IT'S ABOUT TEMPERATURE

PENTRONIC

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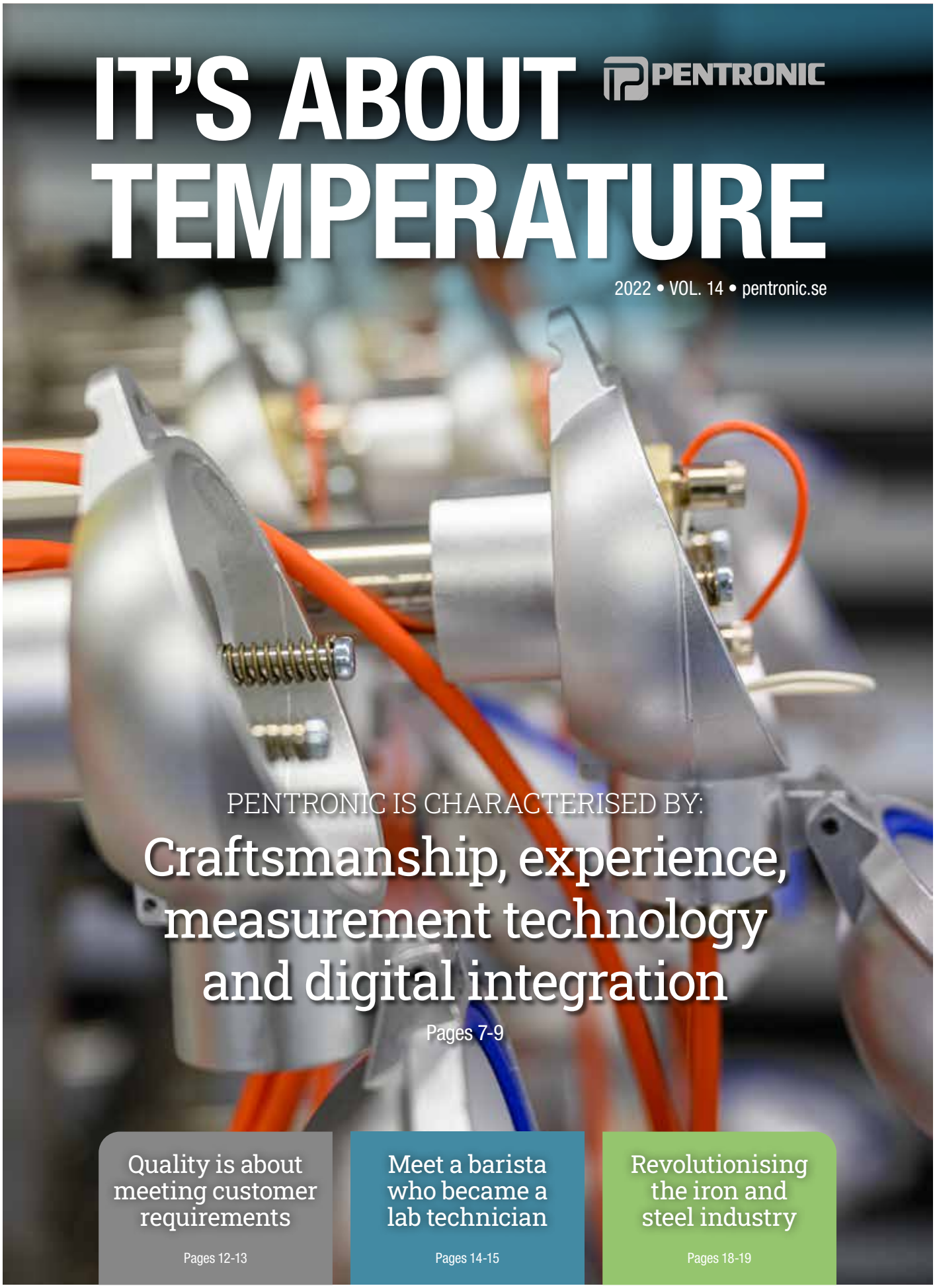

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Welcome to "It's about temperature"!

We are pleased and proud to present a new generation of **Pentronic News** under the name **It's about Temperature**. In times of great and increasingly rapid change it is also important to maintain continuity.

We have thought a lot about this in relation to our much-appreciated customer magazine, which recently celebrated its 30th anniversary. How can we keep up with developments and simultaneously represent recognition and security to our readers? The issue you are holding in your hand or reading on the computer/tablet/telephone is the answer to the question. It is a sustainable product which can be made available in many channels, including in paper format, and which offers interesting reading for people who want to stay updated and learn more about the latest in temperature measurement. I hope that the new format will attract both new and existing readers. We have chosen to combine what was previously published in four issues into a single edition containing fascinating articles, news and knowledge-enhancing content that can be read whenever you want and wherever you are.

Finally, all of us here at Pentronic hope you have had a wonderful summer and a relaxing and sunny holiday. We're looking forward to an exciting and intensive autumn together!

Rikard Larsson, Managing Director, Pentronic

IT'S ABOUT TEMPERATURE

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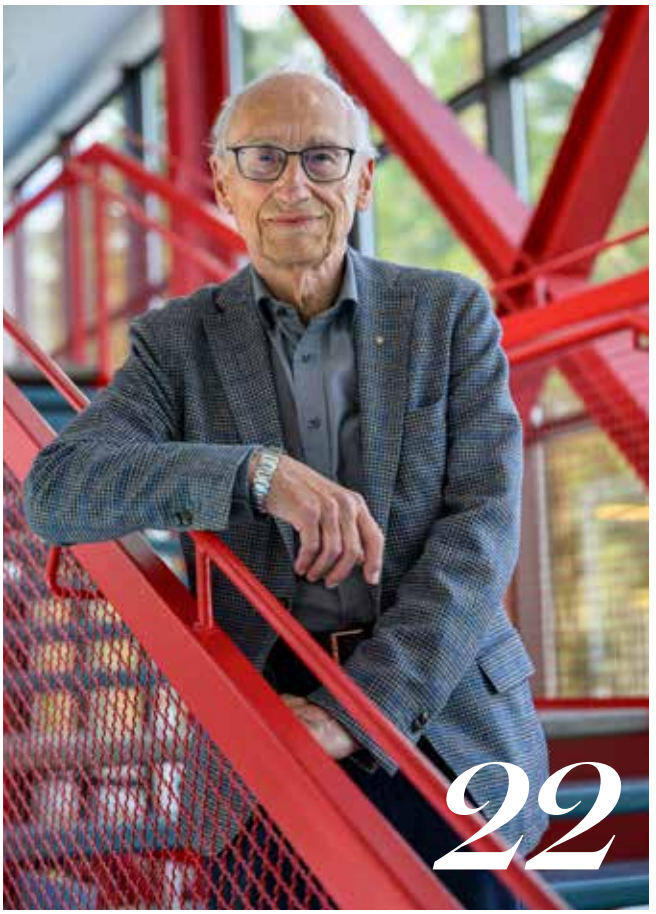

PENTRONIC IN BRIEF

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.

102 EMPLOYEES

Pentronic has:

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

Steel grades are usually identified by their trade name or number in the EN10027-2 standard, but American and other standard designations also exist. Pentronic currently works with over 25 different steel grades for use in various applications.

1965

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

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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.**

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.

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.

SWEDAC ACKREDITERING
Ackred.nr 0076
Kalibrering
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 Västervik and one in Karlstad.

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 for 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.


Design and preparation, Edin Beganovic.

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 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", continues Erik.

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.

Operator Jimi Huhtala.

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**

CNC operator Lise-Lotte Karlsson.

Group coordinator Daniel Westerlund.

Pentronic is part of the Indutrade industrial group

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

Since its inception in 1978, Indutrade's business philosophy has been to operate a decentralised organisation where operational responsibility rests with each individual subsidiary. This is and has been one of the keys to the company's success.

Indutrade's strong, people-focused corporate culture permeates all its work and its vision: an entrepreneurial world where people make the difference.

You can find more information at **www.indutrade.se**

Indutrade

At **Pentronic** it's all about the **details**

In Pentronic's production process, the feeling for quality and craftsmanship is literally in the fingertips of the fabricators. Jessica Bergman is one of the fabricators who ensures Pentronic's quality every day.

"I build a sensor from start to finish. It's fun to watch it grow and I feel responsible all the way."

AT PENTRONIC'S production facility in the small Småland village of Verkebäck, Jessica Bergman is building some twenty sensors. A number of components must be assembled in each sensor and it's a time-consuming job that tests both patience and accuracy.

"Before I started working at Pentronic, I didn't think that building sensors was such a craft skill as it is. Tiny components must be put in place and we work a lot with our hands. It suits me – I've always had a great interest in crafts."

Many steps

Jessica is currently building a newly developed wireless temperature sensor called BEB-20, a sensor that will eventually be installed in an engine. But there are still many steps left, which makes assembling the components a very varied task. The types of products Jessica assembles also vary. They range from advanced wireless sensors with integrated electronics to traditional sensors with a cable and connector.

"We make some sensors in larger batches whilst others are more specialised and rarely recur. The number of BEB-20s, for example, can vary quite a lot depending on the customer's needs – sometimes I assemble four and sometimes twenty like today. The variety of the work here is probably one reason why many of my colleagues work at Pentronic until they retire."

What's the most important thing you need to think about as you assemble?

"The most important thing is to be meticulous and not to stress unnecessarily. Some things that can go wrong, you can't see with the naked eye. That's why it's important to follow instructions and standards and do things in the right order. For example, moisture must not get into the sensor or it will show the wrong value and all the soldering must be done correctly or the wires will come loose."

Relaxing in the garden

All sensors assembled in Pentronic's production share a single destination: the final inspection. This acceptance test guarantees that the product works and meets the customer's requirements before it is shipped to the customer. Then Jessica's work is done but when she finishes her working day, another occupation takes over. In her newly bought house a stone's throw from Pentronic, she works in the garden and sews clothes.

"It's really relaxing to come home to the garden of our house in the country."

Name: Jessica Bergman
Age: 29
Work as: Fabricator for the past three years.
Leisure activities: Sewing clothes, taking care of sheep, working in the garden.
About her future at Pentronic: "I want to continue to develop and try new things. Over the past three years I have become more independent in my work – I've learned a lot!"

Calibration at a high **technical level**

Pentronic's accredited calibration laboratories play a key role in the company's development and quality control work.

"Our strength is the high technical level and low measurement uncertainty of our laboratories."

Andreas Holm, Laboratory Manager.

THE SPEAKER IS Laboratory Manager Andreas Holm, who is in charge of Pentronic's accredited calibration laboratories in Västervik and Karlstad. Pentronic has continuously invested in modern technology and equipment and has developed methods to achieve low measurement uncertainty.

"The fact that a number of customers have been using us for calibration for 20 to 30 years is proof that we do it well," Andreas says.

He leads a team of four laboratory technicians in Västervik and one in Karlstad.

"Our technicians have slightly different roles and areas of expertise. We aim to be a source of knowledge and serve our customers in the best possible way. The advantage of this geographical spread is our proximity to our customers when we go out to do field calibrations."

What does field calibration involve?

"Primarily it is the calibration of complex measuring equipment that is unsuitable or difficult to move. For example, this could be in the steel industry, where hardening furnaces have instrument cabinets that measure about 20 different sensors. In such cases we go out to the customer, connect to the equipment and measure the values. It's important to help our customers secure their processes in an efficient way."

What does the calibration of temperature sensors or measuring instruments involve?

"Calibration involves comparing the object to a known normal to determine how large the error is at a given temperature but it does not involve adjusting the object. The customer receives a calibration certificate with the measured value. When we perform calibration for repeat customers, it's an advantage to be able to see the history – for example, if a sensor is judged to have come to the end of its service life and must therefore be replaced."

LABORATORY

Accredited according to ISO / IEC 17025

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). Pentronic also performs field measurements and external calibrations on behalf of customers and industry colleagues. The laboratory in Västervik was accredited in 1988 by Swedac, Sweden's national accreditation body. To be accredited by Swedac, competence, procedures and methods are tested so that all quality requirements specified in a standard are met.

Three roles

Andreas is the lab manager and has technical and quality responsibility.

"I have to ensure that we have calibrated reference equipment for all the measurements we take, as well as maintaining an efficient and reliable quality system that we follow."

What's the best part of your job?

"First and foremost it's the variety of different tasks. Because we calibrate all types of temperature sensors, the calibrations are rarely exactly the same."

He benefits from having worked on Pentronic's production line, making temperature sensors for a few years before he joined the laboratory in 2013.

"It's an advantage to have been there and seen how sensors are built."

Andreas took over the technical responsibility in 2015 and became the laboratory manager in 2020.

What do you do in your spare time?

"I've always had a keen interest in technology, ranging from building with Lego to computers and engines – I have a sports car with a 700 horsepower engine!"

"Quality is about meeting customer requirements"

From the pharmaceutical industry to 3M and on to Pentronic. Graduate engineer Josefin Knutsson's career has taken exciting paths in a broad range of industries.

TODAY JOSEFIN ensures that Pentronic maintains the quality and environmental profile that the company stands for.

"Quality is about meeting the customer's requirements and everyone knowing their role in the flow."

Everybody's contribution is important

The right quality at the right time. That's the basis of Pentronic's quality work. Customer requirements may differ depending on the industry and where the product will be used. Regardless, it's about understanding the customer's needs and neither under- nor over-working the result.

"I like structure and systems but there must also be a balance. Everything has to be applicable in real life – you mustn't get lost in documentation. The desire to know how things basically work is what drives me," says Josefin and continues:

"Quality is a special function. Although I have the role of Quality Manager and I build the structure and systems for quality, it is all of us at Pentronic who collectively maintain the quality in our work every day."

Long experience in quality control

Josefin's experience in quality management dates back to when she entered the pharmaceutical industry with a Master of Science in chemical engineering. Her years at a pharmaceutical company in Stockholm gave her a deep understanding of the importance of quality control.

"It was a highly controlled business with very high standards. But I was given freedom and responsibility as my career progressed, which really helped me grow."

Moving to the manufacturing industry

A few years later Josefin accepted a position at 3M in Västervik on Sweden's Baltic coast. The change involved moving to both a smaller town and a completely new working environment. Her lab coat was replaced by a protective coverall and in 2012 her move was completed.

"It was a turning point – in the pharmaceutical industry we wear protective clothing to protect the product but in the manufacturing industry we wear protective clothing to protect ourselves," she says with a laugh and continues:

"3M is a big company. We collaborated a lot between its business units in Sweden and worked with Lean principles, among other things. It was a really good experience. I learned a lot that I still have with me today."

Reducing environmental impact

As well as being a passionate supporter of quality, Josefin is also interested in environmental issues. She drives an electric car to work, has solar cells at home and eats almost no meat. She tries to think carefully about what she consumes and flies very rarely. Because Pentronic is ISO certified for environmental and quality management, Josefin is also responsible for envi-

Josefin Knutsson, Quality and Environmental Manager.

ronmental issues. Pentronic's products are important in many customers' work because accurate temperature measurements are often the foundation for increasing energy efficiency. It is also important for Pentronic to constantly try to reduce the environmental and climate impact of its own operations.

"We analyse how we consume resources and how much waste we generate. In addition, hybrid cars are available as company cars and we've installed charging points."

Where do you see Pentronic in the future?

"Pentronic has developed from a small company into a larger one, which makes it even more important to set a shared standard. It is vital that everyone works to the same standard. I look forward to us mapping our processes more, while we are also continually improving. The foundation of good quality is to keep working on improvements going forward."

Name: Josefin Knutsson
Work as: Quality and Environmental Manager.
Background: MSc in chemical engineering. Has worked in the pharmaceutical industry.
What drives me: "I want to discover how things fundamentally work by taking things apart and seeing how everything fits together – in production but also at other levels throughout the company."

Meet a **barista** who became a **lab technician**

A few years ago Emma Rosenblad's career took a new direction. "Before I became a laboratory technician in Karlstad I managed Löfberg's coffee bar."

EMMA'S DUTIES at Pentronic's accredited laboratory in Karlstad include calibrating temperature sensors and measuring instruments. In her work she benefits from the knowledge she acquired as a barista and coffee expert.

"I worked for 11 years in the restaurant industry and competed in the Swedish Barista Cup for coffee. Then as now, it's very much about technology and technique but of course when I competed the focus was more on flavour."

Swedish championships in coffee making

Emma came sixth in the Swedish Barista Cup. On stage in front of an audience, competitors have 15 minutes to brew and present coffee drinks using carefully selected sorts of coffee.

"During the competition, four taste judges assess whether the flavours match what the contestant has promised. One judge examines the technique and how well the contestant is working and a chief judge monitors the entire competition. The competitive element itself is well rehearsed and analysed down to the last detail," Emma explains.

How can you use these skills in your current job?

"There are many similarities. It's important to be solution oriented especially out in the field, to have a helicopter perspective, to work analytically and to be meticulous."

"I want to learn to understand processes"

"I've always been interested in technology. In my previous job, at the coffee bar, I often fiddled with machines if something broke. I like problem solving and I felt that the job I have now would suit me very well. When I started at Pentronic I'd never visited a steel plant, for example, but I'm a curious and down-to-earth person who wants to learn how to understand processes," says Emma.

PHOTO: Tommy Andersson

» It's exciting both to measure equipment in the lab and the next day to meet customers out in the field. «

Challenges in everyday life

The variety and great flexibility make Emma's job very exciting.

"In the lab I measure temperatures of thermocouples and Pt100s and do electrical calibration of current and resistance. This involves temperature scales from -80 °C to 1200 °C.

"Out in the field I can visit a blood centre in a hospital and calibrate their system for controlling the temperature of the fridges and freezers where they store their blood. The next day I might be out at a steel plant, climbing high furnaces to take measurements and calibrate equipment.

"It's exciting both to measure equipment in the lab and the next day to meet customers out in the field and see our sensors being used in their processes. I also have a great team behind me with a high level of expertise, which enables us to solve the challenges we face."

Do you have any unknown talent?

"I do improvisational theatre, which involves theatrical performances without a script. The great thing is that it's all about raising up the other person on stage and the integration with the audience. It's liberating form of theatre with a lot of laughter."

Emma Rosenblad, Laboratory Technician, Pentronic.

DID YOU KNOW THIS ABOUT **TEMPERATURE?**

Read more about temperature at Pentronic's website.

Temperatures in the universe vary from approx. 3,500,000,000 kelvins (a supernova) to 3 kelvins (outer space). The sun is a yellow class G star. The average temperature of the SUN is

5,600 Kelvins

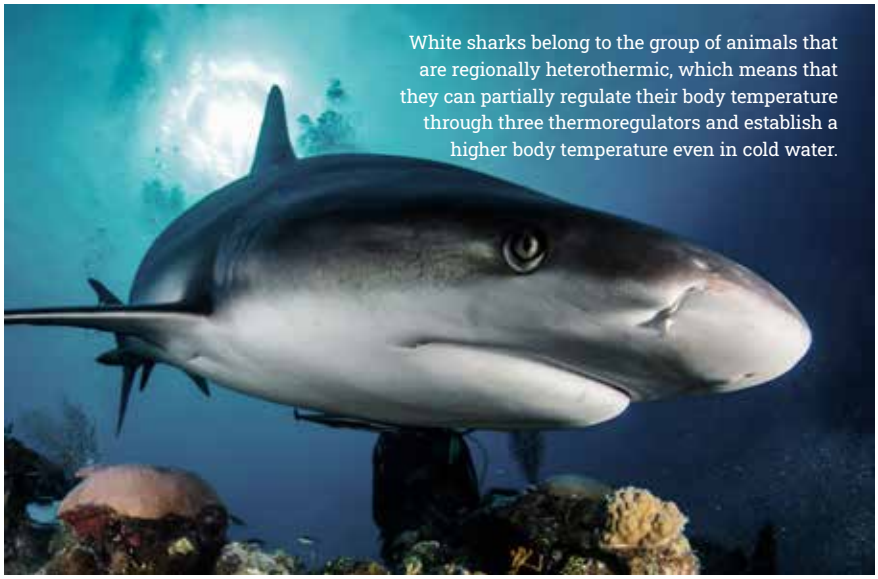
Temperature affects the physical properties of materials, whether solid, liquid, gaseous or plasma: density; solubility; vapour pressure and electrical conductivity. It affects the rate and extent to which chemical reactions take place.

0 ABSOLUTE ZERO is the coldest theoretical temperature. Reaching this temperature has no heat energy. It has been defined as zero kelvins (0 kelvins), which is equivalent to -273.16 degrees Celsius.

A very remarkable fact is that **Fahrenheit** and **Celsius** are equal at **-40 degrees.**

57.8°C is the hottest temperature ever recorded on Earth. It was measured on 13 September 1922 in Al 'Aziziyah in Libya.

CONDUCTION (occurs in solids), **CONVECTION** (occurs in liquids) and **RADIATION** ((passes through space) are the three processes for transferring heat from a substance at a higher temperature to one at a lower temperature.



White sharks belong to the group of animals that are regionally heterothermic, which means that they can partially regulate their body temperature through three thermoregulators and establish a higher body temperature even in cold water.

The temperature of a substance has been defined as a result of the rate at which its molecules move. The theory states that the faster the molecules move, the higher the temperature of the substance.

Temperature affects the amount and properties of thermal radiation emitted from an object's surface.

−89.2 °C is the coldest temperature ever recorded on Earth. It was measured at Vostok Station in Antarctica on 21 July 1983.

Did you know that the triple point of water is not **0 degrees** Celsius but **0.01 degrees.**

ANDERS CELSIUS was a gifted Swedish astronomer. He founded Sweden's first astronomical observatory in Uppsala in 1741 but is best known for the **CELSIUS TEMPERATURE SCALE**, which is used in thermometers all over the world.

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 courses

Pentronic can either offer its regular courses at your premises or tailor a course for your needs. We have extensive experience of providing various types of on-site courses for small or large groups. The training material can be based on your company's own equipment and process, complemented with additions from Pentronic if you wish. The result will be new insights and knowledge that can be directly applied to your own process.

» Not least, this will be of great importance for the environment and the climate, as the HYBRIT technology has the potential to reduce Sweden's total carbon dioxide emissions by at least ten percent. «

Good **temperature monitoring** is important when revolutionising the iron and steel industry

The Swedish iron and steel industry is currently undergoing a revolution which is leading to large and important environmental gains. In order to steer the altered processes in the optimal way and achieve the desired effects, careful temperature measurement is one of many important parameters.

PENTRONIC has been entrusted with supplying temperature sensors for the world-unique HYBRIT (Hydrogen Breakthrough Ironmaking Technology) initiative.

"It is a great pleasure to deliver to a project like this and contribute with our knowledge and experience in temperature measurement," says Morgan Norring, Key Account Manager at Pentronic.

"Not least, this will be of great importance for the environment and the climate, as the HYBRIT technology has the potential to reduce Sweden's total carbon dioxide emissions by at least ten percent."

High accuracy

Temperature measurement is always an important parameter in

the optimal control of a process. The key to Pentronic's delivery to HYBRIT is its employees' high level of competency combined with the company's experience and good reputation in measurement technology.

"Thanks to the many team players and the holistic approach of our skilled employees in production, design and preparation, we are able to create something out of the ordinary and contribute products to a unique project like this," Morgan explains.

"In HYBRIT's pilot plant for direct reduction, it is of great importance that the temperature is measured with high accuracy to give the researchers accurate and reliable information for their calculations and evaluations," says Per Hellberg, Plant Operations Manager at HYBRIT Development AB and responsible for the pilot project in Luleå.

Pentronic is providing customised solutions to measure and verify temperature at several stages during the manufacturing process.

"We supply everything from measurement expertise to developing custom products for specific measurement tasks and situations," says Morgan.

What do you see as the main challenge for Pentronic in delivering to HYBRIT?

"To deliver products that have the right measurement performance combined with challenging mechanical design requirements.

"In general, sensors are exposed to many challenges in the process industry – they are placed in harsh environments and often have to withstand very high temperatures," Morgan concludes. ▮


Morgan Norring, Pentronic.

About HYBRIT

SSAB, LKAB and Vattenfall created HYBRIT (Hydrogen Breakthrough Ironmaking Technology) in 2016 with the aim of developing a fossil-free value chain for iron and steel production. In 2020 a joint pilot plant was built in Luleå.

For over a thousand years, the blast furnace process has used coal and coke as energy in blast furnaces to remove the oxygen from iron ore. The HYBRIT technology is a direct reduction process. This means that instead of coke and coal, fossil-free hydrogen gas is used, which is produced from water with electricity from fossil-free energy sources. A major benefit for the climate is that instead of carbon dioxide, water vapour is produced in the process. In the summer of 2021, the world's first pilot-scale hydrogen-reduced iron sponge was produced.

The HYBRIT technology has the potential to reduce Sweden's total carbon dioxide emissions by at least ten percent. This equates to one-third of the emissions from Swedish industry and could in future help to reduce emissions from iron and steel production worldwide. A key success factor for HYBRIT is a common focus on research, development and collaboration.

CUSTOMER CASE

A **successful** company for **125 years**

Fagerberg is celebrating its 125th anniversary this year. Today the venerable Gothenburg-based company provides Swedish industry with the latest technology for advanced monitoring, control and measurement of flows. Fagerberg has also had a close working relationship with Pentronic for a long time.

LET'S BEGIN with what society looked like before the turn of the last century. Gothenburg was an industrial city on the rise, with expanding transport links and booming technological development. There were gas lamps and horse-drawn trams in the streets and steamships plying the harbour.

It was in this environment that Gustaf Fagerberg founded his company in 1897. His aim was to be an agent selling quality products to shipyards, maritime companies and general industry. At first he focused on wood products and acted as a representative for various manufacturers. In addition his company offered horseshoes, coal shovels, coal buckets and other products typical of the time. It also sold control equipment for ships, engine-room telegraphs and stabilisers.

Customers in demanding industries

Over the years Fagerberg has taken new paths, guided by a vision of becoming Sweden's most sought-after supplier of valves, instruments and safety systems. Today it offers the Nordic region's largest range of valves and instruments, as well as control instruments, pressure proofing and explosion protection systems to the paper, energy, nuclear, chemical, petrochemical and pharmaceutical industries.

"Process industries have high demands on product quality, availability, skills and quality systems," says Peter Sparringsjö, Product and Project Manager for Process Measurement Technology at Fagerberg.

The company cooperates with the leading manufacturers in each product area and actively participates in development work to adapt products to the requirements of Swedish industry. Fagerberg's strength lies primarily in its extensive product knowledge.

"Our product specialists are among the best in Sweden in their fields and use a holistic approach to help our customers optimise their processes," Peter explains.

Delivering total solutions

Having worked in the company for 34 years, Peter has extensive experience in industrial temperature measurement.

The company has been working with Pentronic for almost as long.

"We've had 32 years of cooperation and we know each other well," says Peter.

Qualified temperature measurement is a prerequisite in any process industry. Fagerberg sells Pentronic's temperature sensors, flow meters and other products.

"Together we also offer complete solutions for more complex

deliveries involving a variety of instruments. More and more, customers want to consolidate their purchases to a single supplier," Peter explains.

For system deliveries, Fagerberg is the project manager with technical and delivery responsibility.

"Collaboration in larger projects is the core of our cooperation with Pentronic. For example, we can deliver a package solution that includes temperature sensors together with pressure gauges, flow meters, level gauges and valves from our extensive product range.

"One example where we collaborated was for SCA Graphic when they expanded their paper mill in Timrå. We delivered a complete solution that included a thousand temperature sensors from Pentronic."

What is Pentronic's strength?

"First and foremost, I would emphasise high quality but also fast delivery. Even when we need a product urgently, Pentronic solves the issue quickly," Peter replies.

Peter Sparringsjö, Product and Project Manager for Process Measurement Technology at Fagerberg.

Close dialogue with Pentronic

Fagerberg and Pentronic share a common history. In 1990 Pentronic was acquired by the Fagerberg Group, which was owned by Catena, a company listed on the stock exchange in Sweden. Since 2001 both companies have been part of the Indutrade technology and industrial business group.

Peter Sparringsjö recalls that time:

"I remember when I started as an inside salesman in 1992, having previously worked with Pentronic's temperature sensors in the workshop at Fagerberg. We produced a product catalogue (Temperature Measurement Fagerberg) which included temperature sensors from Pentronic."

Since 2013 Peter has been working in Fagerberg's instrument department and has regular contact with Pentronic.

"Sometimes they call and ask about a certain special product that we've supplied before," he says. "Occasionally I also help Pentronic with product development. For example, we've jointly developed sensors for waste incineration boilers and power plants. The design involves a wear-resistant probe tip on a thermocouple with a long life in demanding environments."

High inventory

A key part of Fagerberg's offering is high stock levels of thousands of items in its large warehouse in Gothenburg, ensuring fast deliveries to customers throughout Sweden. One problem for many industries today is component shortages, a problem that Fagerberg is responding to.

"We've always had a very high inventory but we're now taking the next step. Over the past year we've started to expand our stock. It's becoming even more important for us to be able to quickly deliver products our customers need."

» Our strength is that we can use our expertise to help customers choose the right product for optimal processes. «

The company's service workshops carry out assembly, customisation and on-site service at customers' premises. To Fagerberg, sustainability means that the products it sells should last for a long time, well beyond the warranty period.

"When products wear out after decades of hard work, they should be repairable. That's good for both the environment and the economy," Peter points out.

The key to success

Challenges for Fagerberg include meeting the competition from e-commerce.

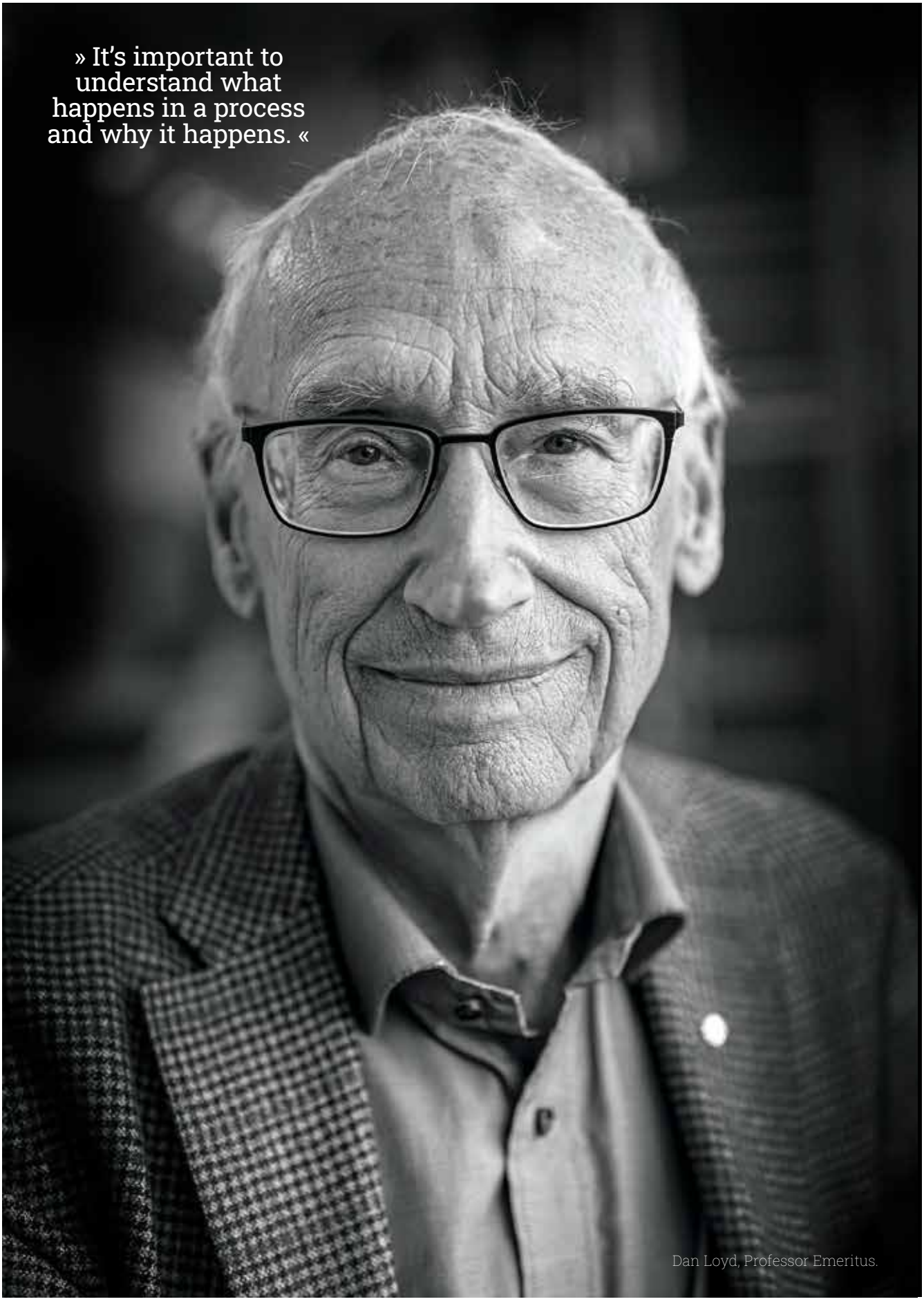
"Our strength is that we can use our expertise to help customers choose the right product for optimal processes. Looking to the future, we know that our products will always be needed in the process industry," says Peter.

What do you see as the key to Fagerberg's success for 125 years?

"There are probably many answers to that. One key year was 1963 when Fagerberg was given the agency for Worcester, which also laid the foundation for today's business. Ball valves from Worcester became a great sales success," Peter concludes. ▮

BRIEF FACTS ABOUT FAGERBERG

Owner: Part of the Indutrade Group.
Head office and warehouse: Västra Frölunda in Gothenburg.
Sales: approximately SEK 300 million.
Number of employees: 60



Dan Loyd, Professor Emeritus.

DAN LOYD, PROFESSOR EMERITUS

"My curiosity is the **driving force** behind my devotion to **research** and **education**"

Partnerships between industry and universities are very important. "Knowledge transfer is a give-and-take situation that works best when both parties benefit," says Dan Loyd, Professor Emeritus at Linköping University and one of Sweden's leading experts in heat transfer and temperature measurement.

PENTRONIC AND DAN first crossed paths back in the early 1990s. Since then their contact has developed into a valuable exchange of knowledge, which benefits both Pentronic and students at Linköping University. Dan has also visited Pentronic with student groups to gain insight into the company's operations.

Why do you think Pentronic is such a successful company in its sector?

"Above all, Pentronic's strength lies in its great knowledge and experience in temperature measurement. The company doesn't just sell measuring instruments and sensors, it sells a function. Pentronic offers standard products but also solves problems that demand special solutions – something that requires great knowledge and interest," Dan says.

Our world is changing

Dan Loyd's own journey began with mechanical engineering studies at Chalmers University of Technology in Gothenburg. He then worked on chemical engineering in Lund before coming to Linköping to focus on research and education in fluid dynamics, heat transfer and thermodynamics.

"My curiosity is the reason why I do research and train students. I want to share my knowledge with both students and industry professionals," he explains.

"Educating engineers who are actively working requires a completely different approach and skill set than training students. It involves a lot of discussion with people who have a different experience, who have seen problems and made observations and know why things happen.

"It's important to understand what happens in a process and why it happens. In our division, Applied Thermodynamics and Fluid Mechanics (MVS), I also have in-house courses for our faculty and I address concrete problems in industry and theorise about them. It's important to continuously develop your skills, as the world around us is changing all the time."

Mutual exchange of knowledge

Some time ago, Per Bäckström, Björn Tunek and Camilla Gustafsson from Pentronic visited Linköping University and met Dan Loyd on his home turf. Together with Roland Gårdhagen, Senior Lecturer and Head of Division, Dan presented the training they are working on.

The subject of applied thermodynamics and fluid mechanics includes heat transfer, aerodynamics, fluid mechanics, bio-fluids and thermodynamics.

"We focus on applications and calculations and we work with education and research in close cooperation with actors in society and industry," Dan and Roland explain. "We have direct contacts with them in our degree projects, course projects and research projects. For knowledge exchange to work, it's important that all parties benefit from it. Companies benefit, we get better skills and educational opportunities, and students

experience the reality they will later encounter."

Refrigerators help to increase understanding

The educational programme combines theory and practical applications. In the basic thermodynamics course, students first make measurements involving refrigerators in order to understand the process.

"The aim is to create a better understanding of heat and temperature in a process," Roland explains.

Students often use simulations to find sustainable and efficient solutions to various flow- and thermal problems.

"One of our projects is to build a solar collector and make measurements and calculations. The upper-year students are given projects with more of an industrial focus, such as measuring and calculating the temperature in the preheating and rolling of aluminium. By addressing real-life problems, students are better prepared when they finish their studies."

Exciting research projects

The research projects cover a wide range of areas. These could be studying flows in blood vessels, increasing process understanding about biogas digestion, or doing practical experiments to evaluate thermal comfort in aircraft cabins. Roland also mentions a project that aims to investigate indoor climate in livestock buildings and to monitor animal movement patterns.

"Temperature measurements are important when simulating indoor climates. The studies are linked to animal welfare, productivity and whether the operation is energy efficient."

> » Knowledge transfer is a give-and-take situation that works best when both parties benefit. «

It's important to have good and developing relationships with companies and organisations.

"This helps to make our students highly sought after, and the research can be used for increased competitiveness and sustainability. For the university, it is a strength that we also have access to Dan's vast knowledge," Roland points out.

How the collaboration developed

Dan, what was it like when Pentronic and you first met?

"Somewhat by chance, we met via a course and found that we had synergetic interests. I was the lecturer of a course in industrial measurement technology run by one of Sweden's leading association of engineers and architects, Svenska Teknologföreningen. The course was aimed at engineers throughout Sweden."

Dan then began writing articles about heat transfer aimed at measurement engineers, which Pentronic published in its customer magazine.

"I raised various problems and supplied an explanation and a solution to the problem. These were not only measurement problems but also heat transfer problems. It was especially good that some readers also sent in questions, which we then answered."

This flow of knowledge had a great impact on both Pentronic and the curriculum.

"It has been interesting and instructive to be able to use real problems from industry in our training for students and in continuing education for teachers," says Dan.

"This is often how our industrial partnerships work. Knowledge transfer is a give-and-take situation that works best if all parties benefit from it."

What do you think made Pentronic see great value in this?

"Pentronic didn't just want a solution to a problem, it perceived greater value in being able to educate its customer base as well," Dan concludes.

Dan Loyd, Professor Emeritus and Roland Gårdhagen, Senior Lecturer.

FACTS

The Division of Applied Thermodynamics and Fluid Mechanics is part of the Department of Management and Engineering (IEI). With more than 500 employees and 20 divisions, IEI is the largest department at Linköping University. Courses and programmes are offered to more than 9,000 students each year. The department strengthens and develops tomorrow's industries, business sector and society through its pioneering research, educational programmes and new innovations.

Björn Tunek, Per Bäckström and Camilla Gustafsson of Pentronic together with Professor Dan Loyd and Roland Gårdhagen in front of one of Linköping University's buildings.

Collaboration with medical researchers

THE DIVISION of Applied Thermodynamics and Fluid Mechanics has a long tradition of also collaborating with the University Hospital in Linköping. With regard to research on flow in the heart and the major blood vessels, Dan was one of the pioneers.

"As is often the case, a research project started by chance," says Dan.

Bengt Wranne, a physician, had read an article in a journal to which he reacted. Based on his own experience, he thought that the information about blood flow in the heart was not correct. He then contacted a researcher at the Centre for Medical Technology Assessment, Per Ask, who knew that Dan was working on fluid mechanics.

"We concluded that the article contained an error in fluid mechanics. This was in the early 1980s when ultrasound had begun being used more often in medicine. I've been working with the University Hospital ever since," says Dan.

What I want to measure and what I actually measure

THE INTERPLAY BETWEEN TEMPERATURE MEASUREMENT AND HEAT TRANSFER

When measuring temperature, we must always consider the difference between the temperature we want to measure and the temperature that the sensor actually measures. An ordinary thermometer (contact thermometer) always measures its own temperature and absolutely nothing else. Examples of contact thermometers are thermocouples, resistance thermometers (e.g. Pt100s) and thermistors.

ONE EXAMPLE OF a contact thermometer is the sensor that measures the temperature outside a car. The sensor's placement varies between car models. In some cars the sensor sits on the underside of the car's right side mirror. Another common location is by the front bumper. Whatever the placement, more or less the same debate occurs about which factors influence the temperature measured by the sensor.

A car driver may want to know the temperature of the road in order to assess if there is a risk of a slippery surface. But the kind of sensor installation just described will almost certainly not give the driver relevant information about the road temperature. True, the sensor is influenced by the road temperature via radiation, but it is also influenced by the temperature of the air, the car, the surrounding terrain, the sky, the sunshine (if any) etc.

The right side mirror's heat exchange with the air, and thereby that of the sensor, occur via convection. A heat exchange also occurs via radiation between the side mirror and its surroundings (i.e. the road, the side of the car, the terrain at the side of the road, and the sky). The side mirror is also influenced by the heat flow to/from the place where the mirror joins the car door. Inside the side mirror, the heat is transferred via thermal conduction. The sensor's reading can also be influenced by water that reaches the sensor.

Sensor's temperature

Car drivers become aware that the car's speed also influences the measurement result. In queues of cars and in dense, slow traffic, factors such as hot exhaust gases disrupt the temperature measuring process. The faster we drive, the more the convective heat exchange with the air influences the sensor temperature. At high speeds, the air temperature will therefore have a dominant influence on the sensor's temperature.

Unfortunately, many factors influence what we are measuring. Some examples: The air temperature often varies according to the sensor's height above the road, which means that the sensor's location influences the measurement reading. The temperature and emission coefficient of the road, the surroundings and the car vary and influence the heat exchange via radiation. The side mirror's thermal balance and temperature also influence the sensor temperature. Rain, air humidity and dirt can also influence the reading.

The measured outside temperature can be used with caution to assess whether there is a risk of slippery conditions. Unfortunately, the road temperature is only one of the factors influencing the sensor. The air temperature at the sensor's height above the road can very well be above 0 °C even though the road temperature is below 0 °C. In this case, there is a considerable risk of making the wrong judgement.

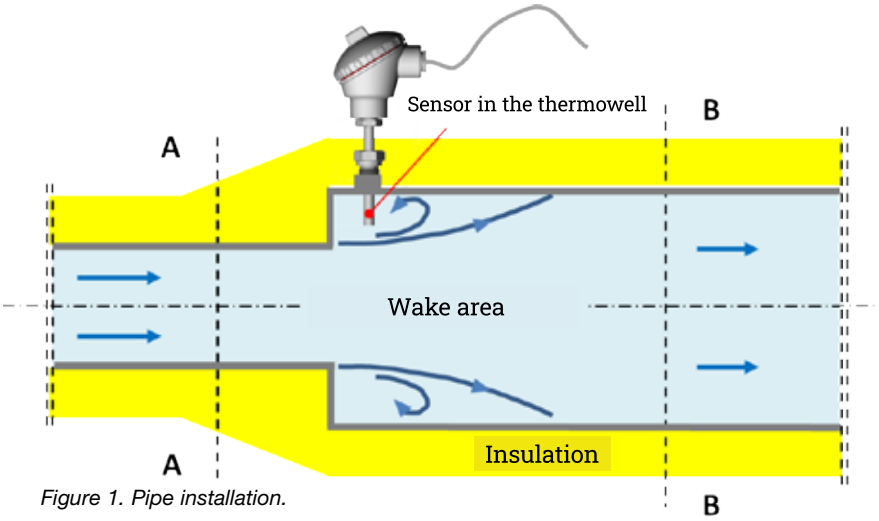


Figure 1. Pipe installation.

Measurement equipment's response time

If the air temperature or another parameter changes, the driver does not receive any immediate information about the change – in this situation, the influencing factor is the measurement equipment's response time, which in some cases can be fairly long. For example, if your car has been standing in a warm garage overnight and you drive it out on a cold morning, you will find that it can take several minutes before the sensor measures a relevant temperature. Another example is when you are out driving under a cloud-free autumn night sky when the temperatures of both the road and the air are a few plus degrees. On bridges the road surface can have a temperature that is below 0 °C and sometimes this also holds true for the air temperature. In many cases, the measurement system's response time can be so long that you have had time to cross the bridge before you receive information about the temperature change.

Car manufacturers are, of course, well aware of the limitations of this measurement system. In many cases, they often therefore warn the driver by activating a warning light or displaying a suitable symbol when the measured temperature is a few degrees above 0 °C. The manufacturer then gives the driver the responsibility of determining whether there is a risk of a slippery road surface.

Based on this example of the car thermometer, we can assume that in almost all cases of temperature measurement, there is a difference between the temperature that we want to measure and the temperature that the sensor measures. The measuring system's response time also means that we receive information about temperature changes with a certain amount of delay. We can also note that the measurement result depends on the interplay between the heat transfer and the flow around the contact sensor. The heat transfer is influenced by convection, heat conduction and radiation. In turn, the convection depends on the properties of the flow.

Another example of a measuring problem with multiple complexities is measuring the temperature inside a hot water pipe in which a sheathed thermocouple has been installed in a thermowell as shown in Figure 1. Let us consider the measurement error and the response time that we get in this case. We can also think about whether the chosen placement of the temperature sensor is the best or if another, optimal placement exists.

Sheathed thermocouple

The installation of the sheathed thermocouple in the thermowell is shown in Figure 2. Heat is transferred from the water to the thermowell via forced convection. Inside the thermowell and sheathed thermocouple, the heat transfer occurs via thermal conduction. Here we must always check that the contact between

the sheathed thermocouple and the thermowell is excellent. Poor contact will result in an unnecessary measurement error. The heat transfer to the surrounding air occurs via thermal conduction in the thermowell, the sheathed thermocouple, the steel pipe, the insulation etc. The heat flow from the exterior surface of the insulation and from the measurement equipment outside the insulation to the air occurs via convection and radiation.

The heat transfer from the water to the surroundings means that the sensor will measure a slightly lower temperature than the water temperature, which results in a small measurement error. By reducing the thermowell's diameter and increasing its length, we will reduce this type of measurement error. By increasing the thickness of the insulation, we will reduce the heat flow to the surroundings. This will also reduce the temperature difference between the water and the sensor – and thereby reduce the measurement error.

Many urban centres in Sweden heat homes and buildings by operating a central district heating plant from which underground heating pipes run to individual buildings. Inside the buildings, heat exchange then occurs between the district heating water and the water inside the building's own heating system. The water in the district heating pipes is normally very clean and therefore we do not need to worry about any possible contamination to the thermowell. However, in cases involving dirty fluids, problems can arise. If the thermowell becomes contaminated and acquires a coating, it is true that the increased thermal resistance in the coating will reduce the heat flow to the thermowell and on to the surroundings, but the contamination will also increase the temperature difference between the fluid and the measuring junction – and the measurement error will increase.

With a contaminated thermowell, there is greater thermal resistance between the liquid and the measuring junction than in the case of a clean thermowell. If the water temperature changes, the heat flow from the water to the measuring junction will therefore be less with the contaminated thermowell than with the clean one. The lessened heat flow means that the response time increases when the water temperature changes. Accordingly, the contamination negatively influences both the measured value and the response time.

We should also consider how the placement of the measurement equipment inside the pipeline influences the response time. For example, if we want to achieve the shortest possible response time in this particular pipe configuration, we should avoid the installation shown in Figure 1.

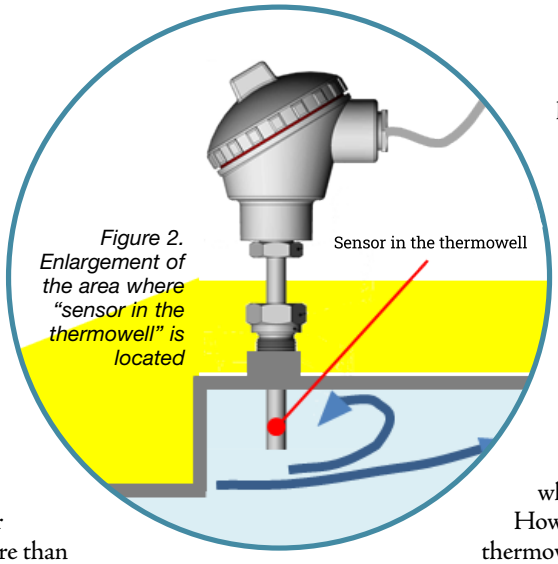


Figure 2. Enlargement of the area where "sensor in the thermowell" is located

Dirty fluids

This is because downstream from the pipe's increased diameter, there occurs a wake which is characterised by low flow velocity and recirculating flow. The low velocity means that the water temperature in this area adapts relatively slowly to the temperature of the main flow. A low velocity around the thermowell also limits the convective heat flow to the thermowell and thermocouple. This means that the sensor reacts slowly and its response time can be fairly long. In the case of dirty fluids, the dirt often accumulates in the wake area. However, one advantage of this particular installation is that it leads to a minimal extra pressure drop.

If you want the shortest possible response time, you should install the sensor in section A-A in Figure 1, where the water velocity is highest. However, the pressure drop caused by the thermowell will be slightly greater in the pipeline of this particular installation. The flow velocity in section B-B is lower than that in section A-A. A sensor installation in section B-B will therefore result in a slightly smaller pressure drop, but it will also lead to a slightly longer response time than in the case of an installation in section A-A. The risk of contaminating the thermowell is less in sections A-A and B-B than it is in the original installation.

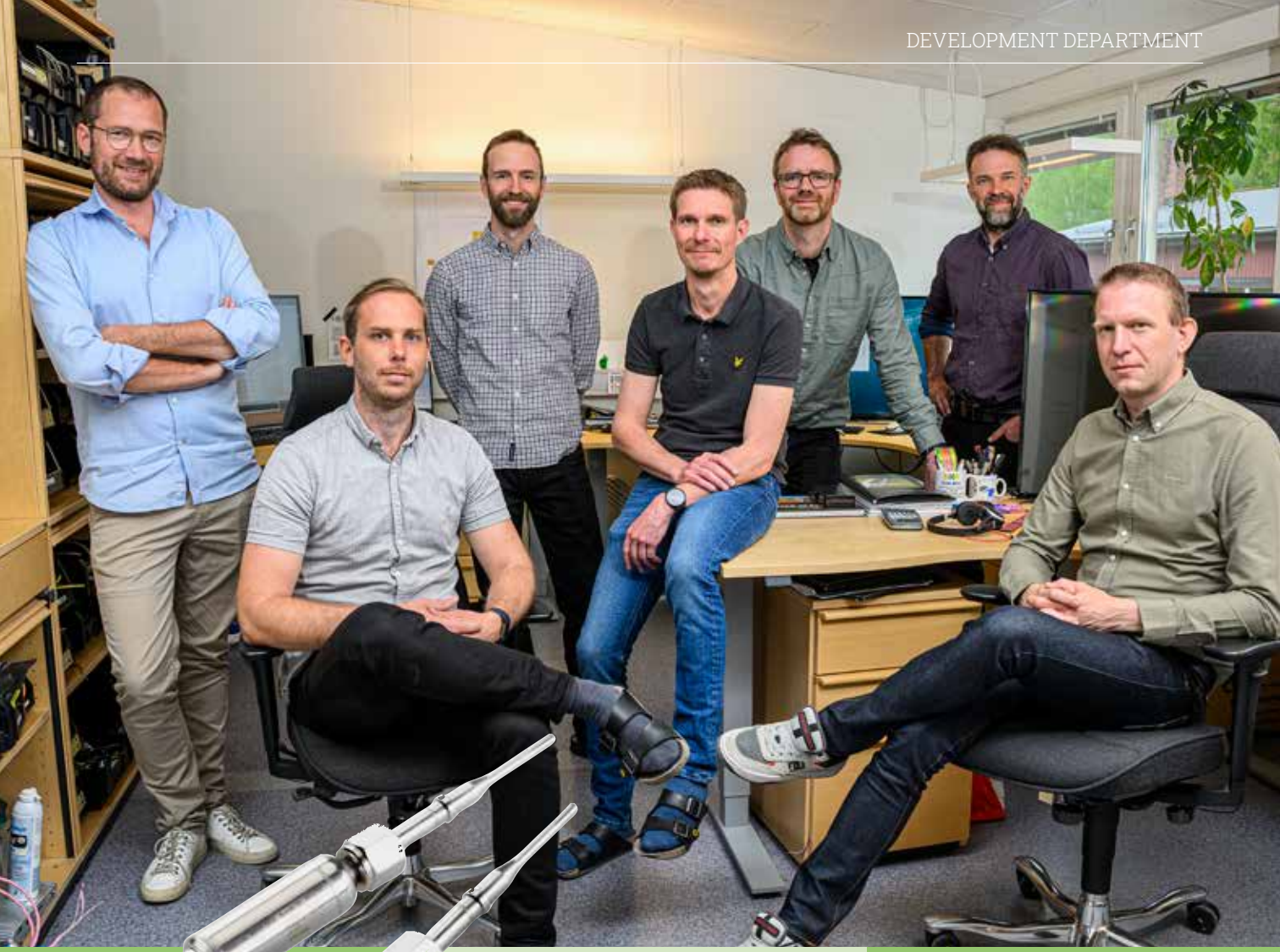
In many cases, the pressure drop caused by the thermowell is of limited significance to the total pressure drop in the pipeline. As usual, assessing how the pressure drop and other disturbances caused by the thermowell influence the flow and heat transfer must be done on a case-by-case basis. To determine the response time and pressure drop, it is necessary to take a measurement or do a calculation. The influencing factors include the geometry and properties of the sensor, thermowell, pipe and insulation, as well as the properties of the flow. If we want to minimise the pressure drop in the pipeline, we must also replace the abrupt joint between the pipes with a conical one.

Measurement system influences the response time

To summarise the lessons learned from both these examples, a difference almost always exists between the temperature that we want to measure and the temperature measured by the sensor. This difference is due to such factors as the design of the measurement system, which also influences the response time. Both the measurement error and the response time are influenced by the heat transfer and the flow. We can also note that if we know how the measurement error and response time arise and are influenced by the heat transfer and flow in the particular measurement system in question, the measurement problem will be both simpler and more manageable.

Somewhat drastically, we could say that we are measuring the wrong temperature on the wrong occasion. However, by using the right equipment and the right installation, we can minimise the measurement error and achieve an acceptable response time. ▮

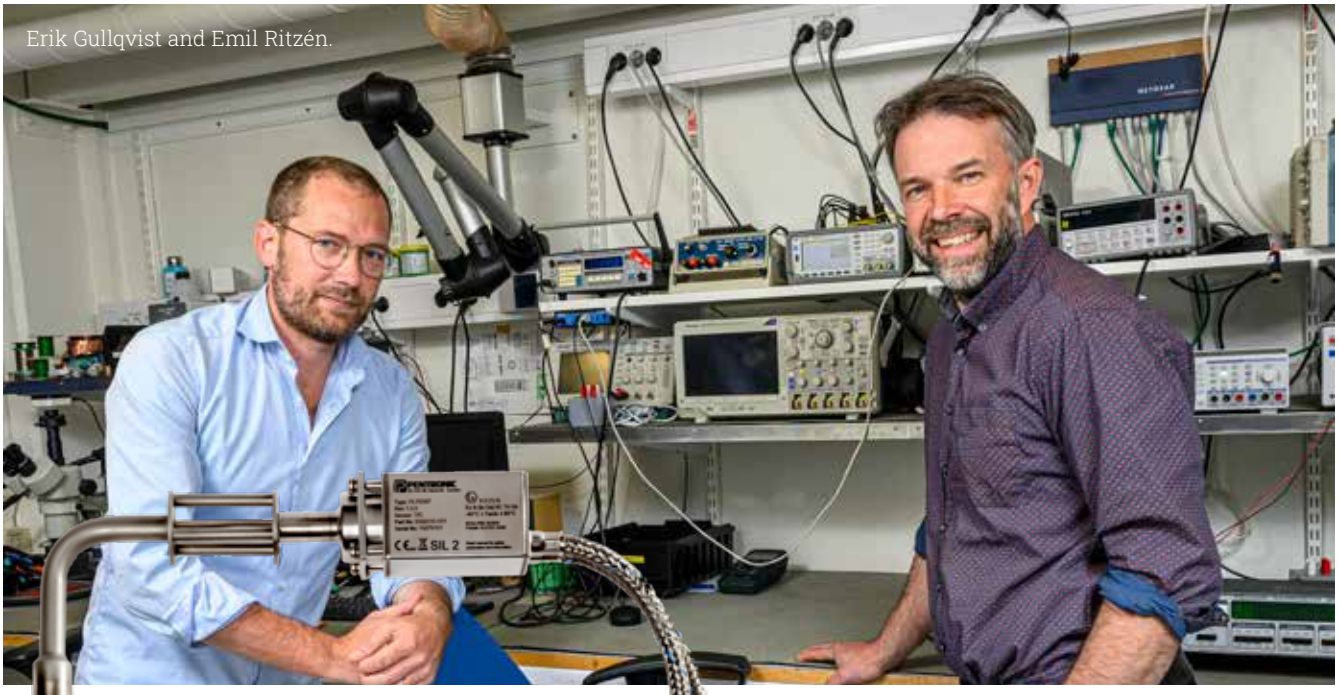
– Dan Loyd, Professor, Emeritus
Linköping University



Pentronic's development department possesses top-level expertise for developing mechanical solutions, electronics software and hardware, and sophisticated testing equipment.

The development department, consisting of Erik Gullqvist, Jonas Thellman, Jan-Erik Johansson, Daniel Sjögren, Viktor Nilsson, Emil Ritzén and Per Johansson, has a central position in Pentronic's business activities. The department is located at the heart of the workshop close to the production department and is in daily contact with it.

Integrates **mechanics and electronics** in customer-unique **temperature sensors**


Erik Gullqvist and Emil Ritzén.

"BECAUSE OUR entire production chain is in house, we have good capacity for successfully responding to the challenges and tasks we encounter," say Product Development Manager Erik Gullqvist and Electronics Development Manager Emil Ritzén at Pentronic. "Because we're a small organisation we can act quickly but we're also equipped to handle large projects."

Smart sensors in demand

In response to market demand, Pentronic decided to set up its electronics department in 2005.

"Our customers asked us as their subcontractor if we could also supply them with smart sensors," Emil explains. "That led to the electronics department being founded and since then its activities have gradually increased. Often they involve supplying specially adapted and customised solutions."

"The process industry and OEM machine builders want suppliers who can deliver quickly and who offer customised solutions," Erik says.

"Our great flexibility means that we can supply customer-unique temperature sensors in which we integrate mechanical constructions with electronics.

"In order to quality assure the software and the optimal functioning of our projects in environments where they will be used, we have created a rigorous testing environment and we apply sophisticated testing methodology."

The path to greater digitalisation

"Temperature measurement principles have basically stayed the same ever since the nineteenth century but new, smart technical solutions are leading to improved temperature measurement performance," Emil explains.

Thanks to a high level of engineering expertise, Pentronic has managed to respond well to the development from electrical cabinets to digital transmitters.

"We've known of the trend towards more digitalisation for a long while but we took our first step in 2005. Traditionally, electronic equipment for processes was enclosed in control cabinets, which required long cables leading to the measurement equipment. By instead using digital technology close to a process, and integrating mechanical constructions with electronics in temperature sensors, we can achieve a very precise product."

Certified products

Pentronic's broad range of certified products for specific applications meets high demands for various processes. The products include explosion-proof versions as well as Pt100s and thermocouples for Ex environments.

"We offer integrated technology both for small installations and for large machinery builders and the process industry, which place high demands on functional safety," Erik says. "We supply sensors for specific measurement tasks, whose critical parameters can include temperature range, measurement accuracy and rapid response times. This can even involve entire measurement systems with digital connectivity."

Two returnees brought valuable expertise

ERIK GULLQVIST AND EMIL RITZÉN both graduated in engineering from Linköping University and both have come home to Västervik.

"I'm really an accompanying returnee," Emil says. "In 2006 my wife and I chose to move to beautiful Västervik after eight years in Södertälje. I brought with me knowledge about software and electronics and since then I have worked in the development department."

Erik originally comes from Västervik and has worked for Pentronic during the summers.

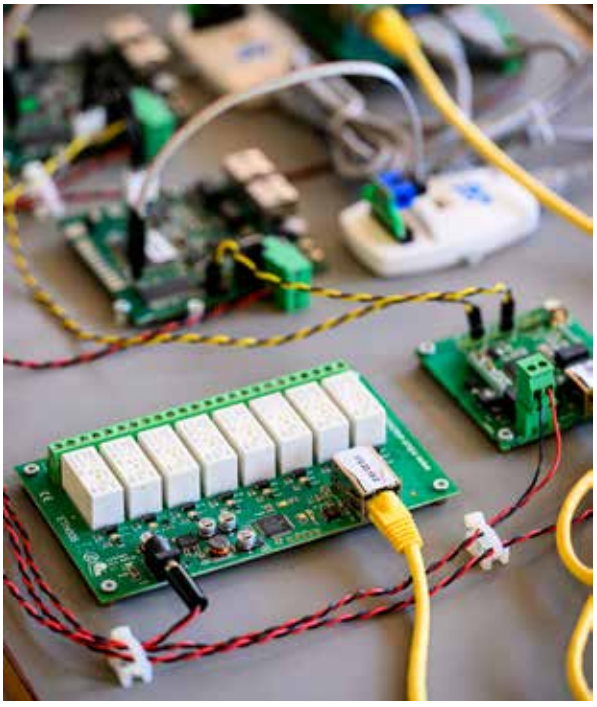
"After having lived in Strängnäs for a number of years, our family chose to move to Västervik in 2008. At the development department I began working with software, systems architecture and certification," Erik says.

About Erik Gullqvist

Job position: Joined Pentronic in 2008 and has been Product Development Manager since 2021.
Leisure interests: His main interest is cooking, which he thinks is both fun and relaxing. Also grows vegetables in his garden.

About Emil Ritzén

Job position: Joined Pentronic in 2006 and has been Electronics Development Manager since 2018.
Leisure interests: Is a hobby farmer. The dream that attracted Emil when he moved to Västervik was to have a farm by the sea. His farming activities include working with a North Swedish horse.



Faulty connections of **thermocouples**

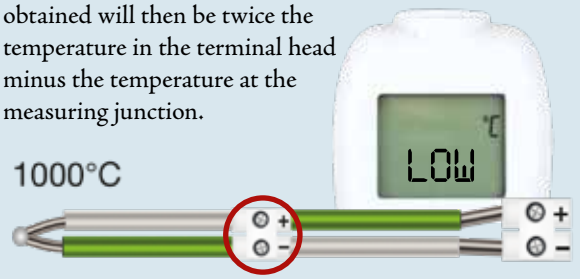
Here is some advice to ensure that your instrument will display the correct temperatures.

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".

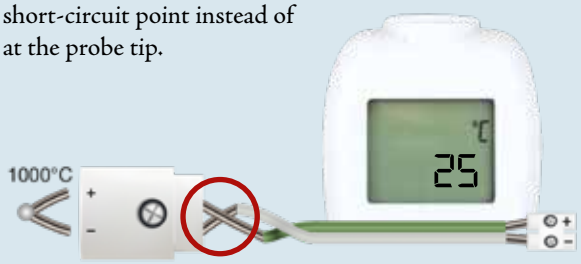
Reversed polarity within the measuring circuit

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.



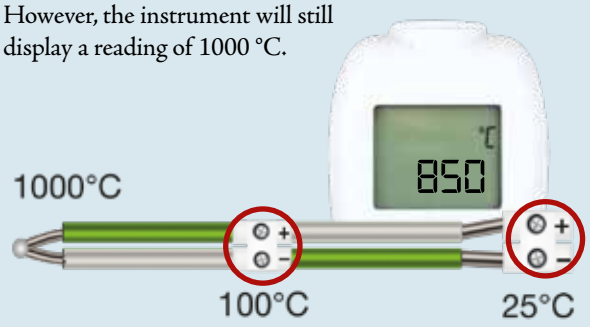
Short circuit

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.



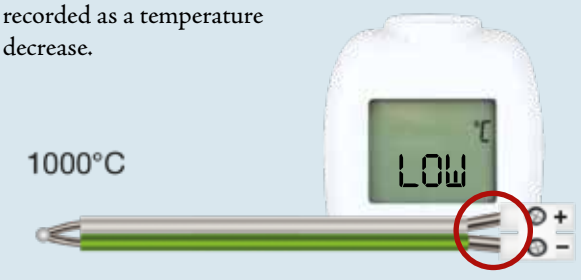
Double reversed polarity

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.



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.



NB! The labels in the figures do not refer to Pentronic's own markings on connectors etc.

TECHNICAL ARTICLE

Common connection errors with **RTDs**

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.

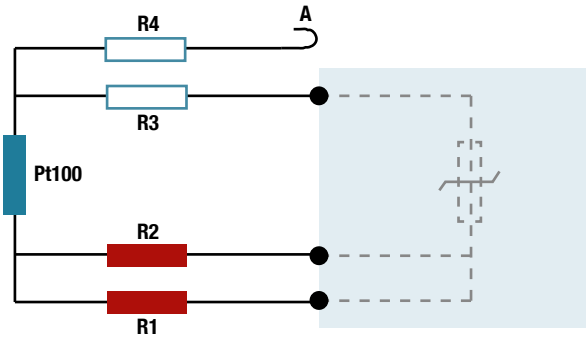
With a 10 m 4 x 0.25 mm^2 extension cable the measurement error is approx. 0.9 °C.

3-wire Pt100 to a 4-wire indicator

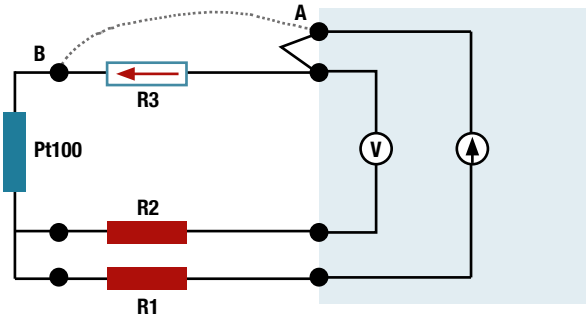
A Pt 100 with 3 wires plus an instrument for 4-wire connection. The changeover from 4 wires to 3 is done as close to the sensor as possible. In the adjacent figure this is done at B, as shown by the dashed line.

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 mm^2 wire).

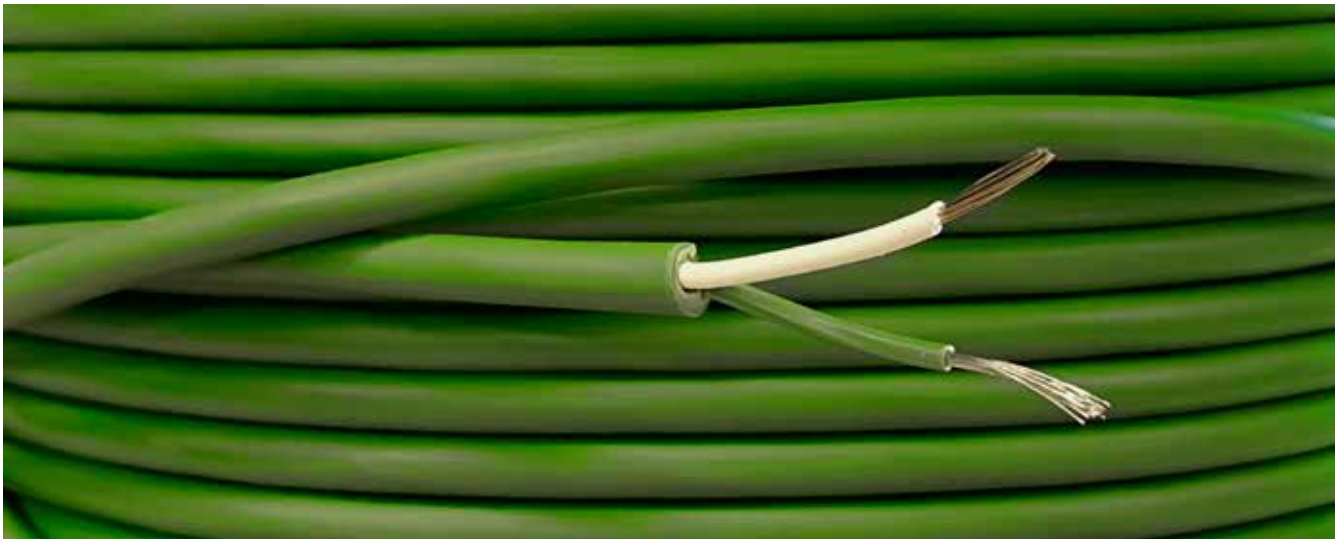
When the connection is correctly made at B, the measuring current encounters less resistance en route to the Pt100. For a short process sensor, the increase can lead to a measurement error of approx. 0.1 °C.



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



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.

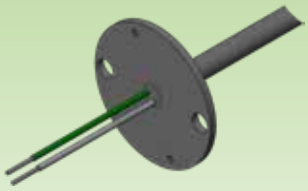


Common connector options for **thermo-couples** and **resistance thermometers**

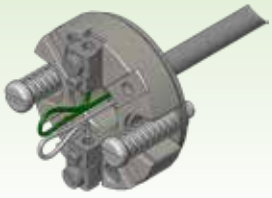
Connectors are a critical part of your measurement chain and when choosing which one to use, it is important to consider not only the measurement uncertainty but also the accessibility, the surrounding environment and the ease of replacement. There is now a great variety of both connectors and casings, 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

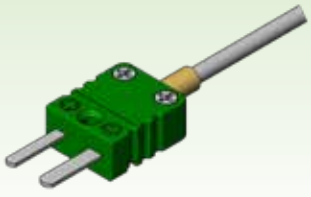


Measurement insert ready for mounting of a terminal head or transmitter (T/E or Pt100)



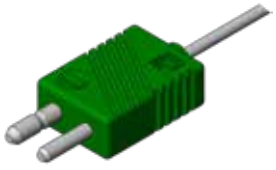
Measurement insert with terminal head (T/E or Pt100)

Miniature female connector mounted on a cable



Miniature male connector mounted on a sheath

Standard female connector mounted on a cable

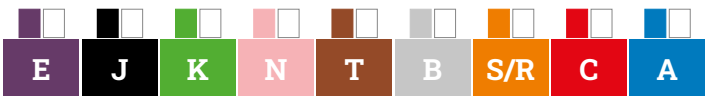


Standard male connector mounted on a sheath

M12 connector mounted on a cable or sensor

LEMO connector mounted on a cable

Measurement insert with transmitter (T/E or Pt100)



The thermocouple connectors shown above are available not only for green type K but also for other thermocouple types in accordance with IEC 60584:3 – 2022. They are also available for three different levels of temperature resistance (+200 °C, +350 °C and +650 °C).

Instrument portfolio

Here is a selection of our products.

Temperature indicators

Measurement systems

Wireless IR pyrometers

Flow meters

Glass flow meters (GFM)

Moisture meters and NIR equipment

Data loggers

Transmitters

Calibration equipment

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.
Example models: 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.
Example models: 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.
Example models: 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.
Example models: 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 to 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.
Example models: PAT 1101, PLT1101, PIO 1101.

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. IEC/Atex approved.
Example models: PLB 5000, PCX5451, PLT5167, PLZ5291.

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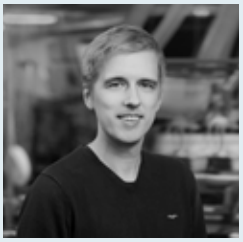

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