

Using Guided Wave Radar for Level in High Pressure Steam Applications

1.0 Key points

- Accurate and reliable level measurement under changing process conditions with Dynamic Vapor Compensation
- Meeting the extreme temperature and pressure challenges with robust probe design and multiple layers of protection
- Low maintenance with no moving parts to freeze or stick

2.0 Introduction

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

3.0 Challenges

It is a challenge to measure level accurately and reliably in high pressure saturated steam applications. Level is critical for safe operation and good measurement helps to optimize plant performance. Application challenges for good level measurement include:

- Phase changes
- Extreme high pressures and temperatures
- Magnetite coating
- Vibrations

3.1 Phase changes

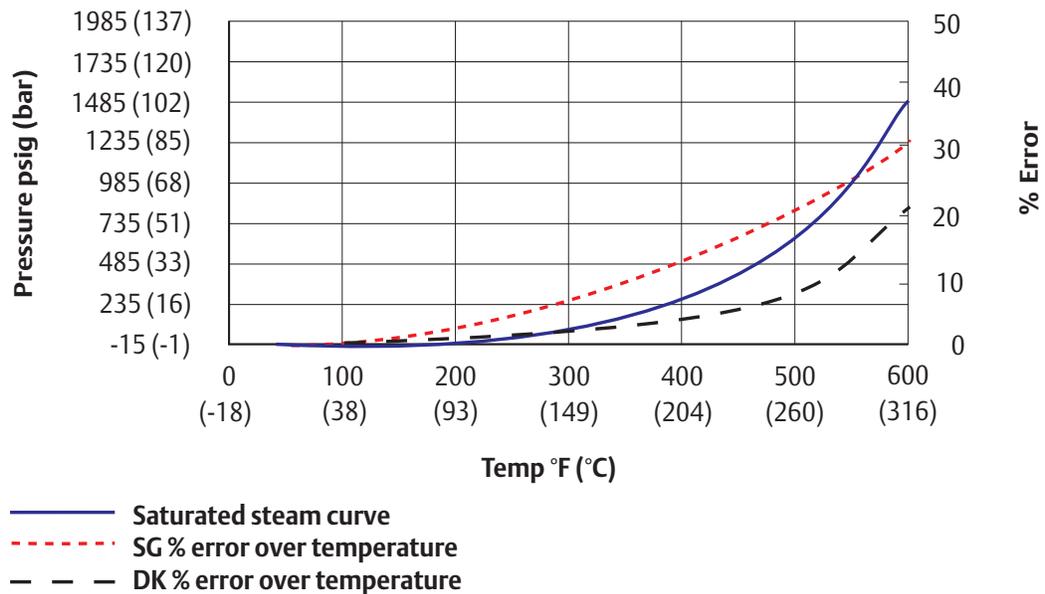
It is especially common during startup to experience varying temperature and pressure. Both the liquid and steam phases of the system will have density changes as the system reaches the operating temperature and pressure. That can cause up to 30 percent error for temperatures up to 600 °F (315 °C).



Any density-based level measurement device will need compensation 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. Compensation can be slow which results in erroneous reading.

There will also be dielectric property changes both in the liquid and steam phases. Steam under high pressure and temperature will slow down the propagation speed of a radar signal which can cause up to a 20% error, if not compensated.

Specific gravity and dielectric constant - Uncompensated error



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

Even though the dielectric of water decreases with temperature increase, the level can be measured as long as the water dielectric remains sufficiently high, which results in a reflection back from the surface. Reliable measurements within the specified accuracy can even be maintained up to pressures and temperatures of 2610psi (180 bar) and 676 °F (358 °C).

3.2 Extreme high pressures and temperatures

In these applications temperatures above 300 °F (150 °C) and pressures above 580 psi (40 bar) are common. Therefore, having robustly designed equipment which prevents leakage and performs reliably is vital for safety.

3.3 Magnetite coating

While these applications are generally considered to be composed of clean water and steam, it is normal to have a layer of magnetite on metallic surfaces. In some cases, the deposits can be heavy enough to cause some mechanical linkages to freeze and stick resulting in a need for maintenance. With no moving parts in the GWR probe assembly, magnetite poses no issues for sticking.

3.4 Vibrations

Vibrations from pumps can cause a noisy signal from mechanical-based techniques.

4.0 Solution

4.1 Advantages of GWR over other techniques

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

GWR has no moving parts that can freeze or stick from magnetite coating or cause noisy signals due to vibration. Therefore, GWR offers additional advantages of lower maintenance and greater stability.

4.2 Dynamic Vapor Compensation functionality

In the Rosemount 5300 Series GWR, Dynamic Vapor Compensation is used to compensate vapor space dielectric in steamy applications. This becomes more important for high pressure applications which 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.

The compensation occurs in the transmitter electronics and a corrected level measurement is provided to the control system. No additional compensation is required.

Table 1. Error 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	14/1	57.26	1.005	0.2
300/149	72/5	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
618/325	1740/120	16.7	1.55	24.5
649/343	2176/150	14.34	1.8	34.2
676/358	2611/180	11.86	2.19	48
691/366	2900/200	9.92	2.67	63.4
699/370	3046/210	8.9	3.12	76.6
702/372	3120/215	<i>Above critical point, distinct liquid and gas phases do not exist.</i>		

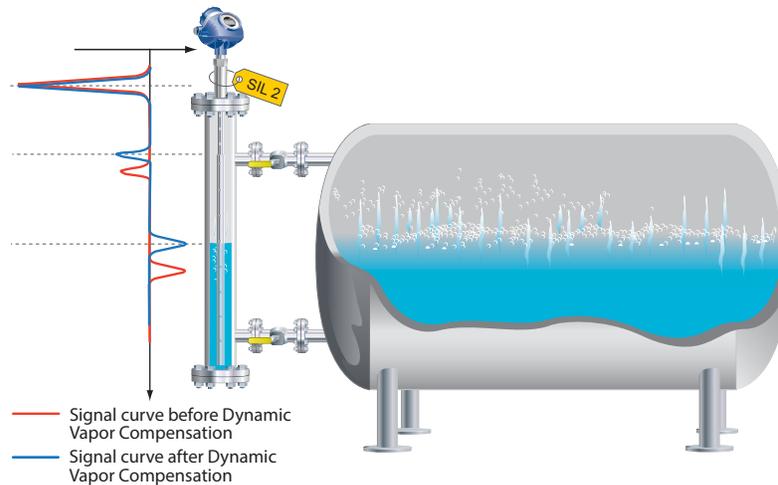
As seen in Table 1, at 247 psia (17 bar), there is an error in distance of 3.4%. At 1543 psia (106 bar), there is an error of 20.9% when there is no compensation for the vapor dielectric.

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 maintain high accuracy.

Full benefits of using Dynamic Vapor Compensation is achieved for pressures exceeding 247 psia (17 bar) as an uncompensated steam induced error becomes as large as 3.4% or more. For temperatures of 350 °F (177 °C) where errors are greater than 2% the Dynamic Vapor Compensation will be beneficial for accurate level measurement as well.

Dynamic Vapor Compensation works by using a target at a fixed distance. With this target, the vapor dielectric is measured continuously. The transmitter knows where the reflector pulse should have been if there were no vapor present. However, since there is vapor in the tank, the reflector pulse appears beyond the actual reflector point. The distance between the actual reflector point and the apparent reflector point is used to calculate the vapor dielectric. 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.

Rosemount's Dynamic Vapor Compensation solution is available in two versions depending on the chamber size. A single rigid vapor probe for 2-in. (50 mm) chambers and an integrated still pipe vapor probe for 3- and 4-in. (75 and 100 mm) chambers (if the chamber meets our engineered specifications).



The figure illustrates the radar signal curve before and after vapor compensation. Without compensation, the surface pulse appears to be beyond the actual level. After compensation the surface appears at the correct surface level point.

4.3 Rosemount design advantages

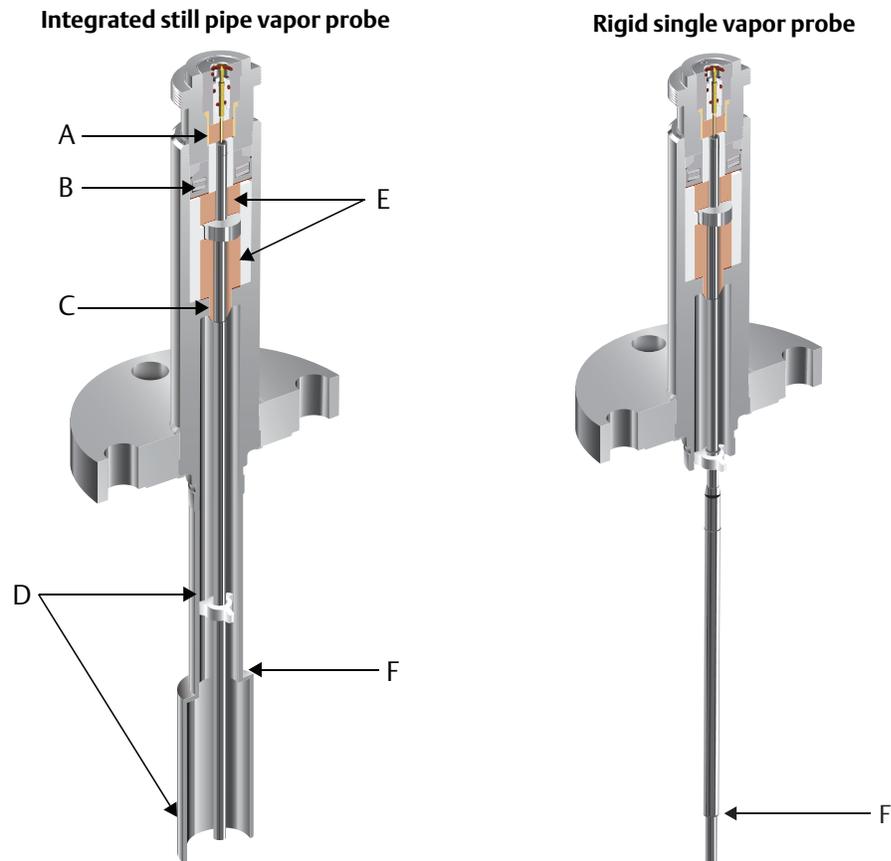
Rosemount 5300 GWR extreme temperature and pressure probes are designed to prevent leakage and perform reliably when exposed to extreme process conditions for extended periods of time. Materials are selected to avoid stress fractures commonly induced by changes in temperature and pressure conditions.

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

Every flange intended for high temperature and pressure applications is pressure tested to ensure it withstands extreme pressures. After production, every flange is pressure tested to 360 bar (standard) and P1 option flanges are pressure tested to 1.5 times the maximum flange rating at Rosemount's production sites.

4.4 Multiple layers of protection

Figure 1-1. Rosemount Dynamic Vapor Compensation



- A. Brazed hermetic/gas-tight ceramic seal is isolated from the process and is unaffected by temperature shocks, vibrations and outside forces on the probe.
- B. Flexible probe load and locking system with active springs and PTFE frame, compensates for stress and protects the ceramics.
- C. Drip-off sleeve for condensation and dirt protection.
- D. Spacer, up to three ceramic spacers will be used depending on the probe length. One near the top of the probe and the rest further down the probe. A stainless steel centering disc is placed at the end of the probe.
- E. Ceramic insulators and graphite gaskets provide a robust thermal and mechanical barrier and offer chemical resistance.
- F. Reference reflector.

4.5 Dynamic Vapor Compensation installation best practices

A specially designed HTHP probe with reference reflector for vapor compensation should be used. For 2-in. (50 mm) chambers, this probe is a single rigid vapor probe and for 3- and 4-in. (75 and 100 mm) chambers this is an integrated still pipe vapor probe.

The GWR should be mounted in a bypass chamber with flanges appropriately sized for the pressure and temperature of the application. A 3- or 4-in. (75 or 100 mm) diameter chamber is recommended as best practice, but the GWR can also be mounted in a 2-in. (50 mm) chamber.

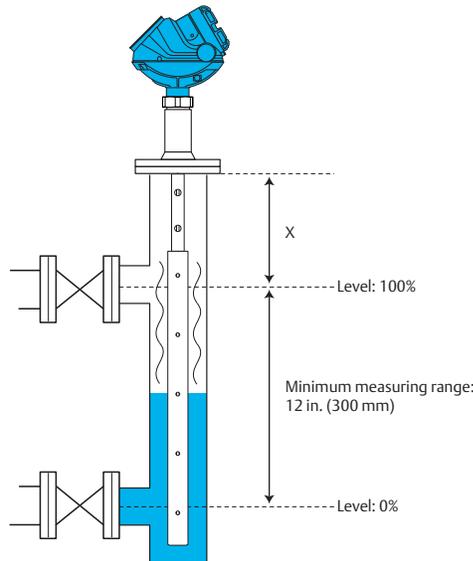
Materials used for the chamber should meet local boiler code requirements and the chamber should be isolated directly from the boiler or high pressure heater by valves.

Probes up to 13.1 ft. (4 m) for the integrated still pipe vapor probe and 9.8 ft. (3 m) long for the rigid single vapor probe 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 (indicated by X in the [Figure 1-2](#)) is 28-in. (710 mm) for the long reflector and 22-in. (560 mm) for the short reflector, to dynamically compensate up to 100%. If the distance from the flange to the upper inlet is less than 28-in. (710 mm), the short reflector should be chosen. The minimum measuring range for this functionality is 12-in. (300 mm).

Figure 1-2. Minimum Distance



Probe length min.	Probe length max.	Reflector	Minimum distance X
43-in. (1100 mm)	Integrated Still Pipe Vapor Probe - 158-in. (4000 mm) Rigid Single Vapor Probe - 118-in. (3000 mm)	20-in. (500 mm)	28-in. (710 mm)
35-in. (900 mm)	Integrated Still Pipe Vapor Probe - 158-in. (4000 mm) Rigid Single Vapor Probe - 118-in. (3000 mm)	14-in. (350 mm)	22-in. (560 mm)

The Rosemount Dynamic Vapor Compensation integrated still pipe vapor probe with a long reflector is recommended for best practice. Depending on the application, probe type, reflector length and internal as well as external conditions the accuracy errors can vary; down to 2% accuracy errors can be achieved. Application and installation conditions, such as a lower temperature in the bypass chamber, can cause changes within the measured media. Therefore, the error readings can vary depending on the application conditions and may cause an increase of the measuring error by a factor of 2 to 3.

Rosemount recommends using the integrated still pipe vapor probe with the Rosemount 9901 Chamber bypass chamber. This provides an ideal installation with minimum disturbances. The 3-in. chamber of the Rosemount 9901 enables the Rosemount Dynamic Vapor Compensation integrated still pipe vapor probe to be used at all times.

The Rosemount Dynamic Vapor Compensation integrated still pipe vapor probe is not affected by the chamber. The still pipe functionality enables the radar waves to travel in a controlled environment.

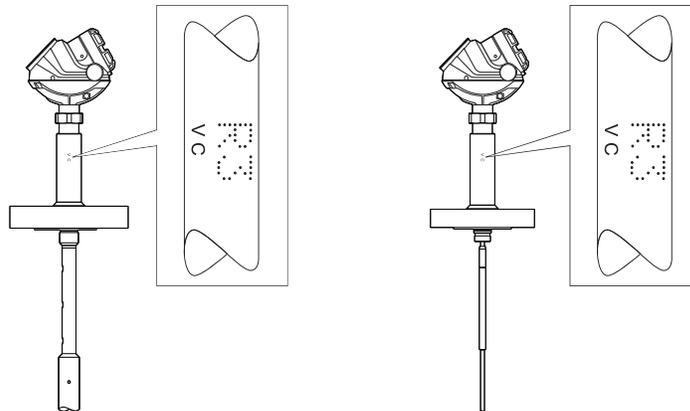
Note

Internal obstructions in non-Rosemount chambers such as bad welds or protruding inlets and outlets can severely impair the level measurement and accuracy error reduction when using a Rosemount Dynamic Vapor Compensation rigid single vapor probe. Internal obstacles can also impair the fitting of the Dynamic Vapor Compensation rigid single vapor probe or deform both probe and centering disc when fitted.

The Rosemount Dynamic Vapor Compensation rigid single vapor probe is delivered with a centering disc suitable for 1.5-in. chambers.

The following installation guidelines should be considered when mounting the transmitter:

- Only vapor probe types may be used. Check the “VC” and “R3” marking on the seal.



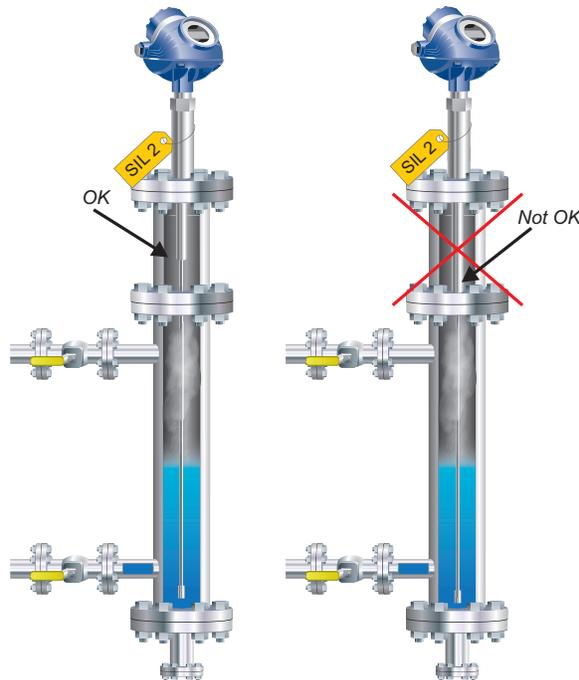
- The maximum probe length is 13.1 ft. (4 m) for the integrated still pipe vapor probe and 9.8 ft. (3 m) for the rigid single vapor probe.
- For Rosemount Dynamic Compensation rigid single vapor probe, Pipe/chamber is the only supported mounting type.

Always ensure there are no disturbances from inlets close to the reference reflector end when using the Dynamic Vapor Compensation rigid single vapor probe for 2-in. chambers.

If a Rosemount 5300 Series GWR Transmitter is ordered with a Rosemount 9901 Chamber, these space requirements are met by using the option code G1 or G2 for the chamber. G1 is used with the short reflector and G2 is used with the long reflector.

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 with the Dynamic Vapor Compensation rigid single vapor probe, 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. For a spool piece with the Dynamic Vapor Compensation integrated still pipe vapor probe, this is not a requirement.



If a spool piece is used with the Rosemount Dynamic Vapor Compensation rigid single vapor probe for 2-in. chambers, it is important that the reference reflector and the spool piece do not have the same length.

To minimize errors due to installation, it is recommended that:

- The distance between the chamber and the vessel be kept as short as possible
- Connections to the chambers be large enough to allow good fluid flow through
- The chamber should be well insulated so the fluid temperature is as close as possible to the vessel temperature

4.6 Calibration

When a transmitter is ordered with the optional Dynamic Vapor Compensation, the function is activated from factory and the special probe is supplied. For the Rosemount Dynamic Vapor Compensation rigid single vapor probe, a calibration procedure is needed on-site during the commissioning phase. For the Rosemount Dynamic Vapor Compensation integrated still pipe vapor probe, the transmitter is calibrated from factory and no calibration on site is normally needed. There are however two cases where a calibration procedure is needed for the Rosemount Dynamic Vapor Compensation integrated still pipe vapor probe; if the transmitter is reset to factory settings, or if a different transmitter head is mounted on the Dynamic Vapor Compensation probe.

If a calibration procedure is needed, this should be performed with an empty chamber at ambient conditions.

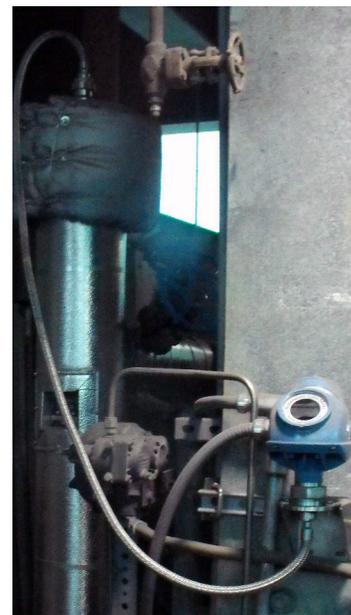
For best performance, it is recommended that the chamber is cleared of any steam and/or condensation prior to the calibration. See the Rosemount 5300 [Reference Manual](#), supplied with the transmitter for details on the calibration procedure.

4.7 Remote housing

A remote housing connection can be used with Rosemount 5300 Series GWR Transmitters to enable reliable measurement in environments where very high ambient temperatures or excessive vibrations exist at the mounting location of the vessel. It enables the transmitter electronics to be mounted away from the probe, such as to lower the ambient temperature, or to place the housing in a better location, for example to be able to read the display, or enable installation in tight spaces.

The remote housing connection is specified to handle ambient temperatures of 302 °F (150 °C). The cable used is a stainless steel flexible armored coaxial cable which is delivered with a mounting bracket for wall or pipe mounting.

The remote housing connection is available in the lengths of 3.2 ft. (1 m), 6.5 ft. (2 m), or 9.8 ft. (3 m).



5.0 Summary

The Rosemount 5300 Series GWR with Dynamic Vapor Compensation offers a unique choice for level measurement in high pressure steam applications. Its accuracy and reliability provide the following benefits:

- Help optimize plant performance and improve safety
- Increase plant availability, due to reduced trips
- Decrease the risk of production interruptions and increase throughput with an optimized thermal cycle
- Easy to install, gives an automatic compensation with very robust process seal solution
- Use of non-mechanical techniques
- No need for re-calibration reduces maintenance



6.0 References

For more information, download the following documents:
Rosemount 5300 Series [Product Data Sheet](#), SIL 2 [certificate](#)
Rosemount 9901 [Product Data Sheet](#)
Replacing Displacers with Guided Wave Radar [Technical Note](#)
Complete Point Solution [Technical Note](#)
Look for related proven results at Emerson.com/en-us/documents-and-drawings

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