

# Using Guided Wave Radar for Level in High Pressure Steam Applications

## INTRODUCTION

This document describes the advantages of using a Rosemount 5300 Series Guided Wave Radar (GWR) with Dynamic Vapor Compensation (DVC) in high pressure saturated steam applications, such as boiler drums, high pressure feed water heaters and steam separators.

GWR is used for direct level measurement and is completely independent of density. With no moving parts, it offers the advantages of lower maintenance and greater reliability. The Rosemount 5300 Series Superior Performance GWR also provides a Dynamic Vapor Compensation function.

## BACKGROUND

A good level measurement in a boiler application will:

- Prevent wet steam carryover to turbine
- Optimize heat exchanger performance
- Continuously control condensate level
- Control condenser vacuum
- Ensure pump safety
- Optimize drum level control

The cylindrical vessel where the water-steam interface occurs is called the boiler drum. The boiler drum level is a critical variable in the safe operation of a boiler. A low drum level risks uncovering the water tubes and exposing them to heat stress and damage.

High drum level risks water carryover into the steam header and exposing steam turbines to corrosion and damage. An accurate level measurement helps to optimize the level control of the boiler.

Steam separators and HP feed water heaters have similar level control needs as boilers.

In all of these applications, as the pressure and temperature increases, the accuracy of the level measurement can be impacted by changes in fluid properties. The two fluid properties of most concern are the density and the dielectric.



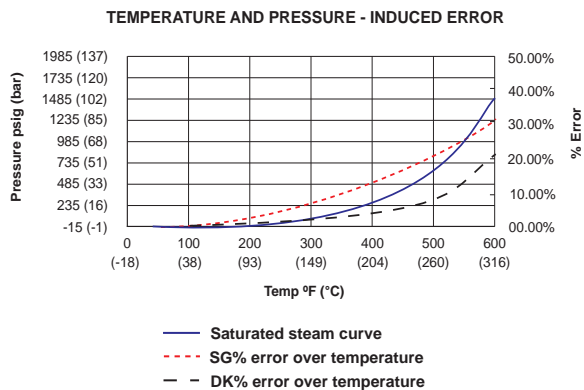
## ADVANTAGES OF GWR OVER OTHER TECHNIQUES

Both the liquid and steam phases of the system will have density changes as the system reaches operating temperatures and pressures. Any density-based level measurement device will need to be compensated to discern the actual level from the density-associated errors. Algorithms have been developed to make this compensation as seamless as possible in the control systems, but require input of operating pressure as well as level.

Since GWR measurement devices are completely independent of density, these associated errors are not present, thus eliminating the need for this compensation.

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While these applications are generally considered to be composed of clean water and steam, with the higher pressures and higher pH, there is often a layer of magnetite coating the metallic surfaces and this can cause some mechanical linkages to freeze and stick. With no moving parts, GWR offers additional advantages of lower maintenance and greater reliability.

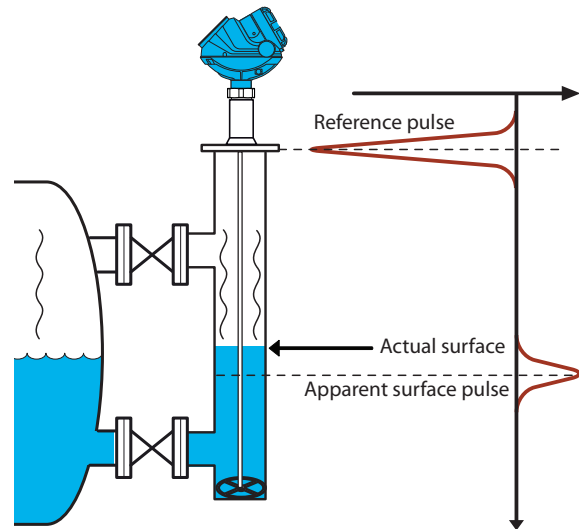


Both the density (SG) and dielectric (DK) properties of water and steam change with pressure and temperature. If not compensated, significant errors can result.

## CHANGING DIELECTRICS

For radar level measurements, the actual quantity being measured is the propagation time through the empty space between the radar transmitter and the liquid surface. In order for the accuracy to remain high, it is important that the propagation speed of the radar signal is very close to the perfectly constant velocity of light in vacuum. With most fluids, there is a negligible change in dielectric of the vapor. Water, however, is a notable exception.

Water vapor under high pressure and varying temperature will have different dielectric constants and these changes can influence the radar level transmitter measurements. An increase in the dielectric constant slows propagation down, causing the signal for the liquid level to appear beyond the actual level point. In some important cases, this deviation is not negligible and must be taken into account, in order to get high accuracy. High tank pressures in combination with certain gases are examples of these cases.



The figure illustrates how the surface appears to be beyond the actual level point because of the vapor present. No vapor compensation is used in this case.

Even though the dielectric of water decreases with temperature increase, the level can be measured as long as the water dielectric remains sufficiently high so there is a reflection back from the surface.

However, as the temperature increases, the dielectric difference between the liquid and the steam becomes smaller and at a certain point it will be too small for a reliable measurement with radar transmitters.

Beyond this point, at approximately 2030 psi (140 bar)<sup>(1)</sup>, guided wave radar transmitters are no longer a suitable choice for level measurements. In the very high pressure systems, there is no level measurement, since there is no distinct liquid/steam interface.

(1) This is the process pressure, design pressure can be higher.

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## VAPOR COMPENSATION FUNCTIONALITY

In the Rosemount 5300 Series Superior Performance GWR, there are two functions to compensate for the vapor dielectric; one static and one dynamic. The default vapor dielectric value is set to 1, which corresponds to the dielectric of vacuum.

TABLE 1. Table showing the error in distance with changing temperature and pressure, without vapor compensation.

Temp. °F/°C	Pressure psia/bar	DK of liquid	DK of vapor	Error in distance %
100/38	1/0.1	73.95	1.001	0.0
200/93	12/1	57.26	1.005	0.2
300/149	67/5	44.26	1.022	1.1
400/204	247/17	34.00	1.069	3.4
500/260	681/47	25.58	1.180	8.6
600/316	1543/106	18.04	1.461	20.9
687/364	2900/200	~13	2.5	58

As can be seen in the table above, at 247 psia (17 bar) there is an error in distance of 3.4% and at 1543 psia (106 bar) there is an error of 20.9% when there is no compensation for the vapor dielectric. The error in distance increases with the pressure and at some point this deviation is not negligible and must be taken into account, in order to get high accuracy.

### Standard Function: Static Vapor Compensation

For the static compensation function, the dielectric of the vapor at expected operating pressure and temperature is manually entered as part of the configuration of the transmitter. This allows the unit to compensate for the dielectric at operating conditions.

The static compensation works well under stable conditions and in these applications, the standard high temperature/high pressure probe is used.

### Optional Function: Dynamic Vapor Compensation

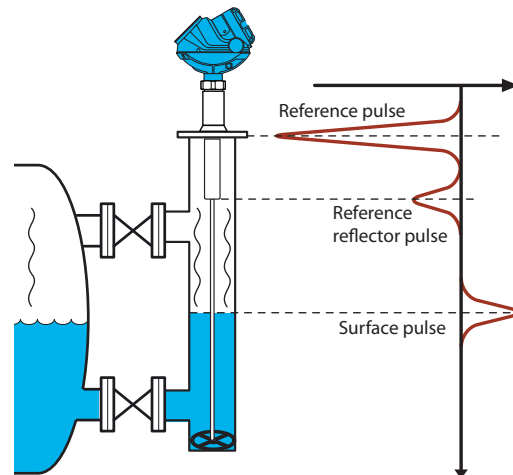
Dynamic Vapor Compensation becomes more important for the higher pressure applications that may have more variations in the operating conditions or where the users want to be able to verify the unit under near ambient conditions, such as during start-up and shut down, without having to modify the vapor dielectric settings.

Vapor Compensation does not have an effect on the accuracy until the pressure is higher than 145 psi (10 bar). When to recommend Dynamic Vapor Compensation depends on what accuracy the application requires, but around 600 psi (40 bar) and higher it makes a significant difference in accuracy.

In these cases, Dynamic Vapor Compensation will reduce the error to less than 2% under varying conditions.

Dynamic Vapor Compensation works by using a target at a fixed distance. With this target, the vapor dielectric will be measured continuously.

The transmitter knows where the reference reflector pulse should have been if there were no vapor present. However, since there is vapor in the tank, the reference reflector pulse will appear beyond the actual reflector point. The distance between the actual reflector point and the apparent reflector point will be used to calculate the vapor dielectric.



The figure illustrates how the surface appears at the correct surface level point when using Dynamic Vapor Compensation.

The calculated dielectric is then dynamically used to compensate for vapor dielectric changes and eliminates the need to do any compensation in the control system.

When the distance between the mounting flange and the surface is less than 17.3 in. (440 mm) for short probes (<78.7 in. (2000 mm)) and 28 in. (710 mm) for long probes (>78.7 in. (2000 mm)), the function switches from dynamic to static vapor compensation using the last known vapor dielectric constant.

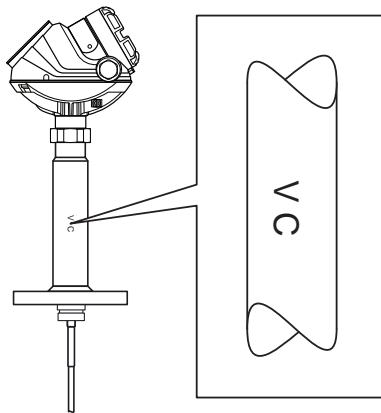
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## COMPETITIVE ADVANTAGES

For the Rosemount 5300 with Dynamic Vapor Compensation, the single rigid probe is used. This offers a great advantage compared to solutions with a coaxial probe, since the single probe is more tolerant of coating and also reduces maintenance.

Rosemount GWR extreme temperature and pressure probes are designed to prevent leakage and perform reliably when exposed to extreme process conditions for extended periods of time. Materials are selected to avoid stress fractures commonly induced by changes in temperature and pressure conditions.

The robustness of the probes and the materials, means high safety for these extreme temperature and pressure applications.



Probe with reference reflector marked "VC" for recognition

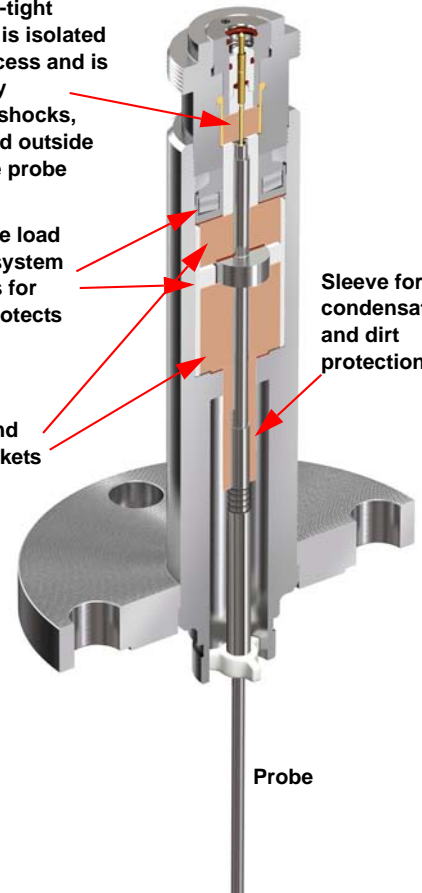
## The GWR Probe Design Provides Multiple Layers of Protection

Brazed hermetic/gas-tight ceramic seal is isolated from the process and is unaffected by temperature shocks, variations and outside forces on the probe

Flexible probe load and locking system compensates for stress and protects the ceramics

Ceramic insulators and graphite gaskets provide a robust thermal and mechanical barrier and offer chemical resistance

Sleeve for condensation and dirt protection



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## DVC INSTALLATION REQUIREMENTS

The GWR should be mounted in a 2, 3, or 4 - in. (50, 75, and 100 mm) inner diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application. Materials used for the chamber should meet ASME boiler code requirement and the chamber should be isolated directly from the boiler or HP heater by valves.

A rigid single lead HTHP probe with reference reflector for vapor compensation should be used. A centering disk will keep the probe centered in the chamber. The single lead probe can tolerate any magnetite layer that may occur. Probes up to 13.1 ft. (4 m) length are supported for Dynamic Vapor Compensation.

Dynamic Vapor Compensation requires a minimum distance from the flange to the surface level to measure the change in the vapor dielectric constant. If the level rises within this area, the unit switches over to static compensation, using the last known vapor dielectric constant.

This minimum distance (X in the picture) is 17.3 in. (440 mm) for probe length < 6.6 ft (2 m), and 28 in. (710 mm) for probe length > 6.6 ft (2 m) (see diagram below), to dynamically compensate up to level 100%.

The minimum measuring range for this functionality is 12 in. (300 mm).

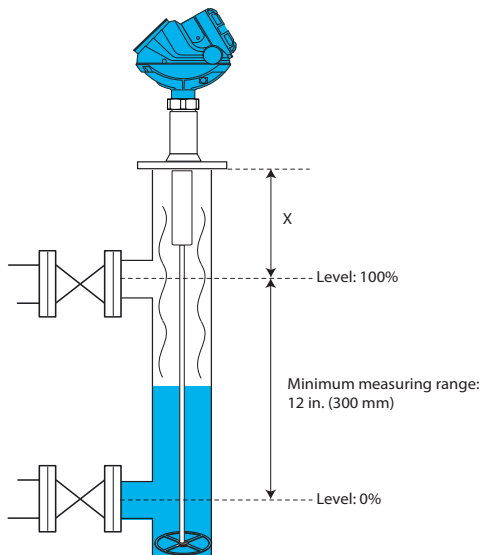
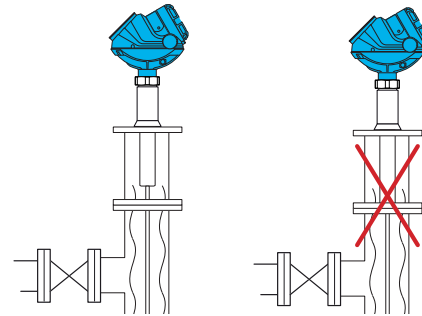


TABLE 2. Minimum distance X.

Probe Length	Reflector	Minimum Distance X
< 78.7 in. (2000 mm)	9 in. (230 mm)	17.3 in. (440 mm)
> 78.7 in. (2000 mm)	20 in. (500 mm)	28 in. (710 mm)

If a 5300 Series transmitter is ordered from Rosemount together with a 9901 Chamber, these space requirements are met. If an existing chamber is used, which does not meet these space requirements, a spool piece can be added. For an installation with a spool piece, it is important to make sure that the reference reflector and the spool piece do not have the same length. The spool piece needs to be at least 2 in. (50 mm) longer or shorter.



**If a spool piece is used, it is important that the reference reflector and the spool piece do not have the same length.**

When a transmitter is ordered with the optional Dynamic Vapor Compensation, the function is activated from factory and the special probe is supplied. However, a calibration procedure with an empty chamber is needed on-site during the commissioning phase. The installation wizard in Rosemount Radar Master will prompt for this and guide the user through the necessary steps.

Note that Probe End Projection and Signal Quality Metrics are disabled when Dynamic Vapor Compensation is enabled.

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