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DEALING WITH SATURATED STEAM: ACHIEVE ACCURATE GUIDED WAVE RADAR READINGS IN CHALLENGING BOILER APPLICATIONS

Authored by Adam Krolak, Honeywell Process Solutions

White Paper

Abstract

Across power generation, chemical processes and refining, accurate measurement and control of water levels in the drum or other vessels in the steam loop are essential to process efficiency, equipment health and, potentially, the safety of the plant and its personnel. Guided Wave Radar provides reliable water level measurement with easy installation, virtually no maintenance, and compliance with SIL requirements. This document provides insight into the benefits of using Guided Wave Radar in steam applications.

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Introduction

To operate a boiler successfully, you must know the water level within the boiler. Across power generation, chemical processes and refining, accurate measurement and control of water levels in the drum or other vessels in the steam loop are essential to process efficiency, equipment health and, potentially, the safety of the plant and its personnel.

Unfortunately, many of the measurement technologies suffer inherent weaknesses. Multiple point switches, whether capacitive, conductive or mechanical, for example, only provide discrete level indication (with no visibility of the level between each switch), rather than continuous readings. The result is poor level control. Displacer transmitters, including magnetic level gauges, meanwhile, are designed for a specific liquid density. If the density of the process changes, as it frequently will with temperature, the measurement accuracy will suffer.

The same is true of differential pressure transmitters, which are perhaps the most advanced and best of the alternatives mentioned. It relies on measuring the pressure in the vapour (empty) space of the drum, measured by a sensor near the top, and the pressure in the liquid, measured by a sensor near the bottom. The difference between the two gives the pressure exerted by that liquid. If its density is known, the amount of liquid and therefore the level in the tank, can be calculated. At a constant density and performing well, differential pressure provides continuous, accurate readings.

However, crucially, the technology provides no or unreliable measurement at the boiler's start-up. Condensate must fill the impulse lines before differential pressure transmitters can give an accurate reading. The measurement is also easily undermined:

•By changes in the density of the liquid in the boiler when the liquid is heated or cooled

•By changes in the density of fluid filling the impulse lines due to the ambient temperature around the boiler

•Due to drifting of the pressure measurement over time, unless repeated calibrations are performed

•By clogging of impulse lines unless they are frequently cleaned.

Guided wave radar: A more reliable solution

Guided wave radar avoids almost these shortcomings.

In ordinary level measurement applications (not featuring saturated steam), the theory is relatively simple (Figure 1): Electromagnetic measurement pulses are guided to the liquid by a metallic probe running down the tank. When they reach a product surface or interface (boundary between two liquids), a portion of the pulse will propagate through the surface and the rest will be reflected up the probe to the transmitter. The speed of the electromagnetic radiation pulses through the air is known. Based on this, the travel time of the reflected signal can be used to calculate the distance to the reflection point and therefore the level of the liquid.

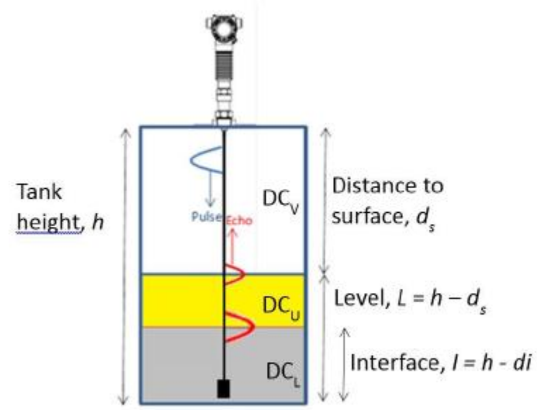


Figure 1: d_s = distance to surface; t = time for the pulse to travel distance ds; V_{wg} = speed of light in a vacuum on the probe; DCv = dielectric constant of the material in the head space above the level (for air, DC_V = 1)

In ordinary applications, the benefits of guided wave radar (GWR) are manifold:

•The electromagnetic signals are less sensitive than acoustic waves (used by ultrasonic measurement, for example) to vapours, dust, changes of temperature and pressure, or foaming

•There are no moving parts to require maintenance – an additional weakness of magnetic and other displacer gauges

•The strong signal (concentrated around the metallic waveguide probe) allows reliable measurement in small, tall and narrow, or busy tanks.

Most significantly, GWR is immune to changes in the density the measured liquid, overcoming the key weakness of differential pressure transmitters.

A dielectric dilemma

GWR has an Achilles heel however: saturated steam.

The speed electromagnetic signals travel is the speed of light in a vacuum; in other environments, it is affected by the refractive index, the ability of the material to refract light. Air is a poor refractor of light (and therefore has little impact on the speed of the electromagnetic signals). The refractive index increases as the density of the material does, however: Water significantly refracts light. This means as the pressure and temperature of saturated steam in the empty (vapour) space of the tank changes (therefore affecting its density), it will affect the speed with which the pulses travel to and return from the surface of the liquid.

Without compensation for this, the result will be significant inaccuracy in the level measurement as the temperature in the boiler and amount of steam increases (Table 1). At higher temperature, this would effectively render the measurement useless (Figure 2).

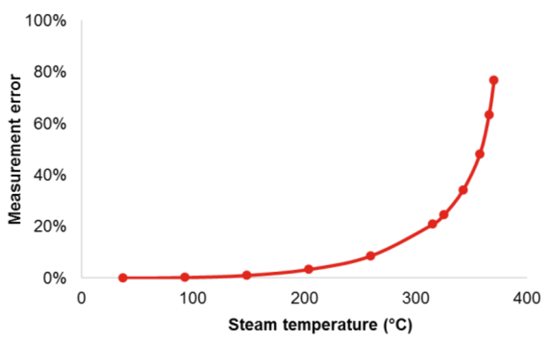


Figure 2. The magnitude of error increases rapidly at higher temperatures.

Saturated steam dielectric constants vs temperature & pressure						Error with no compensation
°F	°C	psia	bar	DC_{Liquid}	DC_{Vapor}	% error
100	38	1	0.1	73.950	1.001	0.0%
200	93	14	1.0	57.260	1.005	0.2%
300	149	72	5.0	44.260	1.022	1%
400	204	247	17.0	34.000	1.069	3%
500	260	681	47.0	25.580	1.180	9%
600	316	1543	106.4	18.040	1.461	21%
618	326	1740	120.0	16.700	1.550	24%
649	343	2176	150.0	14.340	1.800	34%
676	358	2611	180.0	11.860	2.190	48%
691	366	2900	199.9	9.920	2.670	63%
699	371	3046	210.0	8.900	3.120	77%

Table 1A. As the temperature and pressure changes so does the dielectric constant in the vapour space.

As the table illustrates, both the dielectric constant at any temperature and its impact on the speed of the electromagnetic signals are known. We can therefore build in a correction factor to the transmitter to compensate for the effect of steam and achieve accurate readings at a specific temperature – such as the standard operating temperature.

This can only be done at the cost of inaccurate readings outside a narrow range, however. In fact, the readings at temperatures below that used for the compensation will be less accurate than if they had not been corrected. In these circumstances, such as when starting up or shutting down the boiler, operators are effectively flying blind (as they are with differential pressure measurement).

A more dynamic approach

The solution is to have the compensation automatically adjust to changes in the dielectric constant as temperatures rise or fall. As saturated steam in the empty space increases, so must the correction factor; as it decreases, the adjustment to the calculation should be reduced.

To achieve this, Honeywell's SmartLine level SLG700 offers an option for high temperature and pressure applications to include an impedance transition at a known position. This can automatically measure the dielectric constant of the steam and recalculate the level measurement to give its true value.

In practice, this is done by inserting a section of rod with a different diameter to the rest of the waveguide (Figure 3) at a known distance from the electromagnetic transmitter in the empty part of the tank.

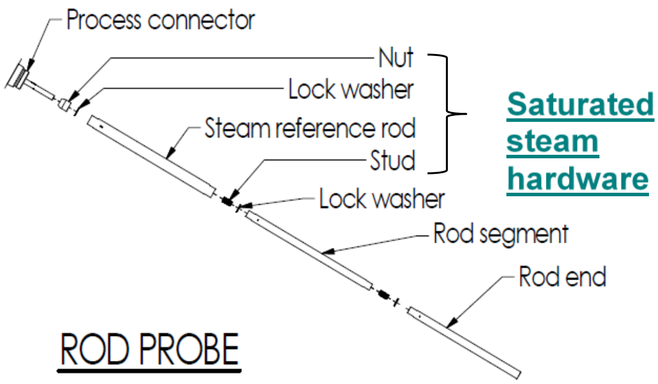


Figure 3. A different diameter reference rod is inserted into the GWR probe.

The change of waveguide diameter (from a 22-mm rod to a 16-mm rod) is detectable by the radar pulses (Figure 4). Some of each pulse is reflected to the transmitter (while the rest continues to the surface of the liquid). Since the distance from transmitter to the steam reference rod is known, the time taken for the pulses to reflect the change in diameter is used to determine their speed.

This technique is used to dynamically and automatically correct the level measurement to achieve accurate readings across all temperature ranges.

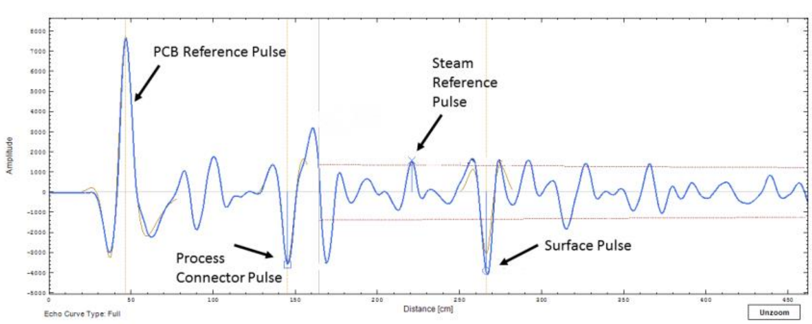


Figure 4. The steam reference rod clearly shows up in the pulse signal.

A final polish

The diagram above shows something else worth noting, too: the importance of being able to accurately determine the correct pulse to use for the level measurement. This peak (or rather trough) must be distinguished automatically by the instrument from other signals and interference caused by thin interfaces, probe ends, in-tank obstacles, build-up and so on.

To ensure the most accurate readings, Honeywell's SLG 700 series level transmitters employ advanced signal processing techniques. In particular, the usual simple peak-finding algorithm, they employ a correlation algorithm to help to discern the true peak from unwanted reflections. This uses an internal reflection model, stored in the memory of the radar instrument. The pulse-shape information of this model, including amplitude, width and side-lobe attenuation, is used to compare with those of the signals being captured by the transmitter. This comparison is used to find the best candidate for the surface pulse, providing the measurement of the level.

Finally, in difficult conditions or when the measured material attenuation (used to determine the model) is not well known, the SLG 700 also employs amplitude tracking. This enhances the user specified pulse model information using historic measurement data, so that, once the sensor has locked onto a correct level, it will track the amplitude rather than use the model amplitude.

Ease of use

SLG 700 instruments can be shipped with segmented probes (the minimum length of a segment is 500 mm), which makes them easier to transport and install in setting where the space above the tank is limited: There is no need to fit long probe above the tank for insertion.

The compensation functionality is not always beneficial for all applications. It may add complexity and cost in case where additional precision is not necessary. We offer an online selection tool, (Figure 5) that includes automatic estimation of the error from the influence of saturated steam. Based on the user temperature or pressure input, this automatically calculates the accuracy of measurement, and helps the user decide whether compensation is needed or not for a specific application.

Conclusion

The importance of accurate level measurement in many boiler applications is only matched by the challenge of achieving it. Guided Wave Radar has come closer than most to overcoming this, but the difficulties around saturated steam have proved a significant limitation on the technology in the past.

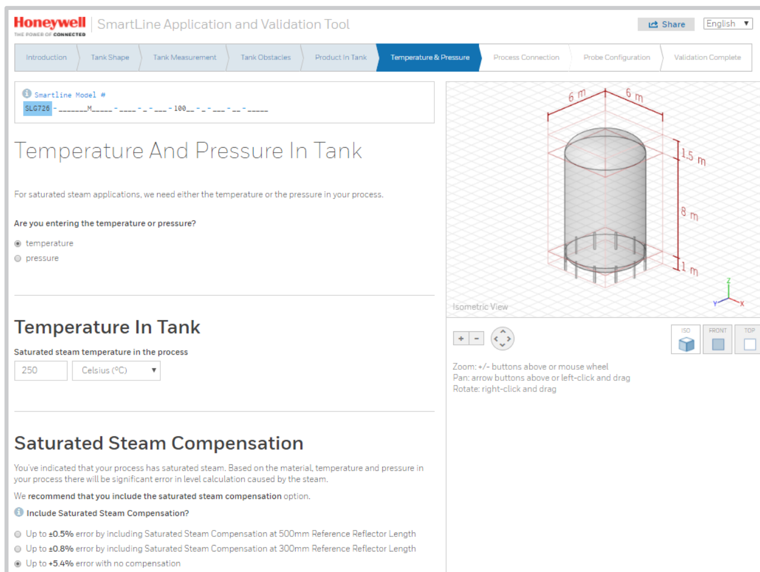
Dynamic compensation addresses this problem and delivers a solution that can provide reliable, accurate measurements across a wide range of operating temperatures and pressures.

It also does so while retaining all the benefits of the technology: low maintenance, with no moving parts; continual and real-time level measurement; and immunity to mechanical interference and changes in density.

It deserves to become the level measurement technology of choice in boiler applications. The strength of the solution chosen, meanwhile, will be determined by the accuracy with which the GWR technology can reliably identify the correct surface pulse for a true measurement of the level. For level measurement technology manufacturers, this is likely to be the key battleground of the future.

Honeywell's SLG 700 SmartLine Guided-Wave Radar offer a wide range of benefits, including dynamic compensation of pulse height and width, which avoids changes in semiconductor electronics due to temperature. They also offer easy setup and multiple protocol support. The technology enables users to get accurate level measurement in the most challenging applications, with an efficient, effective solution.

Figure 5. Honeywell's online application and validation tool available at https://config.honeywellsmartline.com/



For More Information

To learn more about SmartLine , visit www.honeywellprocess.com or contact your Honeywell Account Manager or Distributor.

Honeywell Process Solutions

1250 West Sam Houston Parkway South
Houston, TX 77042

Honeywell House, Skimped Hill Lane
Bracknell, Berkshire, England RG12 1EB UK

Building #1, 555 Huanke Road,
Zhangjiang Hi-Tech Industrial Park,
Pudong New Area, Shanghai 201203

www.honeywellprocess.com

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