2 = 1.095 748 422 8 x 10^{-2} a_3 = –9.384 111 155 4 x 10^{-5} a_4 = –4.641 203 975 9 x 10^{-8} a_5 = –2.630 335 771 6 x 10^{-9} a_6 = –2.265 343 800 3 x 10^{-11} a_7 = –7.608 930 079 1 x 10^{-14} a_8 = –9.341 966 783 5 x 10^{-17} **0°C to 1300°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 2.592 939 460 1 x 10^{1} a_2 = 1.571 014 188 0 x 10^{-2} a_3 = 4.382 562 723 7 x 10^{-5} a_4 = –2.526 116 979 4 x 10^{-7} a_5 = 6.431 181 933 9 x 10^{-10} a_6 = –1.006 347 151 9 x 10^{-12} a_7 = 9.974 533 899 2 x 10^{-16} a_8 = –6.086 324 560 7 x 10^{-19} a_9 = 2.084 922 933 9 x 10^{-22} a_{10} = –3.068 219 615 1 x 10^{-26}	**Temperature Range** **-270°C to 0°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 5.866 550 870 8 x 10^{1} a_2 = 4.541 097 712 4 x 10^{-2} a_3 = –7.799 804 868 6 x 10^{-4} a_4 = –2.580 016 084 3 x 10^{-5} a_5 = –5.945 258 305 7 x 10^{-7} a_6 = –9.321 405 866 7 x 10^{-9} a_7 = –1.028 760 553 4 x 10^{-10} a_8 = –8.037 012 362 1 x 10^{-13} a_9 = –4.397 949 739 1 x 10^{-15} a_{10} = –1.641 477 635 5 x 10^{-17} a_{11} = –3.967 361 951 6 x 10^{-20} a_{12} = –5.582 732 872 1 x 10^{-23} a_{13} = –3.465 784 201 3 x 10^{-26} **0°C to 1000°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 5.866 550 871 0 x 10^{1} a_2 = 4.503 227 558 2 x 10^{-2} a_3 = 2.890 840 721 2 x 10^{-5} a_4 = –3.305 689 665 2 x 10^{-7} a_5 = 6.502 440 327 0 x 10^{-10} a_6 = –1.919 749 550 4 x 10^{-13} a_7 = –1.253 660 049 7 x 10^{-15} a_8 = 2.148 921 756 9 x 10^{-18} a_9 = –1.438 804 178 2 x 10^{-21} a_{10} = 3.596 089 948 1 x 10^{-25}	**Temperature Range** **-50°C to 1064,18°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 5.289 617 297 65 a_2 = 1.391 665 897 82 x 10^{-2} a_3 = –2.388 556 930 17 x 10^{-5} a_4 = 3.569 160 010 63 x 10^{-8} a_5 = –4.623 476 662 98 x 10^{-11} a_6 = 5.007 774 410 34 x 10^{-14} a_7 = –3.731 058 861 91 x 10^{-17} a_8 = 1.577 164 823 67 x 10^{-20} a_9 = –2.810 386 252 51 x 10^{-24} **1064,18°C to 1664,5°C** $E = \sum_{i=0}^{n} a_i (t_{90})^i$ µV **where** a_0 = 2.951 579 253 16 x 10^{3} a_1 = –2.520 612 513 32 a_2 = 1.595 645 018 65 x 10^{-2} a_3 = –7.640 859 475 76 x 10^{-6} a_4 = 2.053 052 910 24 x 10^{-9} a_5 = –2.933 596 681 73 x 10^{-13} **1664,5°C to 1768,1°C** $E = \sum_{i=0}^{n} a_i (t_{90})^i$ µV **where** a_0 = 1.522 321 182 09 x 10^{5} a_1 = –2.688 198 885 45 x 10^{2} a_2 = 1.712 802 804 71 x 10^{-1} a_3 = –3.458 957 064 53 x 10^{-5} a_4 = –9.346 339 710 46 x 10^{-12}	**Temperature Range** **-50°C to 1064,18°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = 5.403 133 086 31 a_2 = 1.259 342 897 40 x 10^{-2} a_3 = –2.324 779 686 89 x 10^{-5} a_4 = 3.220 288 230 36 x 10^{-8} a_5 = –3.314 651 963 89 x 10^{-11} a_6 = 2.557 442 517 86 x 10^{-14} a_7 = –1.250 688 713 93 x 10^{-17} a_8 = 2.714 431 761 45 x 10^{-21} **1064,18C to 1664,5°C** $E = \sum_{i=0}^{n} a_i (t_{90})^i$ µV **where** a_0 = 1.329 004 440 85 x 10^{3} a_1 = 3.345 093 113 44 a_2 = 6.548 051 928 18 x 10^{-3} a_3 = –1.648 562 592 09 x 10^{-6} a_4 = 1.299 896 051 74 x 10^{-11} **1664,5°C to 1768,1°C** $E = \sum_{i=0}^{n} a_i (t_{90})^i$ µV **where** a_0 = 1.466 282 326 36 x 10^{5} a_1 = –2.584 305 167 52 x 10^{2} a_2 = 1.636 935 746 41 x 10^{-1} a_3 = –3.304 390 469 87 x 10^{-5} a_4 = –9.432 236 906 12 x 10^{-12}	**Temperature Range** **0°C to 630.615°C** $E = \sum_{i=1}^{n} a_i (t_{90})^i$ µV **where** a_1 = –2.465 081 834 6 x 10^{-1} a_2 = 5.904 042 117 1 x 10^{-3} a_3 = –1.325 793 163 6 x 10^{-6} a_4 = 1.566 829 190 1 x 10^{-9} a_5 = –1.694 452 924 0 x 10^{-12} a_6 = 6.299 034 709 4 x 10^{-16} **630.615°C to 1820°C** $E = \sum_{i=0}^{n} a_i (t_{90})^i$ µV **where** a_0 = –3.893 816 862 1 x 10^{3} a_1 = 2.857 174 747 0 x 10^{1} a_2 = –8.488 510 478 5 x 10^{-2} a_3 = 1.578 528 016 4 x 10^{-4} a_4 = –1.683 534 486 4 x 10^{-7} a_5 = 1.110 979 401 3 x 10^{-10} a_6 = –4.451 543 103 3 x 10^{-14} a_7 = 9.897 564 082 1 x 10^{-18} a_8 = –9.379 133 028 9 x 10^{-22}

Table 3.5: *Expressions for the Standard Thermocouples According to BS EN 60584.1*

4.0 Resistance Thermometer Detectors (RTD's)

The resistance that an electrical conductor exhibits to the flow of an electric current is related to its temperature, essentially because of electron scattering effects and atomic lattice vibrations. The basis of this theory is that free electrons travel through the metal as plane waves modified by a function having the periodicity of the crystal lattice. The only little snag here is that impurities and what are termed lattice defects can also result in scattering, giving resistance variations. Fortunately, however, this effect is largely temperature-independent, so does not pose too much of a problem; we just need to be aware of it.

In fact, the concept of detecting temperature using resistance is considerably easier to work with in practice than is thermocouple thermometry. Firstly, the measurement is absolute, so no reference junction or cold junction compensation is required. Secondly, straightforward copper wires can be used between the sensor and your instrumentation since there are no special requirements in this respect. However, there's more to it than this (for a full comparison see Part 3, Section 1).

The first recorded proposal to use the temperature dependence of resistance for sensing was made in the 1860's by Sir William Siemens, and thermometers based on the effect were manufactured for a while from about 1870. However, although he used platinum (the most widely used material in RTD thermometry today), the interpolation formulae derived were inadequate. Also, instability was a problem due mainly to his construction methods - harnessing a refractory former inside an iron tube, resulting in differential expansion and platinum strain and contamination problems. Callendar took up the reins in 1887, but it was not until 1899 that the difficulties were ironed out and the use of platinum resistance thermometers was established.

Basically, it is now accepted that as long as the temperature relationship with resistance is predictable, smooth and stable, the phenomenon can indeed be used for temperature measurement. But for this to be true, the resistance effects due to impurities must be small - as is the case with some of the pure metals whose resistance is almost entirely dependent on temperature. Beyond this, however, since in thermometry almost entirely is not good enough, the impurity-related resistance must also be (for all practical purposes) constant - such that it can be ignored. This means that physical and chemical composition must be kept constant. An important requirement for accurate resistance thermometry, therefore, is that the sensing element must be pure. It must also be, and remain, in an annealed condition, via suitable heat treatment of the materials such that it is not inclined to change physically. Then again, it must be kept in an environment protected from contamination - so that chemical changes are indeed obviated.

Meanwhile, another challenge for the manufacturer is to support the fine, pure wire adequately, while imposing minimum strains due to differential expansion between the wire and its surroundings or former - even though the sensors may be attached to operating plant, with all the rigours of this characteristically arduous environment. Depending upon the accuracy you are after, the relationship governing platinum resistance thermometer output against temperature follows the quadratic equation:

$R_t/R_0 = 1 + At + Bt^2$
(above 0°C this second order approach is more than adequate)
or $R_t/R_0 = 1 + At + Bt^2 + Ct^3(t-100)$
(below 0°C, if you are looking for higher accuracy of representation, the third order provides it).

Therefore:

$t = (1/\alpha)(R_t - R_0)/R_0 + \delta(t/100)(t/100 - 1)$

Where: R_t is the thermometer resistance at temperature t; R_0 is the thermometer resistance at 0°C; and t is the temperature in °C. A, B and C are constants (coefficients) determined by calibration. In the IEC 60751 industrial RTD standard, A is 3.90802 x 10^{-3}; B is -5.802 x 10^{-7}; and C is -4.2735 x 10^{-12}. Incidentally, since even this three term representation is imperfect, the ITS-90 scale introduces a further reference function with a set of deviation equations for use over the full practical temperature range above 0°C (a 20 term polynomial).

The α coefficient, $(R_{100} - R_0)/100 \cdot R_0$, essentially defines purity and state of anneal of the platinum, and is basically the mean temperature coefficient of resistance between 0 and 100°C (the mean slope of the resistance vs temperature curve in that region). Meanwhile, δ is the coefficient describing the departure from linearity in the same range. It depends upon the thermal expansion and the density of states curve near the Fermi energy. In fact, both quantities depend upon the purity of the platinum wire. For high purity platinum in a fully annealed state the α coefficient is between 3.925x10^{-3}/°C and 3.928x10^{-3}/°C.

For commercially produced platinum resistance thermometers, standard tables of resistance versus temperature have been produced based on an R value of 100 ohms at 0°C and a fundamental interval $(R_{100} - R_0)$ of 38.5 ohms (α coefficient of 3.85x10^{-3}/°C) using pure platinum doped with another metal (see Part 2, Section 6). The tables are available in IEC 60751: 1983, tolerance classes A and B (BS EN 60751: 1996) (see the temperature vs resistance characteristics and tolerances for PRT detectors according to IEC 60751 in this guide).

4.1 RTD Materials

Several materials are available to fulfil the basic requirements of providing a predictable, smooth and stable temperature with resistance relationship. They include copper, gold, nickel, platinum and silver. Of these, copper, gold and silver have inherently low electrical resistivity values, making them less suitable for resistance thermometry - although copper does exhibit an almost linear resistance relationship against temperature.

In fact, because of this and its low price, copper is used in some applications, with the caveat that above moderate temperatures it is prone to oxidation, and is generally not all that stable or repeatable. This notwithstanding, it can come into its own in applications where average temperatures over a long stem length are required, especially within the range -100°C to +180°C.

Nickel and nickel alloys are also relatively low cost, and have high resistivities and high resistance versus temperature coefficients, making them very sensitive.

However, they suffer from being non-linear with temperature and sensitive to strain. They also exhibit an unfortunate inflexion around the Curie point (358°C) which makes the derivation of the resistance to temperature expressions rather more complicated. These materials are therefore restricted to the temperature range of about -100°C to +180°C.

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CODE **K**

International Thermocouple Reference Tables for
Nickel Chromium / Nickel Aluminium
To IEC60584.1:1995 / BS EN 60584.1 Part 4 : 1996

CODE **K**

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (μV).

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-270	-6458										-270
-260	-6441	-6444	-6446	-6448	-6450	-6452	-6453	-6455	-6456	-6457	-260
-250	-6404	-6408	-6413	-6417	-6421	-6425	-6429	-6432	-6435	-6438	-250
-240	-6344	-6351	-6358	-6364	-6370	-6377	-6382	-6388	-6393	-6399	-240
-230	-6262	-6271	-6280	-6289	-6297	-6306	-6314	-6322	-6329	-6337	-230
-220	-6158	-6170	-6181	-6192	-6202	-6213	-6223	-6233	-6243	-6252	-220
-210	-6035	-6048	-6061	-6074	-6087	-6099	-6111	-6123	-6135	-6147	-210
-200	-5891	-5907	-5922	-5936	-5951	-5965	-5980	-5994	-6007	-6021	-200
-190	-5730	-5747	-5763	-5780	-5797	-5813	-5829	-5845	-5861	-5876	-190
-180	-5550	-5569	-5588	-5606	-5624	-5642	-5660	-5678	-5695	-5713	-180
-170	-5354	-5374	-5395	-5415	-5435	-5454	-5474	-5493	-5512	-5531	-170
-160	-5141	-5163	-5185	-5207	-5228	-5250	-5271	-5292	-5313	-5333	-160
-150	-4913	-4936	-4960	-4983	-5006	-5029	-5052	-5074	-5097	-5119	-150
-140	-4669	-4694	-4719	-4744	-4768	-4793	-4817	-4841	-4865	-4889	-140
-130	-4411	-4437	-4463	-4490	-4516	-4542	-4567	-4593	-4618	-4644	-130
-120	-4138	-4166	-4194	-4221	-4249	-4276	-4303	-4330	-4357	-4384	-120
-110	-3852	-3882	-3911	-3939	-3968	-3997	-4025	-4054	-4082	-4110	-110
-100	-3554	-3584	-3614	-3645	-3675	-3705	-3734	-3764	-3794	-3823	-100
-90	-3243	-3274	-3306	-3337	-3368	-3400	-3431	-3462	-3492	-3523	-90
-80	-2920	-2953	-2986	-3018	-3050	-3083	-3115	-3147	-3179	-3211	-80
-70	-2587	-2620	-2654	-2688	-2721	-2755	-2788	-2821	-2854	-2887	-70
-60	-2243	-2278	-2312	-2347	-2382	-2416	-2450	-2485	-2519	-2553	-60
-50	-1889	-1925	-1961	-1996	-2032	-2067	-2103	-2138	-2173	-2208	-50
-40	-1527	-1564	-1600	-1637	-1673	-1709	-1745	-1782	-1818	-1854	-40
-30	-1156	-1194	-1231	-1268	-1305	-1343	-1380	-1417	-1453	-1490	-30
-20	-778	-816	-854	-892	-930	-968	-1006	-1043	-1081	-1119	-20
-10	-392	-431	-470	-508	-547	-586	-624	-663	-701	-739	-10
-0	0	-39	-79	-118	-157	-197	-236	-275	-314	-353	0
0	0	39	79	119	158	198	238	277	317	357	0
10	397	437	477	517	557	597	637	677	718	758	10
20	798	838	879	919	960	1000	1041	1081	1122	1163	20
30	1203	1244	1285	1326	1366	1407	1448	1489	1530	1571	30
40	1612	1653	1694	1735	1776	1817	1858	1899	1941	1982	40
50	2023	2064	2106	2147	2188	2230	2271	2312	2354	2395	50
60	2436	2478	2519	2561	2602	2644	2685	2727	2768	2810	60
70	2851	2893	2934	2976	3017	3059	3100	3142	3184	3225	70
80	3267	3308	3350	3391	3433	3474	3516	3557	3599	3640	80
90	3682	3723	3765	3806	3848	3889	3931	3972	4013	4055	90
100	4096	4138	4179	4220	4262	4303	4344	4385	4427	4468	100
110	4509	4550	4591	4633	4674	4715	4756	4797	4838	4879	110
120	4920	4961	5002	5043	5084	5124	5165	5206	5247	5288	120
130	5328	5369	5410	5450	5491	5532	5572	5613	5653	5694	130
140	5735	5775	5815	5856	5896	5937	5977	6017	6058	6098	140
150	6138	6179	6219	6259	6299	6339	6380	6420	6460	6500	150
160	6540	6580	6620	6660	6701	6741	6781	6821	6861	6901	160
170	6941	6981	7021	7060	7100	7140	7180	7220	7260	7300	170
180	7340	7380	7420	7460	7500	7540	7579	7619	7659	7699	180
190	7739	7779	7819	7859	7899	7939	7979	8019	8059	8099	190
200	8138	8178	8218	8258	8298	8338	8378	8418	8458	8499	200
210	8539	8579	8619	8659	8699	8739	8779	8819	8860	8900	210
220	8940	8980	9020	9061	9101	9141	9181	9222	9262	9302	220
230	9343	9383	9423	9464	9504	9545	9585	9626	9666	9707	230
240	9747	9788	9828	9869	9909	9950	9991	10031	10072	10113	240
250	10153	10194	10235	10276	10316	10357	10398	10439	10480	10520	250
260	10561	10602	10643	10684	10725	10766	10807	10848	10889	10930	260
270	10971	11012	11053	11094	11135	11176	11217	11259	11300	11341	270
280	11382	11423	11465	11506	11547	11588	11630	11671	11712	11753	280
290	11795	11836	11877	11919	11960	12001	12043	12084	12126	12167	290

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
300	12209	12250	12291	12333	12374	12416	12457	12499	12540	12582	300
310	12624	12665	12707	12748	12790	12831	12873	12915	12956	12998	310
320	13040	13081	13123	13165	13206	13248	13290	13331	13373	13415	320
330	13457	13498	13540	13582	13624	13665	13707	13749	13791	13833	330
340	13874	13916	13958	14000	14042	14084	14126	14167	14209	14251	340
350	14293	14335	14377	14419	14461	14503	14545	14587	14629	14671	350
360	14713	14755	14797	14839	14881	14923	14965	15007	15049	15091	360
370	15133	15175	15217	15259	15301	15343	15385	15427	15469	15511	370
380	15554	15596	15638	15680	15722	15764	15806	15849	15891	15933	380
390	15975	16017	16059	16102	16144	16186	16228	16270	16313	16355	390
400	16397	16439	16482	16524	16566	16608	16651	16693	16735	16778	400
410	16820	16862	16904	16947	16989	17031	17074	17116	17158	17201	410
420	17243	17285	17328	17370	17413	17455	17497	17540	17582	17624	420
430	17667	17709	17752	17794	17837	17879	17921	17964	18006	18049	430
440	18091	18134	18176	18218	18261	18303	18346	18388	18431	18473	440
450	18516	18558	18601	18643	18686	18728	18771	18813	18856	18898	450
460	18941	18983	19026	19068	19111	19154	19196	19239	19281	19324	460
470	19366	19409	19451	19494	19537	19579	19622	19664	19707	19750	470
480	19792	19835	19877	19920	19962	20005	20048	20090	20133	20175	480
490	20218	20261	20303	20346	20389	20431	20474	20516	20559	20602	490
500	20644	20687	20730	20772	20815	20857	20900	20943	20985	21028	500
510	21071	21113	21156	21199	21241	21284	21326	21369	21412	21454	510
520	21497	21540	21582	21625	21668	21710	21753	21796	21838	21881	520
530	21924	21966	22009	22052	22094	22137	22179	22222	22265	22307	530
540	22350	22393	22435	22478	22521	22563	22606	22649	22691	22734	540
550	22776	22819	22862	22904	22947	22990	23032	23075	23117	23160	550
560	23203	23245	23288	23331	23373	23416	23458	23501	23544	23586	560
570	23629	23671	23714	23757	23799	23842	23884	23927	23970	24012	570
580	24055	24097	24140	24182	24225	24267	24310	24353	24395	24438	580
590	24480	24523	24565	24608	24650	24693	24735	24778	24820	24863	590
600	24905	24948	24990	25033	25075	25118	25160	25203	25245	25288	600
610	25330	25373	25415	25458	25500	25543	25585	25627	25670	25712	610
620	25755	25797	25840	25882	25924	25967	26009	26052	26094	26136	620
630	26179	26221	26263	26306	26348	26390	26433	26475	26517	26560	630
640	26602	26644	26687	26729	26771	26814	26856	26898	26940	26983	640
650	27025	27067	27109	27152	27194	27236	27278	27320	27363	27405	650
660	27447	27489	27531	27574	27616	27658	27700	27742	27784	27826	660
670	27869	27911	27953	27995	28037	28079	28121	28163	28205	28247	670
680	28289	28332	28374	28416	28458	28500	28542	28584	28626	28668	680
690	28710	28752	28794	28835	28877	28919	28961	29003	29045	29087	690
700	29129	29171	29213	29255	29297	29338	29380	29422	29464	29506	700
710	29548	29589	29631	29673	29715	29757	29798	29840	29882	29924	710
720	29965	30007	30049	30090	30132	30174	30216	30257	30299	30341	720
730	30382	30424	30466	30507	30549	30590	30632	30674	30715	30757	730
740	30798	30840	30881	30923	30964	31006	31047	31089	31130	31172	740
750	31213	31255	31296	31338	31379	31421	31462	31504	31545	31586	750
760	31628	31669	31710	31752	31793	31834	31876	31917	31958	32000	760
770	32041	32082	32124	32165	32206	32247	32289	32330	32371	32412	770
780	32453	32495	32536	32577	32618	32659	32700	32742	32783	32824	780
790	32865	32906	32947	32988	33029	33070	33111	33152	33193	33234	790
800	33275	33316	33357	33398	33439	33480	33521	33562	33603	33644	800
810	33685	33726	33767	33808	33848	33889	33930	33971	34012	34053	810
820	34093	34134	34175	34216	34257	34297	34338	34379	34420	34460	820
830	34501	34542	34582	34623	34664	34704	34745	34786	34826	34867	830
840	34908	34948	34989	35029	35070	35110	35151	35192	35232	35273	840
850	35313	35354	35394	35435	35475	35516	35556	35596	35637	35677	850
860	35718	35758	35798	35839	35879	35920	35960	36000	36041	36081	860
870	36121	36162	36202	36242	36282	36323	36363	36403	36443	36484	870
880	36524	36564	36604	36644	36685	36725	36765	36805	36845	36885	880
890	36925	36965	37006	37046	37086	37126	37166	37206	37246	37286	890

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
900	37326	37366	37406	37446	37486	37526	37566	37606	37646	37686	900
910	37725	37765	37805	37845	37885	37925	37965	38005	38044	38084	910
920	38124	38164	38204	38243	38283	38323	38363	38402	38442	38482	920
930	38522	38561	38601	38641	38680	38720	38760	38799	38839	38878	930
940	38918	38958	38997	39037	39076	39116	39155	39195	39235	39274	940
950	39314	39353	39393	39432	39471	39511	39550	39590	39629	39669	950
960	39708	39747	39787	39826	39866	39905	39944	39984	40023	40062	960
970	40101	40141	40180	40219	40259	40298	40337	40376	40415	40455	970
980	40494	40533	40572	40611	40651	40690	40729	40768	40807	40846	980
990	40885	40924	40963	41002	41042	41081	41120	41159	41198	41237	990
1000	41276	41315	41354	41393	41431	41470	41509	41548	41587	41626	1000
1010	41665	41704	41743	41781	41820	41859	41898	41937	41976	42014	1010
1020	42053	42092	42131	42169	42208	42247	42286	42324	42363	42402	1020
1030	42440	42479	42518	42556	42595	42633	42672	42711	42749	42788	1030
1040	42826	42865	42903	42942	42980	43019	43057	43096	43134	43173	1040
1050	43211	43250	43288	43327	43365	43403	43442	43480	43518	43557	1050
1060	43595	43633	43672	43710	43748	43787	43825	43863	43901	43940	1060
1070	43978	44016	44054	44092	44130	44169	44207	44245	44283	44321	1070
1080	44359	44397	44435	44473	44512	44550	44588	44626	44664	44702	1080
1090	44740	44778	44816	44853	44891	44929	44967	45005	45043	45081	1090
1100	45119	45157	45194	45232	45270	45308	45346	45383	45421	45459	1100
1110	45497	45534	45572	45610	45647	45685	45723	45760	45798	45836	1110
1120	45873	45911	45948	45986	46024	46061	46099	46136	46174	46211	1120
1130	46249	46286	46324	46361	46398	46436	46473	46511	46548	46585	1130
1140	46623	46660	46697	46735	46772	46809	46847	46884	46921	46958	1140
1150	46995	47033	47070	47107	47144	47181	47218	47256	47293	47330	1150
1160	47367	47404	47441	47478	47515	47552	47589	47626	47663	47700	1160
1170	47737	47774	47811	47848	47884	47921	47958	47995	48032	48069	1170
1180	48105	48142	48179	48216	48252	48289	48326	48363	48399	48436	1180
1190	48473	48509	48546	48582	48619	48656	48692	48729	48765	48802	1190
1200	48838	48875	48911	48948	48984	49021	49057	49093	49130	49166	1200
1210	49202	49239	49275	49311	49348	49384	49420	49456	49493	49529	1210
1220	49565	49601	49637	49674	49710	49746	49782	49818	49854	49890	1220
1230	49926	49962	49998	50034	50070	50106	50142	50178	50214	50250	1230
1240	50286	50322	50358	50393	50429	50465	50501	50537	50572	50608	1240
1250	50644	50680	50715	50751	50787	50822	50858	50894	50929	50965	1250
1260	51000	51036	51071	51107	51142	51178	51213	51249	51284	51320	1260
1270	51355	51391	51426	51461	51497	51532	51567	51603	51638	51673	1270
1280	51708	51744	51779	51814	51849	51885	51920	51955	51990	52025	1280
1290	52060	52095	52130	52165	52200	52235	52270	52305	52340	52375	1290
1300	52410	52445	52480	52515	52550	52585	52620	52654	52689	52724	1300
1310	52759	52794	52828	52863	52898	52932	52967	53002	53037	53071	1310
1320	53106	53140	53175	53210	53244	53279	53313	53348	53382	53417	1320
1330	53451	53486	53520	53555	53589	53623	53658	53692	53727	53761	1330
1340	53795	53830	53864	53898	53932	53967	54001	54035	54069	54104	1340
1350	54138	54172	54206	54240	54274	54308	54343	54377	54411	54445	1350
1360	54479	54513	54547	54581	54615	54649	54683	54717	54751	54785	1360
1370	54819	54852	54886								1370

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G**, **C** & **D** page 70	

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

This, of course, leaves platinum, which has considerable advantages that make it well suited to resistance thermometry. Firstly, being a noble metal, it has a wide, unreactive temperature range. Secondly, its resistivity is more than six times that of copper. Thirdly, it has a reasonable, simple and well understood, although not entirely linear, resistance vs temperature relationship. Fourthly, it can be obtained in a very pure form, and drawn into fine wires or strips very reproducibly, making the production of interchangeable detectors relatively easy.

Although platinum is not cheap, only very small amounts are needed for resistance thermometer construction - and its expense is therefore not a significant factor in calculating the overall cost. On the down side, it is contaminated by a number of materials, particularly when heated, so support and sheath materials have to be chosen carefully. Furthermore, heat treatment of the material is particularly important in view of the presence of vacancy defects which are present at all temperatures unless annealed out.

Beyond these materials, molybdenum film resistors are available, with useful, stable ranges around the -50 to +200°C mark. Semiconductor materials, like thermistors made from various metal oxides, are also available, which, with the advent of better manufacturing methods and improved linearisers, can cover a very wide temperature range. However, no standardisation of these devices has been achieved, and they are beyond the scope of this guide.

Meanwhile, there is a place for germanium RTD's below 100K, and especially 10K where the resistivity of platinum is too small for practical purposes. However, the resistance/temperature relationship is not exactly trivial - and neither is calibration. Then we get into the realms of carbon-glass RTD's which exhibit negative temperature coefficients and high sensitivity at very low temperatures. Beyond this, there is the rhodium-iron alloy for temperatures right down to 0.5K.

4.2 RTD Self-Heating Effects

In order to measure the resistance of a platinum resistance thermometer, an electric current has to be passed through the sensor. However, ironically, in doing so the passage of the current produces a heating effect - and the temperature of the thermometer element is raised slightly above the equilibrium of the surroundings it is trying to measure. This is known as self heating.

Clearly, self-heating effects will tend to become more significant when, for example, slow moving gas streams are being measured, as opposed to fast flowing liquids, where the heat transfer away from the sensor will render the effect negligible. To give an idea of how great this effect is, for an industrial style RTD immersed in water at the ice point, the effect of 1mA on a standard 100 ohm resistor will be about 20mK. In still air, it would be say 50mK; but move the current up to 3mA and the error is 0.5K. Heat generated in the RTD is directly proportional to the sensor resistance and to the square of the applied current. Meanwhile, the temperature rise is dependent not only upon the quantity of heat generated, but also the size and construction of the sensor as well as the nature of the thermal contact between it and the surrounding medium. Thus, by making thermal contact between the sensor wire and sheath as good as possible and similarly ensuring good contact of the sheath with the outside surroundings, the effect is minimised. Likewise, the energising current needs to be minimised whilst still providing adequate sensitivity.

Incidentally, it is sometimes possible to quantify the error in temperature determination arising from these self-heating effects. Basically, the resistance of the RTD is measured at constant temperature with two energising currents; resistance values are then plotted against the square of the currents, and the line extrapolated to indicate the resistance value at zero current.

4.3 IEC 60751: RTD Standards and Tolerances

For the purposes of the IEC 60751: 1983 (BS EN 60751: 1996) standard, the RTD itself comprises the sensing resistor within its protective sheath (if applicable), internal connecting wires and external terminals for onward connection. Mounting equipment and connection heads can also be included. IEC 60751 actually applies to industrial devices, primarily sheathed, over the temperature range -200°C to 850°C, and offers two tolerance classes, A and B - these defining the maximum deviation in degrees Celsius from the nominal temperature relationship table figures. Class A RTD's can show deviation of ±0.06 ohms (±0.15°C) at 0°C, while Class B sensors can be within ±0.12 ohms (±0.3°C) at 0°C.

Standard thermometers are constructed from platinum having an α coefficient of 3.85 x 10^{-3}/°C, and have nominal resistances of 100 ohms or 10 ohms at 0°C, the latter harnessing heavier gauge wire, and being aimed at use in the range above 600°C. With 100 ohm devices, Class A only applies up to 650°C; also the A classification is not applicable to two wire devices (see Part 3, Section 3). Clearly, devices which conform to the standard as defined can be interchanged - always useful! See the reference and tolerance tables in this Guide.

The standard also covers a range of other factors - but not construction. For example, the RTD's have to be suitable for DC and AC current measuring systems - the latter up to 500Hz. So there are certain inductance and coupling constraints on design. Insulation resistance, response times, self-heating effects, immersion errors, thermo-electric effects, tests for temperature limits and temperature cycling, mechanical vibration and pressure effects are also specified.

IEC 60751 also says that manufacturers can reveal electrical characteristics, like thermometer capacitance, capacitance to earth, and inductance, as well as the ohmic resistance of the internal connecting wires. Also, calibration immersion depth, minimum usable depth, thermal response time and self-heating effects can be stated.

4.4 IEC 60751: Colour Coding

Beyond this, because internal connections and terminals are not specified, the standard also deals with identification, requesting notification of class, connecting wire configuration (colour or marking) and temperature range. Two and three wire devices are simply red and white (two red for three wire), while four wire devices are either two blue, plus one red and one white (as for bridge based measuring systems) or two red and two white (for potentiometric). See Part 3, Sections 3.2, 3.3, 3.4 and 3.7 for more details.

5.0 Linearisation

Linearisation is more a problem for thermocouples than for resistance temperature detectors. With the exception of very narrow temperature ranges, the relationship of thermoelectric emf to temperature certainly cannot be regarded as a linear function. BS EN 60584.1 gives full details of the relationships between emf and temperature for all of the standard thermocouples in tabular format, assuming a reference junction temperature of 0°C. It also gives best mathematical descriptions of approximations of the variations across the temperature spectrum (see also Part 1, Section 3.16). For Type K it describes an eight term power series expansion plus an exponential term, with constants expressed to 11 significant figures (see table 3.5).

For Type R the picture is not dissimilar. To cover the range -50°C to +1,767.6°C requires four polynomials, from third to seventh order. So, considerable mathematics is required to get it right!

As for RTD's, the position is much simpler. The standard platinum resistance to temperature relationship follows the straightforward quadratic equation described in Part 1, Section 4.0 and 4.3 - and also in BS EN 60751. This is normally covered by second order functions, but at most, third order. With some other RTD materials, the situation can be even easier; copper, for example, has a virtually linear resistance to temperature relationship over its useful range.

There is another issue with RTD's, however, involving slight non-linearities with the measurement method itself. If null balance bridge, or potentiometric measuring systems are being used, there is no problem. If fixed bridge circuits are operating, then there is a non-linearity beyond that of the RTD itself, related to the power drawn from the bridge. If the indicator itself is potentiometric, or a high impedance amplifier is involved, again there is no problem. But, if a galvanometer, or similar equipment is used directly, these errors need to be linearised out (see Part 3, Section 3.1).

Today, microprocessor electronics provide a solution. Basically, curve fitting is used, with the emf/temperature, or the resistance/ temperature relationship broken down into manageable and realistic `linear' segments on a look-up table - continuous at the break points but varying in slope between them. Clearly, accuracy depends upon the number of segments used. With modern digital instrumentation having plenty of memory and processing power, accuracy can be high, and instruments with characteristics closely following the thermocouple and RTD reference tables are readily available. Further, modern instruments are often designed to cater for more than one thermocouple and RTD type. Simple switching between areas of the ROM memory map, or changing ROMs, accommodates the different linearisation requirements.

As an alternative, linearisation can be performed as a continuous function, faithfully representing the thermocouple and RTD characteristics. This can be done using analogue electronics - combining logarithmic, exponential, power and root modules, but accuracies are rarely better than 0.2% over a range of a few hundred degrees. Returning to modern digital instruments, most now provide for continuous digital linearisation directly after analogue to digital conversion. They harness microprocessor power, with a model of the thermocouple or RTD characteristic using coefficients stored in ROM. This method obviously avoids the discontinuities caused by the segmentation technique. Very high conversion accuracies can thus be achieved.

6.0 Signal Conditioning, Interference and Isolation

Remembering that electronic thermometry is inevitably bound by the same practical constraints as any other electronic circuitry, there are a number of techniques which need to be harnessed to maximise the signal strength, accuracy and repeatability of the signal (and hence the deduced temperature) that your instrumentation receives. This is what signal conditioning is all about.

The term signal conditioning covers several functions. Included within its regime are all the details of isolation, interference rejection, conversion (voltage to current plus analogue to digital, where relevant), scaling and, depending on who you're talking to, also linearisation and transmission. Certainly in temperature measurement, the functions of signal conditioning are normally provided on the transmitter.

With the latest equipment, hitherto quite intractable signal isolation problems have been solved as a matter of routine. Signals can be resolved accurately and dependably from the background noise and interference with ease. They can also be handled with much greater precision than used to be the case.

Looking at interference, this breaks down basically into the AC and DC components of series and common mode signals - relating respectively to mains and other types of inductive and capacitive pick-up on the signal leads, together with differences in the ground potential between the measurement point and the instrumentation.

6.1 Series Mode

Essentially, series mode interference is usually caused by the unequal coupling of signal lines within the local magnetic fields - and clearly 50Hz is the main problem area in the UK. With signals from thermocouples and RTD's being typically in the mV region, 240V of mains oscillating at 50Hz is hardly going to pass unnoticed! If the interference is DC then there is precious little that can be done, since transmitters are basically measuring DC potential difference. AC interference can, however, be eliminated, or dramatically reduced in a number of ways.

A low pass filter can be used for the higher frequency components - although this may be a little expensive for many temperature applications. In fact, since most temperature movements are relatively slow, measurement signal averaging is a perfectly adequate technique. Here, the input signal is integrated over one or more cycles of the interference using the analogue to digital converter, such that power-related noise and its harmonics self-cancel. Phase locked sampling can also be used.

6.2 Common Mode

Moving on to common mode, which is caused, for example, by electromagnetic or static coupling of a field onto signal lines, or by dissimilar earth potentials, errors can be reduced by the use of a differential input with a very high impedance so that the measurement circuit is effectively floating. Then, induced error voltages can be ignored in practice.

Isolation amplifiers can also be harnessed, or guard systems used. The latter dramatically reduces both common and series mode interference - effectively by providing the equivalent of a fully floating isolation amplifier input. Basically, the guard is connected to the source of the common mode, and is then driven at the same voltage with respect to

Continued on page 12

earth as the input signals. Thus, no common mode current can flow in the signal leads - the current instead flowing down the guard connection, and returning to earth.

6.3 Isolation

On a practical note, it is important to recognise the pitfalls of common and series mode interference, what this means in terms of the need for good isolation - and the various techniques used to overcome it. Most manufacturers now offer at least 500V isolation, in some cases three ways - input to output to power supply - using either transformer-coupled or opto-coupled galvanic isolation, along with a choice of transfer techniques - mark-space ratio, frequency or digital. Typically, common mode rejection can approach 150dB at 50Hz.

Although opto-isolation used to be regarded as the poor relation in this context, while transformer-coupled galvanic isolation was the Rolls Royce approach, as electronics continues to advance and miniaturise this is much less the case. In fact, for a given transfer technique, opto-isolation and transformer coupling offer much the same performance, as long as the time-related drift associated with the former is dealt with at the design stage. Meanwhile, mark-space transfer is inherently limited by timing inaccuracies, and tends to find use in general purpose equipment only. Frequency transfer across the galvanic gap provides for better precision.

7.0 Transmitters/Converters

Accepting that thermocouple emfs range from about 10µV/°C to about 80µV/°C (Figure 7.1) and that 100 ohm RTD outputs are around 0.5mV/°C for a 1mA energising current, there are clearly limitations for remote temperature sensing. Depending upon the device, the range of emfs will be from just hundreds of µV up to say 75mV for a higher output thermocouple near the top of its temperature range, and say 250mV to 750mV for a PRT depending upon the energising current. So in terms of lead lengths and cross section, you can quickly run into practical difficulties in accomplishing successful signal transmission.

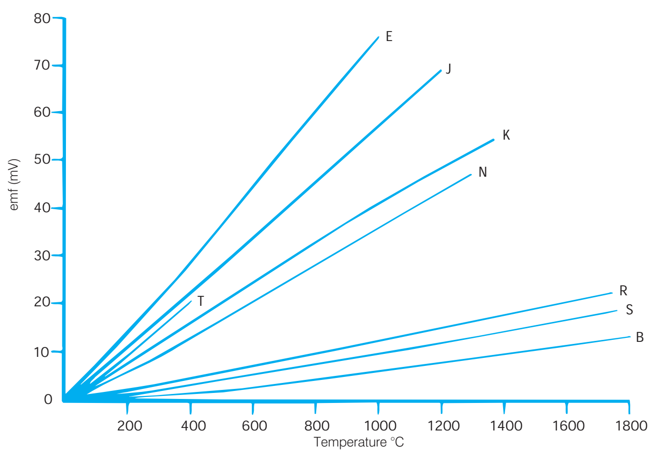

Figure 7.1 *Emf versus Temperature Relationship for Thermocouples*

Two wire temperature transmitters are designed to solve this problem. Basically, they convert and amplify the millivolt level sensor signal outputs into low impedance source current signals, almost without exception spanning the ISA standard 4-20mA range. This provides tremendous advantages for remote temperature measurement applications.

Current signals are, of course, much less sensitive to electrical interference than voltages when transmitted over long distances in characteristically electrically noisy industrial environments. Any noise that does appear in the output current signal can be eliminated by the series and common mode rejection facilities of the receiving instrumentation (see Part 1, Section 6). Further, there are not the transmission (essentially resistance) losses typical of voltage signal transmission. Standard, small cross section twisted pair copper wires are thus perfectly adequate for current signal transmission - as opposed to the expensive screened/guarded, and sometimes unwieldy heavy gauge, compensating and extension cable options necessitated for unamplified or conditioned low level voltage signals.

For thermocouples, cold (floating) junction compensation is often incorporated into the transmitter head itself, where head-mounted devices are concerned. In the case of rack mounting devices, the compensation circuitry is usually in the mounting rack, to act for a group of transmitters. Although linearisation is not normally incorporated into low cost thermocouple transmitters, it is a feature of today's digital devices. In operation, the transmitter draws current from a remote DC power supply (usually 12 to 30V) in proportion to the sensor input. The signal itself is then transmitted as a change in the power supply current. In fact, the device draws 4mA current when measuring the lowest temperature in its calibrated range, while at the top of the range it draws 20mA - and is proportional in between. The transmitter's internal zero and span circuitry (which may be adjustable or programmable/configurable) determines the precise temperature range represented by the output current (see Part 2, Section 10).

Physically, since transmitter circuits draw their power down the signal line, only two wires are needed to connect the transmitter output signal in a series circuit with the remote power supply and the instrumentation. This means that AC power is not needed at the remote location. Also, since 24V DC signals are pretty well standard on process plants, the appropriate power is readily available in the instrumentation areas.

PART TWO - SENSORS, EQUIPMENT AND PRACTICE

1.0 Practical Thermocouples

The reasons for the popularity of thermocouples are not just the existence of a range of types designed to cover almost all temperature, environmental and accuracy requirements, or the fact that they are small. Others include the ease with which they can be made and applied, and the availability of a vast assortment of housings and special packages to match almost every imaginable application.

For simple applications, thermocouples can easily be made from lengths of bare thermocouple wire or insulated cable, the insulation material being selected for compatibility with the application, and likewise the cable itself. As for wire diameter, anything from 0.1mm OD to 3mm or more (especially for industrial use) is the norm. The measuring junction is best constructed by welding the two wires together.

Soldering or twisting are less satisfactory, although with the aid of a clamping screw in a connecting block, greater security can be obtained. The key to success is a good electrical connection which does not disrupt the composition of the thermocouple wires themselves. Bear in mind the expected operating conditions for the measuring junction.

Base metal thermocouples are usually welded electrically in an argon atmosphere, while platinum thermocouples can be welded using a small oxy-hydrogen flame. Beyond this, base metal thermocouple wires are normally supplied ready annealed and are thus prepared for use directly after welding. The same is not usually the case with the platinum equivalents which therefore have to be annealed after inserting the wires into the insulators and making up the junction.

At the other end of the cables, each thermocouple wire can be joined to a copper wire to form the reference junction. Again, welding is the best bet, but silver soldering using a very small quantity of solder in paste form together with a miniature flame is a reasonable alternative - as long as all traces of corrosive flux are removed. The junctions can then be fitted into closed end tubes or potted for immersion in an ice-water mixture.

This method of thermocouple construction is simple, versatile and fine for experimentation in the laboratory. Accuracy will be good since, on the one hand, each element can be placed close to the requisite site, and on the other, the device approaches the theoretical ideal as outlined in Part 1, Section 2.

1.1 Thermocouple Styles

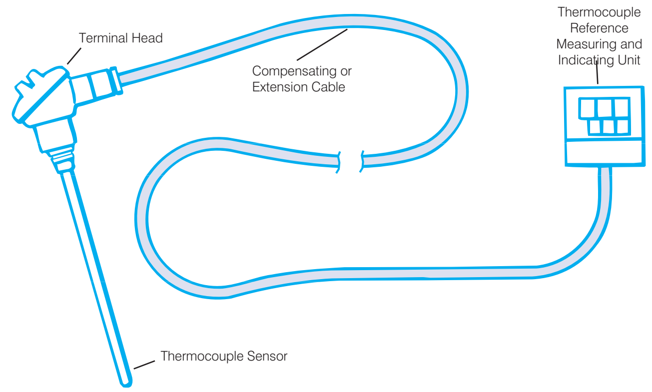

Figure 1.1: *A Typical Industrial Thermocouple*

However, DIY is not everyone's cup of tea; nor is it necessarily ideal for industrial usage, where large numbers are needed, and installation, commissioning, maintenance and replacement must be considered. So, more permanent and operationally convenient ready-made thermocouple sensors are, of course, available. Thermocouple sensors can be bought as separate units from a very wide range of types and styles. At the most basic level there are simple bare wire thermocouples with junctions welded as described previously. These may be insulated according to the applicational needs (see Part 2, Section 2) with anything from PVC to ceramics. Frequently, the thermocouple conductors will be fitted into a closed end probe of some kind, outer sheath (protection tube), or thermowell made from a suitable heat-resistant alloy or refractory material (Figure 1.2).

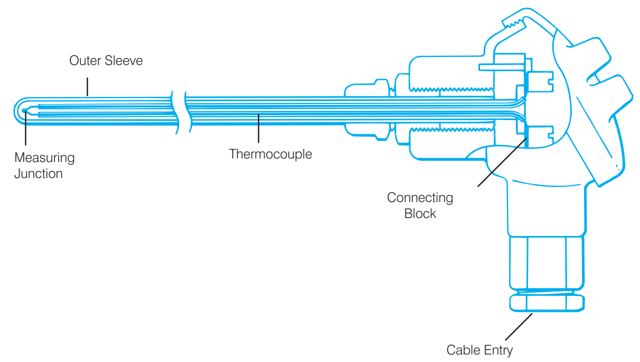

Figure 1.2: *Enclosed Thermocouple Probe and Head*

And, here again there are almost as many sizes and styles as there are applications. Sizes range from sub-miniature (around 0.25mm diameter - sheathed), through miniature and on up to standard (around 6mm) and beyond (20mm and much more) - to cover for all requirements. As for styles, there are general purpose welded sheath probes, bolt style probes, hand-held probes (of several designs), surface probes equipped for direct attachment to pipes of most sizes, others designed to monitor the temperature of point or moving surfaces and so on - all protected by insulation and sheath materials (if required) chosen for the thermocouple and the application (Figure 1.3), with or without grounded sheaths, quick disconnect systems and so on.

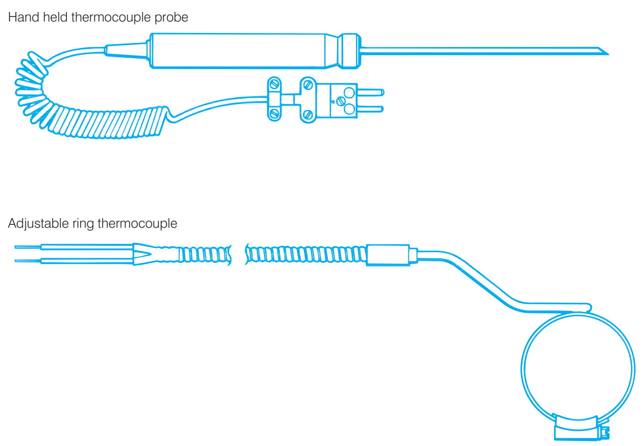

Figure 1.3: *Hand-held Probe and Pipe Probe*

Continued on page 16

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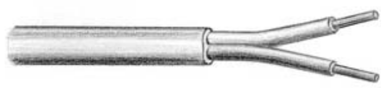
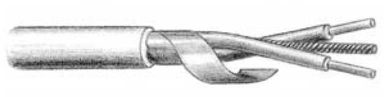
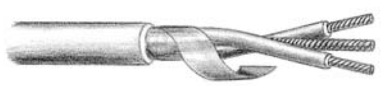
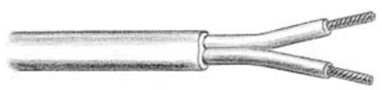
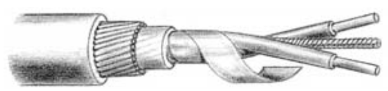
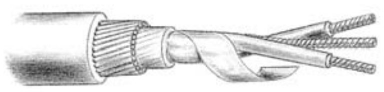
Thermocouple Extension and Compensating Cable

Heat Resistant PVC Insulated Single Pairs

- Incorporates Heat Resistant (HR) PVC suitable for use in the temperature range -30°C to +105°C
- The grade of PVC used on these constructions is to BS7655:Part 4 Section 4.2 Type 5/UL Style 105°C rated (15,000 hours at 105°C)
- We offer a wide variety of constructions from simple bellwire to screened and armoured types in virtually all of the thermocouple combinations
- For Flame Retardant PVC insulated single pairs see page 15 overleaf

			Conductors							Pairs			Overall										Glands	Notes
		Stock Number	No. of Strands	Size of Strand Diameter mm.	Inches	Gauge SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Screen[1]	Insulation	Insulation Rating °C Continuous	Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Diameter Under Armour[2] (mm)	Diameter Over Armour[2] (mm)	Overall Diameter[2] (mm)	Recommended Gland Ref[3] (See page 35)	
	One pair of solid conductors HR PVC insulated. Pair laid flat and welded together in a ripcord construction.	A10	1	.5	.02	25	24	.2	HR PVC	1	Flat	No	–	-30 to +105	–	Yes	Good	Very Good	1	–	–	2x3	10	"Figure of eight" or "bell wire" type.
	One pair of solid conductors HR PVC insulated. Pair laid flat and HR PVC sheathed.	A14	1	.8	.03	21	20	.5	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	4	–	–	3x5	10	Oval section. Good general purpose constructions.
		A15	1	1.29	.05	18	16	1.3	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	5	–	–	4x6	12 or 16	
	One pair of solid conductors HR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drain wire. HR PVC sheathed.	A20	1	.8	.03	21	20	.5	HR PVC	1	Twisted	Yes	HR PVC	-30 to +105	–	Yes	Good	Very Good	4	–	–	6	12 or 16	Round section. Rejects electromagnetic and electrostatic interference.
		A25	1	1.29	.05	18	16	1.3	HR PVC	1	Twisted	Yes	HR PVC	-30 to +105	–	Yes	Good	Very Good	7	–	–	7	12 or 16	
	One pair of stranded conductors HR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drain wire. HR PVC sheathed.	A27	7	.2	.008	36	32	.22	HR PVC	1	Twisted	Yes	HR PVC	-30 to +105	–	Yes	Good	Very Good	3	–	–	4	12 or 16	Round section. Rejects electromagnetic and electrostatic interference.
		A28	14	.2	.008	36	32	.44	HR PVC	1	Twisted	Yes	HR PVC	-30 to +105	–	Yes	Good	Very Good	4	–	–	5	12 or 16	
	One pair of stranded conductors HR PVC insulated. Pair laid flat and HR PVC sheathed.	A30	7	.2	.008	36	32	.22	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	2	–	–	3x4	10	Oval section. Good general purpose flexible constructions. A60, A65 and A70 are more heavy duty.
		A40	14	.2	.008	36	32	.44	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	3	–	–	3x5	10	
		A50	24	.2	.008	36	32	.75	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	4	–	–	4x6	12 or 16	
		A60	32	.2	.008	36	32	1.0	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	5	–	–	4x6	12 or 16	
		A65	40	.2	.008	36	32	1.3	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	6	–	–	5x7	12 or 16	
		A70	3	.91	.036	20	19	2.0	HR PVC	1	Flat	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	7	–	–	5x8	12 or 16	
	One pair of stranded conductors HR PVC insulated. Pair twisted.	A80	14	.2	.008	36	32	.44	HR PVC	1	Twisted	No	–	-30 to +105	–	Yes	Good	Very Good	2	–	–	4	12 or 16	Rejects electromagnetic interference.
	One pair of stranded conductors HR PVC insulated. Pair twisted and HR PVC sheathed.	A82	7	.2	.008	36	32	.22	HR PVC	1	Twisted	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	2	–	–	4	12 or 16	Rejects electromagnetic interference.
		A83	14	.2	.008	36	32	.44	HR PVC	1	Twisted	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	3	–	–	5	12 or 16	
		A85	24	.2	.008	36	32	.75	HR PVC	1	Twisted	No	HR PVC	-30 to +105	–	Yes	Good	Very Good	4	–	–	6	12 or 16	
	One pair of solid conductors HR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. HR PVC bedded. Steel wire armoured and HR PVC sheathed.	A90	1	1.29	.05	18	16	1.3	HR PVC	1	Twisted	Yes	HR PVC	-30 to +105	–	Yes	Good	Very Good	30	7	9	12	16 or 20S	Round section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.
	One pair of stranded conductors HR PVC sheathed. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. HR PVC bedded. Steel wire armoured and HR PVC sheathed.	A95	24	.2	.008	36	32	.75	HR PVC	1	Twisted	Yes	HR PVC	-30 to +105	–	Yes	Good	Very Good	22	6	8	11	16 or 20S	Round section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. Whilst we show gland references for laid flat oval shaped cables, we would recommend you choose a twisted round section construction for a better gland fit. For armoured cables the gland sizes shown are for the CGC and CGE ranges. CGA types are available, however the gland size will change. See page 35 for full details.

The above cable constructions are offered incorporating the following conductor combinations: KX, KCB, JX, TX, NX, EX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
Most of the above constructions can be overbraided with stainless steel or tinned copper braid within a few weeks.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

*Mylar is a trade name.

Ordering Code - Typical example

A40 — KX — IEC

- Stock Number: A40
- Thermocouple Conductor Combination: KX
- Insulation Colour Code: IEC

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CODE T

International Thermocouple Reference Tables for
Copper / Copper Nickel
To IEC60584.1:1995 / BS EN 60584.1 Part 5 : 1996

CODE T

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (µV).

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-270	-6258										**-270**
-260	-6232	-6236	-6239	-6242	-6245	-6248	-6251	-6253	-6255	-6256	**-260**
-250	-6180	-6187	-6193	-6198	-6204	-6209	-6214	-6219	-6223	-6228	**-250**
-240	-6105	-6114	-6122	-6130	-6138	-6146	-6153	-6160	-6167	-6174	**-240**
-230	-6007	-6017	-6028	-6038	-6049	-6059	-6068	-6078	-6087	-6096	**-230**
-220	-5888	-5901	-5914	-5926	-5938	-5950	-5962	-5973	-5985	-5996	**-220**
-210	-5753	-5767	-5782	-5795	-5809	-5823	-5836	-5850	-5863	-5876	**-210**
-200	-5603	-5619	-5634	-5650	-5665	-5680	-5695	-5710	-5724	-5739	**-200**
-190	-5439	-5456	-5473	-5489	-5506	-5523	-5539	-5555	-5571	-5587	**-190**
-180	-5261	-5279	-5297	-5316	-5334	-5351	-5369	-5387	-5404	-5421	**-180**
-170	-5070	-5089	-5109	-5128	-5148	-5167	-5186	-5205	-5224	-5242	**-170**
-160	-4865	-4886	-4907	-4928	-4949	-4969	-4989	-5010	-5030	-5050	**-160**
-150	-4648	-4671	-4693	-4715	-4737	-4759	-4780	-4802	-4823	-4844	**-150**
-140	-4419	-4443	-4466	-4489	-4512	-4535	-4558	-4581	-4604	-4626	**-140**
-130	-4177	-4202	-4226	-4251	-4275	-4300	-4324	-4348	-4372	-4395	**-130**
-120	-3923	-3949	-3975	-4000	-4026	-4052	-4077	-4102	-4127	-4152	**-120**
-110	-3657	-3684	-3711	-3738	-3765	-3791	-3818	-3844	-3871	-3897	**-110**
-100	-3379	-3407	-3435	-3463	-3491	-3519	-3547	-3574	-3602	-3629	**-100**
-90	-3089	-3118	-3148	-3177	-3206	-3235	-3264	-3293	-3322	-3350	**-90**
-80	-2788	-2818	-2849	-2879	-2910	-2940	-2970	-3000	-3030	-3059	**-80**
-70	-2476	-2507	-2539	-2571	-2602	-2633	-2664	-2695	-2726	-2757	**-70**
-60	-2153	-2186	-2218	-2251	-2283	-2316	-2348	-2380	-2412	-2444	**-60**
-50	-1819	-1853	-1887	-1920	-1954	-1987	-2021	-2054	-2087	-2120	**-50**
-40	-1475	-1510	-1545	-1579	-1614	-1648	-1683	-1717	-1751	-1785	**-40**
-30	-1121	-1157	-1192	-1228	-1264	-1299	-1335	-1370	-1405	-1440	**-30**
-20	-757	-794	-830	-867	-904	-940	-976	-1013	-1049	-1085	**-20**
-10	-383	-421	-459	-496	-534	-571	-608	-646	-683	-720	**-10**
-0	0	-39	-77	-116	-154	-193	-231	-269	-307	-345	**-0**
0	0	39	78	117	156	195	234	273	312	352	**0**
10	391	431	470	510	549	589	629	669	709	749	**10**
20	790	830	870	911	951	992	1033	1074	1114	1155	**20**
30	1196	1238	1279	1320	1362	1403	1445	1486	1528	1570	**30**
40	1612	1654	1696	1738	1780	1823	1865	1908	1950	1993	**40**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
50	2036	2079	2122	2165	2208	2251	2294	2338	2381	2425	**50**
60	2468	2512	2556	2600	2643	2687	2732	2776	2820	2864	**60**
70	2909	2953	2998	3043	3087	3132	3177	3222	3267	3312	**70**
80	3358	3403	3448	3494	3539	3585	3631	3677	3722	3768	**80**
90	3814	3860	3907	3953	3999	4046	4092	4138	4185	4232	**90**
100	4279	4325	4372	4419	4466	4513	4561	4608	4655	4702	**100**
110	4750	4798	4845	4893	4941	4988	5036	5084	5132	5180	**110**
120	5228	5277	5325	5373	5422	5470	5519	5567	5616	5665	**120**
130	5714	5763	5812	5861	5910	5959	6008	6057	6107	6156	**130**
140	6206	6255	6305	6355	6404	6454	6504	6554	6604	6654	**140**
150	6704	6754	6805	6855	6905	6956	7006	7057	7107	7158	**150**
160	7209	7260	7310	7361	7412	7463	7515	7566	7617	7668	**160**
170	7720	7771	7823	7874	7926	7977	8029	8081	8133	8185	**170**
180	8237	8289	8341	8393	8445	8497	8550	8602	8654	8707	**180**
190	8759	8812	8865	8917	8970	9023	9076	9129	9182	9235	**190**
200	9288	9341	9395	9448	9501	9555	9608	9662	9715	9769	**200**
210	9822	9876	9930	9984	10038	10092	10146	10200	10254	10308	**210**
220	10362	10417	10471	10525	10580	10634	10689	10743	10798	10853	**220**
230	10907	10962	11017	11072	11127	11182	11237	11292	11347	11403	**230**
240	11458	11513	11569	11624	11680	11735	11791	11846	11902	11958	**240**
250	12013	12069	12125	12181	12237	12293	12349	12405	12461	12518	**250**
260	12574	12630	12687	12743	12799	12856	12912	12969	13026	13082	**260**
270	13139	13196	13253	13310	13366	13423	13480	13537	13595	13652	**270**
280	13709	13766	13823	13881	13938	13995	14053	14110	14168	14226	**280**
290	14283	14341	14399	14456	14514	14572	14630	14688	14746	14804	**290**
300	14862	14920	14978	15036	15095	15153	15211	15270	15328	15386	**300**
310	15445	15503	15562	15621	15679	15738	15797	15856	15914	15973	**310**
320	16032	16091	16150	16209	16268	16327	16387	16446	16505	16564	**320**
330	16624	16683	16742	16802	16861	16921	16980	17040	17100	17159	**330**
340	17219	17279	17339	17399	17458	17518	17578	17638	17698	17759	**340**
350	17819	17879	17939	17999	18060	18120	18180	18241	18301	18362	**350**
360	18422	18483	18543	18604	18665	18725	18786	18847	18908	18969	**360**
370	19030	19091	19152	19213	19274	19335	19396	19457	19518	19579	**370**
380	19641	19702	19763	19825	19886	19947	20009	20070	20132	20193	**380**
390	20255	20317	20378	20440	20502	20563	20625	20687	20748	20810	**390**
400	20872										**400**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

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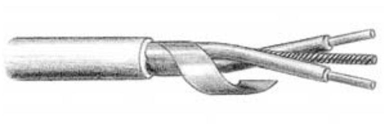
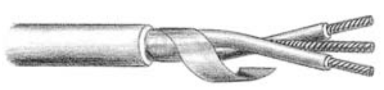
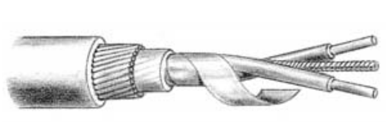
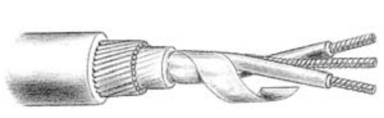
Thermocouple Extension and Compensating Cable

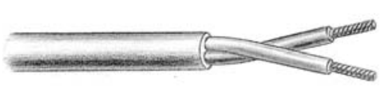
Flame Retardant PVC Single Pairs

- Excellent properties for the reduced propagation of flame by incorporation of flame retardant PVC compounds (FR)
- Suitable for situations where there is a risk of fire. (See also our range of XLPE/LSF cables shown on page 17)
- These cables also meet the requirements of BS4066 Part 1: 1980/IEC 60332.1:2004 covering tests on cables under fire conditions
- The Oxygen Index Value is not less than 30 in accordance with BS2782 Part 1:1989 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811 : 1995

	Stock Number	Conductors							Pairs			Overall										Glands	Notes
		No. of Strands	Size of Strand Diameter mm.	Inches	Gauge SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Screen[1+3]	Insulation	Insulation Rating °C Continuous	Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.[4] (See page 35)	
 One pair of solid conductors FR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. FR PVC sheathed.	FR20	1	.8	.03	21	20	.5	FR PVC	1	Twisted	Yes[1]	FR PVC	-30 to +75	–	Yes	Good	Very Good	4	–	–	5.5	12 or 16	Flame Retardant. Round Section. Rejects electromagnetic and electrostatic interference.
 One pair of stranded conductors FR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. FR PVC sheathed.	FR29	16	.2	.008	36	32	.5	FR PVC	1	Twisted	Yes[1]	FR PVC	-30 to +75	–	Yes	Good	Very Good	5	–	–	5.5	12 or 16	Flame Retardant. Round Section. Rejects electromagnetic and electrostatic interference.
 One pair of solid conductors FR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. FR PVC bedded. Steel wire armoured and FR PVC sheathed.	FR89	1	.8	.03	21	20	.5	FR PVC	1	Twisted	Yes[1]	FR PVC	-30 to +75	–	Yes	Good	Very Good	19	5.5	7.5	9.5	16 or 20S	Flame Retardant. Round Section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.
	FR90	1	1.29	.05	18	16	1.3	FR PVC	1	Twisted	Yes[1]	FR PVC	-30 to +75	–	Yes	Good	Very Good	30	7.0	9.0	11.0	16 or 20S	
 One pair of stranded conductors FR PVC insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. FR PVC bedded. Steel wire armoured and FR PVC sheathed.	FR94	16	.2	.008	36	32	.5	FR PVC	1	Twisted	Yes[1]	FR PVC	-30 to +75	–	Yes	Good	Very Good	19	5.5	7.5	10.5	16 or 20S	Flame Retardant. Round Section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.
	FR95	24	.2	.008	36	32	.75	FR PVC	1	Twisted	Yes[1]	FR PVC	-30 to +75	–	Yes	Good	Very Good	22	6.0	8.0	11.0	16 or 20S	

Flame Retardant Silicone Rubber Single Pairs

- Excellent properties for the reduced propagation of flame by incorporation of flame retardant Silicone Rubber compounds
- Suitable for situations where there is a risk of fire. (See also our range of XLPE/LSF cables shown on page 17)
- Ideal for applications where, for short periods of time, the temperature can fluctuate, which would cause other cables to become inflexible and brittle. These cables also meet the requirements of BS4066 Pt1/IEC 60332.1 covering tests on cables under fire conditions

	Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Screen[1+3]	Insulation	Continuous	Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.[4] (See page 35)	Notes
 One pair of stranded conductors Silicone Rubber insulated. Pair twisted and Mylar* taped. Silicone Rubber sheathed.	SR73	7	.3	.012	31	28	.5	SR	1	Twisted	No	SR	-40 to +200	-50 to +250	Yes	Good	Very Good	4	–	–	7.0	12 or 16	Flame Retardant. Round Section. Rejects electromagnetic interference.
	SR77	19	.3	.012	31	28	1.5	SR	1	Twisted	No	SR	-40 to +200	-50 to +250	Yes	Good	Very Good	7	–	–	8.5	16	
 One pair of stranded conductors Silicone Rubber insulated. Pair twisted and Mylar* taped. Tinned copper wire braided and Silicone Rubber sheathed.	SR74	7	.3	.012	31	28	.5	SR	1	Twisted	Yes[3]	SR	-40 to +200	-50 to +250	Yes	Good	Very Good	5	–	–	7.5	12 or 16	Flame Retardant. Round Section. Rejects electromagnetic and electrostatic interference.
	SR78	19	.3	.012	31	28	1.5	SR	1	Twisted	Yes[3]	SR	-40 to +200	-50 to +250	Yes	Good	Very Good	8	–	–	9.0	16	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. These cables have a tinned copper wire braid which can be used as a screen.
4. For armoured cables, the gland sizes shown are for the CGC and CGE ranges. CGA types are available, however the gland size will change. See page 35 for full details.

The above cable constructions are offered incorporating the following conductor combinations: KX, KCB, JX, TX, NX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

*Mylar is a trade name.

Ordering Code - Typical example

FR95 — KX — IEC

Stock Number
Thermocouple Conductor Combination
Insulation Colour Code

Additionally, there are sheathed probes for autoclave temperature measurement incorporating flexible stainless steel conduit and pressure entry glands, bayonet and compression fitting style thermocouples for the plastics and other industries and heavy duty and high temperature industrial sheathed thermocouples (Figure 1.4) with options like head-mounting terminal assemblies and thermowell extension pieces (see Part 2, Section 9).

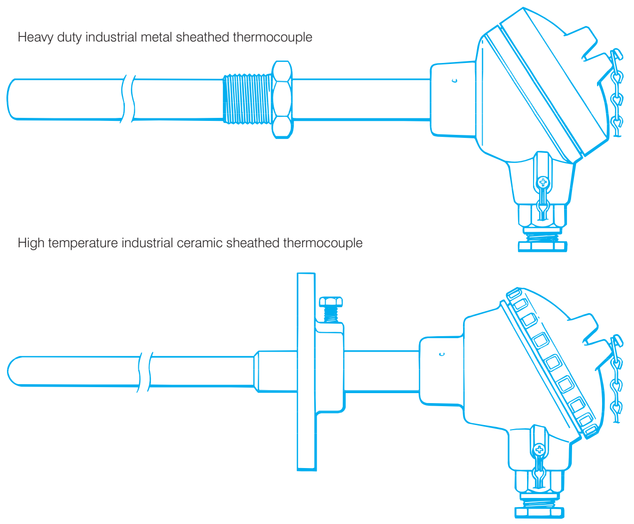


Figure 1.4: *Heavy Duty Industrial Metal Sheathed and High Temperature Ceramic Sheathed Thermocouples with Terminal Head Assemblies*

In all cases, great care is taken by the suppliers to ensure that the conductors are correctly manufactured and installed into the sensor housing under closely controlled conditions. Thus, the amount of change the heated region of the conductors may experience during service (which affects uniformity) is minimised. This is important, since it is this unit that will almost certainly be sitting in the area of greatest temperature gradient, and therefore contributing to most of the output voltage (see Part 1, Section 2).

An alternative form of construction uses mineral insulated (MI) cable (see Part 2, Section 2.3), where the thermocouple conductors are embedded in a closely compacted, inert mineral powder, and surrounded by a metal sheath (like stainless steel or nickel alloy) to form a hermetically sealed assembly. The sheath functions as a useful protective cover. This kind of device is available with outer diameter dimensions ranging now from 0.25mm up to 10.8mm, while lengths can be from a few millimetres up to tens of metres (Figure 1.5) and beyond.

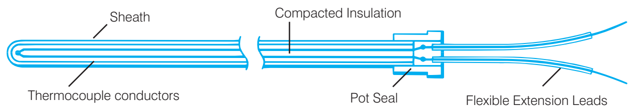


Figure 1.5: *Typical Mineral Insulated Thermocouple Sensor Construction*

For rather special applications, where high speed response is needed, it can be advantageous for an MI thermocouple to be manufactured with the junction itself exposed (see Part 3, Section 7). However, this kind of departure needs the expertise and skill of a regular practitioner (see Part 2, Section 2.3).

Thermocouple sensors are often provided with a connection or terminal box which allows convenient linking to the rest of the circuit. Alternatively, a special plug can be fitted, in which the connecting pins are made from the thermoelectric material concerned - as are those in the mating socket (Figure 1.6). More in Part 2, Section 4.

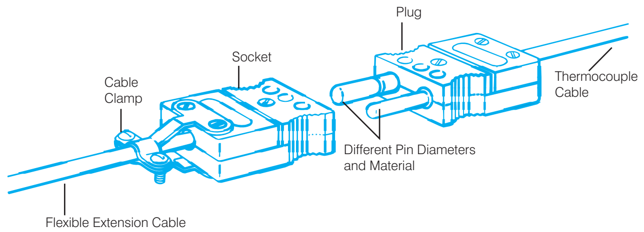


Figure 1.6: *Typical Thermocouple Connectors*

2.0 Thermocouple Insulation

Although there are applications where thermocouples can be used without protection, in most they must be protected from the environment and media in which they are being asked to measure by the use of insulation materials often with protective sheaths. These latter, provided in the form of tubes or whatever, also serve to protect the thermocouple from mechanical damage.

As a general rule of thumb, engineering practice has it that an exposed thermocouple junction is only recommended for the measurement of static or flowing non-corrosive gas temperatures where fast response is a key issue. Beyond this, insulated thermocouple junctions are more suitable, certainly for corrosive gases and liquids, accepting that thermal response is slower whether an outer sheath is involved or not. Incidentally, earthed thermocouple junctions (grounded, where the thermocouple is welded to the sheath tip) are regarded as best for corrosive gases and liquids and for high pressure applications where faster thermal response is required.

2.1 Standard Insulating Materials

There is a wide choice of insulating materials for thermocouples - where practicable, colour coded in accordance with the thermocouple type in use, according to BS EN 60584.3:2008. Although there is no international standard for materials, engineering practice dictates the use of six main materials.

PVC can be used over the range -30 to +105°C and is available in many different types of construction. PFA offers a greater temperature range, covering from -273 to +250°C, or 300°C for short periods.

Moving up the range, we find varnish impregnated glass fibre, which handles from -50 to +400°C, while unvarnished glass fibre takes this up to 500°C and in some cases, 800°C. Throughout the above, all of the standard thermocouple types can be accommodated.

2.2 Ceramic Insulators

Moving into the higher temperature realms of industrial usage, ceramic insulators are available in various forms. Porcelain ceramic twin bore beads can be used on base metal thermocouple wires of about 1mm and beyond. Meanwhile, aluminium silicate (Mullite) insulators are frequently used with Type K thermocouple wires, particularly in furnace type applications - whether the sensor is unprotected or housed in metal or ceramic outer sheaths/tubes. As for platinum-based thermocouples, high purity alumina twin bore insulators are generally favoured to reduce the risk of contamination.

2.3 Mineral Insulated Thermocouples

The most popular insulation and thermocouple protection style for industry today is the mineral insulated, metal sheathed type (MI or MIMS). These are comprised of a seamless metal sheath enclosing highly compacted mineral insulant powder (typically, magnesium oxide) which supports and electrically insulates the thermocouple wires held inside.

Temperature ranges covered are from -200°C to +1,250°C, and the assemblies provide a very high integrity, compact, hermetically sealed, self-armoured, yet quite flexible construction, suitable for very arduous operating conditions. MIMS cables available range from two to six cores, and diameters from 0.25 to 10.8mm. There are many advantages with this construction. They include small size, ease of installation (they can be bent, twisted and flattened without impairing performance), good mechanical strength, excellent isolation of the junction from hostile environments, high long term accuracy and stability, fast response and good insulation resistance. They are also readily available off the shelf and are reasonably priced. They are thus ideal for accurate measurement in a very wide range of applications, including extreme environments, like high vibration and high pressure/vacuum.

Additionally, they allow the use of a wide range of outer sheaths and seal termination styles to suit tremendously diverse operating conditions. Sheath materials offered (usually 15% of the overall probe diameter in length) include mild and stainless steels, Inconel and the Nicrobell alloys, selection being on the basis of application temperature range and environment (Part 2, Section 9.2). Finally, platinum-rhodium alloy sheaths are often used with platinum thermocouples. The finished assembly can be anything from a few millimetres long to tens of metres or more. Beyond this, all of the usual thermocouple alloy combinations are available as MI thermocouples - both rare and base metal types. Also, the measuring junction can be exposed, insulated from the sheath material or bonded to it (grounded - welded to the sheath tip). The former provides for fastest response; insulated versions (offering insulation resistance over 100Mohms) obviate ground loops on associated instrumentation by providing a floating output; and the grounded types offer earthed output with faster response to temperature changes (see Part 3, Section 7 for more details).

On the down side, limitations can include problems due to the different thermal coefficients of expansion of the stainless steel sheath variants, for example, as compared particularly to the Type K and N thermocouple materials - sometimes leading to premature mechanical fatigue failure. Also ironically, with both the stainless steels and Inconel 600 sheaths, there are possibilities of material contamination problems due to vapour diffusion of the elements, leading to actual contamination of the thermocouple wires by the sheath material itself. There can also be problems relating to the ingress of water vapour, resulting in reduced insulation resistance and hence calibration instability and, possibly, again premature failure. This latter phenomenon, however, is really a matter of care in manufacture and repair.

Special sheathing alloys have been developed to deal with these limitations, particularly for higher temperature applications with Type K and N thermocouples. These include the Nicrobell alloys, which take their cue from the inherent advantages of Type N thermocouple materials (see Part 1, Sections 2.4 and 3.8). Basically, Nicrobell B is Nicrosil with added magnesium and niobium which improve the oxidation and high temperature strength properties respectively of the alloy. Also, since it is inherently Nicrosil, the sheath has a much more closely compatible thermal coefficient of expansion especially with Type K and N thermocouple wires. In fact, there is a ten-fold improvement.

Together, this means that MI thermocouples using Nicrobell B can last four to six times longer than their stainless steel based alternatives. And, remembering the transmutation reductions achieved using Nicrobell B, sheaths constructed from this material also out-perform Inconel 600 in terms of long term drift due to thermocouple wire contamination.

A high chrome Nicrobell (Nicrobell D) is also available specifically designed for carburising environments. Although this has slightly poorer high temperature strength than Nicrobell B, it arrests chromium carbide embrittlement effects, and features all of the other advantages of Nicrobell.

In general, it is recommended that the smallest diameter mineral insulated metal sheathed thermocouples should be avoided if possible for very high temperature or corrosive environment measurements. There does seem to be a correlation between MIMS cable diameter and its survival and long term performance. For details of sheath materials and available configurations for non mineral insulated thermocouples see Part 2, Section 9.1.

Continued on page 20

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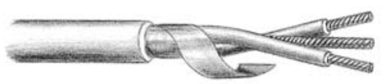
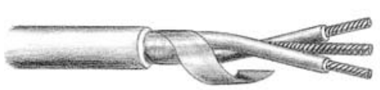
Thermocouple Extension and Compensating Cable

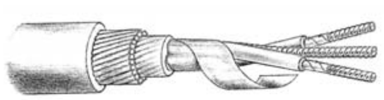
XLPE (Cross Linked Polyethylene)/Low Smoke and Fume Single Pairs including Intrinsically Safe Versions

- These cables incorporate XLPE (Cross Linked Polyethylene) compound on the cores and Low Smoke and Fume (LSF) material on the bedding and/or outer sheath
- These cables meet the requirements of BS4066 Part 3/IEC 60332.3 Category A covering tests on cables under fire conditions
- Ideal for situations where there is a risk of fire and the emission of smoke and gases could threaten life and property
- The sheathing materials used are Halogen free
- The acidic gas which is evolved during combustion is less than 0.5% in accordance with BS6425 Pt 1 1990 and IEC 60754.1: 1996
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1986 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995
- Intrinsically safe versions (Type GS) are coloured specifically for Intrinsically Safe areas with a blue outer sheath. The cores are coloured in accordance with the relevant conductor type. All colouring meets BS EN 60584.3:2008 and IEC 60584.3:2007

Description	Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Gauge: SWG	Gauge: AWG	Total Area mm²	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Screen[1]	Overall: Insulation	Insulation Rating °C: Continuous	Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Diameter Under Armour[2] (mm)	Diameter Over Armour[2] (mm)	Overall Diameter[2] (mm)	Glands: Recommended Gland Ref.[3] (See page 35)	Notes
 One pair of stranded conductors XLPE insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. LSF sheathed.	G29	16	.2	.008	36	32	.5	XLPE	1	Twisted	Yes	LSF	-30 to +75	–	Yes	Good	Very Good	4	–	–	6.0	16	Excellent for fire risk areas. Free of halogens. Round section. Rejects electromagnetic and electrostatic interference.
 One pair of stranded conductors XLPE insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. LSF bedded. Steel wire armoured and LSF sheathed.	G94	16	.2	.008	36	32	.5	XLPE	1	Twisted	Yes	LSF	-30 to +75	–	Yes	Good	Very Good	19	5.5	7.5	10.5	16 or 20S	Excellent for fire risk areas. Free of halogens. Round section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.
	G95	24	.2	.008	36	32	.75	XLPE	1	Twisted	Yes	LSF	-30 to +75	–	Yes	Good	Very Good	22	6.0	8.0	11.0	16 or 20S	
 One pair of stranded conductors XLPE insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with bare tinned copper drainwire. LSF sheathed. Coloured blue for Intrinsically Safe areas.	GS29	16	.2	.008	36	32	.5	XLPE	1	Twisted	Yes	LSF	-30 to +75	–	Yes (IS)	Good	Very Good	4	–	–	6.0	16	Sheath coloured blue for Intrinsically Safe areas. Excellent for fire risk areas. Free of halogens. Round section. Rejects electromagnetic and electrostatic interference.
 One pair of stranded conductors XLPE insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout with bare tinned copper drainwire. LSF bedded. Steel wire armoured and LSF sheathed. Coloured blue for Intrinsically Safe areas.	GS94	16	.2	.008	36	32	.5	XLPE	1	Twisted	Yes	LSF	-30 to +75	–	Yes (IS)	Good	Very Good	19	5.5	7.5	10.5	16 or 20S	Sheath coloured blue for Intrinsically Safe areas. Excellent for fire risk areas. Free of halogens. Round section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.
	GS95	24	.2	.008	36	32	.75	XLPE	1	Twisted	Yes	LSF	-30 to +75	–	Yes (IS)	Good	Very Good	22	6.0	8.0	11.0	16 or 20S	

Fire Resistant MICA/XLPE (Cross Linked Polyethylene)/Low Smoke and Fume Single Pairs

- Resistant to a temperature of 750°C for at least three hours in accordance with the flame test requirements of IEC 60331.
- Essential for situations where it is of strategic importance to ensure that the cable continues to function during a major crisis involving fire.
- The cable incorporates a high temperature rated Mica glass tape with a XLPE (Cross Linked Polyethylene) insulation on the cores and Low Smoke and Fume material on the bedding and/or outer sheath.
- The sheathing materials used are Halogen free.
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1986 Method 141.

Description	Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Gauge: SWG	Gauge: AWG	Total Area mm²	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Screen[1]	Overall: Insulation	Insulation Rating °C: Continuous	Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Diameter Under Armour[2] (mm)	Diameter Over Armour[2] (mm)	Overall Diameter[2] (mm)	Glands: Recommended Gland Ref.[3] (See page 35)	Notes
 One pair of stranded conductors Mica taped and XLPE insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire. LSF sheathed.	G98	16	.2	.008	36	32	.5	MICA and XLPE	1	Twisted	Yes	LSF	-30 to +75	750	Yes	Good	Very Good	5	–	–	7.0	16 or 20S	Excellent for signal continuity in the event of a fire. Free of halogens. Round section. Rejects electromagnetic and electrostatic interference.
 One pair of stranded conductors Mica taped and XLPE insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire. LSF bedded. Steel wire armoured and LSF sheathed.	G99	16	.2	.008	36	32	.5	MICA and XLPE	1	Twisted	Yes	LSF	-30 to +75	750	Yes	Good	Very Good	23	7.0	9.0	12.0	16 or 20S	Excellent for signal continuity in the event of a fire. Free of halogens. Round section. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength.

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. For armoured cables, the gland sizes shown are for the CGC and CGE flanges. CGA types are available, however the gland size will change. See page 35 for full details.

The above cable constructions are offered incorporating the following conductor combinations: KX, KCB, JX, TX, NX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.
In Intrinsically Safe areas, the user must be the best judge as to the suitability of the selected cable and it's use within that area. Users should refer to BS 5345.

*Mylar is a trade name.

Ordering Code - Typical example

G29 — KX — IEC

- Stock Number (G29)
- Thermocouple Conductor Combination (KX)
- Insulation Colour Code (IEC)

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Email: info@tc.co.uk - Web: www.tc.co.uk

01895 252222

CODE J

International Thermocouple Reference Tables for
Iron / Copper Nickel
To IEC60584.1:1995 / BS EN 60584.1 Part 3 : 1996

CODE J

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (µV).

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-210	-8095										-210
-200	-7890	-7912	-7934	-7955	-7976	-7996	-8017	-8037	-8057	-8076	-200
-190	-7659	-7683	-7707	-7731	-7755	-7778	-7801	-7824	-7846	-7868	-190
-180	-7403	-7429	-7456	-7482	-7508	-7534	-7559	-7585	-7610	-7634	-180
-170	-7123	-7152	-7181	-7209	-7237	-7265	-7293	-7321	-7348	-7376	-170
-160	-6821	-6853	-6883	-6914	-6944	-6975	-7005	-7035	-7064	-7094	-160
-150	-6500	-6533	-6566	-6598	-6631	-6663	-6695	-6727	-6759	-6790	-150
-140	-6159	-6194	-6229	-6263	-6298	-6332	-6366	-6400	-6433	-6467	-140
-130	-5801	-5838	-5874	-5910	-5946	-5982	-6018	-6054	-6089	-6124	-130
-120	-5426	-5465	-5503	-5541	-5578	-5616	-5653	-5690	-5727	-5764	-120
-110	-5037	-5076	-5116	-5155	-5194	-5233	-5272	-5311	-5350	-5388	-110
-100	-4633	-4674	-4714	-4755	-4796	-4836	-4877	-4917	-4957	-4997	-100
-90	-4215	-4257	-4300	-4342	-4384	-4425	-4467	-4509	-4550	-4591	-90
-80	-3786	-3829	-3872	-3916	-3959	-4002	-4045	-4088	-4130	-4173	-80
-70	-3344	-3389	-3434	-3478	-3522	-3566	-3610	-3654	-3698	-3742	-70
-60	-2893	-2938	-2984	-3029	-3075	-3120	-3165	-3210	-3255	-3300	-60
-50	-2431	-2478	-2524	-2571	-2617	-2663	-2709	-2755	-2801	-2847	-50
-40	-1961	-2008	-2055	-2103	-2150	-2197	-2244	-2291	-2338	-2385	-40
-30	-1482	-1530	-1578	-1626	-1674	-1722	-1770	-1818	-1865	-1913	-30
-20	-995	-1044	-1093	-1142	-1190	-1239	-1288	-1336	-1385	-1433	-20
-10	-501	-550	-600	-650	-699	-749	-798	-847	-896	-946	-10
-0	0	-50	-101	-151	-201	-251	-301	-351	-401	-451	0
0	0	50	101	151	202	253	303	354	405	456	0
10	507	558	609	660	711	762	814	865	916	968	10
20	1019	1071	1122	1174	1226	1277	1329	1381	1433	1485	20
30	1537	1589	1641	1693	1745	1797	1849	1902	1954	2006	30
40	2059	2111	2164	2216	2269	2322	2374	2427	2480	2532	40
50	2585	2638	2691	2744	2797	2850	2903	2956	3009	3062	50
60	3116	3169	3222	3275	3329	3382	3436	3489	3543	3596	60
70	3650	3703	3757	3810	3864	3918	3971	4025	4079	4133	70
80	4187	4240	4294	4348	4402	4456	4510	4564	4618	4672	80
90	4726	4781	4835	4889	4943	4997	5052	5106	5160	5215	90
100	5269	5323	5378	5432	5487	5541	5595	5650	5705	5759	100
110	5814	5868	5923	5977	6032	6087	6141	6196	6251	6306	110
120	6360	6415	6470	6525	6579	6634	6689	6744	6799	6854	120
130	6909	6964	7019	7074	7129	7184	7239	7294	7349	7404	130
140	7459	7514	7569	7624	7679	7734	7789	7844	7900	7955	140
150	8010	8065	8120	8175	8231	8286	8341	8396	8452	8507	150
160	8562	8618	8673	8728	8783	8839	8894	8949	9005	9060	160
170	9115	9171	9226	9282	9337	9392	9448	9503	9559	9614	170
180	9669	9725	9780	9836	9891	9947	10002	10057	10113	10168	180
190	10224	10279	10335	10390	10446	10501	10557	10612	10668	10723	190
200	10779	10834	10890	10945	11001	11056	11112	11167	11223	11278	200
210	11334	11389	11445	11501	11556	11612	11667	11723	11778	11834	210
220	11889	11945	12000	12056	12111	12167	12222	12278	12334	12389	220
230	12445	12500	12556	12611	12667	12722	12778	12833	12889	12944	230
240	13000	13056	13111	13167	13222	13278	13333	13389	13444	13500	240

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
250	13555	13611	13666	13722	13777	13833	13888	13944	13999	14055	250
260	14110	14166	14221	14277	14332	14388	14443	14499	14554	14609	260
270	14665	14720	14776	14831	14887	14942	14998	15053	15109	15164	270
280	15219	15275	15330	15386	15441	15496	15552	15607	15663	15718	280
290	15773	15829	15884	15940	15995	16050	16106	16161	16216	16272	290
300	16327	16383	16438	16493	16549	16604	16659	16715	16770	16825	300
310	16881	16936	16991	17046	17102	17157	17212	17268	17323	17378	310
320	17434	17489	17544	17599	17655	17710	17765	17820	17876	17931	320
330	17986	18041	18097	18152	18207	18262	18318	18373	18428	18483	330
340	18538	18594	18649	18704	18759	18814	18870	18925	18980	19035	340
350	19090	19146	19201	19256	19311	19366	19422	19477	19532	19587	350
360	19642	19697	19753	19808	19863	19918	19973	20028	20083	20139	360
370	20194	20249	20304	20359	20414	20469	20525	20580	20635	20690	370
380	20745	20800	20855	20911	20966	21021	21076	21131	21186	21241	380
390	21297	21352	21407	21462	21517	21572	21627	21683	21738	21793	390
400	21848	21903	21958	22014	22069	22124	22179	22234	22289	22345	400
410	22400	22455	22510	22565	22620	22676	22731	22786	22841	22896	410
420	22952	23007	23062	23117	23172	23228	23283	23338	23393	23449	420
430	23504	23559	23614	23670	23725	23780	23835	23891	23946	24001	430
440	24057	24112	24167	24223	24278	24333	24389	24444	24499	24555	440
450	24610	24665	24721	24776	24832	24887	24943	24998	25053	25109	450
460	25164	25220	25275	25331	25386	25442	25497	25553	25608	25664	460
470	25720	25775	25831	25886	25942	25998	26053	26109	26165	26220	470
480	26276	26332	26387	26443	26499	26555	26610	26666	26722	26778	480
490	26834	26889	26945	27001	27057	27113	27169	27225	27281	27337	490
500	27393	27449	27505	27561	27617	27673	27729	27785	27841	27897	500
510	27953	28010	28066	28122	28178	28234	28291	28347	28403	28460	510
520	28516	28572	28629	28685	28741	28798	28854	28911	28967	29024	520
530	29080	29137	29194	29250	29307	29363	29420	29477	29534	29590	530
540	29647	29704	29761	29818	29874	29931	29988	30045	30102	30159	540
550	30216	30273	30330	30387	30444	30502	30559	30616	30673	30730	550
560	30788	30845	30902	30960	31017	31074	31132	31189	31247	31304	560
570	31362	31419	31477	31535	31592	31650	31708	31766	31823	31881	570
580	31939	31997	32055	32113	32171	32229	32287	32345	32403	32461	580
590	32519	32577	32636	32694	32752	32810	32869	32927	32985	33044	590
600	33102	33161	33219	33278	33337	33395	33454	33513	33571	33630	600
610	33689	33748	33807	33866	33925	33984	34043	34102	34161	34220	610
620	34279	34338	34397	34457	34516	34575	34635	34694	34754	34813	620
630	34873	34932	34992	35051	35111	35171	35230	35290	35350	35410	630
640	35470	35530	35590	35650	35710	35770	35830	35890	35950	36010	640
650	36071	36131	36191	36252	36312	36373	36433	36494	36554	36615	650
660	36675	36736	36797	36858	36918	36979	37040	37101	37162	37223	660
670	37284	37345	37406	37467	37528	37590	37651	37712	37773	37835	670
680	37896	37958	38019	38081	38142	38204	38265	38327	38389	38450	680
690	38512	38574	38636	38698	38760	38822	38884	38946	39008	39070	690
700	39132	39194	39256	39318	39381	39443	39505	39568	39630	39693	700
710	39755	39818	39880	39943	40005	40068	40131	40193	40256	40319	710
720	40382	40445	40508	40570	40633	40696	40759	40822	40886	40949	720
730	41012	41075	41138	41201	41265	41328	41391	41455	41518	41581	730
740	41645	41708	41772	41835	41899	41962	42026	42090	42153	42217	740

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
750	42281	42344	42408	42472	42536	42599	42663	42727	42791	42855	750
760	42919	42983	43047	43111	43175	43239	43303	43367	43431	43495	760
770	43559	43624	43688	43752	43817	43881	43945	44010	44074	44139	770
780	44203	44267	44332	44396	44461	44525	44590	44655	44719	44784	780
790	44848	44913	44977	45042	45107	45171	45236	45301	45365	45430	790
800	45494	45559	45624	45688	45753	45818	45882	45947	46011	46076	800
810	46141	46205	46270	46334	46399	46464	46528	46593	46657	46722	810
820	46786	46851	46915	46980	47044	47109	47173	47238	47302	47367	820
830	47431	47495	47560	47624	47688	47753	47817	47881	47946	48010	830
840	48074	48138	48202	48267	48331	48395	48459	48523	48587	48651	840
850	48715	48779	48843	48907	48971	49034	49098	49162	49226	49290	850
860	49353	49417	49481	49544	49608	49672	49735	49799	49862	49926	860
870	49989	50052	50116	50179	50243	50306	50369	50432	50495	50559	870
880	50622	50685	50748	50811	50874	50937	51000	51063	51126	51188	880
890	51251	51314	51377	51439	51502	51565	51627	51690	51752	51815	890
900	51877	51940	52002	52064	52127	52189	52251	52314	52376	52438	900
910	52500	52562	52624	52686	52748	52810	52872	52934	52996	53057	910
920	53119	53181	53243	53304	53366	53427	53489	53550	53612	53673	920
930	53735	53796	53857	53919	53980	54041	54102	54164	54225	54286	930
940	54347	54408	54469	54530	54591	54652	54713	54773	54834	54895	940
950	54956	55016	55077	55138	55198	55259	55319	55380	55440	55501	950
960	55561	55622	55682	55742	55803	55863	55923	55983	56043	56104	960
970	56164	56224	56284	56344	56404	56464	56524	56584	56643	56703	970
980	56763	56823	56883	56942	57002	57062	57121	57181	57240	57300	980
990	57360	57419	57479	57538	57597	57657	57716	57776	57835	57894	990
1000	57953	58013	58072	58131	58190	58249	58309	58368	58427	58486	1000
1010	58545	58604	58663	58722	58781	58840	58899	58957	59016	59075	1010
1020	59134	59193	59252	59310	59369	59428	59487	59545	59604	59663	1020
1030	59721	59780	59838	59897	59956	60014	60073	60131	60190	60248	1030
1040	60307	60365	60423	60482	60540	60599	60657	60715	60774	60832	1040
1050	60890	60949	61007	61065	61123	61182	61240	61298	61356	61415	1050
1060	61473	61531	61589	61647	61705	61763	61822	61880	61938	61996	1060
1070	62054	62112	62170	62228	62286	62344	62402	62460	62518	62576	1070
1080	62634	62692	62750	62808	62866	62924	62982	63040	63098	63156	1080
1090	63214	63271	63329	63387	63445	63503	63561	63619	63677	63734	1090
1100	63792	63850	63908	63966	64024	64081	64139	64197	64255	64313	1100
1110	64370	64428	64486	64544	64602	64659	64717	64775	64833	64890	1110
1120	64948	65006	65064	65121	65179	65237	65295	65352	65410	65468	1120
1130	65525	65583	65641	65699	65756	65814	65872	65929	65987	66045	1130
1140	66102	66160	66218	66275	66333	66391	66448	66506	66564	66621	1140
1150	66679	66737	66794	66852	66910	66967	67025	67082	67140	67198	1150
1160	67255	67313	67370	67428	67486	67543	67601	67658	67716	67773	1160
1170	67831	67888	67946	68003	68061	68119	68176	68234	68291	68348	1170
1180	68406	68463	68521	68578	68636	68693	68751	68808	68865	68923	1180
1190	68980	69037	69095	69152	69209	69267	69324	69381	69439	69496	1190
1200	69553										1200

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G, C & D** page 70	

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

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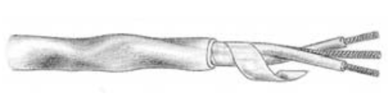
Thermocouple Extension and Compensating Cable

PFA Insulated Single Pairs

- PFA is ideal for higher temperature applications up to 250°C when Heat Resistant PVC is not adequate
- It is also excellent for cryogenic temperatures down to –75°C
- PFA will withstand attack from virtually all known chemicals, oils and fluids. All our PFA cables are made in extruded form and are therefore gas, steam and water tight which makes them most suitable for applications such as autoclaves or sterilizers
- We offer a wide variety of constructions from simple twisted pairs to screened types in virtually all the thermocouple combinations
- For PFA insulated Multipairs see page 29

		Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Size of Strand Gauge: SWG	Size of Strand Gauge: AWG	Total Area mm²	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Screen¹	Overall: Insulation	Insulation Rating °C: Continuous	Insulation Rating °C: Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Overall Diameter² (mm)	Glands: Recommended Gland Ref.³ (See page 35)	Notes
	One pair of solid conductors. Negative conductor Kapton* insulated. Pair laid flat and Kapton* sheathed.	B08	1	.25	.01	33	30	.05	Kapton	1	Flat	No	Kapton	-75 to +285	+400	No	Very Good	Fair	<1	<1	–	Egg shaped section.
	One pair of solid conductors PFA insulated. Pair twisted.	B10	1	.2	.008	36	32	.03	PFA	1	Twisted	No	–	-75 to +250	+300	Yes	Good	Very Good	1	2	–	Rejects electromagnetic interference.
		B11	1	.3	.012	31	28	.07	PFA	1	Twisted	No	–	-75 to +250	+300	Yes	Good	Very Good	1	2	–	
	One pair of stranded conductors PFA insulated. Pair twisted.	B54	7	.2	.008	36	32	.22	PFA	1	Twisted	No	–	-75 to +250	+300	Yes	Good	Very Good	1	3	10	Rejects electromagnetic interference. Gas, steam and water tight insulation.
	One pair of solid conductors. Pair laid flat and PFA sheathed in single shot construction.	B13	1	.376	.015	28	27	.11	PFA	1	Flat	No	–	-75 to +250	+300	Yes	Very Good	Very Good	1	2	10	Gas, steam and water tight insulation. Single shot construction. Ideal for use in autoclaves.
	One pair of solid conductors PFA insulated. Pair laid flat and PFA sheathed.	B20	1	.5	.02	25	24	.2	PFA	1	Flat	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	1	2x3	10	Oval section. Gas, steam and water tight insulation.
		B30	1	.8	.03	21	20	.5	PFA	1	Flat	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	2	3x4	10	
	One pair of solid conductors PFA insulated. Pair twisted and PFA sheathed.	B25	1	.5	.02	25	24	.2	PFA	1	Twisted	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	1	3	10	Round section (pair lay visible through sheath). Rejects electromagnetic interference. Gas, steam and water tight insulation.
		B35	1	.8	.03	21	20	.5	PFA	1	Twisted	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	2	3	10	
	One pair of stranded conductors PFA insulated. Pair laid flat and PFA sheathed.	B50	7	.2	.008	36	32	.22	PFA	1	Flat	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	1	2x3	10	Oval section. Gas, steam and water tight insulation.
		B60	14	.2	.008	36	32	.44	PFA	1	Flat	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	2	2x3	10	
	One pair of stranded conductors PFA insulated. Pair twisted and PFA sheathed.	B55	7	.2	.008	36	32	.22	PFA	1	Twisted	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	1	3	10	Round section (pair lay visible through sheath). Rejects electromagnetic interference. Gas, steam and water tight insulation.
		B65	14	.2	.008	36	32	.44	PFA	1	Twisted	No	PFA	-75 to +250	+300	Yes	Very Good	Very Good	2	3	10	
	One pair of solid conductors PFA insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire. PFA sheathed.	B70	1	.8	.03	21	20	.5	PFA	1	Twisted	Yes	PFA	-75 to +250	+300	Yes	Very Good	Very Good	3	4	10	Round section. Rejects electromagnetic and electrostatic interference. Gas, steam and water tight insulation.
		B75	1	1.29	.05	18	16	1.3	PFA	1	Twisted	Yes	PFA	-75 to +250	+300	Yes	Very Good	Very Good	4	6	12 or 16	
	One pair of stranded conductors PFA insulated. Pair twisted. Screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire. PFA sheathed.	B80	7	.2	.008	36	32	.22	PFA	1	Twisted	Yes	PFA	-75 to +250	+300	Yes	Very Good	Very Good	3	3	10	Round section. Rejects electromagnetic and electrostatic interference. Gas, steam and water tight insulation.
		B85	14	.2	.008	36	32	.44	PFA	1	Twisted	Yes	PFA	-75 to +250	+300	Yes	Very Good	Very Good	3	4	10	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.2mm dia tinned nickel drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. Whilst we show gland references for laid flat oval shaped cables, we would recommend you choose a twisted round section construction for a better gland fit.

The above cable constructions are offered incorporating the following conductor combinations: KX, JX, TX, NX, EX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
Most of the above constructions can be overbraided with stainless steel or tinned copper braid within a few weeks.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

Kapton and Mylar are trade names.

Ordering Code - Typical example

B50 — KX — IEC

Stock Number (B50)
Thermocouple Conductor Combination (KX)
Insulation Colour Code (IEC)

3.0 Extension Leads and Compensating Cables - Operating Characteristics

It is often desirable to connect a thermocouple probe as part of a very long circuit from the sensor itself to a remote reference unit and/or measuring instrumentation. Yet, we would rather avoid the expense of high specification thermocouple cables on a long run. Connecting cheaper cable would be ideal - but we need to do so without having to take particular care that the temperature where the connection is made is known and taken into account. We only want to concern ourselves with the hot junction and remote reference junction temperatures - in the usual way.

For this to be possible, the thermoelectric properties of the additional conductors must not differ too much from those of the thermocouple itself (Part 1, Section 2). Extension and compensating cables provide convenient, economic solutions - each with its pros and cons.

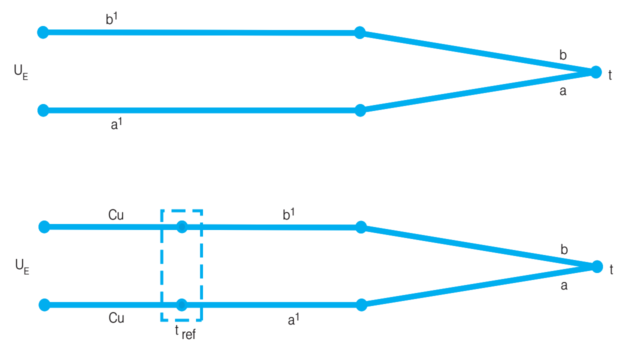


Figure 3.1: *Connection of Extension or Compensating Cable*

Extension cables use wires of nominally the same conductors as the thermocouple itself, which thus inherently possess similar thermopower characteristics, and present no connection problems. Mismatch errors arising from high connecting box temperatures are likely to be relatively small. These cables are less costly than thermocouple wire, although not cheap, and are usually produced in a convenient form for carrying over long distances - typically as flexible wiring or multi-core cables. They are recommended for best accuracy.

Compensating cables, on the other hand, are less precise, but cheaper. They harness quite different, relatively low cost alloy conductor materials whose net thermoelectric coefficients are similar to those of the thermocouple in question, but which do not match them as faithfully as do extension cables. Thus, the combination develops similar outputs to those of the thermocouple, but the operating temperature range has to be restricted to keep mismatch errors acceptably small.

Obvious examples where the use of compensating cables can save cost - and at the same time be a lot more convenient to install - include the situation where rare (say platinum) metal thermocouples, or alternatively heavy gauge base metal thermocouples (say on an industrial furnace or in a nuclear reactor) are being used. Here the cost of the thermocouple material is clearly quite high, and in the latter case far from ideal for weaving long distance around an industrial plant.

Much lower cost compensating cables can provide an instant economic solution to extending the thermocouple circuit. Also, since it is available as relatively light, multi-stranded wires, the practical issues are resolved.

In practice there would be a junction box close to the measuring point, probably in the thermocouple head to allow the coupling of the different wires. It must, however, be borne in mind that if the temperature of the connector is allowed to deviate beyond an acceptable band, the output from the compensating cables will diverge progressively from that of the thermocouple (since their thermopowers are not identical), and errors in the temperature reading will result.

Another example of the use of compensating cables is in situations where Type K thermocouple is closely matched at low temperatures by the combination of Cu vs Cu-Ni conductors. As one conductor is already copper, the number of reference junctions is halved - which provides a distinct advantage, especially with large multi-thermocouple projects. Further, the loop resistance of this cable is also somewhat less than the equivalent Type K conductors.

3.1 Lead Resistance

Loop resistance calculation tables are available for extension and compensating cable combinations in accordance with each of the thermocouple types. They are specified for twin runs of cable on a per metre length basis - as a constant to be divided by the cross sectional area of the conductor to be used (see Table 3.1).

Resistance in Ohms/meter of the common thermocouple extension and compensating cable combinations at 20°C
To obtain loop resistances for twin runs per meter take the constants given below for the required combination and divide the constant by the cross sectional area in mm^2 of the conductor size you intend to use.

Combination Code	Constant	Combination Code	Constant	Combination Code	Constant
KX	1.00	NX	1.37	GC(W)	0.34
KCB(V)	0.51	RX	0.33	CC(W$_5$)	0.40
TX	0.51	SX	0.32	DC(W$_3$)	0.38
JX	0.60	BX	0.39		
EX	1.21	RCA(U)	0.07		

Table 3.1: *Loop Resistance in Ohms/meter for Extension and Compensating Cable*

3.2 Insulation

PVC types can be used over the range -30 to +105°C, and are available in twisted, flat pair, or multi-pair configurations. There is a range of options - with ripcord, PVC sheathed, screened, with a copper wire drain, or steel wire armoured constructions - the conductor itself being solid or stranded.

PFA offers a greater temperature range, covering from -273°C to +250°C, or 300°C for short periods. This, too, is available in flat or twisted pair formats, but not steel wire armoured versions.

Moving up the range, we find varnish impregnated glass fibre, which handles from -50°C to +400°C, while unvarnished glass fibre takes this up to 500°C and in some cases 800°C. Single and multi-pair varieties are available in flat and twisted formats with many of the options.

3.3 Colour Coding and Specification

Extension leads and compensating cables (and plugs, sockets and so on) are distinguished by colour codes and letters to ease identification of the whole circuit. Although the codes used to be different from country to country, standardised colours have been adopted for all standard thermocouples, as in IEC 60584.3 (BS EN 60584.3:2008), and this international coding is now the accepted norm (see Part 1, Section 3.15 for full details).

Main points to note include the following. Firstly, there is no colour differentiation between extension and compensating cable. The letter `X' after the thermocouple Type indicates extension cable, while `C' denotes compensating cable. Also, colour does not distinguish between classes of conductor in extension cable. Instead, details like JX Class 1 indicates the tighter tolerance material for a Type J thermocouple, for example, while JX Class 2 designates the basic tolerance materials.

With compensating cable, the different alloys used are distinguished by KCA and KCB, for example, indicate Type K thermocouple compensating cable using version A and version B alloys respectively. KCB is the old `VX' copper vs constantan combination; KCA is the earlier `WX' iron vs constantan. Clearly, care needs to be taken here. Additional information, like numbers of pairs, conductor cross section, temperature range, manufacturer, etc may be embossed or printed on cables and cable drums.

A table showing colour identification schemes is shown on Page 5. All negative legs are white; insulation of the positive legs is as per the chart; and the sheath (if any) is the same colour as the positive leg - except where intrinsically safe circuits are concerned, where it is blue irrespective of type.

4.0 Connector Types and Styles

Although the simplest of thermocouples and resistance thermometer detectors end in bare wires - as found in many laboratory and industrial/research applications, for example - there are many other applications where a connector is usually desirable to make life easier.

Miniature and standard thermocouple connectors are available for use with all common thermocouple conductor (extension or compensating cable) combinations, and for use with copper conductors in applications involving resistance thermometers, for example. For thermocouple applications, thermocouple grade alloys are incorporated in the contact parts of the connector for the reasons discussed (see Part 1, Section 2 and Part 2, Section 3). This avoids the generation of unwanted emfs if the connector is not held at uniform temperature.

The device is usually harnessed to connect the thermocouple assembly to extension or compensating cables, and thus on to the reference junction and the instrumentation concerned. The arrangement allows for rapid fitting or exchange of sensors without sacrificing thermocouple conductor uniformity. Plug and socket bodies are normally engineered so that their installation can be made simply and securely, usually with designed-in locking mechanisms. Plugs and sockets are polarised by size and are usually marked for negative and positive polarity. Although there is no standard as such, connectors are generally pin compatible with devices from several manufacturers.

In general, although connector bodies for thermocouples are colour coded in accordance with the international thermocouple standards (IEC 60584.1), bodies of the higher temperature rated devices may be coloured brown irrespective of their thermocouple code. Bodies are then marked with their international thermocouple code letter only.

Accessories include connector panels (standard and miniature), for stacking of sockets in multiple thermocouple applications, and barrier terminal strips. The latter have lugs marked to identify both alloy and polarity, and are available for most of the common standard types of thermocouple as well as copper wires for resistance thermometers.

5.0 Reference (Cold) Junction Compensation Methods, etc

As explained earlier, thermocouples provide an output which is related to the temperatures of the two junctions. For them to function as absolute temperature measuring devices, rather than differential, the reference junctions must be maintained at a known temperature (see Figure 5.1).

An established, simple method of maintaining reference temperature stability, still used in laboratories today, is to immerse the reference junctions in a slush of melting ice. Given that you have pure water ice, the temperature plateau during the melting process is established at a constant 0°C within ±0.001°C. In practice, all that is required is an ice-filled Dewar flask, and the set-up is then potentially quite accurate. However, it does require regular attention and replenishment for anything other than short term use, and is clearly inappropriate for industrial requirements. Sources of error include the 4°C reference offset which will occur if enough ice melts so that the reference junctions are actually immersed only in water - with the ice floating above! Remember also that if the ice you use has been stored in a freezer, it will be a lot colder than 0°C.

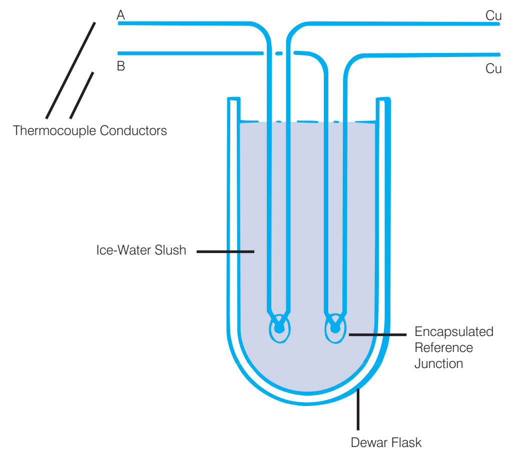


Figure 5.1: *Dewar Flask with Reference Junctions*

Not surprisingly, today there are more practical alternatives for industrial use, also designed to provide a reference temperature of 0°C. One involves an automatic temperature-controlled enclosure, into which the reference junctions are inserted. This holds the junctions continuously at the ice point, using semiconductor thermoelectric cooling (Peltier) devices. Here temperature errors are typically less than 0.1°C. The use of an ice point reference, or its equivalent (however generated), is still preferable to the alternatives, not only on the grounds of accuracy and stability, but also because the reference tables for thermocouples are based on a 0°C reference temperature.

Continued on page 24

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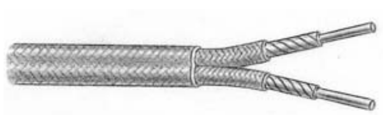
Thermocouple Extension and Compensating Cable

Fibreglass and Ceramic Fibre Insulated Single Pairs

- Excellent for high temperature applications up to 480°C for Fibreglass, 800°C for High Temperature Fibreglass and 1400°C for Ceramic Fibre
- Suitable for use at normal air ambient temperatures where there is a possibility of a hot spot which might damage lower rated cables such as PVC or PFA
- We offer a wide variety of constructions from simple lapped and Fibreglass braided to stainless steel braided types in virtually all the thermocouple combinations
- For Fibreglass insulated Multipairs see page 29

Construction	Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Size of Strand Gauge: SWG	Size of Strand Gauge: AWG	Total Area mm²	Conductors: Insulation	Pairs: No. of Pairs	Pairs: Laid-Flat or Twisted	Pairs: Screen[1]	Overall: Insulation	Insulation Rating °C: Continuous	Insulation Rating °C: Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Overall Diameter[2] (mm)	Glands: Recommended Gland Ref.[3] (See page 35)	Notes
 One pair of solid conductors. Each conductor double glass fibre lapped and silicone varnished. Pair laid flat, glass fibre braided overall and silicone varnished.	C05	1	.2	.008	36	32	.03	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	1	1x2	10	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C09	1	.3	.012	31	28	.07	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	1	1x2	10	
 One pair of solid conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. Pair laid flat, glass fibre braided overall and silicone varnished.	C10	1	.3	.012	31	28	.07	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	1	1x2	10	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C20	1	.5	.02	25	24	.2	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	1	2x3	10	
	C30	1	.8	.03	21	20	.5	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	2	2x3	10	
 One pair of stranded conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. Pair twisted, glass fibre braided overall and silicone varnished.	C37	7	.2	.008	36	32	.22	Fibreglass	1	twisted	No	Fibreglass	+480	+540	Yes	Fair	Fair	1	3	10	Rejects electromagnetic interference. Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C38	14	.2	.008	36	32	.44	Fibreglass	1	twisted	No	Fibreglass	+480	+540	Yes	Fair	Fair	2	4	10	
 One pair of stranded conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. Pair laid flat, glass fibre braided overall and silicone varnished.	C40	7	.2	.008	36	32	.22	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	1	2x3	10	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C50	14	.2	.008	36	32	.44	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	2	2x3	10	
	C51	24	.2	.008	36	32	.75	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	3	3x4	10	
	C52	32	.2	.008	36	32	1.0	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	4	3x4	10	
	C53	40	.2	.008	36	32	1.3	Fibreglass	1	Flat	No	Fibreglass	+480	+540	Yes	Fair	Fair	4	4x5	12 or 16	
 One pair of stranded conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. Pair laid flat, glass fibre braided and silicone varnished. Stainless steel wire braided overall.	C60	7	.2	.008	36	32	.22	Fibreglass	1	Flat	Yes[1]	Fibreglass	+480	+540	Yes	Good	Fair	2	3x4	10	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C65	14	.2	.008	36	32	.44	Fibreglass	1	Flat	Yes[1]	Fibreglass	+480	+540	Yes	Good	Fair	3	3x4	10	
	C66	24	.2	.008	36	32	.75	Fibreglass	1	Flat	Yes[1]	Fibreglass	+480	+540	Yes	Good	Fair	4	4x5	12 or 16	
	C67	32	.2	.008	36	32	1.0	Fibreglass	1	Flat	Yes[1]	Fibreglass	+480	+540	Yes	Good	Fair	5	4x5	12 or 16	
	C68	40	.2	.008	36	32	1.3	Fibreglass	1	Flat	Yes[1]	Fibreglass	+480	+540	Yes	Good	Fair	5	4x6	12 or 16	
 One pair of solid conductors. Each conductor double high temperature glass fibre lapped, double high temperature glass fibre braided and silicone varnished. Pair laid flat, high temperature glass fibre braided overall and silicone varnished.	C76	1	.5	.02	25	24	.2	High Temp Fibreglass	1	Flat	No	High Temp Fibreglass	+800	–	Yes	Fair	Fair	1	2x3	10	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C77	1	.8	.03	21	20	.5	High Temp Fibreglass	1	Flat	No	High Temp Fibreglass	+800	–	Yes	Fair	Fair	2	2x3	10	
	C70	1	1.29	.05	18	16	1.3	High Temp Fibreglass	1	Flat	No	High Temp Fibreglass	+800	–	Yes	Fair	Fair	4	4x6	12 or 16	
 One pair of solid conductors. Each conductor double high temperature glass fibre lapped, double high temperature glass fibre braided and silicone varnished. Pair laid flat, high temperature glass fibre braided and silicone varnished. Stainless steel wire braided overall.	C78	1	.5	.02	25	24	.2	High Temp Fibreglass	1	Flat	Yes[1]	High Temp Fibreglass	+800	–	Yes	Good	Fair	2	3x4	10	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
	C79	1	.8	.03	21	20	.5	High Temp Fibreglass	1	Flat	Yes[1]	High Temp Fibreglass	+800	–	Yes	Good	Fair	3	3x4	10	
	C71	1	1.29	.05	18	16	1.3	High Temp Fibreglass	1	Flat	Yes[1]	High Temp Fibreglass	+800	–	Yes	Good	Fair	5	5x7	16	
 One pair of solid conductors. Each conductor ceramic fibre braided and impregnated with a ceramic binder. Pair laid flat and ceramic fibre braided overall and impregnated with a ceramic binder.	D20	1	.8	.03	21	20	.5	Ceramic Fibre	1	Flat	No	Ceramic Fibre	−185 to +1400	–	No	Fair	Fair	2	2x3	10	Outstanding high temperature performance. Requires free circulation of air. Do not use in a vacuum.

1. These cables have a stainless steel braid which can be used as a screen.
2. These values are nominal and if critical to your application, please request a physical check.
3. Whilst we show gland references for laid flat oval shaped cables, we would recommend you choose a twisted round section construction for a better gland fit.

The above cable constructions are offered incorporating the following conductor combinations: KX, JX, TX, NX, EX, RCB or SCB. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
Most of the above constructions can be overbraided with stainless steel or tinned copper braid within a few weeks.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

Ordering Code - Typical example

C40 — KX — IEC

- Stock Number (C40)
- Thermocouple Conductor Combination (KX)
- Insulation Colour Code (IEC)

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CODE N

CODE N

International Thermocouple Reference Tables for
Nickel Chromium Silicon / Nickel Silicon Magnesium
To IEC60584.1:1995 / BS EN 60584.1 Part 8 : 1996

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (μV).

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-270	-4345										-270
-260	-4336	-4337	-4339	-4340	-4341	-4342	-4343	-4344	-4344	-4345	-260
-250	-4313	-4316	-4319	-4321	-4324	-4326	-4328	-4330	-4332	-4334	-250
-240	-4277	-4281	-4285	-4289	-4293	-4297	-4300	-4304	-4307	-4310	-240
-230	-4226	-4232	-4238	-4243	-4248	-4254	-4258	-4263	-4268	-4273	-230
-220	-4162	-4169	-4176	-4183	-4189	-4196	-4202	-4209	-4215	-4221	-220
-210	-4083	-4091	-4100	-4108	-4116	-4124	-4132	-4140	-4147	-4154	-210
-200	-3990	-4000	-4010	-4020	-4029	-4038	-4048	-4057	-4066	-4074	-200
-190	-3884	-3896	-3907	-3918	-3928	-3939	-3950	-3960	-3970	-3980	-190
-180	-3766	-3778	-3790	-3803	-3815	-3827	-3838	-3850	-3862	-3873	-180
-170	-3634	-3648	-3662	-3675	-3688	-3702	-3715	-3728	-3740	-3753	-170
-160	-3491	-3506	-3521	-3535	-3550	-3564	-3578	-3593	-3607	-3621	-160
-150	-3336	-3352	-3368	-3384	-3400	-3415	-3431	-3446	-3461	-3476	-150
-140	-3171	-3188	-3205	-3221	-3238	-3255	-3271	-3288	-3304	-3320	-140
-130	-2994	-3012	-3030	-3048	-3066	-3084	-3101	-3119	-3136	-3153	-130
-120	-2808	-2827	-2846	-2865	-2883	-2902	-2921	-2939	-2958	-2976	-120
-110	-2612	-2632	-2652	-2672	-2691	-2711	-2730	-2750	-2769	-2789	-110
-100	-2407	-2428	-2448	-2469	-2490	-2510	-2531	-2551	-2571	-2592	-100
-90	-2193	-2215	-2237	-2258	-2280	-2301	-2322	-2344	-2365	-2386	-90
-80	-1972	-1995	-2017	-2039	-2062	-2084	-2106	-2128	-2150	-2172	-80
-70	-1744	-1767	-1790	-1813	-1836	-1859	-1882	-1905	-1927	-1950	-70
-60	-1509	-1533	-1557	-1580	-1604	-1627	-1651	-1674	-1698	-1721	-60
-50	-1269	-1293	-1317	-1341	-1366	-1390	-1414	-1438	-1462	-1485	-50
-40	-1023	-1048	-1072	-1097	-1122	-1146	-1171	-1195	-1220	-1244	-40
-30	-772	-798	-823	-848	-873	-898	-923	-948	-973	-998	-30
-20	-518	-544	-569	-595	-620	-646	-671	-696	-722	-747	-20
-10	-260	-286	-312	-338	-364	-390	-415	-441	-467	-492	-10
-0	0	-26	-52	-78	-104	-131	-157	-183	-209	-234	-0
0	0	26	52	78	104	130	156	182	208	235	0
10	261	287	313	340	366	393	419	446	472	499	10
20	525	552	578	605	632	659	685	712	739	766	20
30	793	820	847	874	901	928	955	983	1010	1037	30
40	1065	1092	1119	1147	1174	1202	1229	1257	1284	1312	40
50	1340	1368	1395	1423	1451	1479	1507	1535	1563	1591	50
60	1619	1647	1675	1703	1732	1760	1788	1817	1845	1873	60
70	1902	1930	1959	1988	2016	2045	2074	2102	2131	2160	70
80	2189	2218	2247	2276	2305	2334	2363	2392	2421	2450	80
90	2480	2509	2538	2568	2597	2626	2656	2685	2715	2744	90
100	2774	2804	2833	2863	2893	2923	2953	2983	3012	3042	100
110	3072	3102	3133	3163	3193	3223	3253	3283	3314	3344	110
120	3374	3405	3435	3466	3496	3527	3557	3588	3619	3649	120
130	3680	3711	3742	3772	3803	3834	3865	3896	3927	3958	130
140	3989	4020	4051	4083	4114	4145	4176	4208	4239	4270	140
150	4302	4333	4365	4396	4428	4459	4491	4523	4554	4586	150
160	4618	4650	4681	4713	4745	4777	4809	4841	4873	4905	160
170	4937	4969	5001	5033	5066	5098	5130	5162	5195	5227	170
180	5259	5292	5324	5357	5389	5422	5454	5487	5520	5552	180
190	5585	5618	5650	5683	5716	5749	5782	5815	5847	5880	190
200	5913	5946	5979	6013	6046	6079	6112	6145	6178	6211	200
210	6245	6278	6311	6345	6378	6411	6445	6478	6512	6545	210
220	6579	6612	6646	6680	6713	6747	6781	6814	6848	6882	220
230	6916	6949	6983	7017	7051	7085	7119	7153	7187	7221	230
240	7255	7289	7323	7357	7392	7426	7460	7494	7528	7563	240

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
250	7597	7631	7666	7700	7734	7769	7803	7838	7872	7907	250
260	7941	7976	8010	8045	8080	8114	8149	8184	8218	8253	260
270	8288	8323	8358	8392	8427	8462	8497	8532	8567	8602	270
280	8637	8672	8707	8742	8777	8812	8847	8882	8918	8953	280
290	8988	9023	9058	9094	9129	9164	9200	9235	9270	9306	290
300	9341	9377	9412	9448	9483	9519	9554	9590	9625	9661	300
310	9696	9732	9768	9803	9839	9875	9910	9946	9982	10018	310
320	10054	10089	10125	10161	10197	10233	10269	10305	10341	10377	320
330	10413	10449	10485	10521	10557	10593	10629	10665	10701	10737	330
340	10774	10810	10846	10882	10918	10955	10991	11027	11064	11100	340
350	11136	11173	11209	11245	11282	11318	11355	11391	11428	11464	350
360	11501	11537	11574	11610	11647	11683	11720	11757	11793	11830	360
370	11867	11903	11940	11977	12013	12050	12087	12124	12160	12197	370
380	12234	12271	12308	12345	12382	12418	12455	12492	12529	12566	380
390	12603	12640	12677	12714	12751	12788	12825	12862	12899	12937	390
400	12974	13011	13048	13085	13122	13159	13197	13234	13271	13308	400
410	13346	13383	13420	13457	13495	13532	13569	13607	13644	13682	410
420	13719	13756	13794	13831	13869	13906	13944	13981	14019	14056	420
430	14094	14131	14169	14206	14244	14281	14319	14356	14394	14432	430
440	14469	14507	14545	14582	14620	14658	14695	14733	14771	14809	440
450	14846	14884	14922	14960	14998	15035	15073	15111	15149	15187	450
460	15225	15262	15300	15338	15376	15414	15452	15490	15528	15566	460
470	15604	15642	15680	15718	15756	15794	15832	15870	15908	15946	470
480	15984	16022	16060	16099	16137	16175	16213	16251	16289	16327	480
490	16366	16404	16442	16480	16518	16557	16595	16633	16671	16710	490
500	16748	16786	16824	16863	16901	16939	16978	17016	17054	17093	500
510	17131	17169	17208	17246	17285	17323	17361	17400	17438	17477	510
520	17515	17554	17592	17630	17669	17707	17746	17784	17823	17861	520
530	17900	17938	17977	18016	18054	18093	18131	18170	18208	18247	530
540	18286	18324	18363	18401	18440	18479	18517	18556	18595	18633	540
550	18672	18711	18749	18788	18827	18865	18904	18943	18982	19020	550
560	19059	19098	19136	19175	19214	19253	19292	19330	19369	19408	560
570	19447	19485	19524	19563	19602	19641	19680	19718	19757	19796	570
580	19835	19874	19913	19952	19990	20029	20068	20107	20146	20185	580
590	20224	20263	20302	20341	20379	20418	20457	20496	20535	20574	590
600	20613	20652	20691	20730	20769	20808	20847	20886	20925	20964	600
610	21003	21042	21081	21120	21159	21198	21237	21276	21315	21354	610
620	21393	21432	21471	21510	21549	21588	21628	21667	21706	21745	620
630	21784	21823	21862	21901	21940	21979	22018	22058	22097	22136	630
640	22175	22214	22253	22292	22331	22370	22410	22449	22488	22527	640
650	22566	22605	22644	22684	22723	22762	22801	22840	22879	22919	650
660	22958	22997	23036	23075	23115	23154	23193	23232	23271	23311	660
670	23350	23389	23428	23467	23507	23546	23585	23624	23663	23703	670
680	23742	23781	23820	23860	23899	23938	23977	24016	24056	24095	680
690	24134	24173	24213	24252	24291	24330	24370	24409	24448	24487	690
700	24527	24566	24605	24644	24684	24723	24762	24801	24841	24880	700
710	24919	24959	24998	25037	25076	25116	25155	25194	25233	25273	710
720	25312	25351	25391	25430	25469	25508	25548	25587	25626	25666	720
730	25705	25744	25783	25823	25862	25901	25941	25980	26019	26058	730
740	26098	26137	26176	26216	26255	26294	26333	26373	26412	26451	740
750	26491	26530	26569	26608	26648	26687	26726	26766	26805	26844	750
760	26883	26923	26962	27001	27041	27080	27119	27158	27198	27237	760
770	27276	27316	27355	27394	27433	27473	27512	27551	27591	27630	770
780	27669	27708	27748	27787	27826	27866	27905	27944	27983	28023	780
790	28062	28101	28140	28180	28219	28258	28297	28337	28376	28415	790

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
800	28455	28494	28533	28572	28612	28651	28690	28729	28769	28808	800
810	28847	28886	28926	28965	29004	29043	29083	29122	29161	29200	810
820	29239	29279	29318	29357	29396	29436	29475	29514	29553	29592	820
830	29632	29671	29710	29749	29789	29828	29867	29906	29945	29985	830
840	30024	30063	30102	30141	30181	30220	30259	30298	30337	30376	840
850	30416	30455	30494	30533	30572	30611	30651	30690	30729	30768	850
860	30807	30846	30886	30925	30964	31003	31042	31081	31120	31160	860
870	31199	31238	31277	31316	31355	31394	31433	31473	31512	31551	870
880	31590	31629	31668	31707	31746	31785	31824	31863	31903	31942	880
890	31981	32020	32059	32098	32137	32176	32215	32254	32293	32332	890
900	32371	32410	32449	32488	32527	32566	32605	32644	32683	32722	900
910	32761	32800	32839	32878	32917	32956	32995	33034	33073	33112	910
920	33151	33190	33229	33268	33307	33346	33385	33424	33463	33502	920
930	33541	33580	33619	33658	33697	33736	33774	33813	33852	33891	930
940	33930	33969	34008	34047	34086	34124	34163	34202	34241	34280	940
950	34319	34358	34396	34435	34474	34513	34552	34591	34629	34668	950
960	34707	34746	34785	34823	34862	34901	34940	34979	35017	35056	960
970	35095	35134	35172	35211	35250	35289	35327	35366	35405	35444	970
980	35482	35521	35560	35598	35637	35676	35714	35753	35792	35831	980
990	35869	35908	35946	35985	36024	36062	36101	36140	36178	36217	990
1000	36256	36294	36333	36371	36410	36449	36487	36526	36564	36603	1000
1010	36641	36680	36718	36757	36796	36834	36873	36911	36950	36988	1010
1020	37027	37065	37104	37142	37181	37219	37258	37296	37334	37373	1020
1030	37411	37450	37488	37527	37565	37603	37642	37680	37719	37757	1030
1040	37795	37834	37872	37911	37949	37987	38026	38064	38102	38141	1040
1050	38179	38217	38256	38294	38332	38370	38409	38447	38485	38524	1050
1060	38562	38600	38638	38677	38715	38753	38791	38829	38868	38906	1060
1070	38944	38982	39020	39059	39097	39135	39173	39211	39249	39287	1070
1080	39326	39364	39402	39440	39478	39516	39554	39592	39630	39668	1080
1090	39706	39744	39783	39821	39859	39897	39935	39973	40011	40049	1090
1100	40087	40125	40163	40201	40238	40276	40314	40352	40390	40428	1100
1110	40466	40504	40542	40580	40618	40655	40693	40731	40769	40807	1110
1120	40845	40883	40920	40958	40996	41034	41072	41109	41147	41185	1120
1130	41223	41260	41298	41336	41374	41411	41449	41487	41525	41562	1130
1140	41600	41638	41675	41713	41751	41788	41826	41864	41901	41939	1140
1150	41976	42014	42052	42089	42127	42164	42202	42239	42277	42314	1150
1160	42352	42390	42427	42465	42502	42540	42577	42614	42652	42689	1160
1170	42727	42764	42802	42839	42877	42914	42951	42989	43026	43064	1170
1180	43101	43138	43176	43213	43250	43288	43325	43362	43399	43437	1180
1190	43474	43511	43549	43586	43623	43660	43698	43735	43772	43809	1190
1200	43846	43884	43921	43958	43995	44032	44069	44106	44144	44181	1200
1210	44218	44255	44292	44329	44366	44403	44440	44477	44514	44551	1210
1220	44588	44625	44662	44699	44736	44773	44810	44847	44884	44921	1220
1230	44958	44995	45032	45069	45105	45142	45179	45216	45253	45290	1230
1240	45326	45363	45400	45437	45474	45510	45547	45584	45621	45657	1240
1250	45694	45731	45767	45804	45841	45877	45914	45951	45987	46024	1250
1260	46060	46097	46133	46170	46207	46243	46280	46316	46353	46389	1260
1270	46425	46462	46498	46535	46571	46608	46644	46680	46717	46753	1270
1280	46789	46826	46862	46898	46935	46971	47007	47043	47079	47116	1280
1290	47152	47188	47224	47260	47296	47333	47369	47405	47441	47477	1290
1300	47513										1300

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G**, **C** & **D** page 70	

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

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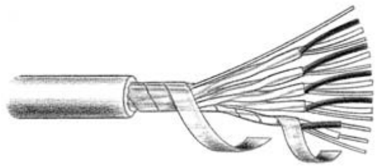
ISO 9001 SGS

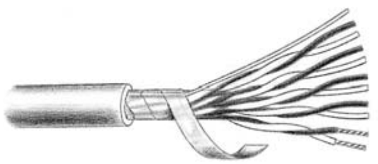
Thermocouple Extension and Compensating Cable

Non Armoured Flame Retardant PVC Multipairs

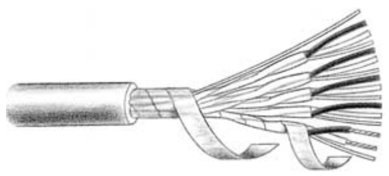
- Extremely useful where there is a need to run a number of thermocouple signals back to instrumentation
- They are available in either solid 1/0.8mm dia ($0.5mm^2$) or stranded 16/0.2mm dia ($0.5mm^2$) types. Both are available with an individual and collective screen (M2500 and M3500 series). Our stranded M3000 series has a collective screen only
- All cables incorporate insulated cores and overall sheath in flame retardant PVC which has good properties for the reduced propagation of flame
- These cables also meet the requirements of BS4066 Part 3/ IEC 60332.3 Category C covering tests on cables under fire conditions
- Armoured versions are also available. See page 25
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1989 Part 1 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995
- All our multipair thermocouple cables are spark tested in accordance with BS5099



Multipairs of solid 1/0.8mm dia conductors FR PVC insulated. Pairs numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



Multipairs of stranded 16/0.2mm dia conductors FR PVC insulated. Pairs numbered and twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire and FR PVC sheathed.



Multipairs of stranded 16/0.2mm dia conductors FR PVC insulated. Pairs numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.

Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Gauge: SWG	Gauge: AWG	Total Area mm^2	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Overall: Insulation	Insulation Rating °C: Continuous	Insulation Rating °C: Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Overall Diameter² (mm)	Glands: Recommended Gland Ref.³ (See page 35)	Notes
M2502	1	.8	.03	21	20	.5	FR PVC	2	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	10	7.9	16	
M2504	1	.8	.03	21	20	.5	FR PVC	4	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	16	11.1	20S	
M2506	1	.8	.03	21	20	.5	FR PVC	6	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	22	13.3	25	
M2508	1	.8	.03	21	20	.5	FR PVC	8	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	29	14.3	25	
M2512	1	.8	.03	21	20	.5	FR PVC	12	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	42	17.9	25	Individually and Collectively Screened. Flame Retardant PVC Insulated.
M2516	1	.8	.03	21	20	.5	FR PVC	16	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	57	20.1	32	
M2520	1	.8	.03	21	20	.5	FR PVC	20	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	69	21.9	32	
M2524	1	.8	.03	21	20	.5	FR PVC	24	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	81	24.9	32	
M2536	1	.8	.03	21	20	.5	FR PVC	36	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	110	29.0	40	
M2550	1	.8	.03	21	20	.5	FR PVC	50	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	154	34.2	50S	
M3002	16	.2	.008	36	32	.5	FR PVC	2	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	8	7.0	16	
M3004	16	.2	.008	36	32	.5	FR PVC	4	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	13	11.0	20S	
M3006	16	.2	.008	36	32	.5	FR PVC	6	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	18	13.2	25	
M3008	16	.2	.008	36	32	.5	FR PVC	8	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	25	14.6	25	
M3012	16	.2	.008	36	32	.5	FR PVC	12	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	33	17.6	25	Collectively Screened. Flame Retardant PVC Insulated.
M3016	16	.2	.008	36	32	.5	FR PVC	16	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	47	19.8	32	
M3020	16	.2	.008	36	32	.5	FR PVC	20	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	58	21.5	32	
M3024	16	.2	.008	36	32	.5	FR PVC	24	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	63	24.8	32	
M3036	16	.2	.008	36	32	.5	FR PVC	36	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	89	28.6	40	
M3050	16	.2	.008	36	32	.5	FR PVC	50	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	120	33.8	50S	
M3502	16	.2	.008	36	32	.5	FR PVC	2	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	11	10.6	20S	
M3504	16	.2	.008	36	32	.5	FR PVC	4	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	17	12.5	20	
M3506	16	.2	.008	36	32	.5	FR PVC	6	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	23	15.2	25	
M3508	16	.2	.008	36	32	.5	FR PVC	8	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	31	16.1	25	
M3512	16	.2	.008	36	32	.5	FR PVC	12	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	45	20.4	32	Individually and Collectively Screened. Flame Retardant PVC Insulated.
M3516	16	.2	.008	36	32	.5	FR PVC	16	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	60	22.8	32	
M3520	16	.2	.008	36	32	.5	FR PVC	20	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	74	24.9	32	
M3524	16	.2	.008	36	32	.5	FR PVC	24	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	89	28.4	40	
M3536	16	.2	.008	36	32	.5	FR PVC	36	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	120	33.2	50S	
M3550	16	.2	.008	36	32	.5	FR PVC	50	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	165	39.2	50	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. The gland sizes shown are for the CGA range.

The above cable constructions are offered incorporating the following conductor combinations: KX, KCB, JX, TX, NX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

*Mylar is a trade name.

Ordering Code - Typical example

M3012KX — IEC

Stock Number including Conductor Combination → M3012KX

Insulation Colour Code → IEC

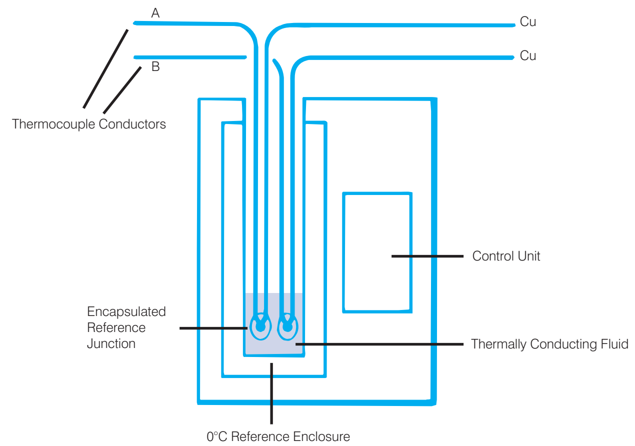


Figure 5.2: *Temperature Controlled Enclosure*

Another very common device today is based on a temperature sensitive electrical network (there are several options) which tracks the reference junction temperature and develops an equivalent voltage. Such so-called cold junction compensation is incorporated into each thermocouple circuit, or the measuring instrument itself at the point of connection (see below). These devices are available as discrete modules, mains or battery powered and provide for accuracy within a few °C.

Many of the instruments designed to operate with thermocouples provide terminals for direct connection to the thermocouple or extension cable conductors without any need for a separate reference junction as such. Such devices as electronic thermometers, temperature controllers, data loggers, etc, frequently incorporate their own equivalent ice point reference voltage generators (as described above).

The temperature at the connection point might be determined by an integral resistance thermometer (see Part 2, Section 6), thermistor or transistor, and thus a suitable reference voltage developed. Incidentally, it is worth taking care over the physical siting of the reference generator, since accuracy and stability of the thermocouple reading are dependent on the network involved actually being in the same temperature environment as the connections themselves.

In any event, the reference voltage can be added to the thermocouple output either by inclusion in the electrical circuit, or, particularly in the case of controllers, data loggers and other digital systems, by data manipulation in the temperature calculations. In fact, many modern controllers, loggers, etc can accommodate the latter approach.

For large schemes involving many thermocouples, racking systems and cabinets are also available having, say, 100 equivalent reference junctions already fitted into a uniform temperature enclosure. The enclosure might be an ice point unit as already described, or it might equally be a thermally stable metal block which maintains a reasonably steady temperature close to that of its surroundings. In the latter case, the temperature of the block is continuously monitored by an electrical compensator, and again, the equivalent ice point voltage is then available to be added to each thermocouple signal output - electrically, or numerically.

Beyond these, there are also reference units designed for enclosures operating at elevated temperatures. These can be useful in areas with particularly high ambient temperatures, but the thermocouple outputs will have to be adjusted to the equivalent 0°C values. In essence, as long as the reference temperature is known, the temperature of the measuring junction can be derived by adding in a correction factor from standard tables covering the thermocouple concerned.

6.0 Practical Resistance Thermometer Detectors

As covered in the theory (see Part 1, Section 4), to achieve high stability, platinum sensor elements must be, and remain, in a fully annealed condition and contamination free. Further, support and sheath materials and construction must be carefully selected and clean to avoid sensor poisoning and strain.

While below 250°C contamination is rarely a problem, above this temperature, materials of construction, insulation and so on (particularly base metals, some forms of mica and borosilicate glass) can react with, or dissolve in the platinum. So, special mounting methods are required. RTD's that are hermetically sealed also need some oxygen in the filling gas to keep the problem elements oxidised and thus relatively harmless to the sensor. As for purity of the platinum, in industrial RTD's lower α coefficient purity platinum wire is used (see Part 1, Section 4), than in primary standard and laboratory style thermometers because the application warrants a physically more robust element and one that is more forgiving of its surroundings in terms of contamination. So pure platinum wire doped with another metal is used to get to the standard specifications of the IEC and British standards for temperature vs resistance definition, and tolerance limits up and down the temperature scale. Other general points include the need to construct the sensors such that thermoelectric voltages, generated through the use of dissimilar metals (as per thermocouples), cancel one another out. Also, the insulation resistance between the RTD itself (including its internal connection wires) and the protective sheath (if any) must be adequate (as per IEC 60751 - see Part 1, Section 4.3). Beyond this, the coil windings need to be non-inductive, current flow must not elicit significant self-heating (see Part 1, Section 4.2) and DC and AC (up to 500 Hz) must be provided for. Also, it is important to ensure that a negligible amount of heat will be conducted along the sheath, internal wires and insulators.

Before we go on to describe some of the sensor styles, it is just worth pointing out that the assemblies detailed can also be used with metals other than platinum, as per the range discussed in Part 1, Section 4.2. Also, a wide range of shapes and sizes is available, the only major restrictions being those of wire support, contamination resistance and an adequate electrical resistance with appropriate insulation. For example, surface areas can be made large in proportion to the volume occupied to encourage fast response. Alternatively, the RTD can be made very small to allow for point temperature sensing. Then again, the sensor could be made long, or large, to facilitate temperature averaging over whatever length, or area, you have in mind.

6.1 Resistance Thermometer Detector Styles

Stepping back in time for a moment, a variety of construction methods have been used in the development of RTD's over the last century. They include: Callendar's original, with its mica cross around which the platinum wire was wound (problems included dehydration and embrittlement of the mica for exposed sensors, and condensation in gas filled and sealed versions); porcelain cross varieties with coiled wire (heavy and introducing time lag difficulties); twisted silica strip units forming a helical support for the coil; machined ceramic formers with grooves for the coil; and so on.

For laboratory standard instruments today, the element may be a thin wire (typically 0.07mm) wound in a helical form and supported by frictional contact in a closely fitting thin walled glass, silica or alumina tube. This may be U shaped, or two separate tubes twisted together for mutual support, with platinum coils in each, connected at the bottom by a thick platinum wire sealed into the glass and welded to the coils. Four platinum connection leads are sealed into the top - two in each limb - and the whole assembly may be provided with a silica outer sheath (see Figure 6.1). All designs are aimed at producing a strain-free thermometer which can expand and contract on heating and cooling without the wire rubbing or being scratched by its support.

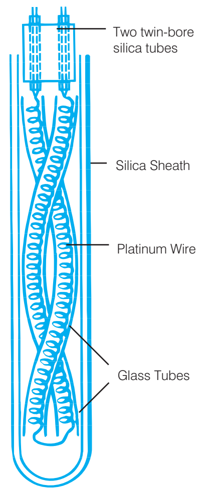


Figure 6.1: *Traditional Laboratory Style RTD sensor*

For high precision thermometry above -189°C, the resistance element is cleaned and mounted in the glass or silica tube with the leads passing through a glass seal at the top. The device is then evacuated and back filled with dry air or high purity argon with a few percent of oxygen - to ensure that the platinum operates under oxidising rather than reducing conditions, such that remaining contaminants are preferentially oxidised during operation. Also, to maximise resistance between leads at higher temperatures, the leads are insulated from one another using mica, silica or sapphire.

Meanwhile, for very low temperature purposes, capsule type designs are favoured (see Figure 6.2). Here, a thin walled platinum tube, about 50mm long by 5mm OD with a glass head, contains the resistance coil wound on a former. After evacuation, this type of device is filled with helium, for good thermal contact, before sealing.

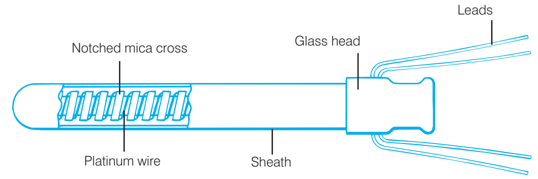


Figure 6.2: *Capsule Design Platinum RTD*

With all these devices, resistance at 0°C is usually 25 ohms, the α value is around 0.003926/°C and sensitivity is around 0.1 ohm/°C. However, for elevated temperature work, RTD resistance is reduced (to between 0.2 and 5 ohms at 0°C) to minimise shunting effects caused by insulation leakage at high temperatures. There are several designs for this kind of work, one of the classics being the National Bureau of Standards' (USA) bird cage device (see Figure 6.3). This has eight parallel platinum lengths threaded through silica discs and connected in series, giving a resistance at 0°C of just 0.2 ohms, moving up to 1 ohm at 1,000°C. However, there are many designs - silica crosses with notches for bifilar helical coil winding (and other winding styles); silica rods with helical wiring grooves; silica strips, again grooved; and so on.

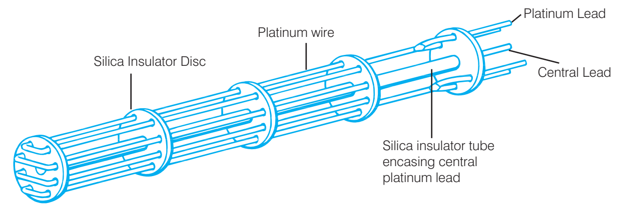


Figure 6.3: *Bird Cage High Temperature RTD*

6.2 Industrial RTD Designs

Although it might be nice to achieve laboratory standard precision using these devices in the industrial arena, realistically this is not possible; price, fragility and poor vibration resistance will not permit. So the more general purpose, industrial type sensors are built to withstand conditions on plants. And, in fact, they do so admirably. Today, accuracies and stabilities of industrial RTD's verge on those achieved with laboratory sensors. Modern pure ceramic materials, along with techniques for winding the wires into their ceramic support assemblies, combined with special annealing processes and advanced vibration resistant, high stability designs have made a substantial impact.

Firstly, the lower α coefficient metal doped platinum wire tends to be used (in accordance with the IEC standard, as mentioned above). Fine wire is drawn through laser drilled sapphire or diamond dies giving fully repeatable results without contamination. Then, manufacturers aim to provide as full support as possible for the wires, to enable best vibration and shock resistance, while also allowing the wires to be reasonably free to expand and contract without strain - thus also ensuring stability (clearly, a compromise situation).

A common style involves wires wound on glass or ceramic bobbin formers that have similar temperature versus expansion characteristics to that of the platinum wire. The windings are then secured and sealed with a coating of ceramic cement or glass (see Figure 6.4), selected to match the expansion rate of the platinum.

Continued on page 28

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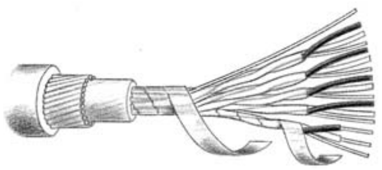
01895 252222

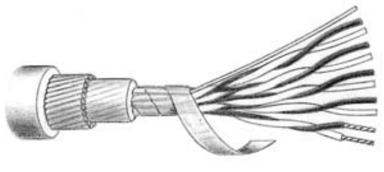
Thermocouple Extension and Compensating Cable

Armoured Flame Retardant PVC Multipairs

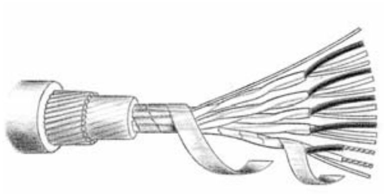
- Extremely useful where there is a need to run a number of thermocouple signals back to instrumentation
- They are available in either solid 1/0.8mm dia (0.5mm²) or stranded 16/0.2mm dia (0.5mm²) types. Both are available with an individual and collective screen (M2500/SWA and M3500/SWA series). Our stranded M3000/SWA series has a collective screen only
- All cables incorporate insulated cores, bedding and overall sheath in flame retardant PVC which has good properties for the reduced propagation of flame
- These cables also meet the requirements of BS4066 Part 3/ IEC 60332.3 Category C covering tests on cables under fire conditions
- Non Armoured versions are also available. See page 23
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1989 Part 1 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995
- All our multipair thermocouple cables are spark tested in accordance with BS5099



Multipairs of solid 1/0.8mm dia conductors FR PVC insulated. Pairs numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.



Multipairs of stranded 16/0.2mm dia conductors FR PVC insulated. Pairs numbered and twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.



Multipairs of stranded 16/0.2mm dia conductors FR PVC insulated. Pairs numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.

Stock Number	Conductors							Pairs			Overall											Glands	Notes
	No. of Strands	Size of Strand Diameter mm.	Size of Strand Diameter Inches	Size of Strand Gauge SWG	Size of Strand Gauge AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen[1]	Insulation	Insulation Rating °C Continuous	Insulation Rating °C Short Term	Colour Coding	Overall Screen[1]	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Diameter Under Armour[2] (mm)	Diameter Over Armour[2] (mm)	Overall Diameter[2] (mm)	Recommended Gland Ref.[3] (See page 35)	
M2502/SWA	1	.8	.03	21	20	.5	FR PVC	2	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	33	7.9	9.7	12.5	16	Individually and Collectively Screened. Flame Retardant PVC Insulated. Armoured for mechanical strength.
M2504/SWA	1	.8	.03	21	20	.5	FR PVC	4	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	50	11.2	13.7	16.7	20	
M2506/SWA	1	.8	.03	21	20	.5	FR PVC	6	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	64	13.3	15.8	18.8	20	
M2508/SWA	1	.8	.03	21	20	.5	FR PVC	8	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	79	14.3	16.8	20.0	25	
M2512/SWA	1	.8	.03	21	20	.5	FR PVC	12	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	106	17.9	21.1	24.5	25	
M2516/SWA	1	.8	.03	21	20	.5	FR PVC	16	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	137	20.1	23.2	26.9	32	
M2520/SWA	1	.8	.03	21	20	.5	FR PVC	20	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	160	21.9	25.1	28.7	32	
M2524/SWA	1	.8	.03	21	20	.5	FR PVC	24	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	198	25.0	28.2	32.0	32	
M2536/SWA	1	.8	.03	21	20	.5	FR PVC	36	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	255	29.0	33.0	37.0	40	
M2550/SWA	1	.8	.03	21	20	.5	FR PVC	50	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	337	34.2	38.2	42.6	50S	
M3002/SWA	16	.2	.008	36	32	.5	FR PVC	2	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	28	6.9	8.8	11.4	16	Collectively Screened. Flame Retardant PVC Insulated. Armoured for mechanical strength.
M3004/SWA	16	.2	.008	36	32	.5	FR PVC	4	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	44	11.0	12.8	15.7	20S	
M3006/SWA	16	.2	.008	36	32	.5	FR PVC	6	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	57	13.2	15.7	18.7	20	
M3008/SWA	16	.2	.008	36	32	.5	FR PVC	8	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	72	14.6	17.1	20.3	25	
M3012/SWA	16	.2	.008	36	32	.5	FR PVC	12	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	88	17.7	20.9	24.3	25	
M3016/SWA	16	.2	.008	36	32	.5	FR PVC	16	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	116	19.8	23.0	26.4	25	
M3020/SWA	16	.2	.008	36	32	.5	FR PVC	20	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	138	21.5	24.7	28.3	32	
M3024/SWA	16	.2	.008	36	32	.5	FR PVC	24	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	162	24.8	28.0	31.8	32	
M3036/SWA	16	.2	.008	36	32	.5	FR PVC	36	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	214	28.6	32.6	36.6	40	
M3050/SWA	16	.2	.008	36	32	.5	FR PVC	50	Twisted	No	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	273	33.8	37.8	42.2	50S	
M3502/SWA	16	.2	.008	36	32	.5	FR PVC	2	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	35	10.6	11.9	14.7	20S	Individually and Collectively Screened. Flame Retardant PVC Insulated. Armoured for mechanical strength.
M3504/SWA	16	.2	.008	36	32	.5	FR PVC	4	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	55	12.5	15.0	18.0	20	
M3506/SWA	16	.2	.008	36	32	.5	FR PVC	6	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	68	15.2	17.7	20.9	25	
M3508/SWA	16	.2	.008	36	32	.5	FR PVC	8	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	84	16.1	19.3	22.5	25	
M3512/SWA	16	.2	.008	36	32	.5	FR PVC	12	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	112	20.4	23.6	27.2	32	
M3516/SWA	16	.2	.008	36	32	.5	FR PVC	16	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	145	22.8	26.0	29.6	32	
M3520/SWA	16	.2	.008	36	32	.5	FR PVC	20	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	168	24.9	28.1	31.9	32	
M3524/SWA	16	.2	.008	36	32	.5	FR PVC	24	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	207	28.4	32.4	36.4	40	
M3536/SWA	16	.2	.008	36	32	.5	FR PVC	36	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	265	33.2	37.2	41.4	50S	
M3550/SWA	16	.2	.008	36	32	.5	FR PVC	50	Twisted	Yes	FR PVC	-30 to +75	–	Yes	Yes	Good	Very Good	347	39.2	44.2	48.8	50	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. The gland sizes shown are for the CGC and CGE ranges. CGA types are available however the gland size will change. See page 35 for full details.

The above cable constructions are offered incorporating the following conductor combinations: KX, KCB, JX, TX, NX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

*Mylar is a trade name.

Ordering Code - Typical example

M3006KCB/SWA — IEC

Stock Number including Conductor Combination

Insulation Colour Code

TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
Tel: +44 (0)1895 252222 - Fax: +44 (0)1895 273540
Email: info@tc.co.uk - Web: www.tc.co.uk
01895 252222

CODE E

International Thermocouple Reference Tables for
Nickel Chromium / Copper Nickel
To IEC60584.1:1995 / BS EN 60584.1 Part 6 : 1996

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (μV).

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-270	-9835										-270
-260	-9797	-9802	-9808	-9813	-9817	-9821	-9825	-9828	-9831	-9833	-260
-250	-9718	-9728	-9737	-9746	-9754	-9762	-9770	-9777	-9784	-9790	-250
-240	-9604	-9617	-9630	-9642	-9654	-9666	-9677	-9688	-9698	-9709	-240
-230	-9455	-9471	-9487	-9503	-9519	-9534	-9548	-9563	-9577	-9591	-230
-220	-9274	-9293	-9313	-9331	-9350	-9368	-9386	-9404	-9421	-9438	-220
-210	-9063	-9085	-9107	-9129	-9151	-9172	-9193	-9214	-9234	-9254	-210
-200	-8825	-8850	-8874	-8899	-8923	-8947	-8971	-8994	-9017	-9040	-200
-190	-8561	-8588	-8616	-8643	-8669	-8696	-8722	-8748	-8774	-8799	-190
-180	-8273	-8303	-8333	-8362	-8391	-8420	-8449	-8477	-8505	-8533	-180
-170	-7963	-7995	-8027	-8059	-8090	-8121	-8152	-8183	-8213	-8243	-170
-160	-7632	-7666	-7700	-7733	-7767	-7800	-7833	-7866	-7899	-7931	-160
-150	-7279	-7315	-7351	-7387	-7423	-7458	-7493	-7528	-7563	-7597	-150
-140	-6907	-6945	-6983	-7021	-7058	-7096	-7133	-7170	-7206	-7243	-140
-130	-6516	-6556	-6596	-6636	-6675	-6714	-6753	-6792	-6831	-6869	-130
-120	-6107	-6149	-6191	-6232	-6273	-6314	-6355	-6396	-6436	-6476	-120
-110	-5681	-5724	-5767	-5810	-5853	-5896	-5939	-5981	-6023	-6065	-110
-100	-5237	-5282	-5327	-5372	-5417	-5461	-5505	-5549	-5593	-5637	-100
-90	-4777	-4824	-4871	-4917	-4963	-5009	-5055	-5101	-5147	-5192	-90
-80	-4302	-4350	-4398	-4446	-4494	-4542	-4589	-4636	-4684	-4731	-80
-70	-3811	-3861	-3911	-3960	-4009	-4058	-4107	-4156	-4205	-4254	-70
-60	-3306	-3357	-3408	-3459	-3510	-3561	-3611	-3661	-3711	-3761	-60
-50	-2787	-2840	-2892	-2944	-2996	-3048	-3100	-3152	-3204	-3255	-50
-40	-2255	-2309	-2362	-2416	-2469	-2523	-2576	-2629	-2682	-2735	-40
-30	-1709	-1765	-1820	-1874	-1929	-1984	-2038	-2093	-2147	-2201	-30
-20	-1152	-1208	-1264	-1320	-1376	-1432	-1488	-1543	-1599	-1654	-20
-10	-582	-639	-697	-754	-811	-868	-925	-982	-1039	-1095	-10
0	0	-59	-117	-176	-234	-292	-350	-408	-466	-524	0
0	0	59	118	176	235	294	354	413	472	532	0
10	591	651	711	770	830	890	950	1010	1071	1131	10
20	1192	1252	1313	1373	1434	1495	1556	1617	1678	1740	20
30	1801	1862	1924	1986	2047	2109	2171	2233	2295	2357	30
40	2420	2482	2545	2607	2670	2733	2795	2858	2921	2984	40
50	3048	3111	3174	3238	3301	3365	3429	3492	3556	3620	50
60	3685	3749	3813	3877	3942	4006	4071	4136	4200	4265	60
70	4330	4395	4460	4526	4591	4656	4722	4788	4853	4919	70
80	4985	5051	5117	5183	5249	5315	5382	5448	5514	5581	80
90	5648	5714	5781	5848	5915	5982	6049	6117	6184	6251	90
100	6319	6386	6454	6522	6590	6658	6725	6794	6862	6930	100
110	6998	7066	7135	7203	7272	7341	7409	7478	7547	7616	110
120	7685	7754	7823	7892	7962	8031	8101	8170	8240	8309	120
130	8379	8449	8519	8589	8659	8729	8799	8869	8940	9010	130
140	9081	9151	9222	9292	9363	9434	9505	9576	9647	9718	140

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
150	9789	9860	9931	10003	10074	10145	10217	10288	10360	10432	150
160	10503	10575	10647	10719	10791	10863	10935	11007	11080	11152	160
170	11224	11297	11369	11442	11514	11587	11660	11733	11805	11878	170
180	11951	12024	12097	12170	12243	12317	12390	12463	12537	12610	180
190	12684	12757	12831	12904	12978	13052	13126	13199	13273	13347	190
200	13421	13495	13569	13644	13718	13792	13866	13941	14015	14090	200
210	14164	14239	14313	14388	14463	14537	14612	14687	14762	14837	210
220	14912	14987	15062	15137	15212	15287	15362	15438	15513	15588	220
230	15664	15739	15815	15890	15966	16041	16117	16193	16269	16344	230
240	16420	16496	16572	16648	16724	16800	16876	16952	17028	17104	240
250	17181	17257	17333	17409	17486	17562	17639	17715	17792	17868	250
260	17945	18021	18098	18175	18252	18328	18405	18482	18559	18636	260
270	18713	18790	18867	18944	19021	19098	19175	19252	19330	19407	270
280	19484	19561	19639	19716	19794	19871	19948	20026	20103	20181	280
290	20259	20336	20414	20492	20569	20647	20725	20803	20880	20958	290
300	21036	21114	21192	21270	21348	21426	21504	21582	21660	21739	300
310	21817	21895	21973	22051	22130	22208	22286	22365	22443	22522	310
320	22600	22678	22757	22835	22914	22993	23071	23150	23228	23307	320
330	23386	23464	23543	23622	23701	23780	23858	23937	24016	24095	330
340	24174	24253	24332	24411	24490	24569	24648	24727	24806	24885	340
350	24964	25044	25123	25202	25281	25360	25440	25519	25598	25678	350
360	25757	25836	25916	25995	26075	26154	26233	26313	26392	26472	360
370	26552	26631	26711	26790	26870	26950	27029	27109	27189	27268	370
380	27348	27428	27507	27587	27667	27747	27827	27907	27986	28066	380
390	28146	28226	28306	28386	28466	28546	28626	28706	28786	28866	390
400	28946	29026	29106	29186	29266	29346	29427	29507	29587	29667	400
410	29747	29827	29908	29988	30068	30148	30229	30309	30389	30470	410
420	30550	30630	30711	30791	30871	30952	31032	31112	31193	31273	420
430	31354	31434	31515	31595	31676	31756	31837	31917	31998	32078	430
440	32159	32239	32320	32400	32481	32562	32642	32723	32803	32884	440
450	32965	33045	33126	33207	33287	33368	33449	33529	33610	33691	450
460	33772	33852	33933	34014	34095	34175	34256	34337	34418	34498	460
470	34579	34660	34741	34822	34902	34983	35064	35145	35226	35307	470
480	35387	35468	35549	35630	35711	35792	35873	35954	36034	36115	480
490	36196	36277	36358	36439	36520	36601	36682	36763	36843	36924	490
500	37005	37086	37167	37248	37329	37410	37491	37572	37653	37734	500
510	37815	37896	37977	38058	38139	38220	38300	38381	38462	38543	510
520	38624	38705	38786	38867	38948	39029	39110	39191	39272	39353	520
530	39434	39515	39596	39677	39758	39839	39920	40001	40082	40163	530
540	40243	40324	40405	40486	40567	40648	40729	40810	40891	40972	540
550	41053	41134	41215	41296	41377	41457	41538	41619	41700	41781	550
560	41862	41943	42024	42105	42185	42266	42347	42428	42509	42590	560
570	42671	42751	42832	42913	42994	43075	43156	43236	43317	43398	570
580	43479	43560	43640	43721	43802	43883	43963	44044	44125	44206	580
590	44286	44367	44448	44529	44609	44690	44771	44851	44932	45013	590

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
600	45093	45174	45255	45335	45416	45497	45577	45658	45738	45819	600
610	45900	45980	46061	46141	46222	46302	46383	46463	46544	46624	610
620	46705	46785	46866	46946	47027	47107	47188	47268	47349	47429	620
630	47509	47590	47670	47751	47831	47911	47992	48072	48152	48233	630
640	48313	48393	48474	48554	48634	48715	48795	48875	48955	49035	640
650	49116	49196	49276	49356	49436	49517	49597	49677	49757	49837	650
660	49917	49997	50077	50157	50238	50318	50398	50478	50558	50638	660
670	50718	50798	50878	50958	51038	51118	51197	51277	51357	51437	670
680	51517	51597	51677	51757	51837	51916	51996	52076	52156	52236	680
690	52315	52395	52475	52555	52634	52714	52794	52873	52953	53033	690
700	53112	53192	53272	53351	53431	53510	53590	53670	53749	53829	700
710	53908	53988	54067	54147	54226	54306	54385	54465	54544	54624	710
720	54703	54782	54862	54941	55021	55100	55179	55259	55338	55417	720
730	55497	55576	55655	55734	55814	55893	55972	56051	56131	56210	730
740	56289	56368	56447	56526	56606	56685	56764	56843	56922	57001	740
750	57080	57159	57238	57317	57396	57475	57554	57633	57712	57791	750
760	57870	57949	58028	58107	58186	58265	58343	58422	58501	58580	760
770	58659	58738	58816	58895	58974	59053	59131	59210	59289	59367	770
780	59446	59525	59604	59682	59761	59839	59918	59997	60075	60154	780
790	60232	60311	60390	60468	60547	60625	60704	60782	60860	60939	790
800	61017	61096	61174	61253	61331	61409	61488	61566	61644	61723	800
810	61801	61879	61958	62036	62114	62192	62271	62349	62427	62505	810
820	62583	62662	62740	62818	62896	62974	63052	63130	63208	63286	820
830	63364	63442	63520	63598	63676	63754	63832	63910	63988	64066	830
840	64144	64222	64300	64377	64455	64533	64611	64689	64766	64844	840
850	64922	65000	65077	65155	65233	65310	65388	65465	65543	65621	850
860	65698	65776	65853	65931	66008	66086	66163	66241	66318	66396	860
870	66473	66550	66628	66705	66782	66860	66937	67014	67092	67169	870
880	67246	67323	67400	67478	67555	67632	67709	67786	67863	67940	880
890	68017	68094	68171	68248	68325	68402	68479	68556	68633	68710	890
900	68787	68863	68940	69017	69094	69171	69247	69324	69401	69477	900
910	69554	69631	69707	69784	69860	69937	70013	70090	70166	70243	910
920	70319	70396	70472	70548	70625	70701	70777	70854	70930	71006	920
930	71082	71159	71235	71311	71387	71463	71539	71615	71692	71768	930
940	71844	71920	71996	72072	72147	72223	72299	72375	72451	72527	940
950	72603	72678	72754	72830	72906	72981	73057	73133	73208	73284	950
960	73360	73435	73511	73586	73662	73738	73813	73889	73964	74040	960
970	74115	74190	74266	74341	74417	74492	74567	74643	74718	74793	970
980	74869	74944	75019	75095	75170	75245	75320	75395	75471	75546	980
990	75621	75696	75771	75847	75922	75997	76072	76147	76223	76298	990
1000	76373										1000

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G, C & D** page 70	

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

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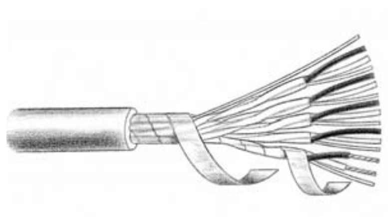
Thermocouple Extension and Compensating Cable

XLPE (Cross Linked Polyethylene)/ Low Smoke and Fume Non Armoured Multipairs

- These cables incorporate XLPE (Cross Linked Polyethylene) compound on the cores and Low Smoke and Fume material on the outer sheath
- These cables meet the requirements of BS4066 Part 3/IEC 60332.3 Category A covering tests on cables under fire conditions
- Ideal for situations where there is a risk of fire and the emission of smoke and gases could threaten life and property
- The sheathing materials used are Halogen free
- The acidic gas which is evolved during combustion is less than 0.5% in accordance with BS6425 Pt 1 and IEC 60754 Pt 1
- The Oxygen Index Value is not less than 30 in accordance with BS2782:2007 Part 1 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995

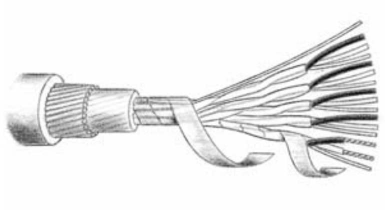


Multipairs of stranded 16/0.2mm diameter conductors XLPE insulated. Pairs numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and LSF sheathed.

	Conductors							Pairs			Overall											Glands	Notes
Stock Number	No. of Strands	Size of Strand Diameter mm.	Inches	Gauge SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Insulation Rating °C Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³ (See page 35)	
M4502	16	.2	.008	36	32	.5	XLPE	2	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	11	–	–	10.6	20S	Excellent for fire risk areas. Free of halogens. Individually and collectively screened.
M4504	16	.2	.008	36	32	.5	XLPE	4	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	17	–	–	12.5	20	
M4506	16	.2	.008	36	32	.5	XLPE	6	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	23	–	–	15.2	25	
M4508	16	.2	.008	36	32	.5	XLPE	8	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	31	–	–	16.1	25	
M4512	16	.2	.008	36	32	.5	XLPE	12	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	45	–	–	20.4	32	
M4516	16	.2	.008	36	32	.5	XLPE	16	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	60	–	–	22.8	32	
M4520	16	.2	.008	36	32	.5	XLPE	20	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	74	–	–	24.9	32	
M4524	16	.2	.008	36	32	.5	XLPE	24	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	89	–	–	28.4	40	
M4536	16	.2	.008	36	32	.5	XLPE	36	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	120	–	–	33.2	50S	

XLPE (Cross Linked Polyethylene)/ Low Smoke and Fume Armoured Multipairs

- These cables incorporate XLPE (Cross Linked Polyethylene) compound on the cores and Low Smoke and Fume material on the bedding and outer sheath
- These cables meet the requirements of BS4066 Part 3/IEC 60332.3 Category A covering tests on cables under fire conditions
- Ideal for situations where there is a risk of fire and the emission of smoke and gases could threaten life and property
- The sheathing materials used are Halogen free
- The acidic gas which is evolved during combustion is less than 0.5% in accordance with BS6425 Pt 1 and IEC 60754 Pt 1
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1986 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995



Multipairs of stranded 16/0.2mm diameter conductors XLPE insulated. Pairs numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and LSF bedded. Steel wire armoured and LSF sheathed.

	Conductors							Pairs			Overall											Glands	Notes
Stock Number	No. of Strands	Size of Strand Diameter mm.	Inches	Gauge SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Insulation Rating °C Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³ (See page 35)	
M4502/SWA	16	.2	.008	36	32	.5	XLPE	2	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	35	10.6	11.9	14.7	20S	Excellent for fire risk areas. Free of halogens. Individually and collectively screened. Armoured for mechanical strength
M4504/SWA	16	.2	.008	36	32	.5	XLPE	4	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	55	12.5	15.0	18.0	20	
M4506/SWA	16	.2	.008	36	32	.5	XLPE	6	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	68	15.2	17.7	20.9	25	
M4508/SWA	16	.2	.008	36	32	.5	XLPE	8	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	84	16.1	19.3	22.5	25	
M4512/SWA	16	.2	.008	36	32	.5	XLPE	12	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	112	20.4	23.6	27.2	32	
M4516/SWA	16	.2	.008	36	32	.5	XLPE	16	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	145	22.8	26.0	29.6	32	
M4520/SWA	16	.2	.008	36	32	.5	XLPE	20	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	168	24.9	28.1	31.9	32	
M4524/SWA	16	.2	.008	36	32	.5	XLPE	24	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	207	28.4	32.4	36.4	40	
M4536/SWA	16	.2	.008	36	32	.5	XLPE	36	Twisted	Yes	LSF	-30 to +75	–	Yes	Yes	Good	Very Good	265	33.2	37.2	41.4	50S	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. For non armoured versions the gland sizes shown are for the CGA range. For armoured versions the gland sizes shown are for the CGC and CGE ranges. CGA types are available however the gland size will change. See page 35 for full details.

The above cable constructions are offered incorporating the following conductor combinations: KX, KCB, JX and TX. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

*Mylar is a trade name

Ordering Code - Typical example

M4506 KCB/SWA — IEC

Stock Number including Conductor Combination

Insulation Colour Code

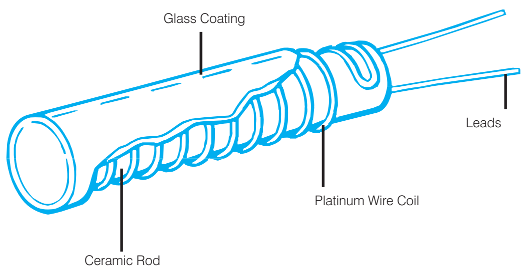


Figure 6.4: *Classic Cylindrical Style Industrial Wire Wound RTD*

Although tough and more than adequate for most requirements, these devices do exhibit poorer stability during temperature cycling, smaller operational temperature range (up to about 500°C) and greater hysteresis than RTD's with partially supported coils. Also, they are not in direct contact with air, if this matters. Another arrangement involves wire coils set in grooves (see Figure 6.5).

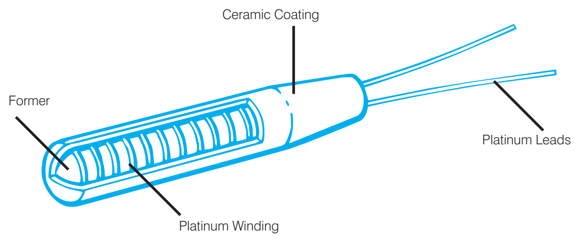


Figure 6.5: *Cylindrical Sensor with Wire Coil set in Grooves*

As an alternative, partially supported coil constructions offer more flexibility in the ruggedness versus stability trade-off. A common assembly comprises helical platinum coils mounted in holes in a multi-bore alumina tube, with the coil being anchored by small amounts of glass - providing partial rather than full support (see Figure 6.6) such that a large proportion of the coils are free to move. The wires are then attached to more robust leads. Then again, another approach relies on embedding the platinum coils in alumina powder to reduce vibration effects further.

These assemblies, if properly engineered, are the closest to meeting the requirements of the working standard thermometer, offering either low vibration resistance and very high stability, or higher vibration resistance and slightly lower, but still excellent stability. With these kinds of industrial devices, stabilities of a few hundredths of a degree over the range -200 to +850°C can be provided. Further, they need not be hermetically sealed - so air can circulate around the platinum wire where the environment allows. Typically, the sensors are about 25mm long by about 3mm diameter, and the resistance element will be trimmed at 0°C to precisely 100 ohms.

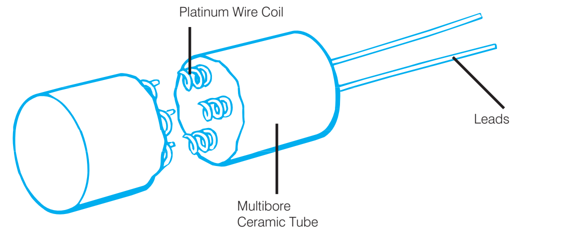


Figure 6.6: *Partial Support using Multi-bore Alumina Tubing*

6.3 Film Thermometers

A more recent development for platinum resistance thermometer construction is that of depositing the platinum material as a film (thick or thin) pattern on a suitable substrate. With thin film devices, platinum is evaporated onto the substrate using vacuum semiconductor fabrication techniques, whereas with thick film sensors, a glass/platinum paste is essentially silk screen printed on to the substrate. Both approaches allow the `element' to be bonded to a flat or cylindrical surface as appropriate to the application (see Figure 6.7).

Performance today can almost equal that obtained with the wire wound devices (certainly the more basic glass coated versions), particularly with thin film sensors over the range -50°C to 500°C. Benefits include: fast thermal response (due mainly to low mass and the intimate contact made with the substrate); insensitivity to vibration; and lower cost than their wire wound counterparts.

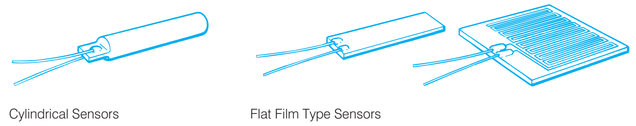


Figure 6.7: *Wire Wound and Thin Film Alternatives for RTD's*

There is, however, some debate about the inherent stability of these designs, particularly over extended ranges. Firstly, they are not as free to expand and contract as their wire wound, partially supported alternatives (although this criticism applies equally to the glass sealed wire wound units). Secondly, with the small quantity of platinum used, they are more subject to contamination, and sealing them with glass is not necessarily the ideal answer. Thirdly, film characteristics can vary from batch to batch - although much less so today. Still, as lower cost surface temperature and air temperature sensors offering medium to high precision - say ±0.05% stability over the temperature range - they have a very useful role to fulfil. It is just worth remembering that equivalent stability for wire wound partially supported devices would be an order of magnitude better at least - ±0.005% stability.

6.4 Leads and Protection Tubes

Beyond this, there are the connection leads and protective sheaths (see Part 2, Section 9) with which to concern ourselves.

With RTD's, the support provided for the internal leads is vital to the stability and longevity of the sensor assembly. This used to be one of the major causes of RTD sensor failure, but manufacturing techniques and methods are now well developed and understood.

As for protection, although it is sometimes perfectly OK to insert the RTD directly into the medium to be monitored (an advantage being fast response), in most situations this is not the case. Protection is thus required - either in the form of ventilated covers to offer mechanical protection only (for static or low velocity air temperature sensing, for example), or fully enclosed and sealed sheaths or protection tubes (for applications where corrosive, abrasive, high pressure, poisoning or electrically conductive media are involved).

Materials of construction for these must be selected to accommodate the temperature and environmental conditions anticipated - typically, nickel alloys up to about 800°C, and ceramic sheaths beyond this. Also, care must be taken to ensure good thermal contact between sheath and sensor (for speed of response and reduced self-heating reasons), while also ensuring minimal thermal conduction along the sheath. These points are particularly important where large, heavy duty thermowells are concerned.

However, the other standard caveat is that a percentage of oxygen is required within the sheath to prevent reduction of metal oxides which would in turn result in poisoning of the platinum. This is particularly important for sensors constructed using glass, due to the presence of lead oxide.

Protection tubes can, of course, be equipped with suitable terminal blocks for connection to the copper cables providing the link to the measuring instrumentation, or transmitter concerned. As with thermocouples, the protection tube can be fitted into a thermowell for further environmental and mechanical protection (see Part 2, Section 9.2).

7.0 Resistance Thermometer Assemblies

Most users of resistance thermometer detectors employ purpose-made platinum RTD sensor assemblies which are available in a wide range of types and styles. They usually include as standard the sensing resistor element (as per Part 2, Sections 6.1, 6.2 and 6.3) in a protective sheath (if required), internal connecting wires, end seals of all sorts and external terminals, often in connection heads. For end seal configurations, terminals, terminal heads, protective tubes, thermowells and other accessories, read Part 2, Section 9. For typical examples of commercially available RTD assemblies, however, read on.

7.1 Basic Sheathed RTD Assemblies

Lower cost general purpose industrial platinum RTD sensor assemblies, typically covering the temperature range -100°C to +350°C (although this can be customised), embody, as standard, detector elements with a resistance of 100 ohms at 0°C as per IEC 60751: 1983 Class B, although alternative element resistances and tolerances are available. Class A elements, for example, can normally be provided, offering down to ±0.01% accuracy, if required. The sensors themselves normally consist of environmentally resistant pure, doped strain-free platinum wire-wound elements encased in either a high temperature, expansion matched glass or a high purity ceramic envelope, although thick or thin film RTD element can also be used.

These assemblies are available with single, duplex and triplex sensor element assemblies all normally offering two, three and four wire connection lead configurations as standard (the four wire versions will be available for connection in compensated or blind loop format - for bridge and potentiometric measuring circuits). Attachment lead-out wires are generally fabricated from Kapton-insulated (or similar) copper.

Typically, minimum immersion depth of these devices will be of the order of 60mm. The recommended measuring current will be less than 5mA, and insulation resistance between the leads and sheath at 240V will be better than 100 Mohms at ambient temperature.

Sheath tips can be designed to suit the application, there normally being a range of constructions, including those with reduced tips and thin sheath walls. Pierced shroud versions are also available for air and gas temperature measurement. Voids within the sheath are normally packed with inert material, for optimum heat transfer characteristics, and the sheaths are hermetically sealed to provide protection against moisture, corrosion and vibration.

Sheaths are generally available with diameters from 2 to 13mm as standard in virtually any sensible length, with bends to suit the application. Materials start with 316 stainless steel, although other grades of steel, Inconel 600, Incoloy 800, nickel, nickel alloys and other materials are usually available. Further, many manufacturers will also provide a range of fluoroplastic sheath cladding materials for the more demanding and corrosive environments.

End seals will be available in a range of shapes, sizes and materials. As standard, most manufacturers' basic platinum RTD ranges offer end seals covering the full spectrum of user requirements, from basic laboratory termination heads, connector blocks and quick release plugs, through hand-held devices, and on to full industrial, heavy duty enclosures complete with ruggedised protection tubes, thermowells and head-mounting connectors or transmitters.

7.2 Mineral Insulated Metal Sheathed RTD Assemblies

As with commercially available thermocouples, a popular style of RTD assembly is the mineral insulated metal sheathed (MI or MIMS) version. Basically, it is very similar to its thermocouple counterpart, comprising a metal, seamless, semi-flexible, high integrity, hermetically sealed probe enclosing the same compacted mineral insulant powder (usually, magnesium oxide) which supports and insulates the RTD element and lead wires inside.

The devices are compact, self-armoured, yet flexible. Again as with thermocouples, there are many advantages. These include small size, ease of installation (they can be bent, twisted and flattened without problems), good mechanical strength, excellent insulation resistance (100Mohm between sheath and conductors), good long term accuracy and stability and acceptably fast response rates. They can cope with most industrial environments, including the extremes, like those with high vibration and high pressure or vacuum, as well as corrosive and aggressive media.

Temperature ranges covered are typically from -100°C to +500°C , typically using 100 ohm resistance at 0°C IEC 60751: 1983 Class B RTD platinum sensor assemblies in single or duplex element configurations. As with other sheathed assemblies, the sensor elements are normally platinum wire in expansion matched glass or high purity ceramic, with film sensor versions optionally available. More sophisticated, high precision Class A elements (see Part 1, Section 4) can also normally be provided, giving greater accuracy.

Again, as with most other sheathed RTD assemblies, two, three and four wire configurations are almost always supported. Lead-out wires are typically insulated copper. Recommended energising current limit will be 5mA. Minimum immersion depth for the probes is typically 60mm.

Sheath wall thickness is normally about 15% of the overall probe diameter, and this construction resists creasing and splitting well,

Continued on page 32

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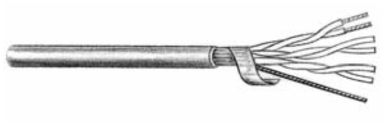
Thermocouple Extension and Compensating Cable

PFA Insulated Multipairs

- PFA is ideal for higher temperature applications up to 250°C when Heat Resistant PVC is not adequate
- It is also excellent for cryogenic temperatures down to –75°C
- PFA will withstand attack from virtually all known chemicals, oils and fluids. All our PFA cables are made in extruded form and are therefore gas, steam and water tight which makes them most suitable for applications such as autoclaves or sterilizers
- By using multipair, the problem of having many unwieldy single pair cables is eliminated
- Available with and without stainless steel braid in the more popular conductor combinations



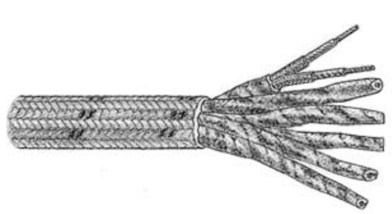
Multipairs of stranded 7/0.2mm dia conductors. Each conductor PFA insulated. Pairs twisted and bunched. Screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire. PFA sheathed overall.

Multipairs of stranded 7/0.2mm dia conductors. Each conductor PFA insulated. Pairs twisted and bunched. Screened with Mylar* aluminium tape in contact throughout by a bare tinned copper drainwire. PFA sheathed. Stainless steel braided overall.

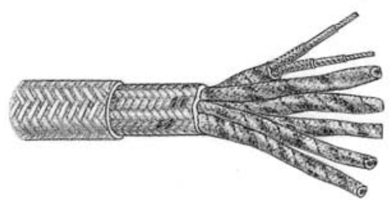
Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Size of Strand Gauge: SWG	Size of Strand Gauge: AWG	Total Area mm²	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Screen[1,3]	Overall: Insulation	Insulation Rating °C: Continuous	Insulation Rating °C: Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Overall Diameter[2] (mm)	Glands: Recommended Gland Ref.[4] (See page 35)	Notes
BM0702	7	.2	.008	36	32	.22	PFA	2	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	2	4	16	Rejects electromagnetic and electrostatic interference. Gas, steam and water tight insulation.
BM0703	7	.2	.008	36	32	.22	PFA	3	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	3	4	16	
BM0704	7	.2	.008	36	32	.22	PFA	4	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	4	5	16	
BM0706	7	.2	.008	36	32	.22	PFA	6	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	5	6	16	
BM0712	7	.2	.008	36	32	.22	PFA	12	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	10	8	20S	
BM0702/SSB	7	.2	.008	36	32	.22	PFA	2	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	3	5	16	Rejects electromagnetic and electrostatic interference. Gas, steam and water tight insulation.
BM0703/SSB	7	.2	.008	36	32	.22	PFA	3	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	5	5	16	
BM0704/SSB	7	.2	.008	36	32	.22	PFA	4	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	6	6	16	
BM0706/SSB	7	.2	.008	36	32	.22	PFA	6	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	7	7	16	
BM0712/SSB	7	.2	.008	36	32	.22	PFA	12	Twisted	Yes[1]	PFA	-75 to +250	300	Yes	Very Good	Very Good	12	9	20S	

Fibreglass Insulated Multipairs

- Excellent for high temperature applications up to 480°C
- Suitable for use at normal air ambient temperatures where there is a possibility of a hot spot which might damage lower rated cables such as PVC or PFA
- By using multipair, the problem of having many unwieldy single pair cables is eliminated
- Available with and without stainless steel braid in the more popular conductor combinations



Multipairs of stranded 14/0.2mm dia conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. Pairs twisted, glass fibre braided and silicone varnished, bunched, glass fibre braided overall and silicone varnished.



Multipairs of stranded 14/0.2mm dia conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. Pairs twisted, glass fibre braided and silicone varnished, bunched, glass fibre braided and silicone varnished. Stainless steel wire braided overall.

Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Size of Strand Gauge: SWG	Size of Strand Gauge: AWG	Total Area mm²	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Screen[1,3]	Overall: Insulation	Insulation Rating °C: Continuous	Insulation Rating °C: Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[2] Kg/100m (Excluding Reel)	Overall Diameter[2] (mm)	Glands: Recommended Gland Ref.[4] (See page 35)	Notes
CM1402	14	.2	.008	36	32	.44	Fibre Glass	2	Twisted	No	Fibre Glass	+480	+540	Yes	Fair	Fair	6	4	16	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
CM1403	14	.2	.008	36	32	.44	Fibre Glass	3	Twisted	No	Fibre Glass	+480	+540	Yes	Fair	Fair	9	6	16	
CM1406	14	.2	.008	36	32	.44	Fibre Glass	6	Twisted	No	Fibre Glass	+480	+540	Yes	Fair	Fair	14	9	20S	
CM1412	14	.2	.008	36	32	.44	Fibre Glass	12	Twisted	No	Fibre Glass	+480	+540	Yes	Fair	Fair	22	14	25	
CM1402/SSB	14	.2	.008	36	32	.44	Fibre Glass	2	Twisted	Yes[3]	Fibre Glass	+480	+540	Yes	Good	Fair	8	6	16	Impregnation retained up to 180°C. Above this temperature the integrity of the cable is maintained to the upper insulation rating limit provided the cable is not flexed particularly when cold.
CM1403/SSB	14	.2	.008	36	32	.44	Fibre Glass	3	Twisted	Yes[3]	Fibre Glass	+480	+540	Yes	Good	Fair	12	8	20S	
CM1406/SSB	14	.2	.008	36	32	.44	Fibre Glass	6	Twisted	Yes[3]	Fibre Glass	+480	+540	Yes	Good	Fair	18	11	20	
CM1412/SSB	14	.2	.008	36	32	.44	Fibre Glass	12	Twisted	Yes[3]	Fibre Glass	+480	+540	Yes	Good	Fair	27	16	25	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.2mm dia tinned nickel drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. These cables have a stainless steel braid which can be used as a screen.
4. The gland sizes shown are for the CGA range.

The above cable constructions are offered incorporating the following conductor combinations: KX, JX, TX, RCA or SCA. Other less popular conductor combinations are available on request.
These cables are normally available from us for **immediate** delivery from stock to BS EN 60584.3:2008 /IEC 60584.3:2007 colour coding. See page 5 for further details.
The cable constructions can also be manufactured to any other colour coding requirement that you may have, but might be subject to a minimum ordering quantity.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
For more general information on thermocouple conductor combinations and insulation colour codes please refer to pages 5 and 7.

Mylar is a trade name.

Ordering Code - Typical example

CM1406 KX/SSB — IEC

Stock Number including Conductor Combination

Insulation Colour Code

TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
Tel: +44 (0)1895 252222 - Fax: +44 (0)1895 273540
Email: info@tc.co.uk - Web: www.tc.co.uk

01895 252222

CODE R

CODE R

International Thermocouple Reference Tables for

Platinum - 13% Rhodium / Platinum

To IEC60584.1:1995 / BS EN 60584.1 Part 2 : 1996

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (µV).

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-50	-226										**-50**
-40	-188	-192	-196	-200	-204	-208	-211	-215	-219	-223	**-40**
-30	-145	-150	-154	-158	-163	-167	-171	-175	-180	-184	**-30**
-20	-100	-105	-109	-114	-119	-123	-128	-132	-137	-141	**-20**
-10	-51	-56	-61	-66	-71	-76	-81	-86	-91	-95	**-10**
0	0	-5	-11	-16	-21	-26	-31	-36	-41	-46	**0**
0	0	5	11	16	21	27	32	38	43	49	**0**
10	54	60	65	71	77	82	88	94	100	105	**10**
20	111	117	123	129	135	141	147	153	159	165	**20**
30	171	177	183	189	195	201	207	214	220	226	**30**
40	232	239	245	251	258	264	271	277	284	290	**40**
50	296	303	310	316	323	329	336	343	349	356	**50**
60	363	369	376	383	390	397	403	410	417	424	**60**
70	431	438	445	452	459	466	473	480	487	494	**70**
80	501	508	516	523	530	537	544	552	559	566	**80**
90	573	581	588	595	603	610	618	625	632	640	**90**
100	647	655	662	670	677	685	693	700	708	715	**100**
110	723	731	738	746	754	761	769	777	785	792	**110**
120	800	808	816	824	832	839	847	855	863	871	**120**
130	879	887	895	903	911	919	927	935	943	951	**130**
140	959	967	976	984	992	1000	1008	1016	1025	1033	**140**
150	1041	1049	1058	1066	1074	1082	1091	1099	1107	1116	**150**
160	1124	1132	1141	1149	1158	1166	1175	1183	1191	1200	**160**
170	1208	1217	1225	1234	1242	1251	1260	1268	1277	1285	**170**
180	1294	1303	1311	1320	1329	1337	1346	1355	1363	1372	**180**
190	1381	1389	1398	1407	1416	1425	1433	1442	1451	1460	**190**
200	1469	1477	1486	1495	1504	1513	1522	1531	1540	1549	**200**
210	1558	1567	1575	1584	1593	1602	1611	1620	1629	1639	**210**
220	1648	1657	1666	1675	1684	1693	1702	1711	1720	1729	**220**
230	1739	1748	1757	1766	1775	1784	1794	1803	1812	1821	**230**
240	1831	1840	1849	1858	1868	1877	1886	1895	1905	1914	**240**
250	1923	1933	1942	1951	1961	1970	1980	1989	1998	2008	**250**
260	2017	2027	2036	2046	2055	2064	2074	2083	2093	2102	**260**
270	2112	2121	2131	2140	2150	2159	2169	2179	2188	2198	**270**
280	2207	2217	2226	2236	2246	2255	2265	2275	2284	2294	**280**
290	2304	2313	2323	2333	2342	2352	2362	2371	2381	2391	**290**
300	2401	2410	2420	2430	2440	2449	2459	2469	2479	2488	**300**
310	2498	2508	2518	2528	2538	2547	2557	2567	2577	2587	**310**
320	2597	2607	2617	2626	2636	2646	2656	2666	2676	2686	**320**
330	2696	2706	2716	2726	2736	2746	2756	2766	2776	2786	**330**
340	2796	2806	2816	2826	2836	2846	2856	2866	2876	2886	**340**
350	2896	2906	2916	2926	2937	2947	2957	2967	2977	2987	**350**
360	2997	3007	3018	3028	3038	3048	3058	3068	3079	3089	**360**
370	3099	3109	3119	3130	3140	3150	3160	3171	3181	3191	**370**
380	3201	3212	3222	3232	3242	3253	3263	3273	3284	3294	**380**
390	3304	3315	3325	3335	3346	3356	3366	3377	3387	3397	**390**
400	3408	3418	3428	3439	3449	3460	3470	3480	3491	3501	**400**
410	3512	3522	3533	3543	3553	3564	3574	3585	3595	3606	**410**
420	3616	3627	3637	3648	3658	3669	3679	3690	3700	3711	**420**
430	3721	3732	3742	3753	3764	3774	3785	3795	3806	3816	**430**
440	3827	3838	3848	3859	3869	3880	3891	3901	3912	3922	**440**
450	3933	3944	3954	3965	3976	3986	3997	4008	4018	4029	**450**
460	4040	4050	4061	4072	4083	4093	4104	4115	4125	4136	**460**
470	4147	4158	4168	4179	4190	4201	4211	4222	4233	4244	**470**
480	4255	4265	4276	4287	4298	4309	4319	4330	4341	4352	**480**
490	4363	4373	4384	4395	4406	4417	4428	4439	4449	4460	**490**
500	4471	4482	4493	4504	4515	4526	4537	4548	4558	4569	**500**
510	4580	4591	4602	4613	4624	4635	4646	4657	4668	4679	**510**
520	4690	4701	4712	4723	4734	4745	4756	4767	4778	4789	**520**
530	4800	4811	4822	4833	4844	4855	4866	4877	4888	4899	**530**
540	4910	4922	4933	4944	4955	4966	4977	4988	4999	5010	**540**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
550	5021	5033	5044	5055	5066	5077	5088	5099	5111	5122	**550**
560	5133	5144	5155	5166	5178	5189	5200	5211	5222	5234	**560**
570	5245	5256	5267	5279	5290	5301	5312	5323	5335	5346	**570**
580	5357	5369	5380	5391	5402	5414	5425	5436	5448	5459	**580**
590	5470	5481	5493	5504	5515	5527	5538	5549	5561	5572	**590**
600	5583	5595	5606	5618	5629	5640	5652	5663	5674	5686	**600**
610	5697	5709	5720	5731	5743	5754	5766	5777	5789	5800	**610**
620	5812	5823	5834	5846	5857	5869	5880	5892	5903	5915	**620**
630	5926	5938	5949	5961	5972	5984	5995	6007	6018	6030	**630**
640	6041	6053	6065	6076	6088	6099	6111	6122	6134	6146	**640**
650	6157	6169	6180	6192	6204	6215	6227	6238	6250	6262	**650**
660	6273	6285	6297	6308	6320	6332	6343	6355	6367	6378	**660**
670	6390	6402	6413	6425	6437	6448	6460	6472	6484	6495	**670**
680	6507	6519	6531	6542	6554	6566	6578	6589	6601	6613	**680**
690	6625	6636	6648	6660	6672	6684	6695	6707	6719	6731	**690**
700	6743	6755	6766	6778	6790	6802	6814	6826	6838	6849	**700**
710	6861	6873	6885	6897	6909	6921	6933	6945	6956	6968	**710**
720	6980	6992	7004	7016	7028	7040	7052	7064	7076	7088	**720**
730	7100	7112	7124	7136	7148	7160	7172	7184	7196	7208	**730**
740	7220	7232	7244	7256	7268	7280	7292	7304	7316	7328	**740**
750	7340	7352	7364	7376	7389	7401	7413	7425	7437	7449	**750**
760	7461	7473	7485	7498	7510	7522	7534	7546	7558	7570	**760**
770	7583	7595	7607	7619	7631	7644	7656	7668	7680	7692	**770**
780	7705	7717	7729	7741	7753	7766	7778	7790	7802	7815	**780**
790	7827	7839	7851	7864	7876	7888	7901	7913	7925	7938	**790**
800	7950	7962	7974	7987	7999	8011	8024	8036	8048	8061	**800**
810	8073	8086	8098	8110	8123	8135	8147	8160	8172	8185	**810**
820	8197	8209	8222	8234	8247	8259	8272	8284	8296	8309	**820**
830	8321	8334	8346	8359	8371	8384	8396	8409	8421	8434	**830**
840	8446	8459	8471	8484	8496	8509	8521	8534	8546	8559	**840**
850	8571	8584	8597	8609	8622	8634	8647	8659	8672	8685	**850**
860	8697	8710	8722	8735	8748	8760	8773	8785	8798	8811	**860**
870	8823	8836	8849	8861	8874	8887	8899	8912	8925	8937	**870**
880	8950	8963	8975	8988	9001	9014	9026	9039	9052	9065	**880**
890	9077	9090	9103	9115	9128	9141	9154	9167	9179	9192	**890**
900	9205	9218	9230	9243	9256	9269	9282	9294	9307	9320	**900**
910	9333	9346	9359	9371	9384	9397	9410	9423	9436	9449	**910**
920	9461	9474	9487	9500	9513	9526	9539	9552	9565	9578	**920**
930	9590	9603	9616	9629	9642	9655	9668	9681	9694	9707	**930**
940	9720	9733	9746	9759	9772	9785	9798	9811	9824	9837	**940**
950	9850	9863	9876	9889	9902	9915	9928	9941	9954	9967	**950**
960	9980	9993	10006	10019	10032	10046	10059	10072	10085	10098	**960**
970	10111	10124	10137	10150	10163	10177	10190	10203	10216	10229	**970**
980	10242	10255	10268	10282	10295	10308	10321	10334	10347	10361	**980**
990	10374	10387	10400	10413	10427	10440	10453	10466	10480	10493	**990**
1000	10506	10519	10532	10546	10559	10572	10585	10599	10612	10625	**1000**
1010	10638	10652	10665	10678	10692	10705	10718	10731	10745	10758	**1010**
1020	10771	10785	10798	10811	10825	10838	10851	10865	10878	10891	**1020**
1030	10905	10918	10932	10945	10958	10972	10985	10998	11012	11025	**1030**
1040	11039	11052	11065	11079	11092	11106	11119	11132	11146	11159	**1040**
1050	11173	11186	11200	11213	11227	11240	11253	11267	11280	11294	**1050**
1060	11307	11321	11334	11348	11361	11375	11388	11402	11415	11429	**1060**
1070	11442	11456	11469	11483	11496	11510	11524	11537	11551	11564	**1070**
1080	11578	11591	11605	11618	11632	11646	11659	11673	11686	11700	**1080**
1090	11714	11727	11741	11754	11768	11782	11795	11809	11822	11836	**1090**
1100	11850	11863	11877	11891	11904	11918	11931	11945	11959	11972	**1100**
1110	11986	12000	12013	12027	12041	12054	12068	12082	12096	12109	**1110**
1120	12123	12137	12150	12164	12178	12191	12205	12219	12233	12246	**1120**
1130	12260	12274	12288	12301	12315	12329	12342	12356	12370	12384	**1130**
1140	12397	12411	12425	12439	12453	12466	12480	12494	12508	12521	**1140**
1150	12535	12549	12563	12577	12590	12604	12618	12632	12646	12659	**1150**
1160	12673	12687	12701	12715	12729	12742	12756	12770	12784	12798	**1160**
1170	12812	12825	12839	12853	12867	12881	12895	12909	12922	12936	**1170**
1180	12950	12964	12978	12992	13006	13019	13033	13047	13061	13075	**1180**
1190	13089	13103	13117	13131	13145	13158	13172	13186	13200	13214	**1190**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
1200	13228	13242	13256	13270	13284	13298	13311	13325	13339	13353	**1200**
1210	13367	13381	13395	13409	13423	13437	13451	13465	13479	13493	**1210**
1220	13507	13521	13535	13549	13563	13577	13590	13604	13618	13632	**1220**
1230	13646	13660	13674	13688	13702	13716	13730	13744	13758	13772	**1230**
1240	13786	13800	13814	13828	13842	13856	13870	13884	13898	13912	**1240**
1250	13926	13940	13954	13968	13982	13996	14010	14024	14038	14052	**1250**
1260	14066	14081	14095	14109	14123	14137	14151	14165	14179	14193	**1260**
1270	14207	14221	14235	14249	14263	14277	14291	14305	14319	14333	**1270**
1280	14347	14361	14375	14390	14404	14418	14432	14446	14460	14474	**1280**
1290	14488	14502	14516	14530	14544	14558	14572	14586	14601	14615	**1290**
1300	14629	14643	14657	14671	14685	14699	14713	14727	14741	14755	**1300**
1310	14770	14784	14798	14812	14826	14840	14854	14868	14882	14896	**1310**
1320	14911	14925	14939	14953	14967	14981	14995	15009	15023	15037	**1320**
1330	15052	15066	15080	15094	15108	15122	15136	15150	15164	15179	**1330**
1340	15193	15207	15221	15235	15249	15263	15277	15291	15306	15320	**1340**
1350	15334	15348	15362	15376	15390	15404	15419	15433	15447	15461	**1350**
1360	15475	15489	15503	15517	15531	15546	15560	15574	15588	15602	**1360**
1370	15616	15630	15645	15659	15673	15687	15701	15715	15729	15743	**1370**
1380	15758	15772	15786	15800	15814	15828	15842	15856	15871	15885	**1380**
1390	15899	15913	15927	15941	15955	15969	15984	15998	16012	16026	**1390**
1400	16040	16054	16068	16082	16097	16111	16125	16139	16153	16167	**1400**
1410	16181	16196	16210	16224	16238	16252	16266	16280	16294	16309	**1410**
1420	16323	16337	16351	16365	16379	16393	16407	16422	16436	16450	**1420**
1430	16464	16478	16492	16506	16520	16534	16549	16563	16577	16591	**1430**
1440	16605	16619	16633	16647	16662	16676	16690	16704	16718	16732	**1440**
1450	16746	16760	16774	16789	16803	16817	16831	16845	16859	16873	**1450**
1460	16887	16901	16915	16930	16944	16958	16972	16986	17000	17014	**1460**
1470	17028	17042	17056	17071	17085	17099	17113	17127	17141	17155	**1470**
1480	17169	17183	17197	17211	17225	17240	17254	17268	17282	17296	**1480**
1490	17310	17324	17338	17352	17366	17380	17394	17408	17423	17437	**1490**
1500	17451	17465	17479	17493	17507	17521	17535	17549	17563	17577	**1500**
1510	17591	17605	17619	17633	17647	17661	17676	17690	17704	17718	**1510**
1520	17732	17746	17760	17774	17788	17802	17816	17830	17844	17858	**1520**
1530	17872	17886	17900	17914	17928	17942	17956	17970	17984	17998	**1530**
1540	18012	18026	18040	18054	18068	18082	18096	18110	18124	18138	**1540**
1550	18152	18166	18180	18194	18208	18222	18236	18250	18264	18278	**1550**
1560	18292	18306	18320	18334	18348	18362	18376	18390	18404	18417	**1560**
1570	18431	18445	18459	18473	18487	18501	18515	18529	18543	18557	**1570**
1580	18571	18585	18599	18613	18627	18640	18654	18668	18682	18696	**1580**
1590	18710	18724	18738	18752	18766	18779	18793	18807	18821	18835	**1590**
1600	18849	18863	18877	18891	18904	18918	18932	18946	18960	18974	**1600**
1610	18988	19002	19015	19029	19043	19057	19071	19085	19098	19112	**1610**
1620	19126	19140	19154	19168	19181	19195	19209	19223	19237	19250	**1620**
1630	19264	19278	19292	19306	19319	19333	19347	19361	19375	19388	**1630**
1640	19402	19416	19430	19444	19457	19471	19485	19499	19512	19526	**1640**
1650	19540	19554	19567	19581	19595	19609	19622	19636	19650	19663	**1650**
1660	19677	19691	19705	19718	19732	19746	19759	19773	19787	19800	**1660**
1670	19814	19828	19841	19855	19869	19882	19896	19910	19923	19937	**1670**
1680	19951	19964	19978	19992	20005	20019	20032	20046	20060	20073	**1680**
1690	20087	20100	20114	20127	20141	20154	20168	20181	20195	20208	**1690**
1700	20222	20235	20249	20262	20275	20289	20302	20316	20329	20342	**1700**
1710	20356	20369	20382	20396	20409	20422	20436	20449	20462	20475	**1710**
1720	20488	20502	20515	20528	20541	20554	20567	20581	20594	20607	**1720**
1730	20620	20633	20646	20659	20672	20685	20698	20711	20724	20736	**1730**
1740	20749	20762	20775	20788	20801	20813	20826	20839	20852	20864	**1740**
1750	20877	20890	20902	20915	20928	20940	20953	20965	20978	20990	**1750**
1760	21003	21015	21027	21040	21052	21065	21077	21089	21101		**1760**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G, C** & **D** page 70	

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

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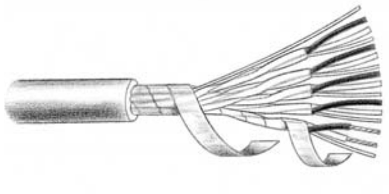
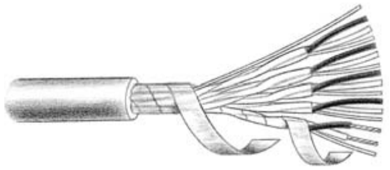
Instrument Cable to BS5308

Non Armoured Cables (Type 1)

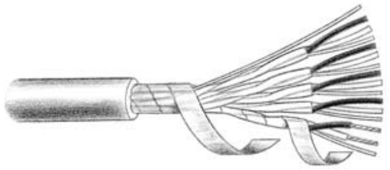
- These cables are manufactured generally in accordance with BS5308:1986
- They are available in a variety of conductor types including 16/0.2mm dia (0.5mm²), 24/0.2mm dia (0.75mm²) and 7/0.5mm dia (1.5mm²)
- Part 1 cables have Polyethylene insulated cores and our range is individually and collectively screened
- Part 2 cables have PVC insulated cores and our range is collectively screened only
- All cables incorporate a flame retardant sheath which has good properties for the reduced propagation of flame
- These cables also meet the requirements of BS4066 Part 3/ IEC 60332.3 Category C covering tests on cables under fire conditions
- Armoured versions are also available. See page 33
- All cables are oversheathed in Black unless required for Intrinsically Safe applications where Blue should be specified. Core colours are shown on page 35
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1989 Part 1 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995
- All our instrumentation cables are spark tested in accordance with BS5099



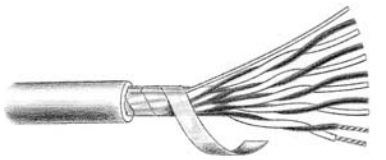
Single or multipairs of stranded 16/0.2mm dia conductors Polyethylene insulated. Pairs twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



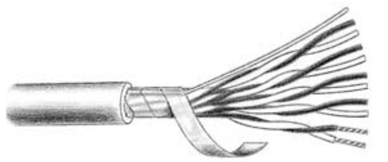
Single or multipairs of stranded 24/0.2mm dia conductors Polyethylene insulated. Pairs twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



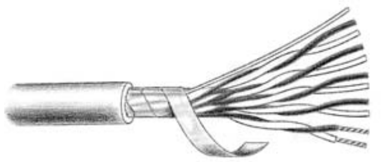
Single or multipairs of stranded 7/0.5mm dia conductors Polyethylene insulated. Pairs twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



Single or multipairs of stranded 16/0.2mm dia conductors PVC insulated. Pairs twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



Single or multipairs of stranded 24/0.2mm dia conductors PVC insulated. Pairs twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



Single or multipairs of stranded 7/0.5mm dia conductors PVC insulated. Pairs twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.

Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Diameter: Inches	Gauge: SWG	Gauge: AWG	Total Area mm²	Insulation	Pairs: No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Overall: Insulation	Insulation Rating °C: Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Overall Diameter² (mm)	Glands: Recommended Gland Ref.³ (See page 35)	Notes
M6101	16	.2	.008	36	32	.5	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	6	7.0	16	Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Part 1 Type 1
M6102	16	.2	.008	36	32	.5	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	11	12.0	20	
M6105	16	.2	.008	36	32	.5	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	25	15.2	25	
M6110	16	.2	.008	36	32	.5	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	48	21.1	32	
M6115	16	.2	.008	36	32	.5	PE	15	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	63	24.5	32	
M6120	16	.2	.008	36	32	.5	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	78	27.3	40	
M6130	16	.2	.008	36	32	.5	PE	30	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	110	32.3	50S	
M6150	16	.2	.008	36	32	.5	PE	50	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	180	41.7	50	
M7101	24	.2	.008	36	32	.75	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	11	7.3	16	Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Part 1 Type 1
M7102	24	.2	.008	36	32	.75	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	16	12.8	20	
M7105	24	.2	.008	36	32	.75	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	27	16.3	25	
M7110	24	.2	.008	36	32	.75	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	55	22.7	32	
M7120	24	.2	.008	36	32	.75	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	96	29.8	40	
M9101	7	.5	.02	25	24	1.5	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	13	8.3	20S	Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Part 1 Type 1
M9102	7	.5	.02	25	24	1.5	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	25	14.7	25	
M9105	7	.5	.02	25	24	1.5	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	40	18.8	25	
M9110	7	.5	.02	25	24	1.5	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	80	26.5	40	
M9120	7	.5	.02	25	24	1.5	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	140	34.4	50S	
M6201	16	.2	.008	36	32	.5	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	6	7.0	16	Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Part 2 Type 1
M6202*	16	.2	.008	36	32	.5	PVC	2	*See Below	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	8	7.9	16	
M6205	16	.2	.008	36	32	.5	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	20	13.1	20	
M6210	16	.2	.008	36	32	.5	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	34	17.2	25	
M6220	16	.2	.008	36	32	.5	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	57	22.3	32	
M7201	24	.2	.008	36	32	.75	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	8	7.3	16	Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Part 2 Type 1
M7202*	24	.2	.008	36	32	.75	PVC	2	*See Below	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	12	8.3	20S	
M7205	24	.2	.008	36	32	.75	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	25	14.3	20	
M7210	24	.2	.008	36	32	.75	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	45	18.7	25	
M7220	24	.2	.008	36	32	.75	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	80	24.5	32	
M9201	7	.5	.02	25	24	1.5	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	13	8.3	20S	Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Part 2 Type 1
M9202*	7	.5	.02	25	24	1.5	PVC	2	*See Below	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	21	9.7	20S	
M9205	7	.5	.02	25	24	1.5	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	36	16.4	25	
M9210	7	.5	.02	25	24	1.5	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	67	21.6	32	
M9220	7	.5	.02	25	24	1.5	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	123	28.5	40	

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. The gland sizes shown are for the CGA range.

These cables are normally available from us for **immediate** delivery from stock.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
In Intrinsically Safe areas, the user must be the best judge as to the suitability of the selected cable and its use within that area. Users should refer to BS5345.

*Mylar is a trade name.
*Two pair cables which are collectively screened only, and are laid up in quad formation around a central dummy.

Ordering Code - Typical example

M6105 — BLUE

Stock Number

Colour Code (if other than black)

typically allowing bending with radius about 12 times the OD. Sheaths are available as standard normally with 3, 6 and 8mm diameters, and with lengths to suit virtually any requirements.

A wide range of sheath materials is typically available, including stainless steel and Inconel 600. Sheaths can also be bonded with a variety of fluoroplastic coatings for the more corrosive environments. 316 stainless steel gives good corrosion resistance. Inconel 600 sheaths are aimed at applications which are extremely corrosive, also covering carburising atmospheres - but not sulphur bearing atmospheres at the upper temperature limit (see Part 2, Sections 9.1 and 9.2).

Seal termination styles and sheath fittings usually include most of the wide range described in Part 2, Section 9, suiting diverse application requirements. These probes are also readily available and are reasonably priced.

About the only negative aspect to note is that with this probe design, there can be problems relating to the ingress of water vapour. This can result in RTD poisoning and reduced insulation resistance, and hence instability and premature failure. This really is, however, completely avoidable, being a matter of quality control in manufacture.

7.3 Extension Leads and Connectors - RTD's

Interconnection cable for RTD assemblies comes in a number of forms, almost all of which are colour coded to the IEC 60751 international standard (Part 1, Section 4). Typically, the cable is provided as three cores of insulated, stranded, silver plated copper, the wires being inter-woven and finished with a braid screen with outer sheathing. Individual, and two, four and six core cabling are also available, and there is a wide range of insulation, braiding and sheathing materials.

A typical basic extension cable of this type would use PVC insulation and sheathing, and the screen would be of tinned copper. Temperature rating would be up to about 105°C. Moving up slightly, we find PFA core insulation and sheathing, and braiding made from nickel plated copper. These extension cables are suitable for use up to 260°C, or for short periods, 300°C. Next are fibreglass insulated and silicone varnished types with stainless steel braiding, and these are rated to 480°C.

Clearly, extension cables are not quite as important as they are in the world of thermocouple thermometry (see extension and compensating cables - Part 2, Section 3). The main consideration is getting the low level signals from point to point with minimum losses and interference from external currents and contactor operation. However, it is important to remember that thermoelectric effects, from the use of different conductors (as per thermocouples), can cause problems, particularly where potentiometric measurement is concerned (see Part 3, Section 3). So use the recommended cable.

Connectors for RTD's come into much the same category; the emphasis is on making good, high integrity connections which do not introduce ohmic resistance. High quality RTD connectors should always be used - and these are exactly the same as those used in thermocouple thermometry (see Part 2, Section 4).

8.0 End seals, Terminal Blocks and Terminal Heads

End seals for thermocouples and RTD's come in all shapes and sizes, according to temperature range, environment and application. Putting it simply you can pretty well have whatever you want. However, as a rough guide to the kinds of standard offerings normally available off the shelf, it is worth having a look at just some of the ranges.

At the bottom end, there are thermocouple sensors and RTD assemblies supplied with bare end conductors, normally with an internal epoxy resin seal capable of handling temperatures up to 150°C, with high temperature resins taking this up to 235°C. On thermocouple sensors, glass and resin versions, taking temperatures up to 300°C, are also available.

Moving up the range, we come to crimped stainless steel pot seals, threaded or not, potted with the same materials and covering the same temperature ranges; these may have an anti-chafe support spring tension fitting. Next, there are brass and stainless steel compression gland pot seal fittings.

Beyond this, there are the full ranges of connectors (see Part 2, Section 4), and these are followed by the die cast industrial terminal heads, which in general are designed for the harsher industrial plant environments. Again, these come in all shapes and sizes. At the simplest level, there are the straight-through designs, made from alloy and having a porcelain connector block and a gasketed and screwed lid, plus pinch glands for the cable entry. These are usually designed for single channel and duplex assemblies. Next, and more common, is the same device, but with the sensor entry and cable exit at 90° to one another.

9.0 Heavy Duty Industrial Assemblies

Then we come to the weather-proof, heavy duty versions of the same, for use with thick wall protective sheaths - of whatever length and shape you need, straight or angled (single or multiple). Materials of construction for the sheaths range from cast iron, or mild steel, through stainless steel alloys and nickel chromium, to iron nickel and chromium iron, etc. Materials are selected against the required duty/environment. Fittings include adjustable flanges and welded or adjustable bushes. Typically, this kind of assembly is designed to withstand temperatures to around 1,150°C with thermocouple systems.

For temperatures up to around 1,600°C with thermocouple probes, ceramic protection sheath versions are also available in materials ranging from aluminous porcelain, through recrystallised alumina, to mullite and silicon carbide (see Part 2, Section 9.1).

Insert thermocouple assemblies are available for use with all of these industrial heads, as well as the full range of metal protection tubes, secondary ceramic sheaths, or thermowells. Here, the end seal is incorporated into a terminal block suitable for mounting into the terminal heads. Ceramic terminal blocks are provided, some with spring loading connections for better thermal transfer where the tip of the assembly is in contact with the bottom of the protection tube/sheath or the thermowell. This is also the point at which head-mounted transmitters can be mounted (see Part 2, Section 10).

9.1 Protective Sheaths

Where thermocouples are concerned, metal protection tubes can be used up to about 1,250°C with base metal sensors, or if a high purity alumina liner is harnessed, with platinum thermocouples up to 1,150°C. Other options include alloys like copper/nickel, handling up to 400°C, carbon steel for use in oxidising atmospheres up to about 700°C, and the 300 series austenitic stainless steels, which take this up to 850°C (for 321S12) and 1,100°C (for 310S24).

When it comes to resistance thermometer detectors, however, there are limitations. Since platinum can be contaminated by a number of materials, like base metals, particularly when heated, special sheathing materials are required. Materials commonly used include various stainless steels, Inconel 600, Incoloy 800, nickel and nickel alloys. Sheaths can also be bonded with various fluoroplastic coatings for the more corrosive environments.

316 stainless steel gives good corrosion resistance. 310 chromium nickel stainless steel offers much the same, but with good resistance to sulphur bearing atmospheres. Inconel 600 is aimed at atmospheres which are extremely corrosive, also covering carburising atmospheres - but not sulphur bearing atmospheres near the upper temperature limit for RTD's. Ceramic tubes, usually recrystallised alumina can also be used at higher temperatures.

Coming back to thermocouples, these same materials can and are used. For temperatures up to 1,150°C in severely corrosive and oxidising and reducing environments, plus sulphur bearing atmospheres, for example, the 400 series ferritic steels are recommended. Also, Inconel 600 can be selected for oxidising and severely corrosive environments up to the same temperature. Meanwhile, Incoloy 800 provides the same protection as Inconel, but with added resistance to carburization and, like the ferritic steels, resistance to sulphur bearing atmospheres. Hastelloy X has improved high temperature resistance to oxidation and attack by sulphur, and is equally applicable to reducing, neutral and inert atmospheres up to 1,220°C. Meanwhile, for the full 1,250°C, and particularly anything above 1,000°C with, for example, Type N thermocouples, Nicrosil and the Nicrobell alloys are highly recommended.

For higher temperatures, or in environments known to be too corrosive or aggressive for metals, ceramic tubes can be used. Materials available for temperatures up to about 1,400°C include impervious alumina porcelain and silicon carbide. The former is ideal for use with base metal thermocouple conductors, and gives excellent resistance to thermal shock because of its very low temperature coefficient of expansion. In particular it is ideal for kiln applications where its high strength and resistance to flux and slag attack are useful.

Silicon carbide, meanwhile, can be taken to larger diameters (up to 50mm), making it ideal as a primary sheath enclosing some secondary material. It is frequently used where greater protection against thermal shock, abrasion and corrosion are required. Silicon carbide is not, however, appropriate for oxidising atmospheres.

Mullite can be used at higher temperatures because of its good mechanical strength and resistance to thermal shock, plus its suitability for use with the noble metal thermocouples. However, this material specifically should not be used with platinum thermocouples because of its silica content. Temperatures handled are up to 1,600°C. Mullite is often used as secondary protection within a silicon carbide primary sheath.

Where platinum thermocouples are to be used at temperatures above about 1,200°C and up to about 1,800°C, or where the tube must be gas tight, recrystallised alumina is ideal. It has a fair resistance to thermal shock, is highly inert to most chemical attack, and is ideal for carbonaceous and reducing atmospheres, also offering good resistance to alkaline and other fluxes.

As for dimensions, most manufacturers will tell you that virtually anything and everything is available. Certainly, as standard, sheaths are available with outer diameters ranging from about 10mm to 50mm, in lengths from 100mm to more than 2 metres.

9.2 Thermowells

Thermowells are closed end re-entrant protection tubes into which temperature sensing elements can be inserted - and come in all shapes and sizes. The message from most manufacturers is that you can have what you want. A typical device is a taper threaded protective process entry tube, typically to BS 2765, or the specific chemical and petroleum industry standards, with a male process entry thread and female thermowell entry head for the thermocouple or RTD assembly attachment. The internal diameter of the thermowell is usually such that the sensor can be easily inserted, but no larger - to minimise the air gap, and thus maximise the thermal response and the atmospheric protection. This can also be achieved by the incorporation of a reduced bore at the tip of the thermowell to accommodate the sensing element or insert assembly.

Materials of construction range from brass (350°C), through mild steel (550°C) but are more typically stainless steel (800°C), Inconel 600 (1,100°C) or Incoloy 800 (1,100°C) with the same environmental constraints as already detailed for these materials (see Part 2, Section 9.1).

10.0 Transmitters - Head Mounted, DIN Rail Mounted, 19 inch Rack Mounting

Despite the vast number of temperature measurements taken throughout industry, relatively few signals from temperature sensors are transmitted in the standard 4-20mA format from the field to the instrumentation or control room. Most are maintained as the original sensor millivolt level signals direct back to the control room, connected by compensating or extension cable in the case of thermocouples, or screened and guarded instrument cables in the case of RTD's. Conditioning and linearisation then take place remotely. This is fine for short distances - it's relatively cheap and it works.

At a fairly ill-specified distance it becomes more economical - and sensible - to install a local transmitter, and run the measurement as part of a standard twisted pair 4-20mA current loop back to the control room. The most significant advantages of this approach are: the reduced cost of cabling against the high grade alternative required to transmit the small voltage signals; the much better signal strength achieved by amplifying and transmitting as a current signal; and immunity to the almost inevitable problems of electrical noise pick-up (see Part 1, Section 7). Hence the argument for using transmitters. However, they come in two main styles - hockey puck shaped head-mounted devices and DIN rail or 19in rack and panel mounting remote units. And the age old problem for many engineers essentially concerns which offers the best bet. The former are close to the point of measurement, sending high level current signals straight away, while the latter two tend to be

Continued on page 36

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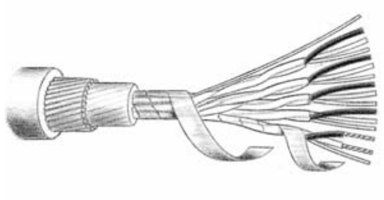
Instrument Cable to BS5308

Armoured Cables (Type 2)

- These cables are manufactured generally in accordance with BS5308:1986
- They are available in a variety of conductor types including 16/0.2mm dia (0.5mm²), 24/0.2mm dia (0.75mm²) and 7/0.5mm dia (1.5mm²)
- Part 1 cables have Polyethylene insulated cores and our range is individually and collectively screened
- Part 2 cables have PVC insulated cores and our range is collectively screened only
- All cables incorporate a flame retardant sheath which has good properties for the reduced propagation of flame
- These cables also meet the requirements of BS4066 Part 3/ IEC 60332.3 Category C covering tests on cables under fire conditions
- Non armoured versions are also available. See page 31.
- All cables are oversheathed in Black unless required for Intrinsically Safe applications where Blue should be specified. Core colours are shown on page 35
- The Oxygen Index Value is not less than 30 in accordance with BS2782:1989 Part 1 Method 141
- The mechanical properties of these cables meet the requirements of BS EN 60811: 1995
- All our instrumentation cables are spark tested in accordance with BS5099

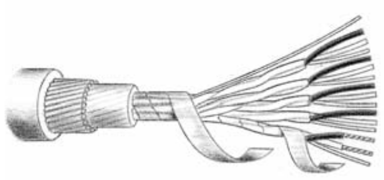
Column groups: Conductors (No. of Strands; Size of Strand: Diameter mm., Inches; Gauge SWG, AWG; Total Area mm²; Insulation) – Pairs (No. of Pairs; Laid-Flat or Twisted; Individual Screen¹) – Overall (Insulation; Insulation Rating °C: Continuous, Short Term; Colour Coding; Overall Screen¹; Abrasion Resistance; Moisture Resistance; Typical Weight² Kg/100m (Excluding Reel); Diameter Under Armour² (mm); Diameter Over Armour² (mm); Overall Diameter² (mm)) – Glands (Recommended Gland Ref.³ (See page 35)) – Notes



Single or multipairs of stranded 16/0.2mm dia conductors Polyethylene insulated. Pairs twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and Polyethylene bedded. Steel wire armoured and FR PVC sheathed.

Notes: Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 1 Type 2

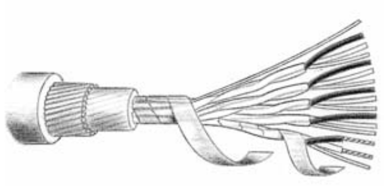
Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³
M6101/SWA	16	.2	.008	36	32	.5	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	25	7.0	8.8	11.4	16
M6102/SWA	16	.2	.008	36	32	.5	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	45	12.0	13.8	16.8	20
M6105/SWA	16	.2	.008	36	32	.5	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	75	15.2	17.7	20.9	25
M6110/SWA	16	.2	.008	36	32	.5	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	130	21.1	24.3	27.9	32
M6115/SWA	16	.2	.008	36	32	.5	PE	15	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	160	24.5	27.7	31.3	32
M6120/SWA	16	.2	.008	36	32	.5	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	185	27.3	30.5	34.3	40
M6130/SWA	16	.2	.008	36	32	.5	PE	30	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	250	32.3	36.3	40.5	50S
M6150/SWA	16	.2	.008	36	32	.5	PE	50	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	380	41.7	46.7	51.5	50



Single or multipairs of stranded 24/0.2mm dia conductors Polyethylene insulated. Pairs twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and Polyethylene bedded. Steel wire armoured and FR PVC sheathed.

Notes: Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 1 Type 2

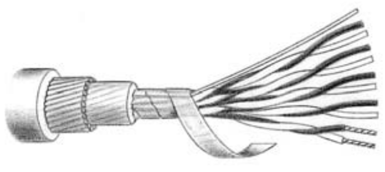
Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³
M7101/SWA	24	.2	.008	36	32	.75	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	30	7.3	9.1	11.7	16
M7102/SWA	24	.2	.008	36	32	.75	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	50	12.8	14.6	17.6	20
M7105/SWA	24	.2	.008	36	32	.75	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	90	16.3	18.8	22.0	25
M7110/SWA	24	.2	.008	36	32	.75	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	160	22.7	25.9	29.5	32
M7120/SWA	24	.2	.008	36	32	.75	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	240	29.8	33.8	37.8	40



Single or multipairs of stranded 7/0.5mm dia conductors Polyethylene insulated. Pairs twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and Polyethylene bedded. Steel wire armoured and FR PVC sheathed.

Notes: Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 1 Type 2

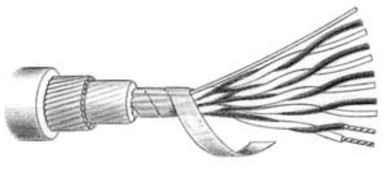
Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³
M9101/SWA	7	.5	.02	25	24	1.5	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	35	8.3	10.1	12.9	20S
M9102/SWA	7	.5	.02	25	24	1.5	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	65	14.7	17.2	20.4	25
M9105/SWA	7	.5	.02	25	24	1.5	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	115	18.8	22.0	25.4	25
M9110/SWA	7	.5	.02	25	24	1.5	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	180	26.5	29.7	33.5	40
M9120/SWA	7	.5	.02	25	24	1.5	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	300	34.4	38.4	42.6	50S



Single or multipairs of stranded 16/0.2mm dia conductors PVC insulated. Pairs twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.

Notes: Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 2 Type 2

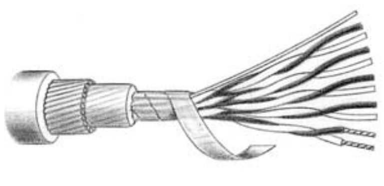
Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³
M6201/SWA	16	.2	.008	36	32	.5	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	25	7.0	8.8	11.4	16
M6202/SWA*	16	.2	.008	36	32	.5	PVC	2	*See Below	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	35	7.9	9.7	12.3	16
M6205/SWA	16	.2	.008	36	32	.5	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	60	13.1	14.9	17.9	20
M6210/SWA	16	.2	.008	36	32	.5	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	100	17.2	19.7	22.9	25
M6220/SWA	16	.2	.008	36	32	.5	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	165	22.3	25.5	29.1	32



Single or multipairs of stranded 24/0.2mm dia conductors PVC insulated. Pairs twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.

Notes: Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 2 Type 2

Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³
M7201/SWA	24	.2	.008	36	32	.75	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	30	7.3	9.1	11.7	16
M7202/SWA*	24	.2	.008	36	32	.75	PVC	2	*See Below	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	40	8.3	10.1	12.9	20S
M7205/SWA	24	.2	.008	36	32	.75	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	75	14.3	16.8	19.8	25
M7210/SWA	24	.2	.008	36	32	.75	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	120	18.7	21.9	25.3	25
M7220/SWA	24	.2	.008	36	32	.75	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	190	24.5	27.7	31.3	32



Single or multipairs of stranded 7/0.5mm dia conductors PVC insulated. Pairs twisted. Pairs laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.

Notes: Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 2 Type 2

Stock Number	No. of Strands	mm.	Inches	SWG	AWG	Total Area mm²	Insulation	No. of Pairs	Laid-Flat or Twisted	Individual Screen¹	Insulation	Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour² (mm)	Diameter Over Armour² (mm)	Overall Diameter² (mm)	Recommended Gland Ref.³
M9201/SWA	7	.5	.02	25	24	1.5	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	35	8.3	10.1	12.9	20S
M9202/SWA*	7	.5	.02	25	24	1.5	PVC	2	*See Below	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	45	9.7	11.5	14.3	20S
M9205/SWA	7	.5	.02	25	24	1.5	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	95	16.4	18.9	22.2	25
M9210/SWA	7	.5	.02	25	24	1.5	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	150	21.6	24.8	28.4	32
M9220/SWA	7	.5	.02	25	24	1.5	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	240	28.5	31.7	35.7	40

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.
3. The gland sizes shown are for the CGC and CGE ranges. CGA types are available, however the gland size will change. See page 35 for full details.

These cables are normally available from us for **immediate** delivery from stock.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
In Intrinsically Safe areas the user must be the best judge as to the suitability of the selected cable and its use within that area. Users should refer to BS5345.

*Mylar is a trade name.
*Two pair cables which are collectively screened only, and are laid up in quad formation around a central dummy.

Ordering Code - Typical example

M6120/SWA — BLUE

Stock Number
Colour Code (if other than black)

TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
Tel: +44 (0)1895 252222 - Fax: +44 (0)1895 273540
Email: info@tc.co.uk - Web: www.tc.co.uk

☎ **01895 252222**

CODE **S**

CODE **S**

International Thermocouple Reference Tables for
Platinum - 10% Rhodium / Platinum
To IEC60584.1:1995 / BS EN 60584.1 Part 1 : 1996

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (µV).

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
-50	-236										-50
-40	-194	-199	-203	-207	-211	-215	-219	-224	-228	-232	-40
-30	-150	-155	-159	-164	-168	-173	-177	-181	-186	-190	-30
-20	-103	-108	-113	-117	-122	-127	-132	-136	-141	-146	-20
-10	-53	-58	-63	-68	-73	-78	-83	-88	-93	-98	-10
0	0	-5	-11	-16	-21	-27	-32	-37	-42	-48	0
0	0	5	11	16	22	27	33	38	44	50	0
10	55	61	67	72	78	84	90	95	101	107	10
20	113	119	125	131	137	143	149	155	161	167	20
30	173	179	185	191	197	204	210	216	222	229	30
40	235	241	248	254	260	267	273	280	286	292	40
50	299	305	312	319	325	332	338	345	352	358	50
60	365	372	378	385	392	399	405	412	419	426	60
70	433	440	446	453	460	467	474	481	488	495	70
80	502	509	516	523	530	538	545	552	559	566	80
90	573	580	588	595	602	609	617	624	631	639	90
100	646	653	661	668	675	683	690	698	705	713	100
110	720	727	735	743	750	758	765	773	780	788	110
120	795	803	811	818	826	834	841	849	857	865	120
130	872	880	888	896	903	911	919	927	935	942	130
140	950	958	966	974	982	990	998	1006	1013	1021	140
150	1029	1037	1045	1053	1061	1069	1077	1085	1094	1102	150
160	1110	1118	1126	1134	1142	1150	1158	1167	1175	1183	160
170	1191	1199	1207	1216	1224	1232	1240	1249	1257	1265	170
180	1273	1282	1290	1298	1307	1315	1323	1332	1340	1348	180
190	1357	1365	1373	1382	1390	1399	1407	1415	1424	1432	190
200	1441	1449	1458	1466	1475	1483	1492	1500	1509	1517	200
210	1526	1534	1543	1551	1560	1569	1577	1586	1594	1603	210
220	1612	1620	1629	1638	1646	1655	1663	1672	1681	1690	220
230	1698	1707	1716	1724	1733	1742	1751	1759	1768	1777	230
240	1786	1794	1803	1812	1821	1829	1838	1847	1856	1865	240
250	1874	1882	1891	1900	1909	1918	1927	1936	1944	1953	250
260	1962	1971	1980	1989	1998	2007	2016	2025	2034	2043	260
270	2052	2061	2070	2078	2087	2096	2105	2114	2123	2132	270
280	2141	2151	2160	2169	2178	2187	2196	2205	2214	2223	280
290	2232	2241	2250	2259	2268	2277	2287	2296	2305	2314	290
300	2323	2332	2341	2350	2360	2369	2378	2387	2396	2405	300
310	2415	2424	2433	2442	2451	2461	2470	2479	2488	2497	310
320	2507	2516	2525	2534	2544	2553	2562	2571	2581	2590	320
330	2599	2609	2618	2627	2636	2646	2655	2664	2674	2683	330
340	2692	2702	2711	2720	2730	2739	2748	2758	2767	2776	340
350	2786	2795	2805	2814	2823	2833	2842	2851	2861	2870	350
360	2880	2889	2899	2908	2917	2927	2936	2946	2955	2965	360
370	2974	2983	2993	3002	3012	3021	3031	3040	3050	3059	370
380	3069	3078	3088	3097	3107	3116	3126	3135	3145	3154	380
390	3164	3173	3183	3192	3202	3212	3221	3231	3240	3250	390
400	3259	3269	3279	3288	3298	3307	3317	3326	3336	3346	400
410	3355	3365	3374	3384	3394	3403	3413	3423	3432	3442	410
420	3451	3461	3471	3480	3490	3500	3509	3519	3529	3538	420
430	3548	3558	3567	3577	3587	3596	3606	3616	3626	3635	430
440	3645	3655	3664	3674	3684	3694	3703	3713	3723	3732	440
450	3742	3752	3762	3771	3781	3791	3801	3810	3820	3830	450
460	3840	3850	3859	3869	3879	3889	3898	3908	3918	3928	460
470	3938	3947	3957	3967	3977	3987	3997	4006	4016	4026	470
480	4036	4046	4056	4065	4075	4085	4095	4105	4115	4125	480
490	4134	4144	4154	4164	4174	4184	4194	4204	4213	4223	490
500	4233	4243	4253	4263	4273	4283	4293	4303	4313	4323	500
510	4332	4342	4352	4362	4372	4382	4392	4402	4412	4422	510
520	4432	4442	4452	4462	4472	4482	4492	4502	4512	4522	520
530	4532	4542	4552	4562	4572	4582	4592	4602	4612	4622	530
540	4632	4642	4652	4662	4672	4682	4692	4702	4712	4722	540

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
550	4732	4742	4752	4762	4772	4782	4793	4803	4813	4823	550
560	4833	4843	4853	4863	4873	4883	4893	4904	4914	4924	560
570	4934	4944	4954	4964	4974	4984	4995	5005	5015	5025	570
580	5035	5045	5055	5066	5076	5086	5096	5106	5116	5127	580
590	5137	5147	5157	5167	5178	5188	5198	5208	5218	5228	590
600	5239	5249	5259	5269	5280	5290	5300	5310	5320	5331	600
610	5341	5351	5361	5372	5382	5392	5402	5413	5423	5433	610
620	5443	5454	5464	5474	5485	5495	5505	5515	5526	5536	620
630	5546	5557	5567	5577	5588	5598	5608	5618	5629	5639	630
640	5649	5660	5670	5680	5691	5701	5712	5722	5732	5743	640
650	5753	5763	5774	5784	5794	5805	5815	5826	5836	5846	650
660	5857	5867	5878	5888	5898	5909	5919	5930	5940	5950	660
670	5961	5971	5982	5992	6003	6013	6024	6034	6044	6055	670
680	6065	6076	6086	6097	6107	6118	6128	6139	6149	6160	680
690	6170	6181	6191	6202	6212	6223	6233	6244	6254	6265	690
700	6275	6286	6296	6307	6317	6328	6338	6349	6360	6370	700
710	6381	6391	6402	6412	6423	6434	6444	6455	6465	6476	710
720	6486	6497	6508	6518	6529	6539	6550	6561	6571	6582	720
730	6593	6603	6614	6624	6635	6646	6656	6667	6678	6688	730
740	6699	6710	6720	6731	6742	6752	6763	6774	6784	6795	740
750	6806	6817	6827	6838	6849	6859	6870	6881	6892	6902	750
760	6913	6924	6934	6945	6956	6967	6977	6988	6999	7010	760
770	7020	7031	7042	7053	7064	7074	7085	7096	7107	7117	770
780	7128	7139	7150	7161	7172	7182	7193	7204	7215	7226	780
790	7236	7247	7258	7269	7280	7291	7302	7312	7323	7334	790
800	7345	7356	7367	7378	7388	7399	7410	7421	7432	7443	800
810	7454	7465	7476	7487	7497	7508	7519	7530	7541	7552	810
820	7563	7574	7585	7596	7607	7618	7629	7640	7651	7662	820
830	7673	7684	7695	7706	7717	7728	7739	7750	7761	7772	830
840	7783	7794	7805	7816	7827	7838	7849	7860	7871	7882	840
850	7893	7904	7915	7926	7937	7948	7959	7970	7981	7992	850
860	8003	8014	8026	8037	8048	8059	8070	8081	8092	8103	860
870	8114	8125	8137	8148	8159	8170	8181	8192	8203	8214	870
880	8226	8237	8248	8259	8270	8281	8293	8304	8315	8326	880
890	8337	8348	8360	8371	8382	8393	8404	8416	8427	8438	890
900	8449	8460	8472	8483	8494	8505	8517	8528	8539	8550	900
910	8562	8573	8584	8595	8607	8618	8629	8640	8652	8663	910
920	8674	8685	8697	8708	8719	8731	8742	8753	8765	8776	920
930	8787	8798	8810	8821	8832	8844	8855	8866	8878	8889	930
940	8900	8912	8923	8935	8946	8957	8969	8980	8991	9003	940
950	9014	9025	9037	9048	9060	9071	9082	9094	9105	9117	950
960	9128	9139	9151	9162	9174	9185	9197	9208	9219	9231	960
970	9242	9254	9265	9277	9288	9300	9311	9323	9334	9345	970
980	9357	9368	9380	9391	9403	9414	9426	9437	9449	9460	980
990	9472	9483	9495	9506	9518	9529	9541	9552	9564	9576	990
1000	9587	9599	9610	9622	9633	9645	9656	9668	9680	9691	1000
1010	9703	9714	9726	9737	9749	9761	9772	9784	9795	9807	1010
1020	9819	9830	9842	9853	9865	9877	9888	9900	9911	9923	1020
1030	9935	9946	9958	9970	9981	9993	10005	10016	10028	10040	1030
1040	10051	10063	10075	10086	10098	10110	10121	10133	10145	10156	1040
1050	10168	10180	10191	10203	10215	10227	10238	10250	10262	10273	1050
1060	10285	10297	10309	10320	10332	10344	10356	10367	10379	10391	1060
1070	10403	10414	10426	10438	10450	10461	10473	10485	10497	10509	1070
1080	10520	10532	10544	10556	10567	10579	10591	10603	10615	10626	1080
1090	10638	10650	10662	10674	10686	10697	10709	10721	10733	10745	1090
1100	10757	10768	10780	10792	10804	10816	10828	10839	10851	10863	1100
1110	10875	10887	10899	10911	10922	10934	10946	10958	10970	10982	1110
1120	10994	11006	11017	11029	11041	11053	11065	11077	11089	11101	1120
1130	11113	11125	11136	11148	11160	11172	11184	11196	11208	11220	1130
1140	11232	11244	11256	11268	11280	11291	11303	11315	11327	11339	1140
1150	11351	11363	11375	11387	11399	11411	11423	11435	11447	11459	1150
1160	11471	11483	11495	11507	11519	11531	11542	11554	11566	11578	1160
1170	11590	11602	11614	11626	11638	11650	11662	11674	11686	11698	1170
1180	11710	11722	11734	11746	11758	11770	11782	11794	11806	11818	1180
1190	11830	11842	11854	11866	11878	11890	11902	11914	11926	11939	1190

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/µV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
1200	11951	11963	11975	11987	11999	12011	12023	12035	12047	12059	1200
1210	12071	12083	12095	12107	12119	12131	12143	12155	12167	12179	1210
1220	12191	12203	12216	12228	12240	12252	12264	12276	12288	12300	1220
1230	12312	12324	12336	12348	12360	12372	12384	12397	12409	12421	1230
1240	12433	12445	12457	12469	12481	12493	12505	12517	12529	12542	1240
1250	12554	12566	12578	12590	12602	12614	12626	12638	12650	12662	1250
1260	12675	12687	12699	12711	12723	12735	12747	12759	12771	12783	1260
1270	12796	12808	12820	12832	12844	12856	12868	12880	12892	12905	1270
1280	12917	12929	12941	12953	12965	12977	12989	13001	13014	13026	1280
1290	13038	13050	13062	13074	13086	13098	13111	13123	13135	13147	1290
1300	13159	13171	13183	13195	13208	13220	13232	13244	13256	13268	1300
1310	13280	13292	13305	13317	13329	13341	13353	13365	13377	13390	1310
1320	13402	13414	13426	13438	13450	13462	13474	13487	13499	13511	1320
1330	13523	13535	13547	13559	13572	13584	13596	13608	13620	13632	1330
1340	13644	13657	13669	13681	13693	13705	13717	13729	13742	13754	1340
1350	13766	13778	13790	13802	13814	13826	13839	13851	13863	13875	1350
1360	13887	13899	13911	13924	13936	13948	13960	13972	13984	13996	1360
1370	14009	14021	14033	14045	14057	14069	14081	14094	14106	14118	1370
1380	14130	14142	14154	14166	14178	14191	14203	14215	14227	14239	1380
1390	14251	14263	14276	14288	14300	14312	14324	14336	14348	14360	1390
1400	14373	14385	14397	14409	14421	14433	14445	14457	14470	14482	1400
1410	14494	14506	14518	14530	14542	14554	14567	14579	14591	14603	1410
1420	14615	14627	14639	14651	14664	14676	14688	14700	14712	14724	1420
1430	14736	14748	14760	14773	14785	14797	14809	14821	14833	14845	1430
1440	14857	14869	14881	14894	14906	14918	14930	14942	14954	14966	1440
1450	14978	14990	15002	15015	15027	15039	15051	15063	15075	15087	1450
1460	15099	15111	15123	15135	15148	15160	15172	15184	15196	15208	1460
1470	15220	15232	15244	15256	15268	15280	15292	15304	15317	15329	1470
1480	15341	15353	15365	15377	15389	15401	15413	15425	15437	15449	1480
1490	15461	15473	15485	15497	15509	15521	15534	15546	15558	15570	1490
1500	15582	15594	15606	15618	15630	15642	15654	15666	15678	15690	1500
1510	15702	15714	15726	15738	15750	15762	15774	15786	15798	15810	1510
1520	15822	15834	15846	15858	15870	15882	15894	15906	15918	15930	1520
1530	15942	15954	15966	15978	15990	16002	16014	16026	16038	16050	1530
1540	16062	16074	16086	16098	16110	16122	16134	16146	16158	16170	1540
1550	16182	16194	16205	16217	16229	16241	16253	16265	16277	16289	1550
1560	16301	16313	16325	16337	16349	16361	16373	16385	16396	16408	1560
1570	16420	16432	16444	16456	16468	16480	16492	16504	16516	16527	1570
1580	16539	16551	16563	16575	16587	16599	16611	16623	16634	16646	1580
1590	16658	16670	16682	16694	16706	16718	16729	16741	16753	16765	1590
1600	16777	16789	16801	16812	16824	16836	16848	16860	16872	16883	1600
1610	16895	16907	16919	16931	16943	16954	16966	16978	16990	17002	1610
1620	17013	17025	17037	17049	17061	17072	17084	17096	17108	17120	1620
1630	17131	17143	17155	17167	17178	17190	17202	17214	17225	17237	1630
1640	17249	17261	17272	17284	17296	17308	17319	17331	17343	17355	1640
1650	17366	17378	17390	17401	17413	17425	17437	17448	17460	17472	1650
1660	17483	17495	17507	17518	17530	17542	17553	17565	17577	17588	1660
1670	17600	17612	17623	17635	17647	17658	17670	17682	17693	17705	1670
1680	17717	17728	17740	17751	17763	17775	17786	17798	17809	17821	1680
1690	17832	17844	17855	17867	17878	17890	17901	17913	17924	17936	1690
1700	17947	17959	17970	17982	17993	18004	18016	18027	18039	18050	1700
1710	18061	18073	18084	18095	18107	18118	18129	18140	18152	18163	1710
1720	18174	18185	18196	18208	18219	18230	18241	18252	18263	18274	1720
1730	18285	18297	18308	18319	18330	18341	18352	18362	18373	18384	1730
1740	18395	18406	18417	18428	18439	18449	18460	18471	18482	18493	1740
1750	18503	18514	18525	18535	18546	18557	18567	18578	18588	18599	1750
1760	18609	18620	18630	18641	18651	18661	18672	18682	18693		1760

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G, C & D** page 70	

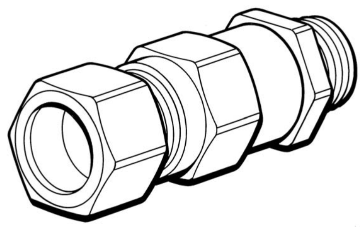
*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

Cable Glands

Our standard range of cable glands are manufactured in brass generally in accordance with BS 6121. All glands are supplied complete with a matching locknut for your convenience. Our cable glands are available for the vast majority of Thermocouple, RTD and Instrument cables that we offer. As a guide we have where possible recommended a gland size for each cable type on the relevant cable selection page.

SECTION 1 Cable Gland Types

Type Ref.	Usage	Cables Suitable for
CGA	Clamps outer sheath only	Non Armoured or Armoured Cables
CGC	Clamps armouring and outer sheath only	Armoured Cables only
CGE	Clamps inner sheath, Armouring and Outer Sheath	Armoured Cables only



A typical cable gland type CGE is shown above.

Other types of cable glands are available including: glands for clamping the armouring only (Type CGB), glands for clamping the inner sheath and armouring only (Type CGD), EX and flameproof versions of all the above styles and glands manufactured in other materials.

SECTION 2 Glands and Cable Sizes

Type CGA Glands for Non Armoured or Armoured Cables

Cable Gland Size (mm)	Cable Outer Sheath Dimensions (mm)	
	Min. Diameter	Max. Diameter
10	1.5	5.0
12	4.0	8.0
16	3.5	8.5
20S	8.0	11.5
20	11.0	13.5
25	13.0	19.5
32	19.0	25.5
40	25.0	32.0
50S	31.5	37.0
50	36.5	43.0

All glands are metric with a 1.5mm thread pitch with the exception of the 10mm gland which has a thread pitch of 1.0mm. All glands are supplied complete with a matching locknut.

Type CGC and CGE Glands for Armoured Cables Only

Cable Gland Size (mm)	Cable Inner Sheath Dimensions (mm) (Type CGE only)		Cable Outer Sheath Dimensions (mm)	
	Min Diameter	Max Diameter	Min Diameter	Max Diameter
16	3.5	8.6	8.4	13.2
20S	8.0	11.6	12.9	15.8
20	11.0	13.9	15.5	20.8
25	13.0	19.9	20.3	27.2
32	19.0	26.2	26.7	33.5
40	25.0	32.1	33.0	39.9
50S	31.5	38.1	39.4	46.3
50	36.5	44.0	45.7	52.6

All glands are metric with a 1.5mm thread pitch and are supplied complete with a matching locknut.

Ordering Code - Typical example

CGE - 16 - B

Gland Type (See Section 1) — CGE
Gland Size (See Section 2) — 16
Gland Material (B = Brass) — B

Instrument Cable to BS 5308 Pair Colour Details

BS5308 Part 1 Cables (Polyethylene Cores)

Pair No.	A-Wire	B-Wire
1	Black	Blue
2	Black	Green
3	Blue	Green
4	Black	Brown
5	Blue	Brown
6	Green	Brown
7	Black	White
8	Blue	White
9	Green	White
10	Brown	White
11	Black	Red
12	Blue	Red
13	Green	Red
14	Brown	Red
15	White	Red
16	Black	Orange
17	Blue	Orange
18	Green	Orange
19	Brown	Orange
20	White	Orange
21	Red	Orange
22	Black	Yellow
23	Blue	Yellow
24	Green	Yellow
25	Brown	Yellow
26	White	Yellow
27	Red	Yellow
28	Orange	Yellow
29	Black	Grey
30	Blue	Grey
31	Green	Grey
32	Brown	Grey
33	White	Grey
34	Red	Grey
35	Orange	Grey
36	Yellow	Grey
37	Black	Violet
38	Blue	Violet
39	Green	Violet
40	Brown	Violet
41	White	Violet
42	Red	Violet
43	Orange	Violet
44	Yellow	Violet
45	Grey	Violet
46	Black	Turquoise
47	Blue	Turquoise
48	Green	Turquoise
49	Brown	Turquoise
50	White	Turquoise

BS5308 Part 2 Cables (PVC Cores)

Pair No.	A-Wire	B-Wire
1	White	Blue
2	White	Orange
3	White	Green
4	White	Brown
5	White	Grey
6	Red	Blue
7	Red	Orange
8	Red	Green
9	Red	Brown
10	Red	Grey
11	Black	Blue
12	Black	Orange
13	Black	Green
14	Black	Brown
15	Black	Grey
16	Yellow	Blue
17	Yellow	Orange
18	Yellow	Green
19	Yellow	Brown
20	Yellow	Grey
21	WHITE-Blue	Blue
22	WHITE-Blue	Orange
23	WHITE-Blue	Green
24	WHITE-Blue	Brown
25	WHITE-Blue	Grey
26	RED-Blue	Blue
27	RED-Blue	Orange
28	RED-Blue	Green
29	RED-Blue	Brown
30	RED-Blue	Grey
31	BLUE-Black	Blue
32	BLUE-Black	Orange
33	BLUE-Black	Green
34	BLUE-Black	Brown
35	BLUE-Black	Grey
36	YELLOW-Blue	Blue
37	YELLOW-Blue	Orange
38	YELLOW-Blue	Green
39	YELLOW-Blue	Brown
40	YELLOW-Blue	Grey
41	WHITE-Orange	Blue
42	WHITE-Orange	Orange
43	WHITE-Orange	Green
44	WHITE-Orange	Brown
45	WHITE-Orange	Grey
46	ORANGE-Red	Blue
47	ORANGE-Red	Orange
48	ORANGE-Red	Green
49	ORANGE-Red	Brown
50	ORANGE-Red	Grey

Where a colour is shown in block letters, it is the colour with the greater area of exposure.
Two pair cables laid up in quads are coloured clockwise Black, Blue, Green and Brown.
For other details including capacitance values and L/R ratios, please contact the company.

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mounted further away, being sited where several sensor cables can be terminated, linearised, conditioned, amplified and transmitted, multiplexed or whatever, en masse.

So, which should you choose? On the one hand, with head-mounted devices, the low level sensor signal will have been conditioned, converted and amplified at source, as well as converted into the standard RFI-immune current signal for transmission over low cost twisted copper pair wires. Meanwhile, the remote (rail, panel or rack) style transmitter (as with direct temperature sensor wiring), involves using relatively expensive extension or compensating cable, or screened and guarded cables for RTD's, from the sensor to the rack or panel, followed by standard copper twisted pair thereafter, and there could be some signal degradation or interference on the way. Arguably, therefore, there is more chance of pulling off the full signal with head-mounted transmitters, and the instrumentation should see a truer representation of the real sensor signal. From the wiring point of view, it should also be the cheaper option - but this depends upon the distance and the application. Against this, there is the very valid point that even with the best of protection, sensitive electronics and industrial plants do not readily mix. Head-mounted devices, aside from having defined operating temperature limits, are subject to the variable operating environment. Notably, their cold junction compensation stability can cause problems, following shifts through the ambient temperature range, resulting in unpredictable errors.

Both approaches have their pros and cons - and both their place. Decisions have to be made by looking at the details of the specific application, and assessing each approach on its overall merits.

One thing is for certain. With the introduction of ever lower cost transmitters, the sensor to instrumentation distance at which it becomes more sensible to install transmitters - of either kind is shrinking. Beyond this, the introduction of smart transmitters (see Part 2, Section 11), with their inherently better accuracy, repeatability and stability, providing either conventional analogue signalling or direct digital communications, is also shifting the goal posts.

10.1 Conventional Units

At the lowest cost end, transmitters use analogue electronics, and are specific to one or two thermocouple types (like K and T, for example), or standard Class B 100 ohm RTD's, providing conditioning and amplification, plus linearising to the voltage signal (not the temperature) on thermocouples, although RTD's may be linearised direct to temperature. They are inexpensive, and ease of replacement (rather than repair), simplicity, robustness and small size are appealing factors.

Moving up the cost range slightly, you will find units offering wider coverage - to include most or even the full range of standard thermocouples and RTD's. Conditioning and amplification are again encompassed, the former (or more usually both) being dip switch selectable for the input device (thermocouple type, or RTD).

10.2 Digital Transmitters

Moving up the range again, with digital devices, functionality is considerably enhanced. Basically, using Application Specific Integrated Circuits and Surface Mounted Devices, a lot of power and stability can be compressed onto cards small enough to be incorporated into racking -based transmitter modules and head-mounted transmitters.

With these, linearising is comprehensive - almost without exception being to actual temperature (according to the thermocouple or RTD characteristic) as opposed to simple linearising to the voltage signal (see Part 1, Section 5). Also, linearisation routines are programmable (configurable, strictly speaking), or loadable via smart card technology, for multiple thermocouples and RTD's (standard and often non-standard as well), along with range, zero, etc, depending upon the device itself and the manufacturer. Sensor burn-out may also be indicated by, for example, upscale signalling.

Power supply range for all of these devices is generally from 12 to 30V, or possibly up to 55V on some models. Outputs are the standard 4-20mA, although serial digital outputs are available on some transmitters. Current limiting and reverse polarity protection may also be provided. Zero and span adjustments are usually provided (in various forms - continuously adjustable, magnetically coupled, programmable and so on), and isolating (typically to 500V DC) and non-isolating versions are available, as are intrinsically safe and flame-proof or explosion-proof options. RFI, EMI and EMC immunity will generally be to the European standards (IEC 60801.3).

Ambient transmitter operating temperatures are normally in the range -20°C to +80°C, although some will function over a wider scale, say -40°C to +100°C without damage - but be aware of cold junction compensation limitations. Clearly, the full sensor temperature range can be covered, and with the range of mounting and probe/sheath extension options available the transmitter's own limits need not be a problem in most applications. Temperature effects, however, are normally in the range ±0.05 to ±0.01% of span for zero and span per °C change in ambient for thermocouples and RTD's. Cold junction compensation for thermocouples is generally quoted at around the ±0.04°C mark.

Meanwhile, linearity is usually about ±0.5 to ±0.05% of calibrated span, and you can expect calibration accuracies also in the range ±0.5 to ±0.05% of calibrated span, including hysteresis and repeatability. Stability will be similar. These figures may be quoted in terms of mV. Bear in mind that in all cases the figures do not include sensor error - only that of the transmitter.

Protection is normally available in the form of any of the usual ranges of head assemblies, from simple to ultra-ruggedised, welded and hermetically sealed in a range of materials according to the environment anticipated (see Part 2, Section 9). Over-pressure and other protection features are also available, and where really tough operating conditions are a consideration, there are also ruggedised devices designed for ease of access, installation and maintenance. Modular assemblies with suitable protection from the rigours of plant life can make a big difference to site operations. Some head-mounting units also offer a local display as well as signal transmission to aid set-up and operation.

10.3 Moving up to Smart

Configurability of all the set-up parameters is one thing, but when digital communications is offered - for networking, diagnostics, advanced control or instrument installation, management and maintenance - you move up to the full definition of smart transmitters (see Part 2, Section 11).

Benefits include addressable measurement points, and therefore digital signal multiplexing - making plant wiring cheaper and easier. Beyond this there are the points regarding direct digital signal transmission, remote re-ranging, transmitter and loop diagnostics, and easier loop testing, maintenance and management, to name but a few.

However, although smart transmitters clearly have their benefits, there are commercial limitations to consider when assessing their viability for temperature monitoring. Whereas the operational benefits and accuracy gains have resulted in considerable control improvements, plus life cycle cost savings with parameters like pressure, this is much less the case with temperature.

Unlike smart pressure transmitters, there is a considerable cost penalty for smart temperature transmitters when compared with the conventional choices - even those with the digital intelligence mentioned above. And, with the common industrial practice of temperature sensing on a grand scale (temperature sensors are by far the most common), most users are finding the smart approach to temperature an expensive luxury. The investment required is simply too high for the achievable gains. There are, of course, exceptions to the rule. Examples include crucial temperature measurements on critical loops, or situations where all digital transmission, re-ranging and the benefits of intelligent sensing and diagnostics are key to plant operations.

11.0 Smart Transmitters

Temperature transmitters, whether head or panel mounted, can be installed in the field to provide a standard 4-20mA signal back to the control room as already described (see Part 2, Section 10). They incorporate galvanic or opto-isolation between input and output to handle ground loop problems, series mode filters, power line surge protection, lightning protection and so on, and have been used (where justified for long distance signal transmission) successfully for decades.

But, their inaccessibility for adjustments, diagnostics and checking, plus their limits on ranges and sensor types covered and limited functionality (on conventional, non-digital devices), can result in fairly high maintenance and spares holding costs. Also, when adjustments (for zero, span and damping) are made on conventional transmitters they are made by screwdrivers and switches, again with all the inherent limits in terms of precision, drift and repeatability.

Digital temperature transmitters, which are direct replacements for conventional devices, get around some of these limitations by introducing local programmability (see Part 2, Section 10.2). But smart transmitters take this a stage further with microprocessor power which handles all operations, from signal sampling and analogue to digital conversion, to diagnostics, data manipulation and communication. This last is the key difference. Not only do smart transmitters provide the digital intelligence to ensure accurate, reliable, programmable temperature signal measurement, linearisation and conversion - they also provide the facility for direct digital signal transmission back to the instrumentation, and for two way communication. Hence, remote accessibility and transmitter monitoring are available via the same medium. And, most importantly, everything is non-interacting and programmable - keyed in from wherever - not screwdriver adjusted on site or in the lab.

Looking at the front end of smart transmitters, the incoming sensor and cold junction reference signals (at the connection terminals) are digitised and measured, and the selected characterisation invoked (from a comprehensive library in memory) for the type of sensor concerned. The compensated signal is thus linearised (for temperature rather than just voltage) to a high degree of precision with digital electronics' drift-free stability and reliability. It is worth noting here that this is a generalised account of smart transmitter operations. Some manufacturers have essentially simply upgraded their analogue input with modern digital equivalents - so the gains in precision and stability need to be checked.

If analogue transmission is required, this signal is then scaled against the programmed span limits and converted to a standard 4-20mA signal proportional to temperature. Only the analogue input and output converters can contribute to time or ambient temperature drifts - and, typically, high grade, temperature stable resistor networks and references are chosen to ensure good performance. Figures like drift of sub -0.05% of span in six months are common. Further, with the option of digital signal transmission for temperature output data, precision can be further enhanced. If you need to be convinced of the precision argument, consider a Type J thermocouple with a conventional transmitter ranged for 100 to 200°C and subjected to an ambient change of 40°C. You would expect errors around ±2.4°C and a ±2°C cold junction error. For a smart transmitter, total error would be of the order of ±0.3°C. As stated, it is the additional features brought by digital technology and communications that make smart transmitters so attractive, at least in principle, if not in initial cost (see Part 2, Section 10.3). Having all transmitter and sensor data fully accessible, and the parameters and ranges reconfigurable, via a remote smart field communicator panel (itself intelligent and easy to use - normally menu-driven and requiring minimal skill) or controller, anywhere on the control transmission loop (or via the control room for that matter), makes site operations far easier, more flexible and less costly - in terms of time, money and effort.

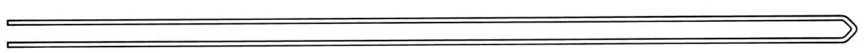
Add to this automatic re-zeroing, auto-calibration and continuous self and sensor diagnostics checks - all handled directly by the transmitter - and installation, set-up, commissioning, troubleshooting and regular inspection and maintenance work can all be handled without all the usual labour intensive hassles - just using a keypad. The current trend is for analogue (4-20mA) signalling to be replaced gradually by all digital transmission with the main benefits of multi-drop plant wiring (instead of individual point-to-point) and higher precision.

Continued on page 40

Thermocouple Sensors: General Styles

Several of the thermocouple types listed below are described in greater detail on other pages. Cross reference to these pages is made wherever appropriate.
An expert thermocouple design service is available to you from TC Ltd for your requirements for assemblies which are not described herein.
UKAS calibration is available for our range of thermocouple sensors (see page 41).

Type 1: Basic Thermocouple



Simple bare wire thermocouple with welded junction. Various wire gauge sizes available with the junction welded in an inert argon atmosphere. Alternative versions are available with the leads insulated in PVC, PFA or fibreglass. Type 1 assemblies are available in thermocouple conductor combinations K, T, J, N, E, R, S, B, G, C and D.

Type No.	Conductor Description
1WA	0.2mm dia Bare conductors
1WB	0.3mm dia Bare conductors
1WC	0.5mm dia Bare conductors (0.45mm for Types R, S & B)
1WD	0.8mm dia Bare conductors
1WE	1.63mm dia Bare conductors
1XA	0.5mm dia PVC insulated A10 conductors
1YA	0.2mm dia PFA insulated B10 conductors
1YB	0.3mm dia PFA insulated B11 conductors
1ZA	0.3mm dia Fibreglass insulated C10 conductors
1ZB	0.5mm dia Fibreglass insulated C20 conductors
1ZC	0.8mm dia Fibreglass insulated C30 conductors

Ordering Code - Typical example

1WA - K - 2 METRES
Type
Calibration
Length

Type 2: Ceramic Twin Bore Insulated Thermocouple Elements

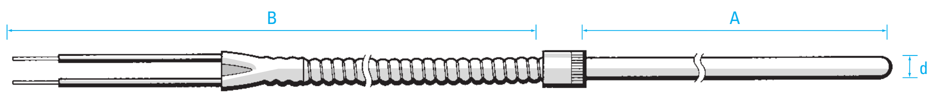
These are suitable for general use and as replacement elements for industrial and high temperature thermocouples similar to our Types 13 and 14 as described on pages 49 and 51. Type 2 assemblies are available for thermocouple conductor combination codes K, T, J, N and E with insulators in Aluminous porcelain and for codes R, S and B with insulators in Recrystallised Alumina. The length of insulators is 25mm, 50mm or 100mm depending on the application and availability. Insulators with 4 bores are available for duplex applications, please consult us for further details.

Type No.	Insulator Material	Conductor Material
2A1	Aluminous porcelain	0.5mm
2A2	Aluminous porcelain	0.8mm
2A3	Aluminous porcelain	1.29mm
2A4	Aluminous porcelain	1.63mm
2A5	Aluminous porcelain	3.2mm
2B1	Recrystallised alumina	0.2mm
2B2	Recrystallised alumina	0.3mm
2B3	Recrystallised alumina	0.45mm

Ordering Code - Typical example

2A3 - K - 1 METRE
Type
Calibration
Length

Type 3: General Purpose Thermocouple



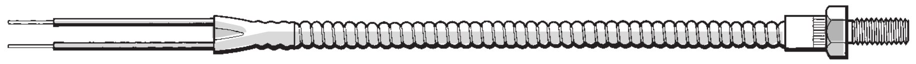
Suitable for general purpose applications up to 400°C subject to lead material used, these assemblies are available in thermocouple conductor combination codes K, T, J, N and E as simplex or duplex units.
Type 3 assemblies are supplied as standard with seamless welded closed end sheaths in 316 Stainless Steel.
Other sheath materials are available but we strongly recommend that for most applications our Type 12 Mineral Insulated Thermocouples may be more suitable. See pages 42 & 43. Junctions are grounded as standard but can be insulated if requested.

Type No.	Lead Arrangement
3AX	PVC leads
3AY	PFA leads
3AZ	Fibreglass leads
3AS	Stainless steel braid over fibreglass leads
3AF	Galvanised steel conduit over fibreglass leads
3AG	Stainless steel conduit over fibreglass leads
3R11	Thermocouple plug termination on sheath
3F11	Miniature thermocouple plug termination on sheath
3TH	Screw top weatherproof head (3P10) on sheath end

Ordering Code - Typical example

3AF - K - 200mm - 2MTRS - 6.0mm - INSULATED
Type
Calibration
Dimension A
Dimension B
Dimension d
Options

Type 4: Bolt Thermocouple



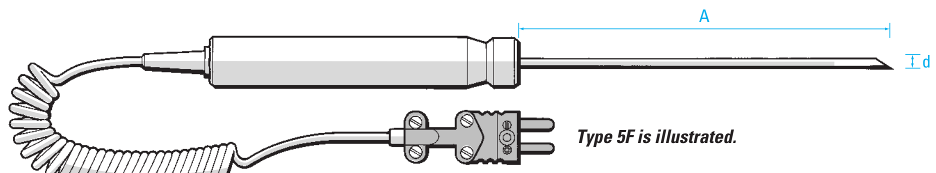
Suitable for extruder nozzle, motor and pipe temperatures etc., these assemblies are available as standard in thermocouple conductor combination codes K, T, J, N and E. They can be supplied mounted into any bolt as required by the application. We welcome receiving your free issued bolts for incorporation into a sensor. Generally suitable up to 235°C depending upon the bolt used. Thermocouples are normally grounded to the bolt but can be insulated in some applications.

Type No.	Lead Type
4A	Stainless steel braided fibreglass cable plus anti chafe spring
4B	Galvanised steel flexible conduit over fibreglass cable
4C	Stainless steel flexible conduit over fibreglass cable

Ordering Code - Typical example

4B - K - M8 x 10mm - BRASS - 1 MTR - INSULATED
Type
Calibration
Thread & Length
Bolt Material
Lead Length
Options

Type 5: Hand Held Thermocouple Probe



Type 5F is illustrated.

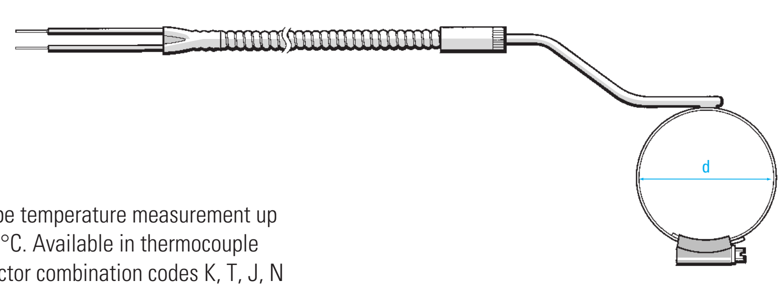
Available in thermocouple conductor combination codes K, T, J, N and E, these assemblies can depending on the type chosen operate up to 1100°C and are supplied with nylon handles rated to 120°C with 2 metre long extension leads (when extended).
All these probes are supplied as standard with a miniature thermocouple plug type F11.

Type No.	Description
5A	Surface temperature measurement assembly with spring loaded copper disc at tip and stainless steel sheath. Maximum operating temperature 600°C at tip. Dimensions: A = 80mm d = 4.7mm
5B	As type 5A but right angled Dimensions: Tip to right angle = 75mm. Right angle to handle = 200mm d = 4.7mm
5C	Heavy duty surface thermocouple assembly with spring loaded coiled element mounted on ceramic former onto stainless steel sheath. Maximum operating temperature 850°C at tip. Dimensions: A = 100mm d = 7.9mm
5D	As type 5C but right angled. Dimensions: Tip to right angle = 20mm. Right angle to handle = 190mm d = 4.7mm
5E	General purpose thermocouple, mineral insulated with a stainless steel sheath. Insulated hot junction. The tip and sheath may be operated up to 1100°C and the sheath may be bent. Can be made to any length and in a variety of diameters. Please contact us with your requirements.
5F	Rigid needle probe for semi solid materials (food, plastics, rubber etc.) Maximum operating temperature 350°C Dimensions: 5F1 A = 75mm d = 1.8mm 5F2 A = 100mm d = 3.2mm
5G	Penetration thermocouple with a pointed tip which can be pushed or hammered into materials such as frozen meat, bitumen etc. All stainless steel construction. Maximum operating temperature at tip 350°C. Dimensions: A = 150mm d = 6mm

Ordering Code - Typical example

5C - K
Type
Calibration

Type 7: Adjustable Ring Thermocouple



For pipe temperature measurement up to 600°C. Available in thermocouple conductor combination codes K, T, J, N and E. Type 7 Ring thermocouples are made with a mineral insulated thermocouple and can be supplied with insulated or grounded junctions. Normally supplied with stainless steel conduit over fibreglass extension leads, although other lead options are available. These sensors can be manufactured with the adjustable ring at a right angle to the sensor. Please contact us with your requirements.

Type No.	Description
7AG	Grounded Junction
7AI	Insulated Junction

Ordering Code - Typical example

7AG - K - 50mm - 2 METRES
Type
Calibration
Exact Diameter required
Lead Length

TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
Tel: +44 (0)1895 252222 - Fax: +44 (0)1895 273540
Email: info@tc.co.uk - Web: www.tc.co.uk

01895 252222

CODE **B**

International Thermocouple Reference Tables for
Platinum - 30% Rhodium / Platinum - 6% Rhodium
To IEC60584.1:1995 / BS EN 60584.1 Part 7 : 1996

This standard is based upon the International Temperature Scale of 1990 (ITS-90). Temperatures are expressed in degrees Celsius (t_{90}) and the emf outputs in microvolts (μV).

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
0	0	0	0	-1	-1	-1	-1	-1	-2	-2	**0**
10	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	**10**
20	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2	**20**
30	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1	**30**
40	0	0	0	0	0	1	1	1	2	2	**40**
50	2	3	3	3	4	4	4	5	5	6	**50**
60	6	7	7	8	8	9	9	10	10	11	**60**
70	11	12	12	13	14	14	15	15	16	17	**70**
80	17	18	19	20	20	21	22	22	23	24	**80**
90	25	26	26	27	28	29	30	31	31	32	**90**
100	33	34	35	36	37	38	39	40	41	42	**100**
110	43	44	45	46	47	48	49	50	51	52	**110**
120	53	55	56	57	58	59	60	62	63	64	**120**
130	65	66	68	69	70	72	73	74	75	77	**130**
140	78	79	81	82	84	85	86	88	89	91	**140**
150	92	94	95	96	98	99	101	102	104	106	**150**
160	107	109	110	112	113	115	117	118	120	122	**160**
170	123	125	127	128	130	132	134	135	137	139	**170**
180	141	142	144	146	148	150	151	153	155	157	**180**
190	159	161	163	165	166	168	170	172	174	176	**190**
200	178	180	182	184	186	188	190	192	195	197	**200**
210	199	201	203	205	207	209	212	214	216	218	**210**
220	220	222	225	227	229	231	234	236	238	241	**220**
230	243	245	248	250	252	255	257	259	262	264	**230**
240	267	269	271	274	276	279	281	284	286	289	**240**
250	291	294	296	299	301	304	307	309	312	314	**250**
260	317	320	322	325	328	330	333	336	338	341	**260**
270	344	347	349	352	355	358	360	363	366	369	**270**
280	372	375	377	380	383	386	389	392	395	398	**280**
290	401	404	407	410	413	416	419	422	425	428	**290**
300	431	434	437	440	443	446	449	452	455	458	**300**
310	462	465	468	471	474	478	481	484	487	490	**310**
320	494	497	500	503	507	510	513	517	520	523	**320**
330	527	530	533	537	540	544	547	550	554	557	**330**
340	561	564	568	571	575	578	582	585	589	592	**340**
350	596	599	603	607	610	614	617	621	625	628	**350**
360	632	636	639	643	647	650	654	658	662	665	**360**
370	669	673	677	680	684	688	692	696	700	703	**370**
380	707	711	715	719	723	727	731	735	738	742	**380**
390	746	750	754	758	762	766	770	774	778	782	**390**
400	787	791	795	799	803	807	811	815	819	824	**400**
410	828	832	836	840	844	849	853	857	861	866	**410**
420	870	874	878	883	887	891	896	900	904	909	**420**
430	913	917	922	926	930	935	939	944	948	953	**430**
440	957	961	966	970	975	979	984	988	993	997	**440**
450	1002	1007	1011	1016	1020	1025	1030	1034	1039	1043	**450**
460	1048	1053	1057	1062	1067	1071	1076	1081	1086	1090	**460**
470	1095	1100	1105	1109	1114	1119	1124	1129	1133	1138	**470**
480	1143	1148	1153	1158	1163	1167	1172	1177	1182	1187	**480**
490	1192	1197	1202	1207	1212	1217	1222	1227	1232	1237	**490**
500	1242	1247	1252	1257	1262	1267	1272	1277	1282	1288	**500**
510	1293	1298	1303	1308	1313	1318	1324	1329	1334	1339	**510**
520	1344	1350	1355	1360	1365	1371	1376	1381	1387	1392	**520**
530	1397	1402	1408	1413	1418	1424	1429	1435	1440	1445	**530**
540	1451	1456	1462	1467	1472	1478	1483	1489	1494	1500	**540**
550	1505	1511	1516	1522	1527	1533	1539	1544	1550	1555	**550**
560	1561	1566	1572	1578	1583	1589	1595	1600	1606	1612	**560**
570	1617	1623	1629	1634	1640	1646	1652	1657	1663	1669	**570**
580	1675	1680	1686	1692	1698	1704	1709	1715	1721	1727	**580**
590	1733	1739	1745	1750	1756	1762	1768	1774	1780	1786	**590**
600	1792	1798	1804	1810	1816	1822	1828	1834	1840	1846	**600**
610	1852	1858	1864	1870	1876	1882	1888	1894	1901	1907	**610**
620	1913	1919	1925	1931	1937	1944	1950	1956	1962	1968	**620**
630	1975	1981	1987	1993	1999	2006	2012	2018	2025	2031	**630**
640	2037	2043	2050	2056	2062	2069	2075	2082	2088	2094	**640**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
650	2101	2107	2113	2120	2126	2133	2139	2146	2152	2158	**650**
660	2165	2171	2178	2184	2191	2197	2204	2210	2217	2224	**660**
670	2230	2237	2243	2250	2256	2263	2270	2276	2283	2289	**670**
680	2296	2303	2309	2316	2323	2329	2336	2343	2350	2356	**680**
690	2363	2370	2376	2383	2390	2397	2403	2410	2417	2424	**690**
700	2431	2437	2444	2451	2458	2465	2472	2479	2485	2492	**700**
710	2499	2506	2513	2520	2527	2534	2541	2548	2555	2562	**710**
720	2569	2576	2583	2590	2597	2604	2611	2618	2625	2632	**720**
730	2639	2646	2653	2660	2667	2674	2681	2688	2696	2703	**730**
740	2710	2717	2724	2731	2738	2746	2753	2760	2767	2775	**740**
750	2782	2789	2796	2803	2811	2818	2825	2833	2840	2847	**750**
760	2854	2862	2869	2876	2884	2891	2898	2906	2913	2921	**760**
770	2928	2935	2943	2950	2958	2965	2973	2980	2987	2995	**770**
780	3002	3010	3017	3025	3032	3040	3047	3055	3062	3070	**780**
790	3078	3085	3093	3100	3108	3116	3123	3131	3138	3146	**790**
800	3154	3161	3169	3177	3184	3192	3200	3207	3215	3223	**800**
810	3230	3238	3246	3254	3261	3269	3277	3285	3292	3300	**810**
820	3308	3316	3324	3331	3339	3347	3355	3363	3371	3379	**820**
830	3386	3394	3402	3410	3418	3426	3434	3442	3450	3458	**830**
840	3466	3474	3482	3490	3498	3506	3514	3522	3530	3538	**840**
850	3546	3554	3562	3570	3578	3586	3594	3602	3610	3618	**850**
860	3626	3634	3643	3651	3659	3667	3675	3683	3692	3700	**860**
870	3708	3716	3724	3732	3741	3749	3757	3765	3774	3782	**870**
880	3790	3798	3807	3815	3823	3832	3840	3848	3857	3865	**880**
890	3873	3882	3890	3898	3907	3915	3923	3932	3940	3949	**890**
900	3957	3965	3974	3982	3991	3999	4008	4016	4024	4033	**900**
910	4041	4050	4058	4067	4075	4084	4093	4101	4110	4118	**910**
920	4127	4135	4144	4152	4161	4170	4178	4187	4195	4204	**920**
930	4213	4221	4230	4239	4247	4256	4265	4273	4282	4291	**930**
940	4299	4308	4317	4326	4334	4343	4352	4360	4369	4378	**940**
950	4387	4396	4404	4413	4422	4431	4440	4448	4457	4466	**950**
960	4475	4484	4493	4501	4510	4519	4528	4537	4546	4555	**960**
970	4564	4573	4582	4591	4599	4608	4617	4626	4635	4644	**970**
980	4653	4662	4671	4680	4689	4698	4707	4716	4725	4734	**980**
990	4743	4753	4762	4771	4780	4789	4798	4807	4816	4825	**990**
1000	4834	4843	4853	4862	4871	4880	4889	4898	4908	4917	**1000**
1010	4926	4935	4944	4954	4963	4972	4981	4990	5000	5009	**1010**
1020	5018	5027	5037	5046	5055	5065	5074	5083	5092	5102	**1020**
1030	5111	5120	5130	5139	5148	5158	5167	5176	5186	5195	**1030**
1040	5205	5214	5223	5233	5242	5252	5261	5270	5280	5289	**1040**
1050	5299	5308	5318	5327	5337	5346	5356	5365	5375	5384	**1050**
1060	5394	5403	5413	5422	5432	5441	5451	5460	5470	5480	**1060**
1070	5489	5499	5508	5518	5528	5537	5547	5556	5566	5576	**1070**
1080	5585	5595	5605	5614	5624	5634	5643	5653	5663	5672	**1080**
1090	5682	5692	5702	5711	5721	5731	5740	5750	5760	5770	**1090**
1100	5780	5789	5799	5809	5819	5828	5838	5848	5858	5868	**1100**
1110	5878	5887	5897	5907	5917	5927	5937	5947	5956	5966	**1110**
1120	5976	5986	5996	6006	6016	6026	6036	6046	6055	6065	**1120**
1130	6075	6085	6095	6105	6115	6125	6135	6145	6155	6165	**1130**
1140	6175	6185	6195	6205	6215	6225	6235	6245	6256	6266	**1140**
1150	6276	6286	6296	6306	6316	6326	6336	6346	6356	6367	**1150**
1160	6377	6387	6397	6407	6417	6427	6438	6448	6458	6468	**1160**
1170	6478	6488	6499	6509	6519	6529	6539	6550	6560	6570	**1170**
1180	6580	6591	6601	6611	6621	6632	6642	6652	6663	6673	**1180**
1190	6683	6693	6704	6714	6724	6735	6745	6755	6766	6776	**1190**
1200	6786	6797	6807	6818	6828	6838	6849	6859	6869	6880	**1200**
1210	6890	6901	6911	6922	6932	6942	6953	6963	6974	6984	**1210**
1220	6995	7005	7016	7026	7037	7047	7058	7068	7079	7089	**1220**
1230	7100	7110	7121	7131	7142	7152	7163	7173	7184	7194	**1230**
1240	7205	7216	7226	7237	7247	7258	7269	7279	7290	7300	**1240**
1250	7311	7322	7332	7343	7353	7364	7375	7385	7396	7407	**1250**
1260	7417	7428	7439	7449	7460	7471	7482	7492	7503	7514	**1260**
1270	7524	7535	7546	7557	7567	7578	7589	7600	7610	7621	**1270**
1280	7632	7643	7653	7664	7675	7686	7697	7707	7718	7729	**1280**
1290	7740	7751	7761	7772	7783	7794	7805	7816	7827	7837	**1290**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

emf/μV

°C(t_{90})	0	1	2	3	4	5	6	7	8	9	°C(t_{90})
1300	7848	7859	7870	7881	7892	7903	7914	7924	7935	7946	**1300**
1310	7957	7968	7979	7990	8001	8012	8023	8034	8045	8056	**1310**
1320	8066	8077	8088	8099	8110	8121	8132	8143	8154	8165	**1320**
1330	8176	8187	8198	8209	8220	8231	8242	8253	8264	8275	**1330**
1340	8286	8298	8309	8320	8331	8342	8353	8364	8375	8386	**1340**
1350	8397	8408	8419	8430	8441	8453	8464	8475	8486	8497	**1350**
1360	8508	8519	8530	8542	8553	8564	8575	8586	8597	8608	**1360**
1370	8620	8631	8642	8653	8664	8675	8687	8698	8709	8720	**1370**
1380	8731	8743	8754	8765	8776	8787	8799	8810	8821	8832	**1380**
1390	8844	8855	8866	8877	8889	8900	8911	8922	8934	8945	**1390**
1400	8956	8967	8979	8990	9001	9013	9024	9035	9047	9058	**1400**
1410	9069	9080	9092	9103	9114	9126	9137	9148	9160	9171	**1410**
1420	9182	9194	9205	9216	9228	9239	9251	9262	9273	9285	**1420**
1430	9296	9307	9319	9330	9342	9353	9364	9376	9387	9398	**1430**
1440	9410	9421	9433	9444	9456	9467	9478	9490	9501	9513	**1440**
1450	9524	9536	9547	9558	9570	9581	9593	9604	9616	9627	**1450**
1460	9639	9650	9662	9673	9684	9696	9707	9719	9730	9742	**1460**
1470	9753	9765	9776	9788	9799	9811	9822	9834	9845	9857	**1470**
1480	9868	9880	9891	9903	9914	9926	9937	9949	9961	9972	**1480**
1490	9984	9995	10007	10018	10030	10041	10053	10064	10076	10088	**1490**
1500	10099	10111	10122	10134	10145	10157	10168	10180	10192	10203	**1500**
1510	10215	10226	10238	10249	10261	10273	10284	10296	10307	10319	**1510**
1520	10331	10342	10354	10365	10377	10389	10400	10412	10423	10435	**1520**
1530	10447	10458	10470	10482	10493	10505	10516	10528	10540	10551	**1530**
1540	10563	10575	10586	10598	10609	10621	10633	10644	10656	10668	**1540**
1550	10679	10691	10703	10714	10726	10738	10749	10761	10773	10784	**1550**
1560	10796	10808	10819	10831	10843	10854	10866	10877	10889	10901	**1560**
1570	10913	10924	10936	10948	10959	10971	10983	10994	11006	11018	**1570**
1580	11029	11041	11053	11064	11076	11088	11099	11111	11123	11134	**1580**
1590	11146	11158	11169	11181	11193	11205	11216	11228	11240	11251	**1590**
1600	11263	11275	11286	11298	11310	11321	11333	11345	11357	11368	**1600**
1610	11380	11392	11403	11415	11427	11438	11450	11462	11474	11485	**1610**
1620	11497	11509	11520	11532	11544	11555	11567	11579	11591	11602	**1620**
1630	11614	11626	11637	11649	11661	11673	11684	11696	11708	11719	**1630**
1640	11731	11743	11754	11766	11778	11790	11801	11813	11825	11836	**1640**
1650	11848	11860	11871	11883	11895	11907	11918	11930	11942	11953	**1650**
1660	11965	11977	11988	12000	12012	12024	12035	12047	12059	12070	**1660**
1670	12082	12094	12105	12117	12129	12141	12152	12164	12176	12187	**1670**
1680	12199	12211	12222	12234	12246	12257	12269	12281	12292	12304	**1680**
1690	12316	12327	12339	12351	12363	12374	12386	12398	12409	12421	**1690**
1700	12433	12444	12456	12468	12479	12491	12503	12514	12526	12538	**1700**
1710	12549	12561	12572	12584	12596	12607	12619	12631	12642	12654	**1710**
1720	12666	12677	12689	12701	12712	12724	12736	12747	12759	12770	**1720**
1730	12782	12794	12805	12817	12829	12840	12852	12863	12875	12887	**1730**
1740	12898	12910	12921	12933	12945	12956	12968	12980	12991	13003	**1740**
1750	13014	13026	13037	13049	13061	13072	13084	13095	13107	13119	**1750**
1760	13130	13142	13153	13165	13176	13188	13200	13211	13223	13234	**1760**
1770	13246	13257	13269	13280	13292	13304	13315	13327	13338	13350	**1770**
1780	13361	13373	13384	13396	13407	13419	13430	13442	13453	13465	**1780**
1790	13476	13488	13499	13511	13522	13534	13545	13557	13568	13580	**1790**
1800	13591	13603	13614	13626	13637	13649	13660	13672	13683	13694	**1800**
1810	13706	13717	13729	13740	13752	13763	13775	13786	13797	13809	**1810**
1820	13820										**1820**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

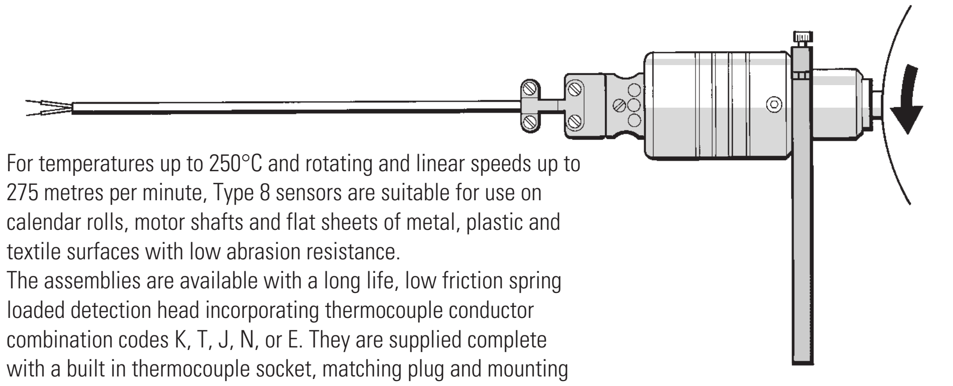
For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G, C** & **D** page 70	

*Note °C(t_{90}) denotes a temperature value expressed in degrees Celsius based upon the International Temperature Scale of 1990 (Acronym ITS-90)

Thermocouple Sensors: General Styles (continued)

Type 8: Moving Surface Thermocouple

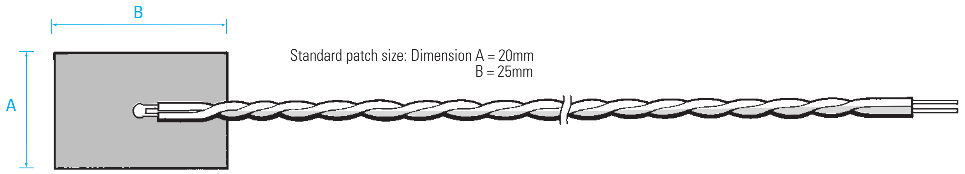


For temperatures up to 250°C and rotating and linear speeds up to 275 metres per minute, Type 8 sensors are suitable for use on calendar rolls, motor shafts and flat sheets of metal, plastic and textile surfaces with low abrasion resistance.
The assemblies are available with a long life, low friction spring loaded detection head incorporating thermocouple conductor combination codes K, T, J, N, or E. They are supplied complete with a built in thermocouple socket, matching plug and mounting bar. Thermocouple extension leads should be ordered separately. Spare replacement thermocouple cartridges are also available. If further information is required please contact the company for our detailed technical bulletin.

Ordering Code - Typical example

8 - K
Type
Calibration

Type 10: Self Adhesive Patch Thermocouple

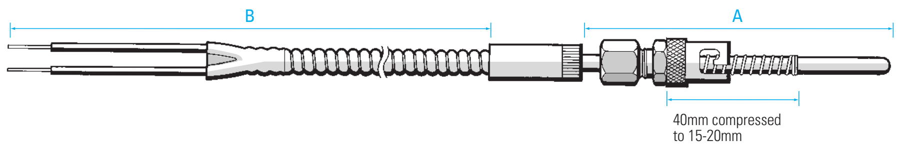


Suitable for attaching to flat or curved surfaces, Type 10 assemblies are rated for operation up to 250°C and are available in thermocouple conductor combination codes K, T, J, N or E as standard. They are made up from PFA insulated single solid 0.2mm diameter conductors. Type 10 units are supplied in packs of 10 normally with one metre leads or with longer leads in increments of one metre.

Ordering Code - Typical example

10 - K - 1 METRE
Type
Calibration
Lead Length

Type 11: Bayonet Thermocouple

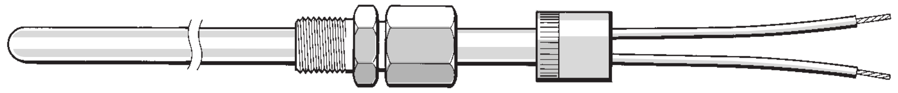


Suitable for plastics machinery and general purpose applications these assemblies are available in thermocouple conductor combination codes K, T, J, N and E with an industry standard one slot adjustable bayonet cap fitting. The fitting can be fine tuned for positioning on site and is suitable where several applications in your plant require individual positioning of the assembly. The sensor is mineral insulated with a diameter of 4.5mm and rated to 800°C and can therefore be bent after installation for exact positioning. A choice of leads is available including stainless steel braided cable (SSB), flexible galvanised conduit (GSC) or stainless steel conduit (SSC). As with any mineral insulated thermocouple the junction can be grounded (G) or insulated (I).

Ordering Code - Typical example

11 - K - 100mm - 1 MTR - SSC - G
Type
Calibration
Dimension A
Dimension B
Lead Material
Junction

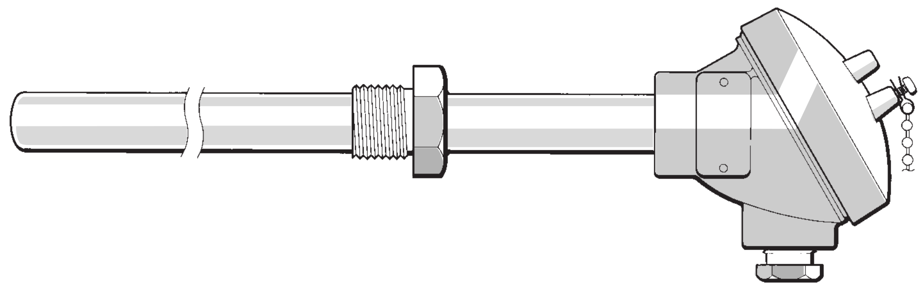
Type 12: Mineral Insulated Metal Sheathed Thermocouple



By far, the most popular type of thermocouple available. They have a wide temperature operating range up to 1250°C, can be bent, twisted or flattened without impairing performance and are available in a wide variety of sheath materials, diameters and end seal terminations. For full details see pages 42 and 43.

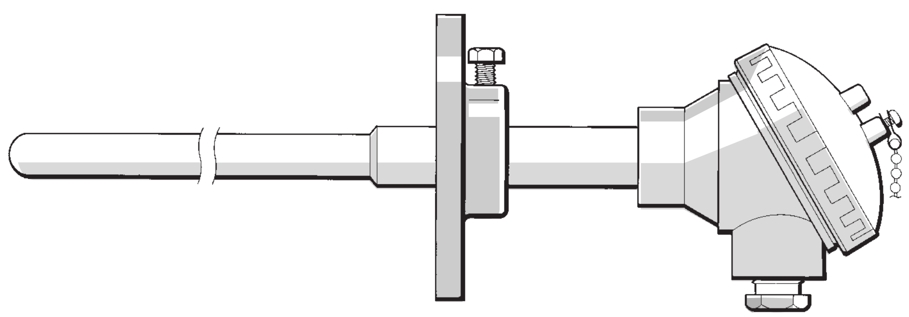
RECOMMENDED

Type 13: Heavy Duty Metal Sheathed Thermocouple



These assemblies are suited for use in arduous industrial environments such as blast or carburizing furnaces, kilns, large ovens and galvanising baths. For full details see page 49.

Type 14: High Temperature Ceramic Sheathed Thermocouple



These assemblies incorporate a ceramic sheath and are suited for temperature measurements up to 1600°C or more in kilns, furnaces or flues. For full details see page 51.

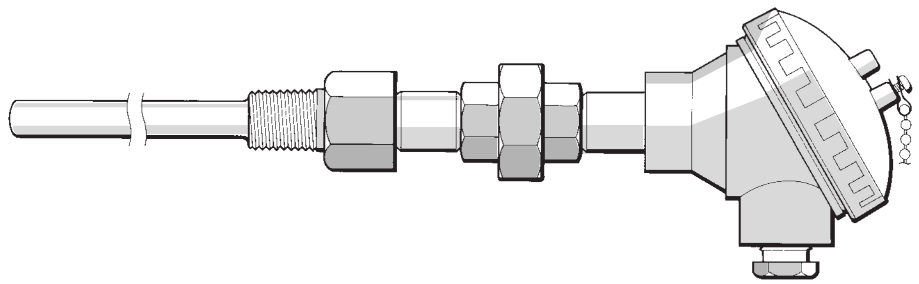
Type 19: Washer Thermocouple

These assemblies which are available in thermocouple conductor codes K, T, J, E and N are suitable for surface temperature monitoring of platens, pipes and vessels etc. up to a maximum operating temperature of 400°C. The crimp washers are made from plated brass and are available in the following sizes; 0BA/M6, 2BA/M5, 3BA/M4, 4BA/M3.5 and 6BA/M3.
The extension leads are made from stainless steel braided fibreglass cable and are then grounded to the washer.

Ordering Code - Typical example

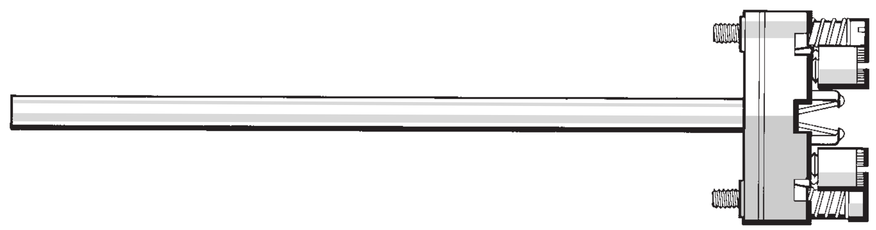
19 - K - 4BA - 1 METRE
Type
Calibration
Washer Size
Lead Length

Thermocouple, Thermowell, Extension Piece and Terminal Head Assemblies



These are available on a prompt delivery, custom assembled to your exact requirements and built up from our large stocks of sub assemblies as described in detail in this publication.

Terminal Head Mounting Thermocouple Inserts and Thermocouple Transmitter Inserts



These insert assemblies form part of many thermocouple and thermowell configurations. They are also available as a replacement sub assembly and consist of a type 12 mineral insulated metal sheathed thermocouple attached to a standard terminal block or current loop transmitter/terminal block both of which can be spring loaded. The assemblies fit our standard type 3P11, 3P12 and 3P17 terminal heads and many other terminal heads accepting standard DIN terminal blocks. These assemblies are available to suit thermocouple conductor calibration codes: K, T, J, N, E, R, S and B. See pages 42 and 43 for further details.

PART 3: FURTHER PRACTICAL POINTS

1.0 Advantages and Disadvantages - Choosing your Sensor Type

Choosing a suitable temperature sensor involves considerations of the required operating temperature range, the maximum temperature, heating rate, response rate, accuracy, stability, ruggedness, sensitivity and useful service life. Then, consider the atmospheric environment, the physical nature of the material to be monitored (liquid, solid or gas) and its location and the practicable contact methods. These last three can have every bit as much impact as the earlier points on selecting the best sensor for the job. On top of this, there is the question of cost - how much is the measurement worth? What are the cost benefits?

As a check list, the following questions are worth asking. First, are the accuracy requirements of the application specified clear and correct. Next, are they achievable - in terms of total system accuracy - by your system? Remember that absolute measurements are more costly and complex than temperature difference measurements - so what are you really trying to achieve? Finally, where thermocouples are concerned, have you selected types which are suitable for the temperature range and the environment? And, for thermocouples and RTD's, are they adequately insulated, sheathed and protected?

As a quick reference guide, Table 1.1 gives a ready reckoner of which device to use under which circumstances. However, it is important to remember that this is generalised, and some of the considerations can be modified by specific design or selection.

Characteristic Thermocouple	Consideration	Characteristic Resistance Thermometer
Less accurate	Accuracy	More accurate
Wider -200°C to +2000°C +	Temperature range	Narrower -200°C to +650°C
Less expensive	Cost	More expensive (x 2-3)
Tip sensitive	Sensitivity	Stem sensitive
Faster	Speed of response	Slower
Very small possible	Size	Larger
Required	Thermocouple reference	Not applicable
Suitable	Surface Temperature Measurement	Generally unsuitable
Suitable	Vibration effects	Less suitable
Not required	Power supply	Required
Not applicable	Self heating	Applicable
Less satisfactory	Long-term stability	Excellent
More suitable	Robustness	Less suitable
Thermocouple Material to reference junction	Connecting leads	Ordinary copper

The above table should be interpreted with caution. The information given shows average application experience, but some of the considerations can be modified by special design or selection.

Table 1.1: *General guide to the selection of thermocouples or RTD's*

Thermocouple Type	Diameter						
	3.3 mm	1.6mm	1.0 mm	0.8 mm	0.5 mm	0.3 mm	0.25 mm
	°C	°C	°C	°C	°C	°C	°C
N: bare	1100	1010	960	930	890	840	800
protected	1250	1180	1110	1040	1000	950	910
K: bare	1050	930	900	860	800	750	710
protected	1150	1080	1050	970	910	860	820
E: bare	890	800	750	700	660	620	580
protected	1000	910	860	810	770	730	690
J: bare	760	760	720	680	650	600	560
protected	760	760	760	760	760	710	670
T: bare	–	400	360	320	280	250	220
protected	–	450	410	370	330	300	270

Recommended maximum operating temperatures for bare and protected base metal thermocouple wires operating continuously in air without temperature cycling.

Table 1.2: *Maximum Recommended Continuous Operating Temperatures for Base Metal Thermocouples*

1.1 Thermocouples

Thermocouples are by far the most common temperature sensors in industrial use. Why? Because they are low cost, simple, versatile, rugged and small. They can also be very sensitive, give fast response, offer a convenient voltage signal output, have a very wide operating range and are tip sensitive. This makes them altogether ideal for multi-point temperature measurement and monitoring in process plants. They are, however, less accurate than resistance thermometers, and require referencing to gauge absolute temperatures. Further, extension cabling is considerably more expensive than straightforward copper wire (as used with RTD's). Also, although the voltage output is convenient, it is also very low level (down in the µV region) and non-linear with temperature, meaning that linearisation, amplification and transmission have to be considered carefully.

BS 1041: Part 4 (1992) provides a detailed insight into thermocouple thermometry and, in particular, guidance on the selection and use of these sensors. For details of which thermocouples to use where, refer to Part 1, Section 3 (Types and restrictions - temperature and environmental); beyond this Section 6 of BS 1041: Part 4 is relevant.

Considering longevity, with base metal thermocouples this is difficult to predict. It depends primarily on temperature, wire diameter and cycling - the main problem being oxidation. General rules are: for every 50°C above 500°C, life expectancy is halved; doubling the wire diameter increases sensor life two to three times; and cycling, particularly from ambient to 500°C, halves sensor life compared with the same device maintained at constant temperature. Beyond this, choosing insulation (including mineral insulated, metal sheathed types) and protective sheathing, as well as thermocouple type, to suit the environment (see Part 1, Section 3, and Part 2, Sections 2 and 9) is clearly essential to avoid problems with corrosion from the whole spectrum of atmospheres encountered.

Thermocouple Type	0.5 mm Diameter		0.25 mm Diameter	
	Continuous	Intermittent	Continuous	Intermittent
	°C	°C	°C	°C
S	1500	1650	1400	1550
R	1500	1650	1400	1550
B	1600	1800	1500	1700

Recommended maximum operating temperatures for noble metal thermocouple wires operating continuously in air without temperature cycling and intermittently in air.

Table 1.3: *Maximum Operating Temperatures for Standard Noble Metal Thermocouples*

As for noble metal thermocouples, the main limiters are grain growth or volatilisation (leading to failure), and contamination (causing calibration drift). To minimise the former, special (fibrous) thermoelement platinum should be used, or increased diameters which reduce stress levels - although 0.25 - 0.5mm is the normal compromise. When it comes to contamination, using close fitting, high purity recrystallised alumina insulators and sheaths of the same material is the recommendation. A point to note is that they should never be inserted directly into metallic tubes, and must be protected from a range of metallic and non-metallic vapours. Again, mineral insulated thermocouples (here, with platinum-rhodium sheaths) provide a good solution for many measurements. (See Table 1.3).

As for the refractory metal thermocouples, drift is, unsurprisingly, dependent on the operating conditions, environment (see Part 1, Section 3) and insulation material. Assuming adequately constructed hot junctions, insulation with beryllia or thoria and operation as per the Type recommendations, drifts of up to 2% of temperature can be reasonably expected after 1,500 hours at 2,000°C. To put more context on this, similar drifts would be likely after 100 hours at 2,500°C, 10,000 hours at 1,750°C and so on.

1.2 Resistance Thermometer Detectors

Why doesn't everyone use thermocouples? Well, there are some drawbacks. Top of the list are: the inevitable metallurgical inhomogeneities which put an inherent limit upon accuracy and long term stability; the non-linearities and hysteresis effects (see Part 1, Sections 2.3 and 2.4); the expense of extension and compensating cables; the need for reference junction or cold junction equivalents; and the very low signal levels encountered.

RTD assemblies are much more accurate and stable than thermocouples, and permit much greater resolution of measurement - providing the highest grade of precision available, albeit over a more limited temperature range (commonly -200°C to +350°C, extendable to +850°C, as opposed to 2,500°C and more with thermocouples). Their non-linearities are much simpler than those of thermocouples - and they're basically parabolic, so relatively trivial to compensate. They are also much simpler to use in circuit wiring and measuring instrument terms - offering much easier extended distance cabling (inexpensive copper wire is adequate), no need for reference junctions, and higher level signal outputs (for example, with potentiometric measuring systems, injecting 1mA on a standard 100 ohm sensor, output per 10°C change will be in the region of 5mV).

Sensing resistor	Normal minimum operating temperature	Normal maximum operating temperature	Special maximum operating temperature
	°C	°C	°C
Metallic sensing resistors			
Copper	-100	+100	+150
Nickel	-60	+180	+350
Platinum	-200	+600	+850
Semiconductor sensing resistors			
Mixed metal oxides	-100	+200	+600
Silicon	-160	+160	+200

NOTE 1. Satisfactory measurement at temperatures above the normal maximum is possible only when special constructions and carefully controlled environments for the sensing resistors are used.

NOTE 2. Platinum resistance thermometer sensing resistors of special construction can be used to measure temperatures down to -259°C (14 K). Below -200°C, sensors have to be individually calibrated.

NOTE 3. Copper resistance thermometer sensing resistors of special construction can be used to measure temperatures down to -200°C.

Table 1.4: *Operating Temperature Ranges for RTD Sensor Materials*

On the down side, however, RTD's are stem sensitive (as opposed to tip sensitive), larger, less rugged and slower to respond than thermocouples (although size, ruggedness and speed of response do depend upon sensor design - and modern thin film devices are whittling away at the differences here). They can also suffer self-heating effects, they require a power supply, and are two to three times more expensive than their thermocouple equivalents (again modern thin and thick film devices are making the cost issue less pronounced).

Temperature	Resistance ratio R_t/R_0		
	Platinum*	Nickel	Copper
°C			
-200	0.18	-	-
-100	0.60	-	0.57
-60	0.76	0.70	0.74
-50	0.80	0.74	0.79
0	1.00	1.00	1.00
50	1.19	1.29	1.21
100	1.38	1.62	1.43
150	1.57	1.99	1.65
180	1.68	2.23	-
200	1.76	-	-
250	1.94	-	-
300	2.12	-	-
350	2.30	-	-
400	2.47	-	-
500	2.81	-	-
600	3.14	-	-
700	3.45	-	-
800	3.76	-	-
850	3.90	-	-

*See BS EN 60751 for more detailed values.

NOTE. Some thermometer sensors use padding resistors to bring the resistance of the sensor within specified limits. Generally, they are used in series with the sensing resistor, but in some types of nickel thermometers both series and shunt padding resistors are used to enable the thermometer sensor to match an exponential resistance/temperature curve.

Table 1.5: *Resistance to Temperature Relationships for the Basic Metallic Resistors*

Continued on page 44

Calibration Services

- Our UKAS accredited laboratory is able to provide certification for most types of thermocouples, platinum resistance thermometers and temperature and process control instrumentation
- These services are provided for equipment of any origin as well as that of our own manufacture and supply
- On site calibration service (Non UKAS) in the UK and in mainland Europe via our group companies is a speciality
- A speedy, economical and reliable service is provided in all respects
- Our application engineers who have all been trained in our own laboratories are available if required to give assistance in recommending the type of calibration strategy that is suitable for your application

If required our service can include planning with you the level and frequency of calibration required, sending you a reminder that your equipment will soon require calibration and planning a spares programme so that you are never without a calibrated replacement.

With the drive towards higher product quality standards and to energy efficiency, end users are demanding more certainty and traceability from the products they purchase. They are having to demonstrate to their clients and to their accreditation bodies that the processes they are running are at the correct parameter values. Our calibration service is directed towards helping you achieve these aims.

UKAS
CALIBRATION
0564

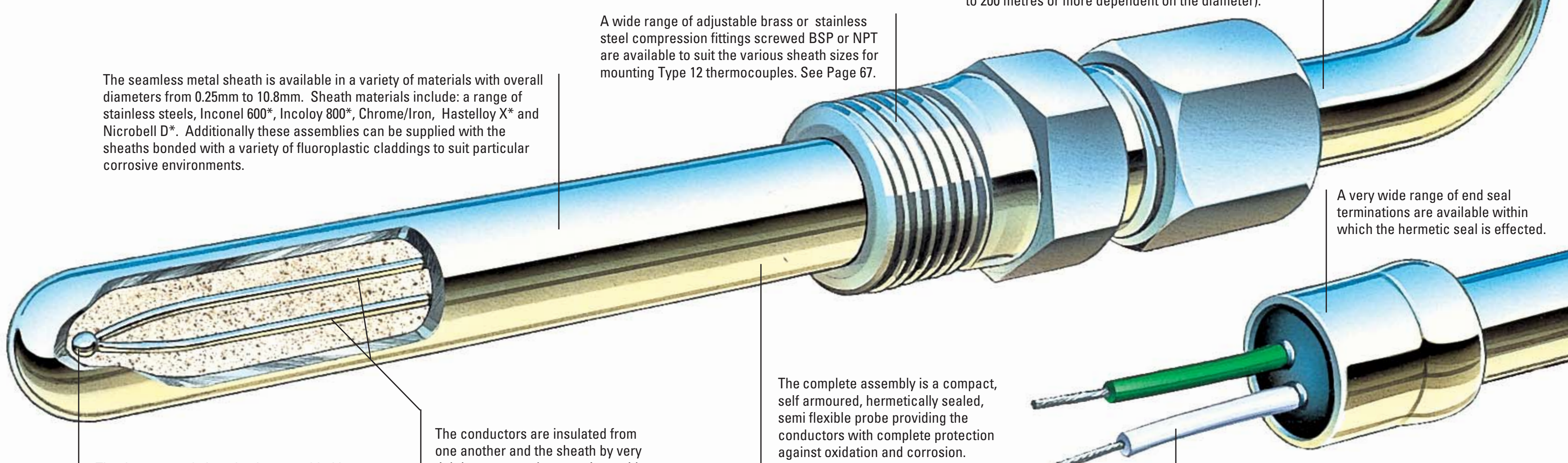
TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
Tel: +44 (0)1895 252222 - Fax: +44 (0)1895 273540
Email: info@tc.co.uk - Web: www.tc.co.uk

01895 252222

TYPE 12 Mineral Insulated Metal Sheathed Thermocouple Assemblies

- High integrity construction suited to arduous operating conditions at temperatures from -200°C to +1250°C
- High accuracy and stability maintained throughout operating life
- Fast response and high insulation resistance
- UKAS calibration is available for our range of Mineral Insulated Thermocouple assemblies (see page 41)
- The cable used to manufacture these assemblies conforms to BS EN 61515: 1996 / IEC 61515: 1995
- Available in K,T,J,N,E,R,S,B,C & D with sheath diameters from 0.25 mm to 10.8 mm and lengths from a few millimetres to 200 metres or more dependent on the sheath diameter selected
- Sheaths can generally be bent, twisted and flattened to suit particular installations without impairing performance
- Swaged end assemblies are available where fast response high strength sheaths or low displacement are a necessity

Schematic Diagram of a Typical Assembly



SECTION 2 Standard Metal Sheath Materials

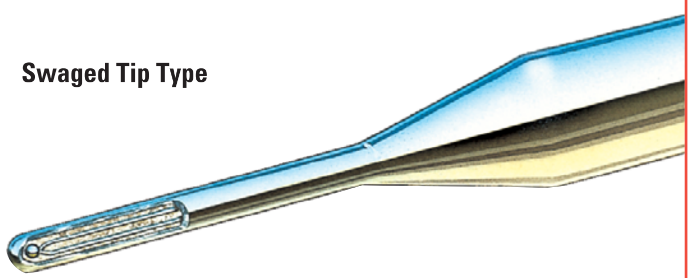
Type 12 thermocouple are available as standard as **Single, Duplex and Triplex assemblies** in a wide variety of sheath materials and diameters as follows:

Type	Sheath Specifications	Operational Properties	Maximum Operating Temperature of Sheath (Approximate) °C
118	**GRADE 321 STAINLESS STEEL** 18/8/1 Nickel/Chromium/Titanium Stabilised To BS 970 Part 4 : 1970	Very good corrosion resistance throughout the operating temperature range. Suited to a wide range of industrial applications. Enjoys high ductility.	800
125	**GRADE 310 STAINLESS STEEL** 25/20 Nickel/Chromium To BS 970 Part 4 : 1970	Good high temperature corrosion resistance and suitable for use in sulphur bearing atmospheres. Has high oxidation resistance which is maintained if subsequent manipulation is strictly limited.	1100
176	**INCONEL 600*** Nickel/Chromium/Iron alloy. BS 3074 : 1974 Grade NA14, ASTM B167, ASME SB 167, DIN NiCr15Fe, Werkstoff No : 2.4816	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys a good resistance to oxidation. Type R, S or B thermocouples with an Inconel 600* sheath are not recommended for use above 800°C. Do not use in sulphur bearing atmospheres above 550°C.	1100
180	**INCOLOY 800*** Iron/Nickel/Chromium alloy. BS 3074 : 1974 Grade NA15, ASTM B163, B407 ASME SB 1635, B407, DIN X10NiCrAITi3220, Werkstoff No : 1.4876	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys a good resistance to oxidation and carburisation. Resistant to sulphur bearing atmospheres.	1100
144	**AISI 446** Chrome/Iron ASTM TP446, AISI 446, DIN X18CrN28, Werkstoff No : 1.4749	Suitable for use in severely corrosive atmospheres to elevated temperatures. Particularly suited for use in high concentration sulphur bearing atmospheres at high temperature. ** Should be mounted vertically at temperatures above 700°C.*	1150
156	**HASTELLOY X*** Nickel/Chromium/Iron/Molybdenum 51/22/18/9	Has improved high temperature resistance to oxidation and attack by sulphur. Retains excellent tensile strength at high temperature. This sheath is applicable to reducing neutral and inert atmospheres. Develops a tightly adherent oxide film which does not spall at high temperatures.	1220
114	**NICROBELL D*** Nickel/Chromium/Silicon/Molybdenum 73/22/1.4/3	Recommended for use with high temperature Type 'K' and almost all Type 'N' applications. Very good high temperature strength. Optimum benefits seen when used with Type 'N' conductors. Excellent performance in oxidising, carburising, reducing and vacuum atmospheres. Do not use in sulphur containing atmospheres.	1250

Other sheath materials can be supplied to special order. *Trade names
These assemblies can be supplied with their sheaths bonded with a variety of fluoroplastic claddings to suit particular corrosive environments.
Normal minimum bending radius is 12 times the sheath diameter. This can be reduced to 4 times given the careful use of a mandrel and bending in one set.

Quality Control. All materials and assemblies are subject to rigorous quality checks during manufacture through to final test and inspection in accordance with our approval to ISO 9001 : 2000.
UKAS calibration is available as an additional service for our range of Mineral Insulated Thermocouple assemblies (see page 41).

Swaged Tip Type



Swaged end reduced tip temperature sensors provide a unique fast response, high strength, low displacement, homogenous solution to many problematical temperature measurement applications. The technique combines the two usually mutually exclusive advantages of having a very rugged large diameter metal sheath over most of its length with a low thermal mass, fast response, reduced diameter swaged tip, and with the transition from one to the other maintaining homogeneity and integrity. See page 45 for further details.

SECTION 1 Standard Thermocouple Alloy Conductor Combinations

Code	Conductor Cobination	Recommended Operating Temperature Range for Conductor Combinations* Continuous °C	Short Term °C
K	Nickel Chromium vs Nickel Aluminium	0 to +1100	-180 to +1350
T	Copper vs Constantan	-185 to + 300	-250 to + 400
J	Iron vs Constantan	+20 to + 700	-180 to + 750
N	Nickel-Chromium-Silicon vs Nickel-Silicon-Magnesium	0 to +1100	-270 to +1300
E	Nickel Chromium vs Constantan	0 to + 800	-40 to + 900
R	Platinum - 13% Rhodium vs Platinum	0 to +1600	-50 to +1700
S	Platinum - 10% Rhodium vs Platinum	0 to +1550	-50 to +1750
B	Platinum - 30% Rhodium vs Platinum - 6% Rhodium	+100 to +1600	+100 to +1820
C†	Tungsten - 5% Rhenium vs Tungsten - 26% Rhenium	+50 to +1820	+20 to +2300
D†	Tungsten - 3% Rhenium vs Tungsten - 25% Rhenium	0 to +2100	0 to +2600

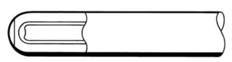
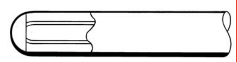
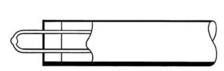
† Type C was formerly known as Type W5. Type D was formerly known as Type W3.
*These figures should be read in conjunction with maximum operating temperature figures for metal sheath materials.
Unless otherwise requested thermocouple units are supplied with nominal EMF/Temperature characteristics meeting the current international thermocouple reference tables.
Tolerances on thermocouple units supplied are to IEC 60584.2:1993 Class 2 (BS EN 60584.2:1993 Class 2).
Assemblies to class 1 of the above standards are available on request. See page 7 for further details.

SECTION 3 Standard Sheath Diameters

mm	Inches
0.25	0.010
0.5	0.020
1.0	0.039
1.5	0.059
2.0	0.079
3.0	0.118
4.5	0.177
5.5*	0.216
6.0	0.236
8.0	0.315
10.8*	0.425

*5.5mm and 10.8mm diameter are thick wall heavy duty constructions.
For types R, S, B, C and D a more limited range of sheath diameters is available.

SECTION 4 Types of Measuring Junction Configuration

Diagram	Description
TYPE 2I 	INSULATED Hot junction insulated from sheath. Gives floating output with typical insulation resistance in excess of 100 megohms (or 2ID if Duplex element is required and 2IT if triplex element is required.)
TYPE 2G 	GROUNDED Hot junction welded to sheath tip giving earthed output and faster response to temperature changes (or 2GD if Duplex element is required and 2GT if triplex element is required.)
TYPE 2X 	EXPOSED Fastest response mainly for the measurement of air temperature in ducts. Restricted to a maximum operating temperature of 300°C (or 2XD if Duplex element is required and 2XT if triplex element is required.)

To suit particular attachment requirements thermocouples with measuring junction configurations 2I or 2G can be supplied with an extended tip or welding pad.
(Contact the company for details of standard welding pad and extension tip configurations).
Other special measuring junction configuration requirements can be met upon request.

SECTION 5 Typical Response Times

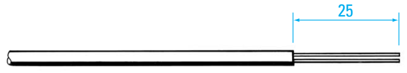
mm	Response Times(S)
0.25	0.015
0.5	0.03
1.0	0.15
1.5	0.3
2.0	0.4
3.0	0.8
4.5	1.4
5.5	4.0
6.0	3.0
8.0	5.5
10.8	9.0

Response times for these assemblies are governed by and vary with the environmental conditions of particular applications. The following information refers to typical response times for assemblies with insulated Type 2I junctions being plunged into boiling water from air at 20°C. The figures refer to the times taken for the thermocouple junctions to achieve 63.2% of this instantaneous step change. For assemblies with grounded Type 2G junctions the response times are approximately 50% of those listed.

SECTION 6 Types of End Seal Configuration

NB: When relevant, longer tails can be supplied on request.

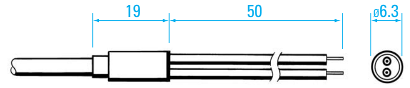
3P1 SERIES



3P1
Supplied as standard with bare conductors 25mm long.
Plain internal epoxy resin seal.
Maximum end seal temperature rated to **135**°C.

3P1B
As 3P1 but sealed with molten glass.
Maximum end seal temperature rated to **300**°C

3P2 SERIES

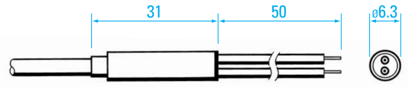


3P2
Crimp on stainless steel pot seal with PTFE sleeved solid tails 50mm long.
Potted with resin.
Maximum end seal temperature rated to **135**°C.

3P2A
As 3P2 but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.

3P2B
As 3P2 but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
3P2 series are not suitable for sheath diameters above 3mm

3P2L SERIES

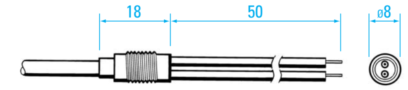


3P2L
As 3P2 but with an overall length of 31mm.
Maximum end seal temperature rated to **135**°C.

3P2LA
As 3P2L but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.

3P2LB
As 3P2L but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*3P2L pot seals are recommended for when additional flying leads are incorporated into the pot.
*3P2L series are not suitable for sheath diameters above 3mm.

3P3 SERIES

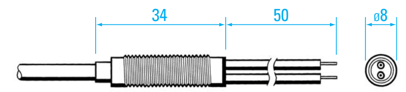


3P3
Crimp on stainless steel pot seal. Screwed 8mm x 1mm ISO with PTFE sleeved solid tails 50mm long. Potted with resin.
Maximum end seal temperature rated to **135**°C.

3P3A
As 3P3 but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.

3P3B
As 3P3 but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*Lock nuts are available in stainless steel to suit the 3P3 series and should be ordered separately as LN08S.
*3P3 series are not suitable for sheath diameters above 3mm

3P3L SERIES

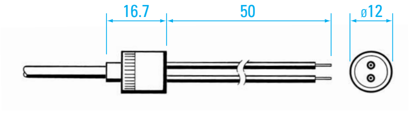


3P3L
As 3P3 but with an overall length of 34mm.
Maximum end seal temperature rated to **135**°C.

3P3LA
As 3P3L but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.

3P3LB
As 3P3L but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*3P3L pot seals are recommended for when additional flying leads are incorporated into the pot or when a longer threaded section is required.
*Lock nuts are available in stainless steel to suit the 3P3L series and should be ordered separately as LN08S.

3P4C SERIES

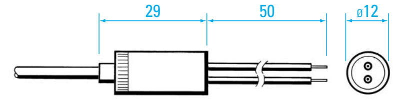


3P4C
Crimp on stainless steel pot seal with PTFE sleeved solid tails 50mm long.
Potted with resin.
Maximum end seal temperature rated to **135**°C.

3P4CA
As 3P4C but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.

3P4CB
As 3P4C but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*3P4C series are not suitable for sheath diameters less than 3mm or more than 8mm.

3P4CL SERIES

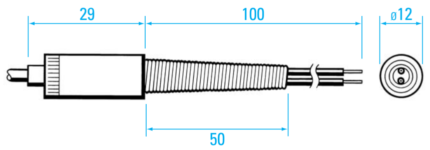


3P4CL
As 3P4C but with the 16.7mm dimension extended to 29mm.
Maximum end seal temperature rated to **135**°C.

3P4CLA
As 3P4CL but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.

3P4CLB
As 3P4CL but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*3P4CL pot seals are recommended for when additional flying leads are incorporated into the pot.
*3P4CL series are not suitable for sheath diameters less than 3mm or more than 8mm.

3P4CTRL SERIES

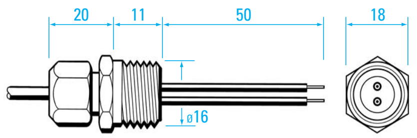


3P4CTRL
Crimp on stainless steel pot seal complete with an anti chafe support spring tension fitting and 100mm stranded PTFE insulated tails.
Potted with epoxy resin.
Maximum end seal temperature rated to **135**°C.

3P4CTRLA
As 3P4CTRL but potted with high temperature epoxy resin.
Maximum end seal temperature rated to **235**°C.

3P4CTRLB
As 3P4CTRL but with fibreglass sleeved stranded tails 100mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*3P4CTRL series are most suited when additional flying leads are incorporated and it is unlikely that any benefit would be derived from specifying this type with the standard 100mm tails.
*3P4CTRL series are not suitable for sheath diameters less than 3mm or more than 8mm.

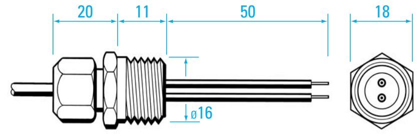
3P5 SERIES



3P5
Brass compression gland pot seal with 16mm x 1.5mm ISO screw thread with 50mm PTFE solid tails. Potted with epoxy resin.
Maximum end seal temperature rated to **135**°C.

3P5A
As 3P5 but potted with high temperature epoxy resin.
Maximum end seal temperature rated to **235**°C.
*3P5 compression glands are also available for loose fitting on the sheath and should be ordered separately as TEG references. See page 67 of this wallchart.
*Other threads including 20mm x 1.5mm ISO are available on request.
*Brass locknuts to suit the 3P5 series are available and should be ordered separately as LN16B.
*3P5 series are not suitable for sheath diameters less than 1.0mm or more than 8mm.

3P5S SERIES

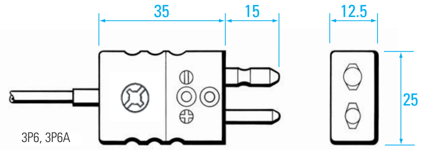


3P5S
Stainless steel compression gland pot seal with 16mm x 1.5mm ISO screw thread with 50mm PTFE solid tails. Potted with epoxy resin.
Maximum end seal temperature rated to **135**°C

3P5SA
As 3P5S but potted with high temperature epoxy resin.
Maximum end seal temperature rated to **235**°C.

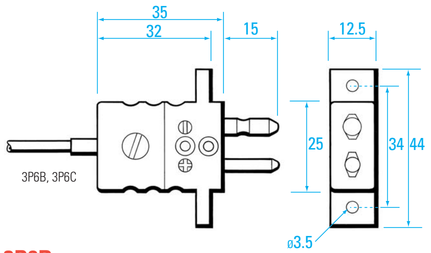
3P5SB
As 3P5S but with fibreglass sleeved solid tails 50mm long.
Potted with molten glass and high temperature resin.
Maximum end seal temperature rated to **300**°C.
*3P5S compression glands are also available for loose fitting on the sheath and should be ordered separately as a TEG reference. See page 67 of this wallchart.
*Other threads including 20mm x 1.5mm ISO are available on request.
*Stainless steel locknuts to suit the 3P5S series are available and should be ordered separately as LN16S.
*3P5 series are not suitable for sheath diameters less than 1.0mm or more than 8mm.

3P6 SERIES



3P6
Standard 2 pin round plastic bodied plug with pins in the appropriate thermocouple alloys.
Maximum end seal temperature rated to **135**°C.

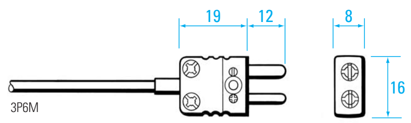
3P6A
As 3P6 but with a high temperature plug.
Maximum end seal temperature rated to **300**°C.



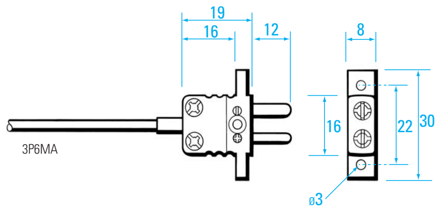
3P6B
As 3P6 but with drilled moulded in mounting lugs for panel mounting.
These are stackable with a rectangular section.
Maximum end seal temperature rated to **135**°C.

3P6C
As 3P6B but with a panel mounting high temperature body.
Maximum end seal temperature rated to **300**°C.
*Mating sockets are available and should be ordered separately.
*Other types of standard connector are available for mounting on thermocouple assemblies (See pages 64/65 for details).

3P6M SERIES

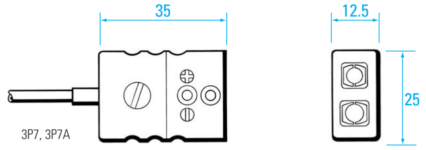


3P6M
Miniature flat 2 pin plastic bodied plug with pins in the appropriate thermocouple alloys.
Maximum end seal temperature rated to **135**°C.



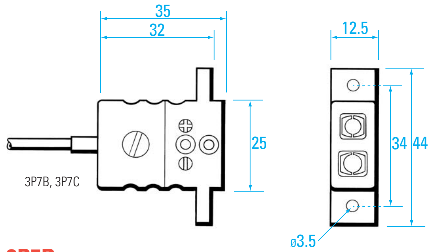
3P6MA
As type 3P6M but with drilled moulded in mounting lugs for panel mounting.
These are stackable with a rectangular section.
Maximum end seal temperature rated to **135**°C.
*3P6M series are not suitable for sheath diameters above 3mm.
*Mating sockets are available and should be ordered separately.
*Other types of miniature connector are available for mounting on thermocouple assemblies (See pages 64/65 for details).

3P7 SERIES



3P7
Standard 2 pin round plastic bodied socket with pins in the appropriate thermocouple alloys.
Maximum end seal temperature rated to**135**°C.

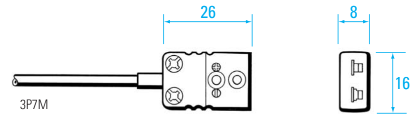
3P7A
As 3P7 but with a high temperature socket.
Maximum end seal temperature rated to **300**°C.



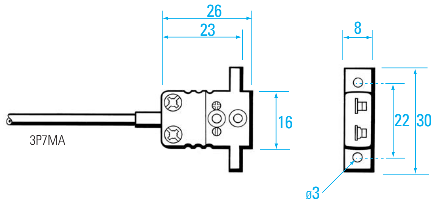
3P7B
As 3P7 but with drilled moulded in mounting lugs for panel mounting.
These are stackable with a rectangular section.
Maximum end seal temperature rated to **135**°C.

3P7C
As 3P7B but with a panel mounting high temperature body.
Maximum end seal temperature rated to **300**°C.
*Mating plugs are available and should be ordered separately.
*Other types of standard connector are available for mounting on thermocouple assemblies (See pages 64/65 for details).

3P7M SERIES



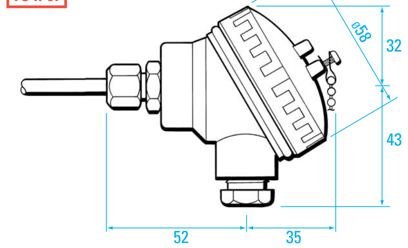
3P7M
Miniature flat 2 pin plastic bodied socket with pins in the appropriate thermocouple alloys.
Maximum end seal temperature rated to **135**°C.



3P7MA
As type 3P7M but with drilled moulded in mounting lugs for panel mounting. These are stackable with a rectangular section.
Maximum end seal temperature rated to **135**°C.
*3P7M series are not suitable for sheath diameters above 3mm.
*Mating plugs are available and should be ordered separately.
*Other types of miniature connector are available for mounting on these thermocouple assemblies (See pages 64/65 for details).

3P10 Weatherproof die cast alloy head

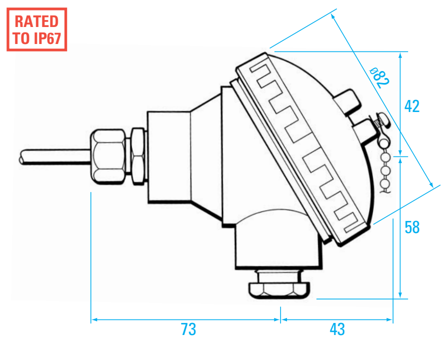
RATED TO IP67



Weatherproof die cast alloy, epoxy coated, screw top terminal head with the tube entry and cable entry at a right angle to each other, with a ceramic terminal block. Suitable for simplex and duplex assemblies. Supplied with a 16mm x 1.5mm ISO metal pinch gland on the cable entry for cables from 3mm to 8mm diameter.
*Not normally suitable for sheath diameters less than 3mm unless suitably supported.

3P11 Weatherproof heavy duty die cast alloy head

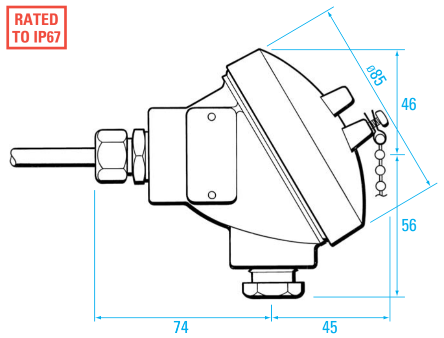
RATED TO IP67



Generally as 3P10 but heavy duty version. Suitable for simplex, duplex and triplex assemblies. Supplied with a 20mm x 1.5mm ISO metal pinch gland on the cable entry for cables from 6mm to 14mm diameter.
*Not normally suitable for sheath diameters less than 6mm unless suitably supported.

3P12 Weatherproof heavy duty cast iron head

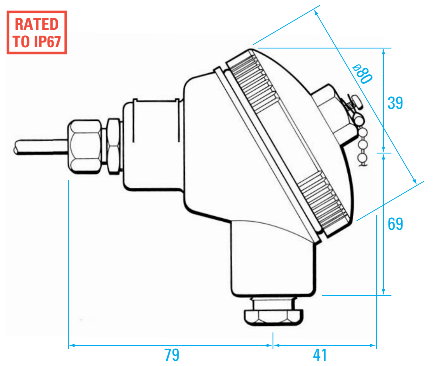
RATED TO IP67



Weatherproof cast iron screw top terminal head with the tube entry and cable entry at a right angle to each other. Suitable for simplex, duplex and triplex assemblies. Supplied complete with 20mm x 1.5mm ISO metal pinch gland on cable entry for cables from 6mm to 14mm diameter.
*Not normally suitable for sheath diameters less than 6mm unless suitably supported.

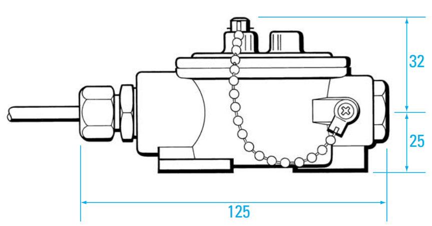
3P17 Weatherproof Bakelite head

RATED TO IP67



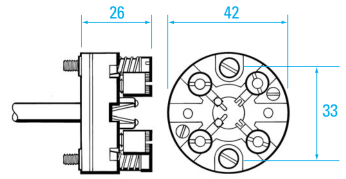
Weatherproof Bakelite plastic screw top terminal head with tube entry and cable entry at a right angle to each other with a Bakelite terminal block. Suitable for simplex or duplex or triplex assemblies. Supplied with a 20mm x 1.5mm ISO plastic pinch gland on the cable entry for cables from 6mm to 14mm diameter.
*A smaller version of this connection head is also available and is referred to as 3P16.
*Not normally suitable for sheath diameters less than 3mm unless suitably supported.

3P18 Die cast alloy straight through head



Die cast alloy straight through terminal head with a bakelite terminal block. Suitable for simplex or duplex assemblies. Supplied with a 20mm x 1.5mm pitch ISO pinch gland on the cable entry for cables from 6mm to 14mm diameter.
*If supported at fixing holes, suitable for diameters of 1mm and above.

3P20



Spring loaded insert assemblies. The end seal is incorporated into a terminal block suitable for mounting into a 3P11, 3P12, 3P17 or any other standard terminal head. Suitable for use with 3mm, 4.5mm, 6mm and 8mm sheaths only. The ceramic terminal block has 2 x 33mm spaced mounting holes. Suitable for simplex, duplex and triplex assemblies. (Previously called 3P14C).

SECTION 7 Extension Leads

All assemblies with pot seals are supplied with short solid or stranded tails as shown. However where leads are several metres or more long, it may be more suitable to have an overall sheathed cable. We recommend the following cables, all of which are 7/0.2mm diameter, laid flat and overall sheathed constructions. Other cables may also be suitable. Please refer to the cable section of this wallchart between pages 13 and 21 or contact us for advice.
A30 - Heat Resistant PVC
B50 - PFA
C40 - Fibreglass
C60 - Fibreglass with Stainless Steel Overbraid

SECTION 8 Compression Fittings

A full range of compression fittings is available to suit our Type 12 Mineral Insulated Thermocouple Assemblies. See page 67 for further details.

SECTION 9 Reduced Tips

A range of swaged reduced tips is available. Please see page 45 overleaf for further details.

SECTION 10 Head Mounted Transmitters

A range of transmitters is available including standard, isolated, fully linearised, Ex and RFI versions. See page 69 for further details.

Ordering code - Typical Example

12 - K - 450 - 118 - 3.0 - 2I - 3P4CL - 2Mtrs A30KX - ACF05S - -

- Type No.
- Conductor Type (see section 1)
- Sheath length in mm*
- Sheath material (see section 2)
- Sheath diameter (see section 3)
- Type of measuring junction (see section 4)
- End Seal Termination (see section 6)
- Soft insulated extension leads (see section 7)
- Adjustable compression fitting if required (see section 8)
- Reduced Tip if required (see section 9)
- Head mounted transmitter if required (see section 10)

*Please note that the sheath length is measured from the tip of the assembly to the nearest point on the end seal termination.

For RTD's, BS 1041: Part 3 (1989) gives a very detailed picture of operation, along with selection criteria and some guidance for their use. For the detail of RTD assembly designs and their pros and cons see Part 1, Section 4 as well as Part 2, Sections 6 and 7. Additionally, Section 7 of BS 1041: Part 3 is worth taking on board. Basically, where the environment is going to include any of the following - high vibration, thermal shock, or nuclear radiation - extra care is needed. Designs are available, as detailed in Part 2, Section 6, to deal with vibration and thermal shock, but neutron bombardment is a particular problem. The main hazards are: a tendency for the RTD to become radioactive; changes in resistance due to transmutation leading to measurement errors; insulation material degradation, again leading to substantial errors; and changes in metallic and ceramic materials leading potentially to sensor failure. Considering more general applications, where point measurements are to be made, RTD's as per IEC 60751 with the sizes specified in BS 2765 are almost always fine. Alternatively, copper, nickel, or nickel alloy devices can be used over restricted temperature ranges where economy dictates (see Table 1.4 for operating ranges, and Table 1.5 for resistance to temperature ratios). There are also the mixed metal oxide and silicon semiconductor material devices. Beyond these, there are special application materials, like tungsten and molybdenum sensors for high temperature use, and rhodium-iron and germanium for very low temperatures. These are infrequently used; for most applications, one material - platinum - is ideal.

2.0 Application Methods and Equipment - Thermocouples

There are several ways of applying thermocouples. The following outlines some of the more common methods in use. In general, however, it is important to bear in mind that thermocouple emfs range from about 10 μV/°C to about 80 μV/°C (see Figure 2.1). Hence the range of emfs is from just hundreds of μV up to say 75mV for a higher output device near the top of its temperature range.

Likewise, the resolution required varies from fractions of microvolts, with platinum thermocouples in particular, to 200 μV for galvanometers and other indicators in use with Type K in typical industrial furnace applications.

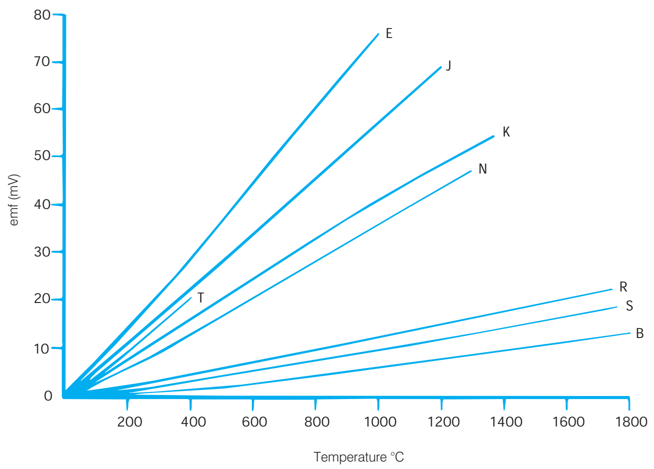


Figure 2.1 *Emf versus Temperature Relationship for Thermocouples*

2.1 Direct Methods - Thermocouples

Looking briefly at older style laboratory methodologies (if for no other reason than because they throw valuable light on more modern alternatives), since thermocouples generate current, they can drive galvanometers and any moving coil meter directly (see Figure 2.2) to provide a cheap, robust and simple temperature indicator.

With this arrangement, the meter simply traverses the scale, often horizontal and hopefully graduated directly in temperature units, and thus gives a direct temperature output. Non-linear emf/temperature characteristics can be handled simply by a non-linear scale. There are, of course, limitations. As the energy available from thermocouples is generally relatively small, these systems are usually confined to indicating a fairly hefty span of temperature - often calibrated in 5 or 10°C divisions, so they're not suited to accurate work.

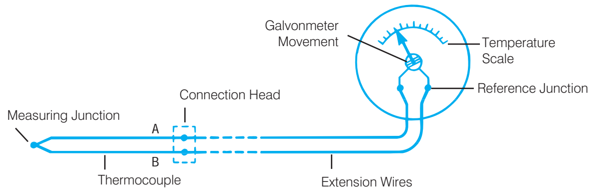


Figure 2.2: *Direct Thermocouple Reading from a Galvanometer*

Further, reference junctions are formed where the thermocouple or extension or compensating cables join the galvanometer circuit itself. As they are close to the ambient temperature, corrections have to be made to simulate a 0°C reference. There are various methods for handling this, including electrical compensation (as described in Part 2, Section 5), movement compensation (using bimetallic devices acting on the hair springs) and scale position changing.

Although there are still direct systems like these in use, both in laboratories and on industrial furnaces, with the advent of reliable, low cost solid state amplifiers they have largely been superseded by electronic methods, often harnessing digital indicators instead of their analogue scale forbears.

An important additional consideration with these systems is that the current flowing in the circuit is dependent on the circuit loop resistance (following Ohms Law - current equals voltage divided by resistance) as well as the temperatures of the thermocouple junctions. Thus, if the sensor is changed or the circuit modified, the value of the loop resistance has to be maintained.

This leads us to the following methods, all of which have the advantage of relying on determining the thermocouple output voltage under zero, or virtually zero current conditions. Here, the above caveat does not apply, since loop resistance is no longer relevant. Quite simply, this allows full freedom in providing or changing thermocouple circuits and switching systems. Additionally, since all the standard thermocouple tables are expressed in terms of voltage values, no further conversions for current are required.

2.2 Potentiometer Methods - Thermocouples

Potentiometers provide a classical method for determining voltages of any kind, and are thus useful candidates for thermocouple voltage measurement. In operation, the voltage from the thermocouple is balanced precisely by adjusting a variable resistance, R, until an indicator, I, shows zero current (see Figure 2.3). The variable resistance, or decades of resistance switches, can be calibrated in suitable voltage values, which are then converted to temperature using the standard thermocouple tables.

This clearly provides a simple, accurate and easily set up solution to temperature measurement. A useful benefit is its problem-free nature in respect of handling electrical noise in industrial environments. And, since it lends itself to portability, a number of temperature monitoring and recording instruments are based on the principle, operating in self-balancing form. Potentiometric chart recorders are the classic. Either mechanical sliders, or more commonly today, microprocessor-based electronics will seek the null point and give a voltage or direct temperature reading.

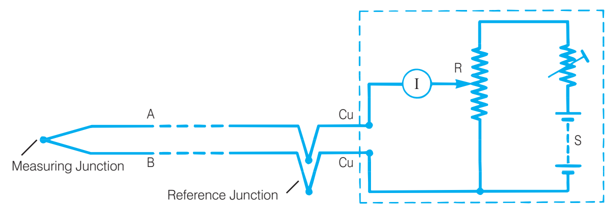


Figure 2.3: *Simplified measuring potentiometer*

2.3 Offset or Zero Suppression - Thermocouples

To overcome limitations of inadequate effective scale length on these devices (where the temperatures of interest are at the top end of the spectrum, or only over a limited range), reference voltage sources can be used to cancel most of the thermocouple emf, allowing the recorder to be operated in a more sensitive mode. Remember, you need sufficiently stable sources. This kind of trickery is rarely necessary with digital instruments since their resolution is so high. However, where it is required, either the same analogue backing-off can be used - or digital subtraction after the analogue to digital conversion stage.

2.4 Amplifiers - Thermocouples

Miniature integrated circuit-based amplifiers with very high input impedances also provide for the virtually zero current condition, valuable with thermocouple thermometry. They enable direct voltage operation, and in practice are now integral components found in voltmeters and digital indicators, as well as in thermocouple signal conditioning modules, cards, etc, and process temperature transmitters – head, rail or rack mounted; and analog, digital or smart.

2.5 Digital Voltmeters - Thermocouples

Many modern digital voltmeters, even relatively low cost units, are now designed to indicate voltage changes at the microvolt level and below. They are thus ideal for thermocouple voltage measurement - particularly since electrical interference, including mains related voltages, can be filtered out or suppressed by integrating at mains frequency.

2.6 Temperature Indicators - Thermocouples

Direct digital temperature indicators are now commonplace and cheap - belying the sophistication of the instruments. Essentially digital voltmeters, but dedicated to temperature measurement through the use of an electrical compensation network (to correct for thermocouple reference temperature) and a linearisation circuit or look up table (to handle the type-specific non-linearities of the thermocouple in use), they can be bench, panel, rack mounted, portable or hand-held.

Many can be switched to suit a range of different thermocouple combinations, including rare and base metal varieties (and often platinum resistance thermometer types as well). Others are designed for battery operation and compactness with restricted functionality, say for type K and N thermocouples.

3.0 Application Methods and Equipment - RTD's

As with thermocouples, RTD outputs measuring temperature change are small - we are looking at less than 0.5 ohms per °C for an IEC standard device. However, the resulting signals are not quite as minute - 1mA energising current with a 100 ohm nominal resistance RTD sensor yields 5mV output for a change of 10°C. Move the current up to 5mA and the output is 25mV for 10°C change - at least an order of magnitude better signal strength than with thermocouples. However, bridge amplifiers (or equivalent) are still required to provide signal levels suitable for most purposes.

There are two main instruments for determining RTD sensor resistance - measuring bridges (null-balance or fixed-bridge direct-deflection), in which the supply current can vary, and potentiometers, where the current has to be known and constant. Both can use AC or DC currents, although a smooth, stable low voltage power supply is the norm.

Early measuring instrumentation relied on null balance bridges (resistive, capacitive, or inductive). In fact, balanced measuring bridges are still used extensively in laboratories where the bridge elements might be resistance decades, or tapped inductances in AC versions. Today, fixed bridge systems are more common - where the imbalance itself is a direct measure of the changing sensing resistance.

However, high accuracy can also be achieved using today's precision potentiometers, digital voltmeters and the like to measure voltage drop directly across the sensor. Stable, constant energising current circuits are available, and these tend to favour potentiometric instrumentation, particularly for industrial use. Notably, they lend themselves to high accuracy, high speed RTD sensor scanning applications.

Also, there is now a plethora of direct reading equipment covering both instrumentation types, interpolating from the quadratic resistance (and therefore voltage, if current is constant) vs temperature relationship to give a direct temperature output. The following provides some insight into methods and equipment available.

Continued on page 46

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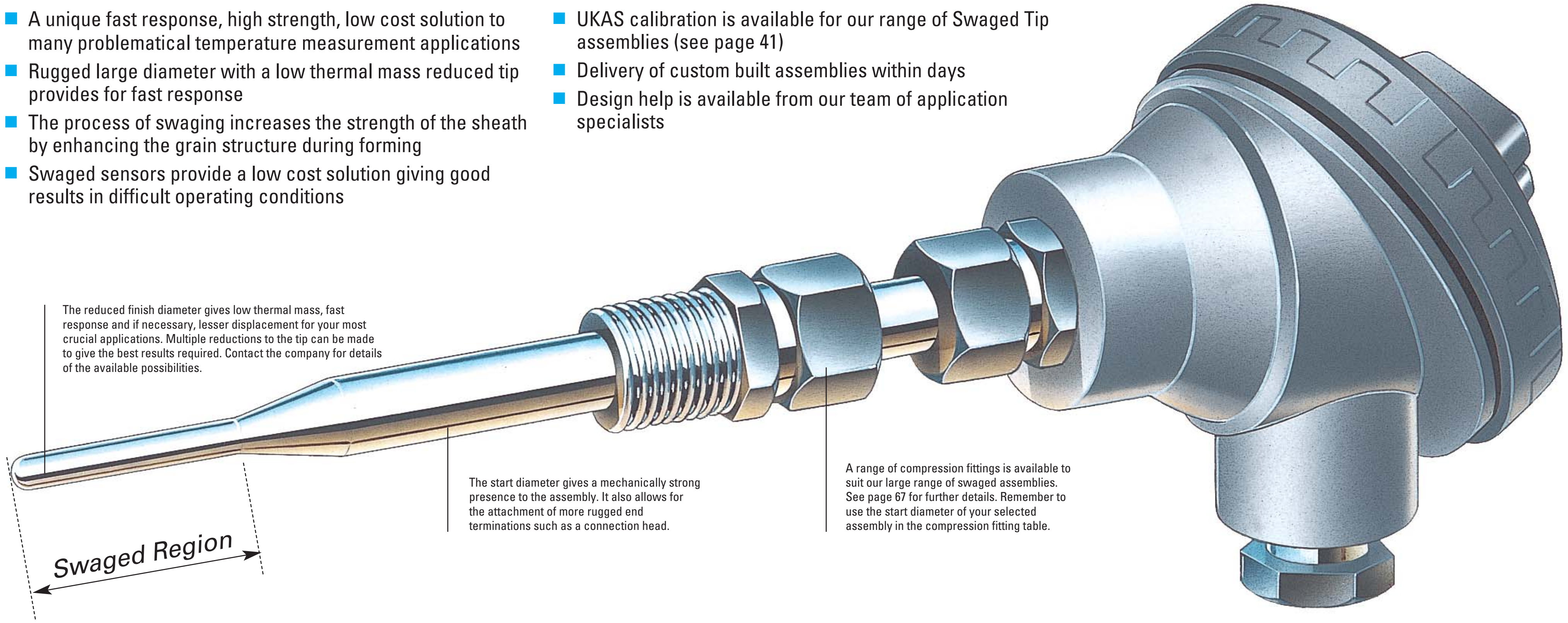
Swaged Tip: Thermocouple and Platinum Resistance Thermometer Assemblies

- A unique fast response, high strength, low cost solution to many problematical temperature measurement applications
- Rugged large diameter with a low thermal mass reduced tip provides for fast response
- The process of swaging increases the strength of the sheath by enhancing the grain structure during forming
- Swaged sensors provide a low cost solution giving good results in difficult operating conditions
- UKAS calibration is available for our range of Swaged Tip assemblies (see page 41)
- Delivery of custom built assemblies within days
- Design help is available from our team of application specialists



A unique fast response, high strength, low cost solution to many problematical temperature measurement applications is now available from TC Ltd, in the form of swaged end thermocouple and resistance thermometer assemblies.

The technique combines the two, usually mutually exclusive advantages of having a very rugged large diameter metal protection sheath over most of the sensor length combined with a low thermal mass fast response reduced tip, with the transition from one to the other maintaining the sheath integrity and homogeneity of the original sheath.

Most of the commonly used metal sheath materials used in thermocouple and platinum resistance thermometry can be swaged although the characteristics of some materials lend themselves more readily to the swaging process than others. Particularly suited to the process of swaging are high integrity mineral insulated metal sheathed thermocouple assemblies.

Swaging is the process of forming metal by hammering and in this case by a pair of precision rotary dies reducing the diameter of the metal protection tube at the tip of the temperature sensor by the swaging machine delivering measured blows to the rotating die and temperature sensor assembly tube, at the rate of typically 500 blows per minute. More than one pass can be made and thus multiple reductions in diameter can be achieved down to a maximum of 60% of the original start diameter.

The swaging technique and subsequent heat treatment procedures are interesting as these processes actually enhance the grain structure and tensile strength over the manipulated region of the sensor sheath without any detrimental effect on sensor calibration.

The range of custom built swaged assemblies available from TC Ltd have start diameters from 12.7mm to less than 1mm. Delivery of small quantities is typically 4/5 days from receipt of order. TC Ltd have developed a database of application experience of swaged temperature assemblies and a team of application specialists are available to customers to provide design assistance.

SECTION 1

Specifications

Start Diameter	Finish Diameter	Recommended Length of Finished Diameter (from below shoulder)	Approximate Finish Diameter expressed as a percentage of Original Start Diameter	Approximate Finish Size expressed as a percentage of Original Cross Sectional Area
12.7 mm	8.0 mm	20-50 mm	63%	40%
8.0 mm	6.0 mm	20-50 mm	75%	56%
6.0 mm	4.0 mm	20-50 mm	66%	44%
4.5 mm	3.0 mm	20-50 mm	66%	44%
3.0 mm	2.0 mm	20-50 mm	66%	44%
2.0 mm	1.5 mm	15-50 mm	75%	56%
1.5 mm	1.0 mm	15-50 mm	66%	44%
1.0 mm	0.6 mm	15 mm	60%	36%
0.5 mm	0.3 mm	10 mm	60%	36%

The above finish diameters are our recommendations. Greater reductions in the finish diameter are possible in most cases.
Please contact us to discuss your application further.
Note: 2.0 mm is the smallest finish diameter available for Platinum Resistance Thermometers.

Ordering Code – Typical example

To make up an order code for a Swaged End Thermocouple or Resistance Thermometer assembly select the standard sensor required (see pages 42/43 for Mineral Insulated Thermocouples, or pages 56/57 for Platinum Resistance Thermometers) remembering to specify the START diameter in the standard part code then finish the part code as follows:-

Eg 1. A typical ordering code for a Type 12 **Mineral Insulated Thermocouple** with the additional information required shown in bold.

12 - K - 300 - 118 - 6.0 - 2I - 3P10 - **SWAGE 6.0mm - 4.0mm - 35mm**

Start diameter
Finish diameter
Length of reduced swaged part

Eg 2. A typical ordering code for a Type 16 **Platinum Resistance Thermometer** with the additional information required shown in bold.

16 - 1 - 3.0 - 3 - 400 - CE6 - R100 - B - **SWAGE 3.0mm - 2.0mm - 25mm**

Start diameter
Finish diameter
Length of reduced swaged part

3.1 Bridge Measuring Systems - RTD's

Commercially available industrial bridge measuring systems use one of several circuit arrangements relying mainly on two versions of the Wheatstone bridge - balanced, or fixed bridge, both resistive. Incidentally, it is worth just noting that inductive ratio bridges can also be used, in which precision wound transformers are used for the ratio arms of the bridge. These can offer several advantages in terms of robustness, portability and stability.

Returning to resistive bridges, whatever the circuit format selected, all bridges can be made self-balancing using servo mechanisms controlled from the balance detector. In industrial applications, the bridge is not normally balanced (by altering variable resistances). Instead, as stated above, the imbalance voltage in a fixed element bridge tends to be used as a measure of the sensor resistance - and hence of temperature.

Irrespective of bridge style, all the bridge resistors, except, of course, the sensor, are set to exhibit negligible resistance change with temperature, and in AC bridges are designed to be non-inductive. Also, bridge arm resistance errors due to sliding contacts on variable resistors (where applicable) are normally prevented by introducing these into the current supply line itself, or the balance detector circuit where they can clearly have no influence on the bridge balance.

The sensing resistor, which may well be some distance away from the bridge in industrial applications, is then attached to the bridge using copper cable - whose resistance is low compared with that of the bridge, but which will obviously vary with temperature, particularly nearer to the measurement point. When the conductors are long, or of small cross section, these resistance changes can be large enough to cause significant errors in the temperature reading. And, hence the emphasis on the wiring schemes - basically two, three or four wire - to take account of this potential problem area.

3.2 Two Wire Configuration

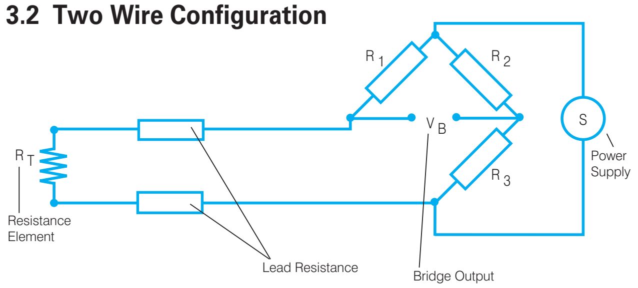


Figure 3.1: *Wheatstone Bridge with RTD in two wire configuration*

The simple two wire connection shown in Figure 3.1 is used only where high accuracy is not required - the resistance of the connecting wires is always included with that of the sensor, leading to errors in the signal. In fact, a standard restriction with this arrangement is a maximum of 1 - 2 ohms resistance per conductor - which is typically about 100 metres of cable. This applies equally to balanced bridge and fixed bridge systems. The values of the lead resistance can only be determined in a separate measurement (without the RTD sensor) and therefore a continuous correction during the temperature measurement is not possible.

3.3 Three Wire Configuration

A better scheme is shown in Figure 3.2. Here, the two leads to the sensor are on adjoining arms - there is a lead resistance in each arm of the bridge and therefore the lead resistance is cancelled out from the measurement. It is assumed that the two lead resistances are equal, therefore demanding high quality connection cables.This allows an increase to 10 ohms - usually allowing cable runs of around 500 metres or more, if necessary - although with the caveats pointed out in Part 1, Section 7 and Part 2, Section 10 regarding signal transmission problems.

Also, with this wiring scheme, if fixed bridge measurement is being made, compensation is clearly only good at the bridge balance point. Beyond this, errors will grow as the imbalance increases. This, however, can be minimised by using larger values of resistance in the opposite bridge arms to reduce bridge current changes.

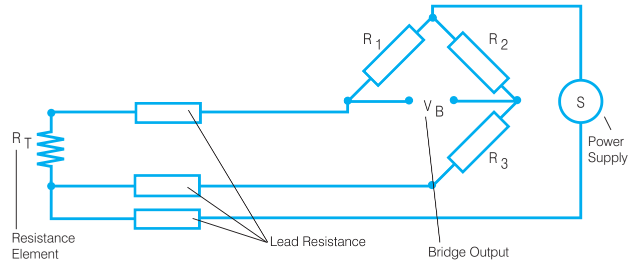


Figure 3.2: *Wheatstone Bridge with RTD in three wire configuration*

3.4 Four Wire Bridge Configurations

Saving the best till last, the most effective method of resistance, and therefore temperature, determination is through the use of a four wire connection scheme. In Figure 3.3, a standard two terminal RTD is used with another pair of wires being carried alongside the thermometer pair, this being connected close to it. The additional loop formed is introduced into the other side of the measurement bridge, and thus the effects of the two sets of leads tend to cancel.

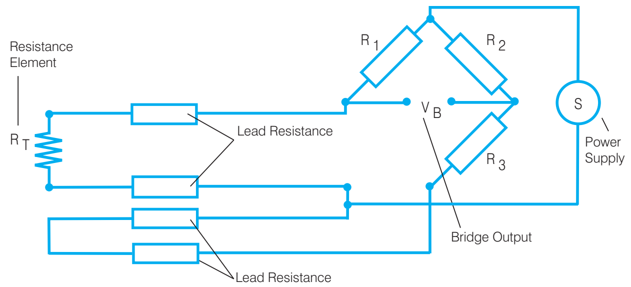


Figure 3.3: *Wheatstone Bridge with RTD in four wire configuration*

However, this approach is a little more costly on the copper wiring. An alternative, better version of the four wire connection scheme uses full four wire terminal RTD's, and is depicted in figure 3.4. This provides for full cancellation of spurious effects with the bridge type measuring technique. Cable resistance of up to 15 ohms can be handled with this arrangement, accommodating cable runs of around 1km. Incidentally, the same limitation as for three wire connections applies if the fixed-bridge, direct-reading approach is being used (see Section 3.3).

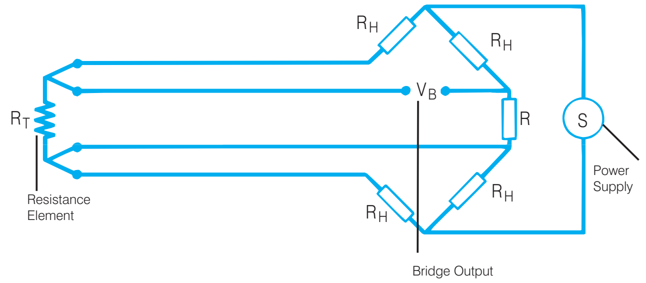


Figure 3.4: *Alternative four wire bridge connection*

3.5 Differential Temperature - RTD's

To measure differential temperatures using bridge circuitry, a second RTD is simply introduced into the bridge arm alongside the first sensor. A twin two-wire arrangement is adequate for this purpose if the cables used are both of similar resistance (see Figure 3.5).

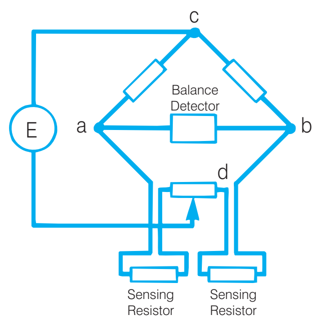


Figure 3.5: *Differential Temperature Measurement - Two Wire, Bridge Configuration*

If, however, high accuracy is required and the two sensing cable lengths, or resistances are dissimilar, then a four wire equivalent is preferable (see Figure 3.6) in which both sensors are equipped with compensating pairs (one per sensing arm of the bridge).

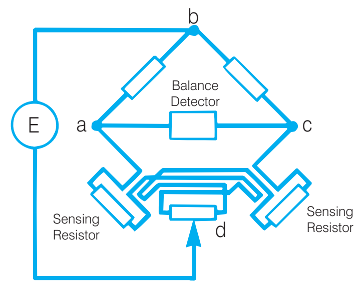


Figure 3.6: *Differential Temperature Measurement - Four Wire, Bridge Configuration*

3.6 Potentiometric Measuring Systems - RTD's

As described above, the resistance thermometer can be energised from a constant current source, and the potential difference developed across it measured directly by some kind of potentiometer. An immediate advantage is that here, incidentals like conductor resistance and selector switch contact resistance are irrelevant. The essentials for this voltage-based method are simply a stabilised and accurately known current supply for the RTD sensor (giving a direct relationship of voltage to resistance and thus to temperature) and a high impedance voltmeter (DVM, or whatever) to measure the voltage developed with negligible current flow.

With this approach, absolute temperature can be derived as long as the current is known. Even where it is not known, if it is stable, differential resistance (and thus temperature) is provided. Also, a number of RTD's can be connected in series using the same current source. Voltage signals from each can then be scanned by high impedance measuring instrumentation.

3.7 Four Wire Potentiometric Systems - RTD's

Again, a four wire configuration is appropriate, although clearly somewhat different to that used with bridge systems. Using the configuration in Figure 3.7 the resistance of the leads has a negligible effect on measurement accuracy.

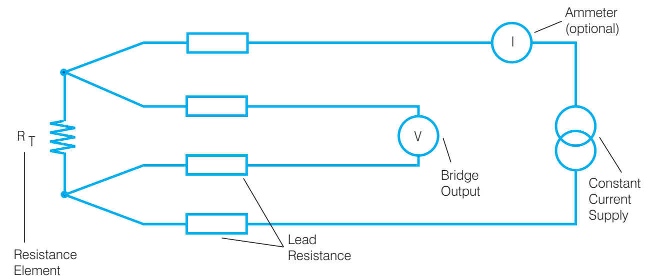


Figure 3.7: *Four Wire Sensing Arrangement*

3.8 Direct Reading Instruments - RTD's

Having looked at the circuitry and measurement methods in detail, it is time to take a look at the measuring instrumentation itself - detecting the null or measuring the imbalance in bridge systems, or sensing the voltage drop in potentiometric systems. The detector can, of course, take the form of a simple galvanometer - this is appropriate to balanced and fixed bridge arrangements. Deflection will indicate resistance (either directly, or indirectly through voltage as described), and the scale can be configured for direct temperature reading should this be required.

Sophistication can be added, with limit detectors set to provide on-off controls or alarms.

3.9 Amplifiers - RTD's

However, in general, low power electronic amplifiers, signal converters or transmitters are used. With the fixed bridge and potentiometric systems, they provide both a high input impedance and adequate power to drive more robust local or remote indicators, recorders or recorder/controllers. For null balance bridges, they are used to drive a servo system to balance the bridge, the system often forming part of an indicator, recorder or controller.

They are usually sited close to the RTD, and give the added advantage of minimising sensor cable resistance and providing a large, relatively RFI-immune signal for transmission to the signal reading instrumentation. The amplifier power supply is remote, and we're back in the realms of standard transmitter technology and 4-20mA signalling (see Part 1, Section 7, and Part 2, Sections 10 and 11).

Continued on page 48

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Miniature Thermocouple and Resistance Thermometer Assemblies

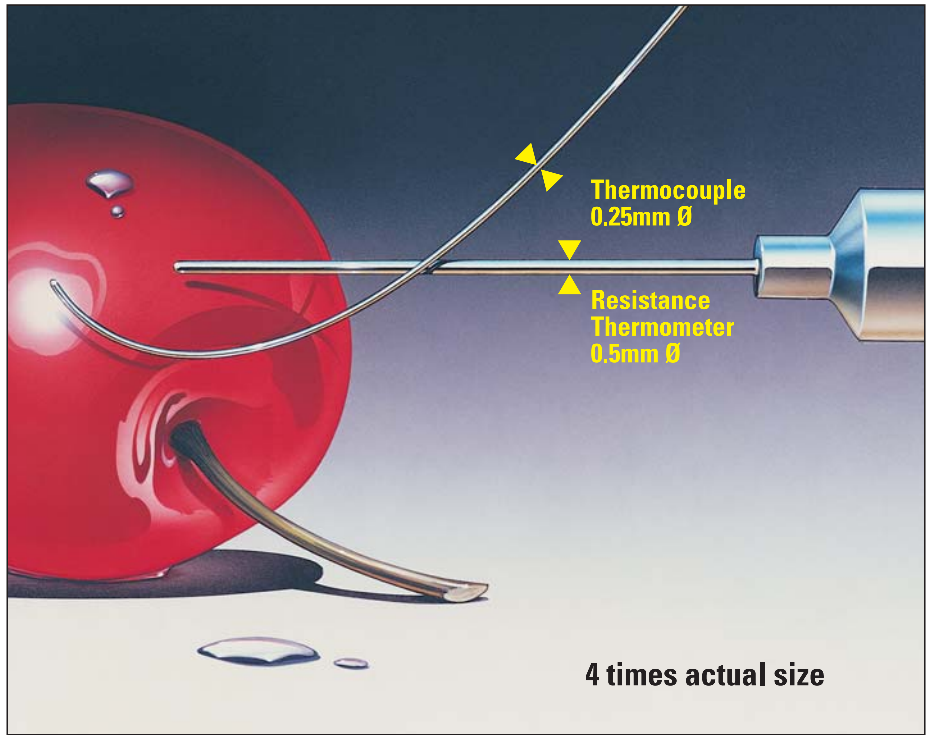
Metal sheathed assemblies with diameters down to 0.25mm

Rapid Response
Minimum Size
Least Displacement

- Many demanding precision temperature measurement applications can now be met due to the response, size, displacement and robustness of these miniature assemblies!
- UKAS calibration is available for our range of Miniature Thermocouple and Resistance Thermometer assemblies (see page 41)

Type	Metal Sheath Diameter Overall	Standard and Tolerance	Configuration and Wiring	Sheath Material	Sheath Length	Temperature Range†	End Seal Termination	Leads	Insulation Rating*
Type 12-M Thermocouple Assembly Semi-flexible metal sheathed Type K or T mineral insulated.	0.25mm 0.5mm	Type K or Type T IEC60584.1:1995 BS EN 60584.1 DIN 60584.1 NF EN 60584.1 IEC 60584.2:1993 Class 1 or Class 2	Simplex with either insulated (I) or grounded (G) junction	Order Code: 176 Inconel 600 to BS704 : 1974	Standard assemblies with sheath lengths of 150mm, 250mm, 500mm and 1000mm are normally immediately available from stock Assemblies custom built to your exact requirements are available.	176 Sheath: 0°C to + 1100°C		PFA insulated flexible leads to your exact length requirements. Our ex stock range is available with 1 metre (or shorter) leads.	>100MΩ @ 100V DC (for insulated junction only)
Type 17-M Platinum Resistance Thermometer Assembly Semi-flexible metal sheathed mineral insulated assembly	1.0mm 1.6mm 2.0mm	100 ohm element IEC 60751 BS EN 60751 Class A or Class B Recommended measuring current limit <1mA	Simplex 4 wire which may be used in 2, 3, or 4 wire configuration. (Some sizes of Type 17-M units are available as Duplex)	Order Code: 116 Grade 316 Stainless Steel to BS970 Pt4 : 1970	Standard assemblies with sheath lengths of 100mm, 150mm and 200mm are normally immediately available from stock Assemblies custom built to your exact requirements are available.	116 Sheath: 0°C to + 400°C	All assemblies are supplied with a stainless steel pot seal as per our type 3P2/CE2.	Silicone Rubber insulated flexible leads to your exact length requirements. Our ex stock range is available with 1 metre (or shorter) leads.	>5MΩ @ 100V DC
Type 16-M Platinum Resistance Thermometer Assembly Rigid metal sheathed assembly	0.5mm 0.6mm 0.8mm 1.0mm								

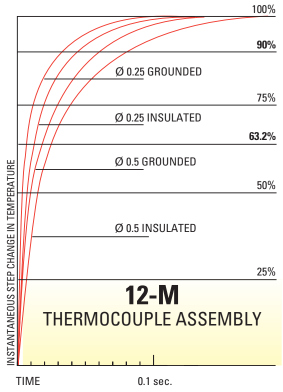
† Typical continuous operating range of sensor assembly including metal sheath (excluding end seal termination and leads). This range may be reduced somewhat by the conditions of use for which you must be the best judge.
* At room temperature

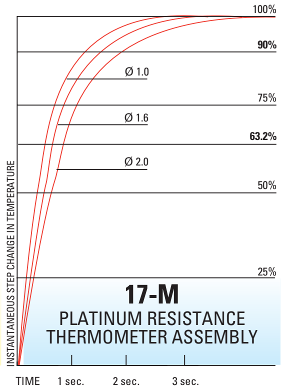


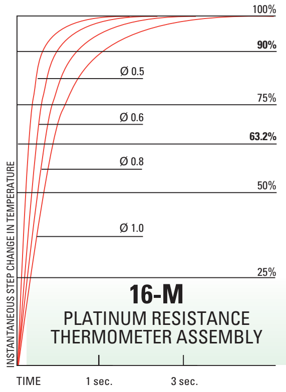
Typical Response Times

Response times for these assemblies are governed by and vary with the environmental conditions of particular applications. The following information refers to typical response times for assemblies being plunged into boiling water from air at 20°C.

Response Curves







Ø	t 63.2%	t 90%
Insulated Junction		
0.25	0.015	0.050
0.5	0.030	0.082
Grounded Junction		
0.25	0.007	0.033
0.5	0.020	0.060

Ø	t 63.2%	t 90%
1.0	0.4	1.3
1.6	0.7	1.5
2.0	0.9	2.0

Ø	t 63.2%	t 90%
0.5	0.1	0.3
0.6	0.2	0.5
0.8	0.3	0.7
1.0	0.4	1.1

All diameters in millimetres and time in seconds.

Ordering Code - Typical example

12-M-K - 0.25 - Class 2 - Simplex - I - 176 - 500 - 1 Metre-TEF

- Type No.
- Sheath diameter (mm)
- Standard and tolerance
- Configuration and wiring
- Insulated (I) or grounded (G) junction (Type 12-M only)
- Sheath material
- Sheath length (mm)
- Lead length & insulation type

3.10 Potentiometric Measuring Instruments - RTD's

Then again, self-balancing direct potentiometric indicators and recorders can also be used to measure either the bridge imbalance voltage, or the direct sensor voltage drop. Constant current supply, bridge resistors, etc are all self-contained in these devices.

3.11 Digital Instrumentation - RTD's

Another more modern alternative involves either the bridge voltage imbalance, or the RTD potential drop being measured using a digital voltmeter. This clearly provides the opportunity for applying digital linearising techniques for direct temperature reading. In fact, there is a range of direct reading instrumentation today which operates more than adequately for industrial grade accuracy temperature measurement in ranges from -200 to +850°C.

Equipment is self-balancing, and the most straightforward comprises basically high resolution digital multimeter technology, with resistance or voltage signals being converted into direct temperature readings. The devices use linearising techniques following the RTD relationship (Part 1, Section 4) to, say, two or three orders. Linearisation is usually generalised to the RTD (as per the IEC 60751 standard quadratic expression), or specific to the sensor, with empirical calibration data taken into account.

In the former case, specifications and tolerances will be to IEC 60751/ BS EN 60751 and accuracy will be to within a few hundredths of a degree. With individual calibration, accuracies to 10mK or better are available. Calibration characteristics can be provided on EAROM, which is plugged into the linearising and indicating system together with the sensor, or data can be programmed into the instrument, either directly via the front panel keypad, or remotely, with configuration performed typically in a PC and then downloaded via a serial port into the instrument.

3.12 Multi-Point Systems - RTD's

Multi-point RTD scanning instrumentation can easily be constructed using either fixed bridge or potentiometric sensing circuitry. Clearly, if selector switches are used, switch contact resistance and thermal emf problems must be minimised, and adequate time left for the sensing and measuring circuitry to respond - this being the upper limit on frequency. Solid state switching is ideal for fast scanning. With potentiometric circuitry, this is relatively simple - the constant current source simply being switched around the sensors, along with the RTD measurement connections. In fixed bridge systems, the common voltage supply is used for all the bridges, but for multiplexing, bridge amplifiers are preferred to ease switching component duties.

Care must be taken with this direct reading equipment to ensure that the measuring current is not so great as to induce excessive self-heating (see Part 1, Section 4.2); also the current must be maintained constant and stable such that any self-heating present is reproducible.

3.13 Laboratory Style Instruments - RTD's

Figure 3.8 illustrates a simple DC potentiometric method of measurement in which the RTD is connected in series with a known standard resistor and a stable current source. A DVM can be used instead of the potentiometer, and the system lends itself to microprocessor control. Thermal emfs are eliminated by reversing the current and the potentiometer polarity and averaging the readings.

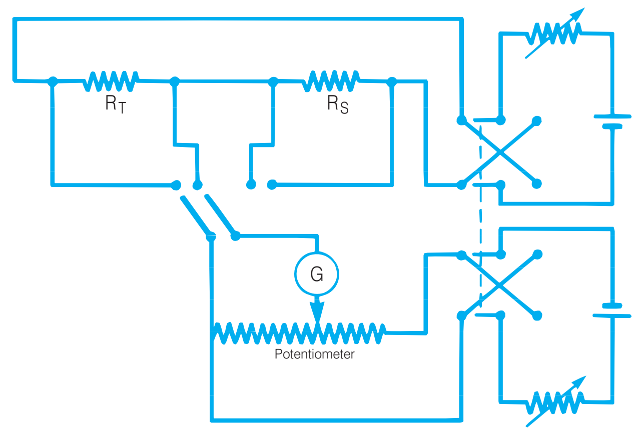


Figure 3.8: *Simple DC Potentiometric Method*

Alternatively, the resistance of the RTD and a variable standard resistor can be compared using a switched capacitor. A galvanometer, or similar, in one of the potential leads provides the null indication (see Figure 3.9).

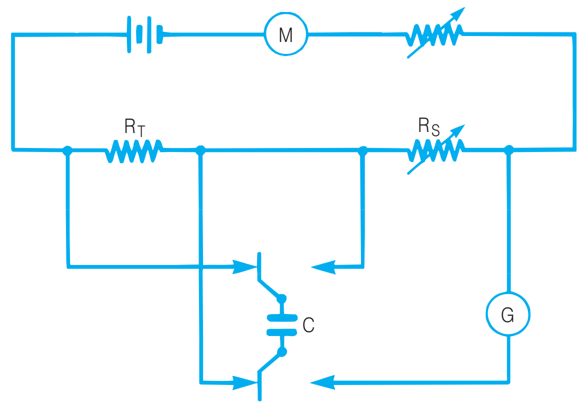


Figure 3.9: *Isolating Potential Comparator*

Beyond this, various DC bridges have been used (notable devices are the Mueller and Smith bridges), but inductive voltage dividers and ratio transformers (with their very high accuracy and stability), coupled with modern electronics (offering phase sensitive detectors and self-balancing systems) have encouraged AC measurement.

Early AC equipment included the Kelvin double bridge (mechanical coupling of the outer dividers giving the same ratio constantly) and various multi-stage transformer bridges, where lead resistance errors have been overcome by removing current flows. Modern AC bridges are self-balancing and computer coupled for direct readout of temperature using the calibration constants of the RTD concerned. Excitation frequency can be down to 25Hz such that conventional DC resistors can be used.

A modern DC bridge using ratio transformer technology is the Kusters current capacitor bridge. Here, the ratio of the currents through the thermometer and a standard resistor is measured, with the potentials across them kept equal. Bridge balancing is manual, lead resistances are irrelevant (no current flow) and automatic current reversing obviates static thermal emf problems.

4.0 Siting Thermocouples and RTD's

An obviously important requirement with temperature sensing is that the sensor should take up the temperature of the medium it is sensing! If you're spending care, attention, effort and money on a good system, but not attending to this fundamental problem, you're definitely onto a loser. The problem to resolve is essentially one of getting good thermal contact, and thus good heat transfer - without losses up the protection tube, supports, internal wires, or whatever (see Figure 4.1).

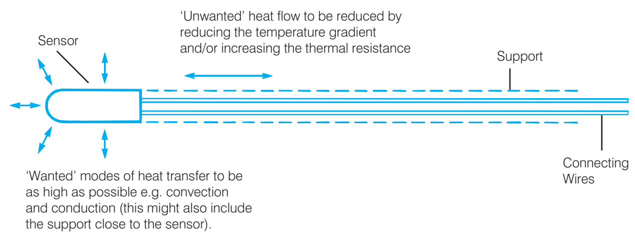


Figure 4.1: *Sensor Heat Transfer Modes*

In general, to obtain good temperature measurements you should first attend to the following three rules. Firstly, there is the question of good thermal linkage. When measuring fluids this means installation in the fastest flowing region, and arranging for the sensor to be in cross-flow if at all possible. The depth of immersion is also important, and if the fluids are slow moving, external finning may be advantageous. With solids, it means inserting the sensor into a closely fitting hole, and using cements, fillers, high conductivity greases and heat transfer fluids. On surfaces, meanwhile, it means the use of pads and greases, cements and solders.

Moving on to the second rule, heat flow to or from the sensor along the support and connecting wires needs to be minimised. This means reducing the temperature gradients close to the sensor, usually by providing enough sensor immersion depth (see Figure 4.2). Further improvements can be made by using pockets and supports with a high axial thermal resistance - like thin stainless steel. Additionally, when mounting either thermocouples or RTD's, you should consider using small diameter and low thermal conductivity connecting wires. Also, the leads should be in contact with the surface for some length to further reduce thermal conduction to and from the sensing point.

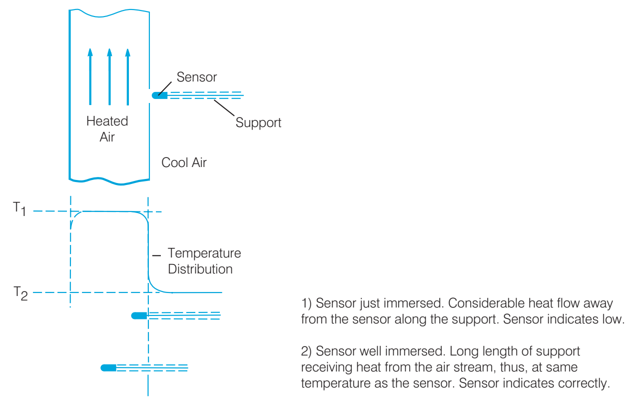


Figure 4.2: *The Importance of Sensor Immersion Depth*

Finally, the third rule; remember that the mere presence of the sensor might itself affect the temperature of the medium to be measured. This is particularly the case with surface measurements, where the sensor might interrupt or modify the heat transfer process at the surface. Keeping the sensor size to a minimum, ensuring that the sensor shape conforms to that of the surface being measured (giving maximum thermal contact with minimum mechanical strain), and providing adequate insulation or isolation (to ensure that its temperature is as close to that of the surface as possible), are the best ways to proceed. Usually, attempts to reduce sensor temperature take-up errors will also reduce the temperature disturbance introduced by the sensor.

Remember that typically, for surface measurements, the sensor could be mounted on a pipe carrying fluid. If the flow and temperature differential are adequate, the internal temperature fluctuations not severe, and the pipe thin enough and made of a thermally conductive material, then its outer wall will be close to that of the fluid. Insulation then placed over the sensor reduces the effects of the environment, and good mounting makes this a viable measurement.

Beyond the three main considerations above, there are other points. Although good thermal contact is indeed required, a large mismatch in thermal expansion coefficients may cause strain in an RTD sensor, for example. This induces a resistance change - and errors in the measured temperature signal (see Part 1, Section 4, and Part 2, Section 6).

4.1 Heat Transfer Modes

As a background to the above, it is probably a good idea to understand a little about the mechanisms of heat transfer. Basically, the main processes are conduction, convection and radiation, and short explanations of each are provided below.

Continued on page 50

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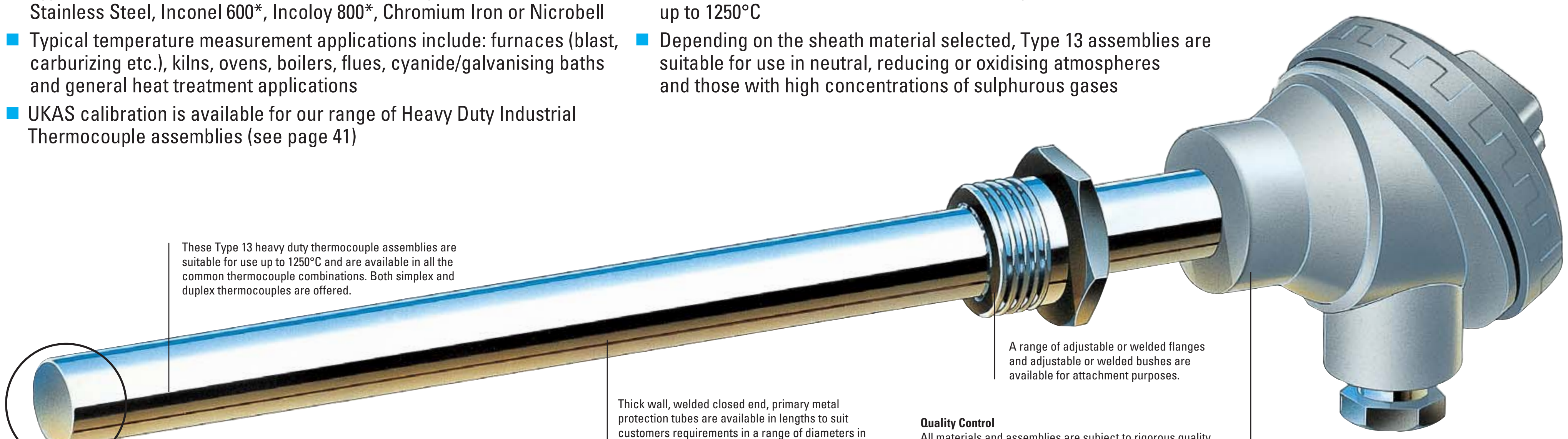
TYPE 13 Heavy Duty Industrial Metal Sheathed Thermocouple Assemblies

- Type 13 assemblies are available with thick wall protective sheaths in Stainless Steel, Inconel 600*, Incoloy 800*, Chromium Iron or Nicrobell
- Typical temperature measurement applications include: furnaces (blast, carburizing etc.), kilns, ovens, boilers, flues, cyanide/galvanising baths and general heat treatment applications
- UKAS calibration is available for our range of Heavy Duty Industrial Thermocouple assemblies (see page 41)
- These assemblies are suited to arduous temperature measurement up to 1250°C
- Depending on the sheath material selected, Type 13 assemblies are suitable for use in neutral, reducing or oxidising atmospheres and those with high concentrations of sulphurous gases



These Type 13 heavy duty thermocouple assemblies are suitable for use up to 1250°C and are available in all the common thermocouple combinations. Both simplex and duplex thermocouples are offered.

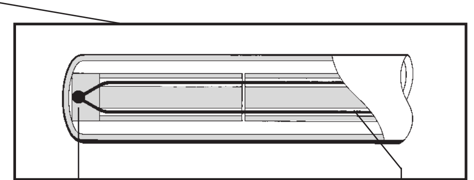
Thick wall, welded closed end, primary metal protection tubes are available in lengths to suit customers requirements in a range of diameters in Stainless Steel, Inconel 600*, Incoloy 800*, Chromium Iron or Nicrobell. Other sheath materials are available on request.

A range of adjustable or welded flanges and adjustable or welded bushes are available for attachment purposes.

Quality Control
All materials and assemblies are subject to rigorous quality checks during manufacture through to the final test and inspection procedures. Facilities are also available for additional inspection including Radiography and Calibration Certification, etc.

Heavy duty, weatherproof, screw top terminal heads are supplied fitted to Type 13 assemblies. Suitable for both simplex and duplex assemblies, they are available in diecast aluminium alloy or cast iron. They are of course supplied complete with terminal blocks.

A secondary ceramic protection sheath may be selected where additional protection is required. See Section 4 below.



Thermocouple junctions are argon arc welded. Thermocouple conductors with diameters up to 3.25mm (10swg) are used for base metal combinations. For precious metal combinations, conductors up to 0.45mm diameter can be supplied.

The simplex or duplex thermocouple conductors are protected and isolated within the sheath by ceramic insulators. Aluminous porcelain for base metal combinations and recrystallised alumina for precious metal types.

SECTION 1 Standard Thermocouple Alloy Conductor Combinations

Code	Conductor Combination	Recommended Operating Temperature Range for Conductor Combinations* Continuous °C	Short Term °C
K	Nickel Chromium vs Nickel Aluminium	0 to +1100	-180 to +1350
T	Copper vs Constantan	-185 to + 300	-250 to + 400
J	Iron vs Constantan	+20 to + 700	-180 to + 750
N	Nickel-Chromium-Silicon vs Nickel-Silicon-Magnesium	0 to +1100	-270 to +1300
E	Nickel Chromium vs Constantan	0 to + 800	-40 to + 900
R	Platinum - 13% Rhodium vs Platinum	0 to +1600	-50 to +1700
S	Platinum - 10% Rhodium vs Platinum	0 to +1550	-50 to +1750
B	Platinum - 30% Rhodium vs Platinum - 6% Rhodium	+100 to +1600	+100 to +1820
C†	Tungsten - 5% Rhenium vs Tungsten - 26% Rhenium	+50 to +1820	+20 to +2300
D†	Tungsten - 3% Rhenium vs Tungsten - 25% Rhenium	0 to +2100	0 to +2600

† Type C was formerly known as Type W5. Type D was formerly known as Type W3.
*These figures should be read in conjunction with maximum operating temperature figures for metal sheath materials.
Unless otherwise requested thermocouple units are supplied with nominal EMF/Temperature characteristics meeting the current international thermocouple reference tables.
Tolerances on thermocouple units supplied are to IEC 60584.2:1993 Class 2 (BS EN 60584.2:1993 Class 2).
Assemblies to class 1 of the above standards are available on request.

SECTION 2 Standard Sheath Diameters

mm	inches
12.7	1/2"
15.9	5/8"
21.3	13/16"
26.7	1 1/16"

SECTION 3 Standard Sheath Materials

Type	Sheath Specifications	Operational Properties	Maximum Operating Temperature of Sheath °C
116	**Grade 316 Stainless Steel** 18/8/1 Nickel/Chromium/Molybdenum Stabilised To BS 970 Part 4 : 1970	Very good corrosion resistance throughout the operating temperature range. Suited to a wide range of industrial applications. Enjoys high ductility.	800
176	**Inconel 600*** Nickel/Chromium/Iron alloy. BS 3074 : 1974 Grade NA14, ASTM B167, ASME SB 167, Din NiCr15Fe, Werkstoff No : 2.4816	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys a good resistance to oxidation. Do not use in sulphur bearing atmospheres above 550°C.	1100
180	**Incoloy 800*** Iron/Nickel/Chromium alloy. BS 3074 : 1974 Grade NA15, ASTM B163, B407 ASME SB 1635, B407, Din X10NiCrAlTi3220, Werkstoff No : 1.4876	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys a good resistance to oxidation and carburisation. Resistant to sulphur bearing atmospheres.	1100
144	**AISI 446** Chrome/Iron ASTM TP446, AISI 446, Din X18CrN28, Werkstoff No : 1.4749	Suitable for use in severely corrosive atmospheres to elevated temperatures. Particularly suited for use in high concentration sulphur bearing atmospheres at high temperatures. ** Should be mounted vertically at temperatures above 700°C.*	1150
114	**Nicrobell D*** Nickel/Chromium/Silicon/Molybdenum 73/22/1.4/3	Recommended for use with high temperature Type 'K' and almost all Type 'N' applications. Very good high temperature strength. Optimum benefits seen when used with Type 'N' conductors. Excellent performance in oxidising, carburising, reducing and vacuum atmospheres. Do not use in high free sulphur atmospheres.	1250

Other sheath materials can be supplied to special order.

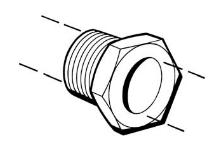
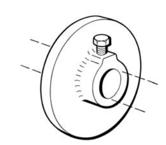
*Trade names

SECTION 4 Optional Ceramic Secondary Protection Sheath Materials

In some cases a composite protection sheath is recommended where in addition to the protection characteristics of the primary thick wall metal sheath other characteristics are required. These requirements can be met by the use of a secondary closed end ceramic sheath within the primary metal protection sheath. This ceramic sheath itself encloses the twinbore or four bore insulators and their associated thermocouple elements.

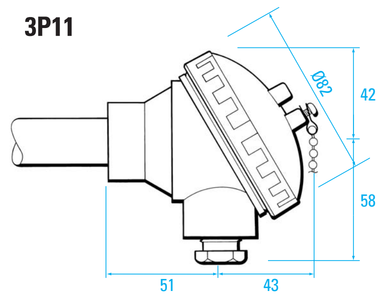
Code	Material	Notes
IAP	Impervious Aluminous Porcelain	Ideally suited for use with base metal thermocouple combinations. Has a very low coefficient of expansion giving excellent resistance to thermal shock.
IRA	Impervious Recrystallised Alumina	Ideally suited for protection of precious metal thermocouple combinations. Has a fair resistance to thermal shock and high resistance to alkaline and other fluxes.
IM	Impervious Mullite	Recommended for use with precious metal thermocouple conductor combinations. Has great mechanical strength combined with good resistance to thermal shock and flux attack.

SECTION 5 Support Tube Mounting Fittings

Code No.	Description	Material	Screwed	Sketch
WBPSA	Welded Fixed Position Screwed Bushes	Stainless Steel	3/4" BSPP	
WBTSA		Stainless Steel	3/4" BSPT	
WBPSB		Stainless Steel	1" BSPP	
WBTSB		Stainless Steel	1" BSPT	
FI1	100 mm dia. Flange Adjustable	Cast Iron	N/A	
FFW	Flange Welded	Stainless Steel	N/A	-

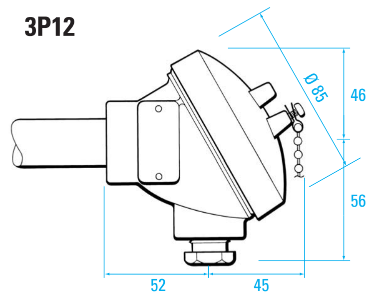
SECTION 6 Terminal Heads

3P11



Weatherproof die cast alloy screw top terminal head with tube and cable entry at a right angle to each other. Suitable for simplex and duplex assemblies. Supplied complete with 20mm ISO metal pinch gland on the cable entry for cables from 6mm to 14mm diameter.

3P12



Weatherproof cast iron screw top terminal head with tube entry and cable entry at a right to each other. Suitable for simplex and duplex assemblies. Supplied complete with 20mm ISO metal pinch gland on cable entry for cables from 6mm to 14mm diameter.

Other connection heads are available. See page 69 for further details.

Ordering Codes - Typical example

13 - K - 1 - 13/16 - 176 - 500 - IRA - WBPSA (350mm under HEX) - 3P12

- Type No.
- Thermocouple Calibration (See section 1)
- Number of elements (ie Simplex 1 or Duplex 2)
- Primary sheath diameter (See section 2)
- Primary sheath material (See section 3)
- Sheath length in mm (under head)
- Secondary sheath material if required (See section 4)
- Sheath fitting if required (See section 5)
  N.B. If fixed specify sheath length under hex (parallel thread) or under thread start (tapered thread) or under flange (welded flange)
- Terminal head (See section 6)

4.2 Conduction

Thermal conduction is the transfer of heat in a medium essentially due to the molecular activity within the material itself. It differs widely across the media spectrum, with metals like silver and copper being good conductors, whereas gases, like still air, are poor conductors. Thermal conductivity of materials is somewhat related to their electrical conductivity, but the near perfect electrical insulating properties of some materials do not exist in the thermal sense. This is the principal mode of heat transfer within the temperature sensor and associated pocket or thermowell assembly itself.

4.3 Convection

Convection is the mode of heat transfer between a body and a moving liquid or gas. When a fluid flows over a surface, the layer of fluid that is in intimate contact with the surface is brought to rest, there being a velocity gradient (at first rapid, but then trailing off) away into the main stream of the flow. Heat transfer is then by molecular conduction across the stationary boundary layer, and a combination of conduction and physical mixing in the body of the fluid. Temperature distribution in the fluid is related to the velocity distribution.

Forced convection refers to a fluid being circulated by mechanical means, like a pump, fan or stirrer. If the fluid moves spontaneously under the influence of gravity by heat-induced density changes, this is natural convection. Most fluid temperature sensors rely on convection heat transfer at their outer boundaries to take up the local fluid temperature.

4.4 Radiation

Any body at a temperature above absolute zero radiates energy, and so radiation heat interchange can be a consideration when installing temperature sensors. The intensity of heat radiated from the body surface is proportional to its absolute temperature to the fourth power. So the radiation interchange is a function of their temperature difference to the fourth power - and thus the effect becomes considerably more important with elevated temperatures.

Radiation intensity is also inversely proportional to the square of the distance to the receiving surface, and to the emissivity (a function of surface condition), the angle of the surface, the nature of the transmission path, and other factors. When measuring temperatures in the working space of an electrically heated high temperature furnace, heat transmission is likely to be almost entirely by radiation to both the contents and the sensor.

This phenomenon can provide unwanted heat transfer when, for example, the temperature of a relatively slow moving gas stream is being measured. The sensor temperature will be brought towards the wanted temperature of the gas by convection at the sensor boundary. If the gas is hotter than its surroundings, the sensor will also lose heat by radiation, and its temperature will thus be lowered.

Conversely, if the gas is cooler than its surroundings, the sensor will gain heat by the net interchange between the surroundings and the sensor, and its temperature will be raised above the wanted value. To reduce radiation effects of this type, the emissivity of the sensor casing can be reduced by choice of materials and their surface condition. Alternatively, shields can be fitted around the sensor to intercept the radiation.

4.5 Stagnation Temperature

As the velocity of a gas flowing over any body (and temperature sensors are no exception) increases, the temperature of the layer of gas in contact with the body begins to rise. So temperature measurement in fast moving gas flows is complicated by this dynamic heating effect. The temperature most frequently required is the free stream, or static temperature (that without the dynamic component), as opposed to the total temperature - that with the dynamic component added.

Total temperature, Tt, is usually measured, using special probes designed virtually to stagnate the gas at the sensor. From this, the static temperature, Ts, can be derived using the formula:

$$T_s = T_t/(0.5(\gamma - 1)M + 1)$$

where γ is the ratio of the specific heat of the gas at constant pressure to constant volume, and M is the Mach number. Some examples of the temperature rise due to dynamic heating in air at atmospheric pressure are: 1°C at 45 meters per second; 10°C at 145 meters per second; and 30°C at 245 meters per second.

5.0 Installation Points - General

Although in some applications protective sheaths are not required, in many more, thermocouples and RTD's need to be protected from the environment. Metal protection tubes, ceramic protection tubes and thermowells following BS 2765, or the specific chemical and petroleum industry standards are available for this purpose. BS 1041 Part 4, Section 7 and BS 1041 Part 3, Section 8 provide some details on thermocouples and RTD's respectively. Part 2, Sections 1, 6 and 9 of this guide provide comprehensive information.

5.1 Installation Points - Thermocouples

Looking at thermocouples themselves, depth of immersion plays an important part in determining measurement accuracy. A good rule of thumb is to make the depth of immersion at least 10 times that of the overall sensor diameter. Then, ensure that the constituent thermoelements are insulated from one another - and from temperature variations! Next, avoid cold working as much as possible - it changes the calibration of thermocouples. Also, make sure that the environment around your thermocouples is reasonably clean. Oils (particularly sulphur-bearing), phosphorous and low melting constituents especially, will quickly destroy most thermocouples.

For most accurate requirements, base metal thermocouples should in general be considered as relatively throw-away units, and discarded after a single use. But, in any event, they should be periodically replaced before calibration shifts become too great (see Part 3, Section 8). Calibration periods are very variable, depending upon the environment and duty, but as a general rule, every six months to one year is usual, with used thermocouples being calibrated in-situ.

At the top of the list as far as wiring is concerned is a reminder always to observe the colour codes and polarity of connections for each type of thermocouple and its associated cabling and connectors. Avoid introducing different metals into the cabling. Preferably, use colour coded extension or compensating cable which matches the thermocouples in use for greatest accuracy, along with the appropriate connectors for reliability and convenience - of installation and maintenance.

Also, make sure that the transition from thermocouple wire to the extension or compensating cable (if used) is as far away from the heat source as the design permits. Remember that subjecting compensating cable to high temperatures will result in inaccuracies. Extension cable is far superior in this respect. A point for the more cavalier among you - don't even think about forming thermo-junctions using compensating cable; even the use of extension cable is not recommended for this purpose.

Next, remember the importance of the reference junctions (see Part 1, Section 2.2 and Part 2, Section 5). These must be sited in an isothermal region whose temperature is known or accounted for by electronic means using cold junction compensation techniques, or mechanically, with indicators and the like.

Beyond this, all connections and contacts must be tight, clean and oxide-free - to facilitate the passage of low level signals. Also, all lead wires and connections should be protected from the ingress of moisture in any form and from mechanical damage. Moisture leads to reduced leakage resistance and the generation of extraneous emfs due to electrolytic action - resulting in errors.

Use screened or braided cable connected to ground in any installation where AC pick-up, contactor (RFI) interference, or lightning strikes are possible. Although the thermocouple itself will not be damaged by electrical noise, or spikes, the instrumentation might be, and the thermocouple measurement signal is likely to be impaired. Also, consider using protected cables (with moulded insulation, armour or steel braid) and metal or plastic conduit or tubing for harsh industrial environments. There are several tests to ensure installation integrity. These include water immersion tests, gas pressurisation or leak detection (where helium is used), flexibility checks and leakage resistance checks.

For very long cable runs, be careful not to use wire diameters that are too small. Although this reduces cost, measurement errors can result if the cable resistance is too great for the instrumentation. Modern electronic instruments are usually happy with up to about 100 ohms. Although they will tolerate much higher lead resistances, errors are likely to occur.

5.2 Installation Points - RTD's

Looking at the sensors, RTD design is inevitably a compromise between the measurement ideal of fully annealed, unrestrained platinum wire, and the practical requirement of robust, rugged devices. Further, there is the question of lead/connection fragility. To avoid problems with breakage, care must be taken during installation to ensure that RTD's are not subjected to excessive vibration or mechanical shocks. For example, long, overhanging pockets can be a problem on industrial plant; equally pockets or thermowells whose internal diameter is too great can be problematic, allowing too much free movement (as well as resulting in poor thermal contact).

Then again, although RTD's are stem sensitive devices, depth of immersion is still important to avoid measurement inaccuracies - see the manufacturer's recommendations as per the IEC 60751 requirement. Remember that thermal conduction along the connection leads or the sheath can result in less than perfect measurements, so take care to make provision to avoid it.

Next, there is the question of protective sheaths; these must be adequate for the application. If not, gradual degradation of the sensor will result, due to platinum poisoning. Remember also that sheaths must include an oxygen content to ensure that metal oxides cannot be reduced - leading to this contamination.

Moving on, as with thermocouples, it is important to remember to use the wiring colour codes and/or the terminal markings to ensure correct connections. Screened cable (twisted, with continuous braiding or a conducting conduit) should be used in installations where AC pick-up or contactor interference is likely to be a problem, but it is always worth avoiding cable runs parallel with current carrying conductors. Also, it is important to note that although single strand wires have the disadvantage that breakage leads to an instant open circuit, multi-strand cables are not without their problems - particularly in bridge circuits, where spurious strand breakage can result in resistance changes leading to incorrect readings.

So care needs to taken with wiring no matter what is selected. Then again, cables need to be laid such that ambient temperature variations cause minimum resistance variations. And, where you are at all worried about the mechanical environment, use armoured or braided cables. Also, for longer cable runs, three and four wire bridge connection systems (each cable having the same resistance) are highly recommended to ensure that lead resistance imbalances do not result in measurement errors. The situation with two wire systems is quite simply that the longer the lead length the greater the error.

However, total resistance must obviously be within what can be tolerated by the instrumentation; modern instruments can handle up to around 100 ohms. Beyond this, normally, the circuits should also be floating - no earth, or at most a resistive earth connection (to remove static problems), being desirable. Do not forget that thermoelectric effects can also result from the use of different conductors (as per thermocouples), so avoid these (this is not a problem if AC excitation is being used). It is also important not to introduce ohmic high resistance connections; high quality RTD connectors should always be used. Junction boxes also make a lot of sense, allowing easy inspection. Avoid vibration, corrosion and thermal cycling of connections. Remember that insecure links will also result in variable resistance - the very quantity you are trying to measure.

Continued on page 52

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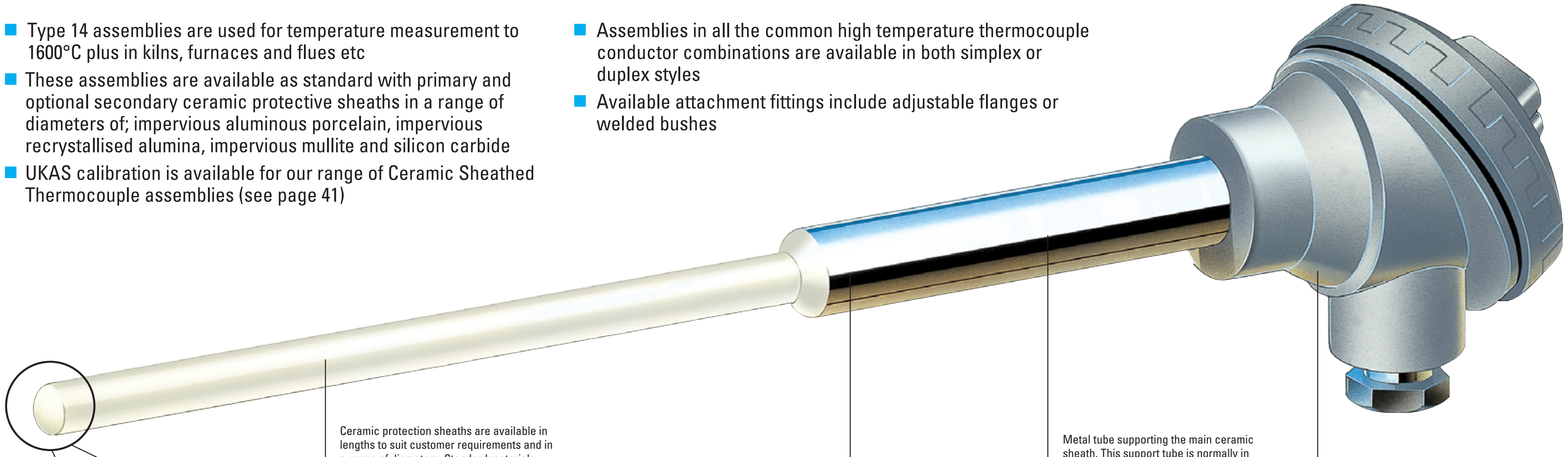
01895 252222

TYPE 14 High Temperature Ceramic Sheathed Thermocouple Assemblies

- Type 14 assemblies are used for temperature measurement to 1600°C plus in kilns, furnaces and flues etc
- These assemblies are available as standard with primary and optional secondary ceramic protective sheaths in a range of diameters of; impervious aluminous porcelain, impervious recrystallised alumina, impervious mullite and silicon carbide
- UKAS calibration is available for our range of Ceramic Sheathed Thermocouple assemblies (see page 41)
- Assemblies in all the common high temperature thermocouple conductor combinations are available in both simplex or duplex styles
- Available attachment fittings include adjustable flanges or welded bushes



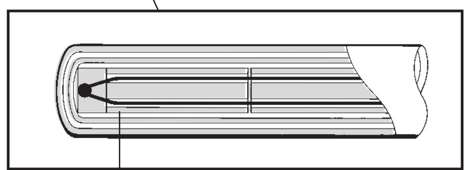
Ceramic protection sheaths are available in lengths to suit customer requirements and in a range of diameters. Standard materials are: impervious aluminous porcelain, impervious recrystallised alumina, impervious mullite and silicon carbide. Alternative ceramic sheath materials are available on request.

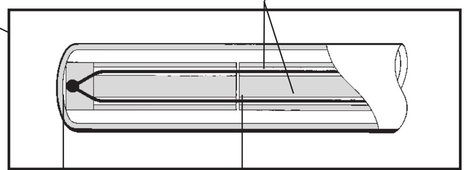
Thermocouple conductors with diameters up to 0.45mm are used for precious metal thermocouple conductor combinations. Conductors up to 3.25mm diameter (10swg) are used for base metal thermocouple conductor combinations. Alternative diameters can be supplied on request.

For attachment purposes a range of adjustable or welded flanges and bushes are available. These are secured to the support tube.

Metal tube supporting the main ceramic sheath. This support tube is normally in stainless steel and is typically 21mm OD x 100mm. See Section 2 below. Support tubes in alternative materials and dimensions are available on request.

Heavy duty, weatherproof, screw top terminal heads are supplied fitted to Type 14 assemblies. They are available in die cast alloy or cast iron. They are of course supplied complete with terminal blocks. The die cast alloy version can be colour coded in accordance with the thermocouple type selected.





In many cases a composite protection sheath is recommended; where in addition to the protection characteristics of the outer primary ceramic sheath other required characteristics are achieved by the use of a secondary ceramic sheath. See Section 3.

Thermocouple junctions are argon arc welded. Simplex or duplex junctions can be provided.

The simplex or duplex thermocouple conductors are protected and isolated within the ceramic sheath by twin bore or four bore ceramic insulators. These insulators will normally be of impervious recrystallised alumina in the case of precious metal thermocouple conductor combinations and of impervious aluminous porcelain in the case of base metal thermocouple conductor combinations.

Quality Control
All materials and assemblies are subject to rigorous quality checks during manufacture through to the final test and inspection procedures. Facilities are also available for additional inspection including Radiography and Calibration Certification, etc.

SECTION 1 Standard Thermocouple Alloy Conductor Combinations

Code	Conductor Combination	Recommended Operating Temperature Range for Conductor Combinations* Continuous °C	Short Term °C
K	Nickel Chromium vs Nickel Aluminium	0 to +1100	-180 to +1350
J	Iron vs Constantan	+20 to + 700	-180 to + 750
N	Nickel-Chromium-Silicon vs Nickel-Silicon-Magnesium	0 to +1100	-270 to +1300
R	Platinum - 13% Rhodium vs Platinum	0 to +1600	-50 to +1700
S	Platinum - 10% Rhodium vs Platinum	0 to +1550	-50 to +1750
B	Platinum - 30% Rhodium vs Platinum - 6% Rhodium	+100 to +1600	+100 to +1820
C†	Tungsten - 5% Rhenium vs Tungsten - 26% Rhenium	+50 to +1820	+20 to +2300
D†	Tungsten - 3% Rhenium vs Tungsten - 25% Rhenium	0 to +2100	0 to +2600

† Type C was formerly known as Type W5. Type D was formerly known as Type W3.
*These figures should be read in conjunction with maximum operating temperature figures for ceramic sheath materials.
Unless otherwise requested thermocouple units are supplied with nominal EMF/Temperature characteristics meeting the current international thermocouple reference tables.
Tolerances on thermocouple units supplied are to IEC 60584.2:1993 Class 2 (BS EN 60584.2 : 1993).
Assemblies to class 1 are available on request.

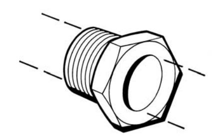
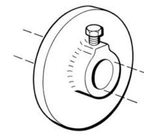
SECTION 2 Standard Sheath Diameters

Ceramic Sheath Diameter (mm)	Metal Support Tube Diameter (mm)
8	21.3
10	21.3
12	21.3
17	26.7
20	26.7

SECTION 3 Standard Metal Sheath Materials

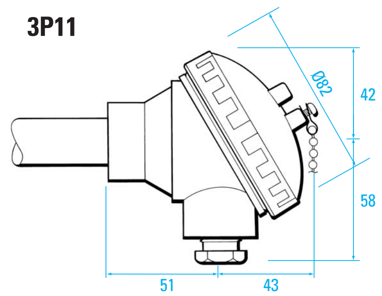
Type	Material	Operational Properties	Maximum Operating Temperature of Sheath °C
IAP	Impervious Aluminous Porcelain	Ideally suited for use with base metal thermocouple conductor combinations. Has a very low temperature coefficient of expansion thus giving excellent resistance to thermal shock. Offers high strength and high resistance to flux and slag attack. Suited to kiln applications where low contamination requirements preclude the use of a metal sheath. NB. Requires support at high temperature if horizontal.	1400
IM	Impervious Mullite	Suited for use with precious metal thermocouples at high temperatures. Has great mechanical strength combined with good resistance to thermal shock. Relatively inert to sulphurous and carbonaceous atmospheres and highly resistant to flux attack. Used very often as a secondary protection sheath within a silicon carbide primary sheath.	1600
IRA	Impervious Recrystallised Alumina	Ideally suited for use with precious metal thermocouples at high temperatures. Provides a fair resistance to thermal shock. High degree of inertness to chemicals. Ideal for reducing carbonaceous atmospheres and offers a high resistance to alkaline and other fluxes.	1800
SC	Silicon Carbide	A porous material but with an outstanding resistance to thermal shock and good-mechanical strength. Normally used in high temperature applications as the primary sheath enclosing some secondary sheath material. Not suitable for use in highly oxidising atmospheres.	1450

SECTION 4 Support Tube Mounting Fittings

Code No.	Description	Material	Screwed	Sketch
WBPSA	Welded Fixed Position Screwed Bushes	Stainless Steel	3/4" BSPP	
WBTSA		Stainless Steel	3/4" BSPT	
WBPSB		Stainless Steel	1" BSPP	
WBTSB		Stainless Steel	1" BSPT	
FI1	100 mm dia. Flange Adjustable	Cast Iron	N/A	

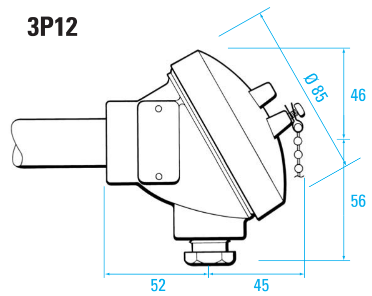
SECTION 5 Terminal Heads

3P11



Weatherproof die cast alloy screw top terminal head with tube and cable entry at a right angle to each other. Suitable for simplex and duplex assemblies. Supplied complete with 20mm ISO metal pinch gland on the cable entry for cables from 6mm to 14mm diameter.

3P12



Weatherproof cast iron screw top terminal head with tube entry and cable entry at a right to each other. Suitable for simplex and duplex assemblies. Supplied complete with 20mm ISO metal pinch gland on cable entry for cables from 6mm to 14mm diameter.

Other connection heads are available. See page 69 for further details.

Ordering Code - Typical example

14 - R - 1 - 20 - IRA - 600 - IRA - FI1 - 3P11

- Type No. (14)
- Thermocouple Calibration (See section 1) (R)
- Number of elements (ie Simplex 1 or Duplex 2) (1)
- Primary sheath diameter (See section 2) (20)
- Primary sheath material (See section 3) (IRA)
- Sheath length under head (including 100mm support tube) (600)
- Secondary sheath material if required (See section 3) (IRA)
- Support tube mounting (See section 4) (FI1)
  N.B. If fixed specify sheath length under:
  a) Hexagon (parallel thread)
  b) Thread start (tapered thread)
  c) Flange
- Terminal head (See section 5) (3P11)

6.0 Averaging Thermocouples and RTD's

With thermocouples it is possible to arrange a number of sensors such that their combined outputs represent an average of their temperatures. There are various convenient schemes.

However, the same is not quite true of resistance thermometer detectors. Since bridge imbalance or voltage drop across standardised resistances is what's being sensed, the best that can be achieved with RTD's is to energise several sensors from the same constant current source, and switch round the devices. A dynamic average can then be obtained using digital computing power in the connected instrumentation.

If the measurement does not warrant an arrangement of this sophistication, the inherent stem sensitivity of RTD's can be used to provide an automatically averaged reading over the stem area - overall resistance change being the measured parameter which derives temperature. Also, remember that many industrial sensor assemblies are available in duplex and triplex forms, facilitating wider area averaging.

6.1 Thermocouples in Parallel

Returning to thermocouples, let's look at connecting the devices in parallel. An immediate and important point to note is that the loop resistances of each separate circuit must be closely matched between the measuring junction and the common connection point. This is easily achieved simply by ensuring that all the thermocouple circuits are of similar construction and length (see Figure 6.1).

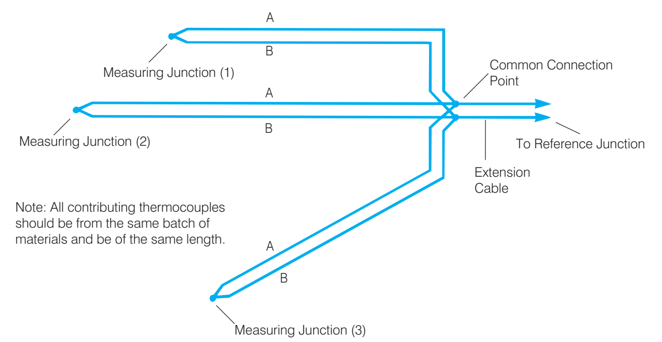


Figure 6.1: *Thermocouples in Parallel*

Another technique involves the use of resistors to balance the circuits to a single value (see Figure 6.2). If separate resistances are to be used in the thermocouple circuit, it is preferable to produce the resistors from the appropriate thermocouple materials. Alternatively, if conventional resistors are to be used, it is best to insert these in the copper circuits and to use components with as similar thermoelectric properties to those of copper as possible.

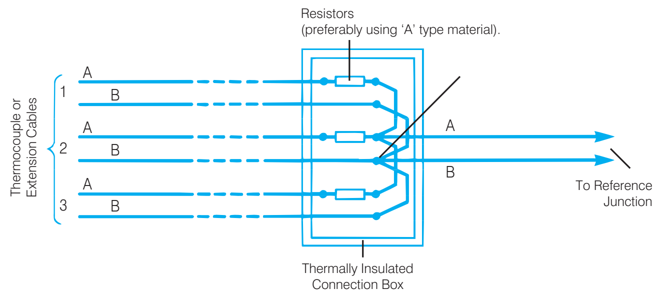


Figure 6.2: *Circuit Balancing using Resistors*

Ideally, the resistance required could be achieved by fitting two similar value resistors, one in each side of the copper circuit. This provides a degree of cancellation of spurious thermal voltages (see Figure 6.3).

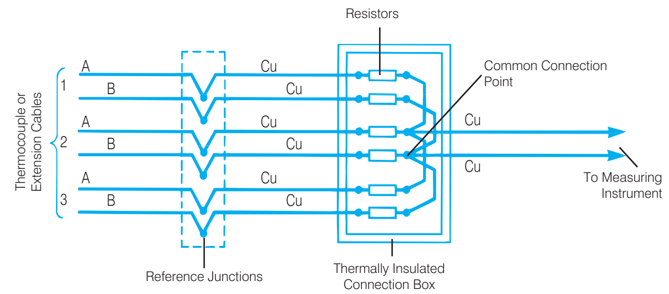


Figure 6.3: *The Ideal Case - with Dual Resistors*

Some caution is required with all of these methods. Although they will produce a reasonable average voltage, and thus temperature output from the thermocouples concerned, accuracy can be impaired by the non-linearity of thermocouple characteristics, and also the variation of the thermocouple resistances themselves with temperature.

Further, the measuring junctions must be electrically isolated from one another to exclude other parallel paths. Also, the effects of non-matched thermoelectric characteristics of added resistors ought to be considered. This can be minimised by containing them in an isothermal (thermally insulated) enclosure.

One final point: the loop resistances of thermocouple circuits are best determined using a low frequency AC bridge. Even a small thermoelectric voltage can significantly affect the indicated value with some DC resistance measuring instruments. So, it is always worth reversing the polarity of a measurement to check that such affects are not present.

6.2 Thermocouples in Series

Temperature averaging can also be carried out by connecting the thermocouples in series. Here, all of the sensors require separate reference junctions; the output is then the sum of the individual thermocouple outputs, and the average temperature is simply this total divided by the number of contributing thermocouples. If a voltage measurement (zero or virtually zero current) is made, the circuit resistances are no longer important. However, other considerations such as measuring junction insulation and change of sensitivity with temperature still apply.

6.3 Data Logging

Numerical averaging is an obvious facility made available by using a data logger or appropriate electronics to monitor individual thermocouple outputs. Averaging can be carried out either on-line in real time, or through subsequent data analysis, depending upon the functionality of the instrumentation.

A clear advantage of this approach is that the thermocouple and RTD circuits need not be tampered with or compromised in any way. Weighting factors can be applied, and doubtful or invalid signals (from failed or degrading thermocouples, for example) can be ignored.

7.0 Response Times

All sensors have a finite response time, and this has to be recognised if the temperature of the medium being measured is changing appreciably with time, yet high speed response is required - for example, where control, switching, or alarm actions need to be equally prompt. The inherent response time of the sensor is a function of its construction, and it is usually determined by a specific test condition. One such method is to plunge the sensor at ambient into rapidly moving water maintained at a different temperature. Clearly, this allows comparisons to be made.

The controlling parameter here is the effective thermal diffusivity of the sensor, k/(c x ρ) where k is the effective thermal conductivity, c is the effective specific heat, and ρ is the density. Basically, this function represents the rate at which a temperature change will be propagated through a medium. Thus, the ideal quick response sensor would be made of high conductivity material, have a low specific heat and low density. Unfortunately, there are many constraints affecting sensor construction, some of which can impair their response rates under this definition - but there are practical steps which can be taken to improve upon the situation. At the top of the list are ensuring the lowest possible thermal resistance at the sensor boundary (this contributes to the conductivity component), reducing the path length (and thus the sensor's effective thermal mass), and using the smallest device possible within the constraints of achieving reliable measurement. Beyond these there are special points for thermocouples and RTD's.

Where thermocouples are concerned, it is best to use versions with the measuring junction itself exposed. Basically, the thermocouple is welded to the sheath tip (designated earthed or grounded). Typical response times for these assemblies are governed by, and vary with, the application environment and the overall diameter, as well as the construction details. Tests show that for insulated junctions to achieve 63.2% of a step change from 20°C to 100°C in water takes 0.015 seconds for a 0.25mm OD MI thermocouple, but 9 seconds for a 10.8mm OD device. These figures are roughly halved for grounded versions.

For resistance temperature detectors, the response times are always a function of the thermal mass (ideally low) and surface area against volume ratio (ideally high) of the sensors, plus the adequacy of contact with the medium concerned. This latter is frequently dictated by the degree of insulation and mechanical/environmental protection required - which effects the full sensor stem length - unlike thermocouples. Sealed sensors can be constructed offering response times in the region of 0.2 to 0.5 seconds. Marginally better responses can be obtained using thin film RTD's. However, heavy, industrial devices fitted in large pockets in the walls of pressure vessels, for example, can take several minutes to respond.

8.0 Calibration

Looking first at thermocouples, thermocouple wires have a guaranteed tolerance on output within limits as specified in the standards (see Part 1, Section 3.14). Typically, Types R and S might be guaranteed to ±1°C at the melting point of gold, while Type K could have limits of ±7.5°C at 1,000°C. Tighter tolerance wires are also usually available for higher accuracy work, and the same applies to extension and compensating cables (see Part 1, Section 3.15). However, the tolerances only apply to new, clean sensors before exposure to the cruel world!

Also, where insulated thermocouple wires, and MIMS thermocouples are concerned, they are supplied in reels from say 50 to 1,000m long - and the calibration from top to bottom of the reel can vary by over one degree, depending upon the test temperature (see Figure 8.1).

As for degradation with time and use, the most common faults found with thermocouples are inadequate insulation resistance, thermoelectric inhomogeneity and deterioration of the junction.

Considering next resistance thermometer detectors, the wire itself is produced to an extremely high standard of precision; so it is the complete element that carries the tolerance limit guarantees - as in BS EN 60751. This specifies two tolerance classes, A and B (see Part 1, Section 4). Class A RTD's are allowed deviation of ±0.06 ohms (±0.15°C) at 0°C, while Class B sensors have a tolerance band of ±0.12 ohms (±0.3°C) at 0°C.

Because of the inherent precision and stability of these devices, they can be relied upon to remain within calibration for longer periods than thermocouples, and hence BS 1041 states that calibration checks on RTD's are required only where the greatest possible accuracy is required, or when overheating or other misuse is suspected. Nevertheless, remember that the tolerance stated still applies to the new, pristine sensor - not necessarily the device on your plant that was installed two years ago!

Overall Sheath Diameter											
mm	0.25	0.5	1.0	1.5	2.0	3.0	4.5	5.5*	6.0	8.0	10.8*
Inches	0.001	0.020	0.039	0.059	0.079	0.118	0.177	0.216	0.236	0.315	0.425
Response Time	0.015	0.025	0.15	0.3	0.4	0.8	1.4	4.0	3.0	5.5	9.0

Response times for these assemblies are governed by and vary with the environmental conditions of particular applications.
The following information refers to typical response times for assemblies with insulated junctions being plunged into boiling water from air at 20°C
The figures refer to the times taken for the thermocouple junctions to achieve 63.2% of this instantaneous step change.
For assemblies with grounded junctions the response times are approximately 50% of those listed.

** Thick Sheath Wall Type*

Table 7.1: *Calculating Response Times for Thermocouples*

Continued on page 54

Useful Additional Data for Thermocouple Thermometry

Metal Sheath and Protection Tubes for Thermocouples and Resistance Thermometers

Recommended operating temperatures; melting points and environmental operation characteristics.

Metal / Alloy	Maximum Operating Temperature °C	Melting Point °C	Sheath Environmental Operating Characteristics			Notes
			Oxidising	Reducing	Sulphurous	
Copper	150	1083	Fair	Good	Poor	Of all the common metals, it has the fastest response to change in temperature.
Brass	Composition dependent	Composition dependent	Poor	Fair	Poor	Suited to general purpose applications particularly light duty steam environments.
Aluminium	371	660	Fair	Fair	Fair	Lightweight and with good resistance to corrosion.
Monel*	538	1325	Good	Good	Fair	High strength and corrosion resistant. Suited to sulphuric acid and caustic solutions.
Mild Steel	550	1525	Poor	Poor	Poor	General purpose sheath with limited corrosion resistance.
Cupro Nickel 70/30	760	1230	Good	Fair	Fair	Good resistance to corrosive environments particularly under wet conditions.
Cast Iron	870	1535	Poor	Fair	Poor	Resistant to concentrated sulphuric and caustic solutions.
Stainless Steel AISI 304	900	1430	Good	Fair	Fair	Fair corrosion resistance over whole operating temperature range.
Stainless Steel AISI 316	900	1430	Good	Fair	Fair	Good corrosion resistance throughout operating temperature range.
Stainless Steel AISI 310	1100	1400	Good	Fair	Fair	Good resistance to oxidation but manipulation is then limited. Limit on high temperature strength.
Stainless Steel AISI 446	1150	1400	Very good	Good	Good	High resistance to oxidation and sulphurous attack. Limited high temperature strength.
Inconel 600*	1100	1400	Good	Fair	Poor	Has good resistance to oxidation and carburisation. Has good hot strength.
Incoloy 800*	1100	1370	Good	Fair	Good	Superior to Inconel for resistance to oxidation and attack by sulphurous compounds.
Hastelloy X*	1222	1300	Very good	Fair	Very good	Very resistant to attack by oxidation and sulphurous compounds.
Nicrobell B*	1250	1420	Very good	Very good	Poor	Good high temperature strength recommended for vacuum atmosphere. Best when used with type 'N' thermocouples.
Nicrobell D*	1250	1420	Very good	Very good	Fair	A high chromium alloy excelling in carburising environments.
Nickel	1260	1455	Good	Good	Poor	Resistant to attack by many chemicals.
Platinum	1677	1773	Very good	Poor	Fair	Extremely resistant to attack by oxidising atmospheres.
Niobium	1982	2497	Poor	Poor	Poor	Very high resistance to attack by many acids. Inert to many molten metals.
Molybdenum	2200	2620	Poor	Fair	Fair	Has very high corrosion resistance to metals.
Tantalum	2480	2996	Poor	Poor	Poor	Extremely ductile and corrosion resistant.

*Trade names

Conductor Gauge / Metric and Imperial Diameter Conversion Table

American Wire Gauge (AWG) Brown & Sharp (B & S)		Gauge Number	Standard Wire Gauge (SWG)	
Diameter Inches	Diameter mm		Diameter Inches	Diameter mm
0.1019	2.488	10	0.128	3.25
0.0907	2.304	11	0.116	2.95
0.0808	2.052	12	0.104	2.64
0.0720	1.829	13	0.092	2.34
0.0641	1.628	14	0.080	2.03
0.0571	1.450	15	0.072	1.83
0.0508	1.290	16	0.064	1.63
0.0453	1.151	17	0.056	1.42
0.0403	1.024	18	0.048	1.22
0.0359	0.912	19	0.040	1.02
0.0320	0.813	20	0.036	0.914
0.0284	0.724	21	0.032	0.813
0.0253	0.643	22	0.028	0.711
0.0226	0.574	23	0.024	0.610
0.0201	0.511	24	0.022	0.559
0.0179	0.455	25	0.020	0.508
0.0159	0.404	26	0.018	0.457
0.0142	0.361	27	0.0164	0.417
0.0126	0.320	28	0.0148	0.376
0.0113	0.287	29	0.0136	0.345
0.0100	0.254	30	0.0124	0.315
0.0089	0.226	31	0.0116	0.295
0.0080	0.203	32	0.0108	0.274
0.0071	0.180	33	0.0100	0.254
0.0063	0.160	34	0.0092	0.234
0.0056	0.142	35	0.0084	0.213
0.0050	0.127	36	0.0076	0.193
0.0045	0.114	37	0.0068	0.173
0.0040	0.102	38	0.0060	0.152
0.0035	0.090	39	0.0052	0.132
0.0031	0.079	40	0.0048	0.122
0.0028	0.071	41	0.0044	0.112
0.0025	0.063	42	0.0040	0.102
0.00220	0.056	43	0.0036	0.091
0.00200	0.051	44	0.0032	0.081
0.00176	0.045	45	0.0028	0.071
0.00157	0.040	46	0.0024	0.061
0.00140	0.036	47	0.0020	0.051
0.00124	0.031	48	0.0016	0.041

Power Series Expansions and Polynomials

For computer applications the following expressions are given for the commonly used thermocouple conductor combinations.
Resultant errors from their use will be less that the last significant digit as per the thermocouple reference tables included in this publication.

K

Temperature range

–270°C to 0°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 3.945 012 802 5 x 10^{1}
a_2 = 2.362 237 359 8 x 10^{-2}
a_3 = –3.285 890 678 4 x 10^{-4}
a_4 = –4.990 482 877 7 x 10^{-6}
a_5 = –6.750 905 917 3 x 10^{-8}
a_6 = –5.741 032 742 8 x 10^{-10}
a_7 = –3.108 887 289 4 x 10^{-12}
a_8 = –1.045 160 936 5 x 10^{-14}
a_9 = –1.988 926 687 8 x 10^{-17}
a_{10} = –1.632 269 748 6 x 10^{-20}

0°C to 1372°C

$$E = b_0 + \sum_{i=1}^{n} b_i (t_{90})^i + c_0 \exp[c_1 (t_{90} - 126.9686)^2] \ \mu V$$

where

b_0 = –1.760 041 368 6 x 10^{1}
b_1 = 3.892 120 497 5 x 10^{1}
b_2 = 1.855 877 003 2 x 10^{-2}
b_3 = –9.945 759 287 4 x 10^{-5}
b_4 = 3.184 094 571 9 x 10^{-7}
b_5 = –5.607 284 488 9 x 10^{-10}
b_6 = 5.607 505 905 9 x 10^{-13}
b_7 = –3.202 072 000 3 x 10^{-16}
b_8 = 9.715 114 715 2 x 10^{-20}
b_9 = –1.210 472 127 5 x 10^{-23}

c_0 = 1.185 976 x 10^{2}
c_1 = –1.183 432 x 10^{-4}

T

Temperature range

–270°C to 0°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 3.874 810 636 4 x 10^{1}
a_2 = 4.419 443 434 7 x 10^{-2}
a_3 = 1.184 432 310 5 x 10^{-4}
a_4 = 2.003 297 355 4 x 10^{-5}
a_5 = 9.013 801 955 9 x 10^{-7}
a_6 = 2.265 115 659 3 x 10^{-8}
a_7 = 3.607 115 420 5 x 10^{-10}
a_8 = 3.849 393 988 3 x 10^{-12}
a_9 = 2.821 352 192 5 x 10^{-14}
a_{10} = 1.425 159 477 9 x 10^{-16}
a_{11} = 4.876 866 228 6 x 10^{-19}
a_{12} = 1.079 553 927 0 x 10^{-21}
a_{13} = 1.394 502 706 2 x 10^{-24}
a_{14} = 7.979 515 392 7 x 10^{-28}

0°C to 400°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 3.874 810 636 4 x 10^{1}
a_2 = 3.329 222 788 0 x 10^{-2}
a_3 = 2.061 824 340 4 x 10^{-4}
a_4 = –2.188 225 684 6 x 10^{-6}
a_5 = 1.099 688 092 8 x 10^{-8}
a_6 = –3.081 575 877 2 x 10^{-11}
a_7 = 4.547 913 529 0 x 10^{-14}
a_8 = –2.751 290 167 3 x 10^{-17}

J

Temperature range

–210°C to 760°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 5.038 118 781 5 x 10^{1}
a_2 = 3.047 583 693 0 x 10^{-2}
a_3 = –8.568 106 572 0 x 10^{-5}
a_4 = 1.322 819 529 5 x 10^{-7}
a_5 = –1.705 295 833 7 x 10^{-10}
a_6 = 2.094 809 069 7 x 10^{-13}
a_7 = –1.253 839 533 6 x 10^{-16}
a_8 = 1.563 172 569 7 x 10^{-20}

760°C to 1200°C

$$E = \sum_{i=0}^{n} a_i (t_{90})^i \ \mu V$$

where

a_0 = 2.964 562 568 1 x 10^{5}
a_1 = –1.497 612 778 6 x 10^{3}
a_2 = 3.178 710 392 4
a_3 = –3.184 768 670 1 x 10^{-3}
a_4 = 1.572 081 900 4 x 10^{-6}
a_5 = –3.069 136 905 6 x 10^{-10}

N

Temperature range

–270°C to 0°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 2.615 910 596 2 x 10^{1}
a_2 = 1.095 748 422 8 x 10^{-2}
a_3 = –9.384 111 155 4 x 10^{-5}
a_4 = –4.641 203 975 9 x 10^{-8}
a_5 = –2.630 335 771 6 x 10^{-9}
a_6 = –2.265 343 800 3 x 10^{-11}
a_7 = –7.608 930 079 1 x 10^{-14}
a_8 = –9.341 966 783 5 x 10^{-17}

0°C to 1300°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 2.592 939 460 1 x 10^{1}
a_2 = 1.571 014 188 0 x 10^{-2}
a_3 = 4.382 562 723 7 x 10^{-5}
a_4 = –2.526 116 979 4 x 10^{-7}
a_5 = 6.431 181 933 9 x 10^{-10}
a_6 = –1.006 347 151 9 x 10^{-12}
a_7 = 9.974 533 899 2 x 10^{-16}
a_8 = –6.086 324 560 7 x 10^{-19}
a_9 = 2.084 922 933 9 x 10^{-22}
a_{10} = –3.068 219 615 1 x 10^{-26}

E

Temperature range

–270°C to 0°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 5.866 550 870 8 x 10^{1}
a_2 = 4.541 097 712 4 x 10^{-2}
a_3 = –7.799 804 868 6 x 10^{-4}
a_4 = –2.580 016 084 3 x 10^{-5}
a_5 = –5.945 258 305 7 x 10^{-7}
a_6 = –9.321 405 866 7 x 10^{-9}
a_7 = –1.028 760 553 4 x 10^{-10}
a_8 = –8.037 012 362 1 x 10^{-13}
a_9 = –4.397 949 739 1 x 10^{-15}
a_{10} = –1.641 477 635 5 x 10^{-17}
a_{11} = –3.967 361 951 6 x 10^{-20}
a_{12} = –5.582 732 872 1 x 10^{-23}
a_{13} = –3.465 784 201 3 x 10^{-26}

0°C to 1000°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 5.866 550 871 0 x 10^{1}
a_2 = 4.503 227 558 2 x 10^{-2}
a_3 = 2.890 840 721 2 x 10^{-5}
a_4 = –3.305 689 665 2 x 10^{-7}
a_5 = 6.502 440 327 0 x 10^{-10}
a_6 = –1.919 749 550 4 x 10^{-13}
a_7 = –1.253 660 049 7 x 10^{-15}
a_8 = 2.148 921 756 9 x 10^{-18}
a_9 = –1.438 804 178 2 x 10^{-21}
a_{10} = 3.596 089 948 1 x 10^{-25}

R

Temperature range

–50°C to 1064.18°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 5.289 617 297 65
a_2 = 1.391 665 897 82 x 10^{-2}
a_3 = –2.388 556 930 17 x 10^{-5}
a_4 = 3.569 160 010 63 x 10^{-8}
a_5 = –4.623 476 662 98 x 10^{-11}
a_6 = 5.007 774 410 34 x 10^{-14}
a_7 = –3.731 058 861 91 x 10^{-17}
a_8 = 1.577 164 823 67 x 10^{-20}
a_9 = –2.810 386 252 51 x 10^{-24}

1064.18°C to 1664.5°C

$$E = \sum_{i=0}^{n} a_i (t_{90})^i \ \mu V$$

where

a_0 = 2.951 579 253 16 x 10^{3}
a_1 = –2.520 612 513 32
a_2 = 1.595 645 018 65 x 10^{-2}
a_3 = –7.640 859 475 76 x 10^{-6}
a_4 = 2.053 052 910 24 x 10^{-9}
a_5 = –2.933 596 681 73 x 10^{-13}

1664.5°C to 1768.1°C

$$E = \sum_{i=0}^{n} a_i (t_{90})^i \ \mu V$$

where

a_0 = 1.522 321 182 09 x 10^{5}
a_1 = –2.688 198 885 45 x 10^{2}
a_2 = 1.712 802 804 71 x 10^{-1}
a_3 = –3.458 957 064 53 x 10^{-5}
a_4 = –9.346 339 710 46 x 10^{-12}

S

Temperature range

–50°C to 1064.18°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = 5.403 133 086 31
a_2 = 1.259 342 897 40 x 10^{-2}
a_3 = –2.324 779 686 89 x 10^{-5}
a_4 = 3.220 288 230 36 x 10^{-8}
a_5 = –3.314 651 963 89 x 10^{-11}
a_6 = 2.557 442 517 86 x 10^{-14}
a_7 = –1.250 688 713 93 x 10^{-17}
a_8 = 2.714 431 761 45 x 10^{-21}

1064.18°C to 1664.5°C

$$E = \sum_{i=0}^{n} a_i (t_{90})^i \ \mu V$$

where

a_0 = 1.329 004 440 85 x 10^{3}
a_1 = 3.345 093 113 44
a_2 = 6.548 051 928 18 x 10^{-3}
a_3 = –1.648 562 592 09 x 10^{-6}
a_4 = 1.299 896 051 74 x 10^{-11}

1664.5°C to 1768.1°C

$$E = \sum_{i=0}^{n} a_i (t_{90})^i \ \mu V$$

where

a_0 = 1.466 282 326 36 x 10^{5}
a_1 = –2.584 305 167 52 x 10^{2}
a_2 = 1.636 935 746 41 x 10^{-1}
a_3 = –3.304 390 469 87 x 10^{-5}
a_4 = –9.432 236 906 12 x 10^{-12}

B

Temperature range

0°C to 630.615°C

$$E = \sum_{i=1}^{n} a_i (t_{90})^i \ \mu V$$

where

a_1 = –2.465 081 834 6 x 10^{-1}
a_2 = 5.904 042 117 1 x 10^{-3}
a_3 = –1.325 793 163 6 x 10^{-6}
a_4 = 1.566 829 190 1 x 10^{-9}
a_5 = –1.694 452 924 0 x 10^{-12}
a_6 = 6.299 034 709 4 x 10^{-16}

630.615°C to 1820°C

$$E = \sum_{i=0}^{n} a_i (t_{90})^i \ \mu V$$

where

a_0 = –3.893 816 862 1 x 10^{3}
a_1 = 2.857 174 747 0 x 10^{1}
a_2 = –8.488 510 478 5 x 10^{-2}
a_3 = 1.578 528 016 4 x 10^{-4}
a_4 = –1.683 534 486 4 x 10^{-7}
a_5 = 1.110 979 401 3 x 10^{-10}
a_6 = –4.451 543 103 3 x 10^{-14}
a_7 = 9.897 564 082 1 x 10^{-18}
a_8 = –9.379 133 028 9 x 10^{-22}

°C/°F Conversion Table

Conversion Method

$$°C = \frac{(°F - 32)}{1.8}$$

$$°F = 1.8\ °C + 32$$

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
–40	–40.0	0	+ 32.0	+ 30	+ 86.0	+ 100	+ 212	+ 250	+ 482	+ 400	+ 752	+ 1000	+ 1832
–38	–36.4	+ 1	33.8	31	87.8	105	221	255	491	405	761	1050	1922
–36	–32.8	2	35.6	32	89.6	110	230	260	500	410	770	1100	2012
–34	–29.2	3	37.4	33	91.4	115	239	265	509	415	779	1150	2102
–32	–25.6	4	39.2	34	93.2	120	248	270	518	420	788	1200	2192
–30	–22.0	5	41.0	35	95.0	125	257	275	527	425	797	1250	2282
–28	–18.4	6	42.8	36	96.8	130	266	280	536	430	806	1300	2372
–26	–14.8	7	44.6	37	98.6	135	275	285	545	435	815	1350	2462
–24	–11.2	8	46.4	38	100.4	140	284	290	554	440	824	1400	2552
–22	– 7.6	9	48.2	39	102.2	145	293	295	563	445	833	1450	2642
–20	– 4.0	10	50.0	40	104.0	150	302	300	572	450	842	1500	2732
–19	– 2.2	11	51.8	41	105.8	155	311	305	581	455	851	1550	2822
–18	– 0.4	12	53.6	42	107.6	160	320	310	590	460	860	1600	2912
–17	+ 1.4	13	55.4	43	109.4	165	329	315	599	465	869	1650	3002
–16	3.2	14	57.2	44	111.2	170	338	320	608	470	878	1700	3092
–15	5.0	15	59.0	45	113.0	175	347	325	617	475	887	1750	3182
–14	6.8	16	60.8	46	114.8	180	356	330	626	480	896	1800	3272
–13	8.6	17	62.6	47	116.6	185	365	335	635	485	905	1850	3362
–12	10.4	18	64.4	48	118.4	190	374	340	644	490	914	1900	3452
–11	12.2	19	66.2	49	120.2	195	383	345	653	495	923	1950	3542
–10	14.0	20	68.0	50	122	200	392	350	662	500	932	2000	3632
– 9	15.8	21	69.8	55	131	205	401	355	671	550	1022	2050	3722
– 8	17.6	22	71.6	60	140	210	410	360	680	600	1112	2100	3812
– 7	19.4	23	73.4	65	149	215	419	365	689	650	1202	2150	3902
– 6	21.2	24	75.2	70	158	220	428	370	698	700	1292	2200	3992
– 5	23.0	25	77.0	75	167	225	437	375	707	750	1382	2250	4082
– 4	24.8	26	78.8	80	176	230	446	380	716	800	1472	2300	4172
– 3	26.6	27	80.6	85	185	235	455	385	725	850	1562	2350	4262
– 2	28.4	28	82.4	90	194	240	464	390	734	900	1652	2400	4352
– 1	30.2	29	84.2	95	203	245	473	395	743	950	1742	2450	4442

Metric / Imperial Conversion Factors

To convert	Multiply by
Feet to Metres	X 0.3048
Metres to Feet	X 3.2809
Inches to Millimetres	X 25.4
Millimetres to Inches	X 0.03937
$Inches^2$ to $Millimetres^2$	X 645.2
$Millimetres^2$ to $Inches^2$	X 0.00155
Pounds to Kilograms	X 0.4536
Kilograms to Pounds	X 2.205

100 Metres = 328.1 Feet
100 Feet = 30.48 Metres

Resistance in Ohms / Metre* of the Common Thermocouple Extension and Compensating Cables Combinations

	Conductor dia.	K	KCB	T	J	N	E	R	S	RCA/B SCA/B	B	GC(W)	DC(W3)	CC(W5)
Solid Conductors	1/0.2mm	31.8	16.2	16.2	19.1	43.6	38.5	10.5	10.2	2.2	12.4	10.8	12.1	12.7
	1/0.3mm	14.1	7.2	7.2	8.5	19.4	17.1	4.7	4.5	1.0	5.5	4.8	5.4	5.7
	1/0.5mm	5.1	2.6	2.6	3.1	7.0	6.2	1.7	1.6	0.4	2.0	1.7	1.9	2.0
	1/0.8mm	2.0	1.0	1.0	1.2	2.7	2.4	–	–	0.1	–	–	–	–
	1/1.29mm	0.8	0.4	0.4	0.5	1.0	0.9	–	–	0.05	–	–	–	–
Stranded Conductors	7/0.2mm	4.5	2.3	2.3	2.7	6.2	5.5	–	–	0.3	–	–	–	–
	14/0.2mm	2.3	1.2	1.2	1.4	3.1	2.8	–	–	0.2	–	–	–	–
	16/0.2mm	2.0	1.0	1.0	1.2	2.7	2.4	–	–	0.1	–	–	–	–
	24/0.2mm	1.3	0.7	0.7	0.8	1.8	1.6	–	–	0.1	–	–	–	–
	32/0.2mm	1.0	0.5	0.5	0.6	1.4	1.2	–	–	0.07	–	–	–	–
	40/0.2mm	0.8	0.4	0.4	0.5	1.1	1.0	–	–	0.06	–	–	–	–
	7/0.3mm	2.0	1.0	1.0	1.2	2.7	2.4	–	–	0.1	–	–	–	–
	3/0.91mm	0.5	0.3	0.3	0.3	0.7	0.6	–	–	0.04	–	–	–	–

To obtain loop resistances for twin runs per metre take the constants given below for the required combination and divide the constant by the cross sectional area in mm^2 of the conductor size you intend to use.
K = 1.00, KCB = 0.51, T = 0.51, J = 0.60, E = 1.21, N = 1.37, R = 0.33, S = 0.72,
B = 0.39, RCA, RCB, SCA and SCB = 0.07, GC = 0.34, DC = 0.38 and CC = 0.40.

* At 20°C

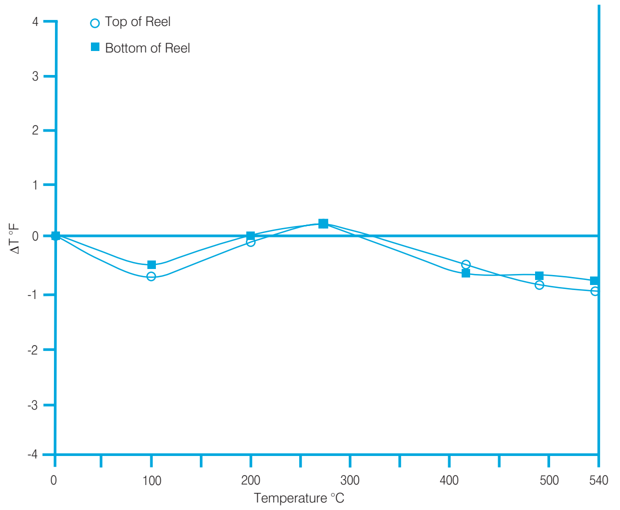


Figure 8.1: *Calibration of Glass Insulated Thermocouple at Top and Bottom Ends of the Reel*

When it comes to RTD degradation, however, inaccuracies can result from a range of causes. Principal among these are chemical attack (due to oxidation and poisoning) and strain, inducing metallurgical changes. Other sources of error can include shock and vibration, reduced insulation resistance creating parallel electrical paths, thermoelectric effects (normally due to incorrect installation using incompatible connection materials) and unequal resistance in the RTD leads (itself resulting from, say, chemical and mechanical degradation), causing incorrect lead wire compensation.

Drift testing has been carried out at various institutions at various times - some rigorous, some not so. An example involved 12 manufacturers' donated sensors. Process cycling conditions were simulated with 126 RTD's over two years, and 66 thermocouples over six months. Of the RTD's: 63 decalibrated at the ice point by more than 0.1°C; 46 experienced calibration changes up to 1°C; and the remaining 17 showed large changes (three more than 25°C) or failed (five). As for the thermocouples, all decalibrated by at least 1.4°C at one of their calibration temperatures, and the greatest was 9.9°C. No predictability could be found.

8.1 Higher Accuracy

For best accuracy, therefore, calibration of the measurement emf (thermocouples) or resistance (RTD's) produced against temperature is recommended. Although not normally necessary for RTD's, this should be carried out for new thermocouples if the quoted tolerances are not adequate, bearing in mind the above statements. Meanwhile, in-service thermocouples should be calibrated every six months to one year, depending upon the equipment, the environment and the accuracy required. Whether this is carried out at a few fixed temperatures, or at several points over the full working range of the sensor, depends upon your intended usage. But, in both cases a curve can be fitted through the calibration points such that a calibration table covering differences, and thus corrections, can be put together.

Calibration is generally carried out in a calibration laboratory by comparison against a stable standard thermometer (whether liquid in glass, platinum resistance thermometer, or radiation pyrometer) traceable to ITS-90 primary standards. As for how you go about actually performing the calibration, this is best left to the commercial calibration laboratories. However, as a brief guide, read on.

Choice of technique depends primarily on the temperature range concerned. Over the range -150°C to +250°C stirred liquid baths are preferred (acetone, water or oil). Then, up to 550°C, salt baths are commonly employed (sodium nitrite and potassium nitrate). In both cases platinum resistance thermometers offer the best reference bet, although some laboratories do occasionally use silver-palladium thermocouples over the range 100 - 600°C. Fluidised sand baths can also be used for temperatures from near ambient to 600°C, or even up to 1,000°C. Above 600°C metal-lined (nickel usually, to reduce temperature gradients) horizontal tube furnaces are harnessed along with platinum-rhodium thermocouple standards, or above 1,100°C, radiation pyrometers.

Providing an alternative to these comparison techniques, platinum-rhodium thermocouples can be calibrated against fixed points (freezing points of zinc, silver, gold and possibly aluminium), either using substantial ingots of the metals, or by allowing the materials whose melting point are being used to bridge the two wires of the thermocouple under test, and simply heating till they melt - observing the emfs. In all calibrations, it is essential to ensure that the real temperature of the bath or furnace is being reached by the thermocouple under test. So adequate immersion must be ensured, and in the case of the larger industrial thermocouples and RTD's, these must be dismantled and removed from their protective tubes before calibration. Clearly, this is a problem for the larger mineral insulated varieties.

Where thermocouples are concerned, ice-water mixtures are best used for the reference junction (see Part 2, Section 5). And, where thermocouple extension cable is used (see Part 2, Section 3), this would be treated as a separate thermocouple for independent calibration over whatever limited range was deemed necessary.

An alternative to laboratory calibration is in-situ calibration. In the case of large furnace thermocouples, and in cases where thermocouples have been in use for some time and may no longer be homogenous, this is the most practical method. The same can be said of industrial RTD's. Essentially, a calibrated reference sensor is inserted alongside the device to be checked, and readings simply compared over the working range (see Section 8.4).

8.2 RTD Checks

As mentioned in Part 1, Section 4, the temperature-independent part of material resistance is affected by dislocations in its crystalline structure. Among the last stages of sensor manufacture, therefore, annealing is performed to remove these strain-induced defects. This increases the platinum α coefficient (purity) and reduces the resistance at 0°C (R_0). In practice, RTD stability is mainly governed by R_0 stability. Experience shows that the calibration constants are very unlikely to have changed appreciably if R_0 is unchanged. So it is this value that is best checked periodically with RTD's.

Increases in R_0 indicate one of three things. Firstly, there has been a strain-induced, residual resistance increase, which can be annealed out. Secondly, platinum oxidation has increased the resistivity of the wires, which can again be dealt with by heat treatment (about one hour at 450°C is normally adequate, and the oxidation dissociates back to platinum and oxygen above 550°C anyway). Thirdly, chemical contamination has occurred, in which case, re-calibration will be necessary.

In general, the accepted method for this determination is measurement of the resistance element value at the triple point of water. This leads directly to the resistance ratio for temperature, which is considerably more stable than the absolute value of resistance.

8.3 Achievable Accuracy

Depending upon the sensor involved, the temperature range, the calibration equipment itself and, let's face it, the aptitude of the user, there is quite a span of calibration accuracies achievable!

Rare metal thermocouples, Types R, S and B can be calibrated to ±0.3°C up to 1,100°C, or ±2°C up to 1,550°C. Meanwhile, base metal thermocouples, like Types K and N, can be calibrated to ±0.1°C over a range like -80°C to +100°C, but only to within a few degrees up to 1,000°C. Bear in mind, however, that at these higher temperatures, base metal thermocouples are inherently unstable. So, not only is it not worth calibrating to tremendous accuracy at these higher levels - it's also worth considering an alternative sensor - like a platinum based thermocouple.

As for RTD's, calibration can be to within a few hundredths or even thousandths of a degree over the range -200°C to +850°C even for industrial devices (and hundredths of a degree over the range -100°C to +500°C for some of the lower cost thin film sensors), and considerably better for laboratory style sensors. Meanwhile, stabilities of the order of ±0.01% over the full temperature range are common with industrial units, and down to at least ±0.005% over one year for wire wound partially supported devices.

8.4 Calibration Problems

Remembering that the output voltage of a thermocouple is actually developed in the regions of temperature gradient (see Part 1, Section 2), and that uniformity of the conductors is assumed throughout thermocouple thermometry, points us to the importance of regular calibration with this sensor type - and to some pitfalls to avoid if high accuracy is to be maintained. On the other hand, the fact that resistance thermometer detectors are stem sensitive (not tip) can also trip up the unaware when calibration is to be performed.

As described, calibration can be carried out either in a liquid bath or furnace, providing isothermal conditions in the working section to allow reference standard instruments to be used to determine each temperature value (see Figure 8.2). However, the temperature gradient is likely to be over a fairly limited length of the sensor being calibrated, the assumption being that the sensor characteristics are uniform throughout its length, and that the section in the temperature gradient is representative.

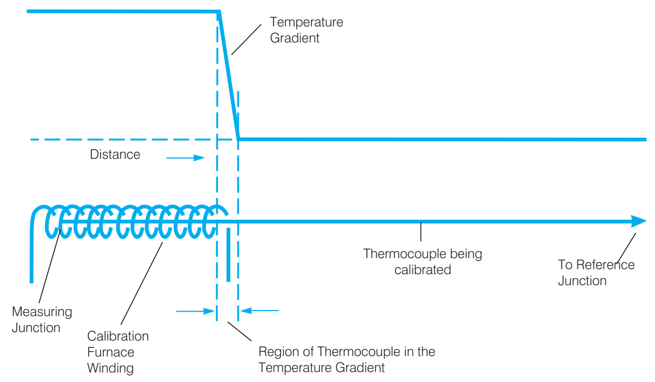


Figure 8.2: *Thermocouple Calibration Using a Furnace*

Whilst with a new, unused temperature sensor this is the case (and thus the calibration is valid for the full length) with older, used devices it could be a different story. Under operating conditions, like particularly high temperature, or aggressive environments, sensor and lead characteristics can change gradually with time and exposure (see Part 1, Sections 2.3 and 4).

If the length of a thermocouple, for example, in the heated region changes, the changed material inevitably extends into the temperature gradient, and the thermocouple output is modified even though all the junction temperatures remain constant. Hence the drift phenomenon (see Figure 8.3).

So, recalibrating such a thermocouple at a calibration facility is a useless exercise. And, the same applies to an RTD with similar ageing problems. It is inherently non-uniform, and the results will be entirely dependent upon the section of the sensor exposed to the calibrating temperatures. Deep or shallow immersion (in a bath), or insertion (in a furnace) will produce different data (Figure 8.4).

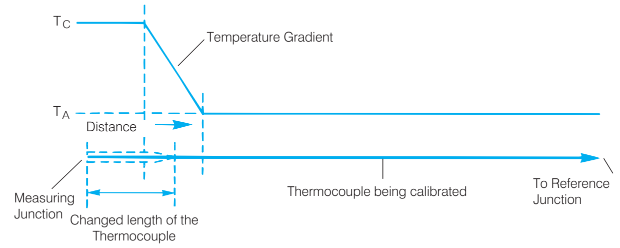


Figure 8.3: *The Effects of Time and Exposure on some Thermocouples*

Since it is clearly impossible to simulate the exact position and temperature gradient away from the operating environment, calibration could show no change, or conversely much greater changes, than those being experienced on site.

There are only two solutions to this dilemma. One is to replace the suspect sensor with a new calibrated device. In fact, base metal thermocouples in particular should be changed periodically anyway, before going too far out of calibration (incidentally, if the environment is severe enough, so should the protection tube, before it no longer provides protection - whether on thermocouples or RTD's). The other solution is to insert a known, transfer standard temperature sensor alongside the working sensor periodically, and to recalibrate it against this unit in-situ.

Continued on page 62

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Platinum Resistance Thermometry:

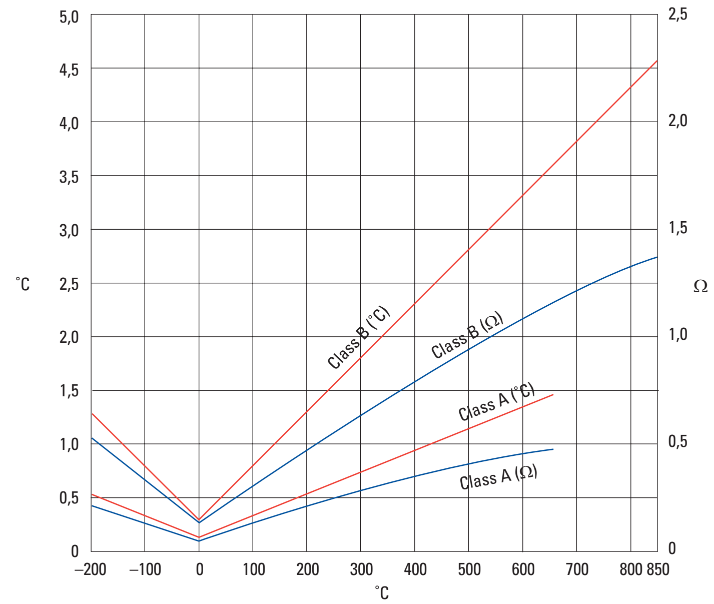
Resistance vs Temperature Relationship, Tolerances, Connection Schematics, Measuring Circuits

Resistance vs Temperature Relationship over the Range –200°C to +850°C for Platinum Resistance Thermometer Detector Elements

°C (t_{90})	0	1	2	3	4	5	6	7	8	9	°C (t_{90})
-200	18.52										-200
-190	22.83	22.40	21.97	21.54	21.11	20.68	20.25	19.82	19.38	18.95	-190
-180	27.10	26.67	26.24	25.82	25.39	24.97	24.54	24.11	23.68	23.25	-180
-170	31.34	30.91	30.49	30.07	29.64	29.22	28.80	28.37	27.95	27.52	-170
-160	35.54	35.12	34.70	34.28	33.86	33.44	33.02	32.60	32.18	31.76	-160
-150	39.72	39.31	38.89	38.47	38.05	37.64	37.22	36.80	36.38	35.96	-150
-140	43.88	43.46	43.05	42.63	42.22	41.80	41.39	40.97	40.56	40.14	-140
-130	48.00	47.59	47.18	46.77	46.36	45.94	45.53	45.12	44.70	44.29	-130
-120	52.11	51.70	51.29	50.88	50.47	50.06	49.65	49.24	48.83	48.42	-120
-110	56.19	55.79	55.38	54.97	54.56	54.15	53.75	53.34	52.93	52.52	-110
-100	60.26	59.85	59.44	59.04	58.63	58.23	57.82	57.41	57.01	56.60	-100
-90	64.30	63.90	63.49	63.09	62.68	62.28	61.88	61.47	61.07	60.66	-90
-80	68.33	67.92	67.52	67.12	66.72	66.31	65.91	65.51	65.11	64.70	-80
-70	72.33	71.93	71.53	71.13	70.73	70.33	69.93	69.53	69.13	68.73	-70
-60	76.33	75.93	75.53	75.13	74.73	74.33	73.93	73.53	73.13	72.73	-60
-50	80.31	79.91	79.51	79.11	78.72	78.32	77.92	77.52	77.12	76.73	-50
-40	84.27	83.87	83.48	83.08	82.69	82.29	81.89	81.50	81.10	80.70	-40
-30	88.22	87.83	87.43	87.04	86.64	86.25	85.85	85.46	85.06	84.67	-30
-20	92.16	91.77	91.37	90.98	90.59	90.19	89.80	89.40	89.01	88.62	-20
-10	96.09	95.69	95.30	94.91	94.52	94.12	93.73	93.34	92.95	92.55	-10
-0	100.00	99.61	99.22	98.83	98.44	98.04	97.65	97.26	96.87	96.48	-0
0	100.00	100.39	100.78	101.17	101.56	101.95	102.34	102.73	103.12	103.51	0
10	103.90	104.29	104.68	105.07	105.46	105.85	106.24	106.63	107.02	107.40	10
20	107.79	108.18	108.57	108.96	109.35	109.73	110.12	110.51	110.90	111.29	20
30	111.67	112.06	112.45	112.83	113.22	113.61	114.00	114.38	114.77	115.15	30
40	115.54	115.93	116.31	116.70	117.08	117.47	117.86	118.24	118.63	119.01	40
50	119.40	119.78	120.17	120.55	120.94	121.32	121.71	122.09	122.47	122.86	50
60	123.24	123.63	124.01	124.39	124.78	125.16	125.54	125.93	126.31	126.69	60
70	127.08	127.46	127.84	128.22	128.61	128.99	129.37	129.75	130.13	130.52	70
80	130.90	131.28	131.66	132.04	132.42	132.80	133.18	133.57	133.95	134.33	80
90	134.71	135.09	135.47	135.85	136.23	136.61	136.99	137.37	137.75	138.13	90
100	138.51	138.88	139.26	139.64	140.02	140.40	140.78	141.16	141.54	141.91	100
110	142.29	142.67	143.05	143.43	143.80	144.18	144.56	144.94	145.31	145.69	110
120	146.07	146.44	146.82	147.20	147.57	147.95	148.33	148.70	149.08	149.46	120
130	149.83	150.21	150.58	150.96	151.33	151.71	152.08	152.46	152.83	153.21	130
140	153.58	153.96	154.33	154.71	155.08	155.46	155.83	156.20	156.58	156.95	140
150	157.33	157.70	158.07	158.45	158.82	159.19	159.56	159.94	160.31	160.68	150
160	161.05	161.43	161.80	162.17	162.54	162.91	163.29	163.66	164.03	164.40	160
170	164.77	165.14	165.51	165.89	166.26	166.63	167.00	167.37	167.74	168.11	170
180	168.48	168.85	169.22	169.59	169.96	170.33	170.70	171.07	171.43	171.80	180
190	172.17	172.54	172.91	173.28	173.65	174.02	174.38	174.75	175.12	175.49	190
200	175.86	176.22	176.59	176.96	177.33	177.69	178.06	178.43	178.79	179.16	200
210	179.53	179.89	180.26	180.63	180.99	181.36	181.72	182.09	182.46	182.82	210
220	183.19	183.55	183.92	184.28	184.65	185.01	185.38	185.74	186.11	186.47	220
230	186.84	187.20	187.56	187.93	188.29	188.66	189.02	189.38	189.75	190.11	230
240	190.47	190.84	191.20	191.56	191.92	192.29	192.65	193.01	193.37	193.74	240
250	194.10	194.46	194.82	195.18	195.55	195.91	196.27	196.63	196.99	197.35	250
260	197.71	198.07	198.43	198.79	199.15	199.51	199.87	200.23	200.59	200.95	260
270	201.31	201.67	202.03	202.39	202.75	203.11	203.47	203.83	204.19	204.55	270
280	204.90	205.26	205.62	205.98	206.34	206.70	207.05	207.41	207.77	208.13	280
290	208.48	208.84	209.20	209.56	209.91	210.27	210.63	210.98	211.34	211.70	290
300	212.05	212.41	212.76	213.12	213.48	213.83	214.19	214.54	214.90	215.25	300
310	215.61	215.96	216.32	216.67	217.03	217.38	217.74	218.09	218.44	218.80	310
320	219.15	219.51	219.86	220.21	220.57	220.92	221.27	221.63	221.98	222.33	320

°C (t_{90})	0	1	2	3	4	5	6	7	8	9	°C (t_{90})
330	222.68	223.04	223.39	223.74	224.09	224.45	224.80	225.15	225.50	225.85	330
340	226.21	226.56	226.91	227.26	227.61	227.96	228.31	228.66	229.02	229.37	340
350	229.72	230.07	230.42	230.77	231.12	231.47	231.82	232.17	232.52	232.87	350
360	233.21	233.56	233.91	234.26	234.61	234.96	235.31	235.66	236.00	236.35	360
370	236.70	237.05	237.40	237.74	238.09	238.44	238.79	239.13	239.48	239.83	370
380	240.18	240.52	240.87	241.22	241.56	241.91	242.26	242.60	242.95	243.29	380
390	243.64	243.99	244.33	244.68	245.02	245.37	245.71	246.06	246.40	246.75	390
400	247.09	247.44	247.78	248.13	248.47	248.81	249.16	249.50	249.85	250.19	400
410	250.53	250.88	251.22	251.56	251.91	252.25	252.59	252.93	253.28	253.62	410
420	253.96	254.30	254.65	254.99	255.33	255.67	256.01	256.35	256.70	257.04	420
430	257.38	257.72	258.06	258.40	258.74	259.08	259.42	259.76	260.10	260.44	430
440	260.78	261.12	261.46	261.80	262.14	262.48	262.82	263.16	263.50	263.84	440
450	264.18	264.52	264.86	265.20	265.53	265.87	266.21	266.55	266.89	267.22	450
460	267.56	267.90	268.24	268.57	268.91	269.25	269.59	269.92	270.26	270.60	460
470	270.93	271.27	271.61	271.94	272.28	272.61	272.95	273.29	273.62	273.96	470
480	274.29	274.63	274.96	275.30	275.63	275.97	276.30	276.64	276.97	277.31	480
490	277.64	277.98	278.31	278.64	278.98	279.31	279.64	279.98	280.31	280.64	490
500	280.98	281.31	281.64	281.98	282.31	282.64	282.97	283.31	283.64	283.97	500
510	284.30	284.63	284.97	285.30	285.63	285.96	286.29	286.62	286.95	287.29	510
520	287.62	287.95	288.28	288.61	288.94	289.27	289.60	289.93	290.26	290.59	520
530	290.92	291.25	291.58	291.91	292.24	292.56	292.89	293.22	293.55	293.88	530
540	294.21	294.54	294.86	295.19	295.52	295.85	296.18	296.50	296.83	297.16	540
550	297.49	297.81	298.14	298.47	298.80	299.12	299.45	299.78	300.10	300.43	550
560	300.75	301.08	301.41	301.73	302.06	302.38	302.71	303.03	303.36	303.69	560
570	304.01	304.34	304.66	304.98	305.31	305.63	305.96	306.28	306.61	306.93	570
580	307.25	307.58	307.90	308.23	308.55	308.87	309.20	309.52	309.84	310.16	580
590	310.49	310.81	311.13	311.45	311.78	312.10	312.42	312.74	313.06	313.39	590
600	313.71	314.03	314.35	314.67	314.99	315.31	315.64	315.96	316.28	316.60	600
610	316.92	317.24	317.56	317.88	318.20	318.52	318.84	319.16	319.48	319.80	610
620	320.12	320.43	320.75	321.07	321.39	321.71	322.03	322.35	322.67	322.98	620
630	323.30	323.62	323.94	324.26	324.57	324.89	325.21	325.53	325.84	326.16	630
640	326.48	326.79	327.11	327.43	327.74	328.06	328.38	328.69	329.01	329.32	640
650	329.64	329.96	330.27	330.59	330.90	331.22	331.53	331.85	332.16	332.48	650
660	332.79	333.11	333.42	333.74	334.05	334.36	334.68	334.99	335.31	335.62	660
670	335.93	336.25	336.56	336.87	337.18	337.50	337.81	338.12	338.44	338.75	670
680	339.06	339.37	339.69	340.00	340.31	340.62	340.93	341.24	341.56	341.87	680
690	342.18	342.49	342.80	343.11	343.42	343.73	344.04	344.35	344.66	344.97	690
700	345.28	345.59	345.90	346.21	346.52	346.83	347.14	347.45	347.76	348.07	700
710	348.38	348.69	348.99	349.30	349.61	349.92	350.23	350.54	350.84	351.15	710
720	351.46	351.77	352.08	352.38	352.69	353.00	353.30	353.61	353.92	354.22	720
730	354.53	354.84	355.14	355.45	355.76	356.06	356.37	356.67	356.98	357.28	730
740	357.59	357.90	358.20	358.51	358.81	359.12	359.42	359.72	360.03	360.33	740
750	360.64	360.94	361.25	361.55	361.85	362.16	362.46	362.76	363.07	363.37	750
760	363.67	363.98	364.28	364.58	364.89	365.19	365.49	365.79	366.10	366.40	760
770	366.70	367.00	367.30	367.60	367.91	368.21	368.51	368.81	369.11	369.41	770
780	369.71	370.01	370.31	370.61	370.91	371.21	371.51	371.81	372.11	372.41	780
790	372.71	373.01	373.31	373.61	373.91	374.21	374.51	374.81	375.11	375.41	790
800	375.70	376.00	376.30	376.60	376.90	377.19	377.49	377.79	378.09	378.39	800
810	378.68	378.98	379.28	379.57	379.87	380.17	380.46	380.76	381.06	381.35	810
820	381.65	381.95	382.24	382.54	382.83	383.13	383.42	383.72	384.01	384.31	820
830	384.60	384.90	385.19	385.49	385.78	386.08	386.37	386.67	386.96	387.25	830
840	387.55	387.84	388.14	388.43	388.72	389.02	389.31	389.60	389.90	390.19	840
850	390.48										850

Tolerance values for 100 ohm elements, 38.5 Ohm Fundamental Interval



Temperature °C	Tolerance IEC 60751:2008 (BS EN 60751)			
	Class A		Class B	
	± °C	± Ohms	± °C	± Ohms
–200	0.55	0.24	1.3	0.56
–100	0.35	0.14	0.8	0.32
0	0.15	0.06	0.3	0.12
100	0.35	0.13	0.8	0.30
200	0.55	0.20	1.3	0.48
300	0.75	0.27	1.8	0.64
400	0.95	0.33	2.3	0.79
500	1.15	0.38	2.8	0.93
600	1.35	0.43	3.3	1.06
650	1.45	0.46	3.6	1.13
700	–	–	3.8	1.17
800	–	–	4.3	1.28
850	–	–	4.6	1.34

°C/°F Conversion Table

Conversion Method

$$°C = \frac{(°F - 32)}{1.8}$$

$$°F = 1.8\,°C + 32$$

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
–40	–40.0	0	+ 32.0	+ 30	+ 86.0	+ 100	+ 212	+ 250	+ 482	+ 400	+ 752	+ 1000	+ 1832
–38	–36.4	+ 1	33.8	31	87.8	105	221	255	491	405	761	1050	1922
–36	–32.8	2	35.6	32	89.6	110	230	260	500	410	770	1100	2012
–34	–29.2	3	37.4	33	91.4	115	239	265	509	415	779	1150	2102
–32	–25.6	4	39.2	34	93.2	120	248	270	518	420	788	1200	2192
–30	–22.0	5	41.0	35	95.0	125	257	275	527	425	797	1250	2282
–28	–18.4	6	42.8	36	96.8	130	266	280	536	430	806	1300	2372
–26	–14.8	7	44.6	37	98.6	135	275	285	545	435	815	1350	2462
–24	–11.2	8	46.4	38	100.4	140	284	290	554	440	824	1400	2552
–22	– 7.6	9	48.2	39	102.2	145	293	295	563	445	833	1450	2642
–20	– 4.0	10	50.0	40	104.0	150	302	300	572	450	842	1500	2732
–19	– 2.2	11	51.8	41	105.8	155	311	305	581	455	851	1550	2822
–18	– 0.4	12	53.6	42	107.6	160	320	310	590	460	860	1600	2912
–17	+ 1.4	13	55.4	43	109.4	165	329	315	599	465	869	1650	3002
–16	3.2	14	57.2	44	111.2	170	338	320	608	470	878	1700	3092
–15	5.0	15	59.0	45	113.0	175	347	325	617	475	887	1750	3182
–14	6.8	16	60.8	46	114.8	180	356	330	626	480	896	1800	3272
–13	8.6	17	62.6	47	116.6	185	365	335	635	485	905	1850	3362
–12	10.4	18	64.4	48	118.4	190	374	340	644	490	914	1900	3452
–11	12.2	19	66.2	49	120.2	195	383	345	653	495	923	1950	3542
–10	14.0	20	68.0	50	122	200	392	350	662	500	932	2000	3632
– 9	15.8	21	69.8	55	131	205	401	355	671	550	1022	2050	3722
– 8	17.6	22	71.6	60	140	210	410	360	680	600	1112	2100	3812
– 7	19.4	23	73.4	65	149	215	419	365	689	650	1202	2150	3902
– 6	21.2	24	75.2	70	158	220	428	370	698	700	1292	2200	3992
– 5	23.0	25	77.0	75	167	225	437	375	707	750	1382	2250	4082
– 4	24.8	26	78.8	80	176	230	446	380	716	800	1472	2300	4172
– 3	26.6	27	80.6	85	185	235	455	385	725	850	1562	2350	4262
– 2	28.4	28	82.4	90	194	240	464	390	734	900	1652	2400	4352
– 1	30.2	29	84.2	95	203	245	473	395	743	950	1742	2450	4442

Temperature / Resistance Relationships of Platinum Resistance Thermometers

The temperature/resistance relationships that should be used are as follows:

For the range –200°C to 0°C: $R_t = R_0\,[1 + At + Bt^2 + C(t - 100°C)\,t^3]$

For the range of 0°C to 850°C: $R_t = R_0\,[1 + At + Bt^2]$

For the quality of platinum commonly used for industrial resistance thermometers, the values of the constants in these equations are:

$A = 3.9083 \times 10^{-3}\ °C^{-1}$
$B = -5.775 \times 10^{-7}\ °C^{-2}$
$C = -4.183 \times 10^{-12}\ °C^{-4}$

For resistance thermometers satisfying the above relationships, the temperature coefficient *a*, defined as:

$$\alpha = \frac{R_{100} - R_0}{100 \times R_0}$$ has the value 0.003 85°C^{-1}

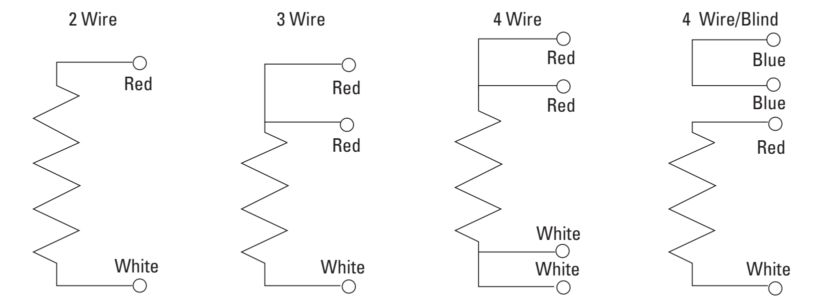
where

R_{100} is the resistance at 100°C; R_0 is the resistance at 0°C.
(For calculation purposes it is useful to use the exact value of 0.003 850 55°C^{-1}.)

These equations are given as the basis for the temperature/resistance tables as shown above and are based on the International Temperature Scale of 1990 (ITS-90) and BS EN 60751/IEC 60751:2008. They are not intended to be used for the calibration of individual sensors. The resistance values specified by the above equations do not include resistance of the leads between the sensing resistor and its terminations.

Typical Connection Schematics for 2, 3 and 4 wire Lead Configuration for Resistance Thermometer Detectors

There are generally four types of wiring schematics available as shown below for each element.

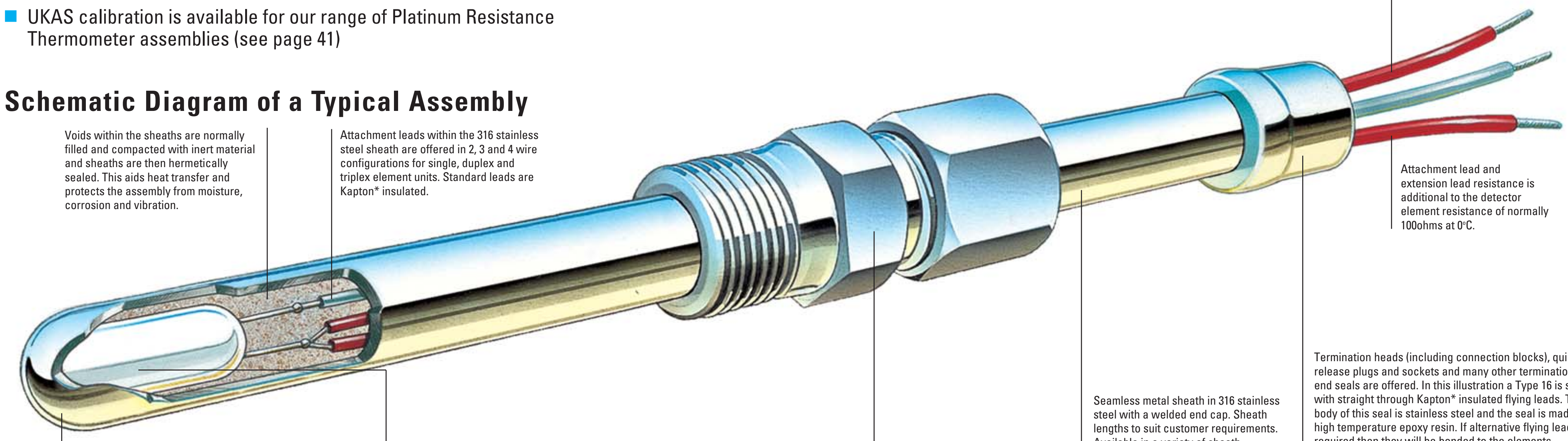


As per IEC 60751:2008 (BS EN 60751 : 1996)

TYPE 16 Platinum Resistance Thermometer Sensor Assemblies

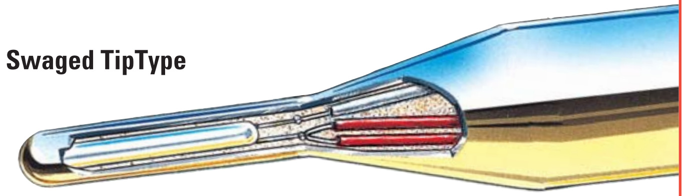
- High accuracy, repeatability and reproducibility as single, duplex and triplex element assemblies
- Low cost and prompt delivery
- Wide operating temperature range of -100°C to +350°C (Alternative operating temperature ranges available on request)
- Comprehensive range of diameters and end seal configurations with sheath lengths to suit customer requirements
- Available in 2, 3 and 4 wire configurations, with a wide range of sheath fittings
- UKAS calibration is available for our range of Platinum Resistance Thermometer assemblies (see page 41)
- Suited to industrial and general applications. These assemblies are supplied with seamless 316 Stainless Steel sheaths. They can be supplied with sheaths in: 310 Stainless Steel, Inconel 600*, Incoloy 800* and other metals on request. Sheaths can also be bonded with a variety of fluoroplastic claddings to suit particular corrosive environments
- Manufactured to IEC 60751:2008 (BS EN 60751 : 1996)
- Available complete with head mounting 4-20mA two wire transmitters if required

Schematic Diagram of a Typical Assembly



Quality Control. All materials and assemblies are subject to rigorous quality checks during manufacture through to final test and inspection in accordance with our approval to ISO 9001 : 2000.

Swaged TipType



Swaged end reduced tip temperature sensors provide a unique fast response, high strength, low displacement, homogenous solution to many problematical temperature measurement applications. The technique combines the two usually mutually exclusive advantages of having a very rugged large diameter metal sheath over most of its length with a low thermal mass, fast response, reduced diameter swaged tip, and with the transition from one to the other maintaining homogeneity and integrity.
See page 45 for further details.

Specifications and General Information

Detector elements	Type 16 general purpose platinum resistance thermometer detector assemblies embody, as standard, detector elements with a resistance of 100 ohms at 0°C with a fundamental interval 38.5 ohms to IEC 60751:2008 Class B (BS EN 60751 : 1996 Class B). Alternative element resistances and tolerances are available (see section 4). Single, duplex and triplex element assemblies are available.
Detector element Attachment Wire Configurations:	Assemblies are supplied with elements in 2, 3 or 4 wire configurations (In the case of 4 wire both compensated or blind loop wiring can be supplied).
Attachment Lead wires	Kapton* coated copper conductors are incorporated as standard. Normally 7/0.2 mm diameter conductors are used.
Sheath Materials	Standard sheaths with welded closed ends are of 316 stainless steel seamless tube. 316 stainless steel is an 18/8 chromium nickel stainless steel modified by the addition of molybdenum which serves to increase its general corrosion resistance and mechanical strength. Assemblies with sheaths in other materials can be supplied upon request. Standard sheath diameters are available between 2.0mm and 12.7mm. See Section 1. Other diameters including imperial sizes are available on request.
End Seals	A large range of termination options are available : (See section 3).
Extension Leads	Where extension leads are required they may be selected from those described overleaf on page 58. They are available in lengths to suit customer requirements. Leads are colour coded.
Operating Temperature Range	Standard Type 16 assemblies have an operating temperature range for the tip and stem of - 100°C to + 350°C with short term excursions to 375°C. End seals are not normally exposed to the tip and stem environment, and as standard are rated to those maximum temperatures listed in section 3. Assemblies with much wider tip, stem and seal operating temperature ranges are available (for details of these please contact the company).
Reduced Tips	For assemblies where maximised response is required, the majority of the standard constructions are available within a swaged reduced tip (See page 45).
Immersion	Minimum immersion length recommended for Type 16 assemblies is 60mm. For reduced immersions contact the company.
Response	Response times for these assemblies are governed by and vary with the environmental conditions of particular applications (contact the company giving details of your particular application).
Measurement Current	Recommended measurement current limit < 5mA.
Insulation resistance	Between the leads and sheath at 240 DC >100 Mohms at ambient temperature.
Standards	The manufacture of Type 16 platinum resistance thermometer assemblies is generally to IEC 60751:2008 (BS EN 60751.1996).

*Trade names

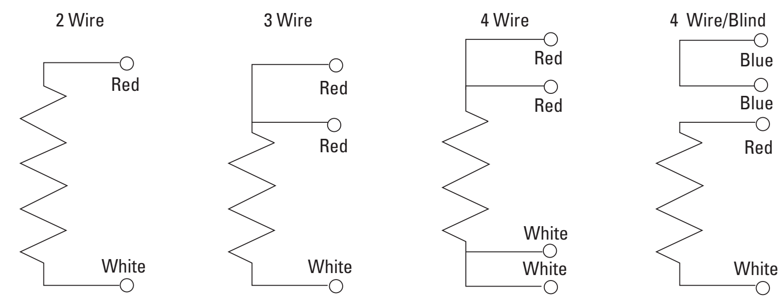
SECTION 1 Assembly Selector Table

Number of Elements	Wiring Configuration	Type Number for use as part of an Order Code*	Tube Diameter in Millimetres Available for each Type							
			2.0	2.38	3.0	4.5	6.0	8.0	10.0	12.7
1	2 WIRE	16 - 1 - DIA - 2	✓	✓	✓	✓	✓	✓	✓	✓
	3 WIRE	16 - 1 - DIA - 3	✓	✓	✓	✓	✓	✓	✓	✓
	4 WIRE	16 - 1 - DIA - 4	✓	✓	✓	✓	✓	✓	✓	✓
2	2 WIRE	16 - 2 - DIA - 2		✓	✓	✓	✓	✓	✓	✓
	3 WIRE	16 - 2 - DIA - 3			✓	✓	✓	✓	✓	✓
	4 WIRE	16 - 2 - DIA - 4					✓	✓	✓	✓
3	2 WIRE	16 - 3 - DIA - 2					✓	✓	✓	✓
	3 WIRE	16 - 3 - DIA - 3					✓	✓	✓	✓
	4 WIRE	16 - 3 - DIA - 4						✓	✓	✓

*Where 'DIA' is shown in the Type Number Box, the required diameter should be inserted.

SECTION 2 Wiring Configuration

There are generally four types of wiring schematics available as shown below for each element.



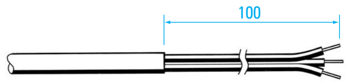
As per IEC 60751:2008 (BS EN 60751 : 1996)

SECTION 3

Type of End Seal Configuration

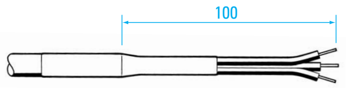
NB: When relevant, longer tails can be supplied on request.

CE1 SERIES



CE1

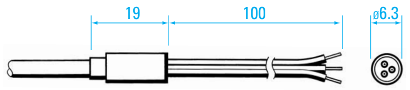
Internal epoxy resin seal supplied unless otherwise specified with 100mm long Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends).
Maximum end seal temperature rated to **135**°C.



CE1A

As CE1 but with an additional PTFE heatshrink sleeve. Length of sheath dimension is taken from where the sheath meets the heatshrink.
Maximum end seal temperature rated to **135**°C.
** CE1 series are not suitable for sheath diameters above 8mm.*
** CE1 series are not necessarily liquid or gas tight.*

CE2 SERIES



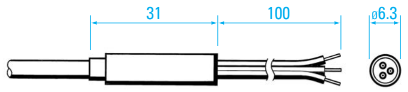
CE2

Crimp on stainless steel pot seal and supplied unless otherwise specified with 100mm long Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Seal potted with resin.
Maximum end seal temperature rated to **135**°C.

CE2A

As CE2 but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE2 series are not suitable for sheath diameters above 3mm.*

CE2L SERIES



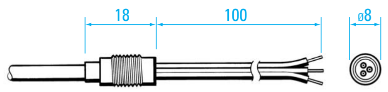
CE2L

As CE2 but with an overall length of 31mm.
Maximum end seal temperature rated to **135**°C.

CE2LA

As CE2L but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE2L series are not suitable for sheath diameters above 3mm.*

CE3 SERIES



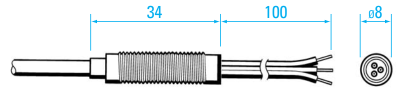
CE3

Crimp on stainless steel pot seal. Screwed 8mm x 1mm ISO and supplied unless otherwise specified with 100mm long Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Seal potted with resin.
Maximum end seal temperature rated to **135**°C.

CE3A

As CE3 but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** Lock nuts are available in stainless steel to suit CE3 series and should be ordered separately as LN08S.*
** CE3 series are not suitable for sheath diameters above 3mm.*

CE3L SERIES



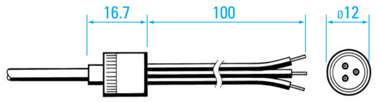
CE3L

As CE3 but with an overall length of 34mm.
Maximum end seal temperature rated to **135**°C.

CE3LA

As CE3L but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE3L pot seals are recommended for when additional flying leads are incorporated into the pot or when a longer threaded section is required.*
** Lock nuts are available in stainless steel to suit CE3L series and should be ordered separately as LN08S.*
** CE3L series are not suitable for sheath diameters above 3mm.*

CE4C SERIES



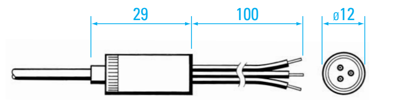
CE4C

Crimp on stainless steel pot seal and supplied unless otherwise specified with 100mm Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Potted with resin.
Maximum end seal temperature rated to **135**°C.

CE4CA

As CE4C but end potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE4C pot seals are not suitable for sheath diameters less than 3mm or more than 8mm.*

CE4CL SERIES



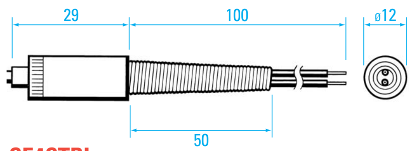
CE4CL

As CE4C but with the 16.7mm dimension extended to 29mm.
Maximum end seal temperature rated to **135**°C.

CE4CLA

As CE4CL but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C
** CE4CL pot seals are recommended for when additional flying leads are incorporated into the pot.*
** CE4CL pot seals are not suitable for sheath diameters less than 3mm or more than 8mm.*

CE4CTRL SERIES



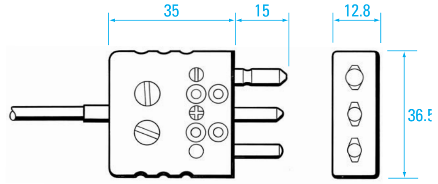
CE4CTRL

Crimp on stainless steel pot seal complete with an anti chafe support spring tension fitting and 100mm long (including spring fitting) Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Potted with resin.
Maximum end seal temperature rated to **135**°C.

CE4CTRLA

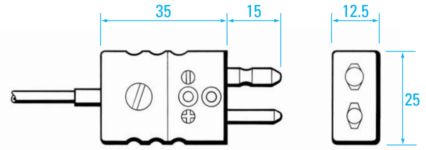
As CE4CTRL but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE4CTRL pot seals are most suited when additional flying leads are incorporated and it is unlikely that any benefit would be derived from specifying this type with the standard 100mm tails.*
** CE4CTRL pot seals are not suitable for sheath diameters less than 3mm or more than 8mm.*

CE6 SERIES



CE6

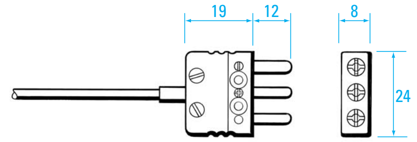
Standard 3 pin round plastic bodied quick disconnect plug for three wire assemblies only.
Maximum end seal temperature rated to **135**°C.



CE6A

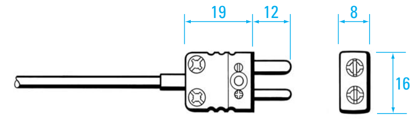
Standard 2 pin round plastic bodied quick disconnect plug for two wire assemblies only.
Maximum end seal temperature rated to **135**°C.
** For other configurations including 4 wire simplex and 2 or 3 wire duplex please contact the company for further details.*
** Mating sockets to suit the CE6 and CE6A are available and should be ordered separately. See pages 64/65 for further details.*
** CE6 series are not suitable for sheath diameters above 6mm.*

CE7 SERIES



CE7

Miniature 3 pin flat plastic bodied quick disconnect plug for three wire assemblies only.
Maximum end seal temperature rated to **135**°C.

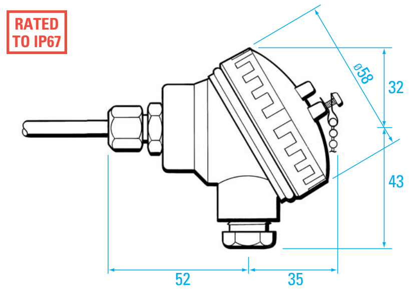


CE7A

Miniature 2 pin flat plastic bodied quick disconnect plug for two wire assemblies only.
Maximum end seal temperature rated to **135**°C.
** For other configurations including 4 wire simplex and 2 or 3 wire duplex please contact the company for further details.*
** Mating sockets to suit the CE7 and CE7A are available and should be ordered separately. See pages 64/65 for further details.*
** CE7 series are not suitable for sheath diameters above 3mm.*

CE10 Weatherproof die cast alloy head

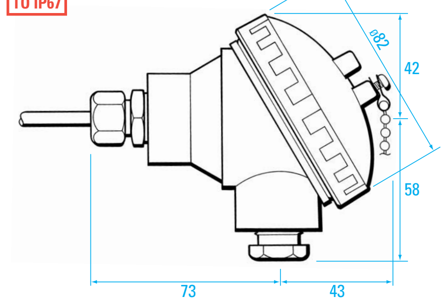
RATED TO IP67



Weatherproof die cast alloy, epoxy coated, screw top terminal head with the tube entry and cable entry at a right angle to each other, with a ceramic terminal block. Suitable for 2, 3 or 4 wire simplex assemblies or 2 wire duplex assemblies only. Supplied with a 16mm x 1.5mm ISO metal pinch gland on the cable entry for cables from 3mm to 8mm diameter.
** Suitable for use with all sheath diameters excluding 12.7mm.*

CE11 Weatherproof heavy duty die cast alloy head

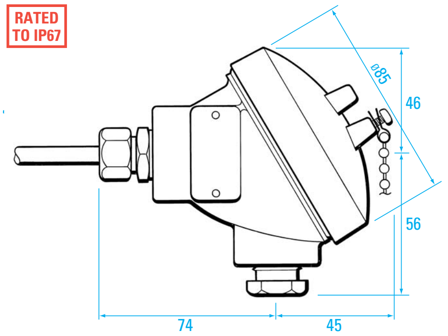
RATED TO IP67



Generally as CE10 but heavy duty version. Suitable for 2, 3 or 4 wire simplex assemblies or 2 or 3 wire duplex assemblies only. Supplied complete with 20mm x 1.5mm ISO metal pinch gland on cable entry for cables from 6mm to 14mm diameter.
** Not normally suitable for sheath diameters less than 6mm unless suitably supported.*

CE12 Weatherproof heavy duty cast iron head

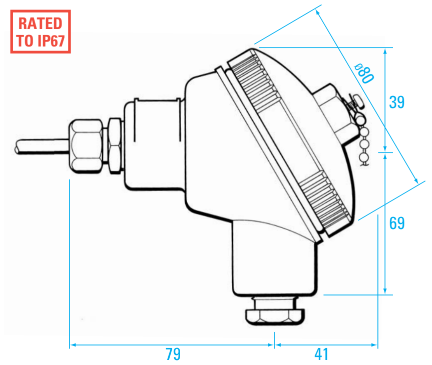
RATED TO IP67



Weatherproof cast iron screw top terminal head with the tube entry and cable entry at a right angle to each other. Suitable for 2, 3 or 4 wire simplex assemblies or 2 or 3 wire duplex assemblies only.
Supplied complete with 20mm x 1.5mm ISO pinch gland on cable entry for cables from 6mm to 14mm diameter.
** Not normally suitable for sheath diameters less than 6mm unless suitably supported.*

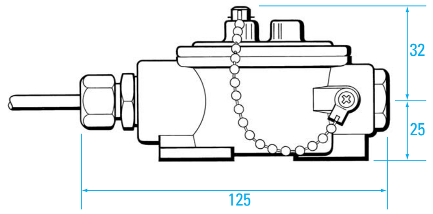
CE17 Weatherproof Bakelite head

RATED TO IP67



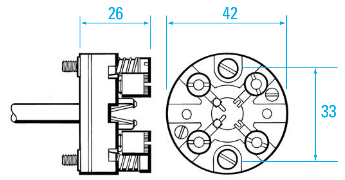
Weatherproof Bakelite plastic screw top terminal head with tube entry and cable entry at a right angle to each other with a Bakelite terminal block. Suitable for 2, 3 or 4 wire simplex assemblies or 2 or 3 wire duplex assemblies only. Supplied with a 20mm x 1.5mm ISO plastic pinch gland on the cable entry for cables from 6mm to 14mm diameter. Terminal head temperature rated to 150°C.
** A smaller version of this connection head is also available and is referred to as CE16.*
** Not normally suitable for sheath diameters less than 3mm unless suitably supported.*

CE18 Die cast alloy straight through head



Die cast alloy straight through terminal head with a bakelite terminal block. Suitable for simplex or duplex assemblies. Supplied with a 20mm x 1.5mm pitch ISO gland on the cable entry for cables from 6mm to 14mm diameter.
** If supported at fixing holes, suitable for diameters of 2mm and above.*

CE20



Spring loaded insert assembly. The end seal is incorporated into a terminal block suitable for mounting into a CE11, CE12, CE17 or any other standard terminal head. Suitable for use with 3mm, 4.5mm, 6mm and 8mm sheaths only. The ceramic terminal block has 2 x 33mm spaced mounting holes. (Previously called CE14C).

SECTION 4

Standard and Tolerance of Detector Element

Resistance Value of Element	Accuracy at 0°C	Accuracy at 100°C	Type Number for use as part of Order Code
100 ohms at 0°C	±0.30°C	±0.80°C	R100 – B
100 ohms at 0°C	±0.15°C	±0.35°C	R100 – A
100 ohms at 0°C	±0.10°C	±0.27°C	R100 – 1/3
100 ohms at 0°C	±0.06°C	±0.16°C	R100 – 1/5
100 ohms at 0°C	±0.03°C	±0.08°C	R100 – 1/10
130 ohms at 0°C	±0.30°C	±0.80°C	R130 – B

Details of detector element accuracies at other temperatures are available on request.

SECTION 5

Extension Leads

All assemblies with pot seals are generally supplied with 7/0.2 diameter Kapton* individually insulated leads as standard (ref. RK 17). However where leads are several metres or more long it may be more suitable to have an overall sheathed cable. Details of the other cables we offer are shown overleaf on Page 58.

SECTION 6

Compression Fittings

A full range of compression fittings is available to suit our Type 16 Platinum Resistance Thermometer Assemblies. See page 67 for further details.

SECTION 7

Reduced Tips

A range of swaged reduced tips are available.Typical reduced dimensions are as follows, however please see Page 45 for further details on swaging.

Starting Sheath Diameter	Reduced Tip Diameter and approximate length of Reduced Part
3.0mm	2.0mm x 20mm
4.5mm	3.0mm x 25mm
6.0mm	4.0mm x 25mm
8.0mm	6.0mm x 40mm
10.0mm	8.0mm x 40mm
12.7mm	8.0mm x 40mm

SECTION 8

Head Mounted Transmitters

A range of transmitters is available including standard, isolated, fully linearised, Ex and RFI versions. See page 69 for further details.

Ordering Code – Typical example

16 - 1 - 6.0 - 3 - 200 - CE4CL - R100 - B - 2Mtrs RP37 - ACF17S - -

- Type No.
- No. of detector elements per assembly (see section 1)
- Sheath diameter (see section 1)
- Wiring configuration (see section 2)
- Sheath length in mm*
- End seal termination (see section 3)
- Resistance value of detector element (see section 4)
- Standard and tolerance of detector element (see section 4)
- Extension leads if relevant and length required (see section 5)
- Adjustable compression fitting if required (see section 6)
- Reduced tip option if required (see section 7)
- Head mounted transmitter if required (see section 8)

*Please note that the sheath length is measured from the tip of the assembly to the nearest point on the end seal termination.

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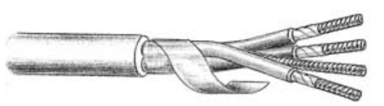
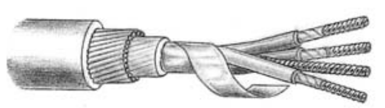
01895 252222

Interconnecting Leads and Cables for use with Platinum Resistance Thermometer Assemblies

The following leads and cables are suitable for connecting to our range of Type 16 (Standard) and Type 17 (Mineral Insulated) Platinum Resistance Thermometer assemblies. Some are quite small and are ideal for extending out of an assembly pot seal but can be unwieldy for longer runs. Others are more robust, offer greater mechanical strength and are more suited for extending out of an assembly connection head or for use in connecting to junction boxes. The types of end seals recommended for each cable are shown on the far right of this page.

Whilst some of these cables are suited for longer cable runs, our range of single and multipair instrumentation cable shown below on page 59 may be more suitable for such applications.

	Insulation	Stock Number	Conductors: No. of Strands	mm.	Inches	Total Area mm^2	Cores: No. of Cores	Insulation	Screen	Overall: Insulation	Insulation Rating °C: Continuous	Short Term	Colour Coding	Abrasion Resistance	Moisture Resistance	Typical Weight[3] Kg/100m (Excluding Reel)	Diameter Under Armour[3]	Diameter Over Armour[3]	Overall Diameter[3]	Suitable for use with the following end seals	Notes
One core of solid copper conductor Kapton* insulated.	Kapton*	RK12	1	.2	.008	.03	1	Kapton	No	–	–75 to +285	+400	No	Very Good	Very Good	<1	–	–	<1	CE1, CE2, CE2L, CE3, CE3L, CE4C, CE4CL and CE4CTRL	Single core fine wire. Not suitable for long runs. Formerly KAP 2 and KAP 3.
		RK13	1	.3	.012	.07	1	Kapton	No	–	–75 to +285	+400	No	Very Good	Very Good	<1	–	–	<1		
 One core of stranded copper conductors Kapton* insulated.	Kapton*	RK17	7	.2	.008	.22	1	Kapton	No	–	–75 to +285	+400	No	Very Good	Very Good	<1	–	–	<1	CE1, CE2, CE2L, CE3, CE3L, CE4C, CE4CL and CE4CTRL	Single core fine wire. Not suitable for long runs. Formerly KAP 7.
 Cores of stranded copper conductors. Each core Heat Resistant PVC insulated. The cores are bunched together. Nickel plated copper wire braided. Heat Resistant PVC insulated.	Heat Resistant PVC	RP37	7	.2	.008	.22	3	HR PVC	Yes[2]	HR PVC	–30 to +105	–	Yes	Good	Very Good	2	–	–	4	CE4CL, CE4CTRL, CE10, CE11, CE12, CE17 and CE18	Ideal for general use in normal ambient applications. (See also our range of Multi-Triads below). Rejects electromagnetic and electrostatic interference. Round section. Formerly RTD 'A'.
		RP47	7	.2	.008	.22	4	HR PVC	Yes[2]	HR PVC	–30 to +105	–	Yes	Good	Very Good	3	–	–	5		
		RP67	7	.2	.008	.22	6	HR PVC	Yes[2]	HR PVC	–30 to +105	–	Yes	Good	Very Good	4	–	–	6		
 Cores of stranded copper conductors. Each core PFA insulated. The cores are bunched together. Nickel plated copper wire braided. PFA insulated.	PFA	RT37	7	.2	.008	.22	3	PFA	Yes[2]	PFA	–75 to +250	+300	Yes	Very Good	Very Good	2	–	–	3	CE4CLA, CE4CTRLA & CE10. Also CE11, CE12, CE17 and CE18 with special gland	Gas, steam and water tight insulation. Rejects electromagnetic and electrostatic interference. Round section. Formerly RTD 'B'.
		RT47	7	.2	.008	.22	4	PFA	Yes[2]	PFA	–75 to +250	+300	Yes	Very Good	Very Good	2	–	–	3		
		RT67	7	.2	.008	.22	6	PFA	Yes[2]	PFA	–75 to +250	+300	Yes	Very Good	Very Good	3	–	–	4		
 Cores of stranded copper conductors. Each core PFA insulated. The cores are bunched together and silicone rubber insulated overall.	PFA/ Silicone Rubber	RS37	7	.2	.008	.22	3	PFA	No	SR	–40 to +200	–50 to +250	Yes	Good	Very Good	2	–	–	4	CE4CLA, CE4CTRLA & CE10. Also CE11, CE12, CE17 and CE18 with special gland	Flame Retardant. Round section.
		RS67	7	.2	.008	.22	6	PFA	No	SR	–40 to +200	–50 to +250	Yes	Good	Very Good	3	–	–	5		
 Cores of stranded copper conductors. Each conductor double glass fibre lapped, glass fibre braided and silicone varnished. The cores are bunched together, glass fibre braided overall and impregnated with silicone varnish. Overbraided with stainless steel wire.	Fibreglass	RF37	7	.2	.008	.22	3	Fibreglass	Yes[2]	Fibreglass	+480	+540	Yes	Good	Fair	2	–	–	3	CE4CLA, CE4CTRLA & CE10. Also CE11, CE12, CE17 and CE18 with special gland	Above 180°C the integrity of the cable is maintained to the upper insulation limit provided the cable is not flexed particularly when cold. Formerly FGSS.
		RF47	7	.2	.008	.22	4	Fibreglass	Yes[2]	Fibreglass	+480	+540	Yes	Good	Fair	3	–	–	4		
		RF67	7	.2	.008	.22	6	Fibreglass	Yes[2]	Fibreglass	+480	+540	Yes	Good	Fair	4	–	–	5		
 Cores of stranded copper conductors. Each core Mica glass taped and XLPE insulated. Cores bunched and overall screened with Mylar* aluminium tape in contact throughout by a bare copper drain wire. LSF sheathed.	MICA Glass / XLPE / LSF	RM37	7	.3	.012	.5	3	MICA and XLPE	Yes[1]	LSF	–30 to +75	+750	Yes	Good	Very Good	10	–	–	8	CE10, CE11, CE12, CE17 and CE18	Excellent for signal continuity in the event of a fire. Free of halogens. Rejects electromagnetic and electrostatic interference. Round section.
		RM67	7	.3	.012	.5	6	MICA and XLPE	Yes[1]	LSF	–30 to +75	+750	Yes	Good	Very Good	13	–	–	11		
 Cores of stranded copper conductors. Each core Mica glass taped and XLPE insulated. Cores bunched and overall screened with Mylar* aluminium tape in contact throughout by a bare copper drain wire. LSF sheathed. Steel wire armoured and LSF sheathed overall.	MICA Glass / XLPE / LSF	RM37/SWA	7	.3	.012	.5	3	MICA and XLPE	Yes[1]	LSF	–30 to +75	+750	Yes	Good	Very Good	32	8	10	13	CE11, CE12, CE17 and CE18	Excellent for signal continuity in the event of a fire. Free of halogens. Rejects electromagnetic and electrostatic interference. Armoured for mechanical strength. Round section.
		RM67/SWA	7	.3	.012	.5	6	MICA and XLPE	Yes[1]	LSF	–30 to +75	+750	Yes	Good	Very Good	50	11	13	16		

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These cables have a metal braid which can be used as a screen.
3. These values are nominal and if critical to your application, please request a physical check.

The above cables where applicable have cores which are colour coded in accordance with IEC 60751:2008 and BS EN 60751.
These cables are normally available from us for **immediate** delivery from stock.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.

Kapton and Mylar are all trade names.

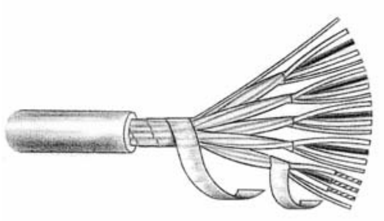
Ordering Code - Typical example

	RP37
Stock Number	⌟

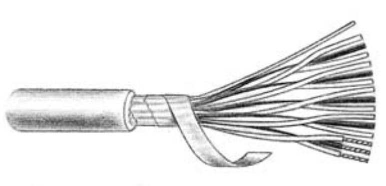
Instrument Cable

Multi Triad Cable suitable for Interconnecting 3 Wire Platinum Resistance Thermometer Assemblies

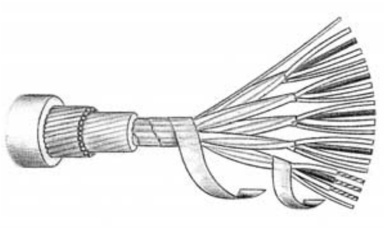
- These Multi Triads (3 cores per channel) are ideal for connecting Platinum Resistance Thermometer Assemblies to Instrumentation. They can also be used for other applications where 3 cores per channel is required
- These cables are manufactured generally in accordance with BS5308:1986
- Part 1 cables have Polyethylene insulated cores and our range is individually and collectively screened
- Part 2 cables have PVC insulated cores and our range is collectively screened only.
- These cables also meet the requirements of BS4066 Part 3/ IEC 60332.3 Category C covering test requirements on cables under fire conditions
- All cables incorporate a flame retardant sheath which has good properties for the reduced propagation of flame
- All cables are oversheathed in Black unless required for Intrinsically Safe applications where Blue should be specified. Core colours are two red and one white per triad



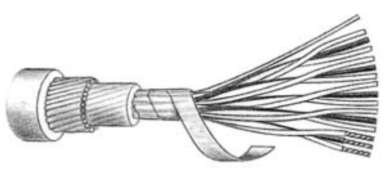
Single or multitriads of stranded 16/0.2mm dia conductors Polyethylene insulated. Triads numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Triads laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



Single or multitriads of stranded 16/0.2mm dia conductors PVC insulated. Triads numbered and twisted. Triads laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC sheathed.



Single or multitriads of stranded 16/0.2mm dia conductors Polyethylene insulated. Triads numbered, twisted and individually screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire. Triads laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and Polyethylene bedded. Steel wire armoured and FR PVC sheathed.



Single or multitriads of stranded 16/0.2mm dia conductors PVC insulated. Triads numbered and twisted. Triads laid up and overall screened with Mylar* aluminium tape in contact throughout with a bare tinned copper drainwire and FR PVC bedded. Steel wire armoured and FR PVC sheathed.

Stock Number	Conductors: No. of Strands	Size of Strand Diameter: mm.	Size of Strand Diameter: Inches	Gauge: SWG	Gauge: AWG	Total Area mm²	Insulation	Triads: No. of Triads	Laid-Flat or Twisted	Individual Screen¹	Overall: Insulation	Insulation Rating °C: Continuous	Short Term	Colour Coding	Overall Screen¹	Abrasion Resistance	Moisture Resistance	Typical Weight² Kg/100m (Excluding Reel)	Diameter Under Armour²	Diameter Over Armour²	Overall Diameter² (mm)	Glands: Recommended Gland Ref. (See page 35)	Notes
M5101	16	.2	.008	36	32	.5	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Part 1 Type 1.
M5102	16	.2	.008	36	32	.5	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	CONTACT TC LTD FOR FURTHER DETAILS				
M5105	16	.2	.008	36	32	.5	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5110	16	.2	.008	36	32	.5	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5120	16	.2	.008	36	32	.5	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5150	16	.2	.008	36	32	.5	PE	50	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		
M5201	16	.2	.008	36	32	.5	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Part 2 Type 1.
M5202	16	.2	.008	36	32	.5	PVC	2	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	CONTACT TC LTD FOR FURTHER DETAILS				
M5205	16	.2	.008	36	32	.5	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5210	16	.2	.008	36	32	.5	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5220	16	.2	.008	36	32	.5	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		
M5101/SWA	16	.2	.008	36	32	.5	PE	1	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		Individually and Collectively Screened. Polyethylene Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 1 Type 2.
M5102/SWA	16	.2	.008	36	32	.5	PE	2	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	CONTACT TC LTD FOR FURTHER DETAILS				
M5105/SWA	16	.2	.008	36	32	.5	PE	5	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5110/SWA	16	.2	.008	36	32	.5	PE	10	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5120/SWA	16	.2	.008	32	32	.5	PE	20	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5150/SWA	16	.2	.008	36	32	.5	PE	50	Twisted	Yes	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		
M5201/SWA	16	.2	.008	36	32	.5	PVC	1	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		Collectively Screened. PVC Cores. Flame Retardant PVC Sheath. Armoured for mechanical strength. Part 2 Type 2.
M5202/SWA	16	.2	.008	36	32	.5	PVC	2	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	CONTACT TC LTD FOR FURTHER DETAILS				
M5205/SWA	16	.2	.008	36	32	.5	PVC	5	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5210/SWA	16	.2	.008	36	32	.5	PVC	10	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–					
M5220/SWA	16	.2	.008	36	32	.5	PVC	20	Twisted	No	FR PVC	+75	–	Yes	Yes	Good	Very Good	–	–	–	–		

1. Aluminised Mylar* tape in contact throughout by a bare 7/0.3mm dia tinned copper drainwire.
2. These values are nominal and if critical to your application, please request a physical check.

These cables are normally available from us for **immediate** delivery from stock.
If you have any specific requirements regarding cable lengths please let us know so that we may make a satisfactory offer to meet your needs.
In Intrinsically Safe areas, the user must be the best judge as to the suitability of the selected cable and its use within that area. Users should refer to BS5345.

*Mylar is a trade name.

Ordering Code - Typical example

M5110 — BLUE

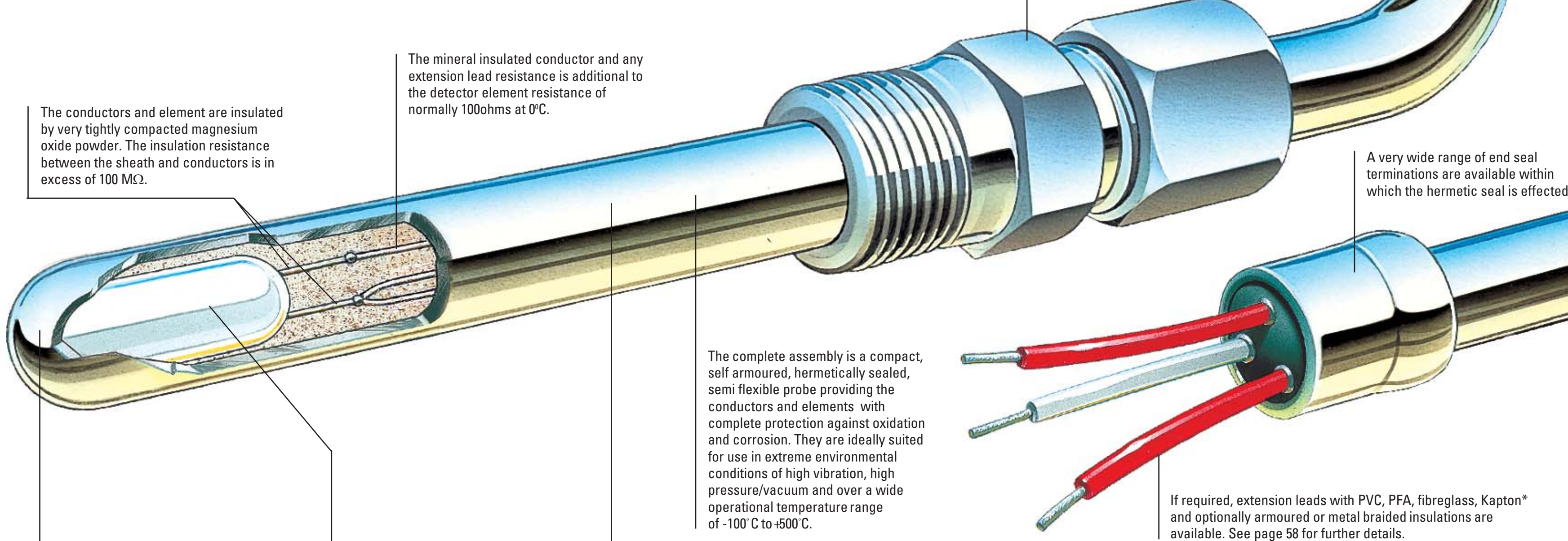
Stock Number: M5110
Colour Code (if other than black): BLUE

TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
Tel: +44 (0)1895 252222 - Fax: +44 (0)1895 273540
Email: info@tc.co.uk - Web: www.tc.co.uk

TYPE 17 Mineral Insulated Metal Sheathed Platinum Resistance Thermometer Assemblies

- High integrity construction suited to arduous operating conditions
- High accuracy, repeatability and reproducibility as single and duplex element assemblies
- Operating temperature range of -100°C to +500°C
- Fast response and high insulation resistance
- Sheaths can be bent, twisted and flattened to suit particular installations without impairing performance
- UKAS calibration is available for our range of Platinum Resistance Thermometer assemblies (see page 41)
- Prompt delivery
- Available in a variety of sheath diameters with sheath lengths to suit customer requirements from 200 millimetres to 200 metres or more. Sheaths can also be bonded with a variety of fluoroplastic claddings to suit particular corrosive environments
- Available in 2, 3 and 4 wire configurations, with a wide choice of end seal configurations and sheath fittings
- Manufactured to IEC 60751:2008 (BS EN 60751 : 1996)

Schematic Diagram of a Typical Assembly



NB. The sheaths of these assemblies have a nominal bending radius 12 times the sheath diameter. This can be reduced to 4 times the sheath diameter given the careful use of a mandrel and bending in one set. The sheath should not be bent or worked within 100mm of the tip of assembly.

Quality Control. All materials and assemblies are subject to rigorous quality checks during manufacture through to final test and inspection procedures. Facilities are also available for additional inspection including Radiography and Calibration Certification, etc.

Specifications and General Information

Detector elements	Type 17 general purpose platinum resistance thermometer sensor assemblies embody, as standard, detector elements with a resistance of 100 ohms at 0°C with a fundamental interval 38.5 ohms to IEC 60751:2008 class B (BS EN 60751 : 1996 Class B). Alternative element resistance and tolerances are available (see section 4). Single and duplex element assemblies are available.
Sheath Materials	Standard sheaths with welded closed ends are of 316 stainless steel seamless tube. 316 stainless steel is an 18/8 chromium nickel stainless steel modified by the addition of molybdenum which serves to increase its general corrosion resistance and mechanical strength. Assemblies with sheaths in other materials can be supplied upon request. Standard sheath diameters available are 3.0mm, 4.5mm, 6.0mm and 8.0mm. Other diameters including imperial sizes are available on request.
End Seal Configuration	A large range of termination options are available : See section 3.
Extension Leads	Where extension leads are required they may be selected from those described on page 58. They are available in lengths to suit customer requirements. Leads are colour coded.
Operating Temperature Range	Standard Type 17 assemblies have an operating temperature range for the tip and stem of - 100°C to + 500°C. End seals are not normally exposed to the tip and stem environment, and as standard are rated to those maximum temperatures listed in section 3. Assemblies with much wider tip, stem and seal operating temperature ranges are available (for details of these please contact the company).
Immersion	Minimum immersion length recommended for Type 17 assemblies is 60mm.
Response	Response times for Type 17 are governed by and vary with the environmental conditions of particular applications.
Measurement current	Recommended measurement current limit < 5mA.
Insulation Resistance	Between the leads and sheath at 240 DC >100 Mohms at ambient temperature.
Standards	The manufacture of Type 17 platinum resistance thermometer assemblies is generally to IEC 60751:2008 (BS EN 60751 : 1996).

*Trade names

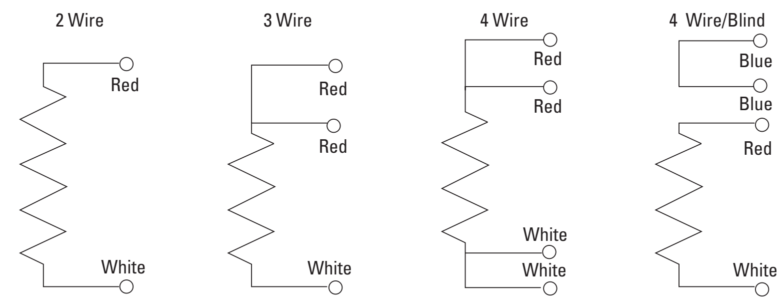
SECTION 1 Assembly Selector Table

Number of Elements	Wiring Configuration	Type Number for use as part of an Order Code*	Tube Diameter in Millimetres Available for each Type			
			3.0	4.5	6.0	8.0
1	2 WIRE	17 - 1 - DIA - 2	✓	✓	✓	✓
	3 WIRE	17 - 1 - DIA - 3	✓	✓	✓	✓
	4 WIRE	17 - 1 - DIA - 4		✓	✓	✓
2	2 WIRE	17 - 2 - DIA - 2		✓	✓	✓
	3 WIRE	17 - 2 - DIA - 3			✓	✓
	4 WIRE	17 - 2 - DIA - 4				✓

*Where 'DIA' is shown in the Type Number Box, the required diameter should be inserted.

SECTION 2 Wiring Configuration

There are generally four types of wiring schematics available as shown below for each element.

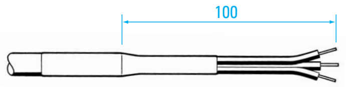


As per IEC 60751:2008 (BS EN 60751 : 1996)

SECTION 3 Type of End Seal Configuration

NB: When relevant, longer tails can be supplied on request.

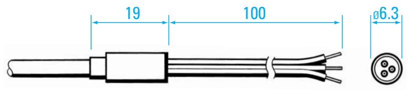
CE1 SERIES



CE1A

As CE1 but with an additional PTFE heatshrink sleeve. Length of sheath dimension is taken from where the sheath meets the heatshrink.
Maximum end seal temperature rated to **135**°C.
** CE1 series are not suitable for sheath diameters above 8mm.*
** CE1 series are not necessarily liquid or gas tight.*

CE2 SERIES



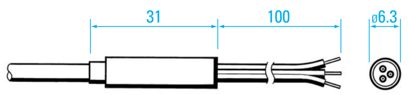
CE2

Crimp on stainless steel pot seal and supplied unless otherwise specified with 100mm long Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Seal potted with resin.
Maximum end seal temperature rated to **135**°C.

CE2A

As CE2 but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE2 series are not suitable for sheath diameters above 3mm.*

CE2L SERIES



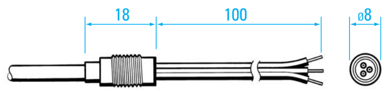
CE2L

As CE2 but with an overall length of 31mm.
Maximum end seal temperature rated to **135**°C.

CE2LA

As CE2L but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE2L series are not suitable for sheath diameters above 3mm.*

CE3 SERIES



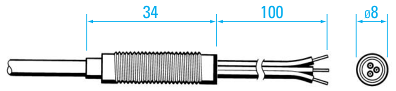
CE3

Crimp on stainless steel pot seal. Screwed 8mm x 1mm ISO and supplied unless otherwise specified with 100mm long Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Seal potted with resin.
Maximum end seal temperature rated to **135**°C.

CE3A

As CE3 but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** Lock nuts are available in stainless steel to suit CE3 series and should be ordered separately as LN08S.*
** CE3 series are not suitable for sheath diameters above 3mm.*

CE3L SERIES



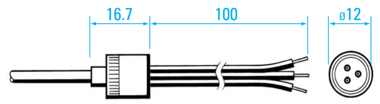
CE3L

As CE3 but with an overall length of 34mm.
Maximum end seal temperature rated to **135**°C.

CE3LA

As CE3L but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE3L pot seals are recommended for when additional flying leads are incorporated into the pot or when a longer threaded section is required.*
** Lock nuts are available in stainless steel to suit CE3L series and should be ordered separately as LN08S.*
** CE3L series are not suitable for sheath diameters above 3mm.*

CE4C SERIES



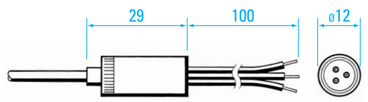
CE4C

Crimp on stainless steel pot seal and supplied unless otherwise specified with 100mm Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Potted with resin.
Maximum end seal temperature rated to **135**°C.

CE4CA

As CE4C but end potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE4C pot seals are not suitable for sheath diameters less than 3mm or more than 8mm.*

CE4CL SERIES



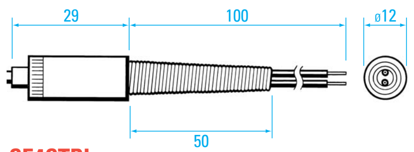
CE4CL

As CE4C but with the 16.7mm dimension extended to 29mm.
Maximum end seal temperature rated to **135**°C.

CE4CLA

As CE4CL but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C
** CE4CL pot seals are recommended for when additional flying leads are incorporated into the pot.*
** CE4CL pot seals are not suitable for sheath diameters less than 3mm or more than 8mm.*

CE4CTRL SERIES



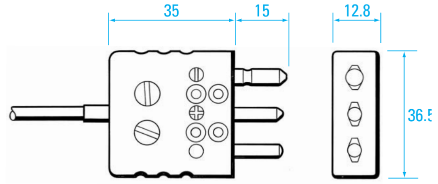
CE4CTRL

Crimp on stainless steel pot seal complete with an anti chafe support spring tension fitting and 100mm long (including spring fitting) Kapton* insulated leads (normally 7/0.2mm diameter copper with bared and tinned ends). Potted with resin.
Maximum end seal temperature rated to **135**°C.

CE4CTRLA

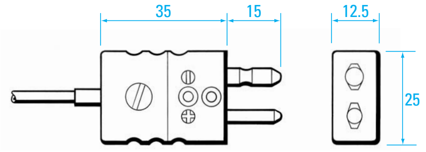
As CE4CTRL but potted with high temperature resin.
Maximum end seal temperature rated to **235**°C.
** CE4CTRL pot seals are most suited when additional flying leads are incorporated and it is unlikely that any benefit would be derived from specifying this type with the standard 100mm tails.*
** CE4CTRL pot seals are not suitable for sheath diameters less than 3mm or more than 8mm.*

CE6 SERIES



CE6

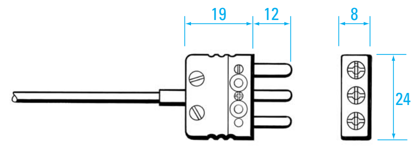
Standard 3 pin round plastic bodied quick disconnect plug for three wire assemblies only.
Maximum end seal temperature rated to **135**°C.



CE6A

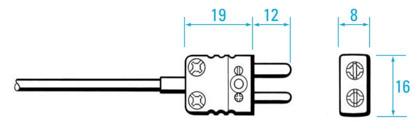
Standard 2 pin round plastic bodied quick disconnect plug for two wire assemblies only.
Maximum end seal temperature rated to **135**°C.
** For other configurations including 4 wire simplex and 2 or 3 wire duplex please contact the company for further details.*
** Mating sockets to suit the CE6 and CE6A are available and should be ordered separately. See pages 64/65 for further details.*
** CE6 series are not suitable for sheath diameters above 6mm.*

CE7 SERIES



CE7

Miniature 3 pin flat plastic bodied quick disconnect plug for three wire assemblies only.
Maximum end seal temperature rated to **135**°C.

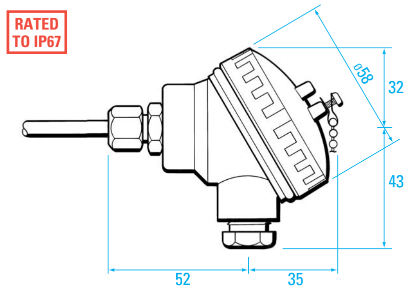


CE7A

Miniature 2 pin flat plastic bodied quick disconnect plug for two wire assemblies only.
Maximum end seal temperature rated to **135**°C.
** For other configurations including 4 wire simplex and 2 or 3 wire duplex please contact the company for further details.*
** Mating sockets to suit the CE7 and CE7A are available and should be ordered separately. See pages 64/65 for further details.*
** CE7 series are not suitable for sheath diameters above 3mm.*

CE10 Weatherproof die cast alloy head

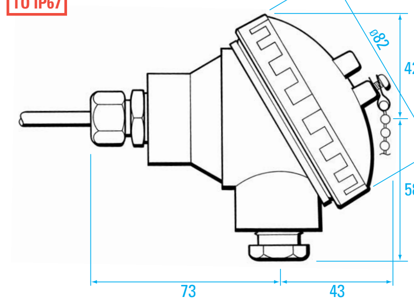
RATED TO IP67



Weatherproof die cast alloy, epoxy coated, screw top terminal head with the tube entry and cable entry at a right angle to each other, with a ceramic terminal block. Suitable for 2, 3 or 4 wire simplex assemblies or 2 wire duplex assemblies only. Supplied with a 16mm x 1.5mm ISO metal pinch gland on the cable entry for cables from 3mm to 8mm diameter.
** Suitable for use with all sheath diameters excluding 12.7mm.*

CE11 Weatherproof heavy duty die cast alloy head

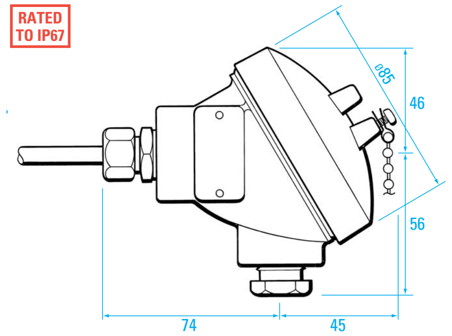
RATED TO IP67



Generally as CE10 but heavy duty version. Suitable for 2, 3 or 4 wire simplex assemblies or 2 or 3 wire duplex assemblies only. Supplied complete with 20mm x 1.5mm ISO metal pinch gland on cable entry for cables from 6mm to 14mm diameter.
** Not normally suitable for sheath diameters less than 6mm unless suitably supported.*

CE12 Weatherproof heavy duty cast iron head

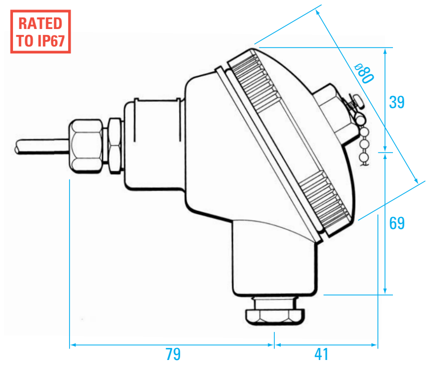
RATED TO IP67



Weatherproof cast iron screw top terminal head with the tube entry and cable entry at a right angle to each other. Suitable for 2, 3 or 4 wire simplex assemblies or 2 or 3 wire duplex assemblies only.
Supplied complete with 20mm x 1.5mm ISO pinch gland on cable entry for cables from 6mm to 14mm diameter.
** Not normally suitable for sheath diameters less than 6mm unless suitably supported.*

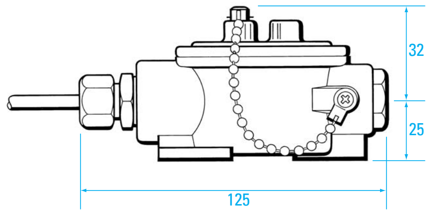
CE17 Weatherproof Bakelite head

RATED TO IP67



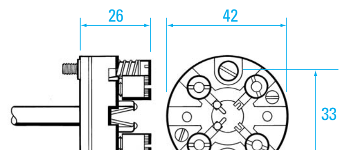
Weatherproof Bakelite plastic screw top terminal head with tube entry and cable entry at a right angle to each other with a Bakelite terminal block. Suitable for 2, 3 or 4 wire simplex assemblies or 2 or 3 wire duplex assemblies only. Supplied with a 20mm x 1.5mm ISO plastic pinch gland on the cable entry for cables from 6mm to 14mm diameter. Terminal head temperature rated to 150°C.
** A smaller version of this connection head is also available and is referred to as CE16.*
** Not normally suitable for sheath diameters less than 3mm unless suitably supported.*

CE18 Die cast alloy straight through head



Die cast alloy straight through terminal head with a bakelite terminal block. Suitable for simplex or duplex assemblies. Supplied with a 20mm x 1.5mm pitch ISO gland on the cable entry for cables from 6mm to 14mm diameter.
** If supported at fixing holes, suitable for diameters of 2mm and above.*

CE20



Spring loaded insert assembly. The end seal is incorporated into a terminal block suitable for mounting into a CE11, CE12, CE17 or any other standard terminal head. Suitable for use with 3mm, 4.5mm, 6mm and 8mm sheaths only. The ceramic terminal block has 2 x 33mm spaced mounting holes. (Previously called CE14C).

SECTION 4 Standard and Tolerance of Detector Element

Resistance Value of Element	Accuracy at 0°C	Accuracy at 100°C	Type Number for use as part of Order Code
100 ohms at 0°C	±0.30°C	±0.80°C	R100 – B
100 ohms at 0°C	±0.15°C	±0.35°C	R100 – A
100 ohms at 0°C	±0.10°C	±0.27°C	R100 – 1/3
100 ohms at 0°C	±0.06°C	±0.16°C	R100 – 1/5
100 ohms at 0°C	±0.03°C	±0.08°C	R100 – 1/10
130 ohms at 0°C	±0.30°C	±0.80°C	R130 – B

Details of detector element accuracies at other temperatures are available on request.

SECTION 5 Extension Leads

All assemblies with pot seals are generally supplied with 7/0.2 diameter Kapton* individually insulated leads as standard (ref. RK 17). However where leads are several metres or more long it may be more suitable to have an overall sheathed cable. Details of the other cables we offer are shown overleaf on Page 58.

SECTION 6 Compression Fittings

A full range of compression fittings is available to suit our Type 16 Platinum Resistance Thermometer Assemblies. See page 67 for further details.

SECTION 7 Head Mounted Transmitters

A range of transmitters is available including standard, isolated, fully linearised, Ex and RFI versions. See page 69 for further details.

Ordering Code – Typical example

17 - 1 - 6.0 - 3 - 1000 - CE4CL - R100 - B - 1Mtr RT37 - ACF17S -

- Type No.
- No. of detector elements per assembly (see section 1)
- Sheath diameter (see section 1)
- Wiring configuration (see section 2)
- Sheath length in mm*
- End seal termination (see section 3)
- Resistance value of detector element (see section 4)
- Standard and tolerance of detector element (see section 4)
- Extension leads if relevant and length required (see section 5)
- Adjustable compression fitting if required (see section 6)
- Head mounted transmitter if required (see section 7)

*Please note that the sheath length is measured from the tip of the assembly to the nearest point on the end seal termination.

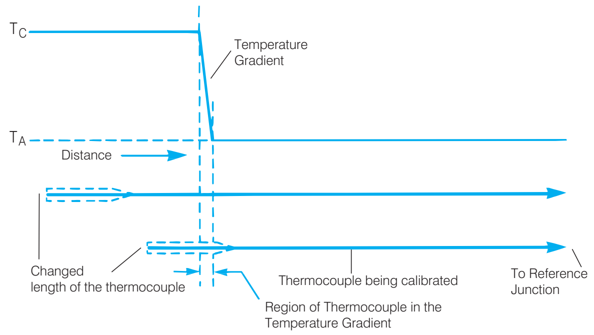


Figure 8.4: *Attempting to Calibrate a Non-Uniform Thermocouple*

8.5 Simulators

At the other end of the spectrum, it is worth noting just briefly that electronic, hand held sensor simulators exist to ease the calibration of indicators, pyrometers, transmitters, recorders and other instrumentation. Essentially, they eliminate the need to connect variable voltage sources to check the equipment, providing precise, repeatable voltages directly for standard thermocouples and RTD's. They also obviate separate ice point references and, most important, make it possible to calibrate and test equipment in-situ on site - rather than bringing it back to the calibration laboratory. Further details are beyond the scope of this guide.

9.0 Trouble Shooting

The most significant errors in temperature measurement arise from the sensor not achieving the temperature of its surroundings. This can be due either to it actually failing to sense due to poor contact - either with the medium, or the probe/sheath/thermowell into which it has been inserted - or due to degradation of the sensor, leading to drift away from calibration and thus inaccurate sensing.

Problems can also arise simply as a result of incorrect, or ageing wiring and connections, or instrument calibration. In fact, wiring faults, as such, are more common than sensor or instrument faults. So, if you are experiencing problems this is a good starting point.

However, looking at sensor thermal contact problems first, if the guidance presented, particularly in Part 3, Sections 1, 4 and 5 is followed regarding sensor selection, siting, installation and protection, these kinds of problems should be avoided. Close examination of junctions, sensor assemblies and the contact area for cleanliness and integrity should reveal obvious trouble spots which tend to arise some time after installation. If the circuit is providing part of a closed control loop, make sure that contact is adequate - if it is not, the lags and inaccuracies that result will positively guarantee poor control.

Next, considering sensor degradation, this usually shows itself as a gradual drift in temperature indication. The degradation paths are somewhat different for RTD's and thermocouples. With thermocouples, the most common faults are inadequate insulation resistance, thermoelectric inhomogeneity along the wires and deterioration of the junction itself. With RTD's, inaccuracies mostly result from internal lead support problems, chemical attack (resulting in poisoning), metallurgical changes, shock and vibration, reduced insulation resistance, thermoelectric effects and unequal resistance in the RTD measuring wire leads.

Tests mentioned in Part 3, Section 5, and calibration routines covered in Part 3, Section 8 should reveal these kinds of problems. When, for example, was the sensor last calibrated, and was the calibration representative? Ageing is generally more of a problem with thermocouples than with RTD's, which tend to enjoy excellent stability. Portable calibrators that can measure or simulate sensor signals can be very helpful in this respect. Resistance checks on both thermocouples and RTD's can usually be used to spot problems quickly and effectively.

Remember, incidentally, that an open circuit condition (with continuous full scale indication) could be the result of thermocouple or RTD failure or simply loose connections. For thermocouples disconnect the sensor and link the input terminals at the instrument; if ambient is indicated, the sensor is at fault. Likewise, with RTD's, disconnect the sensor, and connect a 100 ohm resistor to the instrument input terminals; if 0°C is indicated, again the sensor is the problem.

In the case of thermocouples, low resistance generally indicates that the system is fine, while high resistance could mean that the sensor is nearing the end of its useful life due to reduction of the wire diameter. If the resistance is very low, the sensor could be shorting out - a condition often revealed by down scale indication.

Alternatively, this indicator could also mean that the thermocouple connections are reversed. Continuous low indications tend to indicate use of the wrong thermocouple type, or cable.

Never forget that all of the standard scale error indications could, of course, be just that - scale errors due to incorrect calibration of the instrumentation, rather than sensor problems. This applies to RTD's and thermocouples.

For RTD's, meanwhile, low resistance usually indicates insulation leakage between the resistance element and its supporting former, or between the leads and the outer sheath. Again, early tell-tale signs are down scale, or low indication. A high indication, on the other hand, basically means a high resistance in the sensor circuit due to inadequate wiring, or excessive PRT energising current, causing self-heating. Clearly, replacement of two wire measuring systems with three or four wire alternatives will remedy the first situation, while minimising the current and looking at the sensor assembly and thermal contact should be your approach to dealing with the second problem.

Continuing with the practical observables, beyond calibration errors, high temperature indications have two most likely causes in thermocouple circuits - incorrect thermocouple type or cable type (again), or reversed extension/compensating connections. Check that the polarity of all connections is correct. This is very important - errors of over 100°C can be expected if polarity is reversed, say, on a Type K thermocouple/extension lead circuit. Positive extension or compensating wires should be connected to the positive thermoelement, and vice versa. Similarly, there will be substantial errors if the wrong cable alloy has been used - check the colour codes.

Basically, with wiring and connection problems, again, if the advice given in Part 3, Section 5 covering wiring and connection, has been followed, there should be no problem. Intermittent problems, however, are always the most intractable in this respect. Check all joints, inter-connections and the cable runs themselves for integrity (and isothermal conditions, where thermocouples are concerned) and correctness. If errors, or erratic measurement anomalies persist, look out for sources of noise pick up, although this is more likely with thermocouples than RTD's. If all is OK here, then check the isolators, transmitters and multiplexer systems (if any) and the receiving instrumentation. Again, straightforward electronic/electrical test instruments, portable calibrators and simulators can be used for fastest results in almost all cases. Where thermocouples are concerned, also ensure that the reference unit, or cold junction compensation circuitry is well sited, effective and operational. Then again, check to see if there could be any long term stability problems. Put crudely, there is not a lot else to go wrong!

EPILOGUE

1.0 Future Sensor and Equipment Trends

Although the trend towards increased use of resistance thermometers against thermocouples is set to continue, developments just around the corner will affect both sensor types. New technology is set to emerge over the next few years, bringing considerably enhanced functionality. And, one main area for development is that of the sensors' own self diagnostics - the ability of the sensors (not the smart transmitters) to determine their own health and the corrections required to bring them back into calibration.

Smart sensor systems, involving the processing of arrays of similar or dissimilar sensors, for example can be used for validation. In due course, they will provide for in-situ diagnosis to identify problems, estimate measurement uncertainties and report out-of-tolerance measurements - quite a departure! This will mean the end of inaccurate measurements which are today so often taken at face value. Meanwhile, with improved fabrication techniques and materials the devices will also become more reliable, accurate and durable.

1.1 Smart Thermocouples

With thermocouples, the most common faults found are: inadequate insulation resistance; thermoelectric inhomogeneity; and deterioration of the junction. Solutions to these could be several. On-line insulation resistance measurements could reveal degradation and the creation of virtual junctions. Likewise, loop resistance measurements, wire to sheath capacitance measurements and self heating and cooling tests could all be harnessed.

In the latter, Joule heating occurs throughout the thermoelectric circuit. When the heating stops, the extraneous emf sources relax at a slower rate than the primary junction since they have poorer couplings to heat sinks. Not only does this mean that uncertainty can be monitored (and alarmed); also filters can be designed to compensate for response lags.

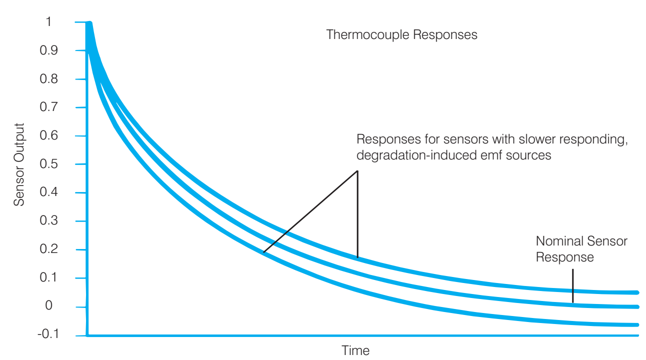


Figure 1.1: *Induced Emf Sources on Loop Current*

1.2 Smart Resistance Thermometers

RTD inaccuracies mostly result from: chemical attack; metallurgical changes due to the environment; mechanical shock and vibration; reduced insulation resistance creating parallel electrical paths to the platinum element; thermoelectric effects; and unequal resistance in the RTD leads, causing incorrect lead wire compensation. One possible technique thought to be applicable for testing RTD's on-line is the measurement of Johnson noise (thermally induced nanovolt emfs in resistors), with its well defined temperature dependence and resistor material independence.

Others are, again, the measurement of insulation resistance and loop resistance - the latter revealing data on the condition of the leads on both sides of the platinum element. Meanwhile, the presence of thermoelectric error in RTD's can be detected by reversing the leads and observing the recorded temperature difference. And, again, self-heating effects can also be used to detect problems.

1.3 Alternative Measurement Techniques

Several sensors including a thermocouple and an RTD (dual diverse sensors) can be built into the same sheath - giving the instant advantage of no common mode degradation mechanism, and thus a powerful sensor validation technique. Alternatively, multi-lead, multi-junction thermocouples provide another method of achieving diverse measurements from one sensor head - and thus, again, validation.

Another technique is the use of melt-freeze technology, where capsules of pure metal are contained near the sensing element. If the metal selected has a melting point below the normal measurement range, a one-point calibration check is provided going each way (up and down the temperature scale) in the form of a temporary arrest in the rate of change of temperature during melting or freezing.

Dynamic compensation is another approach in which two sensing elements are installed in the sheath at different points such that each has a different response rate. Better response is achieved by modelling the response of one against the other to anticipate actual temperature from the different rate of change curves as the measured temperature from both changes. Gradient sensors are similar in concept, using the stem losses - measurement differences along the sensor itself due to heat transfer rates - to extrapolate to fast changing temperatures quickly.

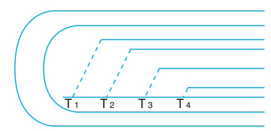


Figure 1.2: *Gradient Thermocouple*

In a slightly different vein, there are also pulsed sensors, designed for measurements well above the normal damage thresholds of the standard sensors. These use cooling jackets to maintain the sensor temperature within its operating limits. Cooling is stopped temporarily, and the sensor allowed to sense rising temperature, before cooling is restarted. Although actual temperature is never reached, extrapolation from the curve shape allows its derivation.

Continued on page 66

TC Ltd., PO Box 130, Uxbridge, UB8 2YS, United Kingdom
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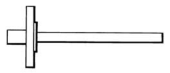
Email: info@tc.co.uk - Web: www.tc.co.uk

01895 252222

TYPE 20 Thermowells for Thermocouple and Platinum Resistance Thermometer Assemblies

- Ideal for when an application demands the removal of a sensor without interrupting the process
- Our thermowells can either be of welded construction with a parallel sheath or machined from solid with a parallel or tapered sheath
- Available in a variety of constructions with either screwed BSP or NPT male process entry or with plain or drilled flanges
- Custom built in either Stainless Steel, Inconel 600 or Incoloy 800 to meet customer requirements on a prompt delivery
- Type 20 Thermowell assemblies are often supplied complete with thermocouple/resistance thermometer inserts, lagging extensions, terminal heads and cable glands from our extensive range

SECTION 1 Thermowell Design Types

Code	Description	Sketch
20WH	Welded fabrication Thermowell with male and female threaded connections. Parallel sheath.	
20SH	Machined from solid Thermowell with male and female threaded connections. Tapered or Parallel sheath.	
20WF	Welded flange onto a welded end fabricated Thermowell with a female threaded connection. Parallel sheath.	
20WFS	Welded flange onto a machined from solid Thermowell with a female threaded connection. Tapered or Parallel sheath.	

The above design types show our standard range of thermowells.
If you have an alternative requirement or a drawing please contact us.

SECTION 2 Standard Sheath Materials

Type	Sheath Specifications	Operational Properties	Maximum Operating Temperature of Sheath (approximate) °C
116	**Grade 316 Stainless Steel** 18/8/1 Chromium/Nickel/Molybdenum Stabilised To BS 970 Part 4 : 1970	Very good corrosion resistance throughout the operating temperature range. Suited to a wide range of industrial applications. Enjoys high ductility.	800
176	**Inconel 600*** Nickel/Chromium/Iron alloy, BS 3074 : 1974 Grade NA14, ASTM 8167, ASME SB 167 Din NiCr15Fe, Werkstoff No : 2.4816	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys a good resistance to oxidation. Do not use in sulphur bearing atmospheres above 550°C.	1100
180	**Incoloy 800*** Iron/Nickel/Chromium alloy. BS 3074 : 1974 Grade NA15, ASTM B163, B407 ASME SB 1635, B407, Din X10NiCrAlTi3220, Werkstoff No : 1.4876	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys a good resistance to oxidation and carburization. Resistant to sulphur bearing atmospheres above 550°C.	1100

Other sheath materials can be supplied to special order. *Trade names

SECTION 3 Process Connections for Types 20WH and 20SH Threaded Thermowells

Parallel or Taper Male Process Entry Thread	Female Entry Thread on Thermowell for Sensor Fitting or Lagging Extension
1/2in BSPP	1/4in BSPP
1/2in BSPT	1/4in BSPT
1/2in BSPT	1/2in BSPT
3/4in BSPP	1/2in BSPP
3/4in BSPT	1/2in BSPT
1in BSPT	3/4in BSPT

We also offer NPT, GAZ and a variety of other thread types. Please contact us for more details.

SECTION 4 Process Connections for Types 20WF AND 20WFS Flanged Thermowells

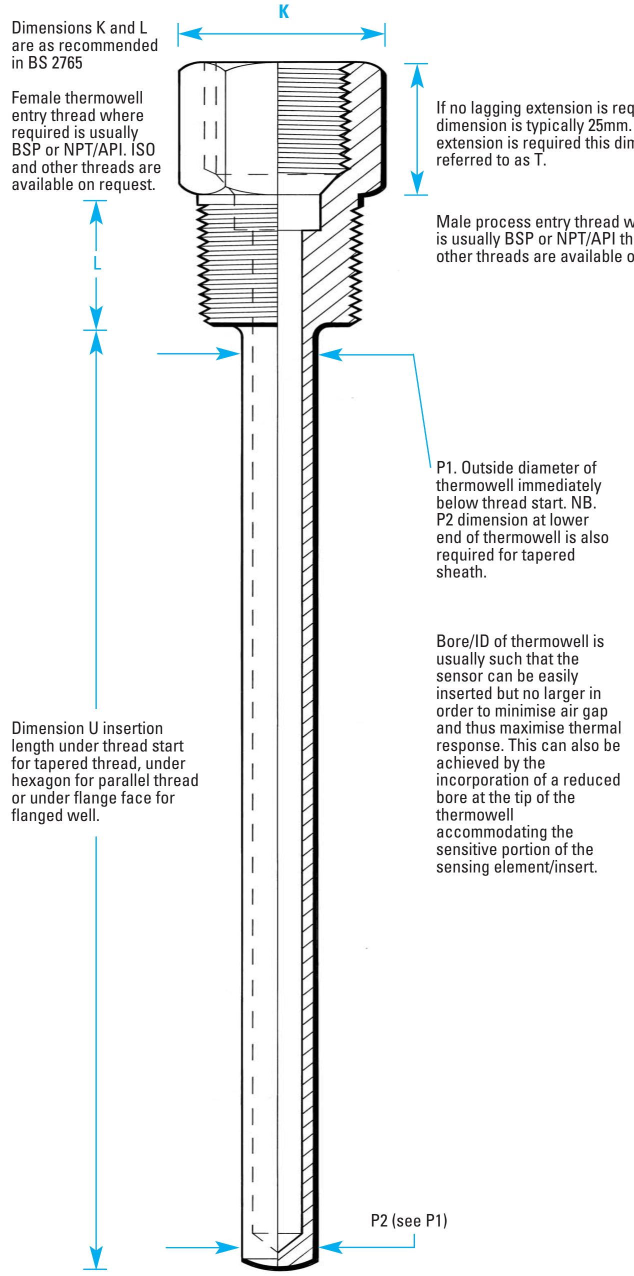
Flange Size (NB)	Rating (LBS)	Facings and Mounting Arrangements
1 Inch 1+1/2 Inch 2 Inch	150 300 450 600 900	Machined raised faces are available to meet your requirements. Flanges are available either plain or drilled to your PCD and hole size requirements. Flanges conform to BS1560 "Steel pipe flanges and flanged fittings for the Petroleum industry".

The above flange connections and ratings are typical of what we can offer.
You may also require a female entry thread with a flanged thermowell. See Section 3.

SECTION 5 Bore and Outer Diameter Dimensions

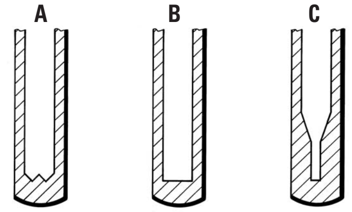
Outer Diameter (mm)	Bore Diameter (mm)
12.7	7.42
15.9	11.8
21.3	15.9
26.7	20.9

The above are suggested bore and outer diameters for 20WH and 20WF thermowell types. For machined from solid 20SH and 20WFS thermowell types the bore size is custom built to your requirements but is typically 7mm to suit a 6mm diameter temperature sensor.



SECTION 6 Alternative Forms of Bottom of Bores

BS2765 suggests the following alternative styles of bottom of bores however for the vast majority of applications our standard type is most suitable.



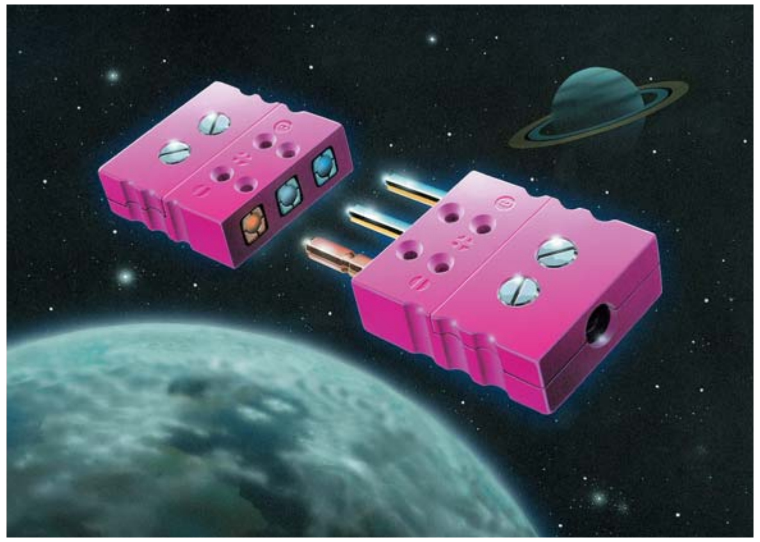
Ordering Code - Typical example

20WH - 116 - 1/2" BSPT - 1/4" BSPT - 200 - 7.42 - 12.7 - 0 - 0 - 0

- Thermowell type code (See Section 1)
- Sheath material (See Section 2)
- Process entry thread (if required) (See Section 3)
- Thermowell entry thread (if required) (See Section 3)
- Insertion length "U" under thread start for tapered threads, under hex/flats for parallel threads, under flange face for flanged thermowell
- Bore of thermowell (See Section 5)
- O/d of thermowell "P1" (See Section 5)
- Taper details "P2" if required (See diagram)
- Flange details: Size, rating, facing, PCD and hole size if required (See Section 4)
- Alternative form of bottom of bore other than standard if required (See Section 6)

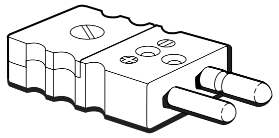
Thermocouple and Resistance Thermometer Connector Systems

- Our range of miniature and standard thermocouple connectors are available for use with all the common thermocouple combinations and should be specified as KX, TX, JX, NX, EX, RCB, SCB or CC (W5)
- They are also available with copper conductors for use with Platinum Resistance Thermometers (Code CU)
- For thermocouple applications thermocouple grade alloys are incorporated for error free thermocouple signals
- A wide range of accessories and panel mounting systems is available
- Our connector range is available with models rated to either 210°C, 350°C or 650°C. The 210°C rated connectors are colour coded as per the international thermocouple colour standard IEC 60584.3:2007/BS EN 60584.3:2008 (See page 5 for further details). The 350°C versions are coloured brown and the 650°C versions are coloured white irrespective of the conductor type however both are marked with the identifying international code letter
- Pins are polarised by size and are marked for negative and positive polarity. These connectors are pin compatible with other miniature and standard sized connectors
- The plug and socket bodies are engineered so that their installation can be made simply and securely via a designed in locking mechanism
- To order simply take the order code shown below and where necessary add the relevant conductor combination.
- Exact connector dimensions for most styles can be found on pages 43 and 57, or alternatively please contact us

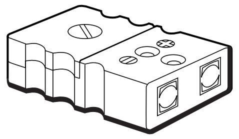


Standard Connectors

Plug 2 Pin
R11
Rated to 210°C
R13
Rated to 350°C
R100
Rated to 650°C

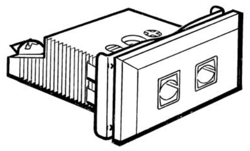


Socket 2 Pin
R20
Rated to 210°C
R22
Rated to 350°C
R200
Rated to 650°C



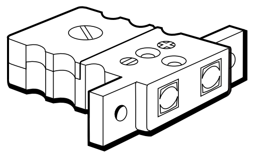
Panel Socket with Metal Clip 2 Pin

R29
Rated to 210°C



Panel Socket with Lugs 2 Pin

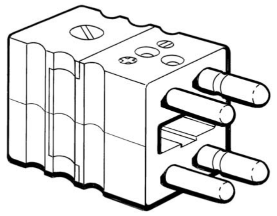
R30
Rated to 210°C



A panel plug is also available referenced R37.

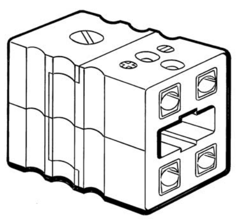
Duplex Plug 2 Pin

R91
Rated to 210°C



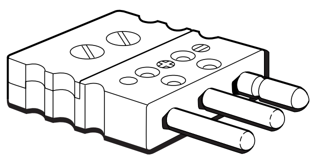
Duplex Socket 2 Pin

R92
Rated to 210°C



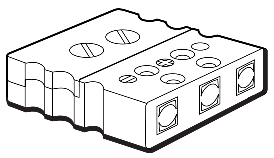
Plug 3 Pin

R16
Rated to 210°C



Socket 3 Pin

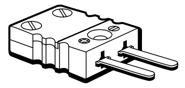
R25
Rated to 210°C



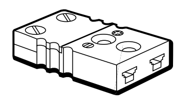
A panel version with lugs is also available referenced R31.

Miniature Connectors

Plug 2 Pin
F11
Rated to 210°C
F13
Rated to 350°C
F100
Rated to 650°C

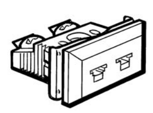


Socket 2 Pin
F20
Rated to 210°C
F22
Rated to 350°C
F200
Rated to 650°C



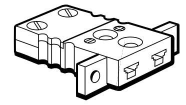
Panel Socket with Metal Clip 2 Pin

F29
Rated to 210°C



Panel socket with Lugs 2 Pin

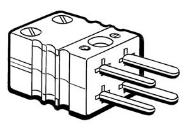
F30
Rated to 210°C



A panel plug is also available referenced F37.

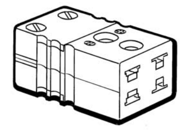
Duplex Plug 2 Pin

F91
Rated to 210°C



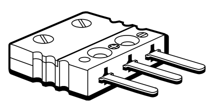
Duplex Socket 2 Pin

F92
Rated to 210°C



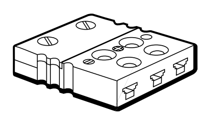
Plug 3 Pin

F16
Rated to 210°C



Socket 3 Pin

F25
Rated to 210°C

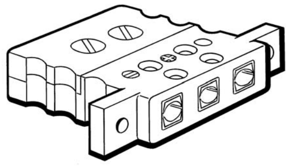


A panel version with lugs is also available referenced F31.

Standard Connectors (continued)

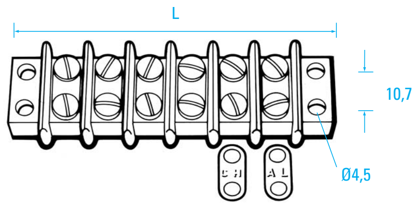
Panel Socket with Lugs 3 Pin

R31
Rated to 210ºC



Barrier Terminal Strips

These terminal strips are available for use with all the common thermocouple conductor combinations or with copper conductors (Code CU). The conductor combination selected determines which alloys will be incorporated as the connection lugs and therefore on thermocouple applications, interconnection errors may be avoided. The lugs are marked to identify the alloy and the polarity.

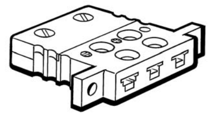


BTS01 1 channel per strip L=41.5mm
BTS02 2 channel per strip L=64.0mm
BTS03 3 channel per strip L=86.5mm
BTS04 4 channel per strip L=109.0mm
BTS05 5 channel per strip L=131.5mm
BTS06 6 channel per strip L=154.0mm
BTS08 8 channel per strip L=199.0mm
BTS10 10 channel per strip L=244.0mm

Miniature Connectors (continued)

Panel Socket with Lugs 3 Pin

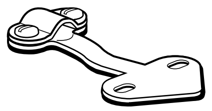
F31
Rated to 210ºC



Accessories for Standard Connectors

Cable Clamp

R40

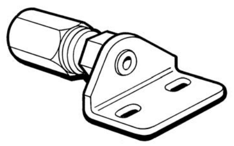


Cable Grommet

R41

Compression Tube Adaptor

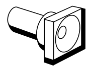
R7015 1.5mm
R7030 3.0mm
R7045 4.5mm



The dimensions shown above are the tube outer diameters that each reference is suited for.

Crimp Insert Tube Adaptor

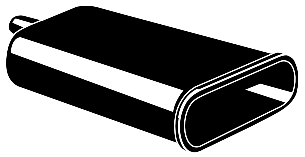
R8910 1.0mm
R8915 1.5mm
R8930 3.0mm
R8945 4.5mm
R8960 6.0mm



The dimensions shown above are the tube outer diameters that each reference is suited for.

Neoprene Boot

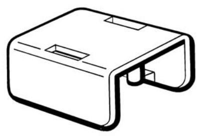
R68



Ideal for added protection in damp environments. One per connector required.

Locking Plate

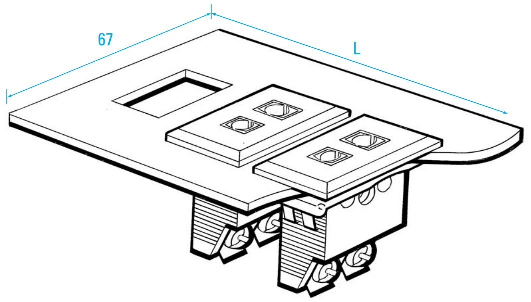
R69



Whilst our connectors have a built in locking mechanism this accessory gives greater security to ensure the connectors do not part during use. One per pair of connectors required.

Panel Systems

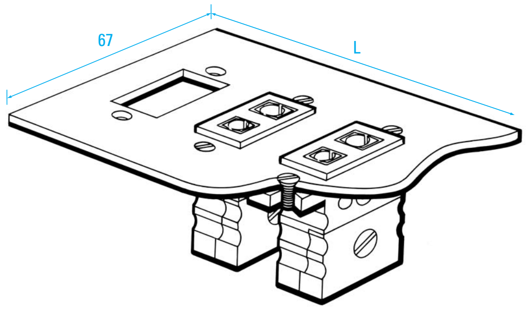
RFP Anodised Aluminium Panel for use with Metal Clipped R29 Connectors



RFP02 2 way L=62mm
RFP04 4 way L=112mm
RFP06 6 way L=162mm
RFP08 8 way L=212mm
RFP10 10 way L=262mm
RFP12 12 way L=312mm

Don't forget to order the R29 panel sockets separately.

RCP Anodised Aluminium panel for use with Lugged R30 Connectors



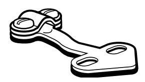
RCP02 2 way L=62mm
RCP04 4 way L=112mm
RCP06 6 way L=162mm
RCP08 8 way L=212mm
RCP10 10 way L=262mm
RCP12 12 way L=312mm

RCP panels come complete with connection fixing screws.
Don't forget to order the R30 panel sockets separately.
A version of this panel is available to suit the R31 3 pin lugged connector.

Accessories for Miniature Connectors

Cable Clamp

F40

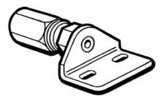


Cable Grommet

F41

Compression Tube Adaptor

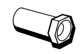
F7015 1.5mm
F7030 3.0mm
F7045 4.5mm



The dimensions shown above are the tube outer diameters that each reference is suited for.

Crimp Insert Tube Adaptor

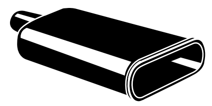
F8910 1.0mm
F8915 1.5mm
F8930 3.0mm
F8945 4.5mm
F8960 6.0mm



The dimensions shown above are the tube outer diameters that each reference is suited for.

Neoprene Boot

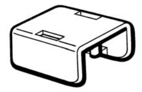
F68



Ideal for added protection in damp environments. One per connector required.

Locking Plate

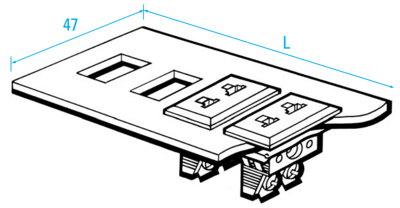
F69



Whilst our connectors have a built in locking mechanism this accessory gives greater security to ensure the connectors do not part during use. One per pair of connectors required.

Panel Systems

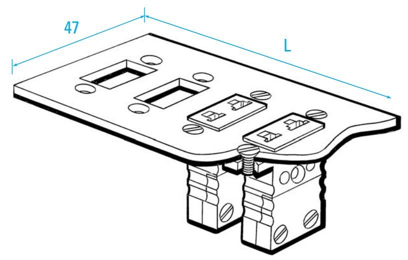
FFP Anodised Aluminium Panel for use with Metal Clipped F29 Connectors



FFP02 2 way L=40mm
FFP04 4 way L=72mm
FFP06 6 way L=104mm
FFP08 8 way L=136mm
FFP10 10 way L=168mm
FFP12 12 way L=200mm

Don't forget to order the F29 panel sockets separately.

FCP Anodised Aluminium Panel for use with Lugged F30 Connectors



FCP02 2 way L=40mm
FCP04 4 way L=72mm
FCP06 6 way L=104mm
FCP08 8 way L=136mm
FCP10 10 way L=168mm
FCP12 12 way L=200mm

FCP panels come complete with connection fixing screws.
Don't forget to order the F30 panel sockets separately.
A version of this panel is available to suit the F31 3 pin lugged connector

TO ORDER SIMPLY TAKE THE ORDER CODES SHOWN ABOVE AND ADD THE RELEVANT CONDUCTOR COMBINATION WHERE NECESSARY

1.4 Semiconductor Sensors

Semiconductor sensors are available as resistors, diodes or p-n junctions of transistors or integrated circuits. Forward biased diodes and transistors have sensitivities around the 2mV/°C mark and can easily now be manufactured and linearised between say -50°C and +100°C and beyond. The future is bound to reveal sensors of this kind built onto chips. Then again, at very low temperatures, deposited films of ruthenium oxide are allowing RTD temperature measurement down to 0.01K.

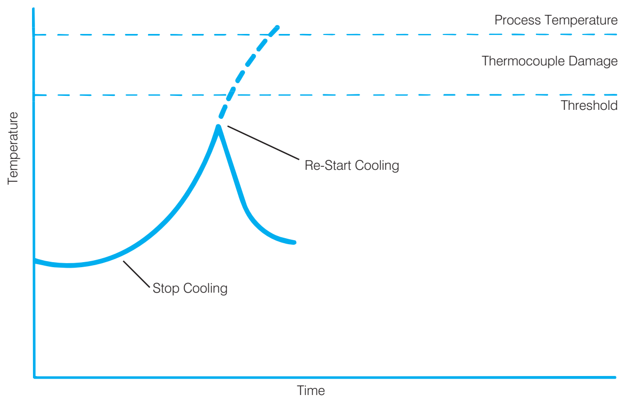


Figure 1.3: *Pulsed Thermocouple Operation*

1.5 Noise Thermometry

Using resistor noise voltage (as mentioned above), noise thermometry is entirely electronic - relating directly to thermodynamic temperature and being independent of sensor calibration. Although not noted for its fast response, the technique may yet come through, and current work is looking at harnessing it alongside a thermocouple for dynamic checking.

1.6 Other Techniques

Moving away from electronic thermometry for a moment, other developing temperature sensor techniques to be aware of include fibre optics, acoustic thermometry, nuclear quadrupole resonance devices and quartz crystal transducers. All of these are, however, outside the scope of this guide.

GLOSSARY OF TERMS

Absolute zero: *The lowest possible temperature of a substance. Zero on the Kelvin scale (-273 .15°C).*
AC: *Alternating current.*
Accuracy: *Nearness of a sensor or indicator measurement reading to the real value of the quantity being measured - usually expressed as a percentage error.*
Alumel: *Trade name of nickel-based, high temperature, negative thermocouple material used with Chromel for Type K thermocouples.*
Ambient temperature: *The average or mean temperature of the surrounding environment in contact with sensor or equipment concerned.*
Ampere (amp): *The unit defining the quantity of electricity (current) flowing in a circuit - units are coulombs per second.*
Ammeter: *Instrument which measures current.*
Annealing: *Heat treatment of materials to relieve internal stresses, dislocations, etc.*
Beryllia: *Beryllium oxide - a high temperature mineral insulation material.*
Black body: *A body that absorbs all thermal radiation that falls on it; also a perfect radiator of energy.*
Boiling point: *The temperature at which a substance in the liquid phase transforms into the gas phase - commonly, of water which is nominally 100°C.*
Bonded hot junction: *Refers to a type of mineral insulated thermocouple where the measuring junction is integral with the tip of the sheath, and thus electrically grounded to it.*
Calibration: *The process of determining or adjusting values of an instrument by independent measurements of the relevant phenomenon.*
Calorie: *The quantity of thermal energy required to raise one gram of water 1°C at 15°C.*
Celsius scale: *The most commonly used temperature scale where degrees Celsius (°C) designate a point on the temperature scale and the magnitude of a temperature interval. 0°C is the ice point; 100°C is the boiling point of water.*
Ceramic insulation: *High temperature compositions of metal oxides insulating thermocouple wires - most commonly alumina, beryllia and magnesium oxide; available as single and multi-hole tubes and as beads.*
Chromel: *Trade name of nickel-based, high temperature positive thermocouple material used in Type K thermocouples with Alumel.*
Cold junction: *Original name for the reference junction of a thermocouple - now implying floating temperature.*
Cold seal: *The enclosure surrounding the flexible tail connections on a mineral insulated thermocouple unit.*
Colour codes: *The IEC standard colour identification and tolerance codes for thermocouple extension and compensating cables, connectors, etc.*
Common mode rejection ratio: *The ability of an instrument to reject interference from a voltage differential at its input terminals with relation to local ground - expressed in dB.*
Compensating cable: *Cable for extending thermocouple circuits more cheaply. It has conductors that, in combination, match the thermocouple characteristics over a limited temperature range.*
Compensating loop: *Lead wire resistance compensation for RTD elements where an extra length of wire is run from the instrument to the RTD and back to the instrument, with no connection to the RTD.*
Compensator: *An externally powered electrical network containing a temperature sensitive element connected to a thermocouple to provide an equivalent 0°C reference voltage.*
Connection head: *A cover or enclosure fitted over a thermocouple or RTD protection tube at the end remote from the sensor. It contains electrical terminals to allow convenient connection of the sensor to the rest of the circuit.*
Constantan: *A copper-nickel alloy originally developed for electrical resistance purposes, now forming the negative leg of Type J and Type T thermocouples.*
Curie point: *The temperature at which a magnetic material becomes substantially non-magnetic.*
DC: *Direct Current*
Drift: *Shift of a signal or reading over long periods due to factors like ambient temperature change, hysteresis of the sensor and other physical, chemical and electromagnetic effects.*
Duplex: *A name commonly given when two thermocouples or RTD's are housed in the same probe.*
EMF: *Abbreviation for electromotive force - the electrical potential difference developed by sources of energy in electrical circuits.*
EMI: *Electromagnetic interference.*
Emissivity: *The ratio of emitted energy from a surface compared with a black body at the same temperature.*
Error: *The difference between the correct or desired value and the real value.*
Exposed junction: *A form of faster response thermocouple probe constructed such that the measuring junction protrudes beyond the sheath, and is thus fully exposed to the medium being measured.*
Extension cable: *A method of extending thermocouple circuits with lower cost or more suitable types of wiring cable - contains similar materials to those of the thermocouple itself.*
Fahrenheit scale: *A temperature scale still in use for historical reasons where degrees Fahrenheit (°F) designate a point on the temperature scale and the magnitude of a temperature interval. 32°F is the ice point; 212°F is the boiling point of water.*
Flexible tails: *The stranded flexible insulated wires attached to mineral insulated thermocouples for connection purposes.*
Freezing point: *The temperature at which a substance changes state from the liquid phase to the solid phase - in water 0°C.*
Gain: *The degree of amplification in an electrical circuit.*
Galvanometer: *An instrument designed to measure small currents via deflecting magnetic coils.*
Ground: *The reference point for an electrical system.*
Grounded junction: *Construction of a thermocouple probe where the measuring junction is in electrical contact with the sheath so that sheath and thermocouple are at the same potential.*
Heat transfer: *Thermal energy flow from one body having higher energy to a body of lower energy - by conduction, convection and radiation.*
Hot junction: *Original and commonly used name for the measuring junction of the thermocouple - see Measuring junction.*
Ice point: *The temperature established by ice melting at a pressure of 1 standard atmosphere. 0°C on ITS-90.*
Impedance: *Total resistance to electrical current flow (resistive plus reactive).*
Insulated hot junction: *A form of construction adopted primarily for mineral insulated thermocouple units where the measuring junction is separated and electrically insulated from the cable sheath.*
Insulation resistance: *The value of the electrical resistance existing between conductors, or between the conductors and the outer casing of an electrical system when the conductors are not connected.*
Intrinsically safe: *An instrument which is designated as intrinsically safe will not pass, contain or generate sufficient electrical energy under any conditions that could lead to the ignition of a hazardous gas mixture.*
ISA: *Instrument Society of America.*
Isothermal: *The condition of uniform, constant temperature.*
ITS-90: *The International Temperature Scale of 1990 defines procedures by which thermometry systems can be calibrated such that the values of temperature obtained are concise and consistent instrument-to-instrument and sensor-to-sensor - while approximating to thermodynamic values within the limits of the technology currently available.*
Joule: *A fundamental unit of thermal energy.*
Junction: *The point in a thermocouple where the two dissimilar metals are joined - see measuring junction.*
Kelvin: *The fundamental unit of temperature. 1 Kelvin is equal to 1°C.*
Kelvin Scale: *The Kelvin thermodynamic scale of temperature is the fundamental temperature scale. It is determined from absolute zero, and is expressed in Kelvins.*
Linearity: *The deviation of an instrument's response from a straight line.*
Loop resistance: *The total resistance of a thermocouple caused by the resistance of the thermocouple wire and associated extension or compensating cable making up the circuit.*
Maximum operating temperature: *The maximum ambient, continuous temperature at which an instrument or sensor can be safely operated.*
Mean temperature: *The average of the maximum and minimum temperatures of a process in equilibrium.*
Measuring junction: *The electrical connection that comprises one end of the conductors in a thermocouple, and is used as the temperature sensor. See Hot junction.*
Melting point: *The temperature at which a substance transforms state from the solid phase to the liquid phase.*
MI (Mineral Insulated) thermocouple: *Common name for a thermocouple unit manufactured from metal sheathed, mineral insulated thermocouple cable.*
Microamp: *One millionth of an ampere.*
Microvolt: *One millionth of a Volt.*
Milliamp: *One thousandth of an ampere.*
Millivolt: *One thousandth of a Volt.*
Mueller bridge: *A high accuracy bridge configuration used to measure three wire RTD's.*
Negative temperature coefficient: *A decrease in resistance with an increase in temperature.*
Nicrosil-Nisil: *An advanced nickel/chrome vs nickel/silicon thermal alloy used in the production of Type N thermocouples.*
Noble metals: *Metals which tend towards a positive electrochemical potential, are inert and have a high resistance to corrosion and oxidation - gold, silver and platinum.*
Noise: *An unwanted electrical interference on the signal wires.*
OD: *Outer diameter.*
Optical isolation: *Two networks connected only via an LED transmitter and photoelectric receiver such that there is no electrical connection.*
Order/disorder transformation: *A change in the arrangement of the solute atoms in some alloys induced by certain heating and cooling regimes.*
Peltier effect: *The absorption or evolution of heat apparent at the junction of two dissimilar conductors when an electric current is flowing.*
Platinum metals: *These are platinum, osmium, iridium, palladium, rhodium and ruthenium. Platinum has a melting point of 1773.5°C, and is used for resistance thermometry. Together with iridium and rhodium alloys, it is also used in thermocouple thermometry - see Noble metals.*
Polarity: *The sign (positive or negative) of an electrical conductor, etc.*
Positive temperature coefficient: *An increase in resistance due to an increase in temperature.*
Primary standard: *The standard reference units and physical constants maintained by the National Standards authorities upon which all measurement units are traceable to.*
Probe: *Usually refers to a temperature sensor fitted in a rigid or semi-flexible cylindrical protection tube of some kind.*
Protection head: *A cover or enclosure fitted over a thermocouple or RTD protection tube at the end remote from the sensor. It contains electrical terminals to allow convenient connection of the sensor to the rest of the circuit - see Connection head.*
Protection tube: *A closed end, cylindrical sleeve fitted over a sensor to provide mechanical and environmental protection. Can be made from metal, plastic, ceramic, or refractory material.*
PRT: *Platinum Resistance Thermometer.*
Pyrometry: *The measurement of temperature.*
Range: *The area between two limits between which a quantity is measured - expressed as lower then upper limit.*
Reference junction: *The electrical connection joining each thermocouple conductor to a copper wire at the ends remote from the measuring junction. These junctions form the reference ends of voltage generating conductors, and are usually maintained at a known temperature - 0°C - see Measuring junction.*
Refractory metal thermocouple: *The class of thermocouples whose materials of construction have melting points above about 1,800°C. Most common are those made from tungsten and tungsten/rhenium alloys, as in Types G, C and D.*
Repeatability: *The ability of a sensor or complete sensing system to generate the same output or reading under repeated identical measuring conditions.*
Resistance: *The restriction to electrical current flow through a material, measured in Ohms; for a conductor wire, resistance is a function of diameter, length and resistivity (resistance per unit length - a physical material property).*
Resistance thermometer: *An instrument or system incorporating a length of wire or film having predictable resistance vs temperature characteristics, forming a temperature sensor. Measurement of the resistance of the device yields its temperature.*
Response time: *The time interval between the application of a sudden change of temperature to a sensor and the attainment of a given output. The change is frequently defined as 63.2% of the final value.*

Continued on page 68

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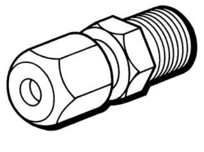
Components and Accessories for Temperature Sensors

Adjustable Compression Fittings



We offer a wide range of adjustable compression fittings in either brass or stainless steel to suit the range of thermocouples and platinum resistance thermometers that we offer. Simply choose the diameter of the tube you wish to fit using the table below to see which threaded fittings we offer. Other sizes are available on request.

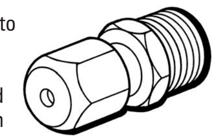
		Tube Diameter (mm)									
		0.5	1.0	1.5	2.0	3.0	4.5	5.5	6.0	8.0	10.8
BSP TaperThread	1/8″	ACF80	ACF01	ACF02	ACF04	ACF05	ACF55	-	ACF15	-	-
	1/4″	-	ACF76	ACF69	ACF53	ACF59	ACF10	ACF13	ACF16	ACF27	-
	3/8″	-	-	-	-	-	-	-	ACF64	ACF85	-
	1/2″	-	-	-	-	ACF58	ACF11	ACF14	ACF17	ACF56	ACF41
	3/4″	-	-	-	-	-	-	-	ACF73	ACF83	-
BSP Parallel Thread	1/8″	-	ACF91	-	ACF92	-	-	-	ACF79	-	-
	1/4″	-	-	-	-	ACF95	-	-	-	ACF57	-
	1/2″	-	-	-	-	ACF60	ACF63	-	ACF61	ACF62	-
NPT/API Thread	1/8″	-	-	ACF70	-	ACF71	ACF82	-	ACF18	-	-
	1/4″	-	-	-	-	ACF72	-	-	ACF19	ACF28	-
	3/8″	-	-	-	-	-	-	-	ACF44	-	-
	1/2″	-	-	-	-	ACF54	-	-	ACF20	ACF74	-

		TUBE DIAMETER (inches)									
		1/16″	1/8″	3/16″	1/4″	3/8″	1/2″	5/8″	3/4″	13/16″	1+1/16″
BSP TaperThread	1/8″	ACF03	ACF06	ACF12	-	-	-	-	-	-	-
	1/4″	-	ACF07	ACF67	ACF21	ACF29	-	-	-	-	-
	3/8″	-	-	-	ACF22	ACF30	-	-	-	-	-
	1/2″	-	-	-	ACF23	ACF31	ACF45	ACF47	-	-	-
	3/4″	-	-	-	-	-	ACF75	ACF49	ACF48	ACF90	-
	1″	-	-	-	-	-	-	-	-	-	ACF77
BSP Parallel Thread	1/8″	-	-	-	-	-	-	-	-	-	-
	1/4″	-	ACF65	ACF66	ACF93	-	-	-	-	-	-
	1/2″	-	-	-	ACF68	ACF42	ACF88	ACF50	-	-	-
NPT/API Thread	1/8″	-	ACF08	-	-	-	-	-	-	-	-
	1/4″	-	ACF09	ACF87	ACF24	ACF32	-	-	-	-	-
	3/8″	-	-	-	ACF25	ACF33	-	-	-	-	-
	1/2″	-	-	-	ACF26	ACF34	ACF46	ACF51	-	-	-

Ordering Code - Typical example

ACF17 - S
Type
Material (S = Stainless Steel, B = Brass)

Termination Entry Glands



For use with thermocouples and platinum resistance thermometers for terminating into conduit boxes, terminal boxes or through bulkheads etc. These are three part components comprising a body, ferrule and locking cap. All glands are available in both brass and stainless steel materials.

Code	To suit Tube Dia.	Male Entry Thread
TEG10M16	1.0	16mm ISO
TEG15M16	1.5	16mm ISO
TEG20M16	2.0	16mm ISO
TEG30M16	3.0	16mm ISO
TEG45M16	4.5	16mm ISO
TEG55M16	5.5	16mm ISO
TEG60M16	6.0	16mm ISO
TEG80M16	8.0	16mm ISO
TEG108M16	10.8	16mm ISO
TEG30M20	3.0	20mm ISO
TEG45M20	4.5	20mm ISO
TEG55M20	5.5	20mm ISO
TEG60M20	6.0	20mm ISO
TEG80M20	8.0	20mm ISO

Ordering Code - Typical example

TEG60M16 - B
Type
Material (S = Stainless Steel, B = Brass)

Locknuts for Termination Entry Glands and Threaded Pots

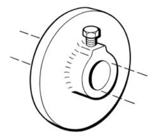
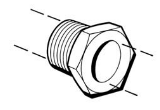
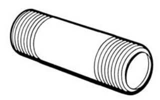
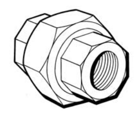
These are available in both stainless steel and brass to suit the above termination glands as well as an 8mm locknut which suits our 3P3/CE3 threaded sensor pot seals.

Code	Thread	Material
LN08S	8mm x 1mm ISO	Stainless Steel
LN16B	16mm x 1.5mm ISO	Brass
LN16S	16mm x 1.5mm ISO	Stainless Steel
LN20B	20mm x 1.5mm ISO	Brass
LN20S	20mm x 1.5mm ISO	Stainless Steel

Ordering Code - Typical example

Code - LN16S

Mounting Fittings for Protection Tubes

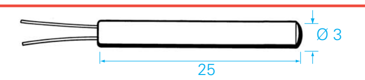
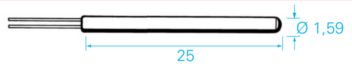
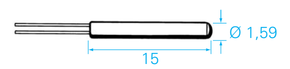
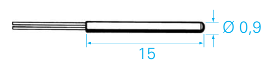
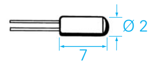
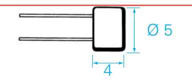
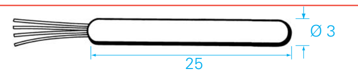
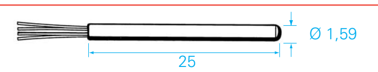
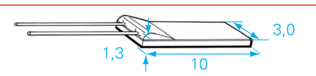
Code	Description	Sketch	Material	Screwed	Notes
FI1	Adjustable Flange		Cast iron	N/A	Suited to all sheath diameters less than 1½″ FI1 diameter is 100mm (4 inches).
FFW	Welded flange	-	Stainless steel	N/A	Please consult company with details of your requirements
WBPSA	Welded fixed position bushes screwed BSP		Stainless steel	¾″ BSP parallel	Suited to all tube diameters up to and including 21.3mm (13/16″)
WBTSA			Stainless steel	¾″ BSP taper	Suited to all tube diameters up to and including 21.3mm (13/16″)
WBPSB			Stainless steel	1″ BSP parallel	Suited to all tube diameters 21.3mm (13/16″) and above
WBTSB			Stainless steel	1″ BSP taper	Suited to all tube diameters 21.3mm (13/16″) and above
EPSS	Extension piece		Stainless steel	½″ BSP male	For lagging extensions or connection to rotating unions. Lengths to suit requirement.
RUSS	Rotating Union		Stainless steel	½″ BSP female	Used in addition to extension pieces to facilitate positioning of terminal heads.

Ordering Code - Typical example

WBTSA - 15.8mm - ¾″ BSPT
Code
Tube Size if any
Thread if any

Platinum Resistance Thermometer Detector Elements

In addition to the detector elements described here, we offer a range of Platinum Resistance Thermometer assemblies incorporating these detector elements. Details are on pages 56/57 and 60/61. Our platinum resistance thermometer detector elements are available either as wire wound or film type.

Code	Wire Wound/ Flat Film	No. of Elements	Sketch and Dimensions (mm)	Leads Length (mm)	Leads Dia. (mm)	Measuring Current Limit per Element (mA)	Notes
CS1	Wire wound	Single		10	0.45	5	Available in all tolerances
CS2	Wire wound	Single		10	0.45	5	Available in all tolerances
CS3	Wire wound	Single		10	0.25	3	Available in all tolerances
CS4	Wire wound	Single		10	0.15	1	Available in all tolerances
CS5	Wire wound	Single		7	0.25	1	Available in all tolerances
CS6	Wire wound	Single		10	0.45	3	Available in all tolerances
CD1	Wire wound	Duplex		10	0.25	3	Available in Grade A and B tolerances*
CD2	Wire wound	Duplex		10	0.25	3	Available in Grade A and B tolerances*
F230	Flat Film	Single		10	0.2	3	Available in Grade A and B tolerances

*Due to the problems of selection, where a high accuracy duplex element is required, we recommend that you choose two single high accuracy elements.
The value of the above elements is 100 ohms at 0°C in accordance with BS EN 60751/IEC 60751:2008, and is given at a point 5mm from the ceramic encapsulation. Other standards can be supplied upon request.

Ordering Code - Typical example

CS2 - B
Code
Tolerance

GLOSSARY OF TERMS (continued)

RFI: *Radio Frequency Interference.*
RTD: *Resistance Thermometer Detector.*
Seebeck coefficient: *First derivative of thermal emf with respect to temperature - expressed as mV/°C.*
Seebeck effect: *The phenomenon whereby thermal energy produces an emf - forms the basis of thermocouple thermometry.*
Seebeck emf: *Open circuit voltage caused by the difference in temperature between the hot and cold junctions of a thermocouple.*
Secondary standard: *A standard for parameter measurement itself derived from, and thus traceable to, a primary national standard.*
Sensitivity: *The output response - in time or magnitude - developed by a thermocouple or RTD for a given temperature change.*
Series mode noise rejection ratio: *The ability of an instrument to reject interference usually of line frequency (50Hz) across its input terminals.*
Sheathed MI cable: *Cable comprising one or more conductors embedded in a powdered insulant and surrounded by a metal sheath. Final diameter is produced by drawing or swaging.*
Signal: *General term for an electrical current or voltage representing a quantity, event, or whatever.*
Span: *The difference between the upper and lower limits of a range.*
Specific heat: *The ratio of thermal energy required to raise the temperature of a body 1°C, to the thermal energy required to raise an equal mass of water 1°C.*
Stability: *The consistency of output of a sensor to given temperatures.*
T/C: *Thermocouple.*
Temperature compensator: *An externally powered device comprising a temperature sensitive electrical network that can be connected to the thermocouple conductors to provide an equivalent ice point voltage.*
Temperature element: *Usually applied to the innermost part of a temperature measuring probe - eg, a ceramic former containing platinum wire, a sleeved thermocouple junction, a glass covered thermistor bead, etc.*
Temperature gradient: *The distribution of a temperature interval existing through a body or across a surface.*
Thermal conductivity: *The rate at which heat flows through a material for a given temperature difference applied to it, with no gain or loss of heat by the material.*
Thermal emf: *Source of electrical energy arising from Seebeck effect. Frequently applied to spurious voltages developed in measuring circuits.*
Thermal expansion: *The increase in material size resulting from an increase in temperature - thermal coefficient normally expressed as the length change per degree Centigrade.*
Thermal gradient: *The rate of change of temperature as measured through a body or across a surface.*
Thermal radiation: *The electromagnetic radiation emitted by any body at a temperature above absolute zero. With two bodies at different temperatures, and in view of each other, there will be a net interchange of heat without the need of an intervening medium.*
Thermistor: *A semiconductor which exhibits a large, non-linear change of resistance with temperature - used as a temperature sensor.*
Thermocouple: *An electrical circuit comprising two dissimilar materials. A voltage is generated that is dependent on the temperatures at the junctions forming the limits of the dissimilar materials. The reference junction at one end of the conductors is usually maintained at 0°C to allow the measuring junction to be used as a temperature sensor.*
Thermowell: *A closed end (re-entrant) metal or ceramic tube, usually fitted permanently in plant to protect a temperature sensor from corrosive environments or mechanical forces.*
Thomson effect: *The change of heat content in a single current carrying conductor when situated in a temperature gradient.*
Time constant: *See Response time.*
Transducer: *A device that converts a physical quantity into a related electrical signal - eg, a resistance thermometer, thermocouple, strain gauge, etc.*
Transistor: *A three electrode, solid state, electronic amplifying device - some types can be used as temperature sensors over a limited range.*
Transmitter: *A device incorporating an electrical circuit that converts a signal from a transducer into a standard transmittable form - typically, a two wire DC current output ranging from 4 - 20mA.*
Triple point: *The temperature at which all three phases of a substance are in equilibrium; the triple point of water is 0.01°C.*
Ungrounded junction: *A thermocouple probe constructed such that the measuring junction is fully enclosed by, and insulated from, the sheath material.*
Volt: *The unit of electrical potential difference between two points in a circuit - derived as work per unit charge, and defined as the potential difference needed to move one coulomb of charge between two points in a circuit using one joule of energy.*
Wheatstone bridge: *A network of four resistances, an emf source and a null reading instrument (eg: galvanometer) connected such that when the four match there is zero current flow through the instrument.*
Zero offset: *The difference between the real measurement zero and the instrument reading.*
Zero power resistance: *The resistance of an RTD element dissipating zero power.*
Zero suppression: *Where the span of an instrument is offset from zero, allowing it to measure with greater sensitivity in the temperature range of interest.*

FURTHER READING REFERENCE

Anderson RL and Ludwig RL; Failure of Sheathed Thermocouples due to Thermal Cycling; Temperature 1982, pp 939-951.

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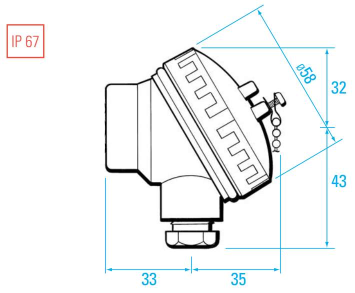
Components and Accessories for Temperature Sensors (continued)

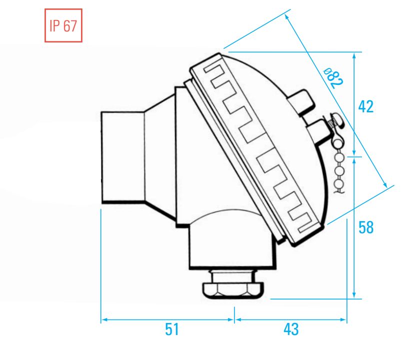
Terminal Heads

P10 Weatherproof die cast alloy head



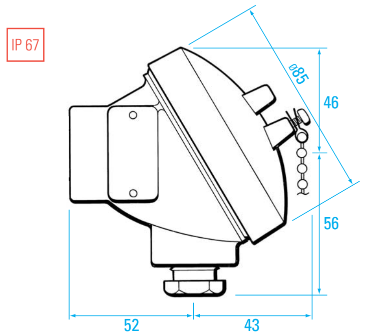
Weatherproof die cast alloy, epoxy coated, screw top terminal head with the tube entry and cable entry at a right angle to each other. Suitable for simplex and duplex assemblies. Suitable for use with TBCM terminal blocks. Supplied with a 16mm x 1.5mm ISO tube entry and a 16mm x 1.5mm ISO cable entry. A metal cable gland is supplied suitable for cables from 3mm to 8mm diameter. Also available in a range of colours including Green, Brown, Black, Pink, Orange, Purple and White.

P11 Weatherproof heavy duty die cast alloy head



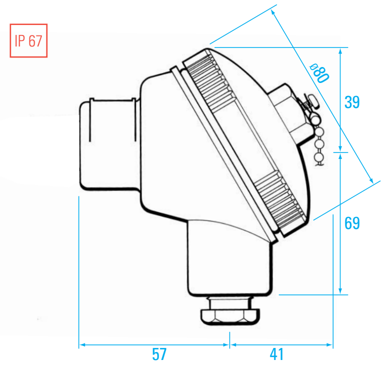
Generally as P10 but heavy duty version. Suitable for use with TBC or TBCSL terminal blocks. Supplied with a 1/2 in BSP tube entry and a 20mm x 1.5mm ISO cable entry. A metal cable gland is supplied suitable for cables from 6mm to 14mm diameter. Also available in a range of colours including Green, Brown, Black, Pink, Orange, Purple and White.

P12 Weatherproof heavy duty cast iron head



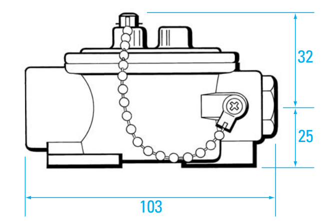
Weatherproof cast iron screw top terminal head with the tube entry and cable entry at a right angle to each other. Suitable for use with TBC or TBCSL terminal blocks. Supplied with a 1/2 in BSP tube entry and a 20mm x 1.5mm ISO cable entry. A metal cable gland is supplied suitable for cables from 6mm to 14mm diameter.

P17 Weatherproof Bakelite head



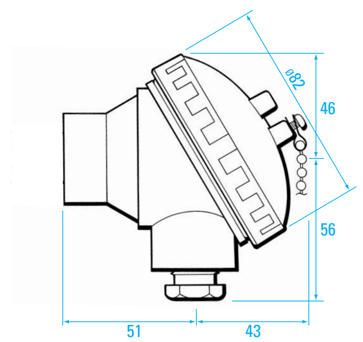
Weatherproof Bakelite plastic screw top terminal head with tube entry and cable entry at a right angle to each other. Suitable for use with TBB terminal blocks. Supplied with a 1/2 in BSP tube entry and a 20mm x 1.5mm ISO cable entry. A plastic cable gland is supplied suitable for cables from 6mm to 14mm diameter. Terminal head temperature rated to 150ÞC.
A smaller version similar to the PI7 is also available and is referred to as P16.

P18 Die cast alloy straight through head



Die cast alloy straight through terminal head suitable for use with TBB terminal blocks. Supplied with a 1/2 in BSP tube entry and a 20mm x 1.5mm ISO cable entry. A metal cable gland is supplied suitable for cables from 6mm to 14mm diameter.

P19 Stainless Steel head

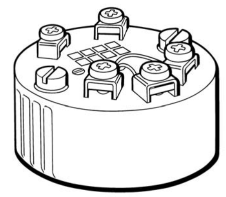


Stainless steel terminal head with the tube entry and cable entry at a right angle to each other. Suitable for use with TBC or TBCSL terminal blocks. Supplied with a 1/2 in BSP tube entry and a 20mm x 1.5mm ISO cable entry. A metal cable gland is supplied suitable for cables from 6mm to 14mm diameter. Ideal for the food industry.

Ordering Code - Typical example

P11 - Green
Code (P11)
Colour (if applicable) (Green)

Head Mounted Transmitters



We offer a range of 4-20mA Transmitters from a basic inexpensive standard model up to a sophisticated universal model which is totally programmable, isolated and available with an optional display for head mounting. A detailed technical sheet is available on all our transmitters.

TXSTD STANDARD
Our standard transmitter is fully linearised for PT100 and voltage linearised for Types K, J, T, N, R & S thermocouples. The electronics are completely sealed in a rugged epoxy coated metal housing. An Ex version is also available.

TXLIN LINEARISED
Since thermocouples provide a non linear signal, errors can occur when conventional transmitters are used over a wide temperature range. The TXLIN eliminates this problem by providing an output that has been linearised to the temperature. RFI protection and/or Ex options are available.

TXISO ISOLATED
The TXISO transmitter incorporates new isolation technology. Combined with SMD technology, it provides a full 1000VDC (AC peak) input/output isolation. The TXLIN completely eliminates earth loop and other problems. RFI protection is an available option.

TXUNI UNIVERSAL
The TXUNI is truly universal. It provides a fully linearised signal for either PT100 or Thermocouple use, full 1000V DC (AC peak) input/output isolation, is totally programmable via a PC and can be ordered with an optional plug on display. It is also available in an Ex version.

Transmitter Selector Table

Type Code	2 wire 4 to 20 mA Output	Fully Linearised* Thermocouple only	Isolated	RFI Protected	EX ia IIC T4 Approved	Customer Programmable	Optional Display
TXSTD	✓						
TXLIN	✓	✓					
TXISO	✓		✓				
TXLIN/RFI	✓	✓		✓			
TXISO/RFI	✓		✓	✓			
TXSTD/EXI	✓				✓		
TXLIN/EXI	✓	✓			✓		
TXUNI	✓	✓	✓	✓		✓	
TXUNI/EXI	✓	✓	✓	✓	✓	✓	
TXUNI/D	✓	✓	✓	✓		✓	✓
TXUNI/EXI/D	✓	✓	✓	✓	✓	✓	✓

*All PT100 transmitters are linearised as standard. Thermocouple transmitters are voltage linear and if required as temperature linearised for superior accuracy should be specified as TXLIN.

If you wish to mount any of the above transmitters in a junction box, DIN plates and DIN rails are available. Please contact us with your requirements.

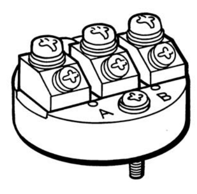
Ordering Code - Typical example

TXSTD - K - 0/150°C
Type (TXSTD)
Sensor (Thermocouple Type or PRT) (K)
Range (0/150°C)

Connector Blocks for Terminal Heads

Our range of connector blocks are suitable for use with the terminal heads shown on this page.

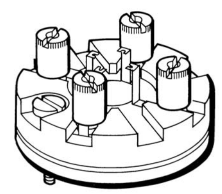
Miniature Ceramic



Rated to 350°C
Suitable for use
with our P10 head only.
Supplied with M27.2 hole centres.

Code	No. of Terminals
TBCM2	2
TBCM3	3
TBCM4	4

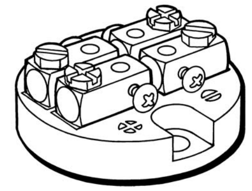
Spring Loaded Ceramic



Rated to 350°C
Suitable for all our
heads except P10 or P18.
Supplied with M33 hole centres.

Code	No. of Terminals
TBCSL2	2
TBCSL4	4
TBCSL6	6

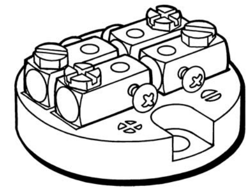
Standard Ceramic



Rated to 350°C
Suitable for all our
heads except P10.
Supplied with M40 hole centres.

Code	No. of Terminals
TBC2	2
TBC3	3
TBC4	4
TBC6	6

Standard Bakelite



Rated to 150°C
Ideally suited
for our P17 Bakelite head.
Supplied with M40 hole centres.

Code	No. of Terminals
TBB2	2
TBB3	3
TBB4	4

Ordering Code - Typical example

TBCM4
Code (including number of terminals)

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01895 252222

Thermocouple Reference Tables for

CODE G

Formerly Code W

Tungsten / Tungsten 26% Rhenium

CODE C

Formerly Code W5

Tungsten 5% / Tungsten 26% Rhenium

CODE D

Formerly Code W3

Tungsten 3% / Tungsten 25% Rhenium

Temperatures are expressed in degrees Celsius and the emf output in microvolts (μV).

Code G — emf/μV

°C	0	10	20	30	40	50	60	70	80	90	°C
1000	14500	14700	14900	15100	15300	15500	15700	15900	16100	16300	**1000**
1100	16500	16700	16900	17100	17300	17500	17700	17900	18100	18300	**1100**
1200	18500	18700	18900	19100	19300	19500	19700	19900	20100	20300	**1200**
1300	20500	20700	20900	21100	21300	21500	21700	21900	22100	22300	**1300**
1400	22500	22700	22900	23100	23300	23500	23700	23900	24100	24300	**1400**
1500	24500	24700	24900	25100	25300	25500	25700	25900	26100	26300	**1500**
1600	26500	26700	26900	27100	27300	27500	27700	27900	28100	28300	**1600**
1700	28500	28700	28900	29100	29300	29500	29700	29900	30100	30200	**1700**
1800	30400	30600	30800	31000	31200	31300	31500	31700	31900	32100	**1800**
1900	32300	32400	32600	32800	33000	33200	33400	33500	33700	33900	**1900**
2000	34100	34300	34400	34600	34800	34900	35100	35200	35400	35600	**2000**
2100	35700	35900	36000	36200	36300	36500	36700	36800	37000	37100	**2100**
2200	37300	37400	37600	37800	37900	38100	38200	38300	38500	38600	**2200**
2300	38800										**2300**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

Code C — emf/μV

°C	0	10	20	30	40	50	60	70	80	90	°C
0	0	135	272	412	554	698	845	993	1144	1296	**0**
100	1451	1607	1765	1925	2087	2250	2415	2581	2749	2918	**100**
200	3089	3261	3434	3609	3785	3962	4140	4319	4500	4681	**200**
300	4863	5047	5231	5416	5601	5788	5975	6163	6352	6541	**300**
400	6731	6921	7112	7304	7496	7688	7881	8074	8267	8461	**400**
500	8655	8849	9044	9239	9434	9629	9824	10019	10215	10410	**500**
600	10606	10801	10997	11192	11388	11583	11778	11974	12169	12364	**600**
700	12558	12753	12947	13142	13336	13529	13723	13916	14109	14302	**700**
800	14494	14686	14877	15069	15260	15450	15640	15830	16020	16208	**800**
900	16397	16585	16773	16960	17147	17333	17519	17704	17889	18073	**900**
1000	18257	18440	18623	18805	18987	19168	19349	19529	19709	19888	**1000**
1100	20866	20244	20421	20598	20774	20950	21125	21299	21473	21647	**1100**
1200	21819	21991	22163	22334	22504	22674	22843	23012	23180	23347	**1200**
1300	23514	23680	23846	24010	24175	24339	24502	24664	24826	24988	**1300**
1400	25148	25308	25468	25627	25785	25943	26100	26256	26412	26568	**1400**
1500	26722	26876	27030	27183	27335	27486	27637	27788	27938	28087	**1500**
1600	28236	28384	28531	28678	28824	28969	29114	29259	29402	29546	**1600**
1700	29688	29830	29971	30112	30252	30391	30530	30668	30805	30942	**1700**
1800	31078	31214	31349	31483	31617	31749	31882	32013	32144	32274	**1800**
1900	32404	32533	32661	32788	32915	33041	33166	33291	33415	33538	**1900**
2000	33660	33782	33902	34022	34142	34260	34378	34494	34610	34725	**2000**
2100	34839	34953	35065	35177	35288	35397	35506	35614	35721	35827	**2100**
2200	35932	36036	36138	36240	36341	36441	36539	36637	36733	36828	**2200**
2300	36922	37015	37107								**2300**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

Code D — emf/μV

°C	0	10	20	30	40	50	60	70	80	90	°C
0	0	97	199	305	414	527	644	764	888	1015	**0**
100	1145	1278	1414	1553	1695	1840	1987	2137	2289	2444	**100**
200	2602	2761	2923	3086	3252	3420	3590	3761	3934	4109	**200**
300	4286	4464	4644	4825	5007	5191	5376	5563	5750	5939	**300**
400	6129	6320	6512	6704	6898	7093	7288	7484	7681	7878	**400**
500	8076	8275	8474	8674	8874	9075	9276	9478	9680	9883	**500**
600	10085	10288	10491	10695	10899	11102	11307	11511	11715	11919	**600**
700	12124	12329	12533	12738	12942	13147	13352	13556	13761	13965	**700**
800	14170	14375	14580	14784	14989	15193	15397	15601	15804	16008	**800**
900	16211	16414	16616	16819	17021	17222	17424	17625	17825	18026	**900**
1000	18226	18425	18625	18824	19022	19220	19418	19616	19812	20009	**1000**
1100	20205	20401	20596	20791	20985	21179	21373	21566	21758	21950	**1100**
1200	22142	22333	22524	22714	22904	23094	23282	23471	23659	23846	**1200**
1300	24033	24219	24405	24591	24776	24960	25144	25327	25510	25693	**1300**
1400	25875	26056	26237	26418	26597	26777	26956	27134	27312	27489	**1400**
1500	27666	27842	28018	28193	28367	28541	28715	28888	29060	29232	**1500**
1600	29403	29574	29744	29914	30083	30251	30419	30586	30753	30919	**1600**
1700	31084	31249	31413	31576	31739	31901	32063	32223	32384	32543	**1700**
1800	32702	32860	33017	33173	33329	33484	33638	33792	33944	34096	**1800**
1900	34247	34397	34546	34695	34842	34989	35134	35279	35423	35565	**1900**
2000	35707	35847	35987	36125	36263	36399	36534	36668	36801	36932	**2000**
2100	37062	37191	37319	37445	37570	37694	37816	37937	38056	38173	**2100**
2200	38289	38404	38517	38628	38737	38845	38951	39055	39157	39258	**2200**
2300	39356	39452	39547	39639	39729	39817	39903	39986	40068	40146	**2300**
2400	40223	40297	40368	40437	40503	40566	40627	40685	40740	40792	**2400**

Absolute thermocouple e.m.f. in microvolts
with the reference junction at 0°C.

For other thermocouple output tables refer to the following pages:

TYPE **K** page 10	TYPE **E** page 26
TYPE **T** page 14	TYPE **R** page 30
TYPE **J** page 18	TYPE **S** page 34
TYPE **N** page 22	TYPE **B** page 38
TYPES **G**, **C** & **D** page 70	

Codes G C and D and their output tables as shown above are not officially recognised symbols or standards.

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Components and Accessories for Temperature Sensors

Thermocouple Conductors: Uninsulated Matched Pairs

Available as matched thermocouple pairs in thermocouple grade materials. They are normally stocked as indicated on the following table.
These conductors comply with the relevant parts of IEC60584.1:1995 (BS EN 60584.1 Pts 1-8) and IEC 60584.2:1993 (BS EN 60584.2 1993) – see page 7 for further information

Order code	Conductor Sizes						Readily Available in Thermocouple Conductor Combination Codes:										
	Diameter		Gauge		Cross sectional area												
	mm	in	SWG	AWG/B&S	mm²	IN²	K	T	J	E	N	R	S	B	G	C	D
BC44	0.076	0.003	44	40	0.0045	0.000007	YES	YES	YES	YES		YES	YES	YES			
BC39	0.127	0.005	39	36	0.0086	0.000002	YES	YES	YES	YES		YES	YES	YES			
BC36	0.2	0.008	36	32	0.03	0.00005	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
BC31	0.3	0.012	31	28	0.07	0.000113	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
BC25	0.5	0.020	25	24	0.2	0.000314	YES	YES	YES	YES	YES	YES*	YES*	YES*	YES	YES	YES
BC21	0.8	0.031	21	20	0.5	0.000706	YES	YES	YES	YES	YES						
BC18	1.29	0.051	18	16	1.31	0.00196	YES	YES	YES	YES	YES						
BC16	1.63	0.064	16	14	2.09	0.00321	YES	YES	YES	YES	YES						
BC10	3.2	0.126	10	8	8.04	0.01247	YES		YES	YES	YES						

Ordering Code - Typical example

BC25 - K
Code
Calibration

* Types R, S and B are offered at 0.45 mm diameter

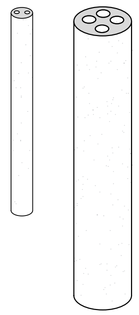
Ceramic Insulators

Our range of twin bore and four bore insulators are normally available ex stock for immediate delivery in the materials and sizes listed below.
If your requirements are for different materials or dimensions please contact us with details against which we can make our proposals.

Aluminous Porcelain Insulators

Suitable for use with base metal conductors at temperatures up to 1400°C.

Order Code		Suitable for Conductor Sizes						Section	Nominal Diameter (mm)	Available Lengths (mm)		
		Diameter		Gauge		Cross Sectional Area						
		mm	in	SWG	AWG/B&S	mm²	in²					
Twin Bores	API36	0.2	0.008	36	32	0.03	0.00005	Round	2.2		50	100
	API31	0.3	0.012	31	28	0.07	0.000113	Round	2.2		50	100
	API25	0.5	0.02	25	24	0.2	0.000314	Round	3.0	25	50	
	API21	0.8	0.03	21	20	0.5	0.000706	Round	4.0	25	50	100
	API18	1.29	0.05	18	16	1.31	0.00196	Round	6.0	25	50	100
	API16	1.63	0.064	16	14	2.09	0.00321	Round	6.0	25	50	100
	API10	3.2	0.126	10	8	8.04	0.01247	Round	15.5		50	100
	API10/1	3.2	0.126	10	8	8.04	0.01247	Oval	12x8	25	50	100
Four Bores	API25	0.5	0.02	25	24	0.2	0.000314	Round	4.5	25	50	100
	API21	0.8	0.03	21	20	0.5	0.000706	Round	4.5	25	50	100
	API18	1.29	0.05	18	16	1.31	0.00196	Round	8.5	25	50	
	API16	1.63	0.064	16	14	2.09	0.00321	Round	8.5	25	50	



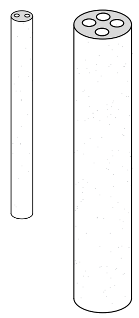
Ordering Code - Typical example

4 - API25 - 100
Number of Bores
Code
Length

Recrystallised Alumina Insulators

Suitable for use with precious metal conductors at temperatures up to 1800°C.

Order Code		Suitable for Conductor Sizes						Section	Nominal Diameter (mm)	Available Lengths (mm)		
		Diameter		Gauge		Cross Sectional Area						
		mm	in	SWG	AWG/B&S	mm²	in²					
Twin Bores	RAI36	0.2	0.008	36	32	0.03	0.00005	Round	2.2		50	100
	RAI31	0.3	0.012	31	28	0.07	0.000113	Round	2.2		50	100
	RAI25	0.5	0.02	25	24	0.2	0.000314	Round	3.0	25	50	
	RAI21	0.8	0.03	21	20	0.5	0.000706	Round	4.0	25	50	100
	RAI18	1.29	0.05	18	16	1.31	0.00196	Round	6.0	25	50	100
	RAI16	1.63	0.064	16	14	2.09	0.00321	Round	6.0	25	50	100
	RAI10	3.2	0.126	10	8	8.04	0.01247	Round	15.5		50	100
	RAI10/1	3.2	0.126	10	8	8.04	0.01247	Oval	12x8	25	50	100
Four Bores	RAI25	0.5	0.02	25	24	0.2	0.000314	Round	4.5	25	50	100
	RAI21	0.8	0.03	21	20	0.5	0.000706	Round	4.5	25	50	100
	RAI18	1.29	0.05	18	16	1.31	0.00196	Round	8.5	25	50	
	RAI16	1.63	0.064	16	14	2.09	0.00321	Round	8.5	25	50	



Ordering Code - Typical example

4 - RAI25 - 100
Number of Bores
Code
Length

Ceramic Protection Sheaths: Closed at One End

Code	Material	Operational Properties	Maximum Operating Temperature	Diameters mm	
				Outside	Inside
IAP	Impervious Aluminous Porcelain	Ideally suited for use with base metal thermocouple conductor combinations. Has a very low temperature coefficient of expansion thus giving excellent resistance to thermal shock. Offers high strength and high resistance to flux and slag attack. Suited to kiln applications where low contamination requirements preclude the use of a metal sheath. *NB.* Requires support at high temperature if horizontal.	1400°C	10	7
				12	8
				17	13
				20	15
				26	20
				30	23
IRA	Impervious Recrystallised Alumina	Ideally suited for use with precious metal thermocouples at high temperatures. Provides a fair resistance to thermal shock. High degree of inertness to chemicals. Ideal for reducing and carbonaceous atmospheres and offers a high resistance to alkaline and other fluxes.	1800°C	10	7
				12	8
				17	13
				20	15
				26	20
				30	23
IM	Impervious Mullite	Suited for use with precious metal thermocouples at high temperature. Has great mechanical strength combined with good resistance to thermal shock. Relatively inert to sulphurous and carbonaceous atmospheres and highly resistant to flux attack. Used very often as a secondary protection sheath within a silicon carbide primary sheath.	1600°C	10	7
				12	8
				17	13
				20	15
				26	20
				30	23
SC	Silicon Carbide	A porous material but with an outstanding resistance to thermal shock and good mechanical strength. Normally used in high temperature applications as the primary sheath enclosing some secondary sheath material. Not suitable for use in highly oxidising atmospheres.	1450°C	16	10
				20	12
				23	17
				35	28
				50	35

These sheaths are available as standard on an ex stock basis for immediate delivery in the following lengths; 500mm, 600mm, 1000mm, 1200mm, 1500mm.

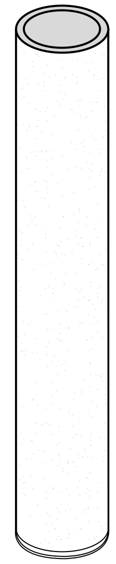
Sheaths are also available cut to specific lengths up to 2500mm.

NB1: Where the application demands alternative sheath; characteristics, diameters and lengths, we will be happy to quote against receipt of your requirements.

NB2: Open ended sheaths are available. Consult the company for details.

Ordering Code - Typical example

IAP - 12 x 8 - 1000mm
Code
O/D x I/D
Length



Thick Wall Metal Protection Tubes: Closed at One End

These welded end sheaths are supplied cut to length to suit your application.

Code	Material	Operational Properties	Maximum Operating Temperature	International Specifications	Equivalent to Materials: Trade Names as below	General	Available Tube Sizes Outside and Inside Dia.					
							Inches to nearest 1/16"		Inches (decimal)		mm	
							Outside	Inside	Outside	Inside	Outside	Inside
116	316 Stainless Steel	Good corrosion resistance throughout operating temperature range.	800°C	BS970 Pt4:1970 BS3605 316 AISI T316 Werkstoff No: 1.4401	–	Oil baths, drying kilns, low temperature ovens, general wet process applications (steam lines, oil refineries and chemical solutions) NB: Resists nitric acid well, sulphur acids moderately and resists pitting in phosphoric and acetic acids.	1/2	5/16	0.5	0.3	12.7	7.42
							5/8	7/16	0.625	0.47	15.9	11.9
							13/16	5/8	0.84	0.625	21.3	15.8
							1 1/16	13/16	1.05	0.84	26.7	20.93
176	Nickel Chromium Iron Alloy	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys good resistance to oxidation and carburization. Do not use in sulphur bearing atmospheres above 550°C. *NB:* Has greater strength than alloy code 144.	1100°C	BS3074:1974 Grade NA14 ASTM B167 ASME SB167 Din NiCr 15 Fe Werkstoff No: 2.4816	Inconel 600 Firebird red AMAL 2A Furnite 2	General heat treatment, furnaces, ovens. Do not use in sulphur bearing atmospheres above 550°C.	1/2	5/16	0.5	0.3	12.7	7.42
							5/8	7/16	0.625	0.47	15.9	11.9
							13/16	5/8	0.84	0.625	21.3	15.8
							1 1/16	13/16	1.05	0.84	26.7	20.93
180	Iron Nickel Chromium Alloy	Suitable for use in severely corrosive atmospheres to elevated temperatures. Enjoys good resistance to oxidation and carburization. Resistant to sulphur bearing atmospheres. *NB:* Has greater strength than alloy code 144.	1100°C	BS3074:1974 Grade NA15 ASTM B163. B407 ASME SB 163SB407 Din X10NiCrAITi3220 Werkstoff No: 1.4876	Incoloy 800 Sanicro 31H Furnite 3	Flues, acids, molten salts (neutral), cyanide baths, Furnaces, ovens. Resistant to sulphur bearing atmospheres.	1/2	5/16	0.5	0.3	12.7	7.42
							5/8	7/16	0.625	0.47	15.9	11.9
							13/16	5/8	0.84	0.625	21.3	15.8
							1 1/16	13/16	1.05	0.84	26.7	20.93
144	Chromium Iron Alloy	Suitable for use in severely corrosive atmospheres to elevated temperatures. Particularly suited for use in high concentration sulphur bearing atmospheres at high temperature. *NB:* Should be mounted vertically at temperatures above 700°C.	1150°C	ASTM TP446 AISI 446 Din X18CrN28 Werkstoff No: 1.4749	Sandvik 4C54 Firebird blue AMAL 1A Furnite 5	Oil firing applications, furnaces, ovens, flues. Suited for use in high concentration sulphur bearing atmospheres	5/8	7/16	0.625	0.47	15.9	11.9
							13/16	5/8	0.84	0.625	21.3	15.8
							1 1/16	13/16	1.05	0.84	26.7	20.93

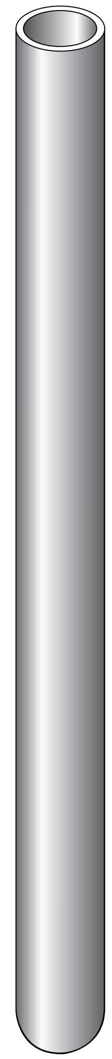
We will be pleased to discuss mounting arrangements for these tubes. They are available either plain or with the options of; a screwed BSP taper male thread, a range of screwed bushes welded in position, adjustable compression fittings or with welded or adjustable flanges.

NB1: Where the application demands alternative sheath characteristics and dimensions we will be happy to quote against receipt of your requirements.

NB2: Open ended sheaths are also available. Consult the company for details.

Ordering Code - Typical example

116 - 15.9x11.9 - 1000mm
Code
O/D x I/D (mm)
Length



A Guide to Thermocouple and Resistance Thermometry - Index

PART 1 : THEORY AND STANDARD

PART 2 : SENSORS, EQUIPMENT AND PRACTICE

PART 3 : FURTHER PRACTICAL POINTS

EPILOGUE

GLOSSARY OF TERMS

FURTHER READING

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