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Non-invasive sensor – Questions from customers

Answers to a subset of technical questions

All the answers pertain to the following pipe and process conditions:

Process Condition	Range
Pipe Dimensions	DN40 – DN2500 (1,5” – >88”)
Pipe Material	Metals
Medium Temperature	- 40°C – 400°C (- 40°F – 752°F)
Medium Type	Liquids, Steam[1]
Medium Density	0,05 s.g or >50 Kg/m^3
Medium Viscosity	0.1-50 mPa·s
Flow Condition	Reynolds number > 10000

1. **Question. What is the accuracy and repeatability of a Non-invasive temperature measurement?**

1.1. Accuracy

Our customers should have an accuracy significantly better than ± 2K/100K and this has been repeatedly demonstrated with all our installations to date. One example is shown in Figure 1. In indoor facilities with little or no air drafts, there is no need to insulate.

1.2. Repeatability

As the Non-invasive sensor device is built on standard, proven PT100 insets, the device has a repeatability similar to traditional devices. Our customers should expect that the 3-sigma confidence interval will be lower than the absolute error in accuracy. For instance, figure 1 also shows the statistical distribution and standard deviation of measurements from one of long-term installations. The average accuracy error was -0.68°C and the 3 sigma deviation is 0.42°C.

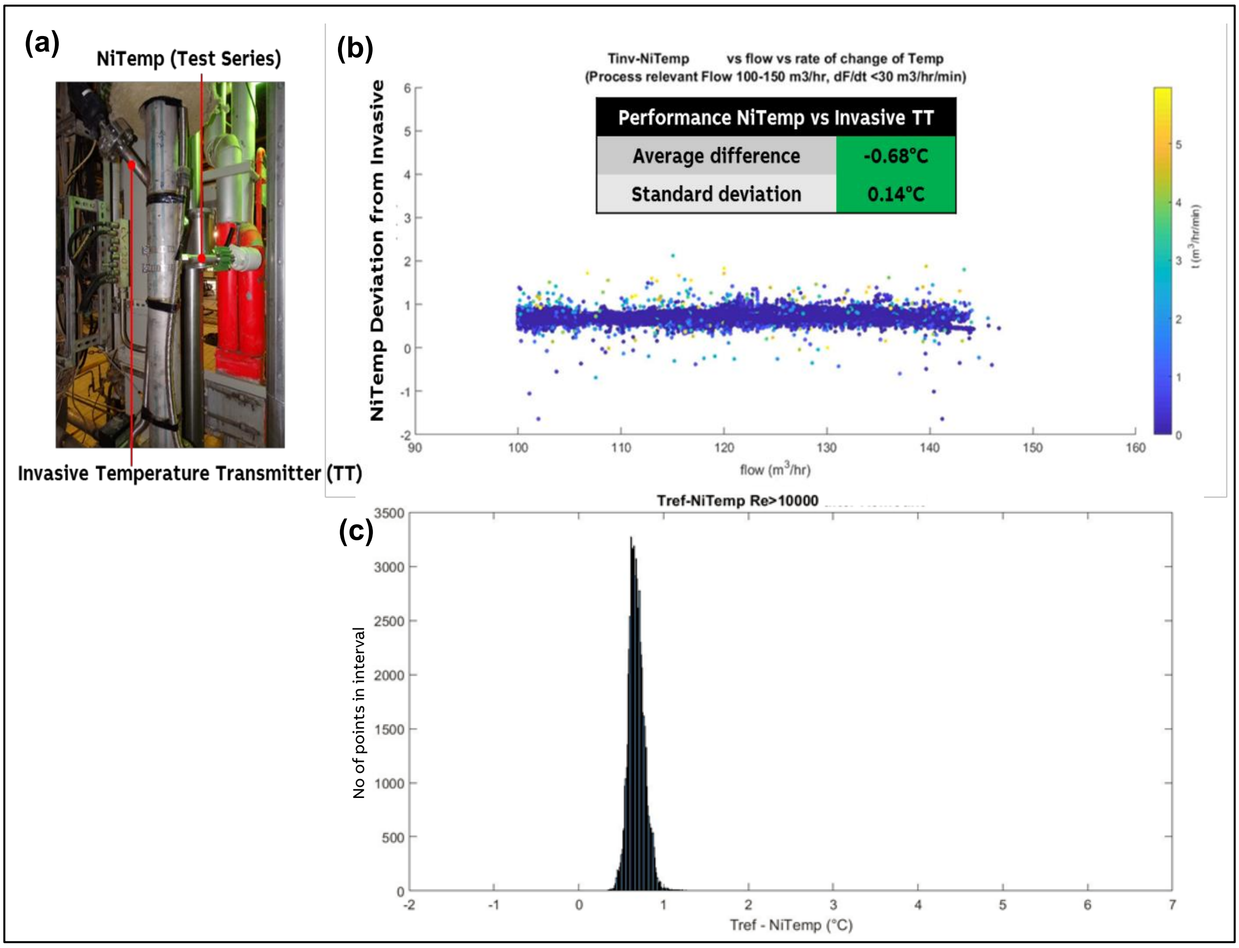

Figure 1: Long-term aggregation of data from pilot series installation of Non-invasive sensor in chemical facility. (a) Non-invasive sensor vs invasive device mounting, b) Temperature difference between Non-invasive sensor and Invasive device, c) Histogram of error Process conditions are Liquid – chemical suspension, Density: 1250 kg/m3, Viscosity: 2 mPas, Flow rate – 100-150 m3/hr

Figure 1:

Question: How does it work?

Simply put, we use a two-step model approach:

Process Model: We utilize a fluid heat transfer based models to infer the deviation between the medium temperature and the pipe outer surface temperature.

Device Model: We use the double sensor architecture to build a thermal model of the device to measure the temperature of the outer surface of the pipe. The design of the double sensor provides not only the accuracy and repeatability but also the response time that matched traditional invasive thermowell performance.

Together, the two models form our non-invasive temperature approach.

2. Question: what if there is a layer of paint on the piping?

A layer of paint on the piping where the device is mounted will lead to a reduction in accuracy but have minimal effect on the repeatability of the measurement. There is also a minimal effect on the response time of the device as the thermal mass is negligible.

For instance, EN10289 specifies the thickness of a dry protective epoxy coating on onshore and offshore pipelines. The thickness vary from 0.4 mm (class A) to 1.5 mm (class B) with an average thermal conductivity of 0.2 W/mK. In some cases, the paint layer may be in the order of a few millimeter.

Assuming that the medium temperature was 60°C and the ambient conditions were 20°C, mounting the device on this kind of piping would results in an additional loss of accuracy as shown in table 1.

Table 1: example of additional error due to epoxy based coating on piping.

Epoxy paint layer	0.4 mm	1.5 mm	3 mm
Added absolute error (40°C process to ambient)	0.2°C	0.77°C	1.2°C

If you need to compensate this difference, we can advise you of the compensation for your system.

3. Question: what is the effect of wall thickness on the accuracy, repeatability and response time of the device?

3.1. Accuracy and repeatability:

The effect of wall thickness on accuracy and repeatability are significantly less than 1°C unless the piping has the following conditions:

1) Not insulated and there is a large temperature difference between the medium and ambient conditions.
2) The piping has poor conductivity (polymer or non-metallic)

To put this in context, assuming a pipe with a thickness of 1 cm (high-pressure) steel pipe, one would need a 250°C temperature difference between the ambient conditions and the process medium in order to create a 1°C error due to the wall thickness.

Some competitors claim to have a value that allows for the compensation but state that the pipe should still be insulated. This would appear to be a marketing aspect with little added value for many customer circumstances.

3.2. Effect on response time:

The response time is proportional to the increase in volume of the piping in the same way a thermowell response lags with an increase in wall thickness.

Take the example in our white paper. We demonstrate a T_{90} ≈ 30s against a DIN43772 3G thermowell with a wall thickness of 3 mm on a DN80 pipe (schedule 10). If we increased the pressure rating of this pipe to an XXS rating, with a wall thickness of 15.5 mm, one would expect a time of approximately T_{90} ≈ 120s keeping all other conditions the same. This response time assumes the necessary insulation

4. Question: A clamp on device with straps can lead to contact and/or galvanic corrosion on a pipe, how do you prevent this?

For any installation outdoors or in a corrosive environment ingress of moisture has to be prevented and most commonly with the use of insulation. The criticality of insulation is for operating temperatures between -20°C to 150°C. Our assumption from a safety standpoint is that above 40°C to 50°C our customers would insulate in any case, and we have experienced the fact that every company has a different policy on how they insulate the piping. However, ABB has an asset integrity consulting engineering unit that provides corrosion management and consulting services to leading oil and gas companies worldwide. They have evaluated the Non-invasive sensor design during development and recommended an industry best practice standard for insulating clamp on devices using an adhesive wrap.

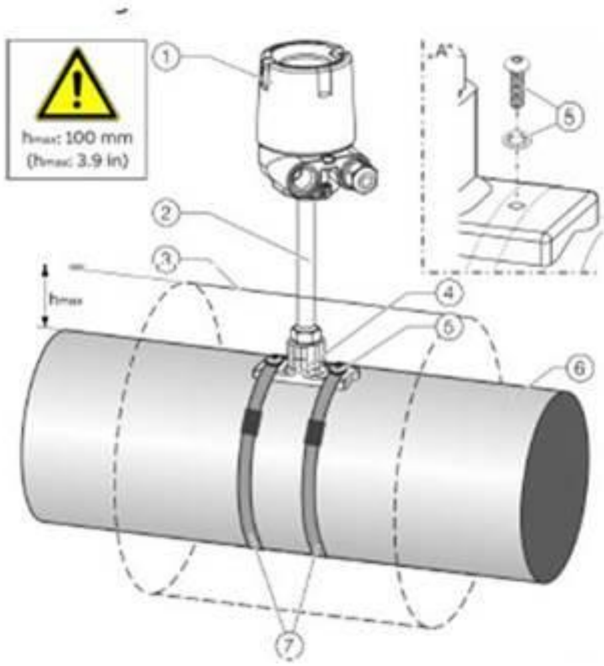

Figure 2: Schematic of ABB non-invasive temperature sensor mounted on a pipe. Snapshot from commissioning instructions

Corrosion prevention without insulating material

The presence of the two securing bands and the retaining plate for the temperature sensor will each create a crevice between them and the pipe. This equipment will be subject to crevice corrosion in an environment where moisture/water is present and can enter the crevice. This would be particularly noticeable in a marine atmosphere where chlorides are also present. In addition, a combination of stainless steel and carbon steel between these items will exacerbate the attack of carbon steel, due to the dissimilar (galvanic) couple in the presence of an electrolyte.

To prevent this the crevice needs to be sealed. This could be done using an appropriate sealant under the bands and the retaining plate, items 7 and 4 respectively. The use of a PTFE or rubber insulant is not sufficient. The sealant needs to “wet” and then “adhere” to each component and be flexible, like a silicone bathroom sealant.

A more robust solution would be to cover the section containing the two bands and the retaining plate with a wrap material. For lower temperatures, -20°C up to +75°C this could be an adhesive bituminous rubber compound e.g. Serviwrap R30[1]. This material is used for corrosion protection in difficult environments and for buried pipelines.

For higher temperatures up to 150°C the preference would be for an “engineered wrap” material which is often applied to offshore pipework for protection and leak sealing. This is a fibreglass composite with epoxy resin. It has a 20-year life for leak sealing which is extendable. For Non-invasive sensor there is no strength required for pressure retaining and is merely to adhere to the pipe and seal in the bands and retaining plate.

Above 150 C there should be no crevice or galvanic corrosion, since, any moisture will have evaporated. However, some account needs to be taken of shutdowns, during which, there could be exposure to crevice corrosion.

[1] https://www.chasecorp.com/products/serviwrap/serviwrap-r30/

5. Question: What is the effect on accuracy if the pipe surface is not smooth and there is rust?

Yes, the piping roughness will play a part as an offset on the temperature accuracy and rust can be insulating. We haven't had many old rusty pipes to test on! To minimize the effects, we use a 3mm Inset vs a 6mm one and in addition increase the contact pressure.

However, since our launch, numerous customers have tested the sensors on their existing piping (Figure 3), and we have run into many of these circumstances. To date the results have shown no significant effect on the repeatability or accuracy of the sensors. For instance, in tests with a customer on a 40 year old (Figure 4), rusty pipe in the open with a rough paint coating we see less than 1°C difference between Non-invasive sensor and the invasive measurement with a repeatability similar to that in figure 1b.

Figure 3: Images from installations from select applications indicating the nature of the piping being tested

Figure 4: Typical older chemical facility. Tests on this piping revealed had the following result: Difference (Non-Invasive – Invasive): Accuracy (Mean) = +0,14°C, Repeatability (Stdev) = 0,13°C