



Effective multi-location water temperature measurement in a Drinking Water Distribution System (DWDS)

Temperature can affect every aspect of the treatment and the delivery of potable water.



Introduction

The temperature of the drinking water delivered to a utilities end-customer is becoming increasingly important. Governments and regulators around the world are looking at ways of improving the overall water quality in the drinking water distribution systems by reducing the risk of microbial contamination. At the same time, they are striving to move away from the current practice of direct disinfection of the water supply using chemical processes, such as chlorination and chloramination.

To date, water temperature measurement carried out by a typical utility has been sporadic, often occurring when the water enters the drinking water distribution system (DWDS) from the treatment plant and not at, or near to, the point of consumption. Sometimes sampling is carried out at the customer's tap as part of a regulatory requirement, but is only performed at a very small number of residences. This means that in some areas of the network the water temperature may rise to the point where microbial and algal growth can escalate, especially when there is little to no flow of water.

Water temperature measurement is usually carried out using a separate device and logged independently. However, a growing number of static residential and commercial meters, such as the latest Xylem Eccus and Cordonel static water meters that utilise ultrasonic technology, can provide accurate water temperature readings on a near-real-time basis.

Such ubiquitous water temperature measurement, combined with accurate flow data, enables the utility to rapidly detect and resolve potential issues, such as initiating pipe flushing if demand is too low in a section of the DWDS. New network management software can easily incorporate this data to provide operators with a complete picture of water temperature across the network, with little or no additional cost above that needed to monitor existing flow and customer consumption.

"...the temperature dependence of most chemical reactions stems from the activation energy associated with them. The rates of chemical reactions decrease with decreasing temperature. The relative concentrations of reactants and products in chemical equilibria can also change with temperature...

Temperature can, therefore, affect every aspect of the treatment and the delivery of potable water."

Guidelines for Canadian Drinking Water



Why is monitoring water temperature important?

The population growth of microbes, algae, invertebrates and bio slime (aka biofilm) are all, in part, affected by the temperature of the water in which they live. In warm climate areas, the high temperatures of distributed water and the difficulty in maintaining disinfectant residuals during transport over long distances may lead to microbial aftergrowth, depending on nutrient availability.

While a water treatment plant can produce potable water with little or no contaminants at its outlet to the DWDS, there is still an opportunity for microbes and other contaminants to enter the distribution system. Contaminants can enter via pipe damage where leakage occurs, pipe repairs, poorly maintained storage tanks, air valves and hydrants. In Europe, levels of contamination have by and large been within acceptable limits, largely through a combination of average water temperatures being below those needed for accelerated population growth and/or the use of chemical additives in the water – such as Chloramines (up to 4ppm in the USA) or Chlorine Dioxide (with up to 0.4ppm used across Europe).



Example of biofilm on the output of a tap

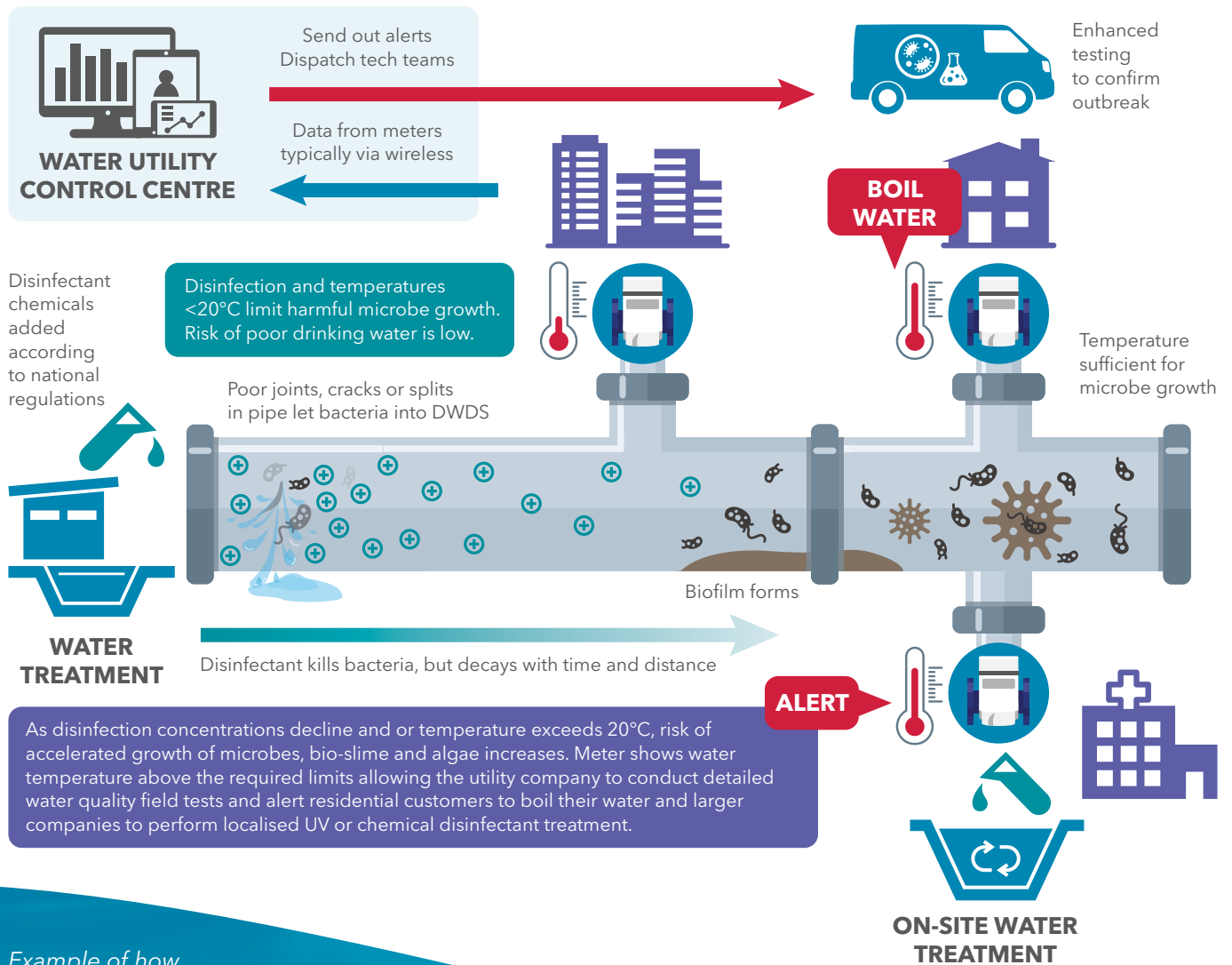


Legionella bacteria

In countries such as Germany, Netherland and Belgium, chemical disinfection is avoided due to concerns about the long-term effects on human health, as well as the potential damage to plumbing components. As a result, chemical disinfection is used only when there is a serious outbreak. Even disinfection efficacy can be affected by temperature, leading to difficulty in maintaining disinfectant residuals during transport over long distances or via complex pipe networks. This can result in microbial aftergrowth, if sufficient nutrients are available.

Overall environmental temperatures are rising due to climate change, and governments and regulators wish to move away from adding disinfectants to water, replacing them when possible with UV and ozone treatment processes. As a consequence, utilities must place greater emphasis on monitoring the temperature of the water reaching customers, as an indicator of potential water quality issues.

Urban areas are unsurprisingly typically hotter than the rural areas that surround them. This is due to less evapotranspiration (i.e. water evaporation to the atmosphere, either directly or via plants), heat storage and release from buildings and urban surfaces, and human activity or man-made heat sources.



Example of how pathogens can develop over time and distance from the utility's water treatment plant.

While the need to ensure human health and safety is of the utmost importance, elevated water temperature can lead to a rise in customer complaints even if there is no direct threat to health, primarily due to real or perceived changes in colour, taste and odour. Utilities have an increased focus on customer engagement and, in many countries, tough targets to reduce overall consumption and water leakage. If consumers believe that the quality of the water they receive is declining, it will be tougher for utilities to convince them to reduce their consumption.

The aesthetic objective for water temperature in the Guidelines for Canadian Drinking Water is only 15°C , as there is an increase in customer complaints regarding colour, odour and taste when tap water is 19°C or higher.



Thermal effects on pipes of different materials in the DWDS

The DWDS for a utility usually consists of various pipes made from different materials, from older cast iron pipes to newer plastic materials such as PVC and Polyethylene (PE). Each material provides a different habitat for microbes and biofilm. For example, cast iron with corroded internal walls has a series of nooks and crannies that can provide an attractive area for them to start growing and developing at the right temperature

The choice of pipe material and the physical dimensions of the pipe and wall thickness all affect how quickly the water within the pipe can be heated by the soil temperature. Tests have shown that with no flow, the temperature of water can heat up from 15 °C to the soil temp of 25 °C in less than an hour for a cast iron pipe. Plastic and asbestos cement pipes are thermal insulators and so take longer, but are not immune from heat transfer.

Elevated temperatures can also affect the corrosion rate of pipes and fittings, together with the absorption of chemicals into the water stream. This is outlined in the EPA Corrosion in Potable Water Systems Report: 1982, meaning there is an additional incentive for utilities to maintain the potable water distribution network within an acceptable temperature range to mitigate against these effects.



Corrosion in an iron pipe showing many areas where microbes could establish themselves

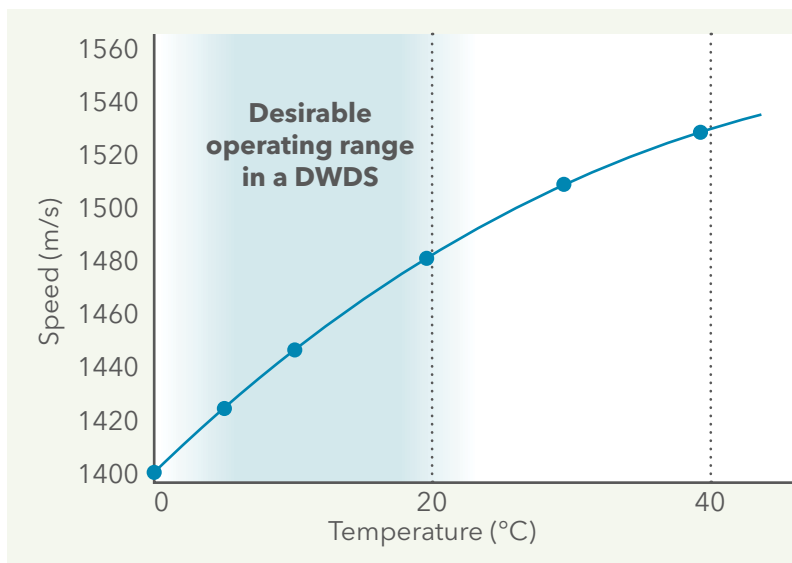


Water temperature measurement by ultrasonic static meters

Ultrasonic static water meters, whether designed for residential or commercial/industrial use, measure the delay with and against the water flow to determine the speed of the flow. The speed of the flow is much slower than the speed of sound in water, and therefore the measurements must be extremely precise. One aspect that must be considered is the effect of water temperature on the speed of the sound pulse emitted by the transducers in the meter.

As the graph shows, this can vary quite considerably over the range of temperatures you would expect in DWDS - leading to a potential variance of 5 -10%.

The algorithms used to determine the flow of the water need to compensate for this variance, which means the temperature of the water needs to be calculated with a relatively high degree of precision. This value can be output from the meter as one of the data measurements, and can subsequently be used to determine the temperature of the water flowing through the meter.



As most meters are at the ingress of the consumers' premises, they provide an accurate measurement of the water temperature being delivered to the customer. This, in combination with the flow rate, can be used to indicate potential problems for the customer.

Many larger customers may specify the range of water temperature that they will accept from their utility as part of a supply contract. This is because regulations and guidance exist to keep water temperatures within certain limits for distribution within a building - primarily, to mitigate against Legionella bacteria from becoming established. For example, the UK Health and Safety Executive (HSE) document HSG274 pt2 (2014) states that the temperature of water distributed within a building should ideally be no more than 20 °C. If the water being delivered is above this threshold, it leaves no room to comply with Health and Safety guidance and apply the corrective actions that need to be made.

In other countries the recommendation varies slightly. The World Health Organisation (WHO) recommends the temperature and distribution of cold water to be below 25 °C, and ideally no more than 20 °C.



Ultrasonic flow meter

Table 1: A sample of drinking water regulations/advisories and Legionella prevention requirements.

Czecia	<p>Decree No. 252/2004 Coll.</p> <p>Recommended temp. of drinking water at the tap is between 8 - 12 °C.</p>	<p>Decree No. 252/2004 Coll.</p> <p>Decree specifying hygiene requirements for drinking and hot water and level of drinking water control. Levels only set for hot water, where the limit of 100 HTP/100 mL is mandatory.</p>
European Union	<p>Recently updated its Drinking Water Directive, which was to be transposed into national laws by Jan 2023.</p> <p>It uses WHO guidelines for some of the basis of its work and a timeline for implementation.</p> <p>This does not specify water temperature requirements directly.</p> <p>The EU "Materials coming into contact with drinking water" circular advises "cold drinking water has to be cold (<25 °C)." It also states that "cold water (between less than 15 °C and 20 °C) and hot water (above 55 °C) will limit bacteria growth."</p>	<p>The EU Drinking Water Directive 2020/2184 provides parameters for action (<100 CFU/l) to be taken w.r.t Legionella, but advises action needs to be taken irrespective of this level should an outbreak occur.</p>
France	<p>Decree (11th Jan 2017) -</p> <p>Temperature at the consumer's tap should be < 25 °C</p>	<p>Standard NF T90-431</p> <p>"Detection and enumeration of Legionella spp. and of Legionella Pneumophila by culture in agar media".</p> <p>New recommendations under development and/or being trialled, while monitoring is mandatory on hot water networks for establishments regulated by ANSES (the agency for Food, Environmental and Occupational Health & Safety).</p>
Germany	<p>Trinkwasserverordnung – TrinkwV 2016 - amended 2021</p> <p>Contains lots of regulation on the tests to be carried out, disinfection limits etc. but no specific guidance on drinking water temperatures.</p>	<p>Trinkwasserverordnung – TrinkwV 2016 - amended 2021</p> <p>Contains sections on Legionella control and testing requirements, however no water temperature guidance is given.</p>
Italy	<p>No legal standard.</p> <p>Rapporti ISTISAN 97/9, Istituto Superiore della Sanità recommends temp. should be between 12 - and 25 °C.</p>	<p>National guidelines from Conferenza Stato-Regioni del 07 maggio 2015. Drinking water temperature must be controlled and kept outside of the critical range 20-50 °C.</p>
Netherlands	<p>The Dutch Drinking Water Directive sets a max. temp. limit of 25 °C at the tap.</p>	<p>National guidelines for the prevention of Legionella infections state drinking water temperature in a building must not exceed 25 °C, and hot water must be at least 55 °C.</p>

Serbia	<p>Official gazette of FRYu, No. 42/98 and 44/99, Official gazette of RS No. 28/19,</p> <p>The temperature at the consumer is not defined, but there is a requirement that it should not be higher than the temperature at the source.</p>	No standards
Spain	<p>No standards. However, Royal Decree 140/2003 of February 7th establishes the criteria for quality of water for human consumption. There are state's criteria for suitable drinking water, alongside the sampling protocols expected by every water utility. However, no water temperature guidance is set.</p>	<p>Royal Decree 865/2003 establishes hygienic-sanitary criteria for the prevention and control of Legionnaires' disease - but focuses on hot water facilities inside the buildings.</p> <p>The Building Technical Standards (CTE) for the design of plumbing installations inside buildings CTE-DB H4 are derived from the decree and contain a non-mandatory recommendation for drinking water to be under 20 °C where weather conditions allow.</p>
South Africa	No standards	<p>No standards in drinking water.</p> <p>The National Institute for Communicable Diseases recommends: "The proper design, maintenance and temperature of potable water systems are the most important method for preventing the amplification of Legionella. Hot water should be stored above 60 °C and delivered to taps above 50 °C. Cold water should be stored below 20 °C, and dead legs or low flow areas eliminated."</p>
UK	<p>No standards, although the Water Fittings Regulations Guidance book advises to aim to keep the water supplied to 20 °C as a maximum.</p>	<p>Health and Safety England uses an "Approved Code of Practice" for the prevention and control of Legionella. This is covered by the 1974 Health and Safety at Work Act (HSWA). In addition, a framework for assessment is set in the Control of Substances Hazardous to Health Regulations 2002 (COSHH).</p> <p>Guidelines suggest control measures in-building of:</p> <ul style="list-style-type: none"> • Cold water stored <20 °C and distributed to all outlets at <20 °C within two minutes of operation. • Hot water stored at 60 °C and distributed to outlets at >50 °C within one minute of operation.

The benefits of distributed water temperature measurement

Integration of temperature measurement into the water meter itself provides the following advantages over existing water measurements:

- Many more data points with which to map the temperature gradient of the water across the whole DWDS.
- The temperature measurement can be made and recorded at the same time as the water volume and flow are measured, providing a much more dynamic view of changing temperatures throughout the system.
- With such an amount of data it will be possible to correlate changing temperatures across the network with external factors including air/soil temperature, flow profiles and flow changes due to customer use.
- The temperature is measured at the point the water leaves the network and enters the customers premises via the meter, marking the demarcation between the responsibility of the utility and that of the customer.
- The temperature can be set as an alarm condition with high or low thresholds, enabling a near-real time warning to be raised should the limits be exceeded. Average temperature readings can also be provided.

Water temperature alone cannot indicate with certainty whether there is a water quality issue in a given area of the network. However, it is a major factor and, when combined with flow data, it provides sufficient information to enable prioritisation of areas within the DWDS that require deeper analysis using dedicated water quality sensors and test equipment (such as those made by YSI, WTW etc).

Alternatively, such data could enable the water utility to reduce the likelihood of a water quality issue developing. The utility can, for example, flush a section of the network which is above a certain temperature limit and has not had sufficient flow over a given amount of time, thereby negating the conditions that could promote microbial and algal growth. Another option would be to facilitate the use of more localised disinfection, if permitted under the applicable regulations. Larger customers, such as swimming pools, hospitals and food/beverage manufacturing could be informed in near real-time, so they could take additional measures, such as ramping up their own treatment and disinfection solutions, including On-Site Hypochlorite Generation Systems (OSEC) from the likes of Evoqua etc.

Next steps

Water utility companies are becoming more aware of the benefits of measuring temperature at the point of delivery. Newer digital intelligence solutions, such as **Xylem Vue powered by GoAigua**, will soon make it possible to correlate and display temperature measurements, alongside flow data and external climate data. This will help highlight potential areas of concern in the DWDS, allowing more precise investigations to be carried out.

Such visibility, alongside the rapidity of the measurement, will enable the utility to optimise its water treatment to be as efficient as possible, while ensuring that the quality of the water delivered to their end-customers meets all local regulatory requirements and safety guidance.

Examples of Xylem water meters that provide temperature measurements

Xylem Eccus

The latest residential static meter from Xylem, utilises ultrasonic technology and can provide maximum and average temperature readings via Wireless MBus and/or LoRaWAN communications.

It measures the water temperature to an accuracy of $\pm 1\text{ }^{\circ}\text{C}$ and so can easily detect the conditions conducive to microorganism growth. In addition, it has an ambient temperature accuracy of $\pm 3\text{ }^{\circ}\text{C}$ which can be used to determine the temperature trend should the flow cease, the rate of change being largely determined the thermal transfer characteristics of the surrounding pipe materials.



Xylem Cordonel

The industry leading commercial and industrial meter can provide temperature measurements via its integrated Wireless MBus or SensusRF radio connectivity or via a wired pulse connection. Smartpoints and gateways enable this information to be collected and transmitted via other connectivity networks if required for further analysis.

Cordonel is typically used both in boundary meters to a DMA (District Metering Area) and for large customers, many of which rely on certain levels of water quality. Some may also have supply contracts that specify the maximum temperature of the water they should receive.

Xylem |'zīləm|

- 1) The tissue in plants that brings water upward from the roots;
- 2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services settings. Xylem also provides a leading portfolio of smart metering, network technologies and advanced analytics solutions for water, electric and gas utilities. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise with a strong focus on developing comprehensive, sustainable solutions.

For more information on how Xylem can help you, go to www.xylem.com



Digital transformation starts with Xylem Vue

Digital adoption is no longer an option, it's an urgent reality to meet the increasing pressures you face. Xylem Vue brings together our full portfolio of digital solutions to solve your most pressing water challenges along your digital journey. Let's see what's possible for you.

For more information on Xylem Vue, go to xylem.com/XylemVue



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