White Paper | Elevated Storage Tank Applications | Measurement Solutions

Water Towers:
Critical Assets for Quality of Life and Fire Safety

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When driving through towns and smaller cities, especially in the South and Midwest, an iconic sight is their water towers. No two are alike – at least on the outside, since most of them are painted with municipality's name and logo. Some are even whimsical, such as Peachoid in Gaffney, South Carolina, and its smaller cousin, Big Peach in Clanton, Alabama. Many universities, manufacturing plants, and other larger facilities have water towers too.

In the late 1800s and early 1900s, water towers in larger cities were often stately structures reflecting the architectural styles in vogue at the time: Neoclassical, Gothic Revival, Art Deco, Art Nouveau, etc. About 100 water towers and tanks – most of them decommissioned – are listed on the U.S. National Register of Historic Places, according to the Pittsburg Tank & Tower Group.

Water Tower Trivia

You think you know about water towers? Test your knowledge with this quiz!

1) NYC has about how many rooftop water tanks?
a. 5,000 to 10,000
b. 10,000 to 15,000
c. 15,000 to 20,000
d. 20,000 to 25,000

2) What type of storage tank is the Chicago Water Tower?
a. Underground storage tank
b. Fluted column
c. Gothic Revival
d. Standpipe

3) Which type of elevated storage tank has a concrete shaft and a steel tank?
a. Cone-top
b. Pedesphere
c. Composite
d. Double cone

4) The decommissioned water tower in Collinsville, Illinois, is famous for…
a. being the world's largest catsup bottle
b. its Dixie Cup shape
c. replicating the Tower of Pisa
d. looking like a Swedish-style coffee pot

1) b, 2) d, 3) c, 4) a

The Dixie Cup Water Tower is in Lexington, Kentucky; the Leaning Tower of Niles is in Niles, Illinois; and there are two (at least) water towers shaped like Swedish-style coffeepots: one in Stanton, Iowa, and one in Lindstrom, Minnesota.

Water Towers: Functions and Forms

Water towers can be landmarks and points of pride. Of course, their larger purpose is functional.

What water towers do

It takes energy to convey water from a source to its destination. Aqueducts constructed during the Roman Empire relied on gravitational energy alone to transport large amounts of water from higher elevations to lower elevations. Today, a system of pumps and pipes use kinetic energy to move water around, such as from a wastewater treatment plant to a city's homes, buildings, factories, and fire hydrants.

Pumps alone could satisfy a municipality's water needs. But buying enough pumps for a city can be expensive, not to mention the cost of fuel to run them continuously. That's why many municipalities have elevated storage tanks. When demand is low, such as overnight, pumps at ground level lift the water, filling the tanks and giving the water potential energy. This stored energy is released, becoming kinetic energy thanks to the pull of gravity, when demand is high, such as in the morning and evening or for fire suppression. This is why a community's water tower is typically sized to hold a day's worth of water.

There are several advantages to storing water in an elevated tank:

- Consistent, reliable water pressure
- Water supply unaffected by occasional power outages
- Cost savings due to running pumps overnight, when electricity is cheaper
- Less wear and tear on expensive pumps by not cycling on and off as demand fluctuates

As a bonus, since water towers are often the highest points for miles, telecoms are leasing these tall structures and installing cellular antennae, giving municipalities an additional source of steady income.

Types of water storage tanks

Elevated water storage tanks come in many shapes and sizes. The oldest and most basic design is the **leg-style tank**: a cone-topped cylinder or an ellipsoidal vessel resting on at least three supporting legs or columns. This is the style of water tanks – made of untreated wood for natural insulation and no contamination – found atop many buildings in New York City. Within the central shaft are the inlet pipe, outlet pipe, and overfill evacuation pipe. Thanks to struts, cross braces, and stay rods, this style of water tanks can be adapted to withstand high winds and seismic activities.

Some water towers are steel structures where a large vessel – spheroidal, double ellipsoidal, torospherical, cone-shaped base, etc. – sits atop a flared support **pedestal** with piping inside. Pedestal-style water towers are popular due to their small land footprint.

Similar to the pedestal-style, **fluted column** (fluted pillar) water towers also have a single support in the center. But the steel column – corrugated for strength – is nearly as wide as the tank, allowing plenty of space for machinery, storage, office space, and staircases inside.

Another popular style is the **composite elevated tank** (CET), so called because while the cylindrical storage vessel is steel, the central shaft is made of reinforced concrete. The column has a smaller diameter than that of the fluted column, but it's still wide enough for storage, office spaces, and interior stairs. One advantage of the CET, besides its ability to support the largest water tanks, is that only the tank needs to be painted, resulting in much lower costs for structural maintenance.

Types of Water Storage Tanks

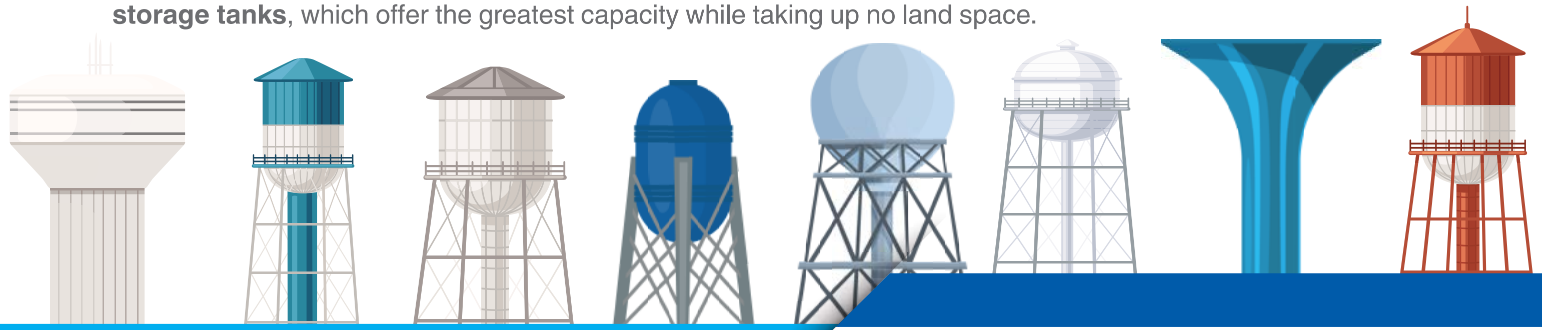
Elevated water tanks

- **Leg-style/multi-column**
  - Cone-topped
  - Ellipsoidal
  - Torus bottom
- **Pedestal-style**
  - Spheroid/pedesphere ("lollipop")
  - Double ellipsoidal
  - Torospherical
  - Cone-shaped base
  - Double cone
- **Fluted column**
- **Composite elevated tank (CET)**

Ground storage tanks, including standpipes

Underground storage tanks

Besides these elevated versions, the water tank itself can be on the ground. **Ground storage tanks** are wider than they are tall, while **standpipes** are taller than they are wide. Some cities keep treated water in **underground storage tanks**, which offer the greatest capacity while taking up no land space.



Pressure: Getting Water to Where It Needs to Go

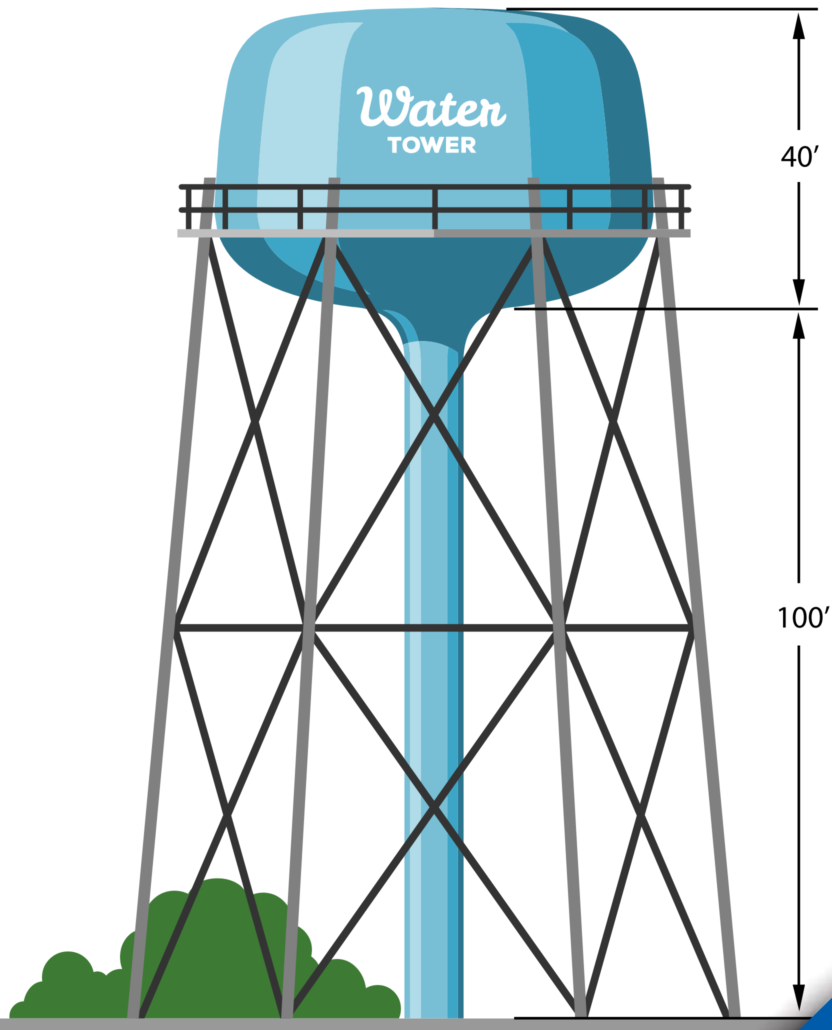
Whether water is going to a storage tank or to consumers, it takes pressure to get it there. This pressure can come from pumps or water towers. When using the latter, the taller the structure is, the more water pressure is available.

Calculating psi / feet of range

For every 1 psi, 2.31 feet of elevation is required. In other words, each foot of height provides 0.433 psi of head pressure. This is the static pressure "pushing down." Only the tank's height, called the head range, matters for psi / feet of range calculations – not its diameter.

Also called the altitude range, psi / feet of range is how the water and wastewater industry refers to the available water pressure. The available pressure of any given water tower will vary according to how much water is currently in the tank. To calculate this head pressure, let's assume that our water tower has a tank with a 40' head range and a 100' support column. An empty water tower means that the water column is 100', whereas a full water tower has a 140' water column. Knowing that 1' in elevation equals .433 psi, we can make the following calculations:

.433 psi x 100' = 43.3 psi (empty)
.433 psi x 120' = 51.96 psi (half full)
.433 psi x 140' = 60.62 psi (full)



So, this 140' water tower has an altitude range of 43.3 psi at 0% capacity (empty) to 60.62 psi at 100% capacity (full). Municipal water supplies usually require 45 to 80 psi of head pressure, enough to reach about the sixth floor of a building. This is why skyscrapers and other tall buildings have their own elevated storage tanks and/or pumps.

Water tower with a 40' head range and 100' from top of foundation to low water level.

Measuring Pressure, Level, and Temperature in Water Tower Applications

Weak water pressure means more than just unsatisfying showers. Appliances like washers and dishwashers require 20–30 psi for efficient operations. What's more, when the water in pipelines is sufficiently pressurized, it creates a barrier that prevents contaminants from entering.

These are some of the critical points for pressure measurement in municipal water delivery systems:

Pumps – pumping stations, booster stations, booster pumps within water tanks

- Suction nozzle (inlet)
- Discharge nozzle (outlet)

Water tower

- Inlet pipe
- Outlet pipe

Pressure instruments located at ground level, installed on the outlet (discharge) pipe of a water tower, can also measure the water level in the tank. By using the above psi / feet of range calculation, if we know the pressure value, we can determine the water level with a simple calculation. Let's use the same example of a water tower with a 40' head range and 100' support column.

measured pressure / .433 psi = water column
water column – height of support column = water level in tank

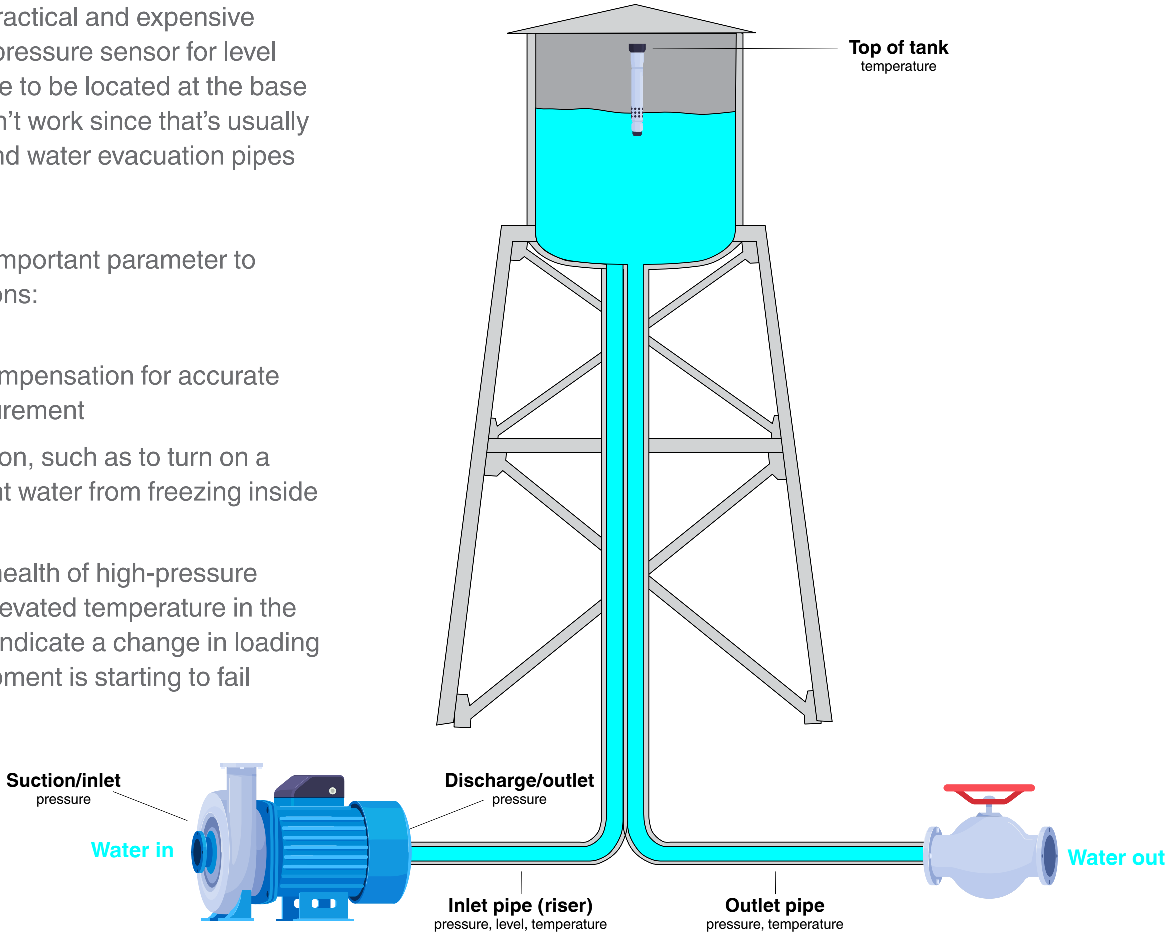
If the pressure sensor measures 50 psi, then the water level in the tank is about 15½ feet deep, or roughly 39% full:

50 psi / .433 psi = 115.47'
115.47' – 100' = 15.47'

Measuring pressure at ground level to determine the elevated tank's water level is preferable to using a level indicator, which would have to be as tall as the head range – an impractical and expensive solution. A submersible pressure sensor for level measurement would have to be located at the base of the tank, which wouldn't work since that's usually where the inlet, outlet, and water evacuation pipes are located.

Temperature is another important parameter to measure, for these reasons:

- Temperature compensation for accurate pressure measurement
- Switching function, such as to turn on a heater to prevent water from freezing inside a pipe
- Monitoring the health of high-pressure pumps, as an elevated temperature in the bearings could indicate a change in loading or that the equipment is starting to fail



Why a Pressure Gauge Might Fail

Mechanical pressure gauges are often exposed to challenging operating conditions that can shorten their service life and, in extreme cases, cause early failures. Here are the top reasons why pressure gauges in a water storage application might fail.

Vibration – Extreme vibrations affect the gauge internals and can cause a Bourdon tube to fracture. Signs of gauges affected by vibrations are severe, erratic pointer flutter, metal shavings inside the case, and a detached pointer.

Solution: *Use a liquid-filled gauge. The glycerin case fill will dampen the movement and lubricate delicate internal parts.*

Pulsation – Severe pulsation and pressure cycles increase the wear and tear of internal components. They also cause pointer flutter.

Solution: *A restrictor or snubber will reduce and/or dampen the impact of pressure cycles and pressure spikes. WIKA recommends using a liquid-filled gauge with a restrictor.*

Pressure spikes – In water storage applications, common sources of pressure spikes are the rapid opening and closing of valves, and turning pumps on and off. A broken or bent pointer, caused by the pointer repeatedly hitting the stop pin, is a sure sign of pressure spikes.

Solution: *Accessorize the gauge with a restrictor, snubber, or – even better – an external overpressure protector.*

Overpressure – Overpressure is when a gauge operates past its full scale. Extreme overpressure leads to a ruptured Bourdon tube. Two signs that a gauge has been exposed to overpressure: a severe pointer shift and a pointer pegged against the stop pin.

Solution: *Choose a pressure gauge with the correct range based on the operating conditions. An overpressure protector also shields the gauge from such conditions.*

See this article for more information.

Pressure Instruments for Water Delivery Systems

A range of pressure gauges and sensors help monitor the pumps that lift water to the elevated storage tanks, as well as the pipes that carry water to and from the tank. Since pumps and their motors create significant vibration, pulsation, and pressure surges that can damage standard instruments (see sidebar), the gauges and sensors used in this application must be able to withstand wide pressure variations.

A-10

The A-10 pressure transmitter is highly resistant to pressure spikes and vibration, thanks to thin-film technology and an all-welded stainless steel measuring cell. It is cost-effective, making this transmitter ideal for OEMs, and has an extremely compact design to fit in tight spaces. When installed at the suction (inlet) side of a pump, the A-10 helps prevent cavitation, which can cause pressure spikes. For the most demanding pressure measuring requirements, use the S-20 superior pressure transmitter.

The UPT-20 with pressure port and HART communication protocol is the recommended universal process transmitter for use with either the A-10 or S-20. It is constructed of stainless steel or stainless steel and PBT plastic, and all wetted parts are made of welded stainless steel with no internal O-rings, gaskets, or other soft sealing materials. The UPT-20 is available with a variety of certificates (NACE MR0103 and MR0175, NIST traceable accuracy, DKD/DAkks calibration per IEC 17025, etc.) and is CE and RoHS compliant.

UPT-20

Moisture is one of the main causes of pressure sensor failure. With high ingress protection, the A-10 and S-20 operate reliably in the humid environments of pumping stations and water storage tanks. Note that the type of electrical connection matters. For example, this pressure transmitter with an angular connector is rated IP65, which protects against low-pressure water jets and sprays. But using a circular connector or cable outlet, the rating rises to IP67, allowing it to be fully immersed in water for a limited duration and to a certain depth.

When selecting a pressure gauge to use in potable water systems, choose from the instruments in the Drinking Water (DW) series. Certified to be lead-free, the 111.10DW, 111.12DW, 111.25DW, and 213.53DW all comply with the 2014 US Safe Drinking Water Act and NSF (National Sanitary Foundation) 61/372. Their pressure connections, Bourdon tubes, and movements are made of a lead-free copper alloy; the solder is also lead-free. Note that the A-10 pressure transmitter also has NSF approval.

For gauges that do not come into direct contact with drinking water, use one of WIKA's heavy-duty XSEL® models. The 21X.34, 23X.34, and 26X.34 feature Swiss-made movements and hardened components that reduce stress and wear – making these gauges an economical choice with their long service life. Liquid case filling offers even greater protection against vibration, pulsation, and pressure surges.

213.53DW

23X.34 XSEL

Level Measurement in Water Towers

Underground storage tanks, which are not gravity-fed, can use submersible pressure sensors for level measurement. For above-ground water tanks, however, a pressure transmitter like the A-10 or S-20 – installed on the discharge pipe – can measure the hydrostatic pressure of the water column above that point.

For even more precise level measurement, use a digital pressure transducer like the CPT6020. It is a self-contained pressure sensing device, meaning that it incorporates a low-hysteresis silicon sensor with electronically compensated pressure linearity over the entire compensated temperature range. This calibration-grade instrument has a ±0.020% full-scale accuracy.

CPT6020

Temperature Instruments for Water Towers and Pumps

Municipalities in the north have to deal with cold-weather situations. In addition to plowing snow and de-icing roads, there's the matter of keeping water tower piping from freezing. Some cities get around the issue by storing treated water below the frost line – around 6 feet deep at 45° latitude. But underground storage is an expensive solution. Not only does it require extensive engineering and excavation at the project outset, but also calls for many pumps operating nonstop to deliver water to customers. In contrast, water towers are much more cost effective to construct, operate, and maintain.

Due to the tanks' depth, the water inside usually won't freeze completely, and any ice that does form is at the top – rising and falling alongside the water level. The piping is another matter. Insulation and heat tape prevent a water tower's riser and discharge pipes from freezing, and the warmed water entering the tank slows down the freezing process. Resistance thermometers (RTDs) in wireless transceiver nodes help monitor temperatures in key locations throughout water tanks.

RTDs are also invaluable for monitoring the condition of high-pressure water pumps, as increasing temperature can indicate that the motor is overheating – a potentially dangerous and costly problem. The TR58 bearing RTD has a solid design with no moving parts, making it vibration-proof. Its compact design allows it to fit in tight spaces like bearing plates, shafts, and motor windings. It can also be spring-loaded into the bearing's housing.

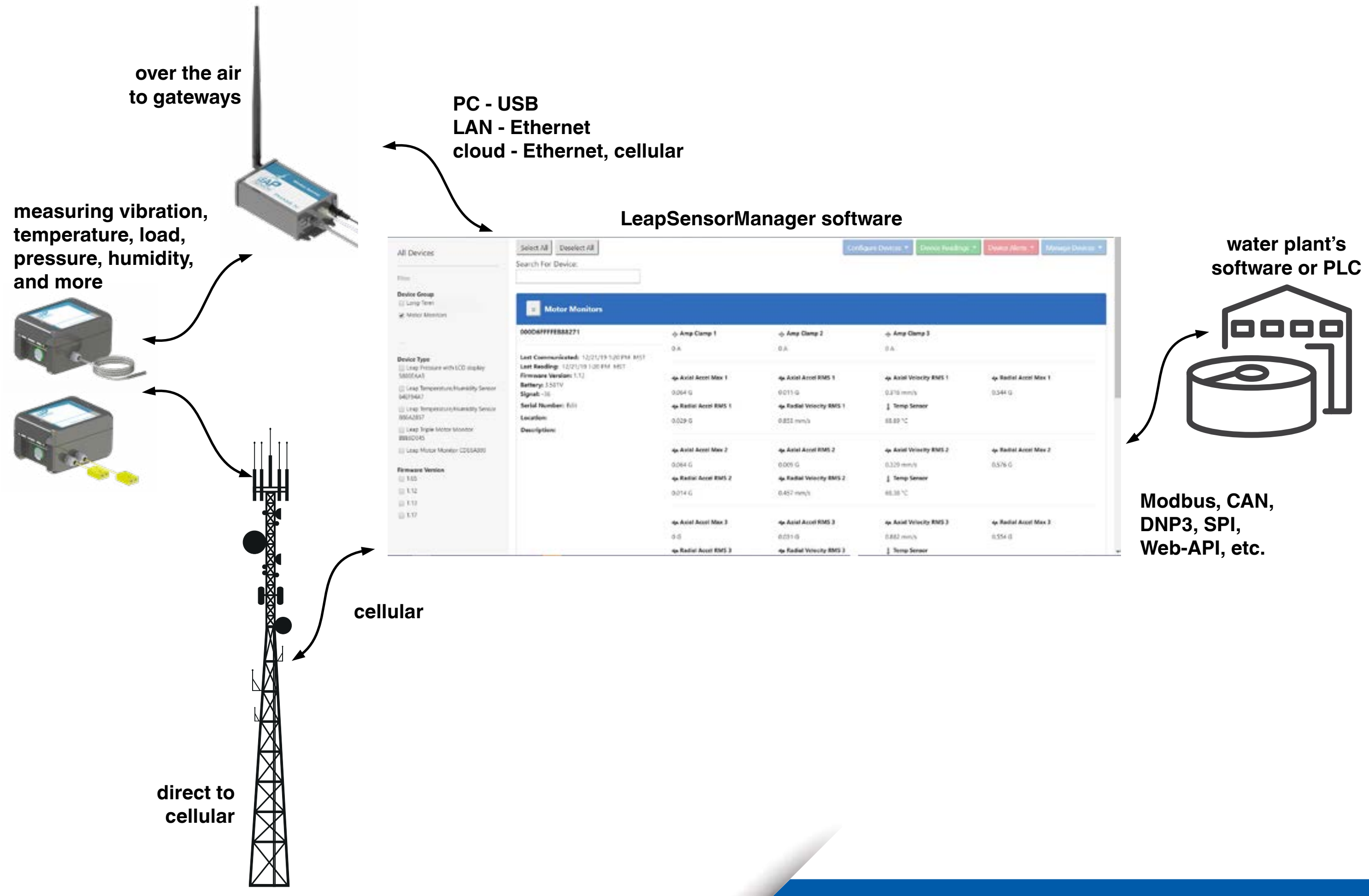

TR58

Wireless Sensors for Condition Monitoring

At the heart of a municipality's water delivery system, pumps are expensive yet vital pieces of equipment. Therefore, it is essential to ensure that their motors remain in good working condition. Wireless, easily configurable, and simple to install, [Leap Sensors] by Phase IV Engineering help users keep an eye on the state of their pumps and other rotating equipment with one transceiver node that measures a variety of parameters:

- Vibration
- Activity – running or not running
- Temperature – via thermocouples and/or RTDs
- Pressure
- Differential pressure – for filter monitoring
- Flow – via ultrasonic bolt-ons and/or pulse counter
- Moisture – humidity level, water, flooding
- Analog input – 4…20 mA (current), 0…10 V (voltage)
- Electric current draw
- Digital input – CAN, RS485 (Modbus RTU), SPI, 12C, etc.
- Strain and load – via force sensors

All this data is transmitted using gateways or directly to cellular, and is fed into the LeapSensorManager software, located on the gateway, a PC, a local server, Phase IV's cloud server, or the client's cloud server. This software analyzes the data and sends alert – via text, email, or phone call – if it detects an issue.



Structural health monitoring for water towers

Water tanks can hold a tremendous amount of weight – from about 40,000 lb. in a 5,000-gallon rooftop units to over 20 million lb. in a 2.5 million gallon composite elevated tank. Structural health monitoring (SHM) is a key factor in infrastructure safety, especially for larger storage tanks.

Traditionally, civil engineers visit the site – be it water towers, bridges, overpasses, or tunnels – at regularly intervals to manually check for potential problems. Scheduled SHM is fine, but what if the tank begins to lean or shift between annual or biannual inspections, or the engineers missed something critical?

A more reliable way of monitoring a structure's health is with wireless sensors, which continually measure strain, incline, vibration, crack propagation, and other variables, then automatically report any significant or sustained changes to operators. Not only does automated SHM increase the safety and reliability of elevated water tanks, but catching potential problems early saves on maintenance, repairs, and the cost of labor.

WIKA, Smart Sensors and Solutions for Municipal Water Utilities

The mission of every municipality's water service is to provide a clean and reliable supply of water for their community at a reasonable cost. Tank manufacturers, EPC (engineering, procurement, and construction) firms, and contractors also want to equip water delivery projects with the highest quality instruments and sensing technology. WIKA is a global leader and trusted partner for measurement solutions in water towers, pumping stations, water treatment plants, and other municipal facilities. Contact the product experts at WIKA USA to help you select the right measuring instruments and sensors that will protect your assets and prolong their service life.

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