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ABB MEASUREMENT & ANALYTICS | WHITE PAPER

TSP341-N

High-precision non-invasive temperature measurement

Measurement made easy

HERMES AWARD 2019

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Temperature sensor for non-invasive temperature sensor TSP341-N

Introduction to Edition II with comparative measurements

This white paper presents ABB's new TSP341-N temperature sensor for non-invasive temperature measurement and provides examples for applications and accuracies that can be achieved.

The present Edition II of the whitepaper additionally presents the results of a direct comparison of non-invasive temperature measurements with classic measurements in a measuring medium, achieved in realistic conditions. These results emphasize the outstanding suitability of the device for multiple applications.

The TSP341-N surface-mounted temperature sensor allows for high-precision, reliable temperature measurement without the need to intervene in the process by taking the ambient conditions into account.

This also contributes to significantly increased system safety. Thanks to the quick and easy surface mounting and by eliminating the thermowell and the need to open the process, substantial cost reductions can be achieved.

In addition, flexibility within the system is increased because the sensor can also be retrofitted at any time, or even temporarily installed for additional measurements.

Classic temperature measurement in the measuring medium

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01 Classic installation of temperature sensors in piping

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02 Robust thermowells for demanding applications

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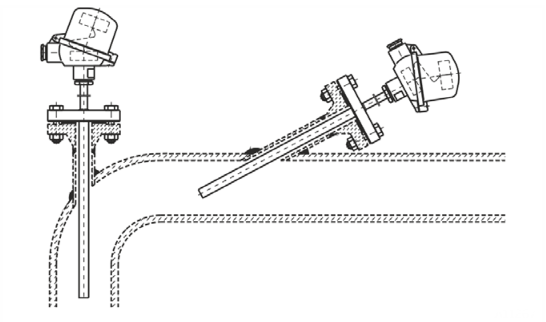
Further reading
[01] "Industrial temperature measurement, basics and practice".
ABB Automation Products GmbH (2013)

Virtually no chemical process can do without temperature measurement. For the most part, its purpose is to guarantee system safety, secure product quality and increase process efficiency.

Classic temperature measurement in process technology is carried out by directly inserting a temperature sensor with a thermowell into a measuring medium, which is usually located in a vessel or piping. Measuring media are made of substances in liquid, pasty or gaseous state and are often also a mixture of these states. In addition, they can contain solid particles. A measuring medium can be chemically aggressive as well as abrasive. It may be at a standstill or it may flow at high speed.



01

The situation described in the classical temperature measurement setup shows that contact with the measuring medium can bring a wide array of difficulties. These difficulties have to be mastered for reliable and, above all, safe system operation, which leads to high costs [1].

Costs are already incurred during the planning and design of a system for openings in vessels and piping, through which the temperature sensor is introduced into the measuring medium. Here, for example, flanges as well as structural reinforcements are required that must satisfy some of the strictest safety requirements.

Thermowells must be designed for the characteristics of the medium to be used to protect the temperature sensor against chemical and mechanical stress. Abrasive dust or sand, which move through the piping at high speeds, present a special challenge. Since both abrasive and chemically aggressive media can lead to a critical removal of the thermowell material, these thermowells must be regularly inspected and replaced if necessary. Special thermowell materials lead to high additional costs.

The inspection and, if necessary, exchange of thermowells requires at the least a partial standstill of the system and usually also a complete emptying of the system. This also applies in the event that additional measuring points need to be installed. Furthermore, the use of thermowells in a pipeline can increase the cost of cleaning, if for example regular cleaning by using so-called "pigs" is not possible.

02

… Classic temperature measurement in the measuring medium

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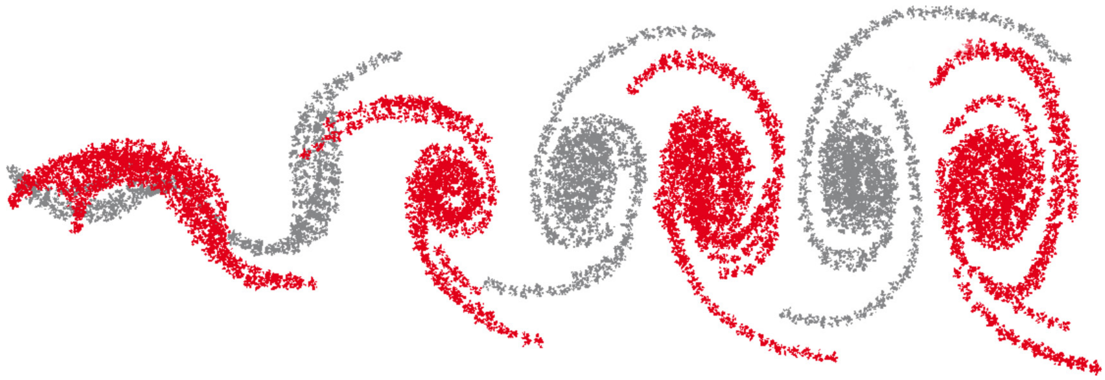
03 Vortex formation in the area of a thermowell in the flowing measuring medium



03

In addition to increased costs, the safety aspect must also be considered:
A thermowell placed in flowing media can begin to vibrate due to vortex formation and in extreme cases it can break. This can have dramatic consequences, not only for the system, but also for the whole environment.

In 1995, at the Monju Nuclear Power Plant, the only 'fast breeder' nuclear power plant in Japan, a serious accident occurred after a fracture of a thermowell due to vortex formation, in which large quantities of leaked sodium led to excessive heat generation after a chemical reaction and melted steel parts of the system.

Therefore, norms and standards such as ASME PTC 19.3 TW 2010 and later on, TW 2016 for the stability of thermowells have become more restrictive over time, and so the costs of maintenance and exchange have increased as well.

The safety risks and cost factors mentioned above can be eliminated if the process temperature could be measured in a non-invasive and reliable manner outside of the process.

ABB's new TSP341-N surface-mounted temperature sensor allows in many cases for process temperatures to be determined with accuracy and repeatability which is sufficient for the specific application.

Temperature sensors from ABB for surface mounting

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04 The non-invasive TSP341-W temperature sensor in use

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Further reading
[2] T. Merlin et al.: "Absolute zero invasion", ABB Review 2015(4), page 62 to 67, November 2015.

In addition to temperature sensors for classic use with thermowells, ABB has been supplying surface mount sensors for non-invasive temperature measurement for quite some time. These currently include the SensyTemp TSC400 series industrial thermometers for universal use in vessel and piping construction, as well as in machine and system construction in general. Special versions of the SensyTemp TSP100 and TSP300 sensors for process measurement technology are also available.

ABB's first new-generation sensor from the line of sensors for non-invasive temperature measurement in process technology is the SensyTemp TSP341-W ('W' stands for 'wireless') introduced in 2014. Thanks to the WirelessHART communications protocol, this surface-mounted temperature sensor is also especially suited for subsequent extensions in industrial facilities.

Optionally, the TSP341-W can be supplied with an Energy Harvester, which recovers the required electric energy from the temperature difference between the process and ambient temperatures, thus allowing for fully autonomous operation.

The TSP341-W successfully stood its first test in an extensive pilot installation, where sensors were installed without the need to interrupt the production processes. Valuable insights were gained here, including the influence of the mechanical design of the sensor at the test point, various types of insulation and different flow conditions. This allowed the measurement accuracy in the installation to be improved from initially several Kelvin to approximately 1 K and the response time to be cut by 75%, which meant that the performance of a classic invasive temperature sensor had almost been reached [2].
With this performance level, the TSP341-W sensor has been successfully implemented worldwide.

04

Non -invasive temperature sensor TSP341-N

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05 The non-invasive temperature sensor TSP341-N (display optional)

Even after the non-invasive TSP341-W provided a very high level of measurement accuracy simply by exploiting the thermo-mechanical optimization potential, it was a natural step to further improve the accuracy with model-based algorithms, taking into account the ambient conditions during measurement. Ambient temperature plays an especially important role here.

05

This demanding development goal was successfully implemented for the new TSP341-N temperature sensor presented here.
The TSP341-N surface temperature sensor now combines non-invasive temperature measurement with the established HART communications protocol in two-wire technology. Therefore, the sensor can be integrated into existing system structures without any issues whatsoever. The 'N' in TSP341-N stands for non-invasive temperature measurement. As it was the goal, the calculation algorithms developed by ABB for non-invasive temperature measurement take ambient conditions into account during the measurement and therefore increase the accuracy of the surface measurement even more significantly.

The TSP341-N temperature sensor has two temperature sensors. In addition to the surface temperature at the measuring point, the ambient temperature in its vicinity can also be measured.
The sensor is equipped with a temperature transmitter with a current output of 4 to 20 mA and communication via the HART 7 protocol, based on the successful and market-established TTH300 HART by ABB.
The calculation algorithms built into the transmitter firmware calculate and output the process temperature in real time over a measuring range of −40 °C to 400 °C
(−40 °F to 752 °F).
The connection head of the TSP341-N is made of epoxy-coated aluminum or stainless steel with optional LCD indicator.

Suited measurement media and their parameters for non-invasive temperature measurement using the TSP341-N
A special development goal for the TSP341-N sensor was a high level of user-friendliness. Following the simple surface installation, the device should also be easy to operate and possible to put into operation immediately. Therefore, the only parameter relevant for the calculation algorithms is the information if an insulation is present at the measuring point (preset at delivery) or not. Other parameters such as thickness, material or the thermal conductivity coefficient of the piping or vessel at the measuring point, or even specific information on the material and geometry of the insulation are not required for proper and accurate operation of the sensor. This also facilitates the ordering process for the TSP341-N, and the device can later be used flexibly at different measuring points.

Extensive research has shown that for many application scenarios, the temperatures of the outer wall, inner wall and process (measuring medium) can be assumed to be virtually the same for metal pipes and vessels. Thus, a calculation of the temperature difference between the pipe outer wall and inner wall is not required and corresponding parameters for this calculation are not needed.

With the high non-invasive measuring accuracy of the TSP341-N, achieved through
a) thermo-mechanical optimizations and
b) special correction algorithms and documented in the following chapter by measurement results, the surface temperature of the outer wall (of the piping or vessel) can be determined with high precision. With the assumption that there is no relevant difference to the process temperature, the temperature of the measuring medium is therefore determined with great accuracy, too.

However, even with metal pipes, the concept of temperature uniformity between the outer wall and the process is not easily permissible for all measuring media and application scenarios.

Low-viscosity measuring media, media with high thermal conductivity as well as processes with high medium velocity or turbulent flow are especially suited for this concept.
Examples: water, watery solutions and water-based liquids as well as fast flowing oil or saturated steam.
Frequently, however, the temperature of the measuring medium (or the process temperature) can also be determined for other materials and other flow behavior with an accuracy that is sufficient for the specific application.

The following examples show, for substances of different viscosity and thermal conductivity, what measuring accuracies at different medium velocities and pipe diameters can be expected in non-invasive temperature measurement using the TSP341-N.

For calculations with the help of empirical formulas, metallic piping and insulation at the measuring point are assumed.
The following parameters are taken into account:

- Temperature of the outer wall T_{surf}
- Temperature of the measuring medium T_m
- Ambient temperatur T_{amb}
- Medium velocity v
- Pipe diameter D
- Dynamic viscosity η und spezific thermal conductivity λ, represented with typical materials in three examples

The three-dimensional presentation on the left side of examples 1 to 3 respectively shows the relative measuring accuracy as a function of medium velocity v and pipe diameter D:

$$error_{medium} = \frac{|T_m - T_{surf}|}{|T_m - T_{amb}|}$$

Thus, for example, the following information $error_{medium}$ = 0,02, referred to in the following examples as ΔT_{err} = 2 K, should be understood as a measuring accuracy of ± 2 K pro 100 K of temperature diffenrence between the measuring medium and the environement.

On the right side of examples 1 to 3, the possible combinations of medium velocity and pipe diameter for a measuring accuracy of $\Delta T_{err} \leq 2$ K are shown, partially scaled logarithmically.

… Non -invasive temperature sensor TSP341-N

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06 Measuring accuracy with low viscosity liquids, for example water

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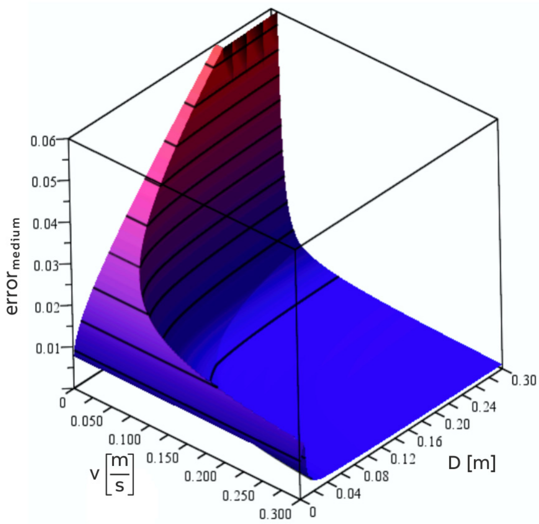
07 Possible combinations of medium velocity and pipe diameter for the measuring accuracy $\Delta T_{err} \leq 2$ K

Example 1 – Liquids with low viscosity

Measuring medium: water, dynamic viscosity η ~1 mPa s



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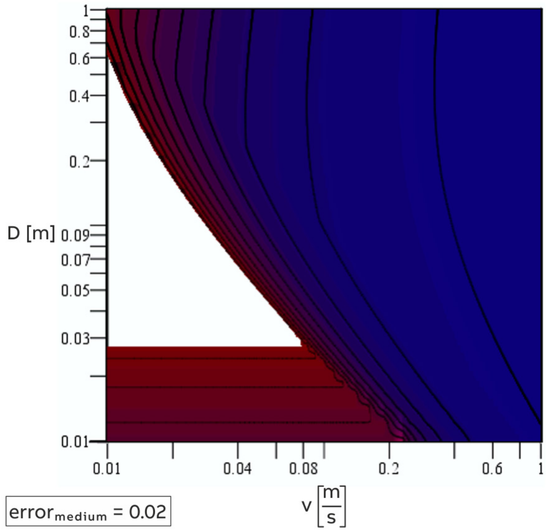

07

Result:

- Regardless of medium velocity v and pipe diameter D, turbulent flow almost always occurs with low viscosity liquids such as water.
- The calculations show a high level of accuracy for all medium velocities for small pipe diameters (D < 3 cm).
- Even at very low medium velocities (v > 10 cm/s), the accuracy is always high regardless of the pipe diameter.

Conclusion:

- For the TSP341-N featuring non-invasive measurement, very high accuracy can be expected for most low viscosity liquid applications.

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08 Measuring accuracy for liquids with low heat conductivity and increased viscosity, for example oil

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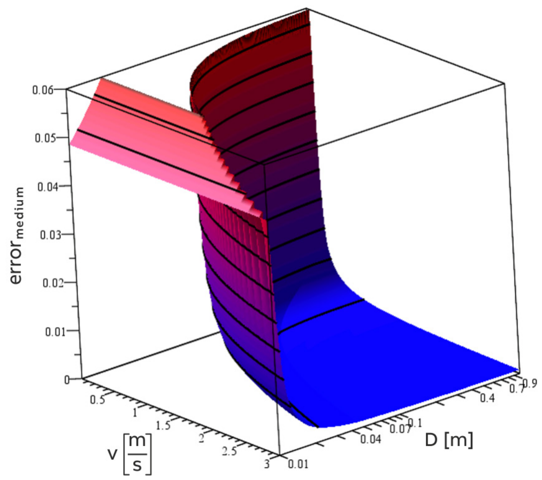
09 Possible combinations of medium velocity and pipe diameter for the measuring accuracy $\Delta T_{err} \leq 2$ K

Example 2 – Liquids with low thermal conductivity and increases viscosity
Measuring medium: Öl, specific thermal conductivity λ ~0,14 W/m K, dynamic viscosity η ~13,4 mPa s



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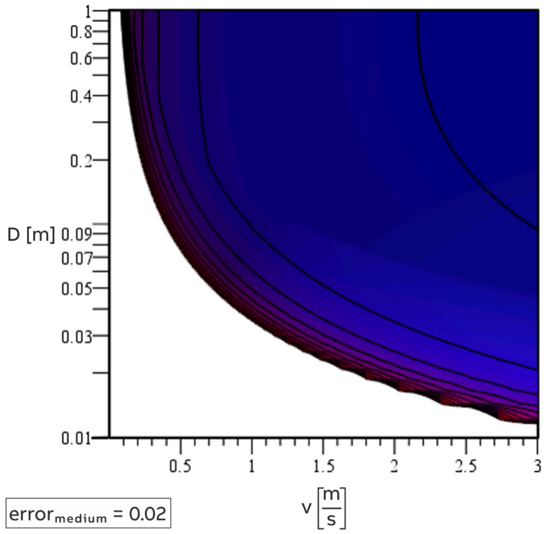

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Result:

- For a high level of measuring accuracy, a turbulent flow behavior of the liquid is required.
- With higher medium velocity v and a larger pipe diameter D, high measurement accuracy can be achieved. For example, with a pipe diameter of D = 5 cm, a medium velocity of v > 70 cm/s is required.

Conclusion:

- For liquids with low thermal conductivity and increased viscosity, non-invasive temperature measurement using the TSP341-N with very high measuring accuracy is possible for high medium velocities and larger pipe diameters.

  In other cases, a possibly insufficient accuracy can be expected due to the physical conditions. ABB will gain further experience here within the scope of pilot projects and special test setups.

... Non -invasive temperature sensor TSP341-N

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10 Measuring accuracy with very high viscosity liquids, for example honey

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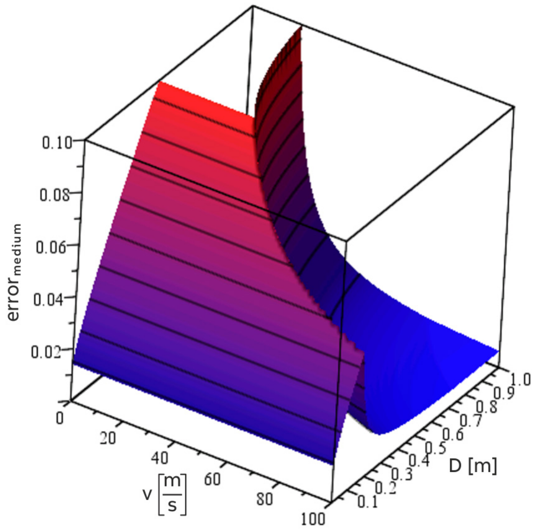
11 Possible combinations of medium velocity and pipe diameter for the measuring accuracy $\Delta T_{err} \leq 2$ K

Example 3 – Liquids with very high viscosity
Measuring medium: Honig, dynamic viscosity η ~10.000 mPa s



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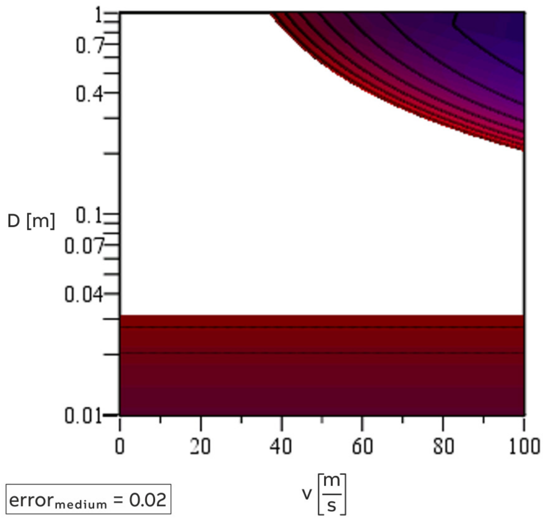

11

Result:

- Regardless of medium velocity v and pipe diameter D, turbulent flow almost never occurs with very high viscosity liquids such as honey.
- The calculations show a high level of accuracy for all medium velocities for small pipe diameters D ≤ 3 cm.

Conclusion:

- For liquids with very high viscosity, non-invasive temperature measurement using the TSP341-N with very high measuring accuracy is possible for small pipe diameters regardless of the medium velocity.
  For larger diameters, the accuracy decreases and increases again only in unrealistic ranges of medium velocity. Here as well, ABB will gain further experience within the scope of pilot projects and special test setups.

Summary
The three examples shown for very different material groups show that the TSP341-N is outstandingly suited for a large number of applications.
In addition to calculations for these three examples, ABB has conducted many more studies on achievable accuracies for a wide variety of materials and applications. Their presentation would go beyond the scope of this document.

ABB now has simulation programs, which allow for a very good assessment of the achievable accuracy of the TSP341-N in a specific application.
Interested parties who are uncertain about the suitability of the TSP341-N for their specific applications are therefore requested to contact their ABB partner in this matter.

Temperatur measurement with the TSP341-N: accuracy and response time

In the previous chapter, the TSP341-N's ability to measure the outside wall temperature of piping for flowing media was the basis for considering suited measuring media. This precision should be confirmed by the measurement results below.

In addition, it is shown that the response time during measurement with the TSP341-N is comparable or in many cases even shorter than during a classic measurement with thermowell.

Precision and response time measurements were performed using an experimental measuring setup that guarantees top accuracy of the reference measurement of actual outer wall temperature with very quick response behavior [3].

To determine the precision of the TSP341-N, the ambient temperature was varied over a period of several hours while the outside wall temperature was kept constant.

12

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12 Experimental measurement setup in a climate chamber to measure the precision and response time of the TSP341-N

Further reading

[3] J. Gebhardt et al.: “Reliable measurement of surface temperature: a step to widespread non-invasive T measurement in industry”, Proceedings of: 19. ITG/GMA-Fachtagung “Sensoren und Messsysteme”, N rnberg, June 2018

... Temperatur measurement with the TSP341-N: accuracy and response time

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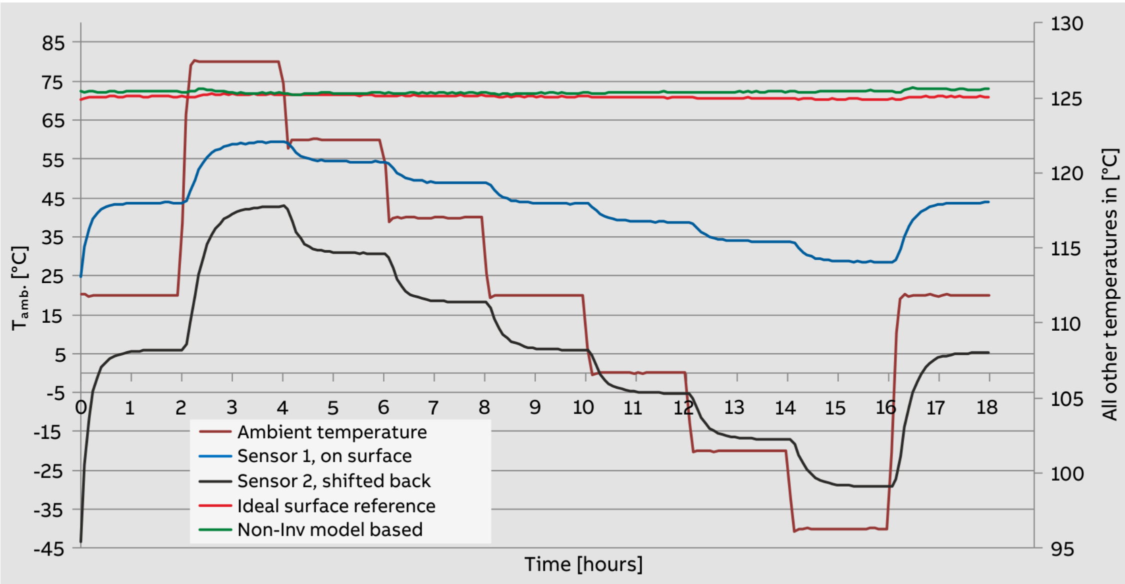
13 Precise and stable measurement of a constant surface temperature at ambient temperature jumps

In the example shown, at a temperature of the outer wall of T_{surf} = 125 °C the ambient temperature T_{amb} is changed over a ambient temperature range of T_{amb} = −40 to 80 °C in increments of 20 °C as well as 60 °C.

The diagram shows the surface temperature measured by the TSP341-N at the measuring point (**Sensor 1, on surface**) and the measured ambient temperature near the measuring point (**Sensor 2, shifted back**).

While the measured temperatures at the measuring point and above all near the measuring point are strongly influenced by the ambient temperature, the outside wall temperature calculated with the help of the algorithms (**Non-inv model-based**) does not deviate at all ambient temperature levels by more than 1 °C from the exact temperature (**Ideal surface reference**). This level of accuracy is also present during the ambient temperature jumps of 20 °C and especially also those of 60 °C:

- The determined temperature remains stable and no oscillation behavior sets in.



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14 Reaction of the TSP341-N to rapid changes in the surface temperature

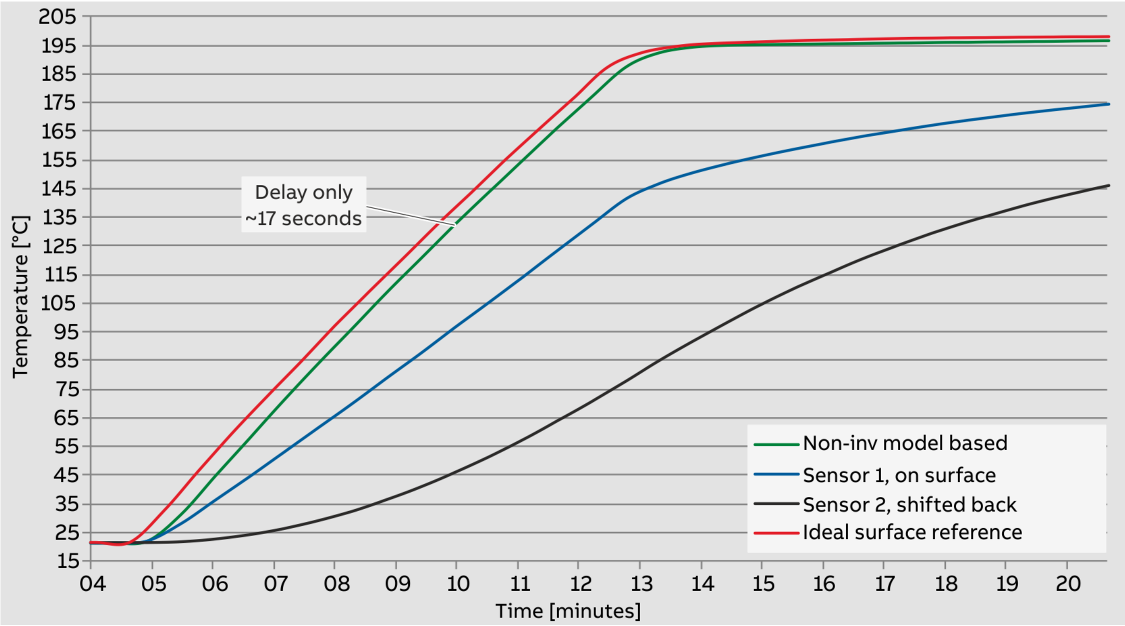
The two diagrams below show the good response behavior of the TSP341-N at rapid temperature changes of the outer wall.
With the steps of the thermo-mechanical optimizations already mentioned above, especially at the test point and with the use of special correction algorithms, not only is very high measuring accuracy achieved, but a surprisingly short response time of this surface sensor as well.

It is comparable to and often even better than the response times of classic temperature measurement with thermowell.

In the following example, the outer wall temperature increased in an almost linear fashion in just 8 minutes from T_{surf} ~20 °C to T_{surf} ~190 °C. The temperature rise is thus ~0,3 °C/s.

Although the temperatures detected by sensor 1 and sensor 2 can only follow the rapid increase in temperature with a delay of several minutes, the outside wall temperature calculated using the algorithms (**Non-inv-model-based**) already reaches the exact temperature (**Ideal surface reference**) after only ~ 17 seconds.
In this case, the outer wall temperature thus calculated deviates from the exact temperature even in this very dynamic phase by no more than ~ 6 °C.

At a constant surface temperature before and after it is increased, the accuracy of ~ 1 °C is immediately reached, as shown in the previous diagram.



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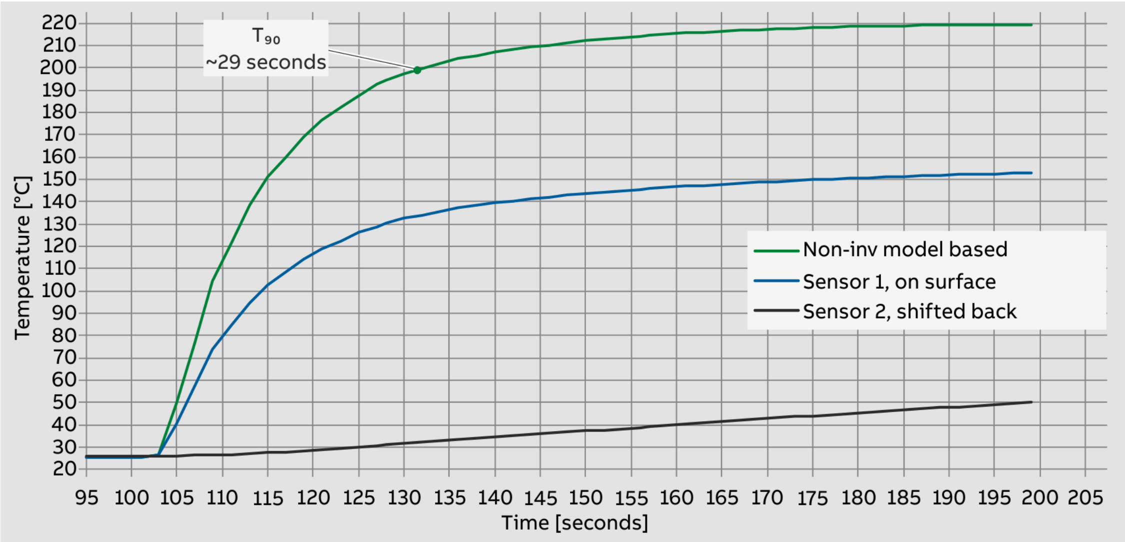
… Temperatur measurement with the TSP341-N: accuracy and response time

The short response time of the TSP341-N can also be seen from its response to a temperature jump (unit step).

In the following example, the temperature jump from 25 °C to 220 °C is achieved by the sudden contact of the surface sensor with a surface heated to this temperature.

With the help of algorithms, already after 29 seconds, an outer wall temperature (**Non-inv model-based**) of > 200 °C was determined, being 90 % of the sudden jump in temperature (T90 ~29 s).

With a response time of T90 < 30 s the TSP341-N surface sensor faired very well compared to classic temperature measurement with thermowell.



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15 Reaction of the TSP341-N to a temperature jump from 25 °C to 220 °C

Summary
The measurements presented in this chapter show that the TSP341-N non-invasive surface-mount temperature sensor makes very accurate temperature measurement possible.
The high measuring accuracy is maintained even with rapid and large changes in ambient temperature. Thanks to its properties, the sensor is able to follow even faster temperature changes of the measuring medium in a short time and with good accuracy. The response time of the TSP341-N is well within the range of classic temperature measurement with thermowell. Due to the required robustness of thermowells in some applications, the response times can be significantly higher there as well.

Direct comparison: Temperature measurement with TSP341-N (non-invasive) and classic (measurement with thermowell in measuring medium)

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16 Measurement setup for comparison of non-invasive and classic temperature measurement

The two preceding chapters addressed the suitability of various measuring mediums for non-invasive temperature measurement and the measurement accuracy of outer surface temperatures by the TSP341-N. From the results, it was derived that the TSP341-N can be used for high-precision temperature measurements in multiple applications.

The present Edition II of the whitepaper underscores this conclusion with concrete measurement results.

The measurements were conducted at the German ABB Corporate Research Center in Ladenburg, just like the measurements described in the preceding chapter. For the measurement setup, a realistic industrial installation was simulated, made up of a tank, a pump and piping with shut-off valves at the beginning and end. Water was used as the measuring medium, which had a constant temperature near the ambient temperature at the beginning of the measurement.

The water in the tank was heated to a defined temperature with closed valves and then the pump was switched on. Only then were both valves opened to achieve the quickest possible temperature jump in the piping made of austenitic stainless steel (material 1.4307) with a diameter of DN 80.

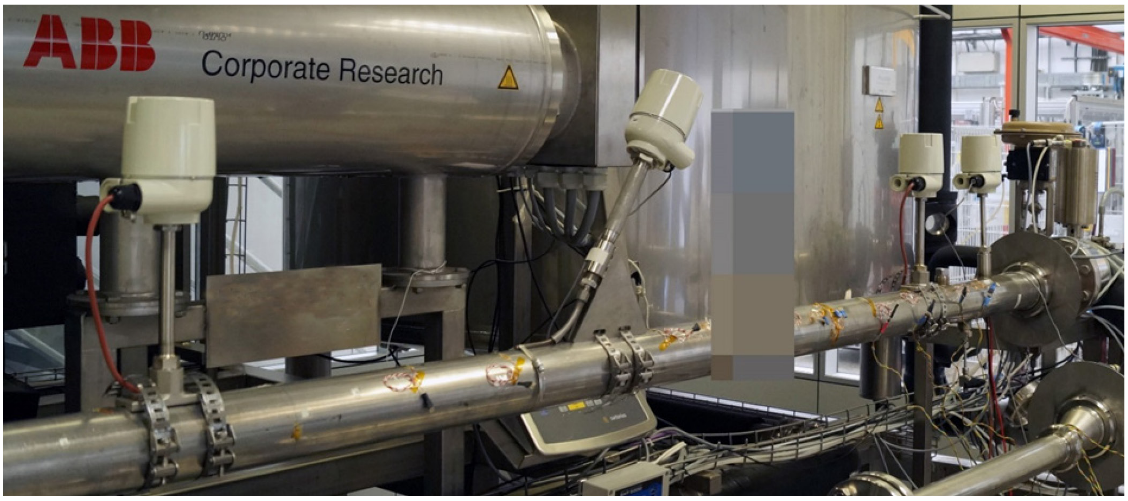
The heated water then flowed through the piping with a flow rate of 4 liters per second.

The thus achieved medium velocity of v ~75 cm/s guaranteed turbulent flow in the pipe and with it, good heat transfer of the measuring medium to the piping. It is well above the speed of v > 10 cm/s determined above, from which good measuring accuracy is achieved for water during a non-invasive measurement.

For the comparative measurement, a fast-responding SensyTemp TSP321 with thermowell for classic temperature measurement was used, in addition to the TSP341-N mounted on the pipe surface. Furthermore, a surface sensor by a competitor as well as a simpler ABB surface sensor without calculation algorithms was used.

The TSP321 sensor used has the following essential features:

- Welded stainless steel thermowell 1.4571 / 316Ti which is screwed in, with a 12 mm diameter, tip tapered 9 mm (Form 3G in accordance with DIN 43772)
- Fast-responding Pt100 Sensor as a thin film resistor, accuracy class AA in accordance with IEC 60751, four-wire circuit



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... Direct comparison: Temperature measurement with TSP341-N (non-invasive) and classic (measurement with thermowell in measuring medium)

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17 Temperature jump from 29 °C to 77 °C. Measuring medium: water, piping not insulated

Measurement results

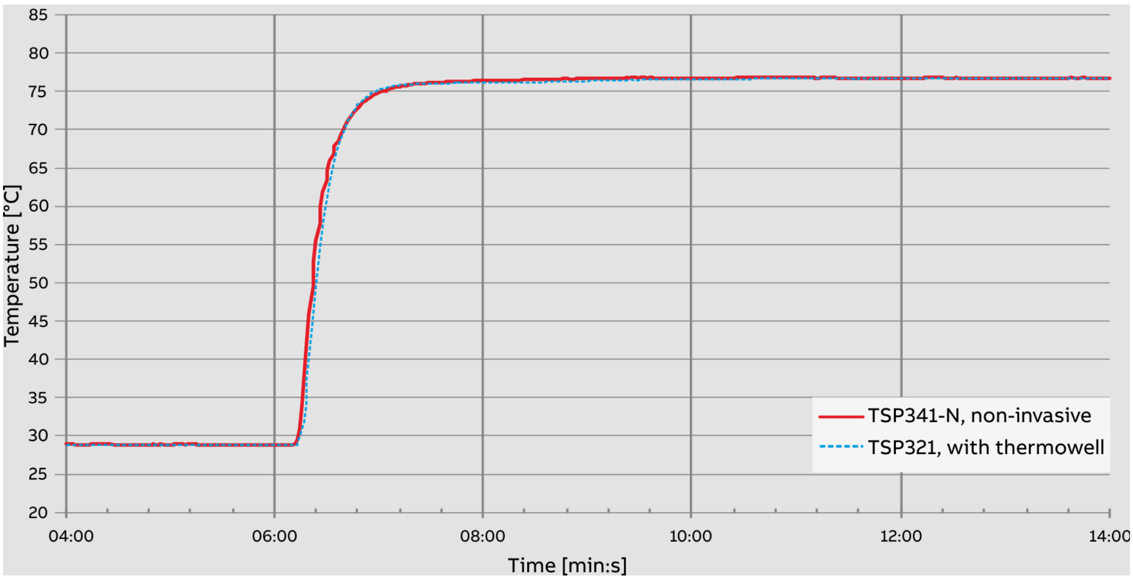
Before and after the temperature jump, the differences between the non-invasive (TSP341-N) and classic (TSP321) temperature measurement are so small that they will not be discussed in any further detail here. Only the response times of both sensors will be observed.

Figure 16 on page 15 shows the measurement setup without insulation of the piping and measuring point. Measurements without insulation, as well as with insulation up to the maximum permissible height of 100 mm at the measuring point (on the extension tube of the TSP341-N), were conducted.

The affect of the insulation on the non-invasive measurement is positive, yet quite small as expected, since the existing insulation on the measuring point is considered by the calculation algorithms.

The following diagrams show temperature jumps of ~50 °C from the ambient temperature on the measurement setup.

Figure 17 shows a temperature jump from 29 °C to 77 °C. In this presentation, no differences in accuracy and responsiveness between the non-invasive and classic temperature measurement can be detected.



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18 Temperature jump from 29 °C to 77 °C. Measuring medium: water, piping not insulated. Elongated time axis compared with Figure 17

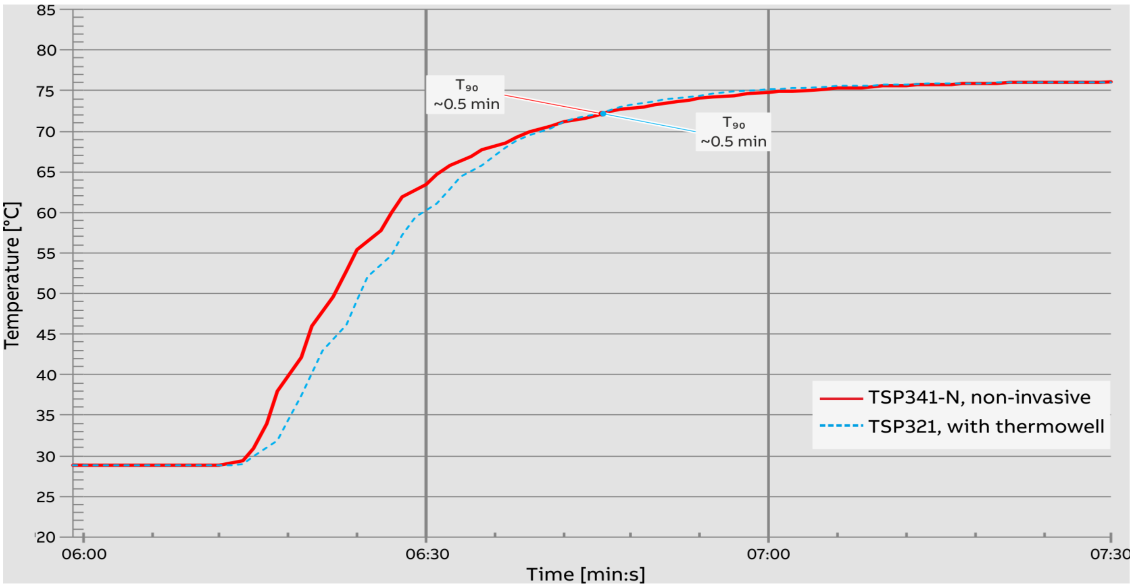
Figure 18 therefore shows the same measurement as in **Figure 17** on page 16 in a significantly reduced time window.
Even with a heavily increased temporal resolution, this figure leaves no doubt on the suitability of non-invasive temperature measurement with a TSP341-N.

The response times T_{90} of the TSP341-N and TSP321 are practically the same, the measured response time T_{90} ~0.5 min is consistent with the reaction time of the sensor to a sudden temperature jump (unit step) determined in the previous chapter.

During the rise of the temperature up to the time T_{90}, the TSP341-N runs ahead of the TSP321 by a few seconds.

But this should not be justified by the fact that the TSP341-N is mounted along the piping in front of the TSP321 and can therefore react sooner to the temperature change of the measuring medium. This time difference is less than 0.5 seconds.

In fact, the non-invasive measuring principle shows its advantages here as well, since surface measurement on the metal pipe can react more quickly to the beginning of the temperature jump than the sensor installed in the thermowell.



18

… Direct comparison: Temperature measurement with TSP341-N (non-invasive) and classic (measurement with thermowell in measuring medium)

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19 Temperature jump from 22 °C to 80 °C. Measuring medium: water, piping insulated (~40 mm), measuring points insulated up to maximum height of 100 mm.

Finally, it should also be shown that the affect of the insulation at the measuring point on non-invasive temperature measurement with a TSP341-N is very small, since its presence or absence will be considered by the calculation algorithms due to the appropriate parameterization of the sensor.

For the measurement shown below, the piping was fully fitted with ~40 mm thick thermal insulation. The mounted TSP341-N as well as the TSP321 were additionally fully wrapped with insulation material up to the maximum permissible height of 100 mm.

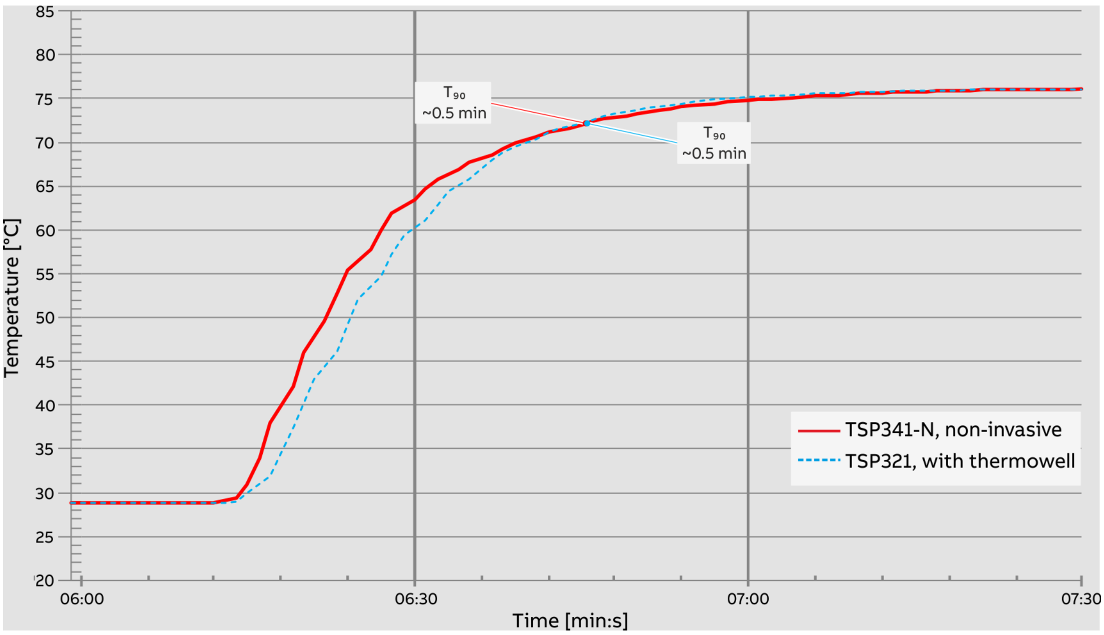
In Figure 19 (measurement with insulation), the same temporal measurement behavior can basically be detected as in Figure 18 (measurement without insulation).
At the beginning of the measurement, the TSP341-N also reacts a bit more quickly than the TSP321 here, the response times T_{90} of both sensors are practically the same and tend to be slightly shorter with the insulation.

Summary

Even when directly compared to the classic temperature sensor which measures in a medium, the non-invasive measuring TSP341-N with the calculation algorithms for non-invasive temperature measurements integrated in the firmware of the transmitter also stands out with its remarkable performance. Significant differences during measurement of a constant temperature cannot be detected.

In terms of reaction time, the TSP341-N is also on par with the sensor with a fast-responding thermowell used here for comparison. In addition, it can respond to the beginning of a quick change in temperature even faster than the sensor built into the thermowell of the classic device.

The TSP341-N is just as well-suited for operation with or without insulation of the measuring point. With the measurement setup used here, a simulation of a realistic industrial in-house installation, the affect of the insulation was positive, yet minor.



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Areas of use and application

In general, the non-invasive TSP341-N temperature sensor is suited for any area of application in which temperature sensors with thermowell are used. This includes all sectors of industry and heavy industry. Examples include the chemical, energy, oil and gas, paper and pulp or petrochemical sectors. Especially for the chemical industry, the sensor is ideally suited by taking into account NAMUR recommendations such as NE24, NE89 and NE107. Global approvals for explosion protection also permit use in potentially explosive atmospheres*.

The TSP341-N is particularly suited for all applications in which an intervention in the process or a thermowell in the process or measuring medium is critical or even undesirable, for example because of the risk of a possible thermowell break or if a thermowell complicates the regularly required cleaning work.

Due to the simple integration into the existing infrastructure of a system (two-wire technology and HART protocol), the sensor is perfectly suited for subsequent and even temporary 'on-the-fly' measuring point extensions, as the system does not need to be shut down and opened for assembly.

The TSP341-N achieves a very high level of measuring accuracy with:

- Measuring media with low viscosity,
- Measuring media with high thermal conductivity,
- Processes with high medium velocities and
- Processes with turbulent flow (often favored by high medium velocity).

Examples:
Water, watery solutions and water-based liquids as well as fast flowing oil or saturated steam.

But the temperatures of other measuring media can often be determined with very high accuracy, as was shown in **Example 3** on page 10.

* The temperature sensor TSP341-N belongs to ABB's product family SensyTemp TSP. It is listed in the related type examination certificates for explosion protection as SensyTemp TSP341-N.

Summary

This white paper discussed the very good level of accuracy obtained by ABB's new TSP341-N and presented the corresponding proof with examples and measurement results. The high precision is achieved in a non-invasive manner, i.e. through pure surface measurement without intervention in the process. Thanks to ABB's long-standing experience in the design of surface sensors and through the use of newly developed calculation algorithms, with the TSP341-N, it is now possible to guarantee lasting and repeatable consistency of measurement quality.

In an initial consideration of classical temperature measurement with thermowells in the measuring medium, the possible risks of a thermowell break are shown. Efforts to prevent such incidents may, depending on the application, require high costs in system planning and operation, costs which are non-existent in surface measurement as a matter of principle. Thus, the use of the non-invasive TSP341-N temperature sensor is potentially both safety-enhancing and cost-reducing. In addition, the sensor can be easily retrofitted and even installed temporarily, since system operation is not affected, thanks to simple installation on the surface, while integration into the usual infrastructure is easily possible.

A look at ABB's first temperature sensor of a new generation of surface sensors, the TSP341-W, successfully introduced in 2014, described how the insights gained with this sensor have been incorporated into the development of the new TSP341-N. The TSP341-N now additionally takes the ambient conditions prevailing during the measurement into account, therefore again significantly increasing the accuracy of the surface measurement.

To achieve high precision of non-invasive temperature measurement, a good heat transfer from the measuring medium to the medium-carrying structure is required, usually a vessel or piping. This heat transfer is often much more important than the transfer of heat from the inside to the outside of the structure. In the case of metallic pipes, it can be assumed that the temperature on outer side, on which the surface measurement takes place, is practically the same as that on the inner side. Therefore, knowledge of the heat transfer from the measuring medium to the piping is of utmost importance for the overall measurement accuracy to be achieved.

The whitepaper shows an example of three different liquids, what transmission behavior can be expected at different flow velocities and pipe diameters and what temperature deviations can be expected:

- Liquids of low viscosity, such as water (see **Example 1** on page 8),
- Liquids with increased viscosity and low thermal conductivity, such as oil (see **Example 2** on page 9) as well as
- Liquids with very high viscosity, such as honey (see **Example 3** on page 10).

We can see that the non-invasive TSP341-N temperature sensor can achieve a very high measuring accuracy for a variety of measuring media of differing viscosity and thermal conductivity under the described boundary conditions.

—
20 Water and waste water

—
21 Power and steam generation

—
22 Chemical and petrochemical

—
23 Oil and gas

—
24Pulp and paper

—
25 Minerals

—
26 Metals

—
27 Food and beverages

—
28 Marine

Afterwards the exact measurement of the pipe surface temperature by the TSP341-N and the influence of the ambient temperature on the measuring accuracy are investigated. It can be seen that even large and sudden changes in the ambient temperature have no influence on the measuring accuracy, which is always in the range of ±1 K. Investigation of the response behavior of the TSP341-N shows that the response time of the sensor is well within the range of classic temperature measurement with thermowell and significantly down-scales the higher response times of massive thermowells.

The present Edition II of this whitepaper now additionally compares the results of non-invasive temperature measurement achieved in realistic conditions using a TSP341-N with the results of classic measurements with a fast-responding thermowell in the measuring medium.

The results are practically identical and emphasize the outstanding suitability of the device for multiple applications.

Investigations described

- the temperature deviation at heat transfer from medium to metallic piping and
- the accuracy and response time of the temperature measurement on the piping surface, as well as
- direct comparative measurements

show that non-invasive temperature measurement by the TSP341-N can replace classic temperature measurement in many cases without loss of accuracy.
This applies to all industrial sectors and for almost all applications.

If you are interested in learning more about the suitability of the non-invasive TSP341-N temperature sensor for your specific applications, please contact your ABB partner on this topic.

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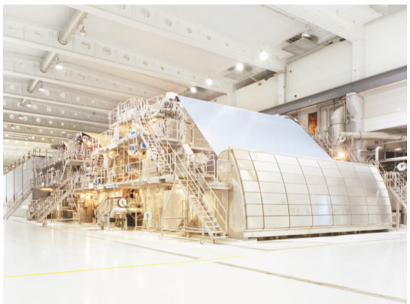

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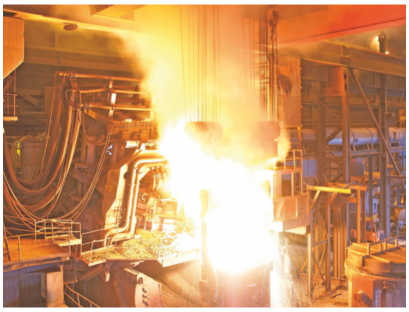

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Notes

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