Guided Wave Radar Interface Measurement

Contents

1.1 Introduction

Output quality of the final product depends in many cases on how well raw materials separate, therefore, reliable data about actual interface level is crucial. Interface applications are very common in many industries, particularly in Oil & Gas, where, for example, oil/water interface needs to be controlled.

Different solutions can be used, but it is Guided Wave (GWR) Radar that has become a popular solution in a wide range of interface applications across different industries. This technical note provides comprehensive yet simple guidelines on how to achieve reliable interface measurements using Guided Wave Radar.

1.2 GWR advantages

GWR provides accurate and reliable interface measurements and can be used in a wide variety of applications. It is a top-down, direct measurement as it measures the distance to the product surface. GWR can be used with liquids, sludges, slurries, and some solids.

A key advantage of radar is that changes in pressure, temperature, and most vapor space conditions have no impact on the accuracy of its level measurements. Moreover, no compensation is necessary for changes in dielectric, conductivity, or density of the fluid.

Changing density is one of the major issues when measuring level or interface using older technologies, such as displacers; they are more likely to happen due to changes in process or ambient conditions, and thus have more influence on the reliability and accuracy of density based technologies. GWR, in turn, provides reliable and maintenance-free measurements.

In addition, radar devices have no moving parts, so maintenance is minimal. GWR is easy to install and enables simple replacement of older technologies, even while there is liquid in the tank.

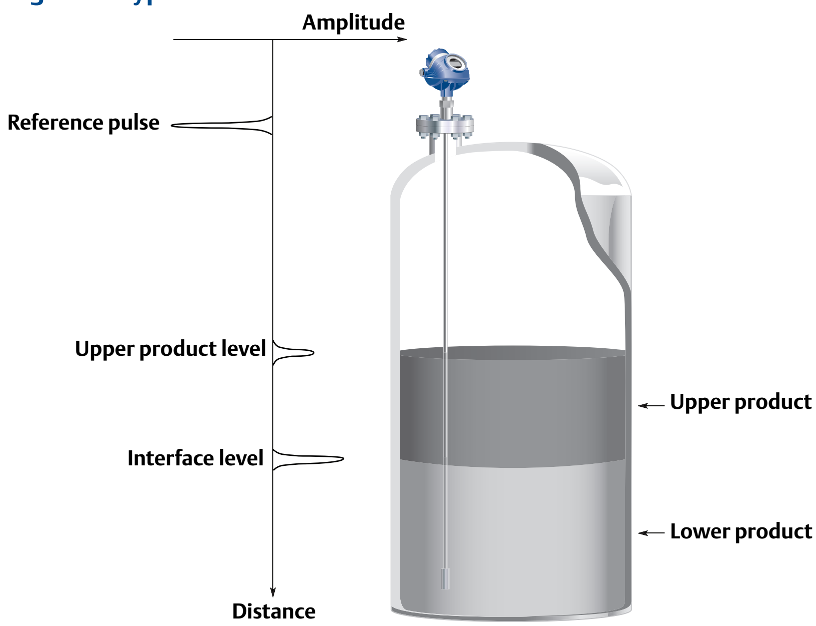
1.2.1 Principle of operation

GWR technology is based on the Time Domain Reflectometry (TDR) principle. Low power nano-second-pulses are guided along a probe submerged in the process media. When a pulse reaches the surface of the material it is measuring, part of the energy is reflected back to the transmitter, and the time difference between the generated and reflected pulse is converted into a distance from which the total level or interface level is calculated.

The speed of travel of the pulse is impacted by the dielectric of the medium. As the pulse travels through a different medium, such as oil, the speed of travel changes. This change in travel time is predictable and allows compensation for the measurement to be accomplished.

The reflectivity of the product is a key parameter for measurement performance. A high dielectric constant (DC) of the media gives better reflection and a longer measuring range.

Figure 1. Typical GWR Level and Interface



When there are two immiscible layers of fluid, and the lower dielectric fluid is the first seen by the GWR, most of the radar signal travels through the low dielectric material. Only a small part of the signal is reflected back to the device. When measuring level of products such as oil, with a dielectric of 2, less than 5% of the signal is reflected back to the transmitter. The rest of the signal travels through to the next fluid, which allows the interface of the two fluids to be detected.

Note
Interface measurement accuracy depends on process conditions, such as product dielectric and a distinct interface between the two fluids.

Examples of typical GWR interface applications are oil over water, oil over acid, low dielectric organic solvents over water, low dielectric organic solvents over acid. Low dielectric organic solvents include: toluene, benzene, cyclohexane, hexane, turpentine, xylene.

Overall, GWR devices provide efficient interface measurements and easy configuration for both interface and level detection.

1.3 Criteria for interface measurement with GWR

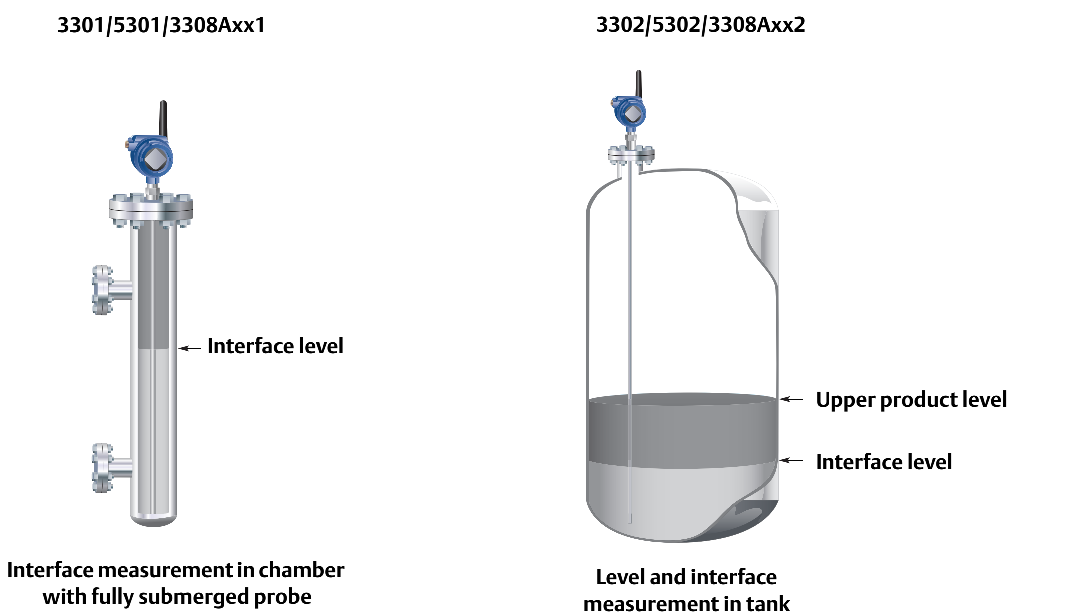
Rosemount GWR offering consists of three series:

- **Rosemount 3300 Series:** versatile, easy to use, and handles most liquid storage and monitoring applications with ease.
- **Rosemount 5300 Series:** superior device for challenging applications, for longer-distance performance with lower dielectrics and higher accuracy.
- **Rosemount 3308 Series:** wireless guided wave radar, perfect for remote locations with no infrastructure.

Rosemount 3301/5301/3308Axx1 are recommended for level or interface measurement in applications where the probe is fully submerged in the liquid. These are mostly chamber installations. Only interface is measured in the submerged probe mode.

Rosemount 3302/5302/3308Axx2 can be used to measure both level and interface. These products are recommended mostly for tank installations. Chamber installations are possible for level and interface in some cases but are not recommended.

Figure 2. Interface Level Measurement

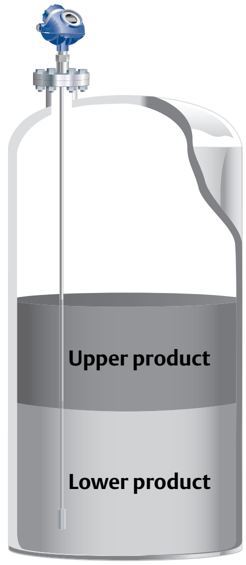


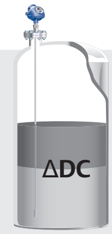
If interface will be measured, the criteria according to Figure 3 must be fulfilled:

Figure 3. Interface Application Guidelines

Target applications

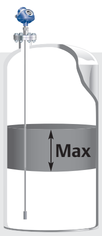
- Low (<3) dielectric constant of upper product
- High (>20) dielectric constant of lower product





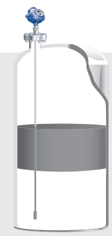
Difference between dielectric constants for the two products

- 3300: Larger than 10
- 5300: Larger than 6
- 3308: Larger than 10



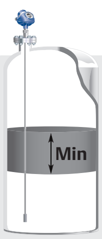
Maximum upper product thickness

- Primarily determined by the dielectric constants of the two liquids, see section "Maximum upper product thickness" for details.



Upper product DC

- Must be known and should be constant.
- Must have a lower DC than the lower product.



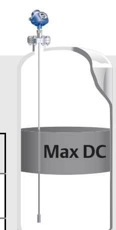
Minimum detectable upper product thickness, in. (m)

Upper product DC: 2.2

Lower product DC: 80

	3300	5300	3308
Rigid single lead	N/A[(1)]	5.1 (0.13)	4.9 (0.125)
Flexible single lead	N/A[(1)]	5.1 (0.13)	4.9 (0.125)
Coaxial	4 (0.1)	5.1 (0.13)[(2)]	4.9 (0.125)
Rigid twin lead	4 (0.1)	5.1 (0.13)	N/A[(3)]
Flexible twin lead	8 (0.2)	5.1 (0.13)	4.9 (0.125)

(1) Application dependent. For more information consult your local Emerson representative.
(2) 8 in. (0.2 m) for HTHP coaxial probe.
(3) Not in the scope of product offering.



Maximum dielectric constant for upper product

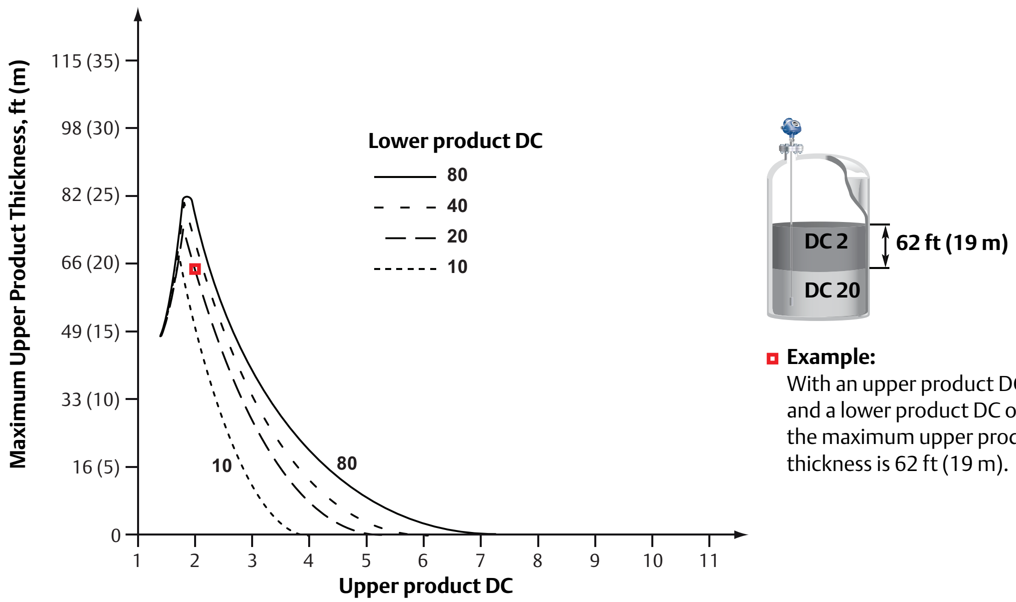
	3300	5300	3308
Rigid single lead	N/A[(1)]	8	5
Flexible single lead	N/A[(1)]	8	5
Coaxial	10	10	10
Rigid twin lead	5	7	N/A[(2)]
Flexible twin lead	5	7	5

(1) Application dependent. For more information consult your local Emerson representative.
(2) Not in the scope of product offering.

1.3.1 Maximum upper product thickness

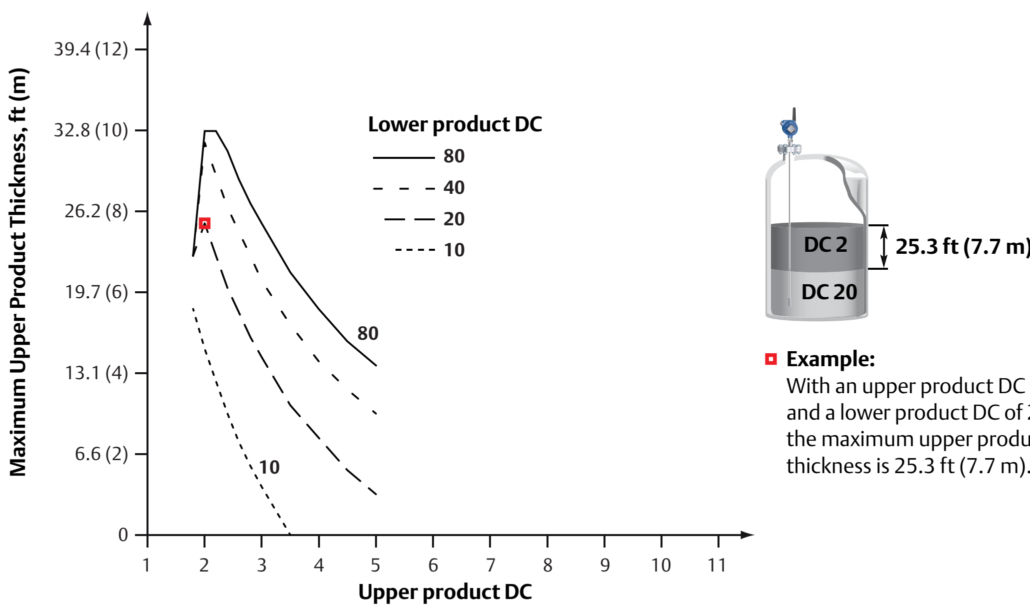
The maximum allowable upper product thickness/measuring range is primarily determined by the dielectric constants of the two liquids. The maximum upper product thickness for the flexible single probe is presented in Figure 4 for the Rosemount 5300 Series and Figure 5 for the Rosemount 3308 Series. However, characteristics may vary between the different applications.

Figure 4. Rosemount 5300 Series - Maximum Upper Product Thickness for the Flexible Single Lead Probe



Example:
With an upper product DC of 2, and a lower product DC of 20, the maximum upper product thickness is 62 ft (19 m).

Figure 5. Rosemount 3308 Series - Maximum Upper Product Thickness for the Flexible Single Lead Probe



Example:
With an upper product DC of 2, and a lower product DC of 20, the maximum upper product thickness is 25.3 ft (7.7 m).

Note

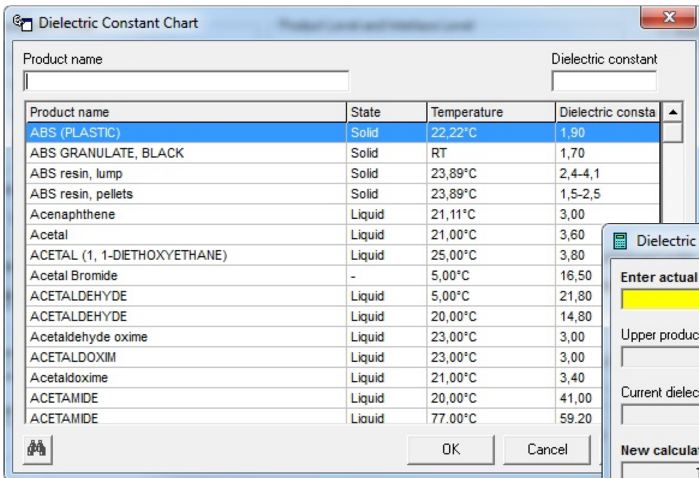
5300: Maximum distance to the interface = 164 ft (50 m) - maximum upper product thickness.

3308: Maximum distance to the interface = 55.8 ft (17 m) - maximum upper product thickness.

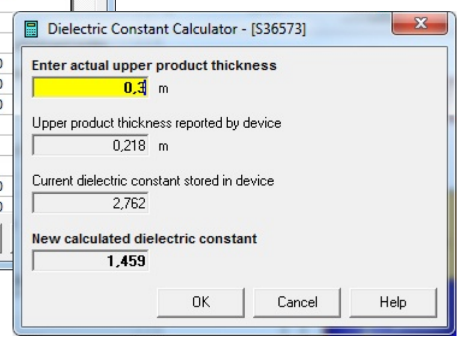
Dielectric constant determination using GWR probe

The correct upper product DC value is vital for accurate GWR interface measurements. In case it is not known, the Rosemount GWR configuration software has tools to determine it in field: Dielectric Constant Chart and Dielectric Constant Calculator, which can be accessed through Radar Configuration Tools, Rosemount Radar Master, AMS or any DD- or DTM™-compatible software tool.

Figure 6. Dielectric Constant Chart and Dielectric Constant Calculator



The Dielectric Constant Chart contains DC values for many products at certain temperatures.

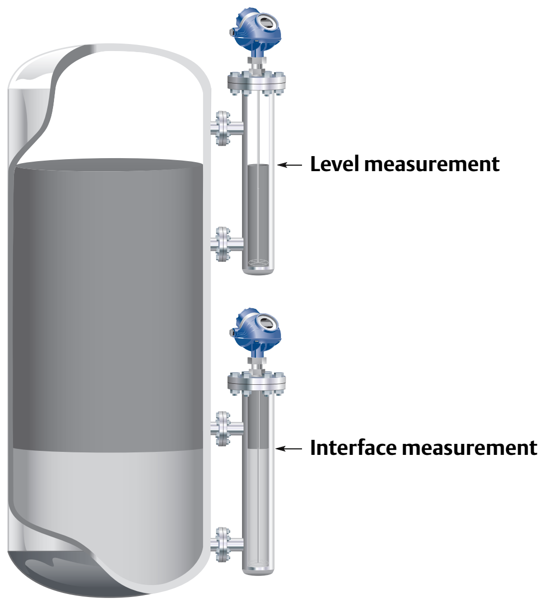


Sometimes more precise DC value is needed. In this case, it can be determined in field, using the Dielectric Constant Calculator. In order to do this, the real upper product thickness must be known.

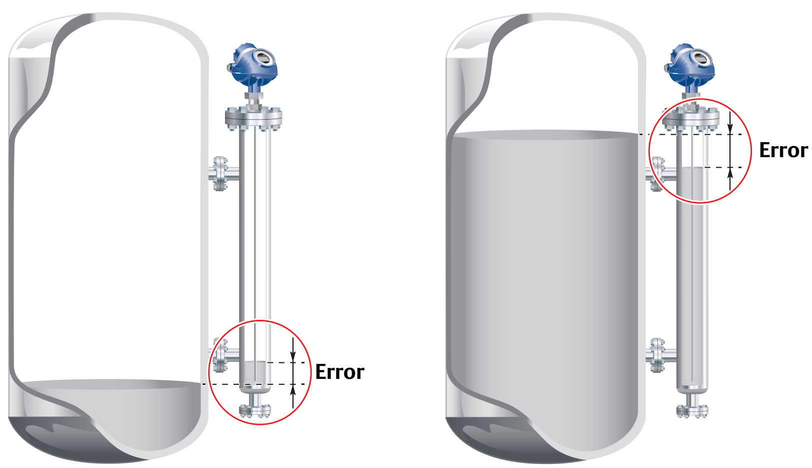
1.4 Interface measurements in chambers

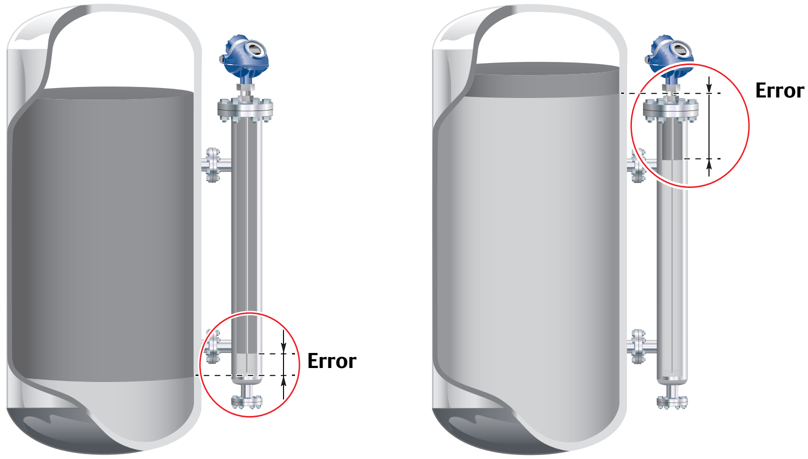
The following information should be taken into account when measuring interface in chambers.

Recommended practice is to measure level **or** interface.



Chambers provide a fixed view of the level in a vessel. Thus, when the level drops below or rises above the chamber, it will not be seen in the chamber. The effective measurement range of a chamber is the area between the taps.

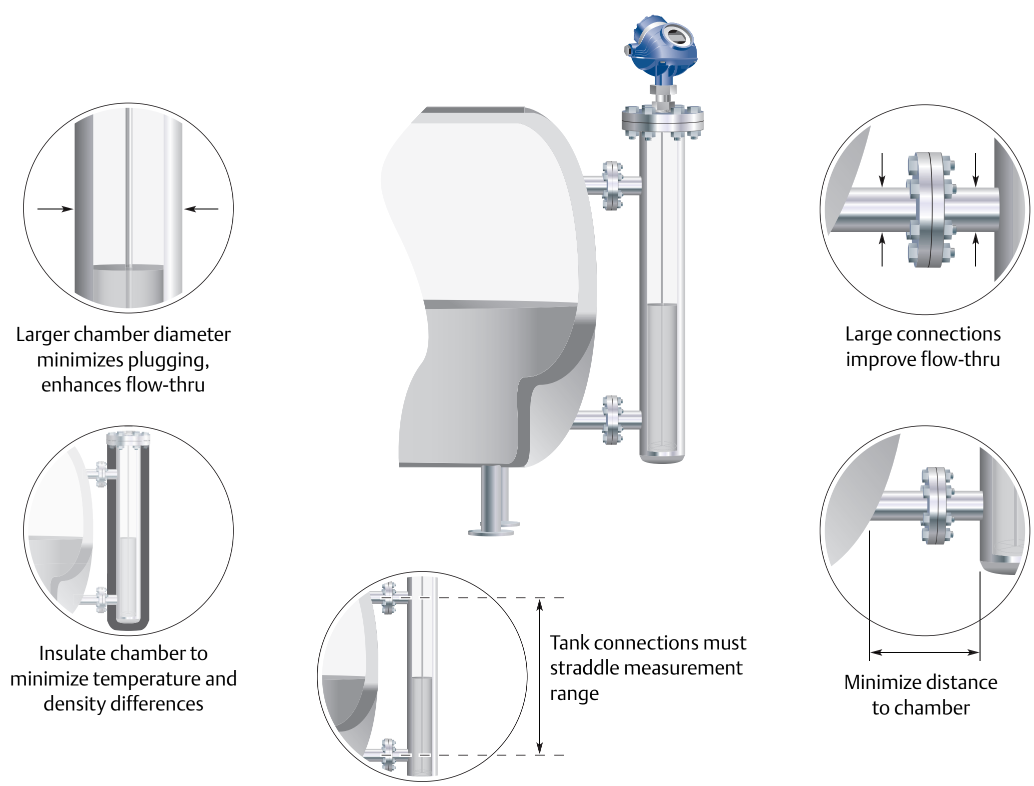




1.4.1 Installation and sizing of chamber

The location of the chamber should be as close to area of measurement as possible. If the chamber is further away, the fluid inside it is less like the fluid in the vessel. More distance gives more time for the fluid to cool (or heat up in cryogenic applications). Cooler fluid will be more viscous and dense. More viscous fluid will not respond as quickly and in extreme cases, may completely plug the chamber. Larger connections between the vessel and the chamber will enhance flow-thru of the fluid and allow fresh fluid to move through the chamber more easily and more closely resemble the material in the vessel.

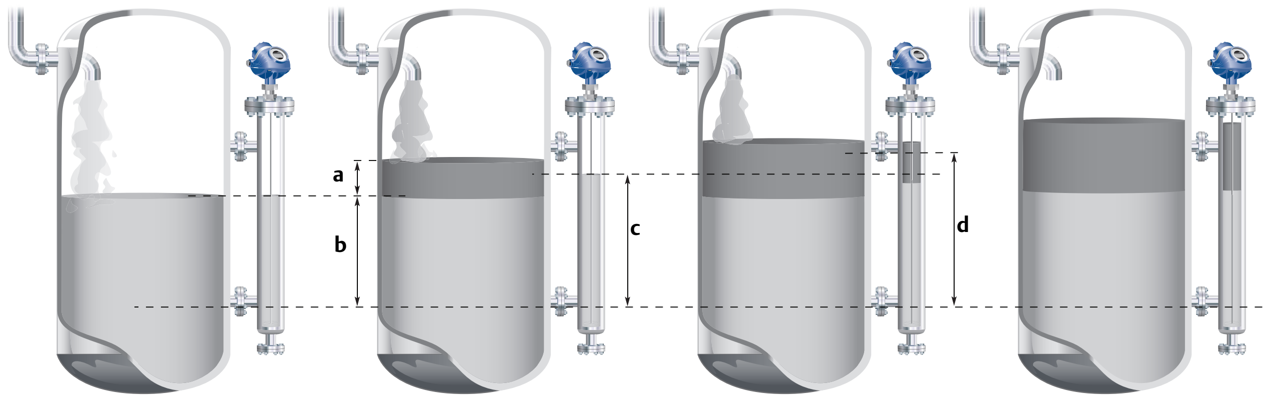
If the density in the chamber is lower than the density of the fluid in the vessel, it may actually appear to "shrink" and cause the level measurement to be lower than it actually is, especially if fluid movement is stagnant.



1.4.2 Match product level in tank and chamber

Below are examples of cases that might occur in field conditions.

Figure 7. Case 1: Difference in Product Specific Gravity (SG)



Start out filling the empty tank.

Fluid fills chamber equally to tank.

Eventually, another product (for example, hydrocarbons) is added, but overall level is not up to top tap.

Fluid in chamber will be pushed up to amount equal to height of upper fluid*SG + previous level.
c = (a*SG) + b,
c cannot be more than the height of the upper tap.

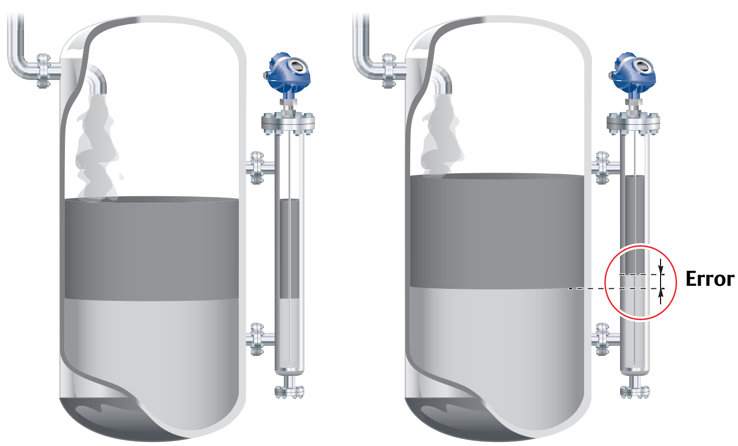
Hydrocarbons continue to be added and pour over into the chamber.

Is the weight of the upper fluid in the chamber sufficient to push back higher density fluid?

To push back the lower fluid the remaining distance, the upper fluid will need to increase until its height*SG is greater than c-b.
Or a > (c-b)/SG.

Once this equilibrium has been reached, then the natural circulation of the fluids will occur and the fluid heights in the chamber will match the fluids in the tank.

Figure 8. Case 2: Lack of Circulation in Chamber



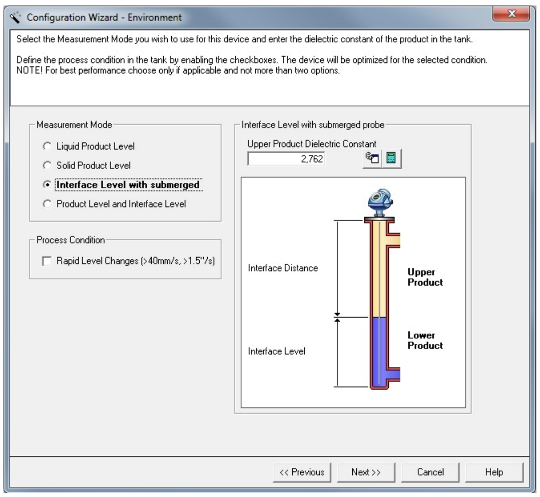
Day 1
A finite amount of fluid is added and separation occurs.

Day 2
More fluid is added in vessel, but lack of circulation in chamber prevents interface from being the same.

1.4.3 Fully submerged interface applications

A submerged interface application is one where the upper portion of the probe is in oil or a similar fluid and the interface between the upper fluid and lower fluid is the desired measurement. Both the Rosemount 3301, 5301 and 3308xx1 can be used for these interface measurements. Often this measurement is done with the probe mounted in a bypass chamber.

Figure 9. Measurement Mode: Interface Level with Submerged



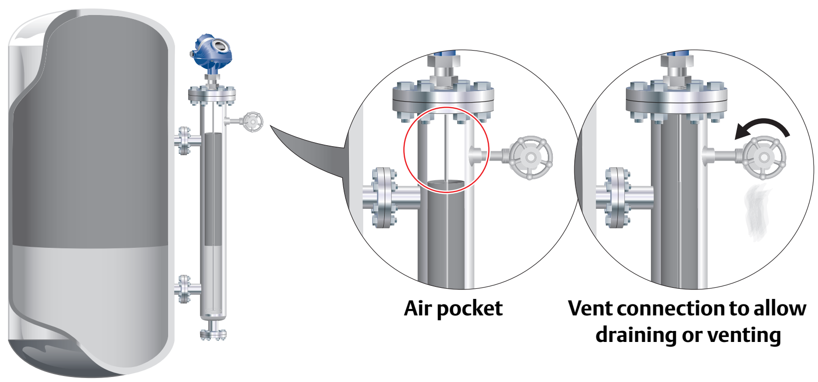
A single lead probe should always be used for this application as this provides the most distinct reference pulse. Ideally, there should be no air gap present at the top of the probe. However, air is often trapped in the chamber.

If there is an air pocket, then it creates an offset in the measurement reading due to the difference in the speed of travel of the microwaves in the air space compared to the upper fluid. For example, if the device is configured with oil as the upper fluid with dielectric constant of 2, the offset error will be 30% of the size of the air pocket (that is, a 15.7 in. (40 cm) air pocket creates a 4.7 in. (12 cm) offset error to the reading).

There are several options to handle this air pocket:

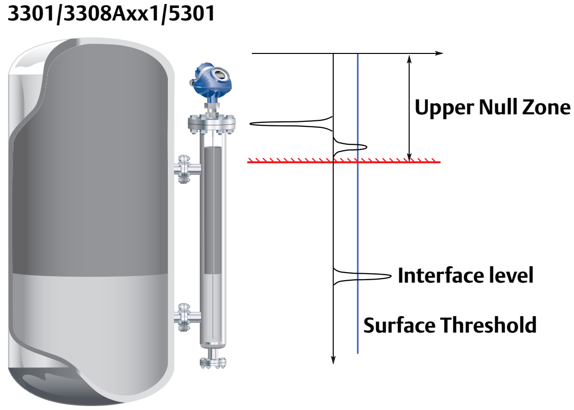
- If process safety allows it, a vent can be included in the top of the chamber that allows the air to be removed. This vent can be piped back to process. A flushing ring can be installed between the GWR flange and the chamber flange to accommodate this.

3301/3308Axx1/5301



- If the air pocket is small and is within the upper blind zone of the device, Upper Null Zone can be configured to block any potential incorrect reading of the surface.

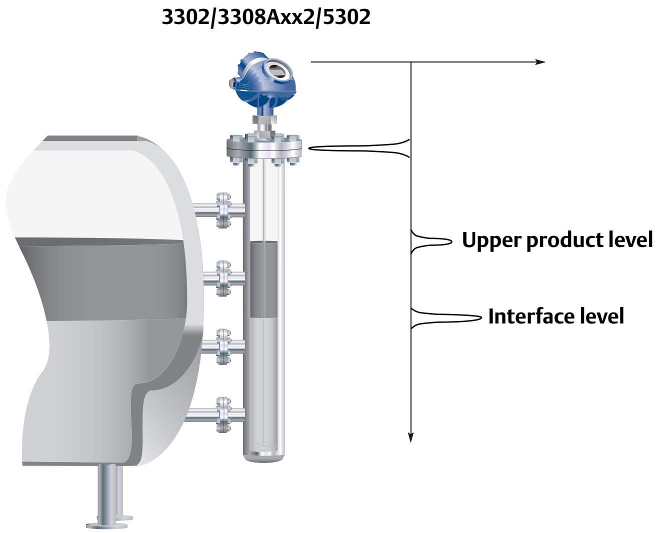
3301/3308Axx1/5301



1.4.4 Level and interface applications

Measurement of level **and** interface in a chamber should be avoided as the lack of fluid flow will not provide representative measurements. However, chambers are often used for interface measurements between oil and water. In cases where it is the only way to get a measurement, multiple connections to chamber will help to enhance fluid flow. The additional crossover connections should be located near the more critical measurement areas.

Figure 10. Chamber with Multiple Connections



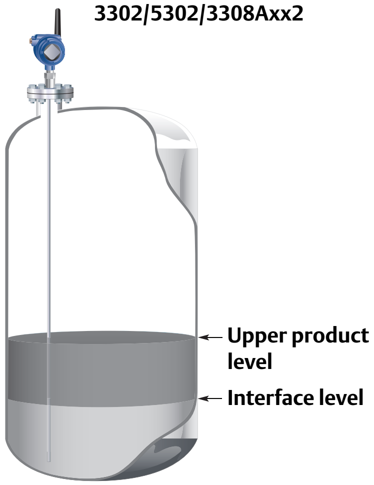
In these applications, there should be good flow-through of both the top and bottom fluid for the interface measurement to be tracked. Care must be taken to avoid having a layer of fluid trapped in the chamber.

Rosemount 3302, 5302 or 3308xx2 is a solution for such applications. Configure the device to measure level and interface, and set the process variable to interface. The GWR will see and measure the distance to the top surface as well as the lower product. The air gap will be measured and included in the calculation of the interface level.

1.5 Interface measurements in tanks

The most common interface application in tanks implies measurements of both upper product level and interface level. In this case, Rosemount 3302/5302/3308Axx2 is the preferred choice.

Figure 11. Level and Interface Measurement in Tank

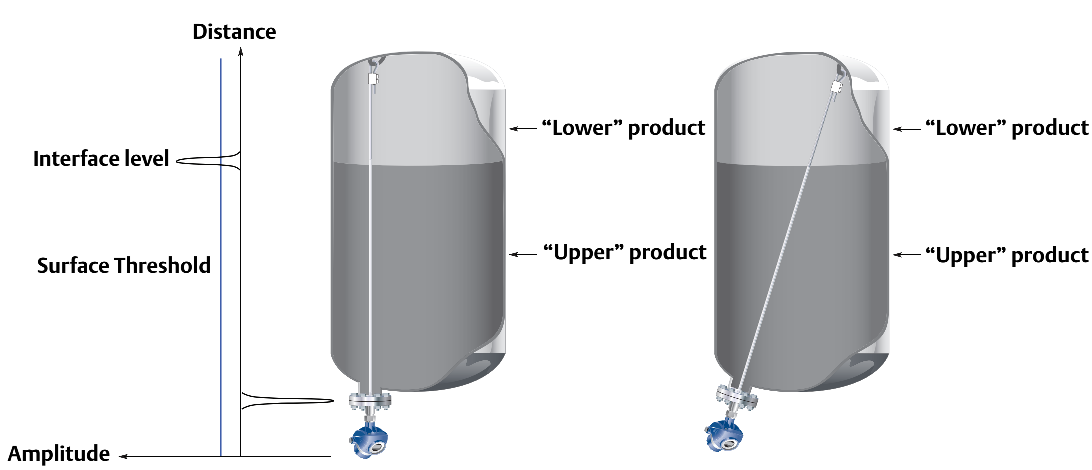


Though not very common, fully submerged tank interface applications can be possible too. A good example of such application are desalters and inverted interface measurements.

1.5.1 Inverted interface measurements

The use cases described in the previous paragraphs cover situations when the upper product has lower DC than the lower one. However, sometimes there are applications where product disposition is inverted: the high dielectric product lies on top of the low dielectric one, which makes top-down measurement impossible for GWR. In this case, the GWR mounting position can be inverted as well so that it is installed on the tank bottom. For applications where there may be some solids or slushy deposits on the bottom of the vessel, it is advisable to put a flushing connection in the mounting nozzle to allow occasional cleaning.

Figure 12. Inverted Interface Measurement



Configuration routine is the same as for standard interface measurements using interface with submerged probe mode.

Note
Dielectric constants have to be set according to product disposition: upper product means the one that is closer to the tank bottom.

When installing GWR on the tank bottom, there is no limit of probe types to be used. Flexible probes need to be attached to the tank roof. This can be done by following the same guidelines, provided for standard installations.

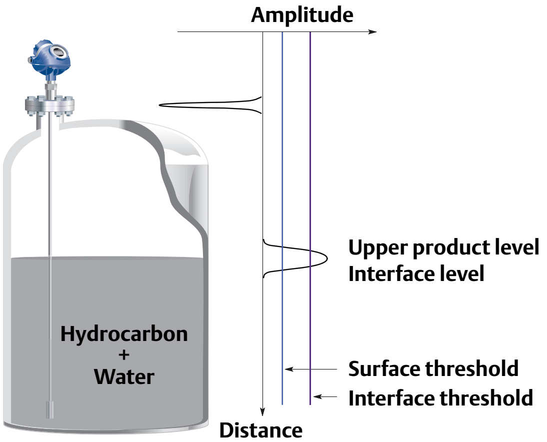
1.6 Emulsion/rag layer

Emulsions may impact interface measurement. The results vary with the fluid mix. In many cases, the interface is measured at the top of the emulsion layer. Emulsion layers smaller than 2 in. (50 mm) are quite manageable and will not prevent the measurement of the interface.

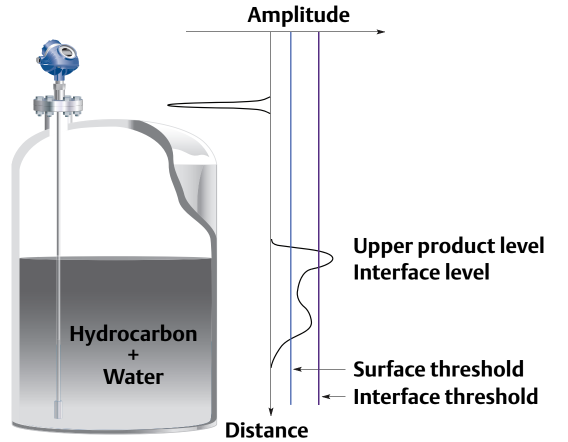
Sometimes emulsion can be formed of a mixture of fine solids combined with emulsified oil and water, sometimes including multiple components. Stable liquid emulsion and solid particles trigger rapid emulsion layer growth. The more particles are present, the larger such an emulsion is.

Although applications with emulsions are difficult for GWR measurement, the usage of a stilling well can help to achieve better product separation and therefore more accurate measurements.

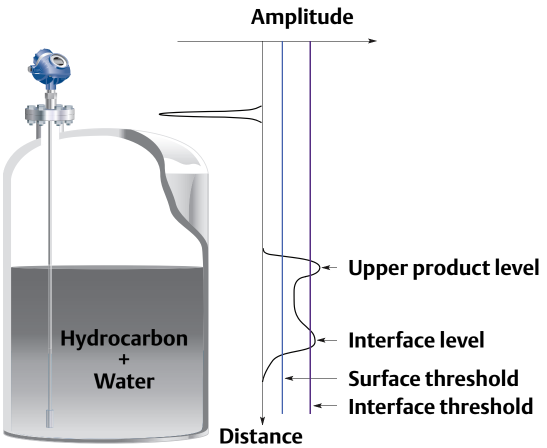
Figure 13. Examples of Different Stages of Hydrocarbon and Water Separation



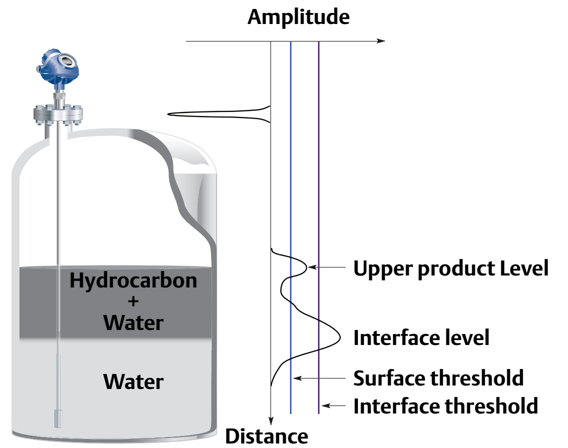
Example 1: Well mixed, uniform emulsion layer, no interface is present.



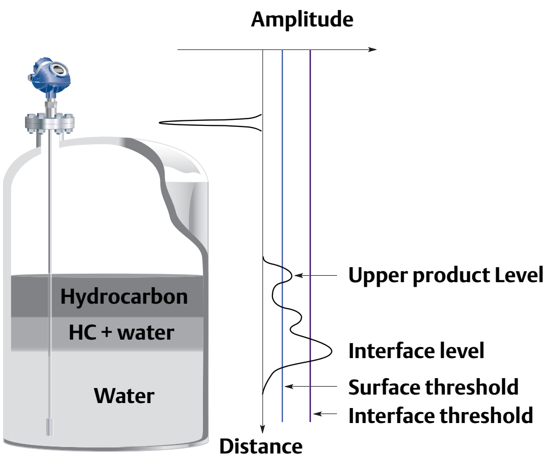
Example 2: Mix of hydrocarbons, emulsion and water with no distinct interface: GWR distinguishes only upper product level.



Example 3: Mix of hydrocarbons, emulsion and water with forming bottom product layer. GWR is able to distinguish both level and interface echoes despite upper product dielectric is still higher.



Example 4: Upper layer is mixed hydrocarbon and water, lower layer is separated water. Interface echo is stronger because of higher water dielectric.



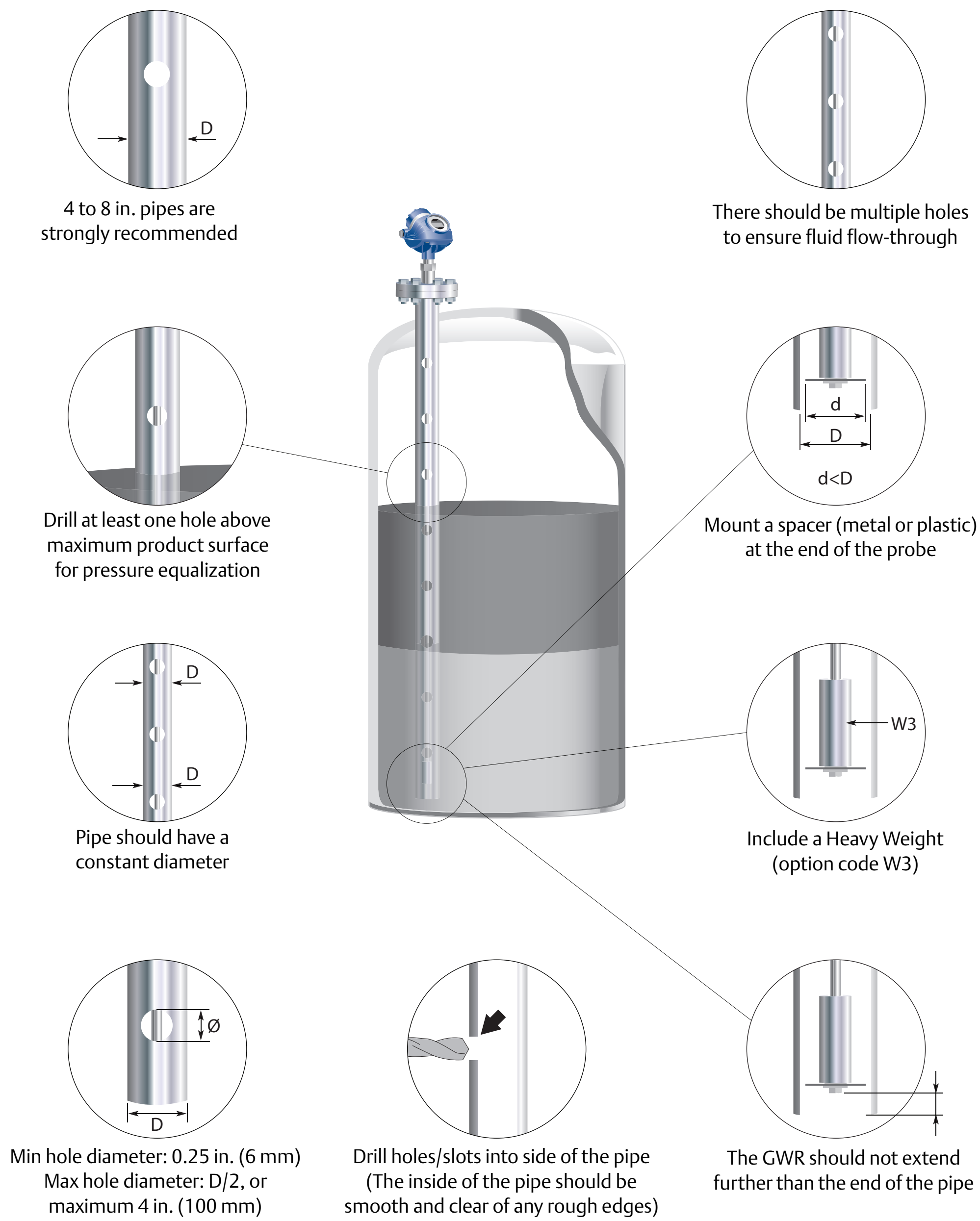
Example 5: Further separation causes formation of 3 layers: separated hydrocarbons and water layers with emulsion in between. GWR correctly reports level and interface, however, an emulsion echo is clearly visible.

1.7 GWR measurements with stilling well

1.7.1 Extra recommendations for stilling well

Stilling well usage provides more robust measurements because of higher degree of liquids separation inside the well. This is helpful if an emulsion layer is present. When installing GWR in a stilling well, consider the following recommendations:

Figure 14. Stilling Well Requirements



1.8 GWR limitations and alternative solutions

There are certain applications where GWR capabilities are limited or GWR are not recommended for use.

1.8.1 Foam

This type of applications should be considered on a case by case basis. Depending on foam properties, GWR may detect the foam/liquid interface **or** the top of the foam **or** the top of the liquid.

1.8.2 Multiple interface layers

GWR can measure the surface layer and only one liquid/liquid interface. There are criteria which must be met to measure the interface of two liquids.

1.8.3 Water/sand interface

Since the sand is embedded in water which is a high dielectric media (DC=80), the transmitter can only see the water. The same is true for all media that are dissolved in water.

1.8.4 Alternative solutions

Interface measurements with Differential Pressure (DP) Level

DP Level is also a viable technology for measuring interface. The following DP technologies are available:

- DP transmitter with impulse piping
- Tuned-System Assembly with seals and capillary
- 3051S Electronic Remote Sensor System

Regardless of which DP technology is used to measure interface, the overall level in vessel must be at or above the low pressure (top) process tap at all times. The 4 mA transmitter range point is set at the DP value that corresponds to the state when the tank is filled with the lighter of the two fluids. The 20 mA range point is set at the DP value that corresponds to the tank being filled with the heavier fluid. The anticipated span can be estimated by the height between the taps multiplied by the difference in specific gravity of the two fluids.

1.9 References

For more information, see the following documents (click title to open document or visit www.rosemount.com)

For more information on interface measurements with Guided Wave Radar:

- Refinery Handbook, see "Dielectric Constant Changes in Hydrocarbons - Affects on Radar Measurement Accuracy in Interface Applications" White Paper

For additional details and consideration on using DP technology to measure interface:

- Technical Data Sheet (document number 00816-0100-3207)

For more information on inverted interface measurement, the Dielectric Constant Chart and Dielectric Constant Calculator (see also the Help menus of the Rosemount Radar Master and the Radar Configuration Tools softwares):

- Rosemount 3300 Series Reference Manual (document number 00809-0100-4811)
- Rosemount 3308 Series Reference Manual (document number 00809-0100-4308)
- Rosemount 5300 Series Reference Manual (document number 00809-0100-4530)

For details about desalter interface measurement with the use of Guided Wave Radar:

- "Improve Reliability of Desalter Interface Measurement While Reducing Maintenance with the use of Guided Wave Radar" White Paper

For details about replacing displacers with Guided Wave Radar:

- "Replacing Displacers with Guided Wave Radar" Technical Note (document number 00840-2200-4811)

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