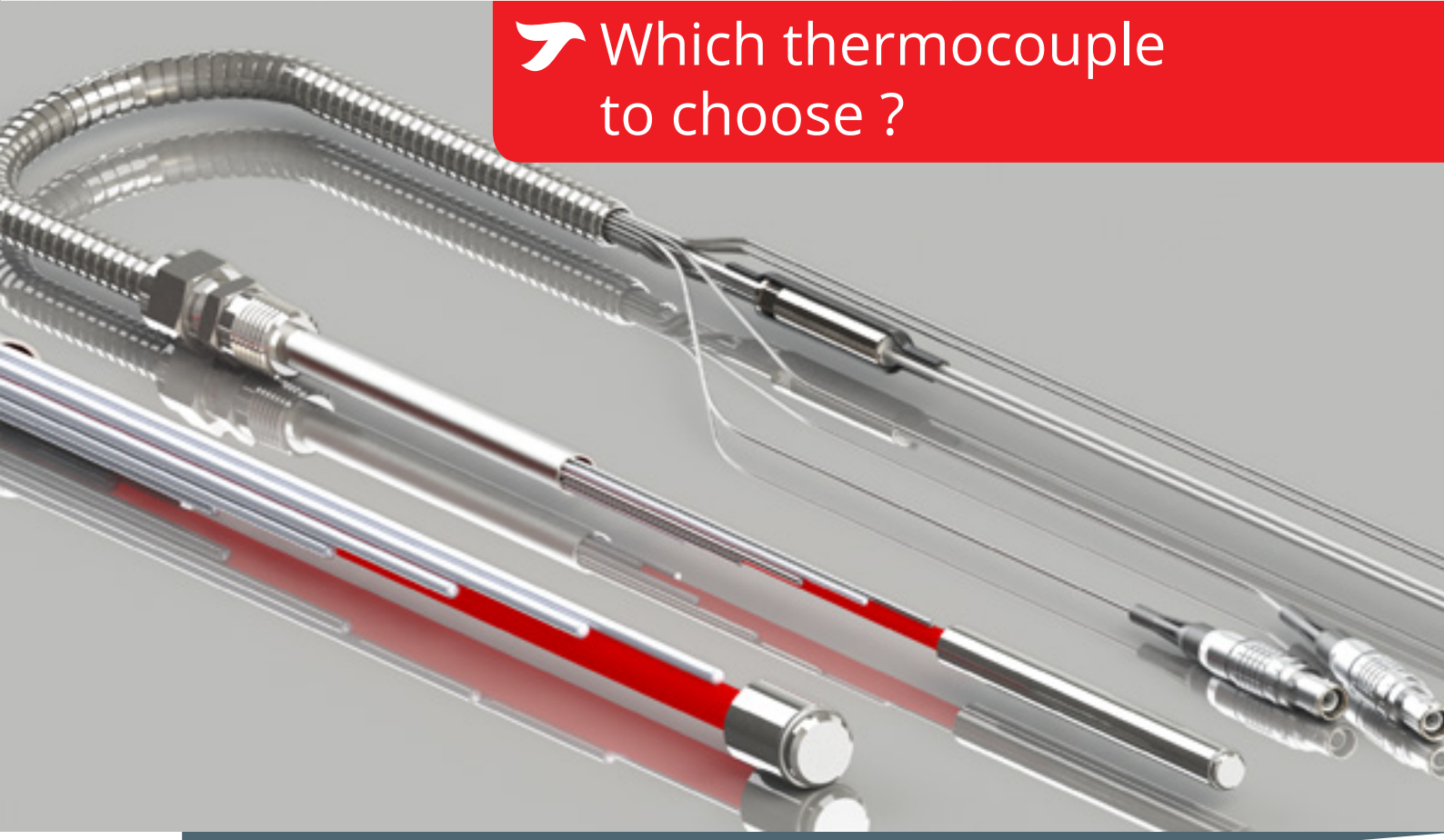
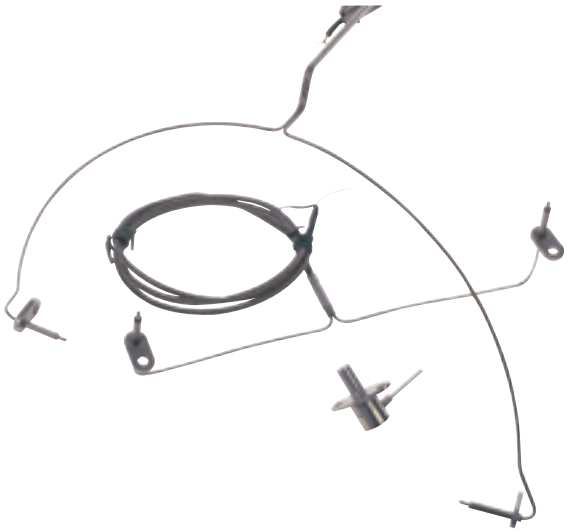
TEMPERATURE MEASUREMENT SOLUTIONS

Which thermocouple to choose ?



THERMOCOAX



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Introduction to temperature

What is temperature

Temperature is a physical « quantity » which follows the thermodynamics laws.

The temperature unit (T symbol) is the Kelvin (K symbol) defined as a fraction of the thermodynamic temperature of the triple point of water (1/273.16).

For temperature above the triple point of water, it is useful to take the Celsius temperature (t symbol) of which the unit is the Celsius degree (°C symbol)

$$t = T - 273.15$$

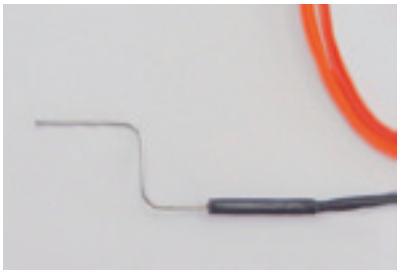
273.15 being the thermodynamic temperature of the melting point of water.

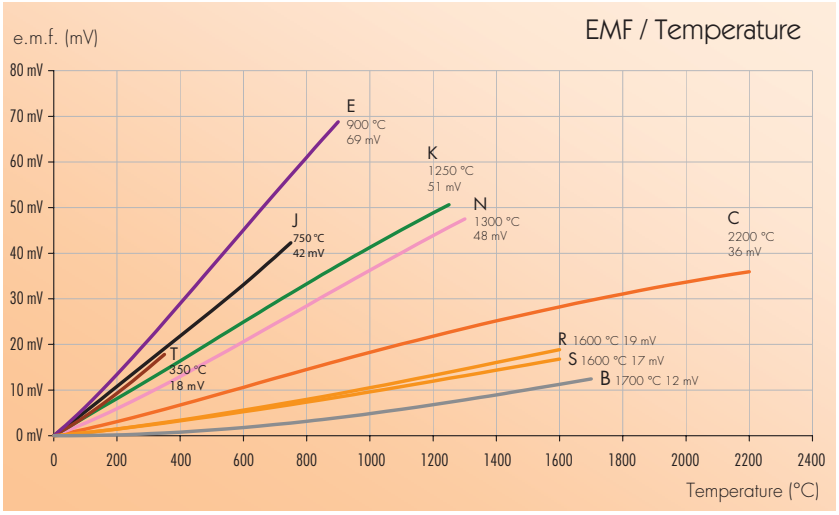
Apart from highly specialized laboratories, it is extremely difficult to use thermodynamic thermometers (gas dilatation, radiation), so the idea to use other phenomenon:

- change of electrical resistivity in metal,
- e.m.f. of thermocouples

gave rise to the development of appropriate sensors.

In order to find the relationship between the temperature and the electrical property of the sensors, they have to be measured and compared at given temperature levels, thus temperature scales were created.





These scales are often represented by "fixed points" which are temperatures where pure elements change their physical states:

- melting (solid to liquid),
- freezing (liquid to solid),
- boiling (liquid to gas),
- triple point (liquid, solid and gas).

Interpolations between these points are made by thermometers which are extremely accurate and precise for given temperature ranges. For the ITS-90 (International Temperature Scale), this means:

- 0.65 to 5 K: saturant vapour pressure of 3He, 4He,
- 3 to 24.5 K (Ne): helium gas thermometers,
- 13.84 (H^2) to 961.78°C (Ag): platinum resistance sensors,
- ≥961.8°C: pyrometer (Planck law).

Historical background

The technical application of thermoelectric effect for temperature measurement began with Professor Le Chatelier. The development continues as new thermocouple materials are tested.

Generally, any combination of two different conductor materials can be used as a thermoelectric wire.

If two different materials are welded to make a hot junction and heated up, an electromotive force (e.m.f.) is generated to make the temperature measurement possible. The sensitivity of the thermocouple is the sum of the thermoelectric power of each conductor.

The sensitivity is very high if there is a big difference between the thermoelectric power of these conductors.

The first thermocouples, developed by Professor Le Chatelier, had the inconvenience that the thermoelectric wires were made of pure metals.

Even light contamination (during production or later during the use) had a negative influence on the thermocouple quality. During production, a lot of care has to be taken over the purity and cleanness of the metals. Therefore, the production process was very complicated. At the beginning of the last century, the American company Hoskins developed the Nickel-Chromium / Nickel alloy thermocouple. In this case, both wires were made of alloys. Slight contamination of these materials does not have any negative influence on the measurement quality. This development of new thermocouples was a great improvement.

Despite of the advantage, this thermocouple type was not able to supersede the Cu-CuNi and the Fe-CuNi thermocouples in the low temperature segment.

The advantage of a higher e.m.f. means a better temperature resolution. Moreover, an almost linear thermoelectric power within its temperature range makes the type K thermocouple the most widely used among all.

Over the past years, only a limited number of thermocouples managed to impose themselves on the market. The thermocouples have been standardized in the industrialised countries. The basic values of the e.m.f. and the tolerances are laid down in the IEC584-1+2 standards.

Thermocouples cover a temperature range from -200°C to +2300°C.

The measurement of temperature is a very important element in many parts of research and industry. A well-known and proven method in temperature measurement is the use of thermocouples.

Temperature measurement with sheathed thermocouples

Accurate and fast measurements, easy mounting, simple utilisation and interchangeability as well as low-cost production are the reasons for the widespread applications of the thermocouples.

They are resistant to heat and pressure and relatively insensitive to parasites.

Specific technical requirements like within nuclear reactors, in space research or in medical fields led to the development of sheathed thermocouples of small dimensions, high insulation resistance and high resistance to aggressive media.

All this is being fulfilled by miniature sheathed thermocouples.

THERMOCOAX thermocouples

Easy fitting

Shielded cables

Continuous sheath

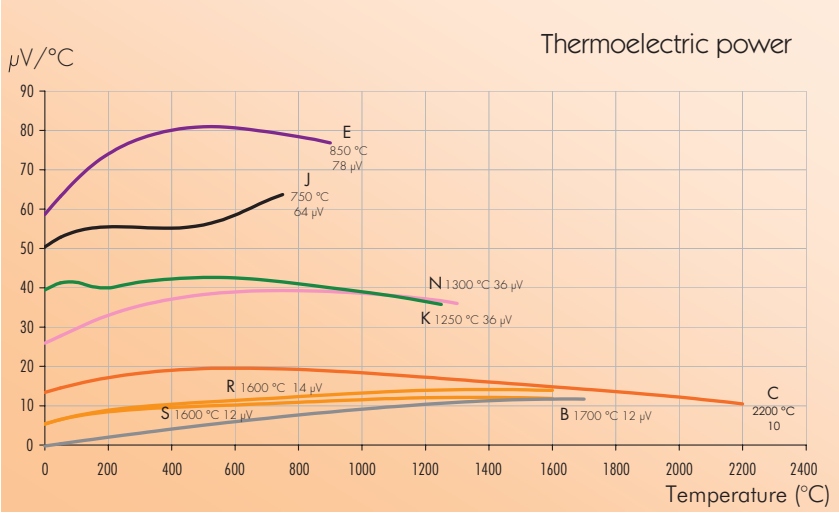
THERMOCOAX thermocouples can be attached directly to metal parts

Tight bending radius

Only 3 times the outer diameter

Small dimensions

Down to 0.25 mm OD, they can be inserted in any tiny equipment



Construction of the THERMOCOAX thermocouple

The essential of THERMOCOAX construction is that both thermocouple conductors, insulation and metal protecting sheath are combined as a cable :

- the two wires make the thermoelectric couple,
- the mineral insulant is a highly compacted powder,
- the continuous metallic sheath ensures a mechanical and chemical protection of the couple.

At one end, the cores and the sheath are welded and constitute the hot junction.

At the other end, the thermocouple is connected to a compensation or extension cable which is adapted to the thermoelectric wires by means of a plug and socket or direct connector.

Advantages

- Small overall dimensions and high flexibility which enable temperature measurement in locations with poor accessibility.
- High mechanical strength.
- Protection of the thermoelectric wires against oxidation, corrosion and chemical pollution.
- Very fast response-time which allows measurement of very short temperature variations.

Tight Bending Radius

Only 3 times the outer diameter

Thanks to the highly compacted insulating powder and the excellent metallographic state of the conductors and the sheath, the THERMOCOAX thermocouples are very flexible and may be bent to a radius equal to three times the outer diameter without causing any damage.

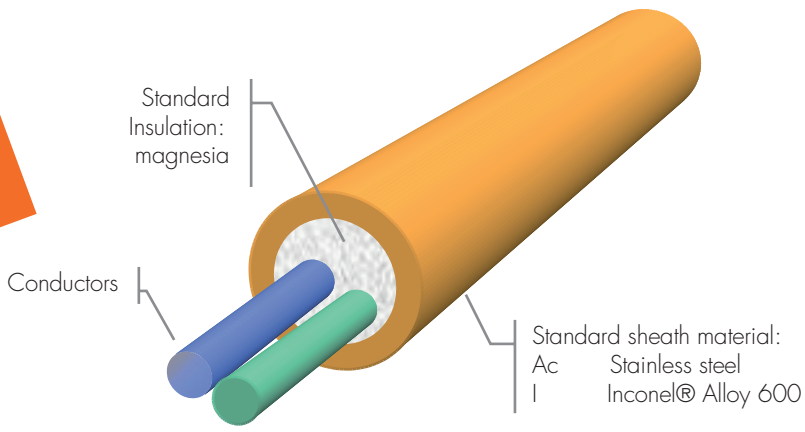
With certain precautions, this can even be reduced. The small overall diameter of the thermocouple permits measurements in places hitherto inaccessible.

Components

The diverse range of the THERMOCOAX thermocouples offers many advantages in a wide range of applications.
To make full advantage of this technology, the following parameters must be taken into account :

- Thermocouple type
- Sheath material
- Insulation materials
- Outer diameter
- Hot junction type
- Connection type
- Compensation, extension or prolongation cable type
- Accessories

Temperature response according to IEC 584-1 and 2 ASTM E 230 and 235



Insulating materials

M.I. thermocouples

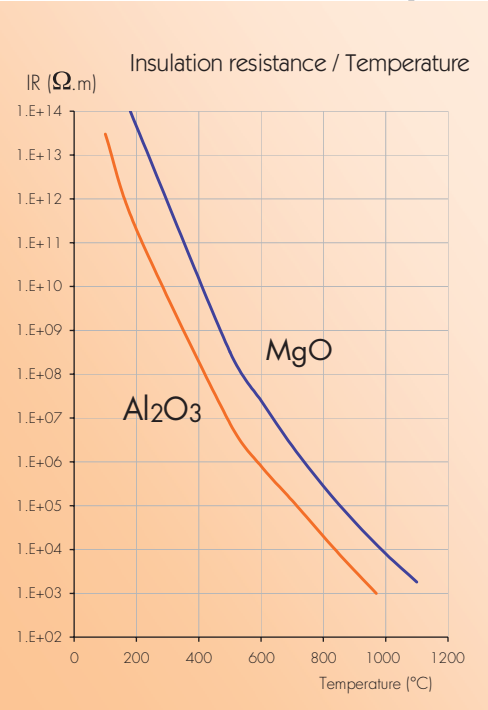
An important criteria for the quality of sheathed thermocouples is the insulation resistance.

An insulation resistance which is too low is often the reason why spurious signals influence the measurement negatively.

Producers of thermocouples carried out intensive investigations to increase the insulation resistance.

The result is an insulation resistance of 10^{12} Ω at room temperature, which is decreasing to several 1000 Ω at 1000°C, a physical phenomenon that cannot be avoided, even for insulation materials for highest temperatures.

When the temperature is decreasing, the high resistance returns.



Mineral Insulated Thermocouples

Due to the small dimensions of M.I. thermocouples, very little space remains for insulating conductor between conductor and between conductors and sheath.

In a thermocouple with 0.5 mm outer diameter, only 0.06 mm remains in each case for this purpose. It is also essential to find an insulator which still adequately fulfils its function at high temperatures.

Intensive investigations finally led to the conclusion that minerals such as magnesium oxide (MgO) or aluminium oxide (Al_2O_3) are the most suitable.

By utilisation of compacted magnesium oxide powder of high quality the required resistance of several thousands MOhm (corresponding to 1 m at room temperature).

Because of the hygroscopic properties of insulation, the open thermocouples are dried for several hours at 100 to 150°C prior further assembly.

If these thermocouples are used, for example in pressurized water reactors, and if the sheath has been damaged, the thermocouple can burst open. The reason for this is the reaction of the magnesium oxide with the incoming water, which leads to a change in structure and an increase in volume. In such case, the use of aluminium oxide is recommended.

Aluminium oxide insulated sheathed thermocouples have an insulation resistance ten to twenty times smaller than magnesium insulated ones. In addition to this, the thermal conductivity decreases.

Other high temperature resistant insulation such as hafnium oxide or beryllium oxide are used in practice. However, for the flexible thermocouples, preference will be given to hafnium oxide due to its good behaviour to corrosion and good electrical resistance, though beryllium oxide has a very higher one but can be dangerous in working when used in the powder form. Nevertheless, for the rigid high temperature thermocouples, the beryllium oxide (BeO) constitutes the best insulant and as it is used in the form of beads, it remains totally harmless.

Sheath materials

The sheath ensures the mechanical and the chemical protection of the thermocouple. Its choice depends on working conditions and is very important to get the maximum lifetime with a good measurement quality.

The most commonly used sheath materials are as follows:

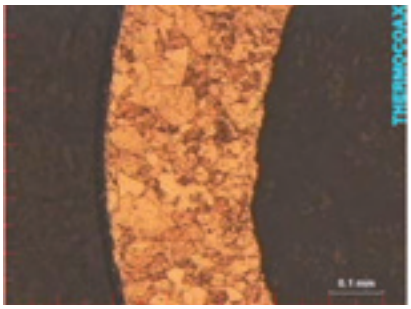
Ac Austenitic stainless steel
I Inconel® alloy 600

and according to specific working conditions:

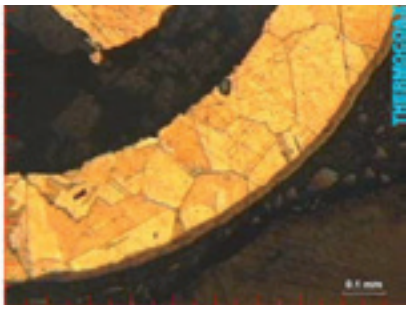
At titanum stabilized stainless steel
An niobium stabilized stainless steel
Ao molybdenum stabilized stainless steel
Ar specific stainless steel
Nm Nimonic ® 75
If specific alloy
Ig refractory alloy
Ih special alloy
It special alloy
Zy Zircalloy ®

For high temperature thermocouples:

Ta Tantalum
Ti Titanium
Nb Niobium
Mo Molybdenum
Mor Mo 50% Rhe 50%
Rhe Rhenium
Re Platinum-Rhodium 10%



Ig sheath Ø 2mm without ageing



Same after ageing 1000 h - 1200°C

Physical characteristics

	Ac (304L)	I INCONEL® 600	Ao 316L	At 321	An 347	Ar 310	NM Nimonic 75	If	Ig
Melting temperature (°C)	1 420	1 420	1 380	1 400	1 400	1 450	1 380	1 370	1 360
Maximum working temperature (°C)	800	1 200	800	800	800	1 100	1 200	1 200	1 200
Thermal expansion coefficient (10^{-6}/°C)	17	12	17	17	17	17.5	13.3	14	15.5
Specific heat (j/kg/°C)	500	460	500	500	500	500	460	460	500
Thermal conductivity (W/m/°C)	17	15	17	15	15	17	13.4	11	18.7
Density (g/cm^3)	7.9	8.4	7.9	7.9	7.9	7.9	8.4	8.1	8.05
Elasticity (GPa)	200	210	200	200	200	200	210	210	218

Diameter

The diameter takes a prominent part in the mounting of the thermocouple and its response-time.

As a general rule, the O.D. 1.5 mm gives the best compromise between:

- response-time
- flexibility
- small size
- mechanical strength
- capacity to withstand corrosion
- stability
- line resistance.

Should the first three factors be the most important parameters, choose an outer diameter of 1 mm or less.

If the others are more important, then the diameter should be 1.5 mm or more.

In both cases, THERMOCOAX thermocouples are very strong.

Based on existing experience, they can withstand several thousand atmospheres without influence on the thermocouple properties. The elements can be welded, soldered or bonded with adhesive.

They can also be bent to a minimum radius equivalent to three times of their outside diameter.

Overview of the sheath materials

Type	Standards	Use
Ac Austenitic stainless steel, Low carbon content	NF Z2CN 18 – 10 DIN X2Cr – Ni 18.9 1.4306 BS 304 S12 AISI 304L	• Easy to weld, • Corrosion and heat resistant steel • Good resistance against a variety of aggressive media, such as steam, gases etc., • Small sensitivity against intra-crystalline corrosion because of the small carbon content, • Maximum temperature for continuous utilisation: 800°C Use : Nuclear energy, Chemical, Food and Car industry, Research and Development
Ao Austenitic stainless steel, molybdenum stabilized, low carbon content	NF Z2 CND 16-12 DIN X2 Cr Ni Mo 18-10 1.4404 BS 316 SI2 AISI 316L	• Similar to Ac, in addition • Good behaviour in sulphuric acid, chlorides (salted environment) and organic acids. Use : Nuclear energy, Chemical industries,…
At Austenitic stainless steel, Titanium stabilized	NF Z6 CNT 18-10 DIN X10Cr – NiTi 18.9 1.4541 BS 321 S12 AISI 321	• Corrosion and heat resistant steel, • Resistant against aggressive media in temperatures from 400 to 800°C, • For continuous utilisation, good resistance against oxidation up to 900°C, • Resistant up to 650°C for utilisation in carbon dioxide, Use : Reactor construction, for the production of several acids, car industry and research and development.
An Austenitic stainless steel, Niobium stabilised	NF Z6 N Nb 18-10 DIN X10 Cr – Ni Nb 18.9 1.4550 BS 347 S17 AISI 347	• Corrosion and heat resistant steel, • Niobium stabilised steel is nearly immune against intercrystalline corrosion, • Resistant up to 700°C for continuous utilisation carbon dioxide. Use : Car industry, heating systems in Research and Chemical.
Ar Refractory stainless steel	NF Z12 CN 25-20 DIN X12 Cr – Ni 25-21 1.4841 BS - AISI 310	• Corrosion and heat resistant steel, • Resistant for continuous utilisation up to 900°C in carbon dioxide and up to 1.150°C in air, • Due to the high Ni –content, the material is very sensitive towards sulphurous gases in reducing atmosphere. Use : recommended over 1000°C.
I Inconel® alloy 600		• Resistant against corrosion and low electrochemical corrosion, • In oxidizing atmosphere usable up to 1150°C, • In carbon dioxide usable up to 500°C, • In sulphurous atmosphere not recommended over 500°C, • Inconel® is permeable to hydrogen at high temperatures, • In chloride-free water, i can be used up to 500°C. Use : in high temperature and corrosive atmosphere
Nm Nimonic® 75	NF NC20T DIN 17742	• Maximum temperature: Use : in exhaust gases of diesel engines and gas turbines (low temperature)
If Specific alloy		• Maximum temperature for continuous utilization is 1100°C, • Very resistant in sulphurous environments, • Resistant in chloride environments. Use : Glass and metallurgic industry, in gas turbines, for production of cement, incineration industry, in furnaces.
Ig Refractory alloy		• Maximum working temperature: 1150°C, • Excellent resistance to oxidation and carburizing, • Good behaviour in chores and chlorides, • Good resistance to nitrides. Use : corrosive environments at very high temperatures
Ta – Ti – Nb – Mo - Mor – Rhe – Re		• For the high temperature thermocouples, the used sheath materials are : • Tantalum, Niobium, Molybdenum, Rhenium, Platinum-Rhodium 10%. • At very high temperatures, the sheath gas tightness, heat resistance and the compatibility with the insulation materials play an important role. Use : extremely high temperatures

Overview of the THERMOCOAX thermocouple range

Standard range

Thermocouple type / Sheath

Type	Working temperature	Mean sensitivity µV/°C	Thermoelectric wires Material		Code	Material	Diameter in mm 0.25	0.34	0.5	1	1.5	2	3
							Code						
K	-200 up to 800°C -200 up to +1000°C 1250°- 1370°C	41	NiCr (+) NiAl (-)	KP KN	2 AB	Ac I Special alloys	025 025 -	034 034 -	05 05 -	10 10 10	15 15 15	20 20 20	30 30 30
J	-40 up to +750°C	55	Fe (+) Constantan® (-)	JP JN	2 FK	Ac	-	-	-	10	15	20	30
N	-40 up to +1200°C - 40 up to + 1300°C	37	NiCrSi (+) NiSi (-)	NP NN	2 LM	I Nm Ig If	- - - -	- - - -	05 05 - -	10 10 10 10	15 15 15 15	20 20 20 20	30 30 30 30
E	-200 up to +900°C	68	NiCr (+) Constantan® (-)	EP EN	2 AK	Ac	-	-	05	10	15	20	-
T	-200 up to +350°C	51	Cu (+) Constantan® (-)	TP TN	2 CK	Ac	-	-	-	10	15	20	30

High temperature

Thermocouple type / Sheath

Type	Working temperature	Mean sensitivity µV/°C	Thermoelectric wires Material		Code	Material (1)	Diameter in mm 1	1.5	2
						Code			
S	0 up to + 1600°C	12	Pt 10 % Rh (+) Pt (-)	SP SN	2PRe	Re	10	15	20
R	0 up to + 1600°C	14	Pt 13 % Rh (+) Pt (-)	RP RN	2PRg	Re	10	15	20
B	0 up to + 1700°C	10	Pt 30 % Rh (+) Pt 6 % Rh (-)	BP BN	2RdRn	Re	10	15	20

Very high temperature

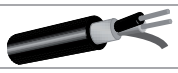
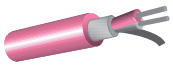
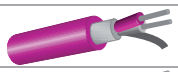
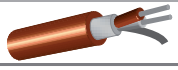
Thermocouple type / Sheath

Type	Working temperature	Mean sensitivity µV/°C	Thermoelectric wires Material	Code	Material	Diameter in mm 0.7	1.2	1.4	1.5	1.6	2	2.1	3.17
						Code							
"C"	0 up to 2300°C	15	Tungsten Rhenium 5% Re (+) Tungsten Rhenium 26% Re (-)	2W5W26	Mo Ta Nb Rhe		- 12 12 12	14 14 - -	- 15 - -	16 16 16 -	2 - - -	- 21 - -	- 31.7 - -
	0 up to 1800°C				Ta	07		14	15	(flexible version)			
"D"	0 up to 1800°C	19	Tungsten Rhenium 3% Re (+) Tungsten Rhenium 25% Re (-)	2W3W25	Rhe	12	-	-	-	-			
					Ta	07		14	15	(flexible version)			

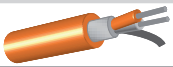
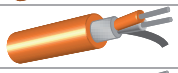
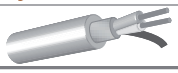
Thermocouples & Heating Elements ATEX certified and notified.

ATEX SENSORS
Please refer to separate documentation

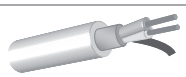
Extension cables

PE or PCV- Ø in mm		PFA - Ø in mm				IEC 584.3 Identification
2.5	3.5	2.5	3.5	2.1	1.7	
Code and Loop Resistance (Ω/m)						
2AB25 (13.5 Ω/m)	2AB35 (4.5 Ω/m)	2AB25T (13.5 Ω/m)	2AB35T (4.5 Ω/m)	2AB21T (13.5 Ω/m)	2AB17T (13.5 Ω/m)	
2FK25 (9.2 Ω/m)	2FK35 (9.2 Ω/m)	2FK25T (9.2 Ω/m)	2FK35T (8 Ω/m)	-	-	
2LM25 (16.4 Ω/m)	-	2LM25T (19.9 Ω/m)	2LM35T (5.6 Ω/m)	-	-	
2AK25 (15.6 Ω/m)	2AK35 (8 Ω/m)	-	-	-	-	
2CK25 (7.68 Ω/m)	-	-	-	-	-	

Compensation, Prolongation cables

PE or PCV - Ø in mm	Copper		IEC 584.3 Identification
Ø 2.5 mm	Ø 2.5 mm	Ø 3 mm	
Code and Loop Resistance (Ω/m)			
2PR25 (2.07 Ω/m)	-	-	
2PR25 (2.07 Ω/m)	-	-	
-	2CC25 (0.56 Ω/m)	2CC30 (0.18 Ω/m)	

Prolongation cables

Stainless steel		PCV		THERMOCOAX Identification
Ø 1 mm	Ø 1.5	Ø 2.5 mm		
Code and Loop Resistance (Ω/m)				
2 XY Ao 10 for thermocouple Ø 1.2 or 1.4 mm	2 XY Ao 15 for thermocouple Ø 1.6 or 2 mm	2 XY 25 (8 Ω/m)	2 XY 35 (2.65 Ω/m)	
Loop resistance				
19 Ω/m	7.6 Ω/m			
- -		PTFE - Ø 2.1 mm 2 VW 21 T (8 Ω/m)		

Sheath materials

Ac	Stainless steel AISI 304L
I	Inconel® alloy 600
If	Specific alloy
Ig	Refractory alloy
Mo	Molybdenum
Nb	Niobium
Nm	Nimonic® 75
Re	Platinum Rhodium 10% Rh
Rhe	Rhenium
Ta	Tantalum

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Extension cables

PE	Polyethylene
PCV	Polyvinyl chloride
PFA	Fluorocarbon co-polymer
PTFE	Polychlortrifluorethylen
PE	Polyethylene
PP	Polypropylene
HFFR	Halogen-Free Flame Retardant

Standard thermocouples

-200°C up to 1 200°C

Use of base metals

Type K

Nickel chromium (+)
Nickel aluminium (-)

The best known and the most used thermocouple belonging to the group chromium-nickel aluminium is type K. Its e.m.f. /temperature curve is virtually linear and its sensitivity is 41µV/°C.

Type J

Iron (+)
Constantan® (-)

This type is still popular but its temperature range is limited. It is used for old instruments calibrated for this type. Its sensitivity increases up to 55µV/°C and its output can be changed by the contamination of the iron.

Type L on request.

Thermocouple						Sheath							
Wire Materials		Type	Mean Sensitivity µV/°C	Working Temperature °C	Code	Material	Diameter in mm						
							0.25	0.34	0.5	1.0	1.5	2.0	3.0
NiCr (+) NiAl (-)	KP KN	K	41	-200 to +1000 1370°C peak	2 AB	Ac I	●	●	●	●	●	●	●
Fe-(+) Constantan®(-)	JP JN	J	55	-40 to +750 1200°C peak	2 FK	Ac	-	-	-	●	●	●	●
NiCr (+) Constantan®(-)	EP EN	E	68	-200 to +900 1000°C peak	2 AK	Ac	-	-	●	●	●	●	-
Cu-(+) Constantan®(-)	TP TN	T	51	-200 to +350 400°C peak	2 CK	Ac	-	-	-	●	●	●	●

Type E

Nickel chromium (+) - Constantan® (-)

Due to is high sensitivity, it is mainly used in the cryogenic temperature range (-200°C). As it is non magnetic could be a further advantage in some special applications.

Type T

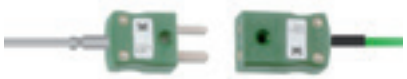
Copper (+)
Constantan® (-)

This thermocouple is used infrequently. Its temperature range is limited to -200°C up to +350°C.

Direct connection D : extension cable mounted on thermocouple through direct nicked brass connector.

Off-the-shelf range

Plug and socket FI - RI : thermocouple mounted on plastic moulded or ceramic plug - extension cable on socket.



Plug and socket MF: thermocouple mounted on metallic socket - extension cable on plug.

Off-the shelf range									
Wire Materials		Type	Sheath Material	Series	Diameter in mm				
					0.5	1.0	1.5	2.0	3.0
NiCr (+) NiAl(-)	KP KN	K	Stainless steel 600°C	TKA SKA LKA (WKA) FKA (RKA)	●	●	●	●	●
			I	TKI SKI LKI (WKI) FKI (RKI)	●	●	●	●	●
Fe-(+) Constantan®(-)	JP JN	J	Ac	TJA SJA LJA (WJA) FJA (RJA)	-	●	●	●	●

Extension cable : polyethylene (PE)

The thermocouple ranges described here are standard:

- Other diameters,
- Other materials
- Other construction

Please consult us.

Standard thermocouples

Up to 1 200°C outstanding thermoelectric stability

Type N

NiCrSi (+) - NiSi (-)

This thermocouple has an outstanding thermoelectric stability which can be compared with platinum based thermocouples. This type has an excellent resistance to high temperature oxidation phenomena.

This thermocouple is ideally suited for accurate measurements in air up to 1200°C. In vacuum or controlled atmosphere, it can withstand 1300°C.

Little sensitivity to Short Range Ordering

In the temperature range 300-600°C a crystalline phenomenon occurs in nickel-chromium alloys which leads to a reversible thermocouple sensitivity drift.

Even if a thermocouple is used in the 900-1300°C range, part of it is submitted to that 300-600°C range, in the application temperature gradient (e.g.: entrance of a furnace) and this section contributes to the total e.m.f. generation. Type N thermocouples are at least 50% less sensitive to this phenomenon than type K.

Little sensitivity to cold work effect

The thermoelectric force is little sensitive to cold work effect. This advantage allows fixing in sinuous lines without inducing local errors of homogeneity, leading thus to e.m.f. interferences.

Resistance to oxidation

There is a good resistance to oxidation since the addition of silicium to both thermoelectric alloys allows to put a protecting silicium film all over the outer surface of the thermoelectric wires.

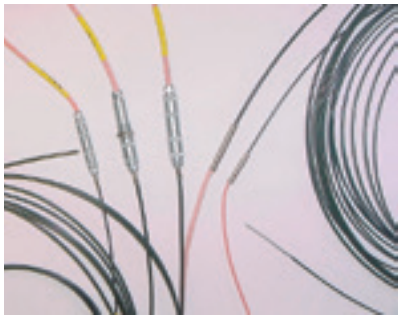
Use in air

Over 1100°C, the sheath must be carefully selected depending on the environment and Inconel® 600 alloy is a very good compromise in terms of corrosion and e.m.f. stability (protection and compatibility with type N wires).

Nimonic® sheath

When requested, type N thermocouples can be equipped with Nimonic® 75 sheath, offering thus an excellent resistance to corrosion, especially in exhaust gas.

Various experiments held at THERMOCOAX show that type N thermocouples are behaving similarly to platinum based thermocouples. They drift 10 to 20 times less than type K thermocouples between 1000 and 1200°C.



The thermocouple ranges described here are standard:

- Other diameters,
- Other materials
- Other construction

Please consult us.

Thermocouple						Sheath					
Wire Materials		Type	Mean Sensitivity µV/°C	Working Temperature °C	Code	Material	Diameter in mm				
							0.5	1.0	1.5	2.0	3.0
NiCrSi (+) NiSi (-)	NP NN	N	37	-40 to +1300	2 LM	I	●	●	●	●	●
						Nm	●	●	●	●	●
						Ig		●	●	●	●
						If		●	●	●	●

High temperature thermocouples

The platinum based thermocouples

Up to 1 700°C

Type S

Platinum 10 % Rhodium (+) - Pure Platinum (-)

Normally used in oxidizing atmospheres up to 1600°C. For a long time, they were the basis of the International Practical Temperature Standard for the range 630°C - 1064°C until the introduction of the ITS90.

Type R

Platinum 13 % Rhodium (+) - Pure Platinum (-)

Similar version to type S with sensitivity between 6 and 14 µV/°C.

Type B

Platinum 30 % Rhodium (+) - Platinum 6 % Rhodium (-)

Allows measurements up to 1700°C. Very stable thermocouple but less sensitive especially in lower range which becomes negligible at room temperature.

NEW
0.7 mm end swaging

These noble metal thermocouples are protected by a Platinum 10% rhodium sheath and a high quality mineral power insulant and are frequently used for measuring temperatures ranging from 1000°C to 1700°C.

Type S thermocouple has been used over years as the base of the international practical temperature scale in the interval 630 – 1064°C up to the publication of the ITS90.

Pure platinum and platinum/rhodium alloys develop electromotive forces less important than common metal couples. However, they offer following advantages:

- inertia in oxidizing atmosphere,
- high melting point,
- stability of the electromotive force.

They are the only thermocouples which can be safely used in oxidizing atmosphere over 1250°C for long periods of time.

When placed in this type of environment, these thermocouples are extremely stable as far as thermoelectricity is concerned; nevertheless, in reducing atmosphere, they are easily contaminated by metals coming from the components dissociation.

Thermocouple						Sheath			
Wire Materials		Type	Mean Sensitivity µV/°C	Working Temperature °C	Code	Material	Diameter in mm		
							1.0	1.5	2.0
Pt 10% Rh (+) Pt (-)	SP SN	S	12	0 up to 1600°C	2 PRe	Re	●	●	●
Pt 13% Rh (+) Pt (-)	RP RN	R	14	0 up to 1600°C	2 PRg	Re	●	●	●
Pt 30% Rh (+) Pt 6% Rh (-)	BP BN	B	10	0 up to 1700°C	2 RdRn	Re	●	●	●

The thermocouple ranges described here are standard:

- Other diameters,
- Other construction

Please consult us.

Very high temperature thermocouples

Up to 2 300°C

The tungsten-rhenium thermocouples

Type C (rigid or flexible)

Tungsten-rhenium 5%Re (+) - Tungsten-rhenium 26%Re (-)

These thermocouples are used for very high temperature measurements, up to 2300°C in reducing neutral atmosphere, or vacuum.

Type D (rigid)

Tungsten-rhenium 3%Re (+) - Tungsten-rhenium 25%Re (-)

These thermocouples are used for very high temperature measurements, up to 1800°C in reducing neutral atmosphere, or vacuum.

These thermocouples have been developed by the International Centres of Nuclear Research and are specially recommended when a longer life time over 2000°C is requested.

They also developed a thermocouple insulated with hafnium oxide. It has been chosen for its exceptional chemical stability in presence of the tungsten wires and the rhenium sheath.

These refractory metal thermocouples are the only thermocouples which can be safely used over 1700°C for long periods of time. The thermocouple design will be made according to the environment (vacuum, neutral, reducing) and can work up to 2300°C.

These alloys have a very high melting point and a very low vapour pressure, but they are not very ductile.

Environment and limits of use

In oxidizing atmosphere, tantalum, niobium, molybdenum and rhenium burn rapidly. Platinum only resists very well to temperatures over 1000°C.

In nitrogen, hydrogen and reducing atmospheres, molybdenum is well adapted up to 1500°C. In nitrogen or hydrogen, niobium and tantalum engender nitrides and hydrides which rapidly make the sheath brittle.

In vacuum atmosphere, due to its relatively high vapour pressure, molybdenum is not recommended over 1800°C.

In presence of graphite, none of these materials can be used over 1200°C. Adequate coating such as titanium or silicide nitride (TiN) could extend their life time.

The rhenium sheath

Rhenium sheathed thermocouples offer various particular properties:

one of the most important ones is high melting point (3180°C),

- it remains ductile when after working at high temperature,
- it is not affected by the oxidoreducing atmospheres,
- it also offers high electrical resistivity,
- it can easily be welded without embrittlement,

it has an excellent behaviour in inert atmosphere and does not react in presence of uranium oxide.

The thermocouple ranges described here are standard:

- Other diameters
- Other materials
- Other construction

Please consult us.

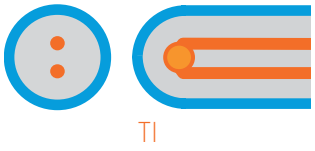
Thermocouple					Sheath								
Wire Materials	Type	Mean Sensitivity µV/°C	Working Temperature °C	Code	Material	Diameter in mm							
						0.7	1.2	1.4	1.5	1.6	2	2.1	3.17
Tungsten-rhenium 5 % Re (+) - Tungsten-rhenium 26 % Re (-)	C	15	0 up to 2300°C	2W5W26	Mo			●		●	●		
					Ta		●	●	●	●		●	●
					Nb		●			●			
					Rhe		●						
			0 up to 1800°C		Ta	●		●	●	(flexible version)			
Tungsten-rhenium 3 % Re (+) - Tungsten-rhenium 25 % Re (-)	D	19	0 up to 1800°C	2W3W25	Rhe		●						
					Ta	●			●	(flexible version)			

Hot junctions

The hot junction is the point where the two cores are joined. This therefore is the sensing part and can take a number of different forms.

The standard insulated hot junction TI

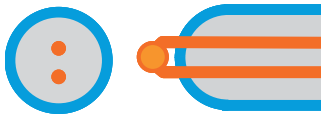
This is the most popular type of hot junction. The thermocouple is welded with a tungsten electrode by the argon-arc-method. After filling the open end of the sheath with insulating powder, the sheath is also argon-arc-welded. The hot junction is insulated from the sheath and is checked for short circuit.



TI

The standard external hot junction TE

In this version, the hot junction is out of the MI cable to reduce the response time over 20%.

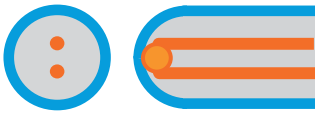


TE

The standard grounded hot junction TM

In this version, the hot junction conductors are welded to the sheath to reduce the response-time by about 20%. This can also be achieved by choosing a smaller diameter with TI junction, or better the same diameter with a TIS junction which allows the advantages of insulated hot junctions to be kept.

This type of junction cannot be performed on the thermocouples of type J, L and E due to the difference of the melting temperatures of constantan and of stainless steel, the same is valid for the platinum/platinum.

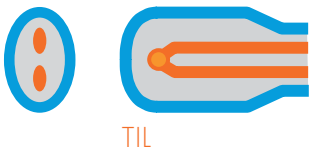


TM

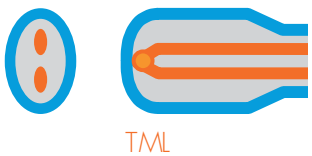
The laminated hot junctions TIL or TML

After performing the hot junction type TI or TM, the end of the type K thermocouple can be laminated so as to give it a thickness of about half of the initial diameter. This sensibly enlarges the width to about 1 1/2 times the initial diameter.

The laminated part has a length of 5 to 50 mm. The TIL hot junctions can only be performed for thermocouples of 0.5 mm OD or greater.



TIL

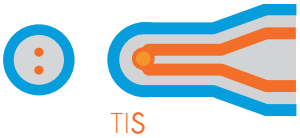


TML

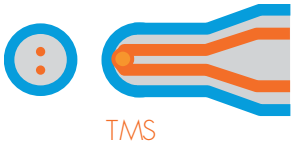
Outer diameter reduced at hot junction TIS or TMS

Insulated in version TIS or grounded in version TMS. Only for the Nickel Chrome - Nickel alloy and NiCrSi/NiSi to obtain a fast response in the measuring of small objects or in places with limited access.

The outer diameter of the thermocouple can be swaged down to a smaller diameter over a length of 50-150 mm. Such thermocouples have the advantage of fast response, but remain easy to handle and to install.



TIS



TMS

Extension, compensation, prolongation cables

The thermocouple is connected to the measurement device by means of an extension or compensation cable.

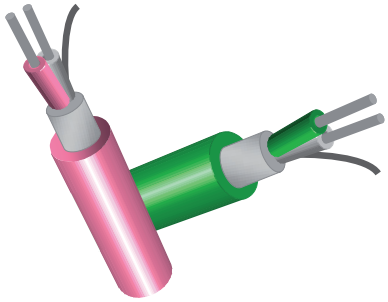
The extension cables, of which the wires are the same as for the thermocouple, avoid any measurement errors and so are particularly recommended for all THERMOCOAX thermocouples.

The whole range is covered except the tungsten-rhenium and platinum-rhodium thermocouples.

Their base materials being rare or noble metals, these thermocouples will be connected to a compensation cable of which the wires are made of adapted alloys but giving the same e.m.f. as the thermoelectric wires of the thermocouples within a working temperature generally under 100°C.

The type B thermocouple which doesn't require compensation at ambient temperature, can be connected to a prolongation cable (copper wires).

Furthermore, when required, any thermocouple can directly be connected to the prolongation cable provided a cold junction compensation is done.



Measurement errors though wrong use of the compensation cable

The compensation cable is necessary for the prolongation of the thermocouple to the measurement place. In order to avoid measurement errors, several conditions have to be fulfilled. Errors in e.m.f. are often due to a mix-up of the polarity of the thermoelectric wires, choosing the wrong kind of compensation cable, too high temperature of the environment, wrong earthing or installation of the thermoelectric wires parallel to an inductivity field. When realising measurement errors, it is recommended to start the checking with the compensation cable.

Compensation and extension cables with metal sheath

For high temperature thermocouples (types S and C), it is possible to mount a metal shielded extension or compensation cable:

- 2 PRE I for temperatures < 600°C
- 2 XY A for temperatures < 871°C

Extension cables range for standard thermocouples.

Cable Outer Diameter	Code	Insulation material Sheath / Wire	Shield	Wire	Max. Operating temperature
2.5mm	2AB25T 2FK25T 2LM25T	PFA/PFA	Aluminium foil with nickel plated Cu-lace	1x 0.3mm massive (0.07mm²)	-100°C - 250°C
	2AB25 2FK25 2LM**25** 2AK25 2CK25	HFFR/PP or PCV / PCV	Aluminium foil with tinned Cu-lace	1 x0.3mm massive (0,07mm²)	-40°C-85°C
3.5 mm	2AB35T 2FK35T 2LM35T	PFA/PFA	Silver plated copper braid	3 x 0.30 mm (or 16x0.2 for 2LM35T)	200°C – 250°C
	2AB35 2FK35 2AK35	PCV/PCV	Tin plated copper braid	1 x 0.32 mm	105°C – 125°C
2.1 mm	2AB21T	PFA/PFA	Silver plated copper braid	1 x 0.32 mm	200°C – 250°C
1.7 mm	2AB17T	PFA/PFA	Aluminium foil with silver lace	1 x 0.32 mm	200°C – 250°C

Connections

In order to ensure the faultless function of the thermocouples, the end has to be closed by means of an organic sealing compound to avoid any ingress of moisture.

As connection to the plastic sheathed cable, transferring the measurement signal to the instrument, direct connections are used. Besides this, it is often necessary especially when being confronted with difficult of complicated measurement problems or specifications, to develop special connections.

Direct connections

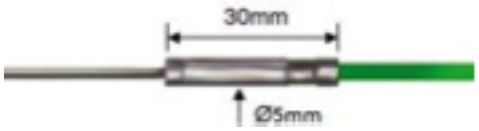
In these connections, the links between the thermoelectric wires of the thermocouple and those of the extension cable are ensured by direct welding without any foreign constituent.

A surrounding compound material ensures absolute tightness, earth continuity and rigidity of the assembly.

The thermocouples from our product range can be fitted with one of the type shown: their choice will be made by taking into account various parameters such as thermocouple diameter, operating temperature.

Nickel brass type D et DT

- Operating Temperature:
  200°C continuous
  230°C short period
- Earth continuity
- Extension cable :
  - PE sheath : Ø 2.5 mm - 85°C
  - PTFE sheath : Ø 2.5 mm - 200°C



Stainless steel type MCT

- Working temperature:
  200°C continuous
  230°C peak
- Extension cable :
  - PTFE sheath : Ø 1.7 mm - 200°C

Ø Thermocouple	Code	Ø in mm	L in mm
0.5 up to 1 mm	MCT	2	12

Moulded and ceramic plug and socket

Both types have pins which are made of thermoelectric materials (compensated connectors).

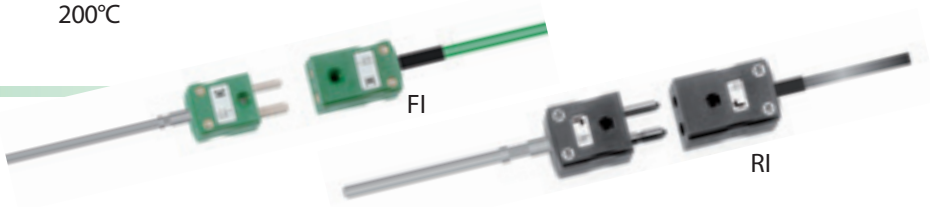
The body does not assure electrical continuity between the sheath of the thermocouples and the screening of the extension cable.

If needed RIM3 and FIM3 have an added copper third pin to assure this screening continuity

Colours acc. to IEC standards.

FI - RI - FC - RC

- Compensated pins
- Compensated connector
- Cable clamp



Flat pins for thermocouples Ø < 3 mm

Material	Plug for thermocouple Type	Plug for thermocouple W x L x H in mm	Socket for thermocouple Type	Socket for thermocouple W x L x H in mm
Plastic	FIM	16 x 19 (+12) x 8	FIF	16 x 26 x 8
Plastic	FIM3	23,9 x 19 (+12) x 8	FIF3	23,9 x 25,4 x 8
Ceramic	FCM	18 x 22 (+12) x 9	FCF	18 x 27 x 9

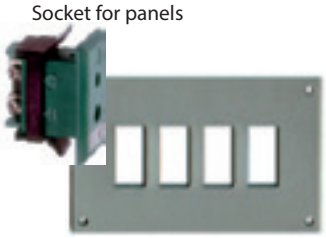
Round pins for thermocouples Ø > 1.5 mm

Material	Plug for thermocouple Type	Plug for thermocouple W x L x H in mm	Socket for thermocouple Type	Socket for thermocouple W x L x H in mm
Plastic	RIM	25,4 x 35 (+15) x 12,8	RIF	25,4 x 35 x 12,8
Plastic	RIM3	36,5 x 35 (+15) x 12,8	RIF3	36,5 x 35 x 12,8
Ceramic	RCM	25,4 x 38 (+15) x 15	RCF	25,4 x 38 x 15

( ) = Length of the pins

Plug and socket	Operating temperature	temperature short time
FI - RI	200°C	230°C
FC - RC	400°C	600°C

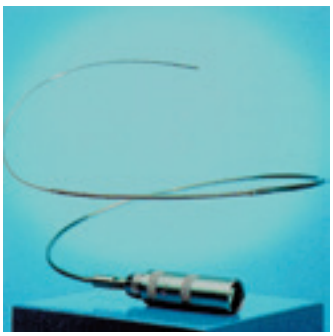
Socket for panels



Metallic plug and socket connection

The link between the thermoelectric wires of the thermocouple and those of the extension cable is made by means of non-compensated male and female pins. The metallic body and casing of these connectors ensure the screening continuity as well as good temperature homogeneity around the pins, ensuring that any measurement errors are reduced to a minimum.

Generally speaking, it is advised not to use these connectors above 100°C, although their insulants could withstand higher temperatures. With the mounted thermocouple, the insulation resistance is 100MW and the contact resistance is $5.10^{-3}\Omega$.



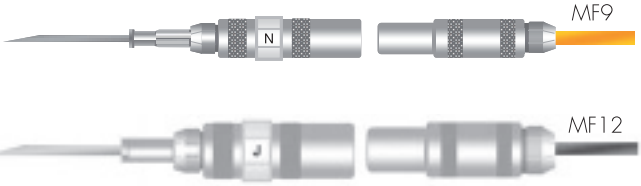
Nickel brass MF7

- Self-locking
- Working temperature : 100°C continuous, 150°C peak
- Pin material : gold plated brass
- Diallylphtalate insulant
- Earth continuity

Ø Thermocouples	Code	Ø in mm	Overall length
Ø ≤ 3 mm	MF7	9.6	81.5

Chromium plated brass MF9 - MF12

- Self-locking
- Working temperature : 200°C continuous, 250°C peak
- Pin materials:
  - male: gold plated brass
  - female: gold plated bronze
- PEEK insulant
- Earth continuity



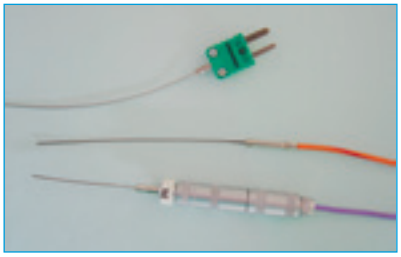
Ø Thermocouples	Code	LEMO®	Ø	Overall length
Ø ≤ 2 mm	MF9	Size 0	9 mm	58 mm
Ø = 3 mm	MF12	Size 1	12 mm	72 mm

Screw socket

Nickel brass MF11

- With screw ferrule
- Working temperature : 100°C continuous, 150°C peak
- Pin material : gold plated nickel bronze
- Diallylphtalate insulant

Ø Thermocouples	Code	Ø	Overall length
Ø ≤ 2 mm	MF11	11 mm	81 mm



Mounting methods

Because of their construction, dimensions and features, sheathed thermocouples can be mounted easily.

Besides that, there are mounting possibilities that can not be realized with ordinary thermocouples. It is now possible to measure in areas where the conventional thermocouples have failed.

The sheath diameter, the flexibility and the small bending radius (three times the outer diameter) are suitable for being fastened in solids, on solid surfaces, in pressure or vacuum vessels as well as in pipes with flowing liquids or gases.

Fastening with adhesive

Particularly simple is the mounting of sheathed thermocouples in borings if the sensitive part is locked into by adhesive. In this case, special metal-adhesives are used.

The diameter of the hole should be about 1/100 to 5/100 wider than the outer diameter of the thermocouple to permit the adhesive to get between the two materials. After the adhesive is cured, it can resist a maximum pressure of 15 bars. The temperature must not be higher than 150°C.

Fastening by soldering

A further possibility to fasten a thermocouple, for example in holes, is by soldering. In case of small outer diameter and soldering, the maximum pressure in pipes is 50 bars at a maximum temperature of 150°C.

Fastening by clamping

Another possibility to mount a thermocouple is to braze our bushings onto the object and the installation into special clamps which can resist an air pressure of 15 bars. The temperature must not exceed 150°C.

Fastening by brazing

For conditions up to a pressure of 300 bars and a maximum temperature of 500°C, the thermocouples can be mounted into special borings. In this case, our weldable bushings should be used.

Fastening by welding

When facing high pressure up to 1000 bars and temperatures up to 1100°C, the only mounting possibility is welding. Because it is generally impossible to weld the thermocouples directly onto the object, special bushings are used.

Fastening by seal glands

A very comfortable mounting method provides the use of our seal glands and springloaded adaptors.

The seal glands have been developed for fast mounting. They can be delivered for thermocouples with an outer diameter of 1 to 3 mm. Because of steel ferrules, they can resist temperatures up to 600°C and a maximum pressure of 500 bars.

The springloaded adaptor has the advantage that the thermocouple is pressed firmly against the surface of the object. Therefore, a good heat transfer is ensured. (see chapter Accessories).

Accessories

Any form of brazing or welding of a thermocouple through a wall requires some skill, and to facilitate thermocouple mounting, a range of small seal-glands have been developed and adapted fort he standard THERMOCOAX dimensions.

THERMOLOK® seal glands MG

Such a seal-gland consists of three stainless steel parts (AISI 316) : a body either with a cone-shaped NPT thread or with a metric thread, a ferrule and a gland nut.

- Tightness is ensured up to 700°C, under atmosphere pressure.
- Tightness up to 500 bars is possible

Cable diameter	NPT thread			With metric thread (thin thread)*			Ferrule	
	Code	Ø	Ø hole (mm)	Code	Thread	Ø hole (mm)	AISI 316 L	PTFE
1 mm	MG 10	1/16	6.25	MG M 10	M8 x 1	7.00	FE 10	FE 10T
1.5 mm	MG 15	1/16	6.25	MG M 15	M8 x 1	7.00	FE 15	FE 15T
2 mm	MG 20	1/16	6.25	MG M 20	M8 x 1	7.00	FE 20	FE 20T
3 mm	MG 30	1/4	11.10	MG M 30	M12 x 1.5	10.50	FE 30	FE 30T

SGS Seal glands

The tightness is assured at 300°C maximum pressure 25 bars when using a metallic ferrule and 200°C at maximum 2 bars when using a PTFE ferrule.

Cable diameter	With ferrule				Ferrule	
	Metallic	PTFE	Thread	Length	Metallic	PTFE
1 mm	SG S-M 10	SG S6T 10	M8x1	23.5	SES 10	SET 10
1.5 mm	SG S-M 15	SG S6T 15	M8x1	23.5	SES 15	SET 15
2 mm	SG S-M 20	SG S6T 20	M8x1	23.5	SES 20	SET 20
3 mm	SG S-M 30	SG S6T 30	M8x1	25	SES 30	SET 30

Bushings SB

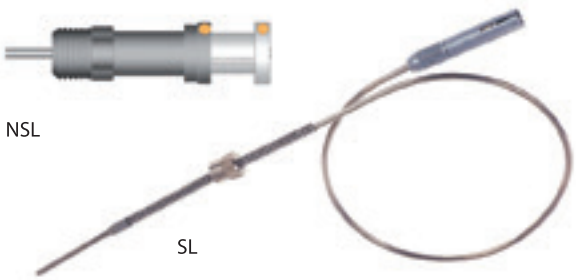
Made of stainless steel AISI 304 or INCONEL® 600 alloy, they can be brazed or welded onto the thermocouple sheath.

Cable diameter	Stainless steel			INCONEL® alloy		
	Code	Length	Ø	Code	Length	Ø
1 mm	SB 10	45 mm	5 mm	SBI 10	35 mm	5 mm
1.5 mm	SB 15	45 mm	5 mm	SBI 15	35 mm	5 mm
2 mm	SB 20	45 mm	5 mm	SBI 20	35 mm	5 mm
2.5 mm	SB 25	45 mm	6 mm	SBI 25	35 mm	6 mm
3 mm	SB 30	45 mm	6 mm	SBI 30	35 mm	6 mm

Springloaded adaptors SL and NSL

This adaptor allows the hot junction to be continuously pressed against a wall. The endstop is drilled to match the thermocouple diameter and then crimped at a specified point on the sheath.

Cable diameter	Code	Thread	Code	Thread	SW
1 mm	SL 10	M6 x 0.75	-	-	-
1.5 mm	SL 15	M8 x 1	NSL 15	M8 x 1	SW10
2 mm	SL 20	M8 x 1	NSL 20	M8 x 1	SW10
3 mm	SL 30	M8 x 1	NSL 30	M8 x 1	SW10



Calibration

The THERMOCOAX thermocouples are in conformity with the internationally accepted tolerances as to their electromotive force versus temperature : IEC-584.2

For types K, J and E, they are :

- ± 2.5° up to 333°C
- ± 0.75% over 333°C.

Limit of validity of these tolerances :

- K (Nickel-Chromium–Nickel aluminium): 1200°C
- J (Iron-Constantan®) : 750°C
- E (Nickel-Chromium-Constantan®): 900°C.
- N (NiCrSi-NiSi) : 1300°C

The types K and N thermocouples can be supplied within the Class 1 of IEC-584-2, the tolerances are then :

- ± 1.5°C up to 375°C,
- ± 0.4 % from 375 up to 1000°C.

These closer tolerances are generally achieved for thermocouples with special diameter and nature (ask for information about availability).

This is also a possibility of supplying individually calibrated thermocouples.

Calibration by comparison: salted bath

The calibration is made by means of the method of fixed points :

Fixed points	Temperature level assigned by EIT90 at fixed point	Uncertainty	Methods and means used
Melting ice point	0.00°C	±0.3°C	Platinium resistance thermometer Cells for triple point of water, tin, lead and zinc Multimeter
Triple point of water	0.01°C	±0.3°C	
Melting point of tin	231.928°C	±0.5°C	
Melting point of lead	327.46°C	±0.5°C	
Melting point of zinc	419.46°C	±0.5°C	
Freezing point of antimony	630.62°C	±0.9°C	Thermocouple type S Antimony and silver cell Multimeter
Freezing point of silver	961.78°C	±1.1°C	

The calibration is made by comparison :

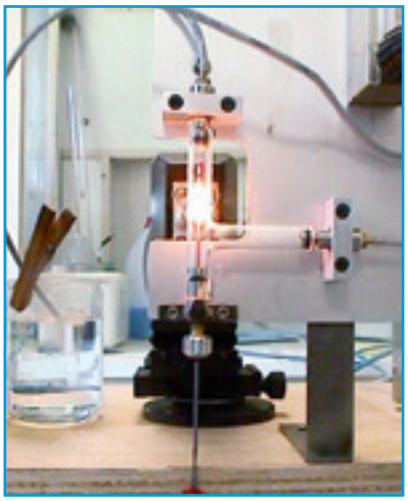
Measurement field	Uncertainty	Methods and means used
-40°C to 0°C	±0.4°C	Comparison to a platinum resistance thermometer immerged in a liquid bath with a thermal block Multimeter
0°C to 80°C	±0.3°C	
50°C to 200°C	±0.4°C	Comparison to a platinum resistance thermometer immerged in a oil bath with a thermal block Multimeter
150°C to 400°C	±0.5°C	Comparison to a platinum resistance thermometer immerged in a melted salt bath with a thermal block Multimeter
400°C to 500°C	±0.6°C	
500°C to 700°C	±1.3°C	Comparison to a type S thermocouple placed in a tubular furnace with a thermal block Multimeter
700°C to 1100°C	±1.4°C	
1100°C o 1200°C	±1.6°C	
1200°C to 1310°C	±2.1°C	

The metrology department located at the THERMOCOAX production plant in Planquivon (France) is accredited by the COFRAC Calibration Section under the registration number: 2.1384 referring to calibration at fixed points of the thermo electrical couples.

Scope available on www.cofrac.fr

cofrac
ETALONNAGE

Controls



Radiography

For standard production, X-ray examination is not normally necessary, but the possibility exists of obtaining a picture for extreme quality requirements, which will verify the exact position of the hot junction and check the welding operation. Each radiographic picture is taken at two positions (at 90° to each other) and presented as a slide (5x5 cm) ready for projection).

Sheath integrity test and tightness of the welding

Both can be performed by various methods :

- the liquid nitrogen leak test (this is our normal production test for hot junction integrity),
- the boiling water test (or water plus teepol test) ; any possible leak is detected by insulation measurement afterwards,
- the steam test for which the thermoelectric cable closed at both ends is submitted to a steam pressure (200°C, 15 bars); as in the previous test, any possible defect can be detected by an insulation measurement,
- the hydrostatic test: the cable is immersed in water at room temperature and submitted to a pressure of 200 bars. Leaks are detected by an insulation measurement,
- the helium test is mainly used for the external welds.

In practice, we generally use the steam test for the thermoelectric cable, the liquid nitrogen test for the weldings and the helium test for the bushings and other fixing components.

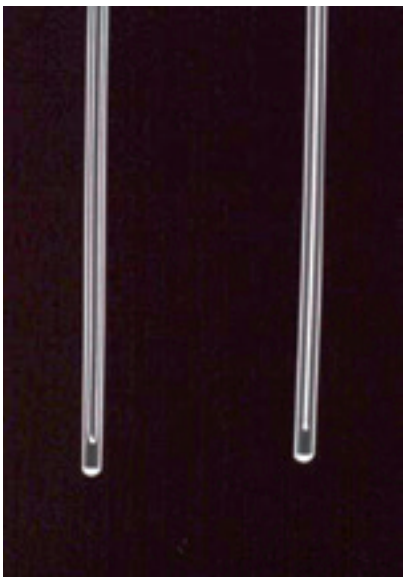
Metallographic control

The main tests used are as follows :

- the grain size measurement which allows the quality of the reduction and the mechanical characteristics of the cable to be controlled,
- the corrosion test which determines the cable resistance, in particular to aggressive media.

THERMOCOAX Laboratory :
Tests and qualifications equipment :

- Oven 1500°C
- HF loop
- Oven 2100°C



Measurements in various environments

Measurements on solids

Temperature measurements on solid surfaces require a good thermal contact between the thermocouple and the object to be measured. With laminated hot junctions, this condition is fulfilled best.

In every case, it has to be determined whether the thermocouple should only be pressed onto the solid or better be soldered to it. The measurement error caused by the thermal conductivity of the sheath can be neglected if the longest possible contact between the sheath and the isothermal zone of the solid has been ensured. In this case the hot junction will be very approximately at the same temperature as the solid.

Very precise measurements are possible if the thermocouple is placed into a hole in the solid. When doing this the following requirements have to be taken into consideration: the outer diameter of the hole has to be exactly adjusted according to the outer diameter of the hot junction/ thermocouple. In addition to this, the thermocouple has to be set into the hole in as sufficient depth : Nickel-Chromium-Nickel alloy couples with a sheath of stainless steel have to be set into a depth three times the outer sheath diameter.

Thermocouples made of materials with higher thermal conductivity require to be set in more deeply. The depth should correspond to about ten times their outer diameter.

When measuring very small objects with fast changing temperatures, the thermocouple response time has to be taken into account. The smallest possible sheath diameter and a hot junction of the TM-type lead to a very short response time.

Measurement in gases

Generally, measurements in gases have to be carried out with great care.

These measurements are not critical as long as the gas is kept within an isothermal vessel. Everywhere within this vessel, a equilibrium temperature exists which can be measured ideally with thermocouples.

In practice, the situation can be different because the heat transfer between sheath, gas and the wall of the vessel influences the temperature measurement.

Convection between the sheath and the gas is the heat exchange which is of interest for the measurement. The heat losses through this sheath have to be much lower than the convection between the sheath and the gas. The losses due to heat conduction are extraordinarily low for Nickel-Chromium-Nickel alloy (with stainless steel sheath). They can be reduced if it is ensured that the thermocouple is not directly exposed to the source of the heat.

However there is no generally applicable solution as how to reduce these losses. Large errors can be introduced into the gas temperature measurement if the vessel walls are at a temperature different from the one of the gas.

These errors can be reduced by a shielding between the thermocouple and the vessel wall. The shielding itself will heat up to a temperature which lies between the one of the vessel wall and the one of the thermocouple.

It is recommended to take as many measurements under various measurement arrangements as possible.

In addition to this, the response time of the thermocouple plays a very important role when measuring flowing gases. In air and gases with low fluid speed, the time-constant is low because of the low heat transfer.

If the fluid speed is increased, the time-constant is reduced.

Measurement errors

Errors due to inhomogeneities

In homogeneities of thermocouples can be caused by a changed chemical composition or changes of the crystalline structure.

Within the thermoelectric wires, additional and uncontrollable e.m.f. emerges, which only have a negative influence on the exactitude of the measurement if the thermocouple is measuring in a temperature gradient. The error depends on the inhomogeneity as well as on the temperature gradient.

Thermoelectric wires can undergo changes in their structure because of sharp bending, folding, stretching of short range ordering, which causes inhomogeneities. This phenomenon can be reversed in most cases by heating up the thermocouple to 800°C.

In order to determine the inhomogeneities, the following experiment can be carried out :

the hot junction is held at a constant temperature level and is connected to a measuring device. A source of temperature is moved along the thermocouple. The measured temperatures should not differ significantly.

Errors because of wrong use of the compensation cable.

Please refer to the chapter "Compensation cables".

Errors due to drift

Thermocouples are not only defective in cases of mechanical destruction or any other breakage of the thermocouple but also if the e.m.f. is no longer located within the tolerance. This phenomenon, known as drift, can appear without any external changes of the thermocouple and can, gradually deteriorate the e.m.f.. One of the common reasons of this drift is pollution of the thermoelectric wires due to the influence of temperature.

Examples: type K thermocouples drift at high temperature due to the fact that the chromium in the positive wire oxidizes more easily than the nickel. Because of this, a reduction of chromium takes place and the e.m.f. is getting lower. This error appears mostly when the thermocouple is used in an atmosphere with a lack of oxygen. This lack of oxygen hinders the further oxidation and therefore the formation of a natural shielding. The emerging green rot then destroys the thermoelectric wires.

During temperature measurements in sulphureous fumes, the nickel wire of the type K thermocouple is particularly affected. The cause is an embrittlement of the material.

A further reason for changes in the e.m.f. is a cooling down from a temperature of over 700°C which happens too fast.

Alterations of thermocouples might appear in a different way and do not have to be due to any effect described above.

At this point the phenomenon should only be described shortly.

In general, it is recommended to verify from time to time any thermocouple used in high temperature areas.

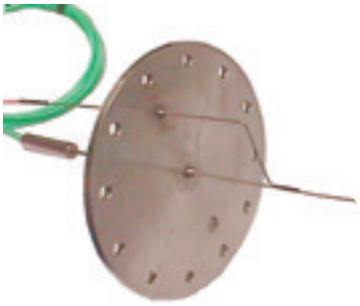
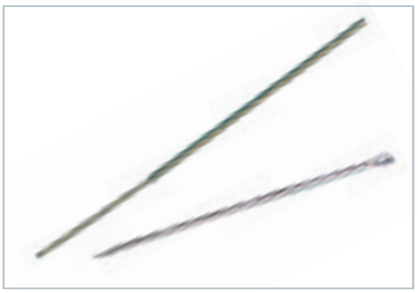
Errors due to wrong measuring location

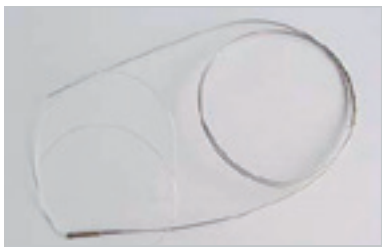
In general, the hot junction – meaning the sensitive part of the thermocouple – has to be located in the hot zone of the object of which the temperature is being measured. If this is not the case, the temperature is not measured correctly. In addition to this, a disturbance of the temperature field can have a negative influence on the measurement.

Because of the thermal conductivity of the constructive materials such as insulation, thermoelectric wires and sheath, a heat transfer takes place. If the sheath is at a higher temperature than the hot junction, heat can be transported towards it. In the same way, heat can be transported away from it. In both cases, the temperature measurement is disturbed. An improvement is often attained by specific construction and installation of the thermocouple. Between hot junction and the object to be measured, the best possible heat exchange has to exist.

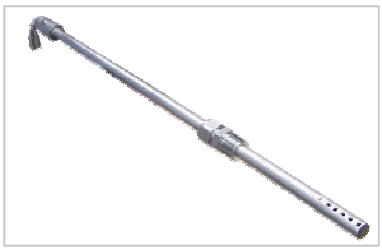
A powerful potential

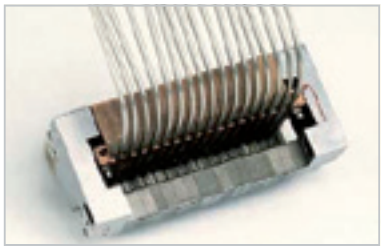
Small diameter



Customized design





Control and Quality

All THERMOCOAX thermocouples are subject to dimensional and electrical controls (line resistance and insulation resistance).

Mechanical, electrical, dimensional controls are often required for devices working in severe media conditions and for which a perfect reproducibility and/or accuracy is needed. These controls can be defined with the customer and our techical services within precise specifications.

In order to fulfil the particular demands of the nuclear, aeronautical and space industries, THERMOCOAX can on request set up a Quality Assurance Program focused on the whole development cycle of the products.

Whether they are standard or manufactured to customers specifications, all THERMOCOAX products are developed with the same procedures, the same control principes, the same feed back and the same qualified personnel.

Temperature measurement

- Temperature sensors (thermocouples, and also specialised sheath materials, high temperature, platinum resistance thermometers)
- Temperature harnesses
- Specific sensors (fluxmeters…)

Heating solutions

- Heating cables and elements (cold ends, or with a coiled core)
- Rod heaters
- Heating devices according to customer specifications : heating platens, ovens

Other measurements and Detection

- Mineral Insulated Signal Transmission cables
- Silica insulated cables
- High temperature capacitive sensors TURBOCOAX®
- Neutron Detectors NEUTROCOAX®
- Overheating and fire detectors NEGACOAX®
- Traffic sensors VIBRACOAX®

THERMOCOAX

OUR COMPANY

With nearly 60 years of experience in heating solutions and temperature measurement, THERMOCOAX has acquired a great deal of skill and expertise.
THERMOCOAX products are widely used and endorsed in many industries where the highest quality and utmost reliability are essential.
All our mineral insulated cables are manufactured in-house with our proprietary and unique procedures.

www.thermocoax.com

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ETALONNAGE N°2.1384

Thermocouples & Heating Elements ATEX certified and notified

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