IT'S ABOUT TEMPERATURE

PENTRONIC

2023 • VOL. 15 • pentronic.se

Europe's leading manufacturer of industrial temperature sensors

Pages 7-9

A great interest in technology

Pages 14-15

Meva Energy – Unique energy technology

Pages 18-19

Fredrik Arrhén, senior researcher at RISE

Pages 20-23

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Claes Arnesson takes over as Managing Director of Pentronic

When I look in the rear-view mirror I see how fast time has passed. Suddenly it has been almost a decade since I had the privilege of succeeding Lars Persson as Managing Director of the company.

I still remember that first day in February when I travelled to Västervik early on a dark winter morning to learn all about temperature measurement. I've had ten fantastic years of being involved in developing the business and watching the company's turnover almost doubling over that time span.

But everything comes to an end and when I was asked last year to lead a branch in the Measurement and Sensor Technology business area, I felt that it could be time for a change.

Following a recruitment process during the winter, the choice finally fell on Claes Arnesson as the new Managing Director of Pentronic. Claes was born and grew up in Västervik and after completing his engineering studies in Luleå and a short period of employment at Arla in Vimmerby, Claes worked at Gunnebo Fastening for 16 years. Most recently he has served as Managing Director of the Swedish section of Simpson Strong-Tie, which includes Gunnebo.

Claes began working with us on 1 August and after he has been introduced to the company he will be an excellent successor to me. As I will stay within the Group, I look forward to following Pentronic's continued journey to new heights under Claes's leadership.

I would like to take this opportunity to wish Claes good luck with the challenges that come with the role of Managing Director of one of Sweden's and Indutrade's finest companies.

/ Rikard Larsson

Claes Arnesson has succeeded Rikard Larsson as the new Managing Director as of 1 August.

IT'S ABOUT TEMPERATURE

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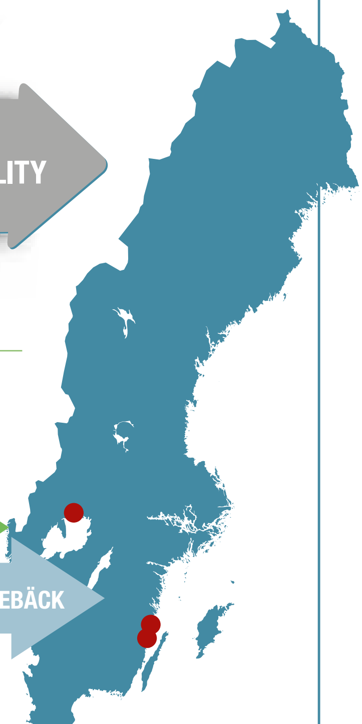
PENTRONIC IN BRIEF

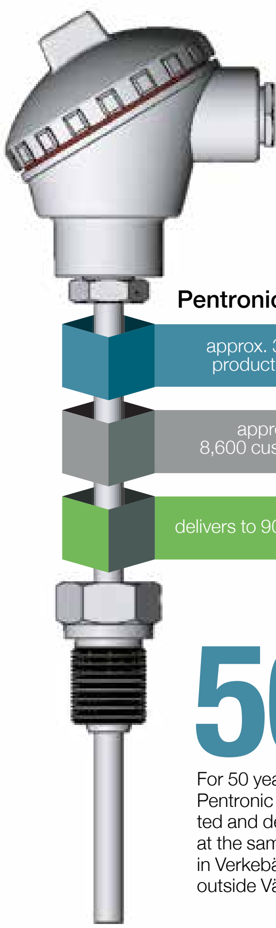
Pentronic collaborates with and delivers to world-leading manufacturers in many industries. Examples include: food and food packaging, power generation, pharmaceuticals & medical equipment, vehicles & engines and the process industry.

COMPETENCE
DEDICATION
FLEXIBILITY

103 EMPLOYEES

KARLSTAD
VÄSTERVIK
VERKEBÄCK





Pentronic has:

- approx. 30,000 product items
- approx. 8,600 customers
- delivers to 90 countries

1965

Is the year that the company Telemetric Instrument was founded. It later became the basis of today's Pentronic.

108

Over a hundred issues of Pentronic's news magazine have been published since 1990. The magazine contains everything from customer case studies and information from the in-house accredited laboratory to technical articles and product information. At first the magazine was called *StoPextra*, then *Pentronic News* and now ***– It's About Temperature.***

SWEDAC ACKREDITERING
Accred. no. 0076
Calibration
ISO/IEC 17025

1988 is the year when Pentronic's in-house calibration laboratory became accredited by Swedac, the Swedish Board for Accreditation and Conformity Assessment. At that time it was Sweden's first laboratory outside the national testing institute, which realised parts of the temperature scale with its own fixed points. Pentronic now has two calibration laboratories, one in Verkebäck and one in Karlstad.

Pentronic is part of Indutrade, an international technology and industrial group. Indutrade develops and acquires companies characterised by a high level of technology and the ability to build long-term, close relationships with customers and suppliers.

50

For 50 years, Pentronic has operated and developed at the same location in Verkebäck, just outside Västervik.

PENTRONIC ACADEMY

The course **"Traceable temperature measurement"** was launched in 1991 and has been updated over the years to meet current knowledge requirements. The follow-up course, "Traceable temperature measurement 2", is for people who want to explore the topic in greater depth. Pentronic also gives courses at its customers' premises.

RS Technics B:V and **Thermo Electric Instrumentation B.V.** (TEI) in the Netherlands are two wholly owned subsidiaries of Pentronic.

AS A WORKPLACE PENTRONIC IS CHARACTERISED BY:

Craftsmanship, experience, measurement technology and digital integration

Temperature is a physical quantity in many applications. It is used to secure processes in the food industry, to give heat-treated steel the right properties and to make engines as efficient as possible.

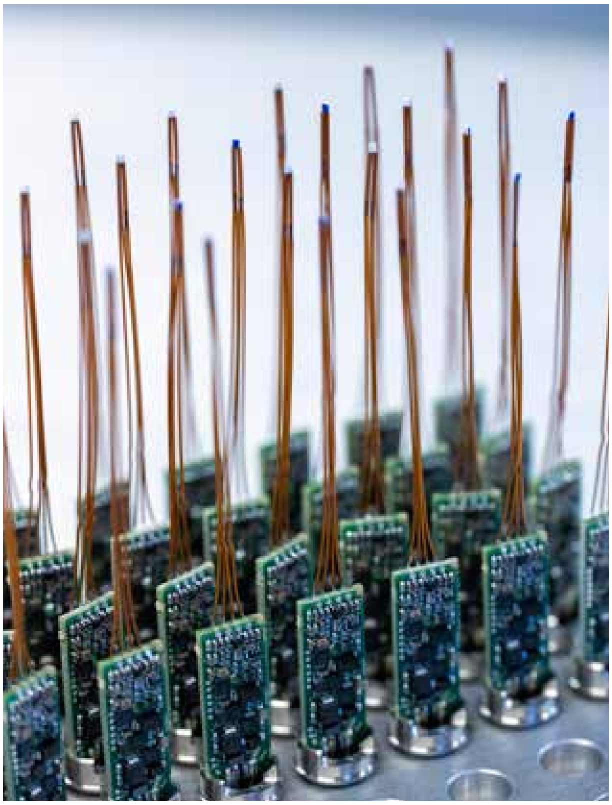
THESE ARE JUST A FEW EXAMPLES of many applications. As a result, many different types of thermometers are required. The number of thermometer variants is almost infinite and they have differing requirements.

Continuous product development

Here at Pentronic we always put measurement technology first. We know how important it is to measure as correctly as possible and at the best possible place in a process. This means that many of our sensors are specially adapted to suit specific applications.

"Some of our sensors are built in larger and recurring series. They are also unique to us at Pentronic in some way," emphasises Product Development Manager Erik Gullqvist and continues:

"We've been in business for many years and have around 30,000 different items in our product range. Some people might think that by now we should have all the variants but the reality is that as our customers' needs



Assembler Carl Halling.

change, we must continue developing our methods. Energy efficiency is an example of an area that's more important than ever.

"When a customer equips a newly developed machine with temperature sensor, they are aware of how important it is to be careful about where and how the temperature is monitored. In recent years we have developed the integration of signal processing into our sensors, which also increases the demands on how they are manufactured," Erik concludes.

High quality

As a workplace Pentronic is characterised by great variety and flexibility. Because no two products are the same, the work is very varied. A core characteristic of the company is that everyone has personal responsibility for the product they produce.

"As a rule, one employee works on the same sensor throughout the entire flow until the finished product is submitted for final inspection. When our employees are allowed to take personal responsibility for the whole process, the quality remains high," says Oscar Riis, HR generalist at Pentronic.

"This is a challenge for us when we are looking for new employees but in return we get highly qualified and committed colleagues," he continues.

Personal responsibility and competency characterise the whole company.

"In order to best serve our customers in different industries, we must understand many different processes," emphasises Sales Manager Björn Tunek.

"Chemistry, thermodynamics, mechanical engineering and materials science are familiar areas for us. Through the development of integrated signal conversion, Pentronic's product development department has also grown with significant expertise in hardware and software development," he concludes.

Are you our next employee?

Pentronic is constantly on the lookout for new employees with a wide range of skills. Because we are part of Indutrade, our employees have many exciting development opportunities plus a wide network of colleagues around the world. For more information, please contact us. You can also submit an unsolicited application via our website: **www.pentronic.se**

Markus Rosén – CNC operator.

Assembler Anneli Daag Nyman.

Assembler Andreas Ege.

A true engineer and entrepreneur has passed away

JUST BEFORE CHRISTMAS we received the sad news that Lars Persson, formerly Pentronic's Managing Director for many years, had suddenly passed away. This happened just a few days after our traditional Christmas party. We always invite former employees who have retired to take part in our Christmas celebrations. Lars joined us as usual and I had the privilege of sitting next to him. As ever, he was interested in the company's development and its relationship with customers and other stakeholders.

Lars joined Pentronic as an engineer in 1973 when founder Torsten Lindholm decided to move the business from Stockholm to Västervik. I remember Lars describing to me how he and a few others sat on the loading dock waiting for the movers to arrive.

After working with technology and later as Sales Manager, it was natural for Lars to take over as Managing Director in 1991 when Torsten left. Lars led the company successfully for more than 20 years, through the IT bubble and financial crises, and saw the business grow into the leading player in temperature measurement in the Swedish and Nordic markets.

I have had the privilege of continuing to work with Lars in the local business organisations in Västervik municipality, where his commitment to business and community development was just as great as it was for Pentronic.

Alongside his work, his family with his wife, children and grandchildren played an important role in Lars's life. He was also curious, which led to many journeys and excursions to discover the world.

We mourn that Lars is no longer with us but we appreciate that we got to know him and had the privilege of working with a true engineer and entrepreneur.

Rikard Larsson, Managing Director, Pentronic

Climate guide and sustainability award

Two new elements in **Indutrade's** work for sustainable development are a climate guide which was launched in 2022 and a a newly established sustainability awards which was awarded to the first winners.

THE PURPOSE OF INDUTRADE'S strategic sustainability work is to promote business opportunities, attract the best talent, drive sustainable profitable growth and support the global Sustainable Development Goals.

To monitor how Indutrade develops in different areas, all companies report sustainability data linked to Group-wide targets, key figures and other important issues via a digital platform. The outcome is followed up at Group level and at business area and company level in order to identify areas for improvement and to implement relevant measures.

Guide for structured climate work

Indutrade has developed a climate guide which was launched in 2022. The guide contains concrete examples of measures that companies can implement to reduce their climate footprint throughout the value chain. This is also accompanied by a climate training.

Indutrade also monitors the proportion of the Group's companies which have analysed their climate impact and, based on this, have taken measures regarding the largest sources of emissions. The results 2022 show that about half of the companies have done this so far. The goal is 100 per cent, as Indutrade considers active climate work to be a business-critical factor both now and in the future.

Indutrade Sustainability Awards

In 2022 the Indutrade Sustainability Awards was launched. Companies were given the opportunity to nominate themselves and each other in three categories: people, environment and products & customers. The winners received the awards at Indutrade's leadership conference and have been an inspirational element for continued sustainability work among the companies. The sustainability awards will be a an annually recurring event.

Strong focus on sustainability work

Indutrade is firmly convinced that responsible and sustainable behaviour creates long-term value and improves competitiveness.

Desiré Haglund, Head of Sustainability at Indutrade AB.

THE SUSTAINABILITY WORK done by companies within the Indutrade Group has high priority. Desiré Haglund, Head of Sustainability at Indutrade AB, describes one of a number of strategic initiatives the Group has taken to help limit global warming.

"We have taken a stand and joined the Science Based Targets initiative, with the ambition to further develop our ambitious climate targets so that they are in line with climate science," she explains. "We are convinced that this commitment will benefit Indutrade as a group and our individual companies in many ways."

Products and solutions at the forefront

Indutrade's strategic framework for sustainable development summarises the most important sustainability issues for the entire Group.

"We work with overall goals in the areas of people, environment, and products & customers," says Desiré.

While the companies within Indutrade work on reducing their carbon footprint, innovation and business development are important to remaining a market leader with products and solutions. This in turn helps customers to reduce their own footprint and creates business opportunities.

Indutrade consists of approximately 200 companies that offer their services in over 30 countries on six continents.

A broad field of technology

Today about 200 companies are part of the Indutrade international technology and industrial Group. Pentronic has been part of Indutrade for more than 20 years. The companies operate in more than 30 countries around the world and the entire Group has around 9,100 employees.

Indutrade's philosophy is to develop and acquire technology and industrial companies with great potential. The companies are both trading and manufacturing companies that produce, develop and sell components, systems and services with a high technological content. Product areas include valves, measurement technology, industrial equipment, medical technology, construction materials, pumps, filters and process technology, among others. Customers are found in a variety of industries, such as infrastructure and construction, engineering, process industry, energy, pharmaceuticals, food, automotive and marine operations, etc.

Creating engagement

One success factor is the corporate culture and leadership structure which allows operational responsibility to rest with each individual subsidiary. The vision is an entrepreneurial world where people make a difference.

"We believe in giving people freedom and trust. This creates job satisfaction, pride and engagement. Employees' well-being and development within the organisation are priority areas and are crucial to the Group's success," says Desiré.

One major challenge over time is to ensure access to the right expertise within the Group. Skills development takes place through education and training at both company and Group-wide level and through internal skills transfer. In order to attract new employees it is important to be an attractive employer in the labour market.

"There is great competition for expertise and talent in recruitment. We are proud that Indutrade was named one of the 2023 career companies," Desiré Haglund concludes.

Find more information at **www.indutrade.com**

Together they have 64 years of employment in the company

Helen and Sirpa work at P2, Pentronic's production facility in Västervik. "When we started this was a completely new world for us!" they say.

THAT'S WHAT HELEN KLAESSON, who was hired in 1986, and Sirpa Hiltunen, who started at Pentronic ten years later, say.

Requires a trained eye

The plant in Västervik manufactures thermocouples and Pt100 temperature sensors. For many years Sirpa made thermocouples but since 2017 she has been doing final inspection and packing.

"We call it 'check-out' and it's our quality control process for all our products," she explains.

Because Pentronic offers thousands of different models of sensors, a trained eye is needed to inspect all products before they are delivered to customers.

"Among other things, I check that the reference values for the different materials are within the specified limits and that the products are correctly connected, and I perform insulation inspections to ensure that the insulation is correct. We also ID label all components," Sirpa says.

Learned the craft

Helen has always focused on Pt100s ever since she learnt the handcrafting skills from scratch 37 years ago. She had previously worked in industry at the former Electrolux plant in Ankarsrum and later at Gunnebo Industrier. For a while she was also an hourly employee in the home care sector.

"When I joined Pentronic I was looking forward to having a regular daytime job and I started at the Verkebäck production facility. I immediately got to build Pt100 sensors.

"At that time eleven employees worked in production," she remembers. "I learnt the job from scratch with the help of my colleagues. I had never welded before and at that time we had no technical drawings. We were given a piece of paper with the dimensions of the sensor but even back then the quality requirements were very high."

Millimetre-thin silver wires

It was a big challenge for Helen but she quickly settled into her new job.

– My first thought was - how would I manage this craft? It's not easy to weld millimetre-thin silver wires into a measuring junction on which the whole instrument is based. I

Sirpa Hiltunen and Helen Klaesson.

was given an order and there were many steps to perform on each product. It was important to get everything right."

When Pentronic built the production facility in Västervik in 2002, Helen went to work there and she still builds Pt100 sensors with a skilful hand.

"I've always enjoyed it. We are a good group who help each other and work well together," she concludes.

New career path

Originally from Rovaniemi in northern Finland, Sirpa moved with her parents to Västervik in 1970 at the age of six. When she was 20 she got a job at Storebro Royal Cruiser and built boats for ten years. The financial crisis in the mid-90s left her unemployed but after a nine-month labour market training course at Pentronic, she was hired.

"During the training, we had to learn how to build thermocouples. I'd never done anything like that before or even seen a welder like the one we had to use. At first I thought the job was quite difficult and required a lot of accuracy," Sirpa says.

She believes that her training course, which included a lot of practical work, was well organised.

"We were a great group and it was fun to learn a new craft and see a finished product take shape."

Sirpa had the same job until 2017. Then she was asked to start working with final inspection and packing when Pentronic started that department in Västervik. Over the years she had gained a great deal of product knowledge.

"It was a new challenge and it felt good to do something completely different after having made sensors for many years," she says.

What opportunities are there for personal development within the company?

"If you want to develop, the opportunities are good," says Helen.

"I've accumulated lots of knowledge over the years but I'm still learning," Sirpa adds.

What are the differences in production now compared to when you started?

"New tools and new equipment have changed the production methods. In the past there was a lot of soldering and we screwed connectors together by hand. Today we use laser welders to assemble sensors, and special press tools have replaced several soldering operations," Helen and Sirpa conclude.

» We call it 'check-out' and it's our quality control process for all our products «

HELEN KLAESSON

Lives: In a house at Torsfall Överdragsstation south of Västervik.
Employed at Pentronic since: 1986
Duties: Makes Pt100 temperature sensors at the facility in Västervik.
Hidden talent: I am good with dogs and have recently started training a puppy.
Leisure time: Horses used to be my main interest but now it's dogs. I knit, read books and spend time with my grandchildren.

SIRPA HILTUNEN

Lives: In a terraced house in Västervik.
Employed at Pentronic since: 1996
Duties: Works at final inspection and packing at the facility in Västervik.
Hidden talent: I am good at knitting mittens and other things and I take care of the indoor plants at work.
Leisure time: I swim regularly in the morning and go to water aerobics. I grow some vegetables, though not as much as before, and I also spend time with my grandchildren.

A great interest in technology

Per Johansson is a real technology enthusiast. This comes in handy for his involvement in the local narrow-gauge railway association but of course also for his work at Pentronic.

PER IS AN ELECTRONICS DESIGNER at Pentronic's development department at Verkebäck, where he can be found holding a mug of tea in his hand.

"No one would recognise me otherwise," he jokes.

He joined the development department six years ago.

"I came from the nuclear power plant in Oskarshamn, where I worked for 13 years, first in maintenance and later in the engineering department. They had different types of measurement systems and reactor protection systems to work with," he explains.

He used to be an electronics designer at the former Electrolux plant in Västervik and has a degree in engineering from Blekinge Institute of Technology.

"For a while I also worked at an IT company in Västervik."

What attracted you to Pentronic?

"When the decision was made to close the Oskarshamn 2 nuclear power reactor, I saw a job ad that Pentronic was looking for an electronics designer. I had long known of Pentronic and over the years I'd had some contact with the company. Because Pentronic develops and manufactures electronic equipment, the job appealed to me."

What is it like to work here?

"Of course, this is a much smaller workplace, for better or worse. I enjoy my work very much and now I don't have to drive a long way to my job. I live in Ytterhult outside Västervik and I have a boat so I sometimes take the boat to work."

What is the source of your great interest in technology?

"I've always liked technology ever since my father gave me a kit for doing experiments as a child. You had to take things apart and put them back together and make lights blink. Then my interest developed over time. I got into digital technology and microprocessors early on, and my broad interest in technology also led to an interest in mechanics."

Railbuses and steam locomotives

After a working day at Pentronic, when

» The challenge is that I may need to learn about unknown or new technology. These constant challenges are what drives me. «

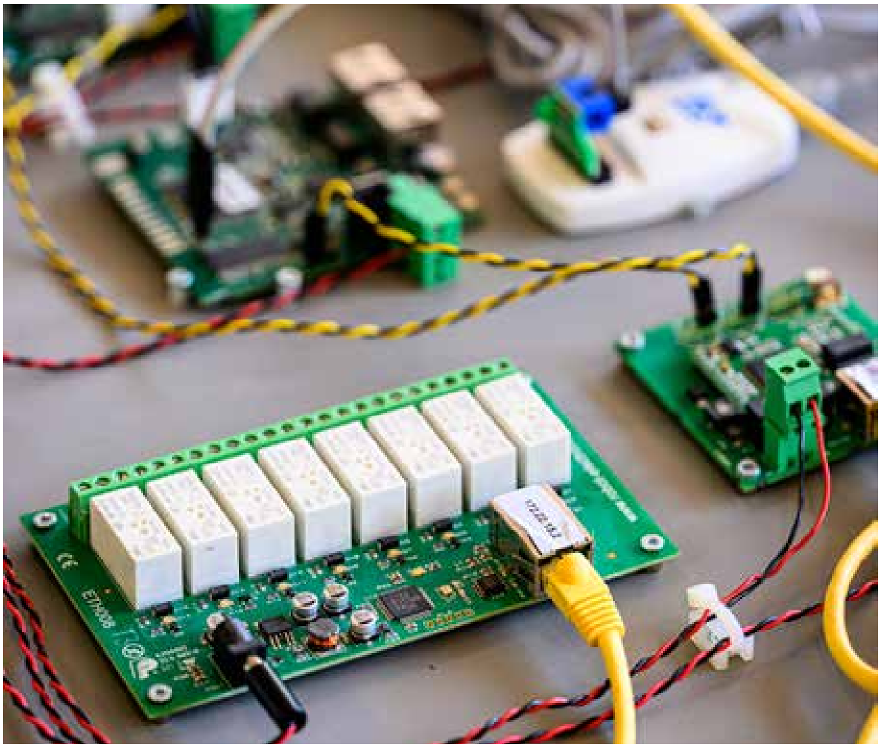
Per spends a lot of time working on small, surface mounted components so he finds it relaxing to immerse himself in more large-scale technology. For many years he has been involved in Tjustbygdens Järnvägsförening, which runs the narrow-gauge railway between Västervik and Hultsfred.

"Sometimes I drive the trains but mostly I'm in the workshop, tinkering with electrical systems and powertrains on the association's railcars and steam locomotives," he says. "It wasn't initially the trains themselves that attracted me, but rather mainly my great interest in technology."

What is your role in the development department at Pentronic?
"I work in three different areas. One is the design of circuit boards for new smart sensors of all kinds, where I develop hardware. Then there is testing the products we manufacture. And I also repair our in-house equipment."

What is the best part of your job?
"Often an urgent task will turn up that I have to prioritise. So my job is rarely routine – there's always something new happening. Constantly having to think in new ways is stimulating. The challenge is that I may need to learn about unknown or new technology. These constant challenges are what drives me."

What products do you see in ten years?
"We're already seeing a big shift towards ever-more connected and wireless products, but they must be reliable products so they measure accurately. Safety-critical applications – such as those used in the control of infrastructure and energy supply – must be well separated. Many customers are rightly cautious and want traditional connections to ensure stability and security in their processes."

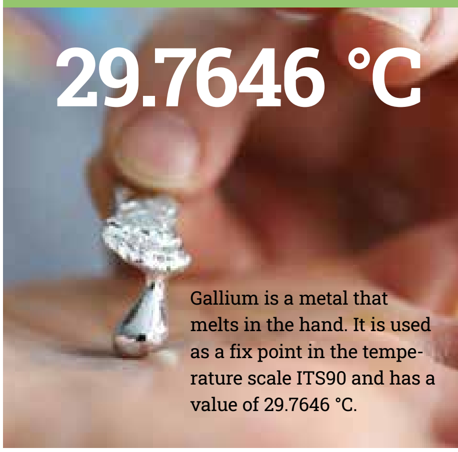


Per is an electronics designer at Pentronic's development department.

PER JOHANSSON
Lives: In Ytterhult outside Västervik.
Employed at Pentronic since: 2017.
Job description: Electronics designer in the development department.
Hidden talent: I'm a real whizz at rolling meatballs.
Free time: A lot of technology. I might be playing vinyl records and reel-to-reel tapes or getting old tape recorders or telex machines to work. I like to watch films at the cinema and it's enjoyable to use an old fun technology like LaserDisc when I want to be at home. I also ride a sport bike, a Yamaha R1 1000 cc, on the country roads. I spend a lot of time on the lake, I fish, I hunt deer and moose, and I have a garden and woods to take care of. I also enjoy socialising with friends and eating out. Sitting and twiddling my thumbs is not my thing!"

DID YOU KNOW THIS ABOUT **TEMPERATURE?**

Read more about temperature at Pentronic's website.



29.7646 °C

Gallium is a metal that melts in the hand. It is used as a fix point in the temperature scale ITS90 and has a value of 29.7646 °C.

Best toffee temperature

At 122–125 °C the toffee mixture has been boiled just enough to make soft toffee. At 140–145 °C you will get hard toffee that is a bit chewy in the centre. At 160 °C the toffee will be totally hard.

The temperature at the center of the earth is assumed to be everything between 5000 to 6000 °C.

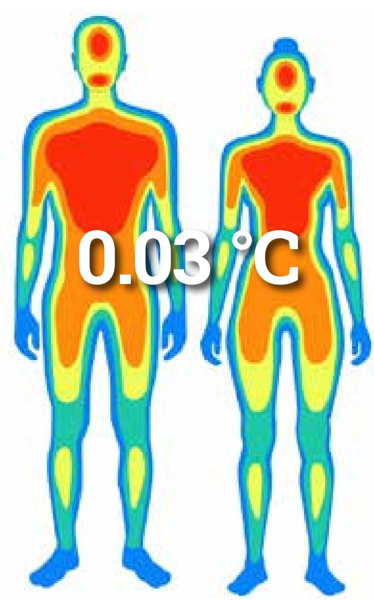
5-6000 °C

The temperature for deep frying is 160–180 °C

Hot water from the tap should preferably be hotter than 50 degrees, otherwise there is a risk of Legionella.

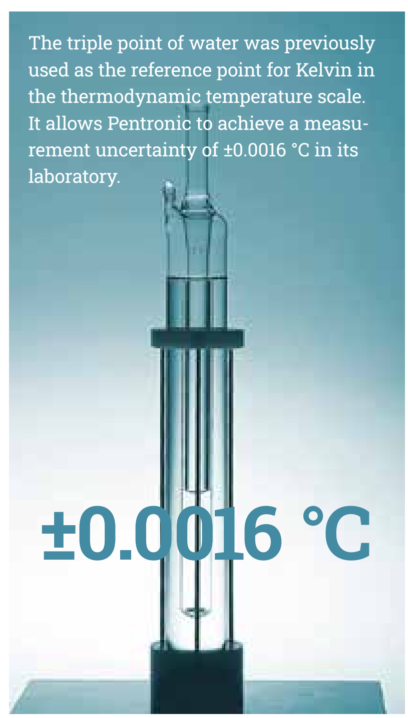
50 °C

According to Stanford University, humans' body temperature has slowly but steadily decreased by **0.03 °C** per decade.



0.03 °C

The triple point of water was previously used as the reference point for Kelvin in the thermodynamic temperature scale. It allows Pentronic to achieve a measurement uncertainty of ±0.0016 °C in its laboratory.



±0.0016 °C

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". Pentronic also offers customised courses for on-site training at our customers' premises. 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.

CUSTOMER CASE

A unique energy facility commissioned this summer is contributing to increased sustainability and the circular economy. **Meva Energy** will use new patented energy technology to produce renewable energy for Sofidel's tissue paper mill in Kisa in the Swedish county of Östergötland. Pentronic played a key role in the project and functioned as an important sounding board.

For Meva Energy's first commercial plant in Kisa, Pentronic has functioned as an important sounding board for the customer. This spring Pentronic's Camilla Gustafsson, Jens Jupiter and Per Bäckström visited the energy installation, where Philip Beckman gave a tour.

Unique energy technology generates major **environmental benefits**

MEVA ENERGY is a world-leading supplier of gasification technology for renewable energy production based on small fuel fractions. The company has developed technologies in thermochemical process engineering, gasification and gas cleaning. After the verification of a full-scale demonstration plant in Piteå in northern Sweden, the first project for green energy production is now being realised.

"Kisa is our first commercial facility and customers from many parts of the world are showing interest in our energy technology," explains Philip Beckman, instrument and automation engineer at Meva Energy.

In parallel with the first energy facility, a new plant is being planned in Zbąszynek, Poland, for IKEA Industry to produce renewable electricity based on the thermochemical conversion of waste material from the factory's furniture production.

Customised sensors

In Kisa some 100 suppliers have been involved in the project. Based on the client's requirements specification, Pentronic has delivered unique customised products and contributed its expertise. Philip says the collaboration has been a great success:

"Since this is our first project, it was important for us to be able to exchange ideas about the equipment required in our process and to have flexible contractors. The co-operation with Pentronic has worked very well, with good support and high availability, and they have delivered products on schedule," he explains and adds:

"Pentronic has developed sensors adapted to the applications we have and has been very flexible even when changes and adaptations had to be made at a late stage."

The heart of the facility

Sensors are used to measure temperature at multiple locations in the facility, including for the process water, the cooling water systems, and a reactor that is the heart of the entire plant.

"Pulverised pellets are gasified in the reactor and converted at high temperature into syngas, a low-energy gas. The gas is purified in a water treatment stage and finally transported via a gas pipeline to the Sofidel tissue mill," says Philip.

Reduces carbon dioxide emissions

Replacing fossil gas with renewable gas for the mill's burners leads to fossil-free paper production and important environmental benefits. Sofidel expects to reduce its carbon dioxide emissions by 8,500 tonnes per year. The raw material for Meva Energy's energy plant is supplied by Scandbio, Sweden's largest producer of wood pellets.

"The idea is to build this type of facility locally at the customer's premises and to use the customer's wood-based residual product as fuel," Philip explains.

Due to the high demands on process heat in paper production, it has not previously been possible to replace fossil gas with bioenergy. It is therefore a major breakthrough to be able to use Meva Energy's gasification technology to convert biomass into renewable gas and to use the gas in sensitive industrial processes.

How does it feel to be involved in a unique project like this?

"It is great fun and also educational. The concept is based on a good idea that benefits the environment and we have managed to put together a very good team at Meva Energy," Philip Beckman concludes.

ABOUT THE KISA FACILITY

The fuel in the process is wood pellets that are crushed to create pulverised pellets. The biomass is gasified in a reactor and converted into a low-energy gas. The gas is purified in a water treatment stage and finally transported in a gas pipeline to the Sofidel tissue mill. One residual product of the process is biochar, which can be used, for example, as a soil improver in agriculture. The facility is part-funded by the Swedish Environmental Protection Agency's climate investment programme Klimatklivet.

MEVA ENERGY

Meva Energy is based in Gothenburg, Sweden and specialises in the thermochemical conversion of solid waste streams and biomass. The company is a world-leading supplier of gasification technology for renewable energy production based on small fuel fractions. The company was founded in 2008 in Sweden as a result of biomass gasification research at Luleå University of Technology and the Energy Technology Centre (ETC) gasification centre. Meva Energy is funded by Just Climate and EIT InnoEnergy, the world's largest innovation actor in sustainable energy.

"When we build new plants in the future, we will bring valuable knowledge from this project with us," says Philip Beckman, instrument and automation engineer at Meva Energy, shown here with Jens Jupiter, sales engineer at Pentronic.

MEET FREDRIK ARRHÉN, SENIOR RESEARCHER AT RISE

"My time at **Pentronic** gave me **valuable insights**"

Fredrik Arrhén's five years as laboratory manager at Pentronic gave him valuable insights, which he has used in his research work at RISE Research Institutes of Sweden.

"I brought with me the importance of measurement quality and an understanding of metrology, which is a major determinant of the needs of industry and processes," he says. "I also realised how crucial skills transfer and training are."

FREDRIK IS A SENIOR RESEARCHER at the Mechanics and Dynamics unit at RISE in the city of Borås in western Sweden. The institute's predecessor was the Swedish Testing and Research Institute (SP).

"Since the beginning of the 2000s I've worked on issues in such areas as dynamic measurements. First with a focus on pressure and now also with dynamic measurements of force and torque," says Fredrik when we meet at RISE, which as Sweden's National Metrology Institute is an almost sacred place for many physicists.

In the entrance hall you can read: "Sweden's first nationwide regulation on standardised units of measurement was issued in 1665 and is considered to be the beginning of RISE's activities."

As Sweden's National Metrology Institute, RISE is responsible for all physical quantities, except ionising radiation, and is the country's foremost body for quality-assured measurement technology (metrology). By helping to establish and disseminate the international system of units of measurement, SI, and conducting metrological research and development, RISE disseminates knowledge and provides metrological traceability to enable innovations and strengthen Swedish industry.

What does it feel like to work at Sweden's National Metrology Institute?

"When I was studying metrology at Linköping University, we came here on a study visit and I thought that this is as far as you can come in metrology here in Sweden," says Fredrik and continues: "Metrology has always been important and measurement technology is one of the oldest professions in the world. Traces have been found in the tombs of the Pharaohs and metrology is mentioned in the Book of Exodus in the Bible."

What drives you?

"My curiosity – there is so much to learn and understand in this field. It's also stimulating to work with global colleagues and discuss issues at the international level."

What challenges can be expected in your field?

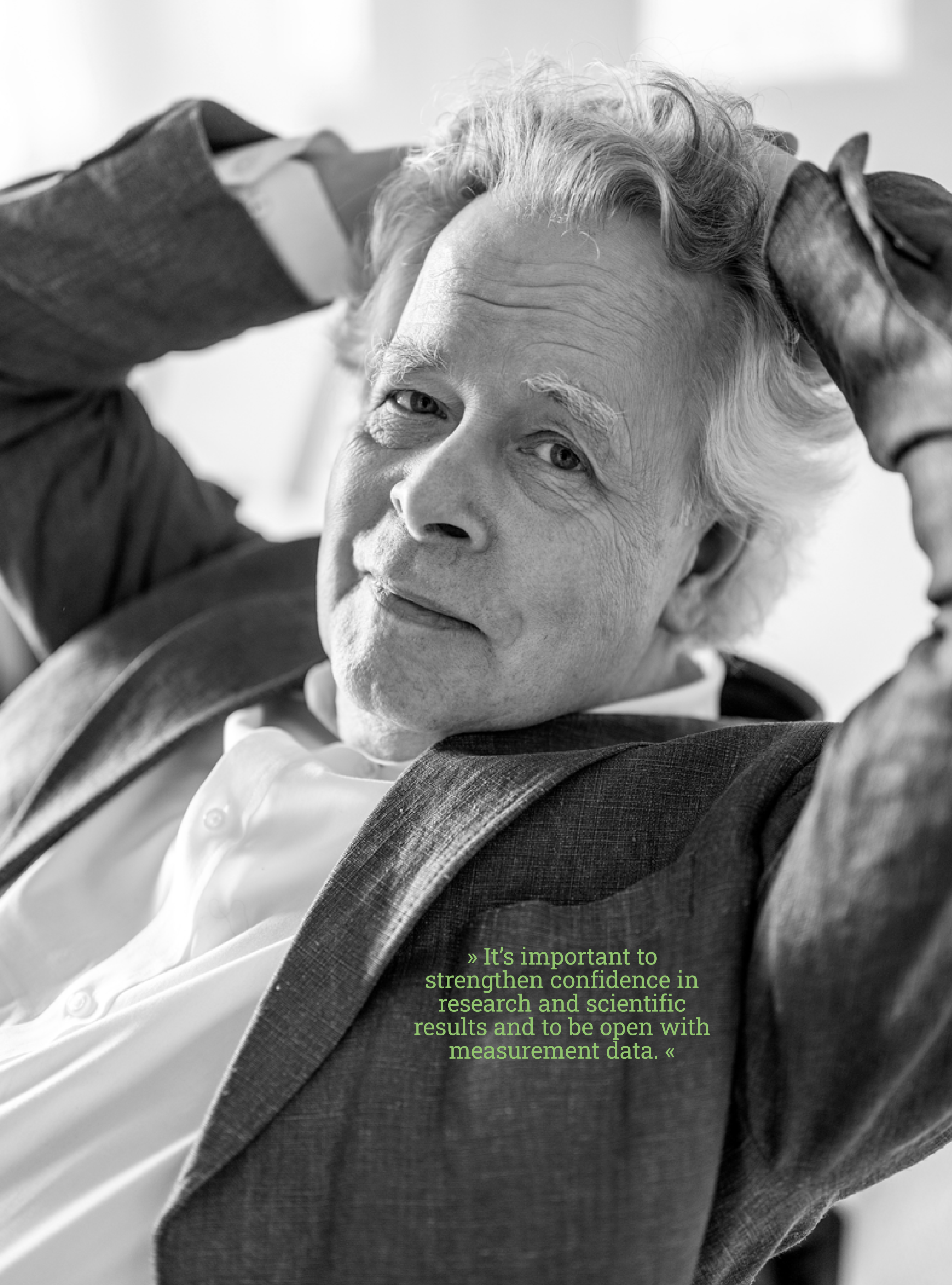
"Measurement requires a global consensus and that it is done openly and transparently. Measurement data are important for the climate crisis, in the transition to green energy and the development of batteries for electrified vehicles. Self-driving cars require sensors and the number of sensors is increasing dramatically. They must be reliable and good enough for their purpose.

"Another challenge is to fight against fake news. It's important to strengthen confidence in research and scientific results and to be open with measurement data."

Tomorrow's innovations

As the National Metrology Institute, RISE has Sweden's broadest and most accurate resources for most physical measurements. More than 3,000 employees – researchers, technicians, testers and other experts – work on tomorrow's innovations. This enables RISE to offer unique expertise and over 100 testbeds and demonstration environments for future-proof technologies, products and services. The unit where Fredrik works focuses, among other things, on dynamic processes in its research, as he explains:

"Dynamic measurements and dynamic calibration are an area with great potential because many of the measurements in industrial processes occur under dynamic conditions. We are continuously working to develop and produce measurement methods to meet industry's need for traceability."



» It’s important to strengthen confidence in research and scientific results and to be open with measurement data. «

Grew up in Katrineholm

Fredrik comes originally from the county of Södermanland, where he grew up and attended school in the town of Katrineholm. While studying at Linköping University he came into contact with Professor Emeritus Dan Loyd, who gave a course on metrology. After graduating, Fredrik worked at Electrolux Motor (now Husqvarna) and then at ABB STAL AB in Finspång (now Siemens Energy).

"During my first years at Siemens I worked with control systems and control engineering. I then joined the instrument department, where I was responsible for measuring pressure and temperature."

Laboratory manager at Pentronic

The next challenge was the position of laboratory manager at Pentronic's accredited calibration laboratory.

"I learned a lot while I was there and I still use a lot of the issues that came up as examples in my lectures. For example, I place a lot of emphasis on process needs and the customer's requirements for temperature measurement," Fredrik explains.

"I also brought with me the importance of continuous skills transfer in order to gain a deeper understanding of measurement technology. RISE invests considerable resources in courses in metrology."

The International System of Units (SI)

When Sweden's National Metrology Institute for pressure moved from the Aeronautical Institute of Sweden in Solna to SP in Borås, the latter wanted to hire a person responsible for pressure calibration. Fredrik took up the position in the summer of 2001. In 2016 he had the opportunity to work at the BIPM in Paris, the institute in charge of the international system of units of measurement, SI.

"The task was to develop a system for measuring carbon dioxide in air based on pressure- and temperature measurements," says Fredrik. "I worked on developing methods and systems for six months, and my main contribution was the choice of materials for the measurement system. The BIPM decided to develop this system to create an international reference for measurements of carbon dioxide in air."

New definition for the kilogram

As measurement technology and instruments have evolved, the requirements for accuracy have increased, which has also changed a number of units of measurement. One major event in research was when new definitions were introduced in 2018 for the seven basic units of the SI, including the kilogram. The historic decision was recognised around the world when the General Conference on Weights and Measures (CGPM) voted to approve the change. The international prototype of the kilogram in Paris in 1889 thereby became obsolete.

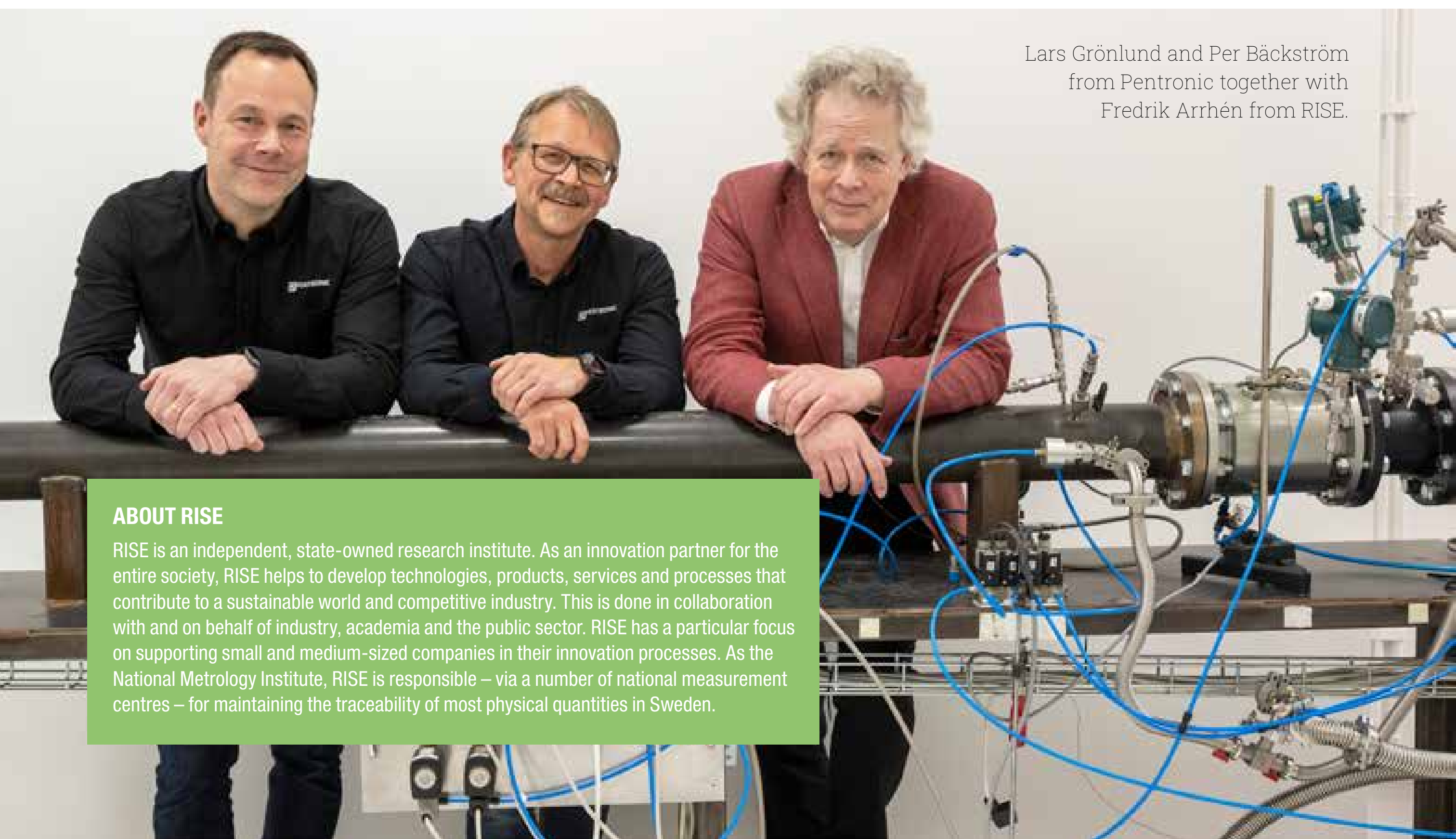
"The result was to define the kilogram on the basis of Planck's constant," Fredrik explains. "Using quantum physics relationships, a Kibble balance can measure a kilogram electronically."

RISE is now developing its own Kibble balance together with, among others, the UK's National Physical Laboratory (NPL) to ensure traceability in Sweden according to the new definition using high-precision weighing. This is of great importance in the industrial, food and pharmaceutical sectors, among others.

Strategic research

Internationally Fredrik has participated in various technical committees and strategic working groups that work on European research projects.

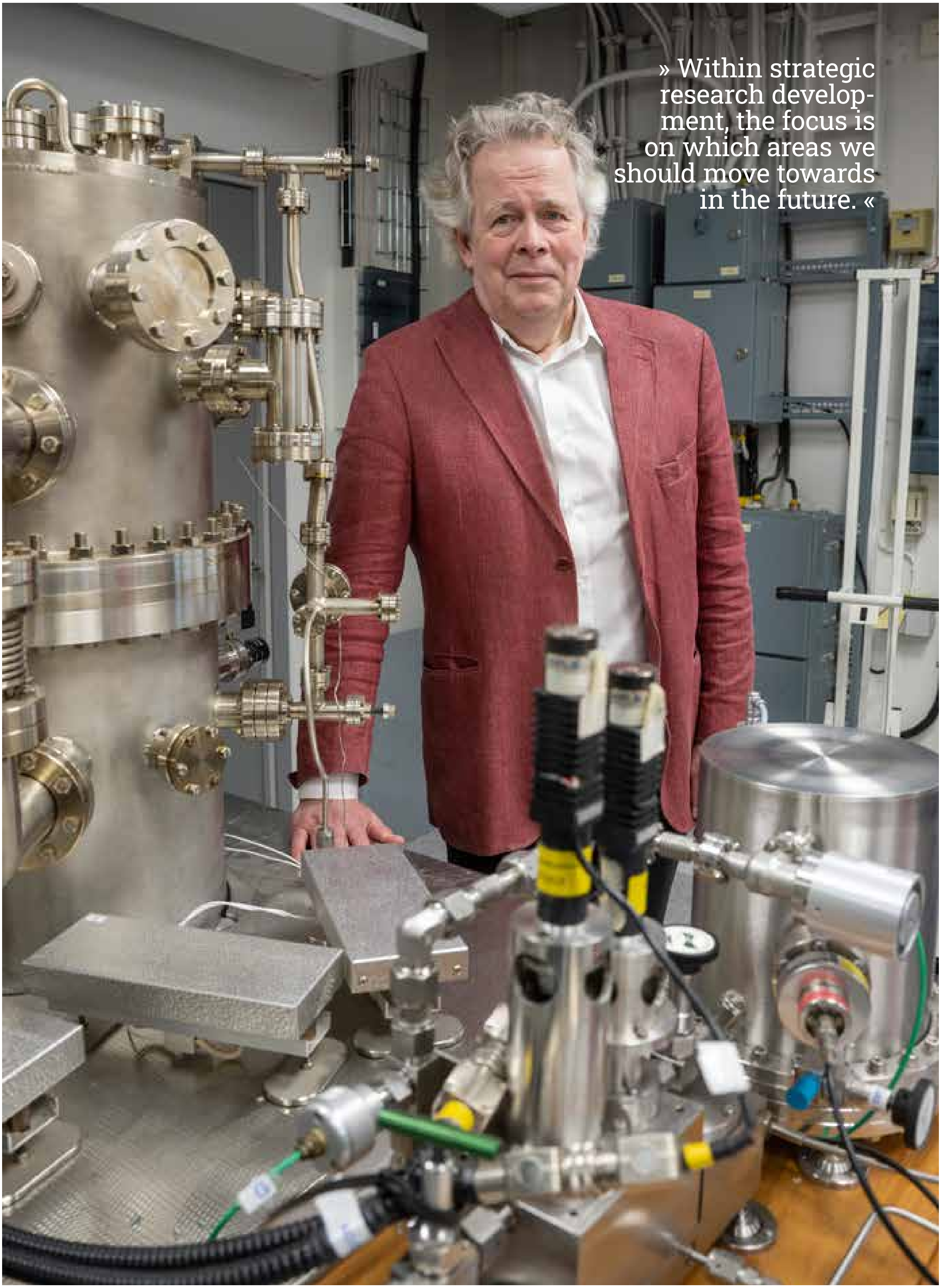
"Within strategic research development, the focus is on which areas we should move towards in the future. They include vacuum technology and semiconductor technology, for which we must also build up expertise in Sweden," he concludes.



Lars Grönlund and Per Bäckström from Pentronic together with Fredrik Arrhén from RISE.

ABOUT RISE

RISE is an independent, state-owned research institute. As an innovation partner for the entire society, RISE helps to develop technologies, products, services and processes that contribute to a sustainable world and competitive industry. This is done in collaboration with and on behalf of industry, academia and the public sector. RISE has a particular focus on supporting small and medium-sized companies in their innovation processes. As the National Metrology Institute, RISE is responsible – via a number of national measurement centres – for maintaining the traceability of most physical quantities in Sweden.


» Within strategic research development, the focus is on which areas we should move towards in the future. «

Laboratories are at the heart of our business

EMMA ROSENBLAD

Works as: Laboratory technician in Karlstad since August 2019.

Earlier career: Worked as a barista and site manager at Löfbergs coffee bar for eight years.

Free time: I have two children and we live in the countryside outside Karlstad. In addition to being with my children, I also spend time with my horse or out in the woods.

JACOB ALMQVIST

Works as: Laboratory technician since October 2021.

Earlier career: Has switched from being a sheet metal worker and began studying natural sciences and laboratory science.

Free time: I have three daughters and a family who take up most of my time. We live in the countryside in Kvill outside Vimmerby and like animals and nature.

FABRICE RACO

Works as: Laboratory engineer since November 2022.

Earlier career: Has worked as a dental technician in France, 1995-2018 and been a laboratory technician at Hitachi in Figeholm.

Free time: I have two children and enjoy a lot of leisure activities together with the children and family. I also have an interest in all types of technology, including mechanical watches.

KAROLINE HANECK

Works as: Laboratory engineer since 2002.

Earlier career: Has worked in the construction and manufacturing industries.

Free time: I live in Norrlandet a short distance from Västervik and enjoy the countryside very much. I like to spend my spare time cooking and being with my family.

NICKLAS HOLM

Works as: Laboratory technician since December 2019. Is a software expert and ensures that the right software is used for the right instrument so that they can communicate with each other.

Earlier career: Has worked in production at Pentronic for seven years.

Free time: My interests are golf and working out at the gym. I have a dog, a 13-year-old Golden Retriever.

ANDREAS HOLM

Works as: Laboratory manager with responsibility for Pentronic's accredited calibration laboratories since 2020.

Earlier career: Began as a trainee at Pentronic in 2011, worked in the production department building temperature sensors, joined the laboratory in 2013 and assumed technical responsibility in 2015.

Spare time: Cars are my great interest and I have a sports car with a 700 horsepower engine. My other interest is my dog, a two-year-old Doberman.

Pentronic continuously invests in modern technology and develops methods to minimise measurement uncertainty. The two accredited calibration laboratories in Verkebäck and Karlstad play a key role in the company's quality control.

PENTRONIC'S calibration laboratories are accredited according to ISO/IEC 17025 for temperature, resistance and electric current (SWEDAC 0076). The laboratory technicians Karoline Haneck, Nicklas Holm, Jacob Almqvist and Fabrice Raco work in Verkebäck, while Emma Rosenblad is stationed in Karlstad. The breadth and flexibility of the work appeals to them.

"It's interesting to measure equipment in the laboratory and the next day meet customers in the field and see where sensors are used in their processes," they say and continue:

"It's important to be solution oriented especially in the field, to have a helicopter perspective, to work analytically and to be precise."

A high technical level

One proof of the high level of quality is that many customers have been using Pentronic's accredited calibration laboratories for a long time.

"Our strength is a high technical level and low measurement uncertainty in our laboratories," emphasises Andreas Holm, Laboratory Manager.

As the person responsible for Pentronic's accredited calibration laboratories, Andreas must ensure that they use calibrated reference equipment in all measurement processes and he must maintain an effective and safe quality system for the laboratories to follow.

New challenges every day

Because the technicians perform measurements in both the lab environment and in the field, Pentronic has a very flexible customer offering.

During the laboratory calibration process the technicians measure both thermocouples and Pt100 sensors and also calibrate the measuring instruments electrically for current, voltage and resistance.

"By using fixed points, liquid baths and ovens, the temperature scale can be realised in the range of -80 °C to 1200 °C," Andreas explains.

"In the field this might involve visiting a hospital blood centre and calibrating their system for regulating the temperature of the coolers and freezers where they store the blood," Emma says. "The next day I might be in a steel factory, climbing high furnaces to take measurements and calibrate equipment."

After the job is done, the customer receives a calibration certificate with the measured value.

"When we perform calibration for recurring customers, it's an advantage to be able to see the history, for example if a sensor is judged to have reached the end of its service life and needs to be replaced," says Andreas.

More and more field assignments

Pentronic is seeing an increase in the number of tasks it performs at customers' premises.

"When we do field calibration it often involves a bigger assignment whereby we visit a customer for several days," Andreas adds. "We have many such jobs in the steel industry. More and more administrative regions and hospitals are also turning to us to have their equipment calibrated and checked by an accredited laboratory."

What does field calibration involve?
"Mainly it is the calibration of complex measuring equipment that is unsuitable or hard to move. For example, there could be a steel factory where furnaces have instrument cabinets that measure about 20 different sensors. In that case we would go to the customer, connect up to the equipment and measure the values. It's important to help our customers secure their processes in an efficient way."

What's the best thing about your job?
"Because we calibrate all types of temperature sensors, we rarely perform exactly the same calibrations. We also have a good teamwork and work together without prestige and solve the challenges we face."

What do you think your business will look like in ten years?
"Hopefully we will have expanded our team and there will probably be more field work. Expertise, flexibility, commitment, high quality and accuracy will always be the keywords in our work."

SWEDAC ACKREDITERING
Accred. no. 0076
Calibration
ISO/IEC 17025

Pentronic's calibration laboratories are accredited according to ISO/IEC 17025 for temperature, resistance and electric current (SWEDAC 0076). The laboratory in Verkebäck was accredited as early as 1988 by Swedac, Sweden's national accreditation body. To be accredited by Swedac, competence, procedures and methods are tested so that all quality requirements are met according to a standard.

Surface mounted sensors

FOR MEASURING FLUID TEMPERATURE IN PIPES

Unfortunately it is not always possible to use an insert probe to measure the temperature of the fluid flowing through a steel pipe. There are several reasons why insert probes should not be used. One reason might be that the fluid in the pipe is very dirty and it is best to avoid having dirt sticking to the insert probe. Another reason is to avoid drilling holes in the pipe.

IF AN INSERT PROBE CANNOT BE USED, the temperature of the fluid can be determined using an external surface mounted sensor *(Figure 1)*. A contact sensor, such as a sheathed thermocouple or Pt100, only measures its own temperature and absolutely nothing else. As a result, the surface sensor will be measuring the temperature of the fluid in the wrong place. We must therefore consider the size of the deviation between the temperature we are measuring and the temperature we want to measure. The size of the deviation is influenced by several factors, which will be discussed here.

In (*Figure 1*) the fluid has a higher temperature than the surroundings and the heat flow is now from the fluid to the environment. On the inside of the pipe the heat transfer occurs by forced convection. In the pipe wall the heat transfer is by thermal conduction and on the outside of the pipe the heat transfer to the environment occurs by radiation and convection. The air velocity in the pipe's environment is often low, which means that this heat transfer is one of natural convection.

Installation of a surface mounted sensor

When installing the sensor you must ensure that the contact between the pipe and the sensor's probe tip is as good as possible. The heat transfer between the pipe and the probe tip will be more controllable if the sensor is mounted in contact with the surface along a certain distance *(Figure 2)*. Because the probe tip is now essentially part of the measurement object – the steel pipe – it assumes more or less the same temperature as the object. Where the sensor leaves the pipe, heat in the sensor is transported by thermal conduction. The heat is then transferred from the sensor to the surrounding air by radiation and convection (*Figure 2*). The heat flow in the sensor influences the temperature of the pipe, especially in the region where the sensor leaves the pipe, but this heat flow has very little effect on the temperature of the probe tip.

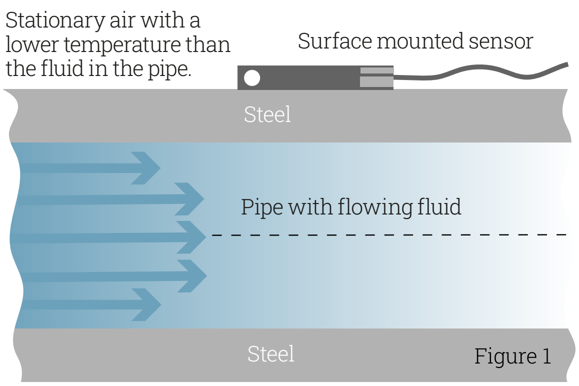


Figure 1

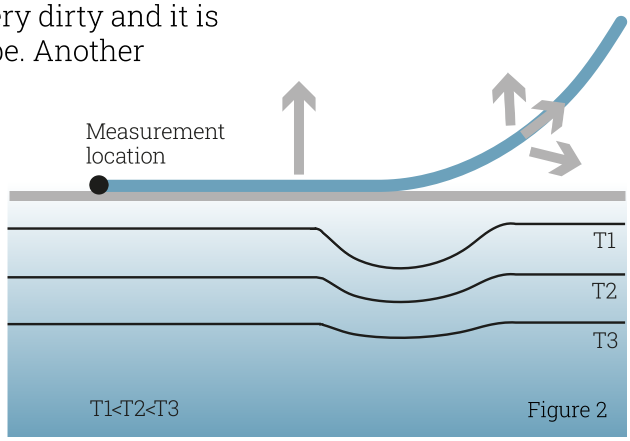


Figure 2

Example of measuring the temperature of air and water in a pipe with a surface sensor and constant flow in the pipe.

We will now consider the example of a long, straight stainless-steel pipe with the inner diameter of 80 mm and a pipe wall thickness of 5 mm. Inside the pipe, water is flowing with a temperature of 70 °C and an average velocity of 2 m/s. The pipe is located in factory premises with an ambient air temperature of 15 °C.

The thermal conductivity of stainless steel (18/8) is 15 W/(m K). The convective heat transfer coefficient on the inside of the pipe can be calculated as 9020 W/(m^{2}K) and the total heat transfer coefficient on the outside of the pipe is estimated to be 8 W/(m^{2}K). This value includes both natural convection and radiation.

Based on these data, the heat flow from the hot water inside the pipe to the factory premises is 124 W/m, the pipe's internal temperature is 69.95 °C and the pipe's external temperature is 69.80 °C. We use a correctly installed sensor to measure the latter temperature. In this case the difference ΔT °C between the temperature we want to measure, 70 °C, and the one we are actually measuring is insignificant: $\Delta T = 0.2$ °C. Note also that the difference between the pipe's internal and external temperature is very small, 0.15 °C.

Let us consider the same pipe as before but the pipe now has air flowing through it with a temperature of 70 °C and an average velocity of 5 m/s. The other geometrical and thermal technical data are the same as before.

The convective heat transfer coefficient on the inside of the pipe can be calculated as 24.1 W/(m^{2}K). Based on these data, the heat flow to the factory premises is 90 W/m, the pipe's internal temperature is 55.1 °C and the pipe's external temperature is 55.0 °C. We use a correctly installed sensor to measure the latter temperature. In this case the difference ΔT °C between the temperature we want to measure, 70 °C, and the one we are actually measuring is considerably larger than in the previous case, ΔT = 15 °C compared with ΔT = 0.20 °C. Note that in this case the difference between the pipe's internal and external temperature is also very small, 0.1 C, which is due to the fact that the thermal resistance in the steel pipe is very small.

In *(Figure 3)* we see a diagram of the two temperature distributions. We can use air and water as representative materials for gases and liquids respectively. In almost all similar cases of pipe flow measurement involving a surface mounted sensor, the measurement error will be larger when a gas is flowing inside the pipe compared with when a liquid is flowing. We could say that "it's easier to measure in a liquid than in a gas."

Influence on the measurement error when the pipe is insulated

If possible, you should insulate the pipe. One reason is to reduce the heat loss from the pipe and another is to help prevent burns. If you have installed a surface mounted sensor, insulating the pipe will also reduce the measurement error. Unfortunately it is not always possible or permitted to insulate the pipe.

The pipe we have discussed above is now insulated with 50 mm mineral wool with the heat conductivity of 0.040 W/(m K). In our calculations we use the same values for the heat transfer coefficients as before. The heat loss decreases from 124 W/m to 17 W/m when water is flowing through the pipe. In the air flow case, the heat loss decreases from 90 W/m to 16 W/m. The thermal resistance is now determined largely by the thermal resistance of the insulation and the thermal resistance on the external surface of the insulation.

In both cases the temperature on the pipe's external surface increases. With water flowing through the pipe the temperature increases from 69.80 °C to 69.97 °C and with air flowing the temperature increases from 55.0 °C to 67.3 °C. Note that in the liquid case the increase is insignificant whereas in the air case the increase is considerable. The insulation means that the measurement error in the air case decreases from 15.0 °C to 2.7 °C. Therefore to reduce the measurement error you should always insulate the pipe.

Contamination of the pipe

Dirt on the inside or outside of the pipe reduces the heat flow. Dirt on the inside increases the measurement error and dirt on the outside decreases the measurement error. Here dirt acts as a type of insulation. It is difficult to make any general comment about what happens if the pipe gets dirty on both the inside and outside. Such a case would require more detailed analysis.

Suitable placement of surface mounted sensors at pipe bends and transition regions

If you intend to install a sensor close to a pipe bend or a transition region in the pipe, you should think twice. See *(Figure 4)*. Downstream of the increase in diameter of the pipe the flow develops a wake, which is characterised by low velocity and backflow. The low velocity means that the fluid in this region adapts slowly to the temperature of the main flow. If a surface mounted sensor were to be installed in this region, the sensor will react slowly to temperature changes in the fluid.

If you want to have the shortest possible response time, you should install the sensor in section A, where the fluid velocity is highest. High fluid velocity produces a higher heat flow to the wall during temperature changes and thereby a short response time. The flow velocity in section B is lower than that in section A. A sensor installed in section B therefore produces a slightly longer response time than an installation in section A.

In cases where the fluid is dirty, you should avoid installing a sensor adjacent to the wake. The dirt collects in the wake and increases both the measurement error and the response time. One or more wakes often occur downstream of a pipe bend. If possible, a surface mounted sensor should therefore be installed upstream of the pipe bend.

Estimation of the response time with an uninsulated and uncontaminated pipe

Determining the response time of a surface mounted sensor is almost always more complicated than determining the response time of an insert probe. In addition to the properties of the flow and the design and thermal properties of the surface mounted sensor, the response time in this case is also influenced by the thermal properties and dimensions of the pipe.

The ability to make a reasonably simple estimate of the response time in this case depends on what fluid is flowing through the pipe. When calculating the response time in this case we must include the pipe, whose mass and dimensions are considerably larger than those of the sensor. Normally this means that it is the properties of the pipe that determine the response time of the surface mounted sensor.

We now consider the same uninsulated pipe as before and discuss some ways to estimate the response time. If we use the lumped-heat capacity method to calculate the response time the following condition must be met for the "lump", which in this case is the pipe wall

$$(hs)/k < 0.1$$

where h is the heat transfer coefficient inside the pipe in W/(m²K), s a characteristic length, which in this case is the thickness of the pipe wall, and k the pipe material's thermal conductivity in W/(m K). The dimensionless parameter (h s)/k is called the Biot number (Bi). In physical terms, the condition Bi < 0.1 means that the temperature difference between the fluid and the pipe will be much greater than the temperature difference between the pipe's inside and outside surfaces.

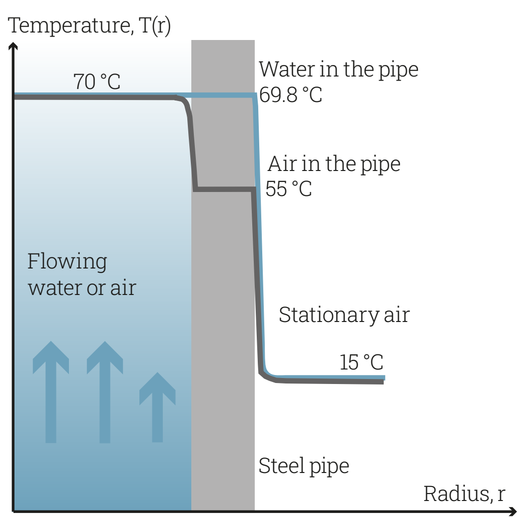


Figure 3

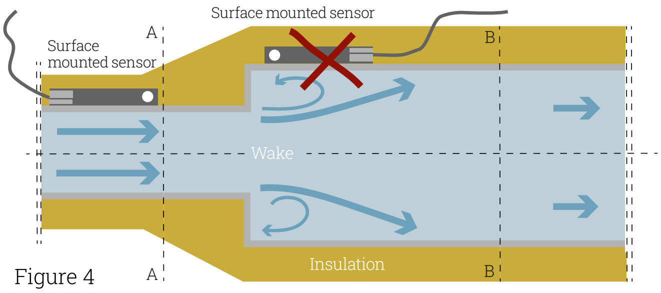


Figure 4

For the earlier example with the air flow, the heat transfer coefficient on the inside of the pipe is 24.1 W/(m²K), the pipe thickness 0.005 m and the pipe material's thermal conductivity 15 W/(m K). We find that Bi=0.008. This means that the condition is more than met and we can use the lumped-heat-capacity method.

The "lump", that is, the pipe together with the surface mounted sensor, is assumed to have the temperature T(t) °C, where t is the time in seconds. The temperature of the pipe wall now depends only on the time and not on the situation inside the pipe wall. The pipe's original temperature is 56.3 °C. The air temperature inside the pipe is now changed stepwise from the initial temperature of 70 °C to the temperature of 75 °C. After the transient time the pipe wall will adopt the temperature of 60.0 °C. To determine the pipe temperature I have used the same calculation method and the same heat transfer coefficients as before but I have disregarded the minimal thermal resistance in the pipe wall.

For the pipe wall temperature, T = T(t) °C, the following differential equation now applies

$$(\rho Vc)\,(dT/dt) = (\alpha_F A)(T_F - T) - \alpha_y A_y (T - T_y)$$

where ρ is the pipe wall's density in kg/m³, V = πDsL the pipe wall's volume in m³, D the pipe's inner diameter in m, s the pipe wall's thickness in m, L the pipe's length in m, c the pipe wall's specific heat capacity in (Ws)/(kg K), h_F the heat transfer coefficient on the pipe's inside in W/(m²K), A = πDL the pipe wall's internal area in m², T_F the fluid's temperature °C, h_y the heat transfer coefficient on the outside of the pipe in W/(m²K), A_y the pipe wall's external area in m² and T_y the ambient temperature in °C.

The left-hand side of the differential equation represents the energy change of the wall over time. The first term in the right-hand side is the heat input to the pipe wall from the fluid and the second term in the right-hand side is the heat transfer from the pipe wall to the environment. We now consider a pipe with the length L=1 m. In this case the difference between the pipe's external and internal areas is very small and we therefore assume A_y=A. The differential equation can now be written

$$dT/dt) + (1/\rho sc)\,(h_F + h_y)\,T = (1/\rho sc)\,(h_F T_F + h_y T_y)$$

For the wall's initial temperature T = T(0) with the fluid temperature T_F=T_{F0} the following equation, which means that the heat flow to the wall is equal to the heat flow from the wall, applies

$$(h_F A)(T_{F0} - T(0)) = (h_y A)(T(0) - T_y)$$
$$T(0) = (h_F T_{F0} + h_y T_y)/\,(h_F + h_y)$$

We now assume that the fluid's temperature changes stepwise from T_{F0} °C to T_{F1} °C. The differential equation with the associated initial temperature can now be written

$$dT/dt) + (1/\rho sc)\,(h_F + h_y)\,T = (1/\rho sc)\,(h_F T_{F1} + h_y T_y)$$
$$T(0) = (h_F T_{F0} + h_y T_y)/\,(h_F + h_y)$$

The solution of the differential equation becomes

$$T(t) = -((h_F (T_{F1} - T_{F0})/(h_F + h_y))\,e^{-mt} + (h_F T_{F1} + h_y T_y)/(h_F + h_y)$$
$$m = (1/\rho sc)\,(h_F + h_y)$$

For the case in question, when we disregard the wall's thermal resistance the initial temperature T=T(0) is

$$T(0) = (h_F T_{F0} + h_y T_y)/\,(h_F + h_y) = 56.3\ °C$$

After the transient time the wall adopts the temperature $T_{meas.}$ °C

$$T_{meas} = (h_F T_{F1} + h_y T_y)/(h_F + h_y) = 60.0\ °C$$

Half the temperature increase of 3.7/2°C is achieved after the response time $\tau_{0.5}$ = 404 seconds = 6.7 minutes. The response time is thus relatively long – almost 7 minutes – and the main reason is the relatively low convective heat transfer coefficient inside the pipe wall.

For the previous example with the water flow, the heat transfer coefficient on the inside of the pipe is 9020 W/(m²K), the pipe thickness 0.005 m and the pipe material's thermal conductivity 15 W/(m K). We find Bi = 3.0. This means that the condition for the lumped-heat-capacity method is not met and therefore we cannot use that method. In this case the temperature difference between the pipe's inside and outside is not negligible compared with the temperature difference between the fluid and the pipe wall.

One way to estimate the response time in this case is that we regard the pipe wall as a flat wall and we also ignore the heat flow to the environment. In this case the latter is much smaller than the heat flow from the fluid. We can then use an analytical solution to this problem and we find that the response time $\tau_{0.5}$ is just over 3 seconds (3.4 s). For air flow in the pipe, the response time in this example is a matter of minutes and for water flow in the pipe it is a matter of seconds.

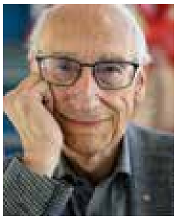
Using surface mounted sensors for measuring fluid temperature in pipes – a summary

Some advantages of using a surface mounted sensor

- There is no need to bore a hole in the pipe for the sensor
- Unlike an insert probe, the sensor does not increase the pressure drop in the pipe
- In the case of dirty fluids the surface mounted sensor does not disrupt the flow

Some disadvantages of using a surface mounted sensor

- The temperature is measured in the wrong place, which can increase the measurement error
- The response time increases
- Poor contact between the pipe and the sensor increases both the measurement error and the response time. ▮

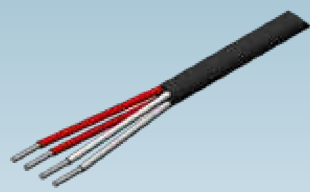


– Dan Loyd, Professor emeritus,
Linköping University.

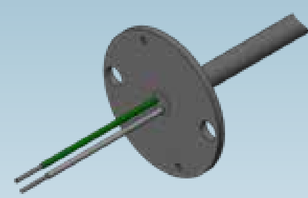
Common connector options for **thermocouples** and **resistance thermometers**

Connectors 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.

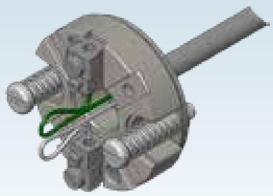
Thermocouple cable with free wires



Pt100 cable with free wires

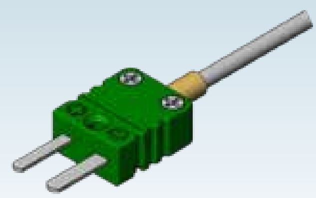


Measurement insert ready for mounting of a terminal head or transmitter (T/E or Pt100)



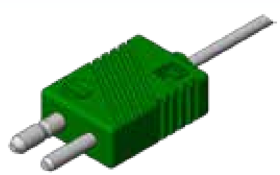
Measurement insert with terminal head (T/E or Pt100)

Miniature female connector mounted on a cable



Miniature male connector mounted on a sheath

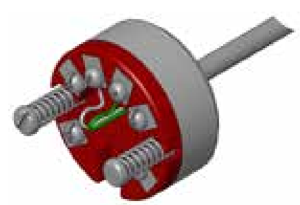
Standard female connector mounted on a cable



Standard male connector mounted on a sheath

M12 connector mounted on a cable or sensor

LEMO connector mounted on a cable



Measurement insert with transmitter (T/E or Pt100)

Thermocouple connector mounted on a terminal head

M12 connector mounted on a terminal head

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 two points, making the sensors highly accurate and fully interchangeable 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.

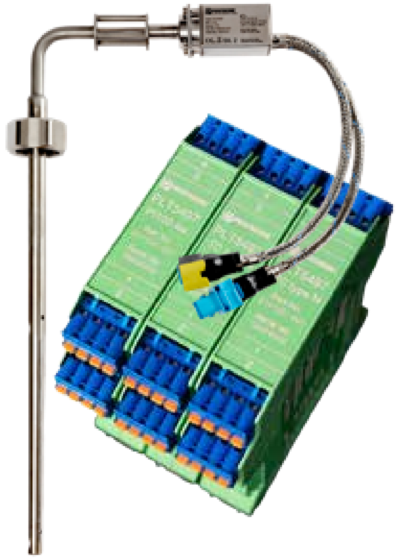
Pentronic offers flexibly customised installation cabling to reduce costs and increase sensor accessibility for maintenance, adjustment and replacement.

	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 con-nectors. 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 field configurations.*

The Pentronic PLB5000 system

– A digital temperature measuring system for demanding environments



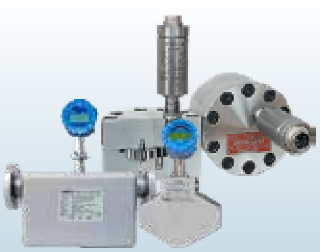
- Cost-effective, compact and robust measurement system
- Up to 120 measuring positions with high accuracy via digital bus
- Simple installation with minimal cabling
- Safety integrity level: SIL 2 IEC61508
- Intrinsic safety systems IECEx and ATEX
- Integrated signal converter with 1, 2 or 3 connected sensors, alternatively: DIN rail-mounted signal converter with up to 4 channels
- Inputs for Pt100/1000 or thermocouple sensors.
- (types: K, N, ...)
- Gateway connects to PROFIBUS DP/PROFIsafe
  Gateway for IECEx/ATEX zone 1 based on PROFINET over APL – launching in 2023
- Redundancy that supports excellent availability

The PLB 5000 system is designed for accurate temperature measurement in demanding environments. The system provides superior measurement and stability in small and robust casings. The signal converter delivers digital measurements, has a uniquely low power consumption and is easy to install with a minimum of cabling. Designed for applications where a high degree of flexibility, accuracy and safety is required.

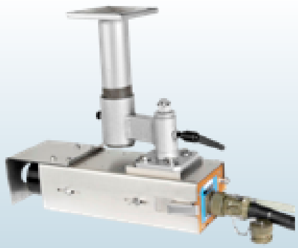
PENTRONIC'S PARTNERS INSTRUMENT RANGE (SELECTION)

For more information, visit our website www.pentronic.se
or contact one of our sales representatives.

Temperature indicators



Flow meters

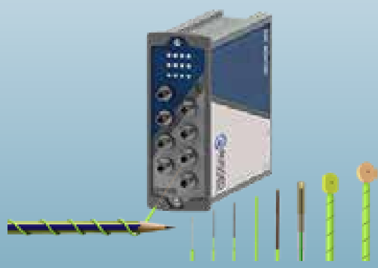


Glass flow meters (GFM)

Moisture meters and NIR equipment

Transmitters

Calibration equipment



Fibre optics

Data loggers

Contactless IR pyrometers

Faulty connections of thermocouples and Pt100

Keep this in mind when connecting thermocouples.

Circuit break (open circuit)

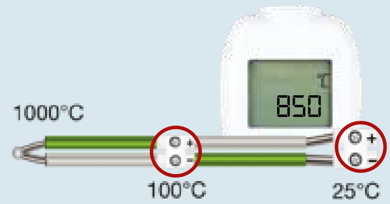
A sensor wire has become detached, loosened or is in poor contact with the instrument. The instrument triggers an alarm, e.g. by displaying the word "Open".

Reversed polarity of entire measuring circuit

If the polarity has been reversed, the instrument will operate "in reverse". A temperature increase will be recorded as a temperature decrease.

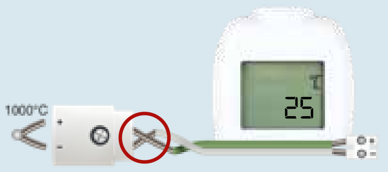
Double reversed polarity

If the polarity of the extension cable has been reversed at both ends, the temperature at the ends will affect the output signal. The reading will be the temperature at the measuring junction minus twice the temperature difference between the terminal head and the reference junction. Keep in mind that if a temperature controller having a set-point value of 1000 °C is connected, the power will be stepped up, thereby giving a true value approximately 150 °C higher than the set-point value. However, the instrument will still display a reading of 1000 °C.



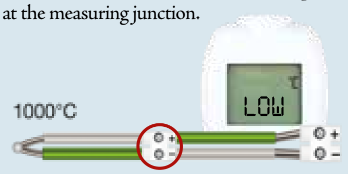
Short circuit

If the insulation wears off and the wires are short circuited, a measuring junction is created. The instrument will then display the temperature at the short-circuit point instead of at the probe tip.



Reversed polarity within the measuring circuit

The extension cable must have the same polarity as the thermocouple wires. If the polarity of the thermocouple is reversed, opposing voltages occur. The reading obtained will then be twice the temperature in the terminal head minus the temperature at the measuring junction.



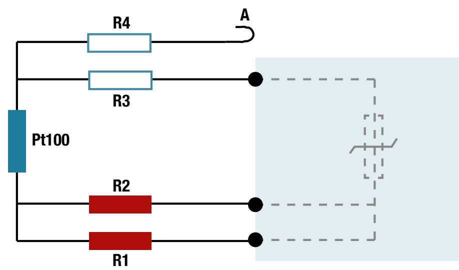
Keep these in mind when connecting Pt100s to avoid misleading measurement results

4-wire Pt100 to 3-wire indicator

Be careful of false 4-wire connections. It can be tempting to connect two wires in the same terminal of an instrument built for 3-wire measurement.

The result will be a 50 percent difference in resistance between the different branches of the 3-wire indicator, where equal resistance is necessary for zero error. See the adjacent figure for the correct way to connect a 4-wire Pt100.

With a 10 m 4 x 0.25 mm² extension cable the measurement error is approx. 0.9 °C.



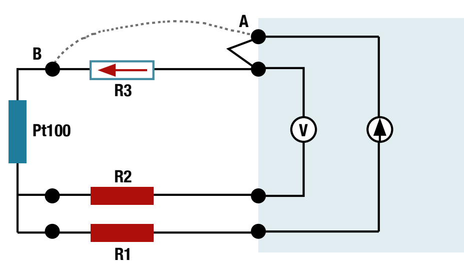
The correct connection of a 4-wire Pt100 to a 3-wire indicator. One of the wires (any will do) must be left unconnected. See A.

3-wire Pt100 to a 4-wire indicator

A Pt 100 with 3 wires plus an instrument for 4-wire connection. The changeover from 4 wires to 3 is done as close to the sensor as possible. In the adjacent figure this is done at B, as shown by the dotted line.

If you connect at A instead, the measuring current must pass through the wire with R3. The indicator then shows the resistance for the Pt100 plus the resistance R3. The error can then be approx. 1.8 °C (for a 10 m 3 x 0.25 mm² wire).

When the connection is correctly made at B, the measuring current encounters less resistance en route to the Pt100. For a short process sensor, the increase can lead to a measurement error of approx. 0.1 °C.



The correct connection of a 3-wire Pt100 to a 4-wire indicator involves transitioning to the 3-wire configuration as close to the sensor as possible to achieve the lowest measurement error. Connecting at B gives a lower error reading than connecting at A. The reason is that the power generating loop must be separated from the voltmeter circuit (R3) except in the Pt100 sensor itself.

TECHNICAL ARTICLE

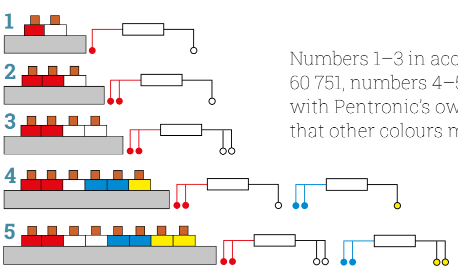
Advice for users of temperature sensors

To ensure the long lifetime and good stability of your temperature sensors, we recommend the following general advice:

1. Do not exceed the sensor's measuring range.
2. Do not subject Pt100/Pt1000 sensors to strong impact or vibration.
3. Ceramic thermowells are fragile. Do not subject them to bending, impact or temperature shock.
4. Do not bend sensors equipped with a sheath material at too sharp an angle. The minimum bend radius should be equal to twice the diameter.
5. Sensors made of tubular material should not be bent at all.
6. The measurement environment can limit the sensor's lifespan. Regularly inspect the sensor's mechanics and signal output.

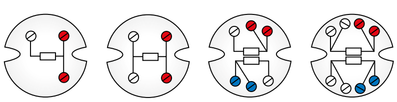
NB! High temperatures and thin sensors shorten the lifespan.
If you are unsure, contact us.

Extension cable for Pt100s



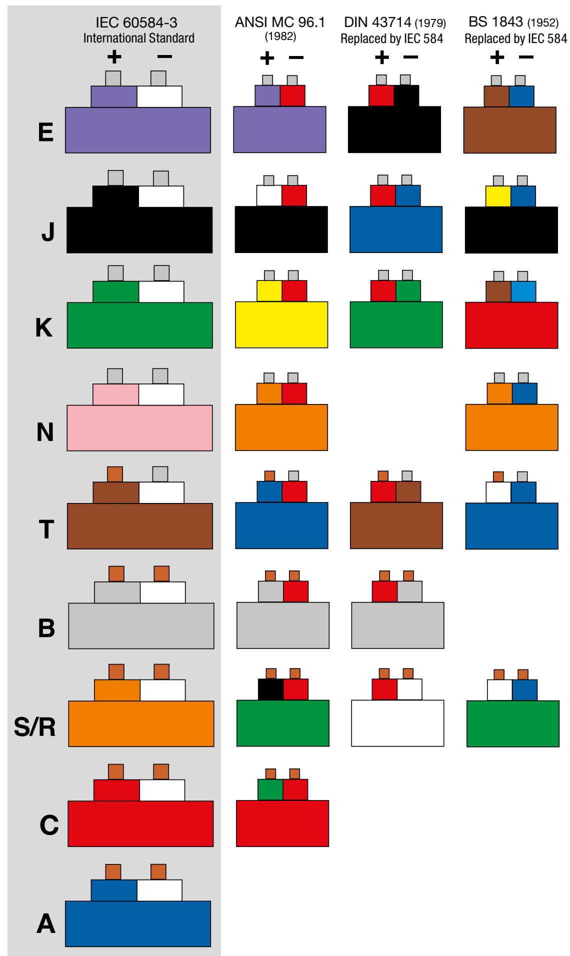
Numbers 1–3 in accordance with IEC 60 751, numbers 4–5 in accordance with Pentronic's own standard. Note that other colours may be used.

Terminal block connector for Pt100s



Note that other colours may be used.

Colour code thermocouple cable



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	90	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
SILICON	-60	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 specifications.

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
Stainless steel	A highly versatile and common material suitable for moderate temperatures and environments.	1.4301 1.4307	X5CrNi 18-10 X2CrNi 18-9	304 304/304L	A2 stainless steel
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	X5CrNiMo 17-12-2 X3CrNiMo 17-13-3	316	A4 acid-resistant steel
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	X2CrNiMo 17-12-2 X2CrNiMo 17-12-3 X2CrNiMo 18-14-3	316L	
Mo alloy stainless steel titanium stablised	Excellent corrosion resistance.	1.4571	X6CrNiMoTi 17-12-2	316 Ti	Classic V4A
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 X9CrNiSiNCe 21-11-2 X6NiCrSiNCe 35-25 CrAl 20 5	446 UNS S30815 UNS S35315	4C54 253MA 353MA Kanthal AF
Nickel-based alloys	Excellent corrosion properties, working temperatures up to 900 °C* Excellent properties in reducing environments.	2.4816 2.4819 2.4951/2.4630	NiCr15Fe NiMo16Cr15W NiCr20Ti	UNS N06600 UNS N10276	Inconel 600* Hastelloy C-276 Nimonic 75
Pressure vessel steel	Standardised material certified for use in industrial pressurised installations.	1.0460 1.5415 1.7335 1.7380	P250GH 16Mo3 / 15Mo3 13CrMo 4-5/13CrMo 4-4 10CrMo9-10	SA 105 A204 Gr.A A387 gr.12 A122 F22	C22.8

* 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. See further in the table below.

Max. recommended working temperatures for thermocouples with sheath material Iconel 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

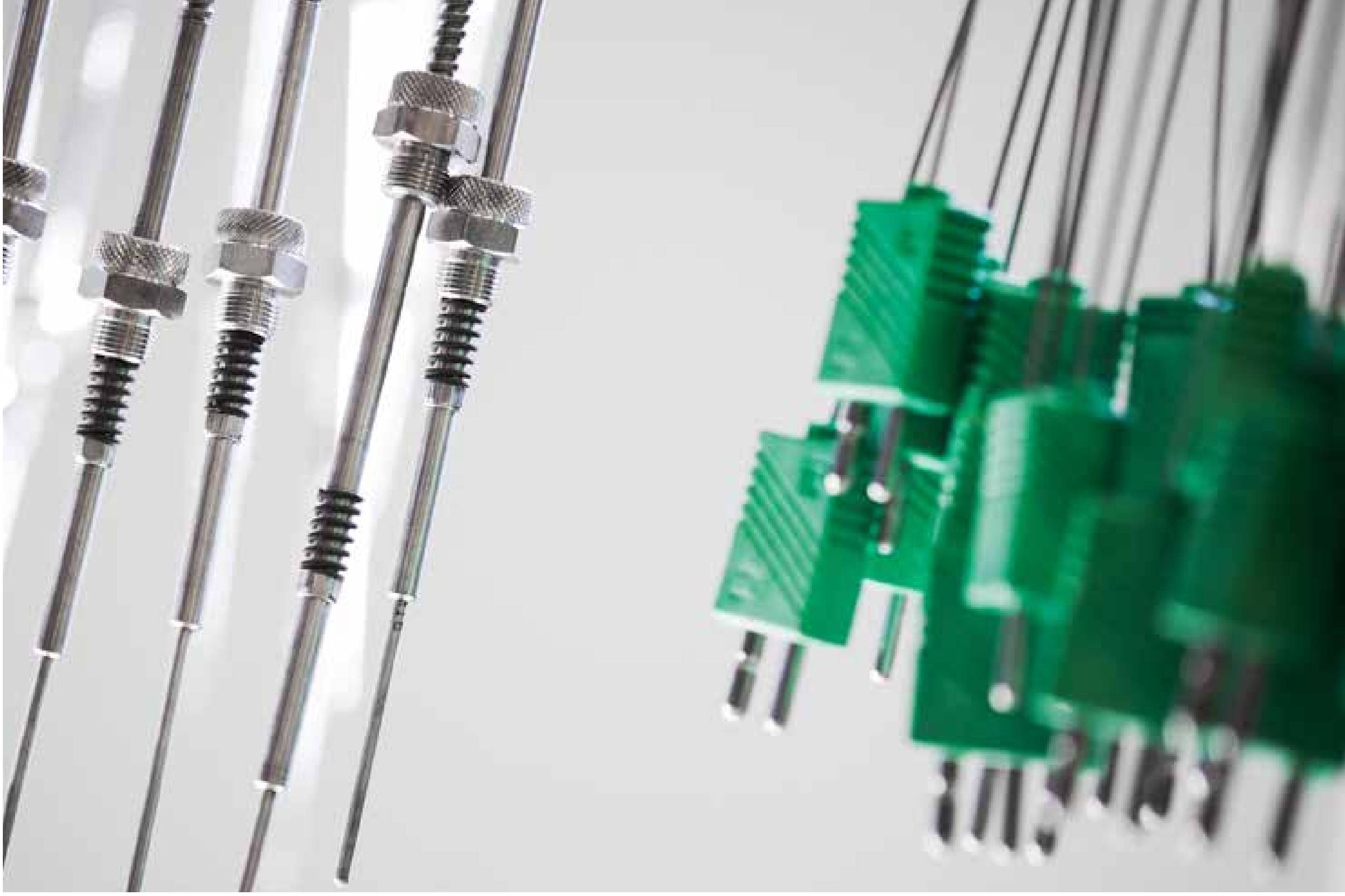
Pentronic also manufactures sensors in specialised sheath alloys for thermocouples, designed for working temperatures up to 1250 °C (e.g. Nicrobel).

With regard to ceramic protection tubes: the AlO3 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	Working range in °C	Atmosphere
E		-200 - 900	Good in oxidising environments
J		-200 - 760	Not in oxidising environments or acids
K		-200 - 1200	Good in oxidising air environments
N		0 - 1300	Like K but standardised to be better over 200 °C
T		-200 - 370	Not in oxidising environments
S/R		0 - 1480	Ceramic protection tubes, all environments
B		0 - 1700	Ceramic protection tubes, all environments
C/D		0 - 2315	Vacuum, not for oxidising environments



Dimensions and **resistance** of various thermocouple wires

Dimensions			Conductor resistance in ohms per metre of wire					
AWG	Diam. mm	Area mm²	K	N	J	T	S	Cu/Cu
18	1.02	0.823	1.2	1.6	0.86	00	0.4	0.04
20	0.81	0.519	1.9	2.6	1.2	1.0	0.6	0.07
22	0.64	0.324	3.1	4.1	1.9	1.5	0.9	0.11
23	0.57	0.259	3.9	5.1	2.3	2.0	1.2	0.13
24	0.51	0.205	4.9	6.5	3.0	2.5	1.5	0.17
25	0.45	0.162	6.2	8.2	3.7	3.1	1.8	0.21
26	0.40	0.128	7.8	10.4	4.7	3.9	2.3	0.27
28	0.32	0.080	11.8	16.5	7.5	6.3	3.7	0.43
30	0.25	0.051	19.8	26.2	12.0	10.0	5.8	0.68
32	0.20	0.032	30.9	41.0	18.8	15.6	9.3	1.08
34	0.16	0.020	49.7	66.1	30.2	25.2	14.8	1.71
36	0.13	0.013	79.0	105.0	48.1	40.1	23.5	2.72
38	0.10	0.008	123.7	164.0	75.3	62.5	37.3	4.33
40	0.08	0.005	205.4	273.1	124.1	103.8	59.3	6.88

AWG = American wire gauge.

The conductor resistance in ohms per metre of wire means the total resistance of 1 metre of both wires in a single pair of wires. For Pt100 wire, the total resistance of 1 metre of two wires is given, which also corresponds to the resistance of 2 metres of one wire.

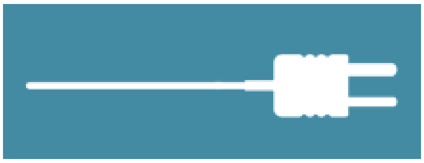
The stated measurements are rounded off and should be considered as guidelines. Deviations may occur.

Compensation material – denoted by the letter C, e.g. KC – has a different resistance than that of the corresponding thermocouple material.

Cu/Cu stands for copper in both wires and has been included for comparison.

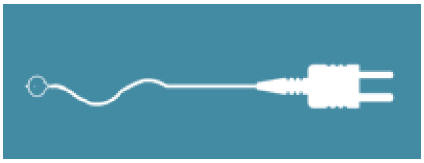
Model portfolio

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.
Disadvantages: Accuracy at low temperatures.
Model examples: 8102000, 8103000, 8105000, 11-00212.



Thread thermocouples

Design: Large variety of designs, optional process connections and contacts.
Advantages: Robust and flexible. Very low response time. Low cost.
Disadvantages: Prone to ageing. Limited protection of inner leads.
Model examples: 6206000, 6101000, 6201000.

Resistance thermometers

Design: Large variety of designs, optional process connections and contacts.
Advantages: High accuracy, very versatile design options.
Disadvantages: Sensitive to shock, not suitable for high temperature applications.
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.
Disadvantages: Bulky design.
Model examples: 8109600, 811000, 7941000, 780900.

Integrated signal conversion

Design: Several forms and process connections available. 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.
Disadvantages: Limited temperature range for electronic parts.
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 accuracy can be achieved. Minimal cabling and significantly simplified installation as well as service. High level of system integrity and safety (IECEx/ATEX).
Model examples: PLB1000 and PLB5000.

www.pentronic.se/products

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Steel & metal industry
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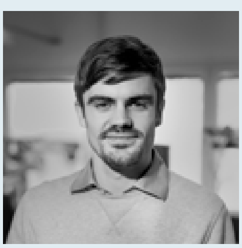

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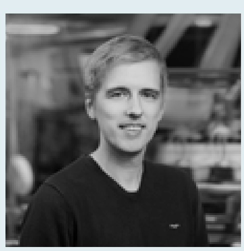

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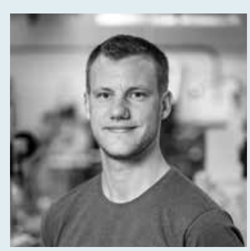

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