MIMS-Cables

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General Information

Mineral insulated cables have an outer sheath of metal with 2 to 8 inner conductors. The insulation material is made from a highly compressed metal-oxide powder (preferably MgO or Al2O3).

Mineral insulated thermocouple cables have inner conductors of thermocouple base material. Mineral insulated cables for RTDs have inner conductors of copper, copper-nickel alloys, nickel, nickel-chromium or nickel-plated copper.

Mineral insulated cables are designed for high-temperature applications and are used wherever there are particularly strict requirements with regard to mechanical, chemical and electrical stability.

On account of their good flexibility, the use of mineral insulated cables is preferred in areas where mounting is difficult and where a high degree of flexibility is required (for example, laboratories or pilot manufacturing plants).The minimum bending radius we test is 3 times the outer diameter of the mineral insulated cable.

Innovations in technology and manufacturing have made it possible for these cables to be used increasingly frequently as a material in the manufacture of standardized thermocouples and RTDs, in particular in industrial measuring and control technology and in automotive sensor technology.

Delivery Program

SensyMIC offers a wide range of mineral insulated cables for the production of mineral insulated thermocouples and mineral insulated RTDs.

All standardized thermocouples type K, J, L, T, U, E and N and the precious metal thermocouples type R, S and B are available as mineral insulated thermocouple cables. Various mineral insulated cables with copper, copper-nickel, nickel and nickel-chromium inner conductors are also available ex stock.

The MIMS cables can be manufactured in a number of combinations. The selection of the base materials depends on various criteria (operating temperature range, required heat treatment during drawing process, etc.). Sheathed cables are available in outer diameters between 0.25 to 12.7 mm and can be delivered in production lengths between 20 and 2,000 m, depending on the diameter. For reasons of occupational safety and better processability, however, production lengths are divided into manageable stock sizes.

However, not all combinations of sheath material and thermocouple are possible as, for example, at high-temperature-resistant sheath materials some of the necessary heat treatments considerably exceed the maximum permissible temperatures for the leads.

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Typical production lengths and typical stock and delivery lengths

outer diameter	typical production length	typical stock length
0,50 mm	4500 m	100-300 m
1,00 mm	1000 m	200-500 m
1,50 mm	3600 m	300-500 m
1,60 mm	3300 m	300 m
2,00 mm	2100 m	300 m
3,00 mm	920 m	300 m
3,20 mm	800 m	300 m
4,50 mm	410 m	200 m
4,80 mm	365 m	155 m
6,00 mm	230 m	110 m
6,40 mm	200 m	100 m
8,00 mm	130 m	60 m
9,50 mm	65-85 m	20-30 m
12,70 mm	30 m	15 m

The minimum quantity for non-stock items corresponds to the
Minimum quantity of the production length

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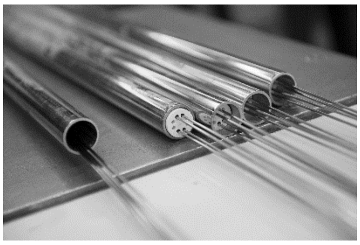
Technical Data



Sheath
Common to all MIMS cables is the metal sheath, which makes it mechanically and chemically resistant to the influences of the medium to be measured. Sheathed cables are produced with a jacket of cold-workable metals, in particular from the entire range of austenitic stainless steels. For the vast majority of applications, nickel-based alloys are used. Special sheath materials are available on request.

Insulation
Standard materials for the ceramic crushables are high-temperature-resistant magnesium oxide (MgO) and also aluminum oxide (Al2O3). For the manufacture of MIMS thermocouple cables, ceramics with a purity of better than 99 % are used. These insulate the inner leads against electrical short circuits and keep them in the desired geometry.

Conductor materials
MIMS thermocouple cables have inner leads of thermo material in accordance with the international DIN EN, IEC, ASTM, BS, JIS standards. Noble metal thermocouples are ideal for high-temperature applications under oxidizing conditions. MIMS cables for resistance thermometers have inner leads of copper, copper-nickel alloy, nickel, nickel-chrome or nickel-plated copper.

Very high insulation resistance
The insulation material from highly compressed magnesium or aluminum oxide (ceramic capillaries) exhibits very good insulation characteristics, even at high temperatures. In the ‚as-delivered' condition, the insulation resistance of all MIMS cables is >30 GOhm at room temperature.

Processing
It is absolutely necessary that the cable is sufficiently dried after the seal is opened or after the mineral insulated cable is cut into the lengths required. Immediately after drying, the cable must be sealed. The cable must not be stored with open ends.

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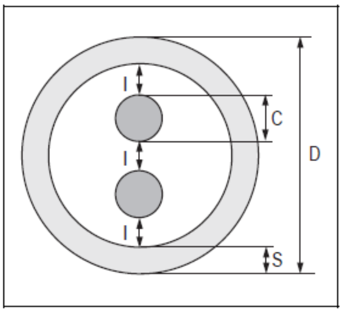
Dimensions

The following table shows the tolerances of the outer diameter, minimum wall thickness, minimum conductor diameter and thickness of the insulation according to DIN EN 61515.

Outer diameter of the cable (D) Nominal value ± tolerance, mm	Minimum wall thickness (S), mm	Minimum diameter of the inner conductor (C), mm	Minimum thickness (I) of the insulation, mm
0.5 ± 0.025	0.05	0.08	0.04
1.0 ± 0.025	0.10	0.15	0.08
1.5 ± 0.025	0.15	0.23	0.12
1.6 ± 0.025	0.16	0.24	0.13
2.0 ± 0.025	0.20	0.30	0.16
3.0 ± 0.030	0.30	0.45	0.24
3.2 ± 0.030	0.32	0.48	0.26
4.0 ± 0.045	0.40	0.60	0.32
4.5 ± 0.045	0.45	0.68	0.36
4.8 ± 0.045	0.48	0.72	0.38
6.0 ± 0.060	0.60	0.90	0.48
6.4 ± 0.060	0.64	0.96	0.51
8.0 ± 0.080	0.80	1.20	0.64
10.0 ± 0.100	1.00	1.50	0.80



D = Outer diameter
C = Conductor diameter
S = Wall thickness
I = Insulation thickness

Homogenous outer Diameters
Homogenous outer diameters are achieved through the use of drawing dies made of industrial diamond. This means, for example, tolerance range 0 in the positive range of the outside diameter is part of our standard, unless otherwise specified by the customer.

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The short-range ordered state in NiCr-Ni thermocouples (type K)

Type K thermocouples are the most widely used thermocouples in process measuring technology, and not only there.
Why?

– Their wide temperature range from – 200 to 1200 °C
– Their excellent long-term stability under oxidizing conditions
– Their high sensitivity of 40 mV/°C
– Their superior suitability within mineral insulated thermocouples
– Their moderate price compared to precious metals

make these thermocouples an optimal solution both technically and financially.

From time to time arguments come up denying the suitability of this thermocouple type for the accuracy required in industrial measuring and control technology because these alloys are subject to the short-range ordered state.

What is the short-range ordered state?
The short-range ordered state is a phenomenon which occurs with nickel-chromium alloys and predominantly affects their thermoelectric properties. It is a magnetic ordering state of the individual elements of the matrix.

A distinction is made between
– the ordered state, the so-called **K state,** and
– the disordered state, which will be called **U state.**

One can imagine that in the K state the matrix elements stand in rank and file, whereas in the U state there is no order to their positions.
These states can be produced by certain temperature treatments and can easily be reversed.
In addition, transition states between the above states often occur.

What is the effect of the ordering states?
The electromotive force (e.m.f.) of a nickel-chromium wire in the K state may differ from an identical wire in the U state by the equivalent of 2 to 3 °C depending on the temperature and test method. In the transition states this value is lower.

How are the ordering states created?
Above 600 °C nickel-chromium alloys are always in the disordered or U state. After reaching this temperature the U state is formed very quickly.

If the alloy is cooled rapidly (in a few minutes) to room temperature, the U state will be kept as long as the temperature of the alloy is not raised above room temperature. The U state is "frozen in".
If the alloy is cooled slowly (in a few hours) to room temperature, a transition state between K and U generally appears.

If the alloy is kept for an extended period (one or two days) within a temperature range of 250 to 500 °C, the K state will be formed and sustained until the alloy is heated to 600 °C or above again.

What heat treatment is applied to mineral insulated thermocouples before delivery?
All manufacturers apply annealing after the last drawing step to reduce any hardening of the sheath and wires caused by plastic deformation, i.e. to make the mineral insulated thermocouple soft and thus flexible and to reverse major changes in e.m.f.

This annealing is applied at temperatures above 600 °C, i.e. the wires are in the U state.

After annealing, the cables are usually cooled as quickly as possible in order to avoid precipitation processes, for example in sheaths of austenitic stainless steels (1.4571 or similar), which would impair the weld ability. This results in a more or less undefined transition state between K and U in the wires; it is possible to achieve such rapid cooling that the U state is frozen in in small cable cross-sections only in some continuous cooling plants.

What is the behavior of thermocouples in the different modes of delivery?
The majority of thermocouples are installed so that the measuring junction is at an elevated temperature and so that the temperature along the length of the thermocouple decreases with various slopes down to room temperature.

With a perfectly homogeneous thermocouple, i.e. the individual wires are completely identical over their whole length and do not have any local impurities or irregularities in their matrix, the e.m.f. will depend exclusively on the difference between the measuring junction and the reference junction.

However, if the thermocouple is not homogeneous, deviations from the original e.m.f. will occur, which depend on the nature and amount of the inhomogeneity and the temperature profile along the thermocouple.

Every thermocouple type K, regardless of the mode of delivery, will change after installation and when first used because it is always led through a temperature range in which the K state is formed after an extended period of time.

It is important to consider that the K state will also be formed at temperatures slightly below 250 °C, but much more slowly, it may take weeks.

What happens when first heated to 600 °C and above?
The following is based on a "regular" installation of the thermocouple as it is common in process control:
The insertion length of the thermocouple is fixed and the operating temperature does not vary significantly.

1. Delivery in the U state
At the measuring junction, nothing happens because the U state is already present. In the so-called temperature gradient, i.e. where the temperature decreases towards the end of the thermocouple, the K state will gradually be formed over weeks (see above). During this period, the deviation from true e.m.f. changes continuously. Reliable temperature measurement and control are not possible. At the cold end of the thermocouple, a local transition from the K state to the U state appears, another inhomogeneity with additional influence on the e.m.f.

2. Delivery in the transition state
At the measuring junction, the U state is formed relatively quickly. In the temperature gradient a creeping transition into the K state occurs and at the cold end a local transition from the K state to the transition state is formed as an additional source of errors.

3. Delivery in the K state
At the measuring junction the U state develops very quickly. In the temperature gradient and at the cold end, nothing happens as the K state is already present everywhere here, i.e. this mode of delivery offers immediate stable and reliable temperature indication.

How are mineral insulated thermocouples tested?
For a reliable e.m.f. test, the samples are transferred to the K state. If this is not done, the effects shown above for the first two delivery modes occur during calibration.

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When can reliable temperature measurement be expected?
Reliable temperature measurement which also corresponds to the e.m.f. determined in the test can only be expected if the mineral insulated thermocouples are delivered in the stable K state. Therefore, mineral insulated thermocouples should only be delivered in the stable K state.

SensyMIC is the only manufacturer who applies an expensive aging process as standard procedure which ensures that all K type cables are delivered in stabilized (aged) condition.

Mineral Insulated Thermocouple Cables with Precious Metal Thermocouples

Precious metal thermocouples are exceptionally suited for high-temperature applications under oxidizing conditions. They are used in chemical plants when absolute resistance to all kinds of acids is required.

Application
When using precious metal thermocouples, it is necessary to be aware that the insulation resistance of the insulation ceramics used decreases very much at high temperatures (over 1000 °C).
If big lengths of the sheath material are exposed to high temperatures, measuring errors can occur as a result of a mean value being taken over the installation length.
Because of the drift behavior at high temperatures, the recommended maximum temperature is 900 °C.

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Standard Sheath Materials

Mineral insulated thermocouples can be manufactured from all ductile sheath materials, especially from the full range of austenitic stainless steels. Nickel-alloy materials can also be used for certain applications. Special sheath materials can also be supplied.

Max. operating temperature	Sheath material	Material properties	Applications
800 °C	1.4301 **AISI 304** 1.4306 **AISI 304 L**	Materials 1.4301 and 1.4306 have different low carbon contents and differ, in particular, in their resistance to intercrystalline corrosion. Good resistance to organic acids at moderate temperatures, saline solutions, such as sulphates, sulphides and sulphites, and alkaline solutions at moderate temperatures. Good welding properties. Welding retreatment is generally not necessary, in particular with 1.4306.	Chemical apparatus engineering, nuclear power, textile and paper industry, grease and soap industry, food processing industry, dairies and breweries, nitric acid industry.
800 °C	1.4404 **AISI 316 L**	As a result of the addition of molybdenum, this material has higher corrosion resistance in non-oxidizing acids such as ethanolic acid, tartaric acid, phosphoric acid, sulphuric acid and others. Increased pitting resistance. Good welding properties. Heat treatment is generally not necessary.	Sulphite, pulp, textile, dyeing, fatty acid, soap and pharmaceutical industries.
800 °C	1.4541 **AISI 321**	Good resistance to intercrystalline corrosion, also after welding. Good resistance to heavy oil products, steam and exhaust gases. Good oxidation resistance. Can be used continuously up to approximately 800 °C. Good welding properties in all standard welding processes without the need for welding retreatment. Good ductility.	Nuclear power and reactor construction, chemical apparatus engineering, annealing furnaces, heat exchangers, paper and textile industry, petrochemical and crude oil industry, grease and soap industry, food processing industry.
800 °C	1.4571 **AISI 316 TI**	Increased resistance against corrosion from certain acids due to the addition of molybdenum. Resistant against pitting, salt water and aggressive industrial influences. Can be used continuously up to approximately 800 °C. Good welding properties in all standard welding processes without the need for welding retreatment. Good ductility.	Nuclear power and reactor construction, chemical apparatus engineering, furnace construction, chemical and pharmaceutical industries.
1150 °C	1.4749 **AISI 446**	Extremely good resistance to reducing, sulphurous atmospheres. Very good resistance to oxidation and air. Good resistance to corrosion caused by incinerator slag and copper, lead and tin smelts. Good welding properties in arc welding and WIG welding. Preheating to 200 - 400 °C is recommended. Retreatment is not necessary.	Petrochemical industry, metallurgy, power technology, recuperators, heat treatment kilns, vortex firing installations, waste incinerators.

Max. operating temperature	Sheath material	**Material properties**	**Applications**
1150 °C	1.4841 **AISI 314**	Excellent resistance to corrosion, also at high temperatures. Also suitable in atmospheres containing carbon and sulphur. Resistant to oxidation in air up to 1000 °C (interrupted service) or 1150 °C (continuous service) . Well suited with high thermal cycling. Recommended for long-term continuous use in the temperature range from 425 to 850 °C. Good welding properties in arc welding processes.	Boilers and blast furnaces, cement and brick kilns, glass production, crude oil and petrochemical industries, furnace construction and power stations
1100 °C	1.4845 **AISI 310 S**	Good resistance to oxidation and sulphidisation. Due to the high content of chromium, the material is resistant to oxidizing hydrous solutions and has good resistance to chlorine-induced tension crack corrosion. Good resistance in cyanide smelts and neutral salt melts at high temperatures. Not susceptible to green mould. Good welding properties. It is recommended to weld with low heat impact. Apply solution annealing after welding to avoid the danger of intercrystalline corrosion.	As 1.4841
1100 °C	1.4876 **Incoloy 800** ™ *	This material provides superior thermal stability due to the addition of titanium and aluminum. Suitable for applications requiring maximum stability under load in addition to scaling resistance. Excellent resistance to carburization and nitrogenisation. The material has good welding properties in arc and WIG welding processes. Heat treatment is not necessary after welding.	Power stations, crude oil and petrochemical industries, furnace construction
1100 °C	2.4816 **Inconel 600** ™ *	Good general resistance to corrosion, resistant to tension crack corrosion. Excellent resistance to oxidation. Not recommended with gases containing CO2 and sulphur above 550 °C and sodium above 750 °C. In air, resistant up to 1100 °C. Good welding properties for all types of welding processes. Excellent ductility even after long-term use.	PWR, nuclear power, furnace construction, plastics industry, heat treatment, paper and food processing industries, boilers, aircraft engines.
1100 °C	2.4951 **Nimonic 75** ™ *	Excellent high-temperature stability and resistance to oxidation and carburization. Due to the combination of nickel and chromium, the material has very good resistance to hot, gaseous media. Resistance to thermal fatigue and thermal shock. Good welding properties for all types of welding processes. Excellent ductility even after long-term use.	Space travel, aircraft construction, nuclear reactors, mechanical engineering, metal working, thermal materials processing.
1300 °C	Pt 10 % Rh	High-temperature resistance up to 1300 °C under oxidizing conditions. High heat resistance up to 1200 °C in the presence of oxygen, sulphur and silicon. Especially resistant to halogens, ethanolic acids, NaHCl solutions, etc. Can become brittle through the absorption of silicon from armoring ceramics. Sulphur eutectics possible at temperatures over 1000 °C. Sensitive to phosphorus.	Glass, electrochemical and catalytic technology, chemical industry, laboratories, melting and annealing furnaces and other furnaces, final storage of nuclear power products

* Trademark of Inco Alloys

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Insulation Ceramics

The standard materials for the ceramic crushables are high-temperature-resistant magnesium oxide (MgO) and also aluminum oxide (Al2O3).
For manufacturing MIMS thermocouple cables, ceramics with a purity of better than 99 % are used, for MIMS RTD-cables a purity of better than 98%

MIMS short description

Our short description serves as a rough guide, details about the respective MIMS-cable can be found in the offer or our order confirmation.
How is our short description composed?:

For example:
SensyMIC short description MTL-1K-3,00-Alloy 600 describes a MIMS-cable with one thermocouple type K (1K), an outer diameter of 3,00mm and alloy 600 sheath material.
SensyMIC short description ML-4Ni-6,00-AISI 316L-WS-4L-V4 describes a MIMS-cable with four Ni (nickel) conductors, an outer diameter of 6,00mm and AISI 316L sheath material. The addition WS-4L-V4 marks the cable as a “wide space” design with four conductors in variant number four. Please compare this description with our SensyMIC geometry specification reference sheet (will be sent on request).
At “wide space” design, the conductors are placed on a wider bolt circle diameter, closer to the sheath. Wide space design enables sensor manufacturers to build a resistance element vice versa into the MI cable.

A detailed and up-to-date version of the SensyMIC part-numbers and the currently available stock can be found under item "stock lists" on our homepage or feel free to contact us under info@sensymic.com