IT'S ABOUT TEMPERATURE

PENTRONIC

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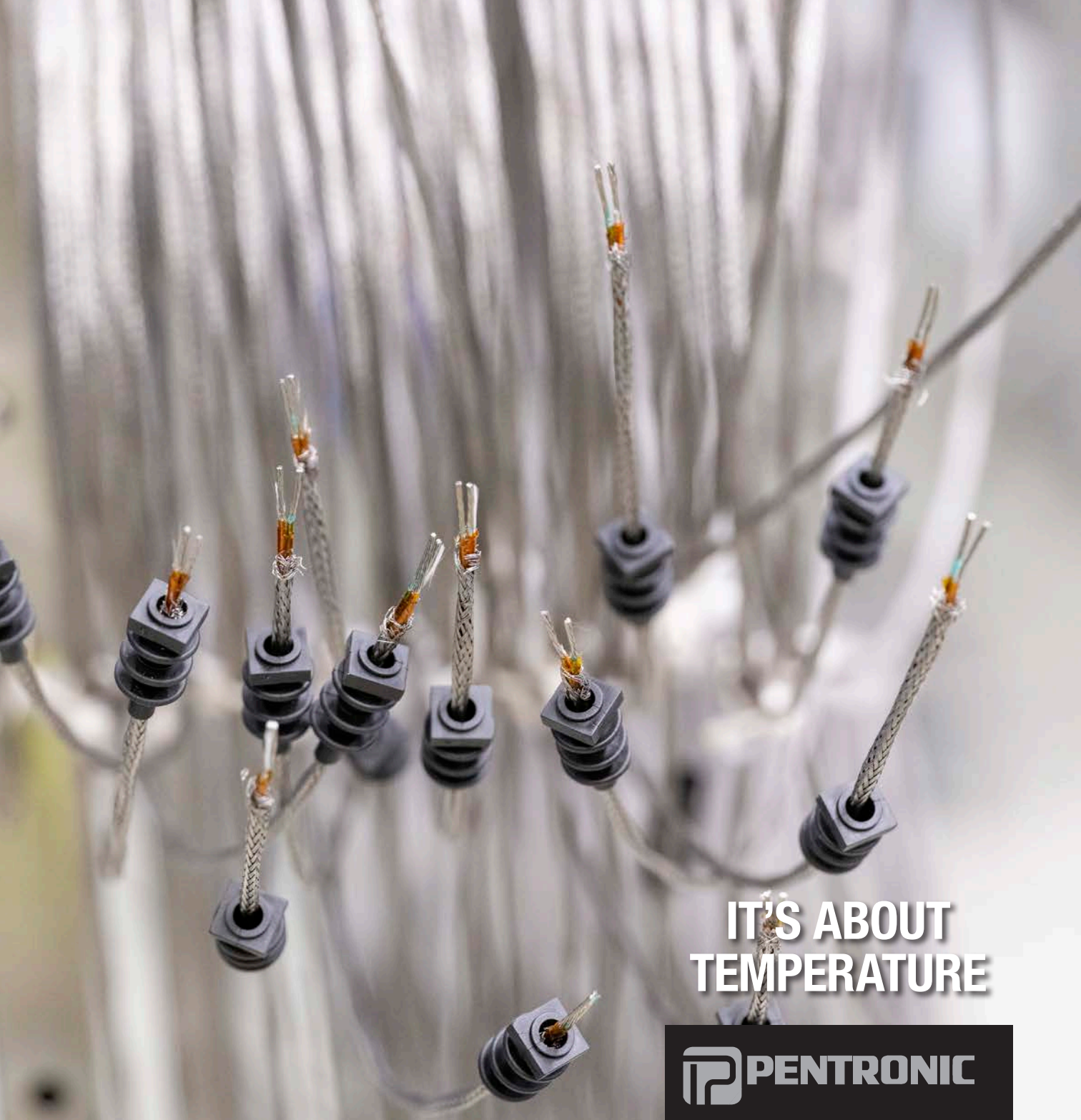
Precision behind the right temperature

Page 14-15

PENTRONIC



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The same foundation, stronger for the future

As we look ahead, our ambition is to continue strengthening our position in an industry that is constantly developing. Pentronic's promise – every degree counts – represents more than a temperature reading. It is a critical factor for our customers' performance, safety and competitiveness.

We have now reached an important milestone in our development as we approach the move into our new factory. The new facility is not only an investment in capacity. It is also a strategic platform for scalability, innovation and long-term sustainability. In short, it gives us the opportunity to meet tomorrow's demands with greater flexibility, higher efficiency and an even stronger customer offering.

At the same time, our foundations remain unchanged. Our expertise and our people remain the same. We will continue to manufacture in Sweden, close to our customers, with the same dedicated and knowledgeable team that turns experience and responsibility into tangible results every day. This combination of local presence, technical expertise and strong customer focus is our true strength.

Our transformation is therefore not about becoming something else. It is about becoming even better at what we already do: improving quality, strengthening collaboration and creating value together with our customers.

In this issue of It's About Temperature, we want to give you an insight into how we are developing our operations to strengthen your competitiveness, improve your efficiency and be a partner that contributes to long-term, sustainable results.

For us, it ultimately comes down to taking responsibility for every detail, creating quality through collaboration and always starting from the customer's reality. Because it is in our daily work – in every degree we measure and every decision we make – that our values make a real difference.

Claes Arnesson, Managing Director

IT'S ABOUT TEMPERATURE

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Magnus Karlsson and Maria Hoffsten jointly manage Pentronic's purchasing chain. Their experience and quality standards help keep production running smoothly. Page 22-23

Pentronic In Brief

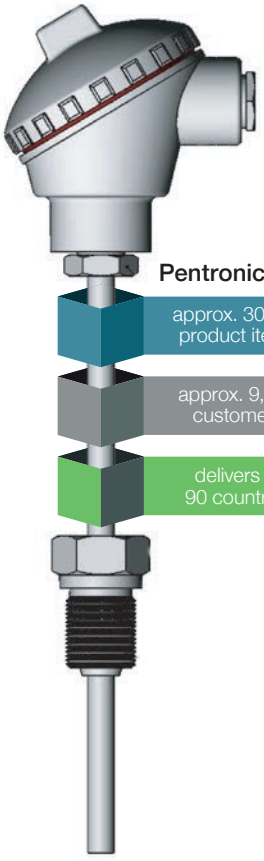
Pentronic collaborates with and supplies world-leading manufacturers across a wide range of industries, including food and food packaging, power generation, pharmaceuticals & medical equipment, vehicles & engines, and the process industry.

Pentronic is dedicated and competent – together!

Pentronic currently has

130

employees



36 YEARS

From 1990 onwards, Pentronic has been publishing their own magazine. With reading about customer projects, collaborations, technology news, employees and the organisation.

4000

Since 1991, around 4,000 people have participated in Pentronic's training courses.

800 NEW PRODUCTS

Pentronic develops around **800** new products each year.

10%

of our turnover is put back into development and innovation.

PENTRONIC
Founded in 1965.

2.0 **Pentronic 2.0.**
New Factory in Västervik.
Opening in 2027.

Overall substainability goals for 2030:

People
100% engaged people

- Employee engagement
- Leadership and skills development
- Diversity and inclusiveness
- Health and safety

Environment
CO_2 neutral

- Reduced CO_2 emissions (Scope 1 and 2)
- Increased proportion of renewable energy
- Energy efficiency
- Resource efficiency

Products & customers
Contribute 100% to sustainable customer value

- Customer satisfaction
- Sustainable innovation
- Products with a small carbon footprint

Employee engagement creates customer value

For Pentronic, sustainability is not only about carbon footprints, energy efficiency and technological development. The people behind the solutions are just as important. 'Sustainability has many dimensions and is about so much more than figures and carbon footprints. It is the commitment and expertise of our employees that make the difference,' says Managing Director Claes Arnesson.

Claes Arnesson.

FOR MORE THAN 60 years, Pentronic has helped customers develop and improve the efficiency of their processes. Accurate temperature measurement is crucial in many industries, from food and medical technology to power generation, the automotive sector and the process industry.

'It is essential for safety, quality and efficiency. As long as the laws of thermodynamics exist, we will have an important role to play,' says Arnesson.

Pentronic's history began in a small garage. Since then, the company has developed step by step, but its core purpose remains the same: measuring the right thing, in the right place, at the right time. For customers, this can mean ensuring that steel has the right properties, that food lasts longer or that critical processes run safely.

Where tolerances are tight, measurements must be accurate.

Values that are reflected in everyday work

Pentronic's values are built on expertise, commitment and collaboration. They should not only be visible in words, but also in how work is carried out every day. This means taking responsibility, supporting each other, sharing knowledge and developing together with both colleagues and customers.

The business is highly varied. The products come in many shapes, which makes the work both demanding and rewarding. In many cases, a production assembler works on the same customer order throughout the process, from manufacturing to final inspection.

'We see that quality is high when our employees are given significant responsibility in the process. This creates commitment and pride in what we deliver,' says Oscar Riis, Head of HR and Sustainability.

This way of working also places high demands on recruitment.

'It presents a challenge when we look for new colleagues, but it also means that we attract highly qualified and motivated people,' says Riis.

Three goals for sustainable development

Pentronic's sustainability work is focused on 2030

WOULD YOU LIKE TO JOIN US?

Pentronic is always looking for new colleagues who want to develop together with the company. Pentronic offers a broad area of expertise, and as part of Indutrade, employees gain access to both development opportunities and an international network.

Does this sound interesting? Read more or send a spontaneous application at **pentronic.se.**

and is divided into three overall target areas: people, the environment, and products & customers.

In the people area, the goal is to have 100% engaged employees. This includes employee engagement, leadership and skills development, diversity and inclusion, and health and safety.

The environmental target is to be CO_2-neutral for Scope 1 and Scope 2 emissions. This means reducing emissions by, for example, switching to renewable energy sources and improving energy and resource efficiency.

For products & customers, the goal is to contribute 100% to sustainable customer value. This includes customer satisfaction, sustainable innovation and products with a low carbon footprint.

Development never stands still

Pentronic develops around 800 new products every year. Behind this figure are both customer adaptation and a constant need to meet new requirements. The company has around 30,000 items and approximately 9,000 customers, with deliveries to 90 countries.

At the same time, 10% of annual turnover is allocated to development and innovation. This is an important part of the company's ability to remain relevant as customers' processes change and demands for energy efficiency, precision and reliability increase.

Why customers choose Pentronic

Pentronic has grown over the years but has always stayed true to its core purpose. The expertise, responsibility and commitment of its employees are what make the company a partner when precision is critical.

Trust has been built up over a long period of time. It is maintained in the details, in relationships and in every solution that leaves the company.

Why? Because every degree counts.

Oscar Riis.

The Road to **Long-Term Growth**

Pentronic is currently undergoing the largest investment in the company's history. The new production facility in Västervik will bring the entire business together under one roof, creating optimal conditions for future expansion. But the focus is not just on building modern premises – of equal importance is the work being done to ensure sustainability and skills supply, and to give shape to an attractive working environment.

A FEW YEARS ago, Pentronic set out a clear strategy for the company's future. The aim is to prepare the business for a higher rate of growth and create the conditions needed to grow faster than the market. The investment in a new production facility is a key component of this new strategy.

'So far, we have followed the plan well; over the past two years, we have seen an increased rate of growth. The new facility secures the physical framework we need to grow over the long term and reduces complexity by consolidating three separate units into one. With modern production capabilities under one roof, we are streamlining and rationalising our processes – while also ensure the long-term needs of our customers,' says Claes Arnesson, Managing Director of Pentronic.

Invaluable expertise

The new facility is expected to be completed in spring 2027. That a Swedish company is building a new factory for the production of temperature sensors in Sweden is relatively unique – manufacturing usually takes place in other parts of the world. By investing in Sweden, Pentronic remains close to its customers and keeps supply chains short, retaining full control by safeguarding both expertise and quality. But success depends on much more than that. Pentronic is very much a knowledge-driven company with specialised operations. As the organization grows, the ability to attract new talent becomes essential — but equally important is ensuring that existing employees thrive and choose to stay.

'Our employees are our greatest asset, and social sustainability is extremely important to our development. The new premises will improve the working environment and increase job satisfaction. At the same time, we are doing what we can to promote employee health, in part via wellness allowances and joint activities. We are happy to report that we have low staff turnover rates, and this has secured expertise within the company and made us strong over time,' says Claes.

Reducing climate impact

Building for the future also means taking responsibility for the environment. The aim is to certify the facility according to the "Miljöbyggnad Silver standard", a Swedish green building certification.

'We want to build sustainably and so we're looking for solutions that can minimise climate impact during both the construction and operation phases. This includes heating systems that produce minimal carbon emissions and the installation of solar panels. Even biodiversity has been factored into the planning process, in that we will have insect hotels and birdhouses installed in the area, among other things' explains Claes.

Employees in the centre

The construction project reflects the long-term approach that permeates all of Pentronic's operations – from environmental responsibility to community engagement. As the moving trucks roll out and everyone comes together under one roof, company culture will take on greater importance than ever before.

'Employee engagement will be crucial to our success. Our values are engagement, expertise and togetherness. As we settle into our new premises, it will be absolutely essential that we retain these values that have paved the way for Pentronic's development up until now,' says Claes. ■

Groundbreaking ceremony, spring 2026. Standing from left: Joacim Larsson, Business Manager at YLAB; Claes Arnesson, Managing Director of Pentronic; and Rikard Larsson, Head of Business Segment Sensor Solutions at Indutrade.

Claes Arnesson, Managing Director of Pentronic.

Pentronic's new centralized production facility in Västervik will serve the company's entire operations. (The image is a conceptual rendering.)

CUSTOMER CASE

From sheet metal coil **to heat exchanger**

Alfa Laval Technologies in Ronneby manufactures heat exchangers that are exported worldwide. The heat exchangers are brazed in vacuum furnaces, a process that requires precise temperature control. Pentronic supplies customised temperature sensors for this sensitive process.

'THIS IS WHERE we braze the heat exchangers. The process can take up to 24 hours,' says Roger Ekström, production engineer at Alfa Laval Technologies.

During our tour of the factory, Ekström stops in front of a vacuum furnace more than three metres high. He explains that the temperature sensors control the furnaces and measure the temperature at several points inside the vacuum chamber.

'The heat exchangers are brazed at temperatures above 1000 °C, and deviations of only a few degrees can have severe consequences for quality. This means that the temperature sensors play a crucial role,' Ekström explains.

MORE ABOUT ALFA LAVAL

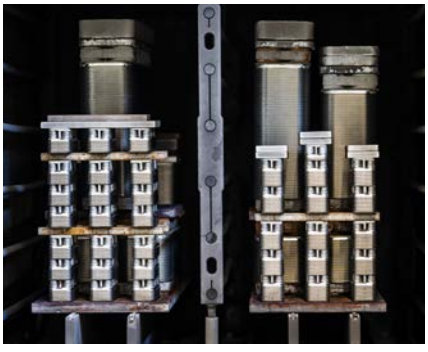
- The company was founded in 1878, when Gustaf de Laval and Oskar Lamm patented their first milk separator.
- Today, Alfa Laval is one of the world's largest manufacturers of plate heat exchangers.
- Production in Sweden employs 2,800 people in Lund, Ronneby, Flemingsberg and Eskilstuna. The Ronneby site also has sister factories in Italy, China and the USA.
- The company's expansion is driven by the global energy transition.

Part of the energy transition

Alfa Laval is a global group with around 23,000 employees and operations in heat transfer, separation and fluid handling. In Ronneby, the company manufactures heat exchangers that are mainly used in heat pumps, but also in other energy-efficient heating and cooling systems, such as those used in data centres.

The products play a crucial role in maximising energy efficiency and reducing climate impact, for example by recovering the vast amount of waste heat generated in modern data centres.

More than 300 people work in production, alongside around 30 robots. As we walk through the production hall,



Ekström explains how the heat exchangers are manufactured from start to finish:

'We receive coils of stainless steel sheet, which are punched and formed into plates. These are stacked together with copper foil and placed in vacuum furnaces, where they are brazed into finished heat exchangers. After testing, the products are packed for delivery.'

Values Swedish quality

Pentronic's partnership with Alfa Laval began more than 20 years ago.

'Over the years, we have developed the

process together. One major advantage is that Pentronic has its own production and can customise the temperature sensors specifically for our production. We also value the ability to buy Swedish-made products,' Ekström says.

'The major challenge is not simply to measure the furnace temperature itself, but to ensure that each product reaches the correct temperature throughout the entire furnace cycle,' says Jonas Bertilsson, technical sales engineer at Pentronic. He continues:

'Alfa Laval is a highly knowledge-driven organisation, where the ambition to remain at the forefront of technology permeates the entire business. The company has a strong focus on measurement and follow-up, both in areas where established methods already exist and in areas where new solutions need to be developed. Together, we are exploring and challenging the limits of what can be measured.'

Understanding the process

By calibrating sensors from the same production batches, Pentronic ensures that they measure consistently and with known accuracy. The results are documented in certificates that provide full traceability. Understanding the customer's process is just as important as supplying high-quality temperature sensors.

'To find the right solution, we need to gain an in-depth understanding of the customer's production. We need to know exactly how the flow works, what challenges exist and how problems can be prevented. That is why we visit our customers as often as we can,' explains Morgan Norring, sales manager for the process industry at Pentronic.

'This is the mindset we value in Pentronic. They are always alert and responsive when we want to make improvements. That is extremely valuable,' says Ekström, before continuing through production.

Roger Ekström of Alfa Laval and Morgan Norring of Pentronic in the production facility where the heat exchangers are manufactured.

A Team Leader with a **Passion for Precision**

Since the start of the year, Peter Wahlin has been team leader for a thermocouple group at Pentronic. He is responsible for day-to-day operations and assign work in production. Alongside his job, he also competes in pistol shooting – a sport where focus and accuracy are crucial.

PETER JOINED PENTRONIC after finishing secondary school in 2005 and has worked in sensor production ever since.

'I enjoyed it right from the start and stayed. What appeals to me the most about the job is the craftsmanship – building, welding, grinding and turning until each sensor is complete. It is a standardised precision task that requires both technical skill and great accuracy at every step,' explains Per.

> "Sometimes it almost feels like a prototype workshop, and I really enjoy that."
>
> Peter Wahlin

A new and challenging role

Today, Peter leads one of the thermocouple groups, which manufactures specially designed thermocouples in smaller runs.

'I am responsible for day-to-day operations. That means it's up to me to assign and direct the work in production, and I also have a certain degree of staff responsibility. This setup is new for Pentronic, and it feels both rewarding and stimulating to be a part of that journey,' says Peter.

A technical mind from an early age

Peter's hands-on interest in technology goes back to his childhood.

'I've always enjoyed taking things apart and tinkering with them. When I was younger, I used to build model aeroplanes, drive radio-controlled vehicles and I even built my own drones before they were commercially available. I suppose that's why I appreciate the kind of specialised equipment we build here. Sometimes it almost feels like a prototype workshop, and I really enjoy that,' he says.

Lessons from the shooting range

Outside work, Peter devotes much of his time to pistol shooting – an interest that began in 2008 when a friend brought him along to a shooting range.

'It's the development opportunities and concentration that appeal to me. You have to learn to shut everything else out and focus fully on the task at hand. Just like in my work, shooting is all about precision – and at the shooting range, I have learned the importance of sticking to the plan and taking things one at a time. That can be applied both at work and at home. When you have a clear goal and you work methodically towards it, the result is often better,' says Peter.

Peter Wahlin works on a custom-designed thermocouple – precision craftsmanship where skill and accuracy go hand in hand.

Nordic champion

In 2025, Peter won team gold at the Nordic Pistol Shooting Championships, as well as an individual silver medal. In recent years, he has also taken up judo again together with his daughter, Ronja.

'Cardio helps with concentration and makes it easier to stay calm during competitions. A big part of it is cultivating an ability to remain calm until this almost becomes muscle memory,' he says. ■

PETER WAHLIN

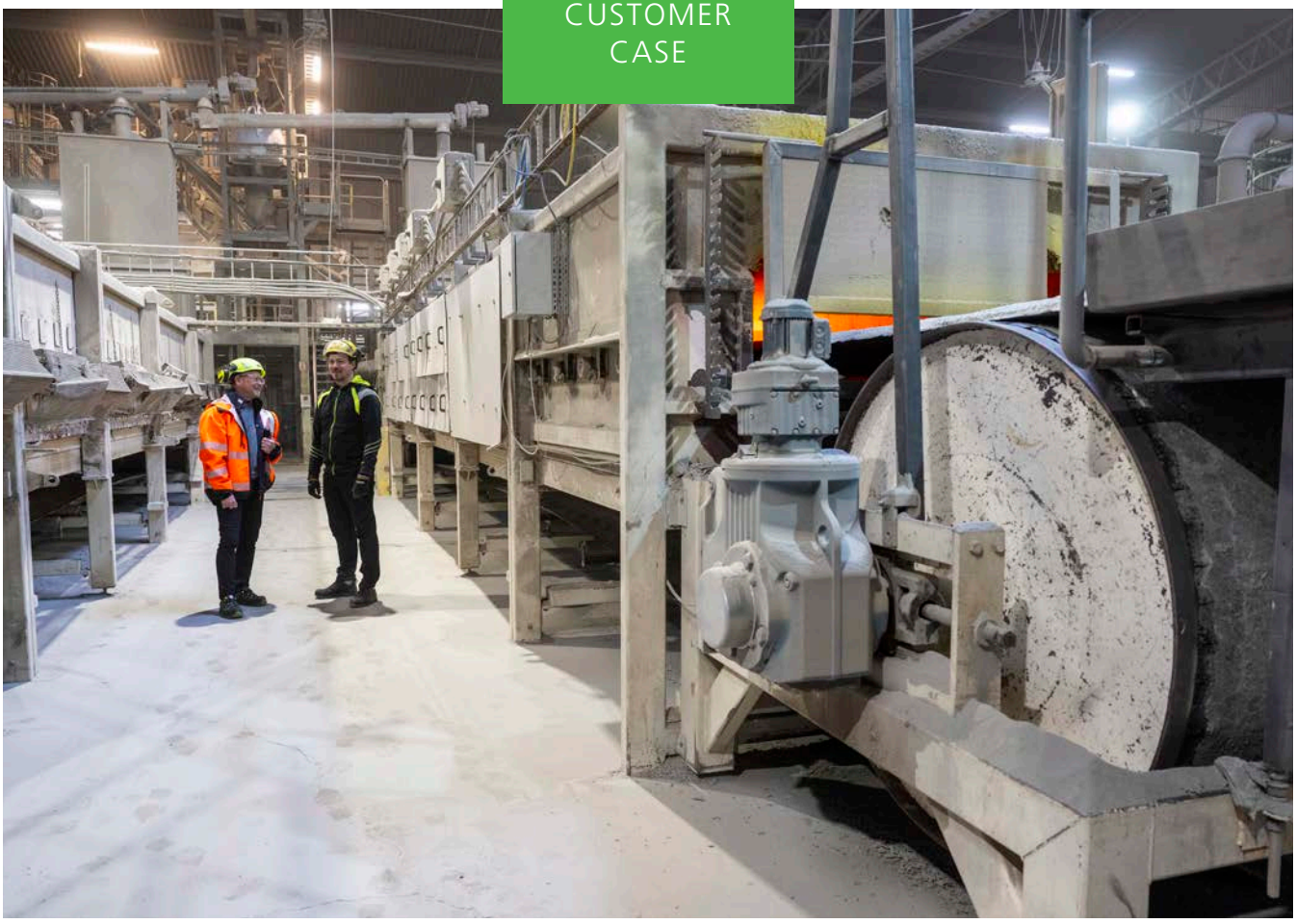
Lives: In Verkebäck, 200 metres from work.

Family: Daughter Ronja, aged seven.

Best thing about Pentronic: "Being able to spend every day honing a craft – building, welding, grinding and turning until each sensor is complete."

Favourite lunchbox item: Pasta bolognese. "I probably have that about two or three times at work every week, haha!"

Favourite way to spend a day off: "Get started with a big cup of coffee then head down to the shooting range in the morning and round things off with a TV show or a movie."



At Hasopor, recycled glass is heated to nearly 1000 °C and transformed into foam glass – a lightweight, high-strength material with a low climate footprint.

High-Quality Measuring Equipment – A Clear Choice for Hasopor

Hasopor uses 100% recycled glass to manufacture foam glass – a lightweight fill material that can bear heavy loads and has a low carbon footprint. As a longstanding partner of the company, Pentronic contributes to Hasopor's process development and manufactures customised thermocouples.

ONE TENTH THE weight of gravel – and ideal for construction projects of any size where it is crucial that the ground pressure does not become too high. Plus a high load-bearing capacity, good drainage and insulating and capillary-breaking properties. These are just some of the advantages offered by the foam glass manufactured by Hasopor – a company based next to the glass recycling plant Swedish Glass Recycling (Svensk Glasåtervinning) in Hammar.

'Svensk Glasåtervinning supplies us with crushed glass, which we grind into a fine powder. We then mix it with a foaming agent and heat the mass until it becomes foam glass. During the process, closed air cells are formed, giving the material a pumice-like structure,' explains Niklas Sörling, Production Manager at Hasopor.

A sustainable product

Hasopor is part of the Finnish group Foamit Group Oy – one of Northern Europe's largest manufacturers of foam glass. Hasopor's customers come primarily from the building and construction industry in Sweden. According to Niklas, the company's foam glass offers several environmental benefits.

'Production uses fossil-free electricity, and we use 100% recycled glass, meaning glass bottles and jars collected for recycling. Using foam glass in the construction

"Production uses fossil-free electricity, and we use 100% recycled glass packaging."

Niklas Sörling

industry can yield considerable benefits for the environment. The material replaces both oil-based cellular plastic and lightweight expanded clay made from virgin clay. This means we can avoid both dependence on oil and the need to extract new natural resources,' he explains.

'Hasopor is a loyal customer of Pentronic's and they manufacture a very exciting product. It is simply fantastic that recycled glass has been able to acquire new value through Hasopor's operations – and that Pentronic gets to play a part in this development,' says Per Bäckström, Sales Engineer at Pentronic.

High process heat

During the production process, the glass mixture is heated up to almost 1,000 °C. This places very high demands on the thermocouples. Pentronic has therefore worked to develop customised solutions in close collaboration with Hasopor.

'The environment is a considerable challenge when it comes to this type of equipment, as it has to function in extreme heat. Especially considering that production runs around the clock, all through the year. Pentronic's sensors are reliable and provide accurate readings. This is absolutely crucial in allowing us to monitor the temperature and control the process,' explains Niklas.

An art of precision

Process development is an ongoing task at Hasopor.

'Manufacturing foam glass is an art of precision. Right from our very beginnings in 2008, we have learned about the process through experimental design and by working with colleagues in the foam glass industry. Pentronic has visited us many times and they share their deep technical expertise within thermocouples with us, helping us to improve and further refine production. The goal is to maximise efficiency and minimise electricity consumption – while also maintaining or improving quality and production volumes,' says Niklas.

Niklas Sörling, Hasopor and Per Bäckström, Pentronic.

FOAM GLASS FROM HASOPOR

- Seven eighths of the material is filled with air – only one eighth of the volume consists of glass.
- The material is manufactured from recycled glass that cannot be turned into new glass or glass wool – around 10–15% of the glass collected by Svensk Glasåtervinning. This type of glass was previously sent to landfill.
- Hasopor produces 155,000 cubic metres of foam glass per year – from 30,000 tonnes of glass.
- Since the start, Hasopor foam glass has helped avoid approximately 139 million kilograms of carbon emissions compared with the next-best environmental alternative.
- Pentronic has been a partner and supplier of thermocouples to Hasopor since 2019.

Expert in repair – and troubleshooting

Per Andersson works as a service technician at Pentronic. His role is to repair and troubleshoot customer measuring instruments – both in the workshop and on site at customer facilities around the world.

PER'S INTEREST IN technology began at an early age. His father was a service technician, and at home their garage was always full of cars and motorbikes.

'I got familiar with the workshop environment when I was still just a kid. I've had an interest in technology ever since,' says Per.

Per Andersson repairs and troubleshoots measuring instruments both in Pentronic's workshop and at customer sites in Sweden and abroad.

Per has worked in industry since 1995. He spent 21 years at Swedish agricultural machinery manufacturer Överums Bruk before joining Pentronic in 2022.

Providing peace of mind for the customer

For customers with critical processes, rapid service can be crucial.

'The fact that we offer servicing on site at the customer's premises means faster support in the event of operational disruptions. This reduces the risk of lengthy production stoppages and provides extra peace of mind. For Pentronic, it also means closer customer relationships and a better understanding of how our instruments are actually used in reality,' explains Per. He then goes on to say:

'Pentronic has around 100 different measuring instruments, and I learn something new every day. In Sweden, I often work with moisture meters in the food and paper industries. Abroad, much of the work involves GFM – Glass Flow Measurements. Every year, I spend around 50 days working on site with customers – both in Sweden and abroad. In my role at Pentronic you must like fault finding and take on a great deal of responsibilty.'

Business travel around the world

Pentronic has customers all over the world. This means Per has travelled a fair amount in his role, both within Europe and beyond. He has served customers in Japan, the USA and Canada.

Per got familiar with the workshop environment when he was still just a kid, and he has had an interest in technology ever since.

'In Canada, it was minus ten degrees and snowing, and we had to drive 150 kilometres to reach the customer – in a hire car with summer tyres. In Japan, we had to keep working until 9pm at the earliest, because that is what everyone else did,' says Per, who hopes to make it to Australia some time.

An active leisure life

Every other week, Per's youngest son, Lynx, stays with him. In their free time, they enjoy magnet fishing together.

'It is unbelievable how much junk there is in our waterways. Once, Lynx pulled up an entire fishing rod, reel and all,' says Per, who adds that he also enjoys playing disc golf with his colleagues.

'We have a really great team here, and we have a lot of fun together off the clock as well,' says Per. ■

"In my role at Pentronic you must like fault finding and take on a great deal of responsibilty"

Per Andersson

PER ANDERSSON

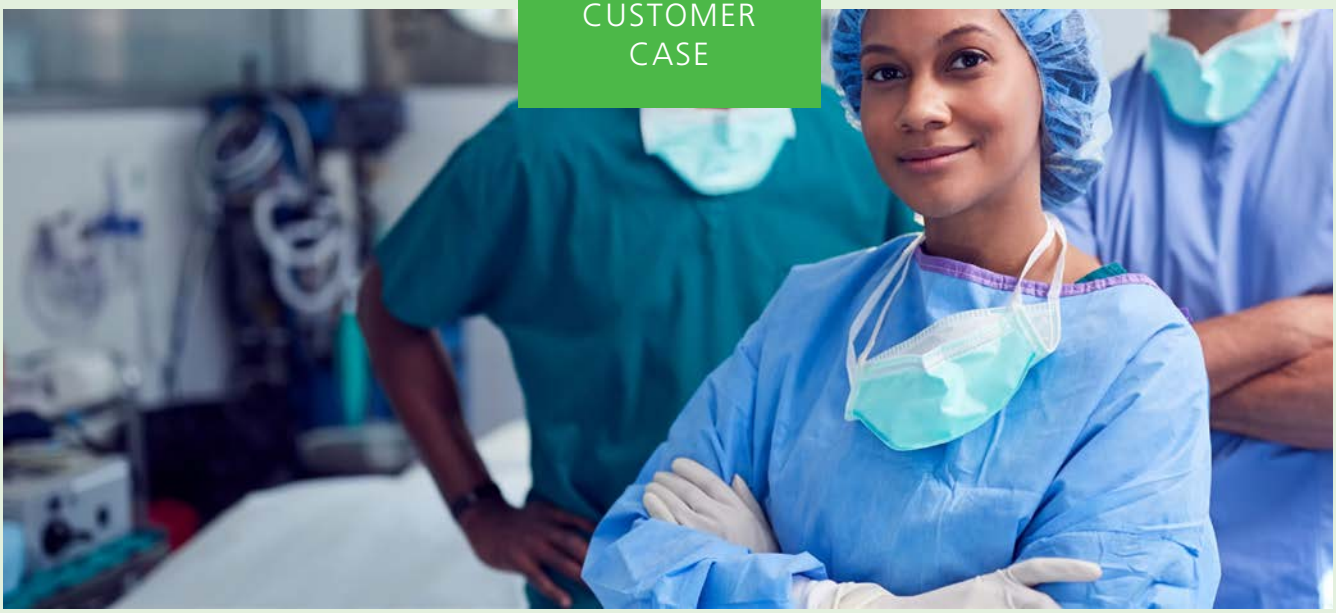
Lives: In Skaftet, south of Gunnebo. "But I'm planning to move to Västervik when the company moves into our newly built premises in 2027."

Family: Sons Lynx and Maximiliam.

Best thing about the job: "My colleagues. I also enjoy the customer contact and the mix of travelling and being in the workshop."

On his former floorball career: "I was a goalkeeper for 25 years, and I played in the third division with Västerviks IBK. I stopped in 2021 at the age of 49. You need quick reflexes when the ball is coming towards you at over 200 km/h – and saving the ball hurts more than what people think! But the feeling you get is unlike anything else!"

CUSTOMER CASE



When Every Degree **Can Be Critical**

Tridentify has developed a medical technology solution that ensures the shelf life of temperature-sensitive products in healthcare. Via continuous temperature monitoring in combination with clinical decision-making support, the system can determine in real time whether a product is still safe to use. Temperature calibration is performed by Pentronic.

Ann-Christine Jungmar, CEO of Tridentify.

THE PRODUCTS MONITORED by Tridentify are of high value. Incorrect handling of blood products, vaccines or medicines can cause medical risks and major financial losses. Maintaining the right temperature is therefore not just a matter of control – it concerns patient safety, quality and cost effectiveness.

Tridentify is a Swedish company with its head office and manufacturing operations on Hönö, an archipelago island outside Gothenburg. Their system is based on small medical technology devices* that automatically record and manage temperature deviations. As a result, healthcare staff can immediately see the status of blood products – and they can act accordingly.

Reliable measurements

When products can quite literally be a matter of life and death, extremely high standards are placed on accuracy, traceability and quality.

Automated medical devices reduce both medical risks and significant financial losses.

'For us, quality is absolutely crucial as we operate in markets with strict regulatory requirements. Pentronic is a high-quality supplier, and also a Swedish one. That is something we really value,' says Ann-Christine Jungmar.

"For us, quality is absolutely crucial as we operate in markets with strict regulatory requirements."

Ann-Christine Jungmar

Pentronic's accreditation under ISO/IEC 17025 means that every calibration meets strictly controlled quality requirements, providing reassurance in connection with both use and audits.

Traceability that proves quality

All units are calibrated before delivery to the customer, and each one is supplied with an accredited calibration certificate.

'Traceability means it is possible to verify that the measurement accuracy really does live up to its promise,' says Andreas Holm, who is responsible at Pentronic's Accredited Laboratories.

'We continuously check our reference equipment and regularly compare our results with those of other laboratories to ensure that our measurements are correct.'

Joint development

The collaboration between Tridentify and Pentronic began around 2019 and has since then developed into a close partnership in which processes and solutions are optimized together.

'We dialogue openly and find Pentronic to be both a flexible and attentive partner. Developing the process together is an important part of a successful collaboration,' says Ann-Christine Jungmar.

* *The products are currently classified under the MDD (Medical Device Directive). Tridentify is planning for MDR certification in 2026, which means adapting to the EU's new, more comprehensive regulatory framework for medical devices – with additional requirements for safety, traceability and clinical evidence.*

LABORATORY

Andreas Holm, Laboratory Manager.

The Lab – Pentronic's Own Knowledge Engine

Pentronic's laboratory is accredited under ISO/IEC 17025 for temperature calibration from −80 °C to +1200 °C. The laboratory is also a strategic knowledge hub in Pentronic's work with quality, method development and customer-specific solutions.

ACCREDITATION ENSURES impartial, accurate and internationally comparable measurement results, giving customers reliable, traceable quality assurance. The laboratory also strengthens Pentronic's expertise and offering while meeting advanced industry requirements. Alongside Pentronic's own temperature sensors, it calibrates sensors from many other manufacturers.

'We are often able to calibrate with very low measurement uncertainties — in many cases, achieving results up to ten times better than the sensor's specifications,' explains Andreas Holm, Pentronic's Laboratory Manager.

Quality assurance for Swedish industry

Pentronic offers accredited calibration both in their own laboratories in Verkebäck and Karlstad and in the field – directly at the customer's premises. This allows the company to support all kinds of needs, from scheduled quality assurance to the measurement of equipment that cannot be sent off for calibration. No matter which service the customer chooses, full traceability is provided through documented methods, references, responsible personnel and measurement uncertainty calculations.

'Depending on the environment, equipment and process, field calibrations can vary greatly. This places high demands on technical expertise and requires close cooperation with the customer in order to ensure that the result is both reliable and useable.'

The laboratory team consists of Andreas and four dedicated laboratory technicians who together run and develop the business.

'It is the combination of the team's experience, knowledge and commitment that enables us to meet the needs of our customers,' says Andreas.

Investing in greater capacity

Development work is currently being undertaken that will allow the company to offer calibration all the way down to minus 196 °C – which is the boiling point of liquid nitrogen. Initially, this service will be offered as traceable measurements, and later also under accreditation.

'Demand for calibration of thermocouples at higher temperatures is increasing, which is why we are now investing in greater capacity in the form of a new furnace. Recently we have also expanded our laboratory with a larger liquid bath for calibrating temperature loggers in the range of −30 to 40 °C,' says Andreas.

Purchasing Duo with **Great Responsibility and Strong Commitment**

They have worked together for almost 20 years and oversee our entire purchasing chain — from selecting suppliers to ensuring that the right materials arrive on time. Magnus Karlsson and Maria Hoffsten play a key role in making sure that production can run smoothly and without interruption.

PENTRONIC HAS CONTRACT customers for whom materials can be secured long term through agreements. Forecasts are often good in these cases, as Magnus and Maria can use previous statistics to gain an approximate picture of what future orders will look like. However, a large share of the volume is also order-driven, with requirements varying from one order to the next.

'There are about 3,500 unique items in our range. We work very closely with around 40 different suppliers, plus a further 100 or so suppliers from whom we also purchase products on a regular basis,' says Magnus.

Two roles – shared responsibility

Industry experience is particularly important in our purchasing department. Maria Hoffsten joined Pentronic in 1991.

'It was essentially my first proper job. I started working at the reception desk. After that, I worked in the order department for ten years before moving into purchasing. Apart from a two-year spell at another company, I have been with Pentronic the whole time,' says Maria, who is now a Purchaser.

Maria and Magnus began working together in 2008 when he was hired as Logistics and Purchasing Manager – a role he still holds today.

'One of the things that attracted me was the size of the company — the fact that you can be involved with and influence the entire purchasing chain. When you work across such a broad area, you learn new things every day,' says Magnus, while Maria nods along in agreement.

Quality at every stage

The purchasing department handles the entire material flow, from supplier evaluation to order placement, follow-up and deviation management. Quality permeates every stage of the process.

'In our business, quality is quite simply paramount. Pentronic's goal is to be at the leading edge of temperature sensor manufacturing. Our suppliers therefore need to have robust environmental and sustainability practices, documented quality management processes, high levels of availability and good delivery reliability,' explains Magnus.

Supplier visits and audits

In order to ensure that our requirements are met, suppliers are evaluated annually on a number of different factors such as quality, environmental legislation and our Code of Conduct — which sets out fundamental principles for human rights, fair working conditions, anti-corruption and environmental responsibility. We also conduct regular and thorough audits on site with our suppliers – both in Sweden and abroad. Ultimately, the aim of this work is to help ensure the best possible end product.

'When appointing suppliers, we benefit greatly from having been in the industry for so long. On paper, a specific product may look the same across suppliers – but we know that this is rarely the case. We always put quality before price,' says Maria.

Valuable experience

For Maria and Magnus, the fact that they are a small, close-knit duo is a huge advantage.

'Over all our years with the company, we have built up a deep understanding of exactly what the materials we purchase will be used for. As a result, we can easily cover for each other when needed. This is crucial in enabling us to provide the best possible service to our customers and to Pentronic as an organisation,' says Maria. ■

MAGNUS KARLSSON

Magnus has two daughters aged 17 and 20. He likes watching sport and he supports Stockholm football team AIK: “Unfortunately, supporting them has brought more misery than joy so far. But the championship title at Råsunda in 1998 was a pretty great moment!” He also plays both golf and disc golf in his free time. The best thing about Pentronic is the variation and the fact that new questions come up every day.

MARIA HOFFSTEN

Maria loves spending time outdoors and enjoys long walks and working in the garden. She lives in an old, renovated wooden house. Interior design is a huge passion of hers. She has four kids and grandchildren and enjoys spending time with her family and friends. Together with her husband Roger, she owns a refurbished wooden rowboat and a sailboat. The best thing about Pentronic? “Never standing still. I learn something new every single week.”

Read more about temperature at Pentronic's website.

DID YOU KNOW THIS ABOUT **TEMPERATURE?**

Bees can 'boil' an enemy to death

When bees are unable to sting an enemy (such as a Japanese giant hornet), they do something ingenious:

The bees surround the attacking wasp and vibrate their flight muscles, raising the temperature to 47 °C. The wasp dies at 46 °C, while the bees can withstand temperatures of up to 48 °C.

That makes this a **thermal precision attack**.

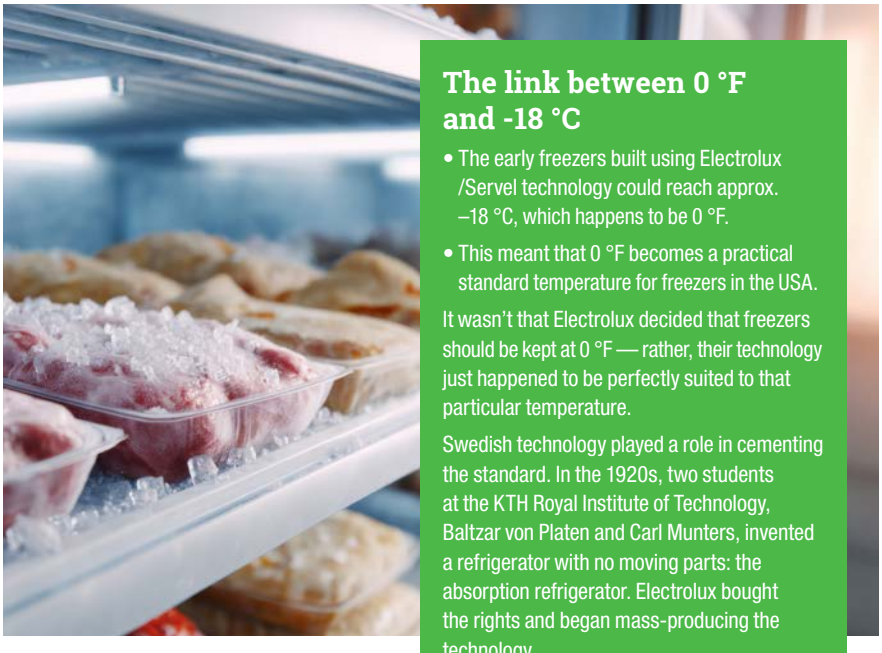
Photo: Valerie Loeb/NOAA, via Wikimedia Commons

Antarctic toothfish

(Dissostichus mawsoni)

This fish lives in water temperatures down to around –2 °C and can grow to over two metres in length.

Anecdote: It is so fatty that it almost floats away. Its extreme fat reserves, low bone density and antifreeze proteins prevent it from freezing and make it almost neutrally buoyant – something unusual for a large fish.



The link between 0 °F and -18 °C

- The early freezers built using Electrolux /Servel technology could reach approx. –18 °C, which happens to be 0 °F.
- This meant that 0 °F becomes a practical standard temperature for freezers in the USA.

It wasn't that Electrolux decided that freezers should be kept at 0 °F — rather, their technology just happened to be perfectly suited to that particular temperature.

Swedish technology played a role in cementing the standard. In the 1920s, two students at the KTH Royal Institute of Technology, Baltzar von Platen and Carl Munters, invented a refrigerator with no moving parts: the absorption refrigerator. Electrolux bought the rights and began mass-producing the technology.

Countries with the oldest temperature records

United Kingdom – Central England Temperature (CET)

- Starting year: 1659
- Type: Instrumental temperature measurements (reconstructed from early thermometers and observations).
- Status: The world's oldest continuous temperature series.
- Often used as a reference in climate research.

The Netherlands – De Bilt

- Starting year: 1706
- One of Europe's oldest official national measurement series.

Sweden – Uppsala

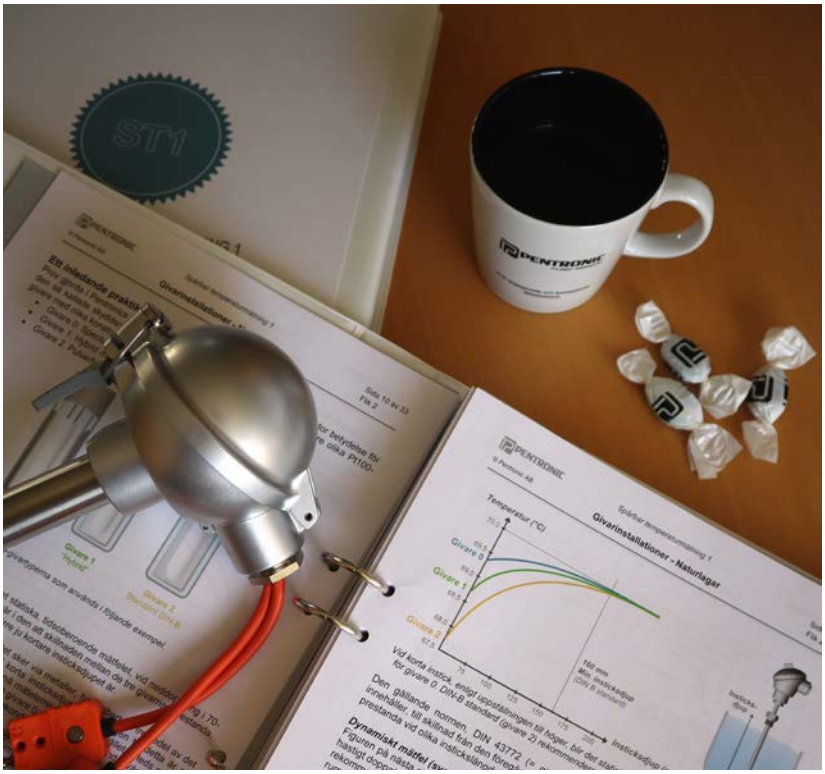
- Starting year: 1722
- One of the world's longest continuous measurement series from the same location and using the same methodology over a long period.

Denmark – Copenhagen

- Starting year: 1768
- Also one of the oldest in the world.

In Gdansk Poland you find the Farenheit Monument

A replica of the original mercury thermometer.



Invest in **knowledge** about **traceable temperature measurement**

Training in temperature measurement can often be a more profitable investment than buying new measuring equipment. When it comes time to invest, you will then have the knowledge to make wise purchasing decisions. We can therefore promise that Pentronic's courses are a valuable investment.

EXTREMELY SMALL TEMPERATURE differences can have major consequences. We all know this, not least in the light of global warming.

Temperature in all industries is measured and regulated at a wide variety of points. This is done to save energy and resources and to give products the correct properties. The constantly increasing specialisation and optimisation of processes are also increasing the demands for extreme measurement accuracy. To guarantee precise measurement results, it is not enough just to install a high-quality sensor. All measurement also depends on being able to either exclude or evaluate a number of error sources in order to ensure highly accurate measurements. Pentronic's training courses are designed to give measurement technicians and engineers good knowledge about measurement uncertainty and traceability. We give course participants knowledge, tools, and practical experience so that they can evaluate a measurement chain comprised of several possible error sources.

Correct evaluations and traceable measurements create good conditions for high quality, fewer errors and reduced costs for your process.

PENTRONIC ACADEMY

Pentronic has been training measurement engineers since 1991 with our courses "Traceable temperature measurement 1" and "Traceable temperature measurement 2". The training is adapted and updated continuously to correspond current needs and knowledge requirements. AKL, our accredited calibration laboratory holds us updated with new methods and standards. Pentronic also offers training courses on site at customers. Our website www.pentronic.se provides extensive information and technical articles about temperature measurement and equipment.

ST1, Traceable temperature measurement 1

This course is for people who want basic training in traceable temperature measurement. No formal basic knowledge is necessary. The course begins with a review of various measurement methods, continues with practical laboratory exercises in calibration and sources of measurement error, and concludes with a summary in the form of an analysis of the measurement uncertainty. The course is held over two days. You have constant access to the instructors and the opportunity to discuss your own questions about measurement. After this course you will know where to find the problems and how accurately you are actually measuring.

ST2, Traceable temperature measurement 2

This course was created to handle the follow-up questions from the course ST1. ST2 is a more in-depth treatment of topics in the basic course with the emphasis on calibration and measurement uncertainty. "Traceable temperature measurement 2" is for people who have previously taken ST1 or have equivalent knowledge. It lasts for three days, one of which is dedicated to the accredited calibration laboratory. There will be time to discuss your measurement problems, either within the group or individually with the instructors.

On-site training

Pentronic has extensive experience of providing training at customers' premises in various forms, for both small and large groups. We can present either our regular training or a customised version based on ST1. An on-site course at your company will lead to new insights and knowledge that can be directly applied in your own business.

TECHNICAL ARTICLE

Heat Flow in Thermowells Causes Measurement Errors

The effect of the thermowell on measurement error

In order to measure the temperature of a liquid in pipe flow, a sheathed thermocouple or a Pt100 sensor is usually used in combination with a thermowell. Both thermocouples and Pt100 sensors are contact sensors that measure their own temperature — and absolutely nothing else. The temperature measured at the measurement point is therefore very rarely the temperature you actually want to measure — the liquid temperature — and the difference can be regarded as a measurement error.

An example of a measurement installation using an insertion sensor can be seen in Figure 1 below.

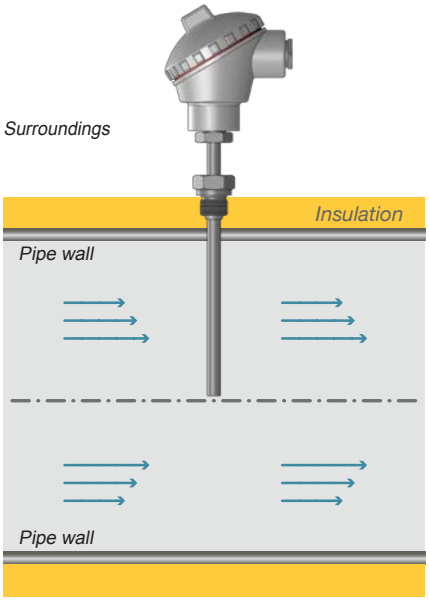


Figure 1. *An example of a measurement installation with an insertion sensor. In this case, the temperature of the flowing liquid is assumed to be higher than the ambient temperature.*

According to the conditions for the measurement installation in Figure 1, the temperature of the liquid is higher than the ambient temperature. The process here is assumed to be steady-state, or time-independent. Normally, the pipe is insulated, and this limits the flow of heat from the liquid to the surroundings.

Under the current conditions, there will always be heat flow from the liquid to the surroundings via the pipe wall and the insulation. The pipe therefore has a slightly lower temperature than the liquid. There is also heat flow from the liquid to the pipe wall via the thermowell and sensor. This means that the sensor's measuring point will measure a temperature that is slightly lower than the liquid temperature, but higher than the temperature of the pipe wall. In many cases, this measurement error is entirely negligible, but, unfortunately, in some cases, it cannot be ignored.

The measuring system's four subsystems

The temperature field in the thermowell and sensor determines the temperature at the sensor's measuring point. The temperature measured is governed by a thermal system consisting of four interconnected subsystems: the radial heat flow in the insulated pipe, the heat flow from the liquid to the thermowell, the heat transfer through the thermowell and sensor to the pipe wall, and the heat flow from the insulated pipe to the surroundings.

The temperature measured is affected by what happens in each of the four interconnected subsystems. In this case, the difference between the temperature of the liquid and the temperature measured is the measurement error.

The radial heat flow in the insulated pipe from the liquid to the surroundings. Subsystem 1.

The temperature of the pipe wall is an important parameter when calculating the measurement error, because the thermowell and the sensor are attached to the pipe. The temperature of the pipe wall is determined by the radial heat flow from the liquid to the surrounding environment outside the insulated pipe. From the liquid to the inside of the pipe, heat is transferred by forced convection. In the pipe and insulation, heat is transferred by conduction. From the outside of the insulated pipe, heat is transferred to the surrounding environment by convection and radiation – see subsystem 4. Heat transfer Q_1 from the flowing fluid to the pipe wall occurs through forced convection

$$Q_1 = h_1 A (T_{liquid} - T_{pipe\ wall})$$

where Q_1 is the heat flow in W, h_1 is the heat transfer coefficient in W/(m²K), A is the area of the inside of the pipe in square metres, T_{liquid} is the temperature of the liquid in Celsius, and $T_{pipe\ wall}$ is the internal temperature of the pipe wall in Celsius. The temperature of the liquid varies in both the radial and axial directions, but for approximate calculations, the mean temperature of the liquid can be used.

In order to reduce heat loss from the liquid to the surrounding environment, the aim is to insulate the pipe effectively. This means that the heat flow Q_1 from the fluid to the surrounding environment is normally relatively small. In the flowing liquid, the heat transfer coefficient is high, which means that, under normal conditions, the temperature difference between the liquid and the pipe wall, $(T_{liquid} - T_{pipe\ wall})$, is very small.

If the flow velocity in the pipe increases, the heat transfer coefficient also increases, and vice versa. The velocity of the liquid normally varies in both the radial and axial directions, but for approximate calculations, the mean velocity of the liquid can be used.

When calculating the heat transfer Q_1 in the insulated pipe, an overall heat transfer coefficient U, in W/(m²K), is used. The overall heat transfer coefficient is determined by the properties and dimensions of the materials involved, as well as by the heat transfer on the inside of the pipe and on the outside of the insulation. See, for example a heat transfer handbook.

In most cases, the pipe will be very well insulated and so the heat flow will therefore be small. Normally the pipe will be made of steel, which has relatively high thermal conductivity. As a result, the temperature difference between the inside and outside of the pipe wall will often be negligible.

If the pipe wall inside the pipe should become fouled for any reason, the fouling layer will act as additional layer of insulation and the heat flow to the surrounding environment will decrease. This also means that the temperature of the pipe wall will fall. As a result, the thermowell and sensor mounting point will be at a lower temperature than it was before the fouling occurred.

Heat transfer from the liquid to the thermowell with sensor. Subsystem 2

From the flowing liquid to the outside of the thermowell, heat transfer Q_2 occurs by forced convection

$$Q_2 = h_2 A (T_{liquid} - T_{thermowell})$$

where Q_2 is the heat flow in W, h_2 is the heat transfer coefficient in W/(m²K), A is an area on the outside of the thermowell in square metres, T_{liquid} is the temperature of the liquid in Celsius, and $T_{thermowell}$ is the surface temperature of the thermowell in Celsius. Under normal conditions, both the velocity and temperature of the liquid vary in both the radial and axial directions inside the pipe, but for approximate calculations, the mean velocity and mean temperature can be used.

The value of the heat transfer coefficient varies both along and around the thermowell. For approximate calculations, a mean heat transfer coefficient for the entire thermowell can often be used. In this case, the mean heat transfer coefficient is very high. The higher the flow velocity in the pipe, the higher the heat transfer coefficient. Reducing the outer diameter of the thermowell also increases the heat transfer coefficient, and vice versa.

The thermowell and sensor are attached to the pipe wall. Under normal conditions, the temperature difference between the liquid and the pipe wall, $(T_{liquid} - T_{pipe\ wall})$, will be very small. The heat flow from the liquid to the pipe wall via the thermowell and sensor is normally relatively small. Because the heat transfer coefficient on the outside of the thermowell is very high, the temperature difference between the liquid and the thermowell is small.

The heat transfer Q_2 to the thermowell can be calculated using, for example, the relationships given in a heat transfer handbook.

The temperature field in the sensor and thermowell. Subsystem 3

Heat is transferred to the thermowell and sensor from the liquid by forced convection. Both the velocity and the temperature of the liquid vary along and around the thermowell, which means that the heat transfer coefficient will also vary. For approximate calculations, a mean heat transfer coefficient can often be used.

The heat flow, and therefore the temperature field in the thermowell and sensor, is affected by factors such as the materials and dimensions of the thermowell and sensor. Other parameters that have an influence are the boundary conditions: the heat flow from the liquid to the thermowell, and the temperature of the pipe wall at the mounting point of the thermowell and sensor.
There is heat transfer to the pipe wall at the thermowell and the sensor. As discussed above, the sensor records a temperature that is slightly lower than the liquid temperature, but higher than the temperature of the pipe wall. If we disregard the temperature variation across the thermowell and sensor, the temperature changes in the axial direction in the manner shown by Figure 2.

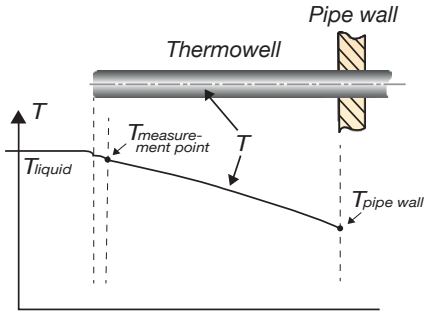
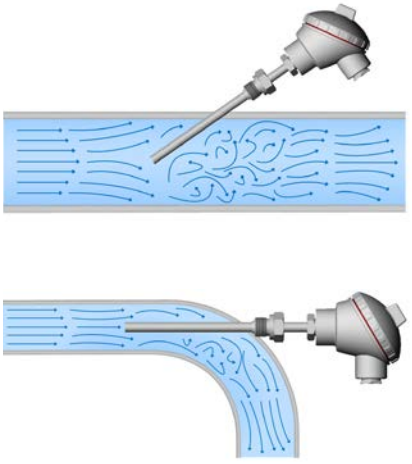


Figure 2. *Temperature change at the sensor of the thermowell and sensor.*

The longer the thermowell and sensor can be made, the smaller the difference between the liquid temperature and the temperature at the measuring point will be. If you want to use a thermowell that is longer than half the internal diameter of the pipe, the thermowell can be mounted at an angle or installed in a pipe bend.



If it is possible to reduce the outer diameter of the thermowell, the difference between the liquid temperature and the temperature at the measuring point will also decrease. For practical reasons, however, the diameter of the thermowell cannot be made too small. Reducing the diameter of the thermowell also increases the heat transfer coefficient on the outside of the thermowell, and this helps reduce the

difference between the liquid temperature and the temperature at the measuring point. Ref. 1 provides a more detailed discussion of heat flow and the temperature field in a measurement installation with a thermowell and sensor.

The temperature and flow field in the surrounding environment. Subsystem 4

The heat flow from the insulation to the surrounding environment is governed by convective heat flow and radiation. The following applies to the convective heat flow Q_{conv} in W

$$Q_{conv} = h_4 A (T_{insulation} - T_{air})$$

where h_4 is the heat transfer coefficient in W/(m²K), A is the heat-transfer area in square metres, $T_{insulation}$ is the surface temperature of the insulation in Celsius, and T_{air} is the ambient air temperature in Celsius. If the pipe is located indoors, natural convection will apply in most cases. For approximate calculations, a value for the heat transfer coefficient within the range 4 – 8 W/(m²K) can then be used.

Heat flow by radiation is in this case significantly more complicated to determine than heat flow by convection. Factors that have an influence include the temperature on the outside of the insulation, the temperature of walls and objects in the surrounding environment, the radiation properties of the surfaces and the geometry in question.

In the absence of better data, it can often be assumed that walls and objects in the surrounding environment will have the same temperature as the air. If it is assumed that the area of the insulated pipe is small in relation to the area of the room, the following expression can be used as an approximation to calculate the heat flow by radiation from the insulated pipe to the surroundings

$$Q_{rad} = A \varepsilon C_s ((T_{insulation})^4 - (T_{air})^4)$$

where A is the heat-transfer area of the insulated pipe in square metres, ε is the emissivity of the insulation, C_s is the radiation coefficient for an ideal black body, 5.67×10^{-8} W/(m²K⁴), $T_{insulation}$ is the surface temperature of the insulation in K, and T_{air} is the wall temperature in the surrounding environment in K. The outside of the insulation is often covered with a thin aluminium sheet, which means that the emissivity is often low initially: 0.1 – 0.2. Unfortunately, the pipe often becomes fouled quickly, and this causes the emissivity to increase: 0.5 – 0.9. The expression for the radiation is based on a large number of approximations.

The sum of the heat flow by convection and radiation on the outside of the pipe is equal to the heat flow supplied from the liquid on the inside of the pipe.

Effect of heat flow in the thermowell on the measurement error – a summary

Under the conditions described in the present case, the process is steady-state and the liquid temperature is higher than the ambient temperature. The heat flow from the liquid to the thermowell, and then through the thermowell and sensor to the pipe wall, means that the temperature at the sensor's measuring point will be slightly lower than the liquid temperature, but higher than the temperature of the pipe wall.

There is a large number of parameters in the four interconnected subsystems that can affect the heat flow and temperature field in the thermowell and sensor, and therefore the temperature at the sensor's measuring point. If a parameter changes in any of the four subsystems, the heat transfer in the thermowell and sensor will also change, and this in turn will affect the temperature measured and thus also the measurement error.

One example of such a change would be if the heat flow from the liquid to the surrounding environment were to increase as a result of the insulation becoming wet. The heat flow to the surrounding environment would increase, the temperature of the pipe wall would fall, the heat flow in the thermowell and sensor would increase, the temperature at the measuring point would fall, and the measurement error would increase. ■

"The temperature measured at the measurement point is therefore very rarely the temperature you actually want to measure – the liquid temperature – and the difference can be regarded as a measurement error."

Dan Loyd

Dan Loyd,
Professor emeritus,
Linköpings University
dan.loyd@liu.se

Ref. 1
www.pentronic.se > Menu > About temperature > Technical article archive > Properties and sources of error in sheathed thermocouples > Measurement error due to heat conduction in sheathed thermocouples

A Treasure Trove of Temperature Measurement Expertise

Sometimes you have to dig a little to find what is truly valuable. At Pentronic, we have been doing exactly that for almost three decades. Ever since the late 1990s, we have been collecting experiences, explanations, mistakes, solutions and principles from real measurement challenges within both industry and process applications. The result is one of the Nordic region's most extensive archives of technical articles about temperature measurement.

THE ARTICLES COVER everything from basic temperature theory to advanced discussions of heat transfer, sensor design, IR measurement, calibration and measurement chains. The articles have been written in collaboration with engineers who face practical problems on a daily basis – in the field, in the lab and in development projects.

Whether you want to brush up on the basics, explore a specific source of error in greater depth or find arguments for a specification, chances are good that someone else has already had the same question as you — and that their answer can be found in our archive. Our archives also offer a journey through time: you can trace how measurement technology has developed since 1997, and see first-hand how many of the fundamental principles are as stable now as they were back then. The technical articles in our archives have been written for designers, process engineers, quality managers, technicians — or anyone with a curious mind.

So get ready to explore our archive. It is full of valuable insights — and they are just a few clicks away. ■

Photo: Generative AI

Scan the QR code to access our archive of technical articles.

TECHNICAL ARTICLE

Temperature sensors in potentially explosive atmospheres must meet strict requirements under ATEX and the relevant parts of the EN 60079 series. Selecting the correct sensor and protection concept, and installing the sensor correctly, is essential for limiting ignition risks and ensuring a reliable process.

Safe measurement with ATEX-certified temperature sensors

GUIDELINES FOR SELECTING AND INSTALLING EX SENSORS

1. Match the equipment to the site's Ex classification

ZONES: Check whether the area is classified as zone 0, 1 or 2 for gas, or zone 20, 21 or 22 for dust. The sensor's certification must match or exceed the requirements for the zone in which it will be installed.

TEMPERATURE CLASS (T CLASS): Make sure that the sensor's maximum surface temperature is below the ignition temperature of any gas or dust that may be present. For example, a T6 classification means that the surface never exceeds 85 °C. This is highly restrictive, but extremely safe. Note that surface temperature is closely linked to process temperature.

GAS AND DUST GROUPS: Make sure that the sensor's Ex classification matches the gas or dust group present in the area, so that the equipment cannot become an ignition source. Example: An area with gas group IIC, such as hydrogen, requires sensors marked IIC.

2. Select the correct protection concept

EX I (INTRINSICALLY SAFE CIRCUIT): Limits the electrical energy in the sensor circuit so that sparks or heat cannot cause ignition. This is common for thermocouples and Pt100 sensors, but requires approved Zener barriers or transmitters. Check the product marking.

EX D (FLAMEPROOF ENCLOSURE): A robust enclosure that can contain an internal explosion and prevent it from spreading to the surrounding atmosphere.

EX E (INCREASED SAFETY THROUGH ROBUST DESIGN): Sparks, hot surfaces and loose parts must not occur. This is a preventive protection method based on ensuring that the equipment cannot become an ignition source, even in the

HISTORICAL MILESTONES FOR ATEX AND IECEX		
Period	**Main event**	**Description and key points**
1950 – 1980	National systems dominate	Each country has its own Ex rules and test houses. Extensive duplicate testing creates major trade barriers.
1980 – 1990	IEC 60079 emerges	International harmonisation begins. Certification is still national.
1994 – 2003	ATEX is introduced in the EU	Free movement of Ex equipment within the EU. Trade barriers remain globally.
1996	IECEx is established	A global certification system is launched. Principle: one test, one certificate, global trust.
2003 – 2010	IECEx gains global acceptance	More countries join. Ex certification bodies are established in Europe, Asia, Australia and the Middle East.
2011	The UN (UNECE) recommends IECEx	IECEx is recognised as the preferred international system. Global confidence increases significantly.
2015 – present	IECEx becomes a global standard	More than 160,000 certificates. Used in more than 90 countries. Many countries accept IECEx directly. Others use it as the basis for national certificates.

COMPARISON BETWEEN ATEX AND IECEX		
Aspekt	**ATEX**	**IECEx**
Legal status	Mandatory in the EU	Voluntary globally
Purpose	Free movement within the EU	Free movement globally
Standard base	EN/IEC 60079	IEC 60079
Certificate	CE marking and Ex marking	IECEx CoC
Trade barriers	Eliminates trade barriers within the EU	Reduces trade barriers globally, but does not eliminate them completely

event of reasonably foreseeable faults.

GOOD TO KNOW: Many standard Pt100 sensors and thermocouples may be classified as simple apparatus. In an Ex i circuit, the sensor itself does not need its own Ex marking, provided that the entire circuit is certified as intrinsically safe.

3. Mechanical installation advice

THERMOWELLS: Metallic, machined thermowells are often used for temperature sensors. They protect the sensor from the environment in which it is installed. A sensor with short service life may increase the risk level.

TORQUE AND BENDING: Avoid sharp bends, impacts and vibration. Follow the manufacturer's recommended tightening torque to avoid compromising the seal or IP rating.

CABLE GLANDS: Use only Ex-approved cable glands that exactly match the cable diameter and type.

4. Electrical installation advice

- Follow the requirements in EN 60079-14. For intrinsically safe sensors (Ex i), EN 60079-25 also applies.
- In many cases, good practice applies. If the site has existing installations, use the same established approach.

5. Maintenance and operation: good practice

WORK WITHOUT VOLTAGE: Never open the connection head or remove the sensor when the equipment is energised or when an explosive atmosphere may be present.

REGULAR INSPECTION: Follow the requirements in IEC 60079-17. Regularly check for dust accumulation, corrosion or deposits of process media on the thermowell.

SPARE PARTS: Always use identical original parts from the manufacturer, for example in accordance with Pentronic's Ex user guide. Otherwise, the Ex approval may cease to apply. ■

Advice for handling temperature sensors

There are basically two different types of temperature sensor – resistance thermometers (often called Pt100 or Pt1000) and thermocouples.

Resistance thermometers (Pt100/Pt1000):

- Do not exceed the resistance thermometer's measurement range
- High temperatures together with thin sensors can shorten service life
- Do not expose the sensors to sudden impacts or vibrations
- Avoid thermal shocks
- Do not bend sensors made of sheath material (MI cable) too tightly. Minimum bending radius equals twice the diameter
- Tube/pipe sensors must not be bent at all
- The measurement environment can shorten service life. You should therefore regularly check the sensor's mechanisms and output signal

Functional testing of resistance thermometers (Pt100/Pt1000):

If the sensor has been exposed to mechanical shock or been bent, you should perform the following tests to determine whether it has been damaged:

- Measure the resistance between red and white, or yellow and blue, with e.g. a multimeter. At room temperature (23 °C ± 4 °C), the resistance should be between 106 Ω and 111 Ω.
- Using an insulation tester, measure the insulation between the inner conductor and the outer sheath. (see the extract from IEC 60751:2022 below).

Test voltage (Vdc)	Min. approved insulation (MΩ)
100	100

- Low insulation resistance is an indicator that the sensor should be replaced.

Thermocouples:

- Do not exceed the thermocouples measurement range.
- High temperatures together with thin sensors can shorten service life.
- Avoid thermal shocks.
- Do not bend sensors made of sheath material (MI cable) too tightly. Minimum bending radius equals twice the diameter.
- The measurement environment can shorten service life. You should therefore regularly check the sensor's mechanisms and output signal.

Functional testing of thermocouples:

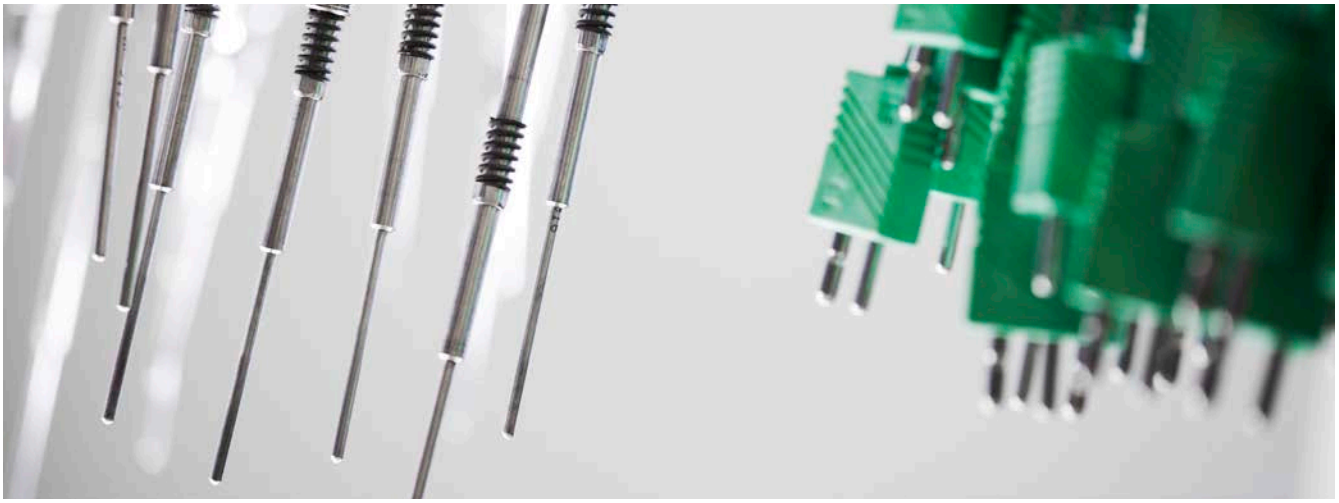
If the sensor has been exposed to mechanical shock or been bent, you should perform the following tests to determine whether it has been damaged:

- With a multimeter, measure the resistance between the conductors.
- The resistance on a healthy sensor should be 0 Ω.
- An open input indicates a broken circuit.
- Using an insulation tester, measure the insulation between the inner conductor and the outer sheath (see the extract from IEC 61515:2016 below).

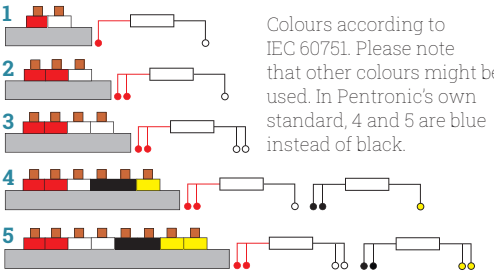
Outer diameter D (mm)	Test voltage (Vdc)	Min. approved insulation (MΩ)
0,5 < D ≤ 1,6	100	20
1,6 < D	50 till 100	1000

- Low insulation resistance is an indicator that the sensor should be replaced.

Contact us if you are unsure about the operation of your temperature sensor. Want to know more about temperature sensors? Visit www.pentronic.se
Download your test certificate at www.pentronic.se

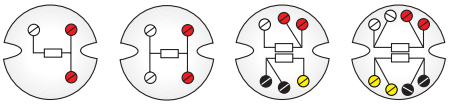


Extension cable for Pt100s



Colours according to IEC 60751. Please note that other colours might be used. In Pentronic's own standard, 4 and 5 are blue instead of black.

Terminal block connector for Pt100s



Note that other colours may be used.

Max. recommended working temperatures for thermocouples with sheath material Inconel 600 (EN 2.4816), type K and N according to IEC 61515:2016

Ø mm	K and N
1 and less	700 °C
1,5	920 °C
2	920 °C
3	1070 °C
4,5	1150 °C
6 and more	1150 °C

Pentronic also manufactures sensors in specialised sheath alloys for thermocouples, designed for working temperatures up to 1250 °C (e.g. Nicrobel).

With regard to ceramic protection tubes: the Al03 tubes C799 and C610 are kept in stock. Recommended for thermocouples and working temperatures up to 1700 °C.

Other options for special applications are available on request.

Types of thermocouples

Type	IEC Color	Ansi MC 96.1 Color	Working-range in °C	Atmosphere
E			-200 - 900	Good in oxidising environments
J			-200 - 760	Not good in oxidising environments or acids
K			-200 - 1200	Good in oxidising environments
N			-200 - 1200	Like K but standardised to be better over 200 °C
T			-200 - 370	Not in oxidising environments
B			0 - 1700	Ceramic protection tubes, all environments
S/R			0 - 1480	Ceramic protection tubes, all environments
C/D			0 - 2315	Vacuum, not for oxidising environments
A			0 - 2500	Vacuum, not for oxidising environments

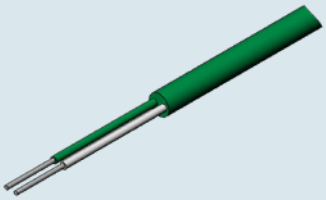
Properties of cable insulation materials

Type of material	T min	T max	Ex. of thermocouples	Ex. of resistance-thermometers	Abrasion resistance	Chemical resistance	Moisture resistance	Solvent resistance	Fire test
PVC	-15	105	8105000	7914000	4	4	3	2	4
PUR	-50	150	NA	7400000	4	3	3	3	3
NYLON	-65	121	6101000	NA	5	5	2	3	1
FEP	-65	200	8105000	NA	5	5	5	5	5
SILICONE	-100	200	6102000	7912000	3	3	4	2	5
PFA	-65	260	6101000	7300000	5	5	5	5	5
PTFE	-265	260	6101000	7300000	4	5	5	5	5
POLYIMIDE	-265	260	6101000	NA	5	5	5	4	4
GLASS FIBRE	NA	510	6102000	NA	1	3	3	5	5
CERAMIC FIBRE	NA	1200	6101000	NA	2	3	2	5	5

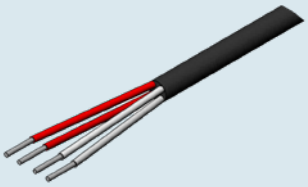
1-5 where 1 is worst and 5 is best. Note that the table describes generalised properties of the insulation material; the properties of specific cables may differ. When selecting a cable always consult the relevant data sheet for the precise specification.

Common connection options for **thermocouples** and **resistance thermometers**

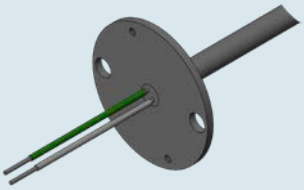
Connections are a critical part of your measurement chain and when choosing which one to use, it is important to consider not only the measurement uncertainty but also the accessibility, the surrounding environment and the ease of replacement. There is now a great variety of both connectors and casings, and in addition to choosing the type of connection it is also possible to choose between different versions of integrated signal converters. Various versions are available with 4 to 20mA or digital signal output.



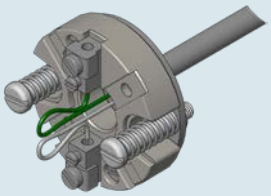
Thermocouple cable with free wires



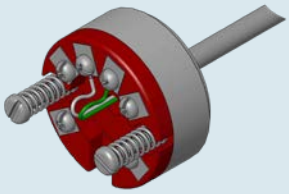
Pt100 cable with free wires



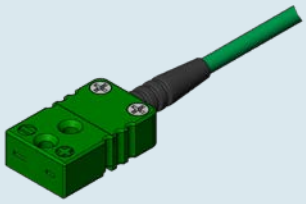
Measurement insert ready for mounting of a terminal head or transmitter (T/E or Pt100)



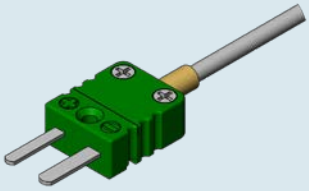
Measurement insert with terminal head (T/E or Pt100)



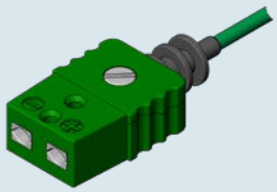
Measurement insert with transmitter (T/E or Pt100)



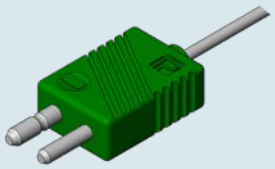
Miniature female connector mounted on a cable



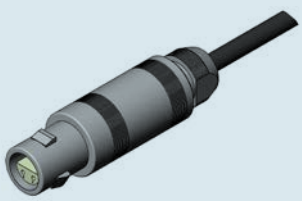
Miniature male connector mounted on a sheath



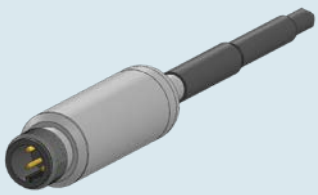
Standard female connector mounted on a cable



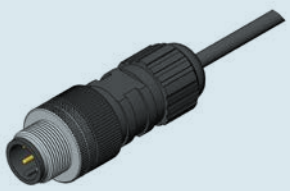
Standard male connector mounted on a sheath



LEMO connector mounted on a cable

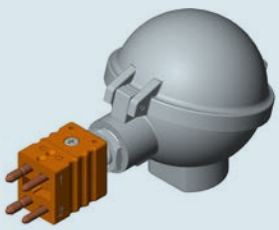


M12 connector with integrated electronics

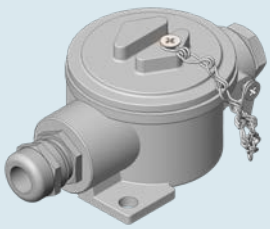


M12 connector mounted on a cable or sensor

M12 connector mounted on a terminal head



Thermocouple connector mounted on a terminal head



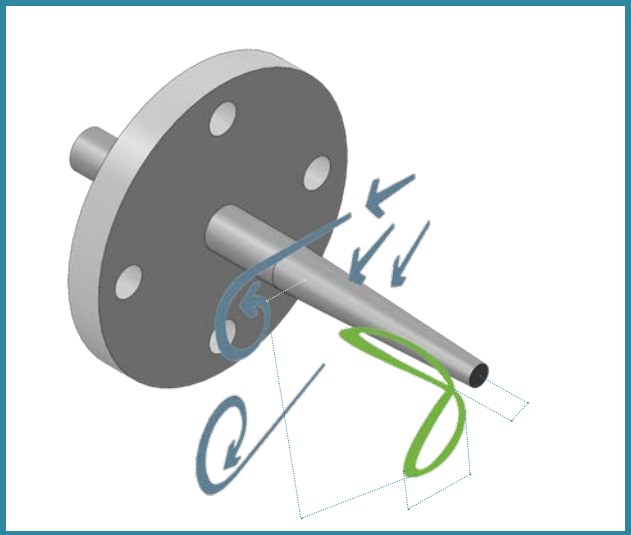
Terminal box for terminal block or transmitter

Properties of **common materials**

We manufacture mechanical components, accessories, thermowells and tube necks from a variety of materials in our own precision tooling workshop. The table below lists a selection of our most common types of steel. We also do custom orders in titanium, copper, and a number of different plastics.

Type of material	Comment	EN 10027-2	EN 10027-1	AISI/SAE/ ASTM	Other designation	Rec. Max. Temp.
Stainless steel	A highly versatile and common material suitable for moderate temperatures and environments.	1.4301 1.4307	X5CrNi18-10 X2CrNi18-9	304 / 304L	A2 stainless steel	300–600 °C
Mo alloy stainless steel	The molybdenum alloy helps improve acid resistance suitable for the process industry. Also called acid-resistant steel.	1.4401 1.4436	X5CrNiMo17-12-2 X3CrNiMo17-13-3	316	A4 acid-resistant steel	300–600 °C
Mo alloy stainless steel Low carbon content	Pentronic's standard material. The low carbon content helps improve properties in the the temperature range 425–925 °C where steel with a higher carbon content can exhibit problems with carbide precipitation/intergranular corrosion.	1.4404 1.4432 1.4435	X2CrNiMo17-12-2 X2CrNiMo17-12-3 X2CrNiMo18-14-3	316L	A4 acid-resistant steel	300–830 °C
Mo alloy stainless steel titanium stablised	Excellent corrosion resistance.	1.4571	X6CrNiMo17-12-2	316 Ti	Classic V4A	300–830 °C
High temperature stainless steel	For temperature ranges up to 1150 °C. Excellent corrosion resistance. Abrasion resistant.	1.4749 1.4835 1.4854 1.4767	X18CrN28 X9CrNiSiNCe21-11-2 X6NiCrSiNCe35-25 CrAl20 5	446 UNS S30815 UNS N 10276	4C54 253MA 353MA Kanthal AF	1100–1300 °C
Nickel-based alloys	Excellent corrosion properties, working temperaturesup to 900 °C* Excellent properties in reducing environments.	2.4816 2.4819 2.4951/2.4630	NiCr15Fe NiMo16Cr15W NiCr20Ti	UNS NO6600 UNS N 10276	Inconel 600 Hastelloy C-276 Nimonic 75	1000–1200 °C
Pressure vessel steel	Standardised material certified for use in industrial pressurised installations.	1.0460 1.5415 1.7335 1.7380	P250GH 16Mo 4-5/13CrMo 4-4 13CrMo 4-5/13CrMo 4-4 10CrMo9-10	SA 105 A204 gr. A A387 gr.12 A122 F22	C22.8	300–550 °C

* Inconel 600 is designed for safe use over a very broad temperature range and is used as a sheath material in high quality sheathed thermocouples. Properly designed, an Inconel 600 sheathed thermocouple can withstand working temperatures up to 1150 °C.



Wake frequency calculations

The American standard ASME PTC 19.3 TW (2016) describes a method for calculating Kármán vortex streets. These oscillations influence fixed thermowells in pipe flows. In flows, there is a risk that the wake effect will cause the thermowell to oscillate violently, with the result that it can break apart or break free from its mounting. The standard describes calculation models for various basic types of thermowell: these calculations are generally termed wake frequency calculations. For the analysis, the thermowell's dimensional, material and shape data are needed, plus data on the relevant environment, such as flow and pressure. The calculations show the thermowell's safe levels in relation to its natural frequency.

Pentronic offers wake frequency calculations as an additional service.

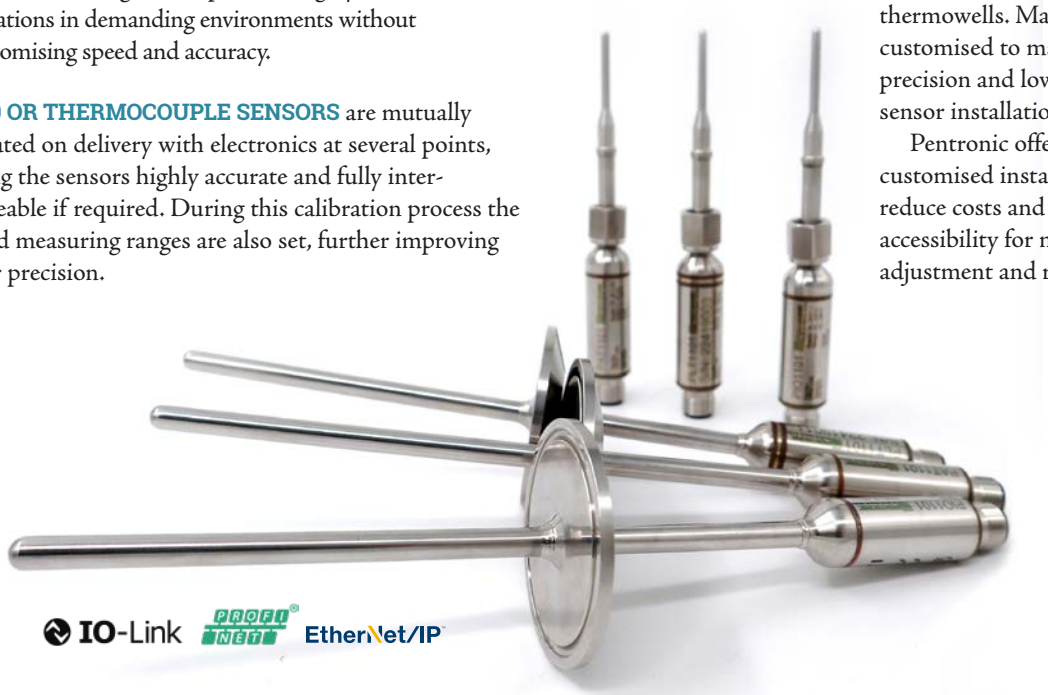
Digital **communication**

PENTRONICS' SERIES of integrated signal converters developed for industrial applications combines a flexible mechanical design with market-leading measurement accuracy at the system level. The modular configuration provides highly secure and reliable installations in demanding environments without compromising speed and accuracy.

PT100 OR THERMOCOUPLE SENSORS are mutually calibrated on delivery with electronics at several points, making the sensors highly accurate and fully inter-changeable if required. During this calibration process the desired measuring ranges are also set, further improving sensor precision.

The process connectors can be made according to a variety of designs to suit the application's requirements, for example for food safety, hygiene or pressure tightness. The standard range includes a number of specially designed weld-in bosses and thermowells. Many of these are also customised to maintain a high precision and low response time of the sensor installation.

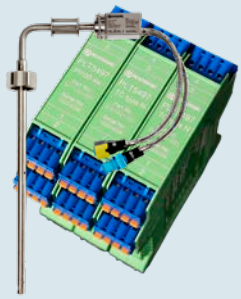
Pentronic offers flexibly customised installation cabling to reduce costs and increase sensor accessibility for maintenance, adjustment and replacement.



	PAT	PLT	PIO
Signal output	4...20mA	PLB® Bus	IO-Link
Probe tip	4w Pt100	4w Pt100	4w Pt100/Thermocouple
Process connections	Multiple options are available including advanced hygienic process connections, TC flanges and bayonet caps but the connections can also be designed with M12, miniature or standard process connectors. Another option is free wires.	Multiple options are available including advanced hygienic process connections, TC flanges and bayonet caps but the connections can also be designed with M12, miniature or standard process connectors. Another option is free wires.	Multiple options are available including advanced hygienic process connections, TC flanges and bayonet caps but the connections can also be designed with M12, miniature or standard process connectors. Another option is free wires.
Rec. max. process temp.	600 °C*	600 °C*	Pt100: 600 °C* Thermocouples: 1200 °C*
Rec. max. ambient temp.	80 °C	80 °C	80 °C
Recommendations	Highly versatile analogue sensors based on proven technology and communication.	Flexible digital systems for very high measurement accuracy. Recommended for installations with many measuring positions. Minimised cabling thanks to cost- and energy-efficient digital bus communication.	Digital and highly versatile system based on standardised communication. Very high accuracy allows for integration into existing systems.
Configuration**	Pentronic UPI1611***	Pentronic UPI1611***	IO-Link standard, several alternatives available.
Accessories	Customised cabling.	Gateway for communication Profinet, EthernetIP	Customised cabling.

**Depending on the requirements for measurement accuracy, mechanical design and the signal converter's configuration.*
*** All integrated sensors are delivered configured to specifications.*
**** UPI1611 configuration tool for PAT- and PLT systems.*

A Selection from Our Instrument Range



Digitalt measuring system

Flow meters

Glass flow meters (GFM)

Moisture meters and NIR equipment

Transmitters

Calibration equipment

Fibre Optics

Data loggers

Contactless IR-pyrometers

Temperature indicators

For more information, visit our web-site at **www.pentronic.se** or contact one of our sales representatives.

You will find all contact details on page 39.

pentronic.se
/contact

Model portfolio

A selection of Pentronic's portfolio is presented below. Please do not hesitate to contact us for more information or visit our webpage at www.pentronic.se

Mineral insulated thermocouples

Design: Large variety of designs, optional process connections and contacts.

Advantages: Very robust and versatile sensors with a wide area of application. Recommended for high temperature applications.

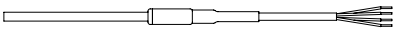
Model examples: 8102000, 8103000, 8105000, 11-00204.

Thread thermocouples

Design: Large variety of designs, optional process connections and contacts.

Advantages: Robust and flexible. Short respons time. Low cost.

Model examples: 6206000, 6101000, 6201000.

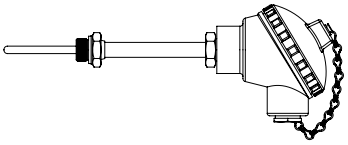


Resistance thermometers

Design: Large variety of designs, optional process connections and contacts.

Advantages: High accuracy, very versatile design options.

Model examples: 740000, 7917000, 7905100, 7913101.

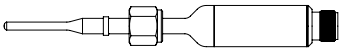


Process thermometers

Design: Large variety of designs. Available both as thermocouple or resistance thermometer. Several standardised process connections can be prepared. Connection head can be fitted with signal converter and several different contact options available.

Advantages: Proven and robust design. High degree of standarisation and interchangeability. Several designs have spare parts such as insertion probes and signal converters. Available in explosion-proof design.

Model examples: 8109600, 811000, 7941000, 7810900.

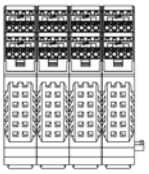


Integrated signal conversion

Design: Available as resistance or thermocouple thermometers. Multiple choice of digital communication protocol or 4...20mA signal available.

Advantages: Extremely good accuracy can be achieved. Minimal cabling and significantly simplified installation as well as service.

Model examples: PAT1101, PLT1101, PIO1101.



Measurement systems

Design: Complete measuring system for thermocouples and resistance thermometers as well as pressure. Signal conversion and low energy field bus protocol for demanding applications.

Advantages: Extremely good measurement accuracy. High safety level (SIL).

Model examples: PLB1000 and PLB5000.

www.pentronic.se/products

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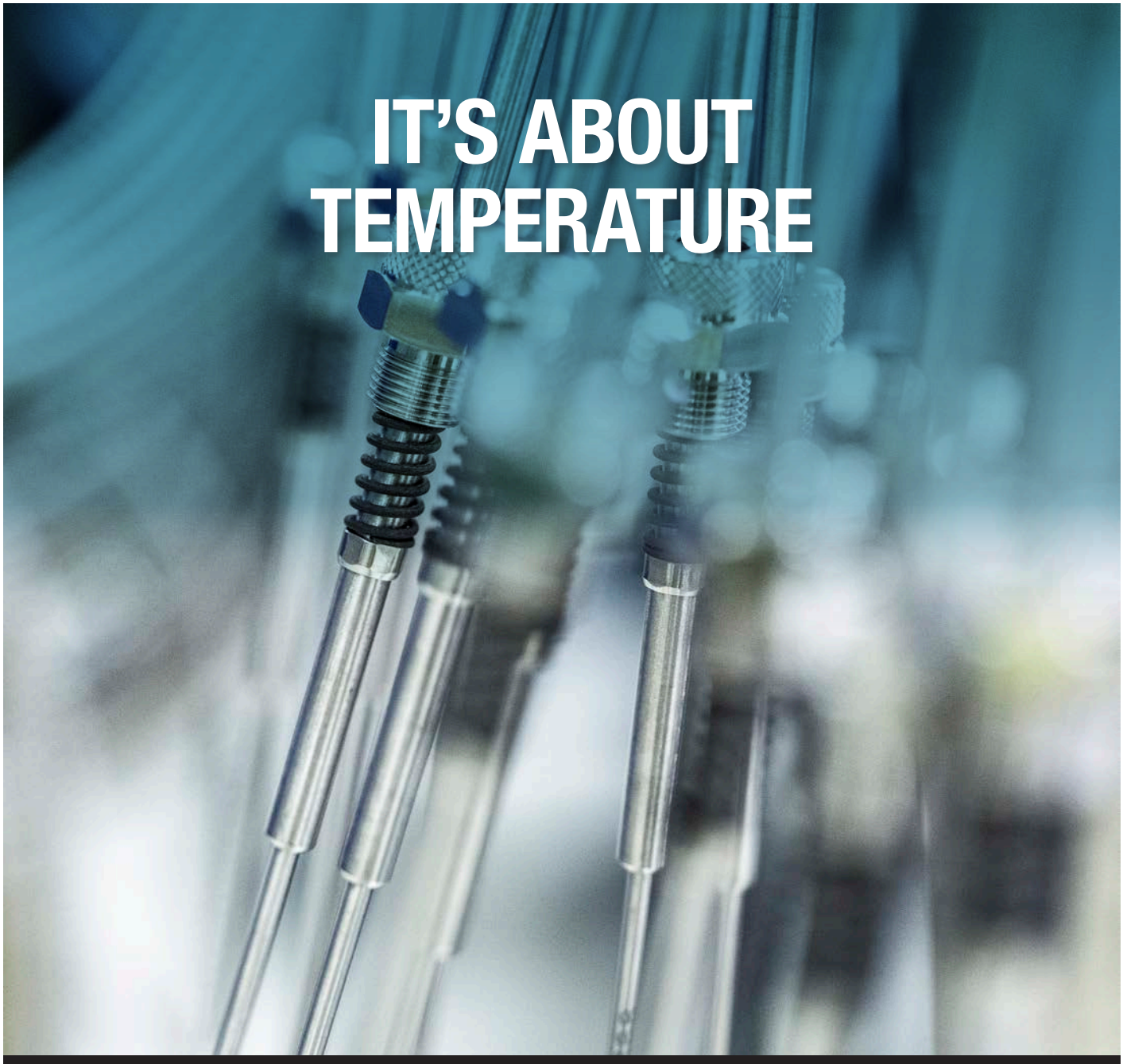

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