THE ENGINEER'S GUIDE TO LEVEL MEASUREMENT

2025 EDITION

Overview
ALL TANKS

TK-1
Crude Oil
5.493 m   0.000 m
10 m³/h   10986 m³

TK-130
LNG
16.123 m   0.000 m
0 m³/h   31224 m³

TK-41
Fuel Oil
15.358 m   0.000 m
0 m³/h   30716 m³

TK-42
Drip gasoline
19.707 m
-54

EMERSON

Legal disclaimer

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This handbook is written as a user guide for level projects in various industries. Level is a wide subject and it is impossible to cover everything in one single book, but we have aimed to include information we know users struggle with. We have included a wide range of level applications, and although not all are included, users should be able to f ind an application that is similar enough to give guidance on their own application. Please remember that choosing the appropriate level device is always up to the user, and these guidelines are rec-ommendations based upon the experience we have gathered through the years. If you are unsure about your choice, please contact your local Emerson representative.

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CHAPTER 1
LEVEL MEASUREMENT

1 Level Measurement

To ensure the safety and profitability of processes, it is essential to be equipped with instruments that provide reliable and precise level measurements. The basics of level measurement is simply about determining the position of a surface inside a tank, reactor or other vessel. More precisely, level measurement is the determination of the linear vertical distance between a reference point (usually the base of a holding container) and the surface of either a liquid, the top of a solid, or the interface of two liquids. Precise control of the level of liquid in a tank, reactor, or other vessel is important in many process applications.

Level measurement is often used for inventory management. To provide good control, accurate measurement is essential, and several devices and systems are available for measuring product level. Each is designed to provide accurate level measurement, although measurement precision and principles of operation vary among devices. All level measurements involve interaction between a sensing device, element, or system and a product inside a holding container.

The following pages will introduce the most common reasons for measuring level and explain why and how the different technologies for level measurement work. They will cover important aspects to consider when selecting a level measurement device or system for a particular application, as well as the benefits and limitations of level measurement products.

1.1 Why measure level?

1.1.1 Inventory

The main reason for measuring level is to keep track of inventory. The industry has however increased its demands on control of inventory. Level measurement is one key component in a tank gauging system for reliable and accurate inventory control.

Other measurements for inventory control are temperature, pressure and water level. Keeping good control over your inventory has become increasingly important over the last several years, not only for operators using the content in a storage vessel, but for the whole company, including company executives, accounting, loss and leakage control managers and others. This is a result of increased focus on safety, cost of ownership and the value of products stored.

It is common to see level accuracy requirements being better than -1/8 in. (3 mm).

1.1.2 Custody transfer

In many instances, the amount of material that is bought and sold (custody transfer) is based on a level measurement converted into volume or weight (from mathematical equations or strapping tables. See strapping table Figure 1.2.9). In custody transfer situations, the required accuracy of the level instrument is very high, since even an error of 1/8 in. (3 mm) of measured level can result in a very large error in terms of uncertain volume.

There are two main types of custody transfer, Legal and Commercial. The commercial custody transfer occurs when two parties agree upon the required volume accuracy of the measurement and what instruments to use. The legal custody transfer is more stringent and requires metrologically approved instruments. Such instruments have a Legal pattern approval to be used for such use and typically have accuracy better than 1/16 in. (1 mm).

Guidelines and recommendations for using level devices for custody transfer are available in international standards, such as the API Manual of Petroleum Measurements (MPMS) and OIML R85. Several countries also have national approvals that need to be followed.

1.1.3 Process efficiency

Accurate level measurement increases efficiency. For example, if a tank farm needs to keep a certain amount of material on hand at all times and the storage tanks are not filled to full capacity, the facility will incur the unnecessary expense of purchasing and maintaining additional storage vessels. The storage tanks in Figure 1.1.1 could hold another 60 units of product before the farm would need to purchase a new tank. Efficient use of storage space prevents the extra cost of needlessly acquiring more storage vessels.
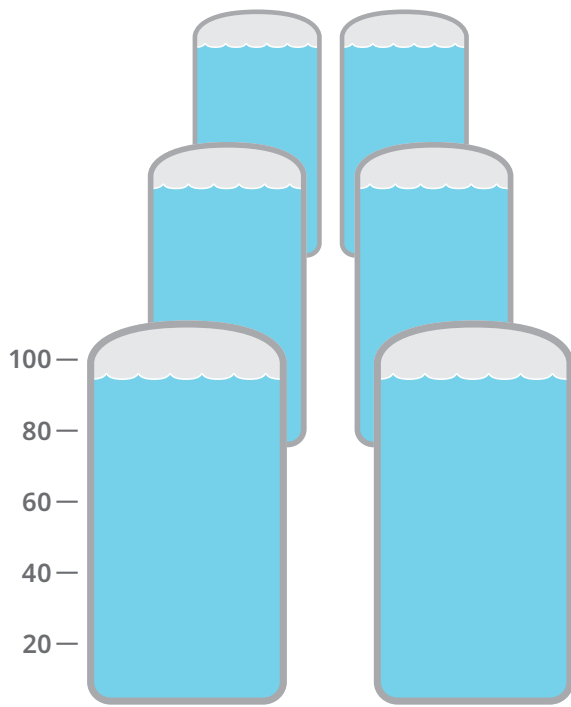
Figure 1.1.1: Storage efficiency

Figure 1.1.2: Ensuring consistent supply

1.1.4 Safety

Level is also measured for safety reasons. Filling vessels above their capacities can cause safety hazards—spills (overflowing) in open vessels. If the vessels are holding caustic, reactive, hot, flammable, or hazardous materials, spills or overpressure could lead to catastrophic results. Monitoring levels in tanks to make sure they are not leaking is important for the same types of hazardous materials. Preventing overfills and leak detection is also important for meeting environmental regulations.

1.1.5 Consistent supply

Many processes require a steady supply of inputs and outputs. A consistent supply may be difficult to maintain if the supply is delivered at varying rates or if there are surges in the supply line. A storage vessel between the supply and the process can act as a buffer to ensure that outflow is kept steady despite fluctuating inflow (Figure 1.1.2). If the process level in the storage vessel is always maintained within an appropriate range, the supply delivery rate to the storage vessel can rise and fall without affecting the supply delivery rate from the storage vessel to the process.

Consistent supply is directly related to product quality in for example pulp and paper industries, where a consistent supply ensures that each sheet of paper has the same thickness as all the other sheets.

1.2 Level terminology

Precise control of product level in a tank, reactor, or other vessel is important in many applications. To provide good control, accurate measurement is essential. This section introduces the concepts and terminology of level technology devices and how they work, as well as how various other material properties (e.g., volume, density) can be determined from a level measurement.

Level measurements are typically expressed in terms of feet or meters. Level may also be given in terms of percent full or percent of measured span. For example, the level of the vessel in Figure 1.2.1 could be expressed as 9 ft. (2.7 m), 90% full, or 50% of measured span. Measured span is the distance between the lowest and the highest level that a level transmitter (LT) can measure in a particular application. In Figure 1.2.1, the measured span is from 8 - 10 ft. (2.45 - 3 m).

Figure 1.2.1: Level measurements

1.2.1 Indication vs. control

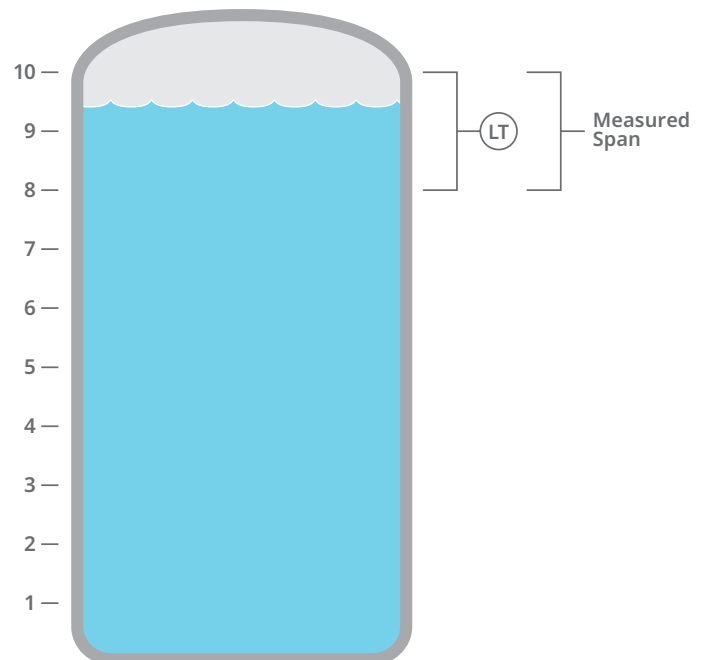Level measurement indicators enable an on-site level check. Indicators require the operator to interpret the measurement and take the appropriate action. Systems with level measurement indicators are referred to as open-loop control systems. Indicators are also frequently used to help calibrate automatic control systems.

Automatic control systems, or closed-loop systems, are able to control level in a vessel electronically. A level measurement device, combined with a transmitter, generates an electronic control signal that is proportional to the level in the vessel. The signal is received by a controller that operates other devices (e.g. valves or pumps), which, in turn, control the amount of product flowing in and out of a vessel. Automatically controlled vessels may also include level measurement indicators.

1.2.2 Tank gauging systems, continuous level, or point level detection

Tank gauging systems
A tank gauging system is used when the user has applications where raw materials enter a plant, are stored in intermediate tanks, or leave the plant as finished goods, and therefore require an inventory management or custody transfer system. These tanks are typically 33 to 100 ft. (10-30 m) in height. Some exceptions, such as additive tanks, are smaller. Accuracy requirements are high, in the order of 1-3 mm.

Typical tank gauging applications:

- Large storage tanks that are found in terminals, pipelines, depots and other storage facilities

- Receiver/intermediate/finished goods storage tanks in refineries

- Some large raw material and product storage tanks that are found in chemical, asphalt, power plants and airport fuel depots

The tank gauging system usually includes temperature, pressure and water bottom measurements in addition to level. Communications equipment, computer hardware and software are also included in the system solution. The measurement values are used to calculate net volumes for custody transfer (commercial and legal purposes), inventory calculations, operational and safety purposes. The results of the measurements are often used for billing purposes and must be highly accurate, repeatable and reliable following industry standards such as API MPMS 3.1B and OIML R85, or national accuracy standards. The Rosemount tank gauging system complies with these international standards and is also approved in many countries for accuracy by governmental authorities, with an instrument accuracy of ± 0.5 mm.

Continuous level measurement
Level transmitters for continuous level measurement are commonly used in many plants. The level measurement is usually an independent input to a control system. Measurement reliability and repeatability is more important than highly accurate readings. The accuracy requirement is typically in the range of 5-10 mm.

Continuous level transmitters are found in all industries including chemical, oil and gas, power, refining, pulp and paper, mining, pharmaceutical, food and beverage and other process plants. The majority of these tanks have a wide variety of sizes and shapes, but most are less than 60 ft. (18 m) high. Many of the level applications may not be directly in the vessel, but rather in bypass chambers located outside the vessel next to the level area of interest.

Being inside the plant process, these applications can be quite varied in terms of difficulty of the measurement. Intermediate buffer or settling tanks are some of the easier applications. Measuring inside a chamber is another common application, while batch reactors and tanks where the product is mixed or agitated offer other challenges.

Point level detection
Point level detection devices, such as switches, are often used in conjunction with continuous level measurements for single point high level and low level alarms. However, they can also be used alone to simply indicate a full or empty state. Size and space constraints as well as the application conditions will determine the choice of technology.

Technology selection based on the application
Understanding the different needs a user has makes the selection between a point/continuous level measurement and a tank gauging system easier. Chapter 4 lists a number of different applications, gives recommendations on suitable technologies, and will provide key installation information and best practices. Since it is not practical to cover all possible applications, the applications chosen for chapter 4 are intended to give a broad overview of some very common types of applications that are found in many industries as well as a few applications that may have specific challenges. It will also provide examples of where the various technologies are used. However, the final decision of the technology choice will include the application conditions, the installation constraints, and the capabilities of the technology.

1.2.3 Contacting vs. non-contacting

In a contacting measurement, part of the measurement system is in direct contact with the contents of the vessel. Examples of contacting measurement techniques include guided wave radar, floats and dipsticks.

In a non-contacting measurement, no part of the measurement system directly contacts the contents of the vessel. Non-contacting methods are preferred when the measured fluid is especially abrasive, solidifying, viscous, dirty or corrosive.

1.2.4 Bottom-up vs. top-down measurement

A top-down measurement poses less potential for leakage (Figure 1.2.2) and enables level measurement devices to be installed or removed without emptying the tank (e.g. radar gauge). Top-down measurements may or may not contact the process fluid.

Level devices that use pressure transmitters are bottom-up measurement systems. A bottom-up measurement typically contacts the process fluid (e.g. DP level).
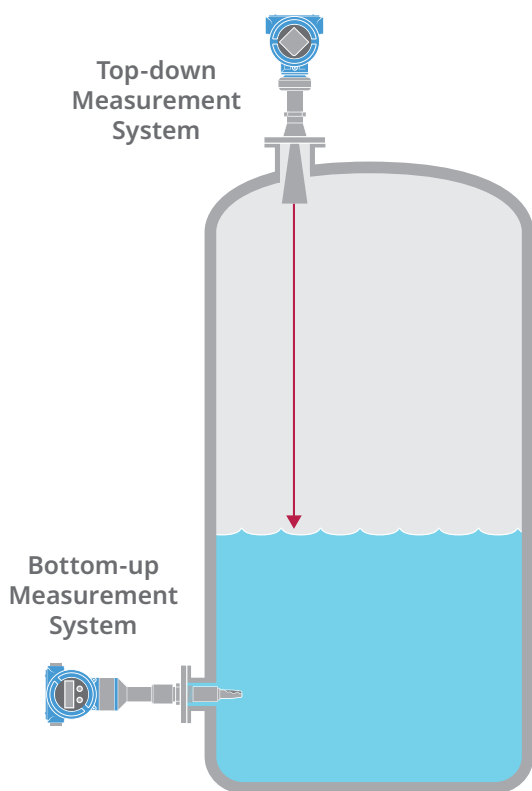
Top-down Measurement System

Bottom-up Measurement System

Figure 1.2.2: Bottom-up vs. top-down measurement

1.2.5 Direct vs. indirect measurement

Direct measurement indicates that the level is measured directly. For example, when you use a dipstick to check the oil level in your car, you are making a direct measurement. A direct measurement is independent of any other process parameters.

Indirect measurement, also known as inferred measurement, indicates that a variable other than level is first measured and then used to determine a level measurement. For example, pressure transmitters use mass and the fluid's specific gravity to calculate level.

1.2.6 Density

Density is the mass of a material per unit of volume. Density is often expressed in terms of pounds per cubic foot (lb/ft.3) or kilograms per cubic meter (kg/ m3). Specific gravity is often used to describe the density of a material compared to the density of water.

Specific gravity

Specific gravity is the ratio of the density of a material to the density of water at a common reference temperature. Water has a density of 62.43 lb/ft.^{3} (1 g/cm^3) at 39.2 °F (4 °C). Glycerin, a compound often found in soaps, has a density of 78.66 lb/ft.^{3} (1.26 g/ cm^3). At the same temperature, therefore, glycerin's specific gravity is 1.26 (78.66 ÷ 62.43).

1.2.7 Volume

Volume is the space occupied by a quantity of material and often the level is used to calculate the volume. Volume is typically expressed in gallons, liters, cubic centimeters, cubic ft., or barrels. Volume is the measurement most commonly derived from level.

Volume is usually determined by first measuring the level in a tank and then calculating the volume based upon the tank geometry.

Many level measurement devices store the level/ volume relationship for common tank geometries in their electronic components, which enables them to calculate a direct volume output.

In other cases, the volume may be calculated in a Distributed Control System (DCS) or a programmable logic controller (PLC) or determined from a look-up table that relates level to volume.

The relationships between level and volume for several common tank shapes are shown overleaf:

Where:

v = tank volume

r = tank radius

H = tank height (or length)

L = product level

$$V = \pi r^2 L$$
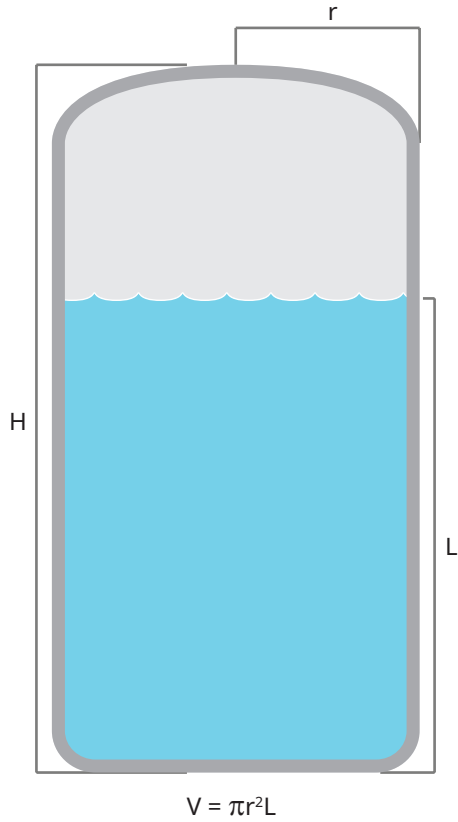
Figure 1.2.3: Vertical Cylinder

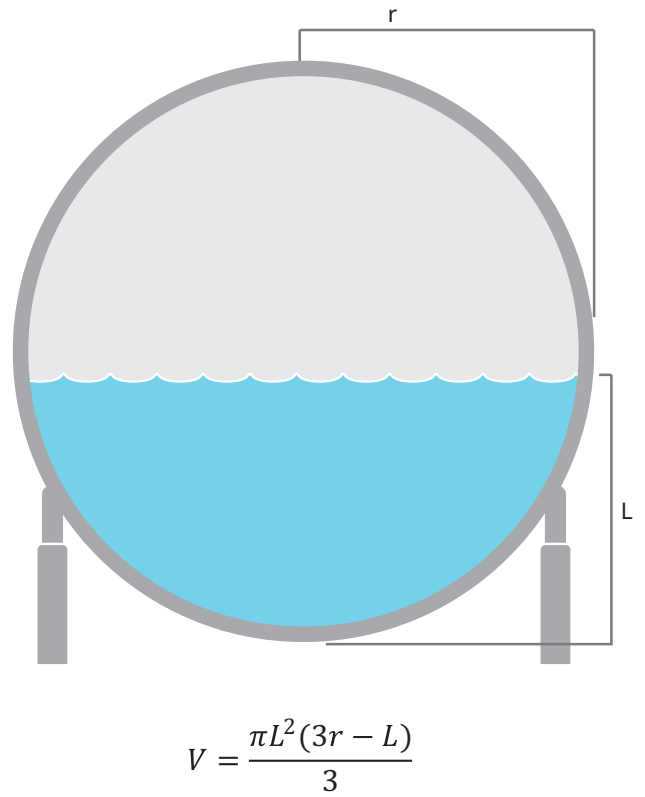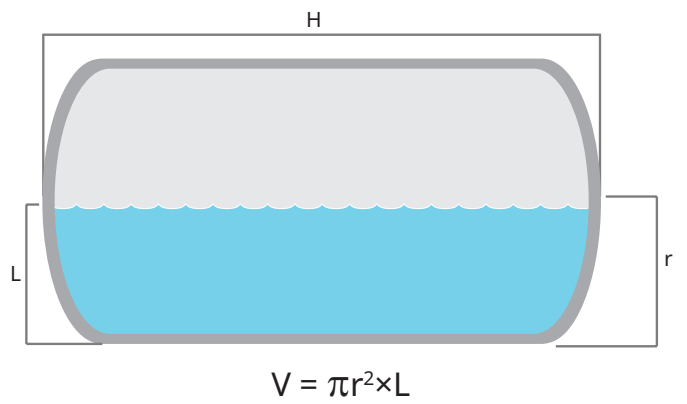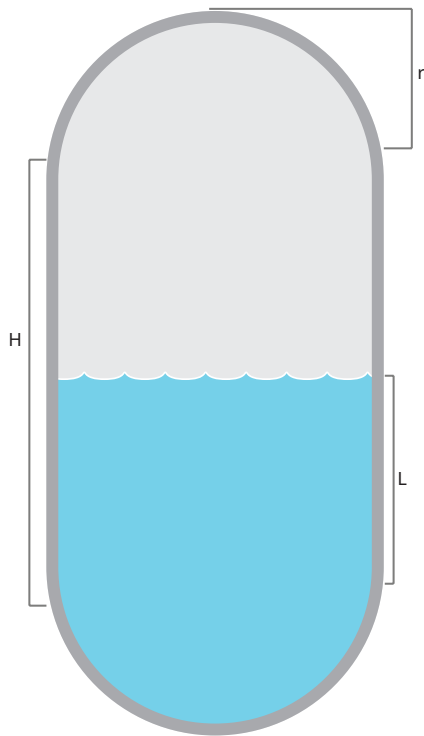$$V = \frac{\pi L^2 (3r - L)}{3}$$

Figure 1.2.5: Sphere

$$V = \pi r^2 \times L$$

$$V = 2r^2 H \operatorname{atan}\left(\frac{\sqrt{L}}{\sqrt{2r - L}}\right) + H(L - r)\sqrt{L(2r - L)}$$

Figure 1.2.4: Horizontal Cylinder

$$If\ L \leq r:$$

$$[V = \frac{\pi L^2}{3} 3r - L]$$

$$If\ r < L < (H - r):$$

$$[V = \frac{2}{3}\pi r^3 + \pi r^2 (L - r)]$$

$$If\ (H - r) \leq L:$$

$$[V = \pi r^2 (H - 2r) + \frac{\pi (L + 2r + H)^2}{3}(3r - (L + 2r - H))]$$

Figure 1.2.6: Vertical Bullet
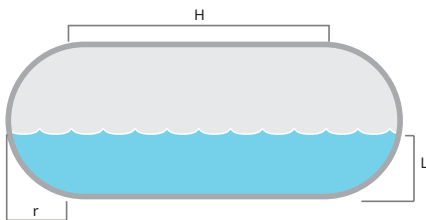
$$V = \frac{\pi L^2}{3}(3r - L) + 2r^2\big(H(-2r)\big)\operatorname{atan}\left(\frac{\sqrt{L}}{\sqrt{2r - L}}\right) + (H - 2r)(L - r)\sqrt{L(2r - L)}$$

Figure 1.2.7: Horizontal Bullet

Tanks with dished ends
Tanks with dished ends do not have a standard shape

(Figure 1.2.8). Therefore, the volume of these tanks cannot be determined strictly from geometry. Instead, strapping tables are used to determine volume.
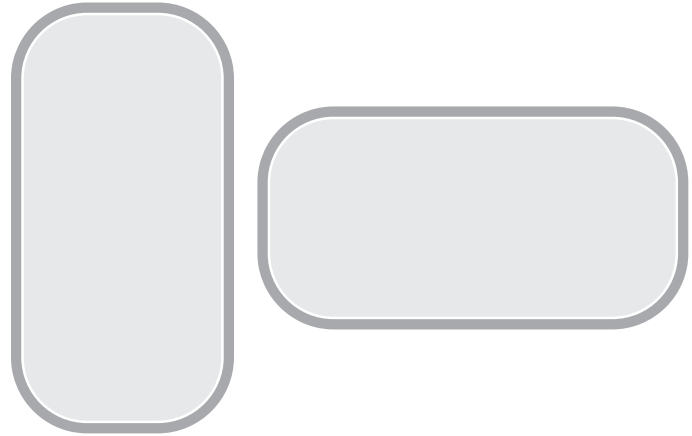
Figure 1.2.8: Tanks with dished ends

Strapping tables or volume tables
Calculating volume from level and tank geometry provides a volume measurement accurate enough for most users' needs. However, in some instances, the geometry of the tank may be irregular, which makes it nearly impossible to model the relationship between level and volume mathematically. In such cases, volume must be determined from the level reading through the use of a strapping table.

A strapping table is a look-up table that relates level to volume for several discrete points in a tank (Figure 1.2.9). Strapping tables are usually derived by adding a known volume of product to a tank and then measuring the level of product that corresponds to that volume (manual strapping). The volume and level measurements are recorded in a strapping table. Then, when a volume measurement is required, level is measured and looked up in the strapping table to find the corresponding volume.

Point	Level (inches)	Volume (gallons)
1	0	0
2	5	10
3	10	32
4	15	68
5	20	115
6	25	173
7	30	230
8	35	313
9	40	394
10	100	957

Figure 1.2.9: Strapping table

Strapping tables can just be a few points to accommodate a tank shape or they can be hundreds of points. Larger numbers of points are used with larger tanks that tend to bulge when filled. If a measured level falls between two points in a table, volume is determined by interpolating the two points. Typically, strapping tables have a higher concentration of points in tank regions where the relationship between level and volume is not linear. For example, in Figure 1.2.9, strapping points are concentrated near the bottom of the tank. This concentration provides for better resolution in the strapping table and a more accurate measurement.

There are several circumstances in which a strapping table may be required for level measurements. When product is added to a tank, the tank's sides bulge. The bulging causes an error in the mathematical calculations for specific tank geometri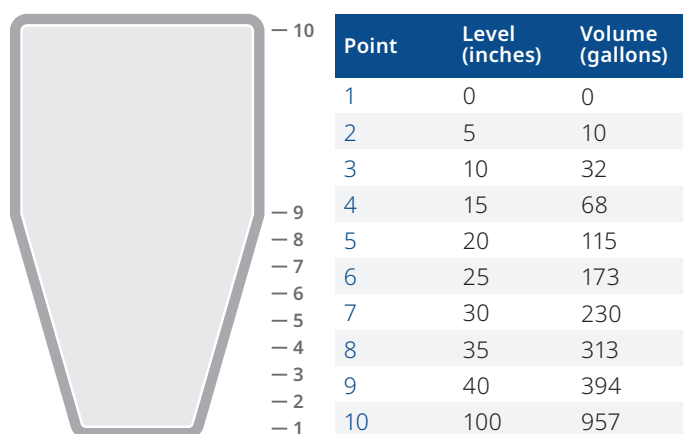es. The amount of error is related to the degree of bulging. Strapping tables are commonly used to eliminate errors in calculations due to bulging error (Figure 1.2.10).

Strapping tables are also used to store level/volume relationships for irregularly shaped tanks (Figure 1.2.9) or for tanks with internal equipment (Figure 1.2.11).
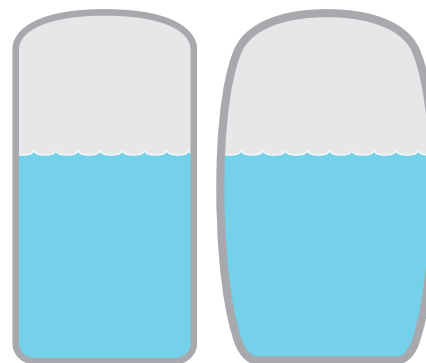
Figure 1.2.10: Bulging error

In certain applications (e.g. petroleum storage and transfer), bulging errors may cause suppliers to over-or under-charge customers.
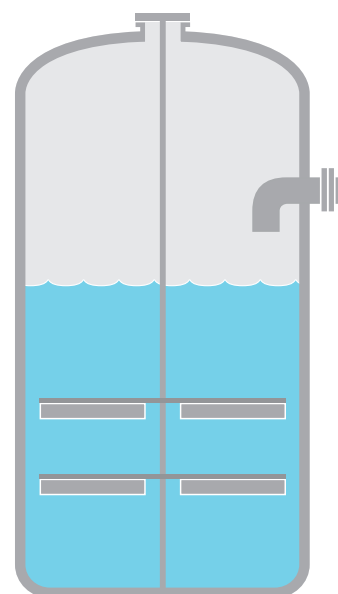
Figure 1.2.11: Tank with internal equipment

1.2.8 Mass

Mass, the amount of matter an object contains, is often equivocated to weight. Mass is typically expressed in terms of kilograms, grams, tons, or pounds. Mass is unaffected by temperature. Thus, 60 lb (27.2 kg) of oil at 50 °F (10 °C) is still 60 lb at 86 °F (30 °C). However, the overall volume of the oil may change due to expansion.

If density is known, mass can be found from a level measurement by first finding volume and then using the following equation:

Mass=Density × Volume

Some level measurement devices measure mass directly (e.g. load cells).

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1.2.9 Interface

An interface is the boundary between two immiscible (incapable of being mixed) fluids with different densities (e.g. oil and water). Interface measurement finds the boundary between two liquids stored in the same tank, each with a different density. For example, when oil and water occupy the same vessel, the oil floats on top of the water. The interface between the two fluids is the upper level of the water and the lower level of the oil (Figure 1.2.12).

Interface is often used when a user has two fluids in a tank and wants to pour off only the top fluid. The interface measurement indicates when to stop.
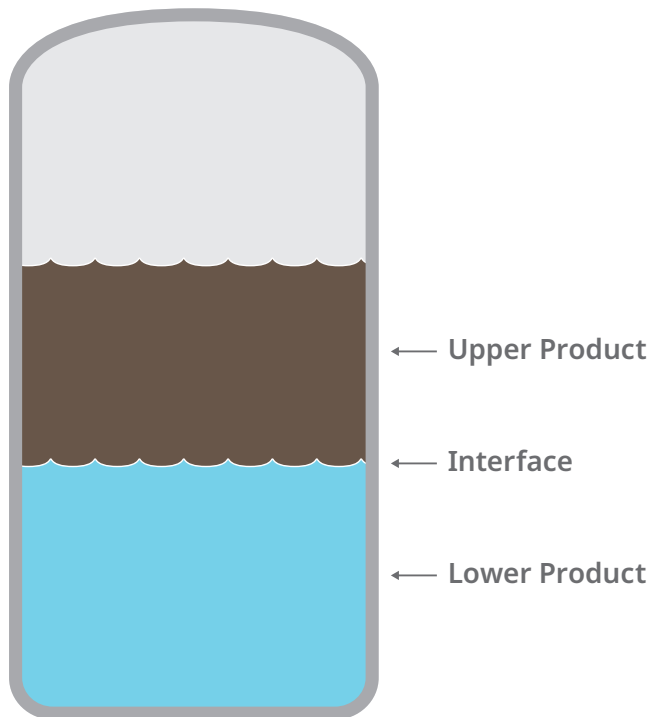
Figure 1.2.12: Interface

Interface measurement can also be used in a separator, where the interface is used to control the flow of the top and bottom fluids out of the vessel with minimum contamination.
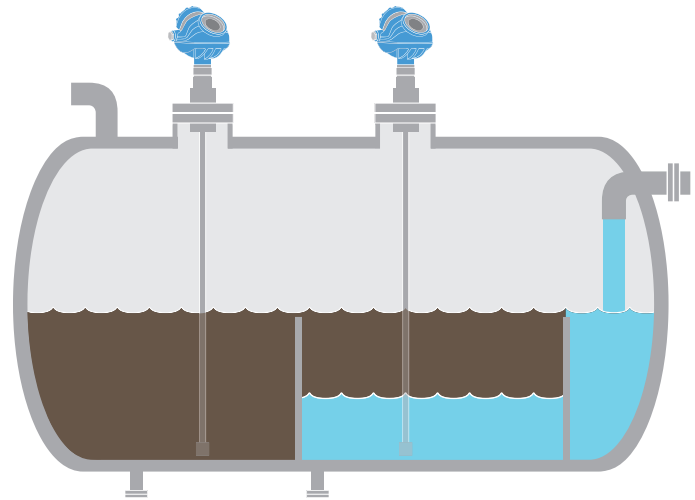
Figure 1.2.13: Level and interface measurement in a separator

1.3 Device selection

Because of the large variety of level measurement devices available, selecting the appropriate device for a particular application can be difficult. While most level measurement technologies are adaptable to more than one process measurement, there is no single level device that will work for every application. However, by asking the right questions and understanding some basic application needs, the user can narrow down the selection pool considerably and determine which device will work best in each application.

1.3.1 Why is level measurement needed?

Do you need a rough indication of product level, or do you want to know exactly how much product is in the vessel?

The answer to this question will indicate what information is needed from the level device and what type of measurement is required (e.g. mass measurement or single-point measurement).

For example, if the user wants to prevent spills or know when to refill a vessel, a single-point level device may be sufficient. If the requirement is to keep the product volume within a certain range in the vessel, a continuous level device is needed. If the user needs to know how many pounds of product are needed, a mass measurement is required. If inventory control or custody transfer is required, a complete tank gauging system is needed.

1.3.2 Is interface measurement needed?

When it comes to selecting a level product for an interface application, there are some factors that need to be considered.

Two suitable technologies for interface measurement are guided wave radar and differential pressure. Below are some factors to consider, when choosing one of these technologies.

Guided wave radar

Interface applications based on dielectric differences between two fluids

Examples of typical applications: Oil over water, oil over acid, low dielectric organic solvents over water or acid. Low dielectric constant organic solvents include toluene, benzene, cyclohexane, hexane, turpentine and xylene.

- Lower dielectric fluid must be on top

- Dielectric difference of two liquids must be at least 10

- Upper dielectric must be known; an in-field determination is possible

- Max thickness of upper layer is dependent upon its dielectric

- For interface to be detected the upper fluid layer must be 1 in. (2.5 cm) thick depending on transmitter model and probe style. See section 5.5 in guided wave radar installation guidelines for details.

- Target applications, low upper layer dielectric (< 3) and high lower layer dielectric (> 20)

- Both level and interface measurements are possible

- Emulsions may impact interface measurement. The results will vary with the fluid mix. In many cases, the interface will be measured at the top of the emulsion layer. Small emulsion layers (< 2 in. (50 mm)) are quite manageable and may not be detected

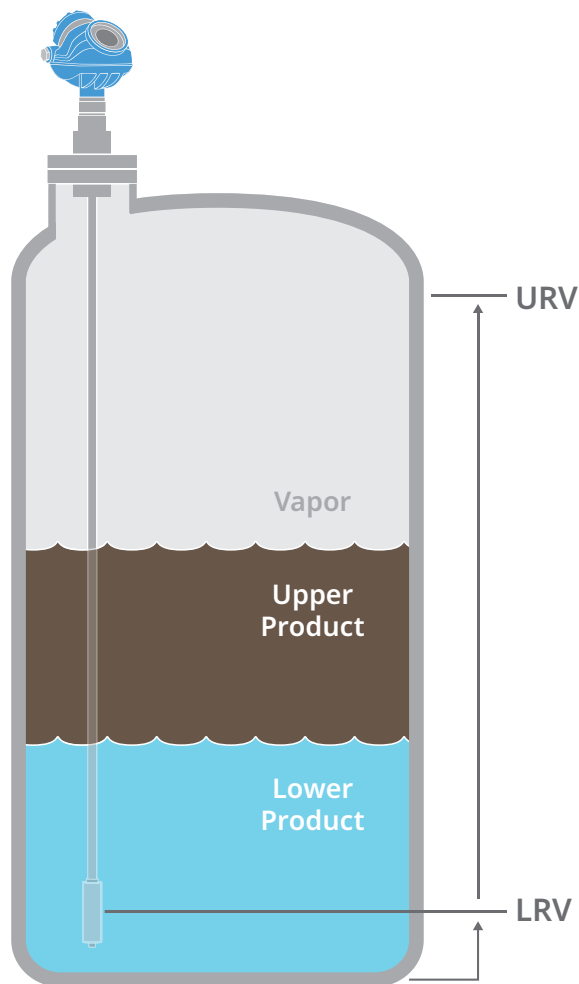*Figure 1.3.1: Interface measurement with guided wave radar*

Differential pressure

Interface applications based on density differences between two fluids

- Both taps must be covered

- Distance between taps (L) × difference in SG = DP

- Suggested minimum DP of 20 in. H_2O (500 mm H_2O)

- Interface measurement only

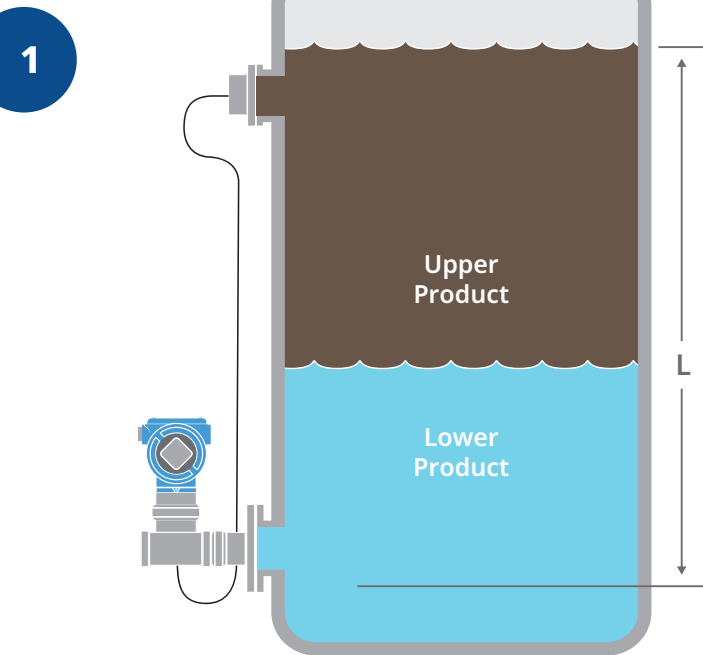- Emulsions or an indistinct interface layer has no effect on measurement

1

Figure 1.3.2: Interface measurement with differential pressure

1.3.3 What are the conditions within the vessel?

Does the level measurement device need to be able to handle high pressures and temperatures?
Some level measurement devices can withstand high temperatures and pressures quite well, while others cannot. Specification limits affect device selection. Table 1.3.1 shows the specification limits of some of the more common level devices. In some devices that can withstand process extremes, performance is compromised. The accuracy of some devices can be affected by temperature changes.

Is there product turbulence from agitation or mixing? Are steam or other vapors present in the space above the product?
Product turbulence or vapors above the product may be difficult to measure for some top-down devices. For example, some devices require that a return signal be reflected from the product surface. The signal may be weakened or not returned at all if there is product turbulence or vapors. Turbulence and vapors are less problematic for bottom-up measurement devices.

Are there any interfaces, temperature gradients, foams, or suspended solids?
Interfaces, temperature gradients, foams, suspended solids, or obstructions in the vessel could potentially affect the validity of a measurement, depending on the technology selected. For example, suspended solids may clog some devices. Foam is an important consideration because some users want to measure level at the top of the foam while others want to measure level underneath the foam.

Are there any mounting constraints on the vessel?
Existing taps should be used if at all possible. Some installations are more difficult if the vessel is glass lined or double walled. Smaller tanks have less available mounting area. Tanks that are underground, close together, close to the ceiling, or wrapped with heating coils may have limited accessibility. Floating roofs may limit the mounting of some top-down devices.

Technology	Pressure*	Temperature
Nuclear	No limit	No limit
Capacitance	Full vacuum* to 5000 psig (345 bar)	-200 to 900 °F and up (-129 to 482 °C)
Pressure with seals	Full vacuum to 4000 psig (276 bar)	-157 to 770 °F (-105 to 410 °C)**
Pressure	Full vacuum to 4000 psig (276 bar)	-40 to 380 °F (-40 to 193 °C)
Ultrasonic non-contact	-3.6 to 44 psig (-0.25 to 3 bar)	-22 to 158 °F (-30 to 70 °C)
Non-Contacting Radar	Full vacuum to 1450 psig (100 bar)	-76 to +482 °F (-60 to +250 °C)
Guided Wave Radar	Full vacuum to 5000 psig (345 bar)	-320 to 752 °F (-196 to 400 °C)
Vibrating Fork	Full vacuum to 1450 psig (-1 to 100 bar)	-94 to 500 °F (-70 to 260 °C)
Displacer	Full vacuum to 4000 psig (276 bar)	-40 to 900 °F (-40 to 482 °C)
Float Switch	Full vacuum to 2900 psig (200 bar)	-72 to 752 °F (-60 to 400 °C)

*Full vacuum = -14.7 psig; atmospheric = 0 psig
**The upper temperature for seals is limited in vacuum applications.

Table 1.3.1: Pressure and temperature limits

Should the instrument be mounted in a chamber?
Chambers provide accessibility to the instruments for calibration or troubleshooting while the process is running. They can be positioned to cover the area of interest instead of the entire range.

To get good representation of the level in the tank, the size of the connections need to be large enough to provide good flow-through in order to keep fluid fresh. Distance between tank and chamber should be minimized for the same reason. Insulation/heat tracing may be required to keep fluid temperature as close as possible to what is in the vessel.

1.3.4 What are the environmental and external conditions?

What effect will environmental conditions have on the instrument's performance?
Indoor installations are likely to have a fairly stable surrounding environment with minimal temperature changes and constant humidity. Outdoor installations are more likely to have temperature and humidity extremes. Vibration, electromagnetic interference, and transients (power surges caused by lightning) are other external issues that must be considered. Transient protectors (or surge protectors) and good grounding practices can help protect against transients.

1.3.5 What are the product characteristics?

All processes cannot be measured by the same type of device. Corrosive processes may require special construction materials on the level sensor. If special materials are required, consider whether these materials are readily available or if it would be better to select a device that does not have to contact the process.

Process characteristics can affect different devices in different ways:

- A viscous product may plug the ports on some devices

- Dust, surface foam, and vapors may interfere with some transmitted signals

- If the process density changes, the level indication for pressure devices could be affected unless compensated for

- If the dielectric constant (electrochemical property of a fluid related to the fluid's ability to transmit electrical charges from one body to another) changes, capacitance measurements will be affected

- Process coating tendencies could affect the sensitivity of devices requiring contact

- Solids tend to pile up in a vessel and are not likely to have a flat surface. Consider at what point on the angle of repose (maximum slope without product sliding) the level should be measured and whether or not this point is consistent

1.3.6 What are the accuracy requirements for the application?

How is the instrument accuracy specified?
A device that works well on a small tank may not provide the accuracy required for a larger tank. For example, a device with an accuracy of 0.1% of span gives an accuracy of ±0.06 in. (1.5 mm) on a 5 ft. (1.5 m) tank level. The same device provides an accuracy of ±0.6 in. (15 mm) on a 50 ft. (15 m) tank level.

Other devices, such as top-down radar devices, generally specify accuracy to within a certain value (± 0.1 in or 3 mm)

or as a percentage of distance measured. The impact of other performance parameters (e.g. temperature effect) should also be evaluated.

Is there a need for high accuracy?
The primary goal in some applications may simply be the ability to make a reliable measurement. In other applications, repeatability may be far more important than accuracy, i.e. the ability to provide the same measurement when repeatedly measuring a steady level.

For tank gauging applications (custody transfer and inventory application) there is huge value in using gauges with a highly accurate, stable and repeatable level measurement. Without them, the economical impact on the financial transactions may be very large and the user may not be able to follow the international and national legal custody transfer requirements.

1.3.7 What are the instrument requirements?

What approvals are needed?
Hazardous approvals need to comply with local requirements. A standard of "explosion proof" may be sufficient for many devices, but some plants or applications may require intrinsic safety or other approvals. In other instances, sanitary requirements may need to be met.

For inventory and custody transfer applications, several different local meteorological approvals are applicable and sometimes are also required in their respective country. The main international standard for custody transfer is the OIML R85.

What are the outputs required?
The most common output is a continuous analog 4–20 mA signal, although digital signals are also widely used. Also wireless signals are gaining popularity. In some instances, an alarm or control relay may be needed.

To maintain the required resolution and accuracy in a tank gauging system, a digital communication is required from the instrument to the distributed control system.

What power is available?
Most devices will run on 12–24 V dc (direct current), although there are some devices that run on 110 or 220 V. A few devices may operate on low power or wireless with battery power.

1.3.8 What is the total cost of the device?

The list price of the level measurement device is important, but the cost of installation and maintenance should be given an equivalent amount of consideration. In general, the lower-cost devices (usually mechanical) tend to require higher levels of maintenance. The more sophisticated electronic instruments are often higher priced, but the maintenance cost is much lower. The initial costs of some

1

of the electronic technologies are dropping as technical capabilities and market demand increase.

Another cost consideration is the life of the measurement device. An inexpensive device that needs to be replaced frequently can be very costly compared to a more expensive device that is more durable, reliable, or better suited to the application. In general, high-performance devices tend to cost more.

1.3.9 What is the operator comfort?

Lastly, consider the ease of using the device.

Will the method selected be understood by the people who have to use it everyday?

Will the device be easy to install, calibrate, and maintain?

While performance and engineering issues are critical, the everyday use of a level measurement device can be a key factor in its ultimate selection and long-term use.

1.4   Classifying level technologies

Many level measurement technologies are available. Choices vary from simple, manual methods to more elaborate methods that do not contact the measured products. Some technologies are available in both continuous level and point level measurement versions. In an effort to group general characteristics, level measurement devices can be organized into the following four categories:

- Manual/mechanical
- Electromechanical
- Electronic contacting
- Electronic non-contacting

This section introduces and explains in detail the function, benefits, and limitations of the devices in each category.

1.4.1 Manual/mechanical

Devices in the manual/mechanical category have no electronic output. The operator uses the device to get a visual indication of the amount of material in the vessel. Examples of level measurement devices in this category are sight glasses or rod gauging systems, or an oil dipstick. These devices are low cost but have no automation.

1.4.2 Electromechanical

Devices in the electromechanical category are mechanical assemblies with a number of moving parts that produce an electronic output for control. Unlike manual/mechanical devices, electromechanical devices provide an automated measurement that can be read remotely.

Devices with moving parts tend to have high maintenance requirements. Exposing electromechanical devices to sticky, viscous, or corrosive fluids creates an environment in which the devices' mechanical parts are subject to fouling (dirtying of moving parts) and corrosion, which leads to frequent cleaning or repairs. An example of a level measurement device in this category is a displacer.

1.4.3 Electronic contacting

Devices in the electronic contacting category have no moving parts. While they are not immune to problems with coating or corrosion, electronic contacting devices tend to be more robust and thus require less maintenance than electromechanical devices. Examples of level measurement devices in this category are guided wave radar, capacitance and pressure-based level transmitters.

1.4.4 Electronic non-contacting

Devices in the electronic non-contacting category provide sophisticated level measurement without ever touching the product. Because they have no moving parts and no direct contact, maintenance is minimal. Electronic non-contacting devices can be easier to install than other level devices because the holding vessel generally does not need to be drained. Vapor and foam might affect the measurement. Examples of level measurement devices in this category are radar and ultrasonic transmitters.

1.4.5 Cost vs. performance

Which level measurement technology is chosen depends on whether the user is more concerned about cost or performance. The two are indirectly proportional. On the other hand, maintenance cost is inversely proportional to the performance. Figure 1.4.1 shows the relationship between initial cost and performance for the level measurement device chosen.
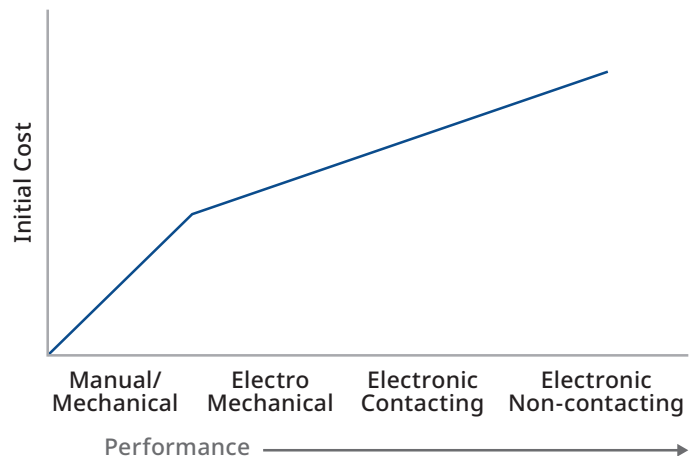
Figure 1.4.1: Initial cost vs. performance

Figure 1.4.2 shows the relationship between maintenance cost and the type of level measurement device chosen.
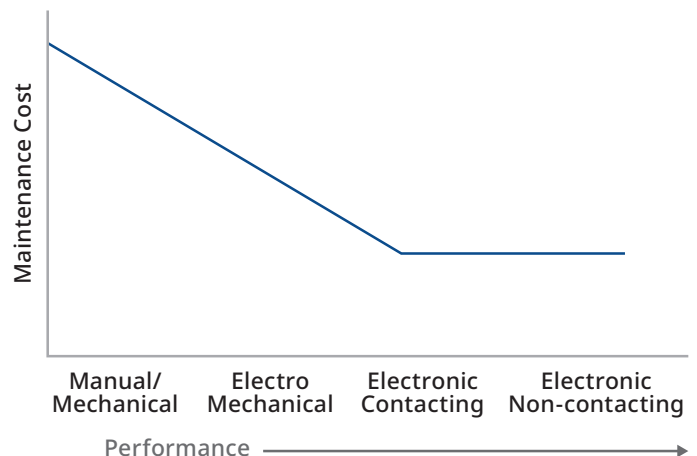
Figure 1.4.2: Maintenance cost vs. technology performance

1

1.4.6 Device summary table

Table 1.4.1. "Level measurement classification" shows the breakdown of the various level measurement technologies into their specific categories. The table also indicates which process properties each device is able to measure.

Level Measurement Category	Continuous Level	Point Level	Density	Interface	Mass
Manual/Mechanical					
Float Switches		●		●	
Float Systems	●				
Rod Gauging / Dip Probes	●	●			
Sight / Gauge Glasses	●			●	
Tape Levels and Tape Systems	●		●	●	
Electronic Contacting					
Capacitance	●	●		●	
Conductivity		●			
Optical		●			
Pressure Based Level Technologies	●		●	●	●
Guided Wave Radar	●			●	
Hybrid (Pressure Level and Radar)	●		●		●
Thermal		●			
Vibrating Level (Tuning Fork)		●			
Ultrasonic Gap Sensors		●			
Electronic Non-Contacting					
Laser	●				
Load Cells	●				●
Nuclear	●	●	●	●	
Non-Contacting Radar	●				
Ultrasonic	●				

Table 1.4.1. Level measurement classification

1.5 Dielectric constants and radar level measurement

"What is its dielectric value?" This is a question that often comes up when radar or capacitance is being considered as the technology. Non-contacting radar, guided wave radar and capacitance level transmitters are all impacted to some degree by the dielectric value of the material to be measured. So what is dielectric, what affects it, and how does it impact the level device?

1.5.1 What are dielectric constants?

To help understand dielectric constant, it helps to consider it in relation to "dielectric". By definition, "Dielectric" is: "A substance with a very low electrical conductivity, i.e., an insulator. Such substances have electrical conductivity of less than 1,000,000 mho/ cm. Those with a somewhat higher conductivity (10-6 to 10-3 mho/cm) are called semiconductors. Among the more common solid dielectrics are glass, rubber and similar elastics, and wood and other cellulosic materials. Liquid dielectrics include hydrocarbon oils, askarel and silicone oils." (Reference: Hawley's Condensed Chemical Dictionary; 12th Edition. Richard Lewis).

The term 'dielectric constant' is widely assumed to be another term for relative permittivity or the amount of energy that can be stored in a material or can accept an electromagnetic field compared to vacuum. The dielectric constant of a material is dimensionless because it is a ratio of the permittivity of the material under discussion to the permittivity of vacuum. The dielectric constant of a conductor (copper, say) is infinite because it cannot accept a field. The dielectric constant of air is 1.0006 because it can accept an electromagnetic field almost as well as can a vacuum.

Materials that are good insulators have a low relative permittivity, or dielectric constant. Materials that are conductive have higher dielectric constants.

Though still in wide use, dielectric constant is not a preferred term as it is not absolute, and because permittivity is not constant - it changes with frequency, pressure and temperature, relative humidity and other variables. (Reference: *A Guide to characterization of dielectric materials at RF and microwave frequencies* - The Institute of Measurement and Control, London 2003).

In level measurement terms, the dielectric constant (DC) is used to indicate the reflectivity of a material. Standard measurements of dielectric are referenced to vacuum with a dielectric of 1. When other materials are measured, they are compared to the vacuum. In reference to this, various materials tested under the same conditions have the following values at 68 °F (20 °C).

- Air: 1.00058
- Benzene: 2.3
- Acetic acid: 6.2
- Ammonia: 15.5
- Ethanol: 25
- Glycerol: 56
- Water: 81

The conductivity of a solution is dependent upon its chemical composition, ionization capabilities, and concentration. While there is not a simple conversion formula from conductivity to dielectric however, it is generally safe to assume that if the material is not conductive then the dielectric value will be low whereas conductive materials have higher dielectric values. A key exception to this generalization is water.

Water-based fluids, alcohols, most inorganic acids, and caustic based materials will have a high dielectric constant. Since water is a polar molecule, its dielectric constant is quite high. Most hydrocarbons are non-polar and thus their dielectric constants tend to be low.

Water has some unique characteristics in regard to conductivity and dielectric properties. For example, the conductivity of water will vary depending upon its level of purity. Deionized and distilled water are very pure due to the removal common minerals such as calcium, magnesium and iron. While distilled or deionized water has a conductivity that is very low (<2 µmho), the dielectric constants are still high (> 40). Drinking water from most cities will have a conductivity of 100 to 300, but the DC is 70 to 80.

1.5.2 What impacts dielectric constants?

Many variables can impact the dielectric constant of a material. Test methodology for determining the value and physical properties of the compound can influence the results. Other significant factors can include temperature, the test frequency. The impact of each component can vary with the compound tested.

The electrical polarity characteristics of a molecule affects the dielectric constant. Asymmetrical compounds, especially those with polar ionization characteristics such as water, have a strong positive charge on one end. This results in higher dielectric constants. More symmetrical compounds, such as most oils and other hydrocarbons, have little polarity and thus low dielectric constant.

Phase changes can result in significant changes in dielectric. For example, ice has a dielectric constant of 3.2 at 10 °F (-12 °C) and freshly fallen snow (which contains a lot more air) has a dielectric constant of about 1.3 at -4 °F (-20 °C). The crystalline structure changes the polarity and thus the dielectric constant drops.

The vaporous phase of material will have a significantly lower dielectric than the liquid phase. In many compounds the dielectric of the vapor is the same as air and does not change significantly as pressure increases. Notable exceptions to this are anhydrous ammonia and steam. These vapors can significantly impact the speed of travel of microwaves in high-pressure applications.

1.5.3 Dielectric constant stability

Dielectric constants can vary with temperature and test frequency. Increasing temperature may cause an increase in dielectric constant. Similarly, an increase in the frequency used to measure the dielectric constant can sometimes result in lower dielectric constants of some fluids. It must be kept in mind that the frequency used for measuring dielectric constants may be 100 Hz to 25 GHz or more. There is a limited amount of data showing these variations. Most data on dielectric constants is only given at a single frequency. Of the available data, for many fluids the dielectric constants change only slightly with measurement frequency, usually in the decimal places. While many compounds are constant, there are exceptions. Examples of the number of variations are shown below for silicone-based oil, an aromatic compound and an aliphatic compound.

Temperature can also cause a dielectric change. Temperature affects a material's dielectric constant because its density can cause molecules to be within a known volume.

As the temperature increases, the dielectric constant decreases because the molecules spread out more and minimize the ability of the material to transmit electrical potential energy. However, the typical changes in dielectric constants observed in Hydrocarbons range from 0.0013 to 0.05% per degree Celsius. The following chart illustrates the percentage of change in relation to the DC change:
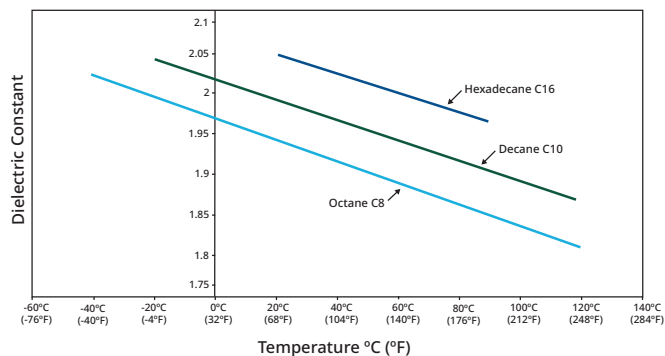
Figure 1.5.1: Dielectric constant vs. temperature for three hydrocarbons

Media	DC	At a Frequency of	DC	At a Frequency of
DC 710	2.98	100 Hz	2.60	10 GHz
Pentachlorobiphenyl	5.58	10 kHz	2.68	10 GHz
Methanol	31	1000 kHz	8.9	10 GHz
Jet fuel JP-1	2.12	10 kHz	2.09	3 GHz

Table 1.5.1: Dielectric constants (DC) for different media at different frequencies

Pressure can increase the dielectric of vapors due to simple compression of molecules. For most vapors, the change with pressure is minimal. Vapors with a minimal dielectric like air, will not increase significantly with compression. With its relatively high dielectric constant at atmospheric pressure, the dielectric of saturated steam will increase significantly as pressure and temperature increase.

Steam at pressure of	Temperature (°C)	DC
14.7 psi (1 bar)	100	1.006
225 psi (15.5 bar)	200	1.064
577 psi (39.7 bar)	250	1.152
1246 psi (85.9 bar)	300	1.351
2398 psi (165.4 bar)	350	1.863

Table 1.5.2: This illustrates the increase of the dielectric of steam as the pressure and temperature is increased.

1.5.4 Impact on level measurements

Signal reflection

In radar level measurement, the measured media needs to provide sufficient reflection of the radar signal. In general, the higher the dielectric constant, the stronger the reflected signal. Other factors do come into play however. The further away the target is, the stronger the reflection needs to be to have enough signal returned to the radar transmitter. Agitation can cause a portion of the signal to be "scattered" and therefore reduces the amount of signal that is received by the radar device. If agitation is present with a low dielectric compound, then other reflections in the vessel could become stronger than the intended liquid level measurement.

The reflectivity of a compound is predictable and is a function of its dielectric permittivity. It can be determined by:

$$R = (\sqrt{\varepsilon r} - 1)2 / (\sqrt{\varepsilon r} + 1)2$$

where R = reflection and εr = relative dielectric permittivity

Figure 1.5.2 shows this reflectivity and permittivity relationship. As the dielectric permittivity increases, the amount of signal reflection also increases. In the chart below, example A (blue line) shows that at a relative permittivity of 4, about 11% of the signal is reflected back and about 10 dB of power is lost. In example B, (purple line), at a higher dielectric such as 30, close to 50% of the signal is reflected back and less power is lost (-3 db).
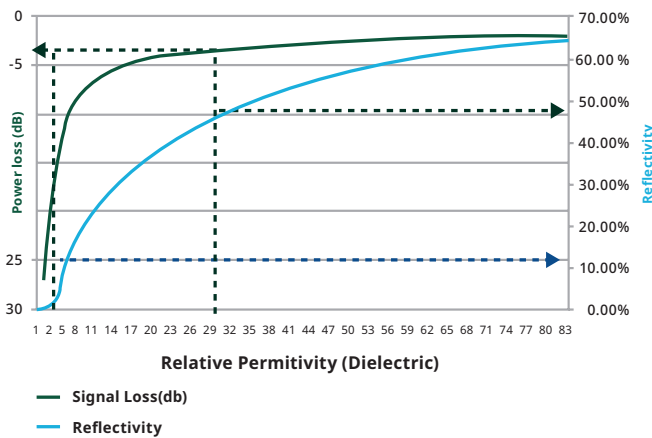
Figure 1.5.2: Reflectivity vs. permittivity

Radar signal strength
Signal generation is based primarily on the frequency and the size of the antenna.

Gain is calculated:

Gain $= \eta(\pi D/\lambda)2$

Where:

D = antenna size (diameter)

λ = wave length

η = efficiency

If antenna size and efficiency are held constant, this equation simplifies to $(1/\lambda)2$. A 26 GHz frequency gauge with a wavelength of 0.5 in. (1.2 cm) will have a gain 6 times higher than a 10 GHz gauze with a wavelength of 1.2 in. (3 cm) for same size antennas.

In figure 1.5.3, the effect of the frequency antenna size and efficiency is compared for a set dielectric and increasing distance. In this chart, the antenna size is the same, but radar frequency varies. The level surface is calm.
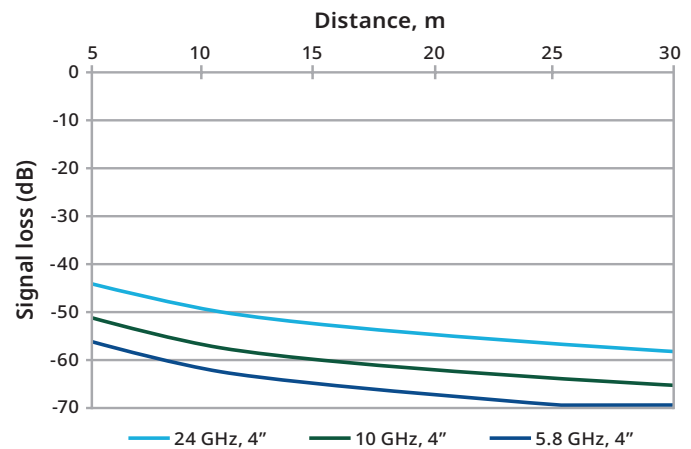
Figure 1.5.3: Chart of received signal for different frequency, same antenna and DC, and increasing distance

The overall beam width of a radar signal is inversely proportional to the frequency of the device. Thus, a higher frequency radar gauge will have a smaller beam width than a lower frequency device for the same diameter antenna. For example, at a distance of 33 ft. (10 m) and with a 4 in. (100 mm) antenna, a 26 GHz gauge has a beam width of 4.9 ft. (1.5 m) and the 6 GHz unit has a beam width of 23 ft. (7 m). The beam width for the 6 GHz device is 4.6 times larger than that of a 26 GHz unit for the same size antenna. Increasing the size of the antenna will decrease the beam width of a unit and will effectively increase its gain. Thus, if the antenna diameter is increased, the amount of reflectivity will also increase.
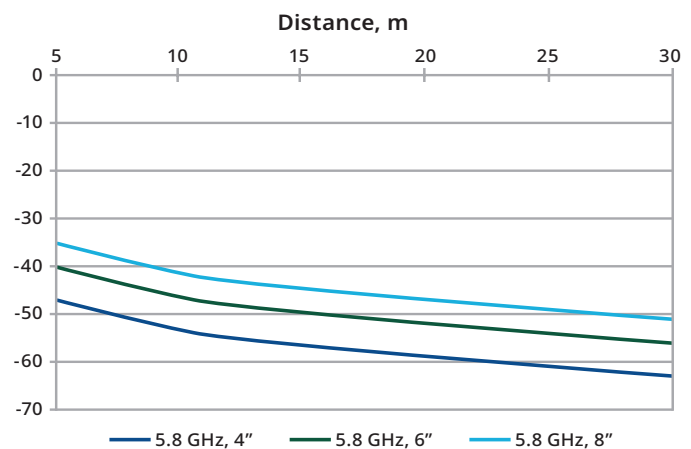
Figure 1.5.4: Chart of received signal for different size antennas, same frequency, same DC and increasing distance

For any radar level device, the amount of reflected signal will decrease for lower dielectric compounds and width distance. Thus, for low dielectric materials, the difficulty of making a good measurement will increase as the distance increases. With non contacting radar, the size of the radar antenna needs to be increased to allow both greater signal strength and better reception of the reflected signal. Using a higher frequency device allows this optimization to occur while keeping the antenna size as small as possible. This can result in significant installation savings and an easier to handle radar unit. Beyond the fundamentals, the signal processing capabilities of the device will determine the overall results with respect to how efficiently a signal is transmitted and received, and how much power loss can be managed.

Guided wave radar
Guided wave radar has similar results for dielectric and distance. The difference with guided wave radar is the probe choice rather than antenna size. In this case, a coaxial probe maintains the strongest signal for the length of the probe while a single lead probe tends to disperse the energy as the signal travels the length of the probe. Ultimately, the returned signal is a function of the dielectric, distance, probe type and the signal processing.
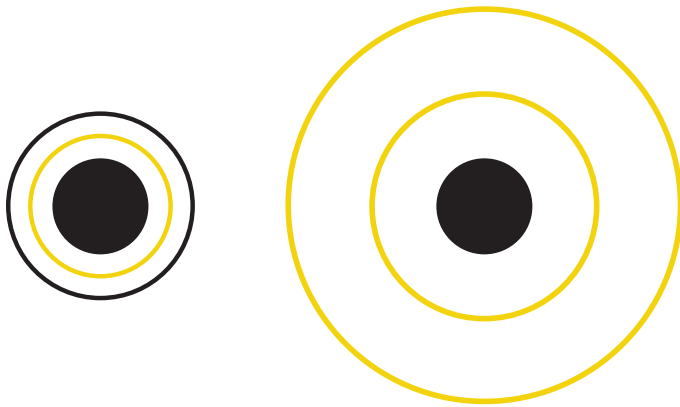
Figure 1.5.5: This graphic compares the signal dispersion from the three basic types of guided wave radar probes styles. From left: coaxial and single.

Interface measurements with radar
In both types of radar, when there are two immiscible layers of fluid and the lower dielectric fluid is the first seen by the radar, most of the radar signal will travel through the low dielectric material. Only a small part of the signal will be reflected back to the device. Thus, with a low dielectric material such as oil with a dielectric of 2, less than 5% of the signal will be reflected back to the transmitter. The rest of the signal will travel through to the next fluid. In an oil and water interface measurement, this allows detection of the two fluids. Since the speed of travel of the microwave

signal changes as it moves through the upper fluid, the determination of the physical distance of the layer needs to include compensation for the change in travel time. If the dielectric of the upper fluid layer is known, this is easily calculated as:

Real distance = Electrical distance / $\sqrt{}$ DC of media

Capacitance level transmitters
Capacitance level transmitters use the principle of the dielectric plate measurement technique to determine a level or interface measurement.

A capacitor is formed when a level sensing electrode is installed in a vessel. The metal rod of the electrode acts as one plate of the capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. As level rises, the air or gas normally surrounding the electrode is displaced by material having a different dielectric constant. A change in the value of the capacitor takes place because the dielectric between the plates has changed. RF (radio frequency) capacitance instruments detect this change and convert it into a proportional output signal.

The capacitance relationship is illustrated with the following equation:

C = 0.225 K (A / D)

where:

C = Capacitance in picofarads

K = Dielectric constant of material

A = Area of plates in square in.

D = Distance between the plates in in.

In actual practice, capacitance change is produced in different ways depending on the material being measured and the level electrode selection. However, the basic principle always applies. If a higher dielectric material replaces a lower one, the total capacitance output of the system will increase.

If the electrode is made larger (effectively increasing the surface area) the capacitance output increases; if the distance between measuring electrode and reference decreases, then the capacitance output decreases. Level is proportional to the capacitance measured. Since the capacitance is dependent on a stable dielectric of the medium throughout the height of the level column, the overall accuracy of either level or interface measurement will be impacted if the dielectric constant changes.

How do dielectric changes affect the accuracy of a radar level device?

For general radar level applications, the dielectric of the material will impact the strength of the returned signal. Any changes in dielectric will have no impact on the accuracy of the measurement. In determining the impact of the dielectric though, an exact number is not crucial. Instead, a relative characterization of the dielectric into low, medium, or high values is one part of the information needed to determine the appropriateness of radar. Other information includes the vessel height, nozzle size, antenna size or probe, and surface conditions to determine the appropriate radar choice.

Interface measurements require precision of the dielectric value for the upper layer thickness. Often, this can be accomplished via an infield adjustment of the dielectric during initial setup. Guided wave radar devices can accomplish interface measurements quite efficiently and are easy to configure for both interface and level detection. See the "Dielectric Constant Changes In Hydrocarbons – Affects On Radar Measurement Accuracy In Interface Applications" for more information on interface measurements with guided wave radar.

1.5.5 Summary

Dielectric properties of a material can impact the level measurement results of non-contacting radar, guided wave radar, and capacitance level technologies. There are several variables in its value derivation. In most cases, the changes are small and have negligible impact on the accuracy of radar-based level measurements as those devices are measuring the travel time to the surface reflection. For capacitance measurements, dielectric changes have a larger impact since a change in the medium between the plates will impact its proportional relationship to level or interface. The dielectric value is one parameter in the choice of technology. Other key factors would include the vessel size and material, probe or antenna selections, and surface conditions such as foam and turbulence.

1.5.6 References

CRC Handbook of Chemistry and Physics – 75th edition

Dielectric Materials and Applications, Arthur von Hippel, ed. 1954

Instrument Engineer's Handbook – 3rd edition. Process Measurement and Analysis, Bela Liptak, editor-in-chief, 1995

Hawley's Condensed Chemicals Dictionary, 12th edition 1995

1.6 Pressure based level measurements

The pressure exerted by a liquid is influenced by three factors:

- Depth of the liquid
- Pressure on the surface of the liquid
- Density of the liquid

With the use of these variables, level measurements can be accomplished using differential pressure.

1.6.1 Depth of a liquid

The pressure at a point below the surface of a liquid increases as the depth of the liquid above the measurement point increases. Pressure is affected by the depth, rather than the volume, of a liquid. If other factors (e.g. density of the liquid and pressure on the surface of the liquid) are constant, the pressure at a depth of 10 ft. in a large tank holding 5,000 gallons of water will be equal to the pressure at a depth of 10 ft. in a smaller tank holding only 5 gallons of water. An example from everyday life might be your experience of swimming 5 ft. beneath the surface of a swimming pool and swimming 5 ft. beneath the surface of a large lake. Even though the lake contains a far greater amount of water, the pressure on your body at a 5 ft. depth is not proportionately greater. The pressure in the lake and in the pool is the same at a depth of 5 ft.

Because liquid pressure is directly affected by the depth (i.e. level) of the liquid, a pressure measurement can be used to infer level.

1.6.2 Pressure on the surface of a liquid

Pressure on the surface of a liquid is pressure that is exerted above a column of liquid being measured. In an open tank, atmospheric pressure (the pressure exerted by the earth's atmosphere) is the pressure on the surface. If a gas is added to the top of a column of liquid in a closed tank, pressure on the surface would result. If there is a vacuum (space void of all pressure) above the liquid in a closed tank, a negative pressure on the surface exists. In a closed-tank application, the pressure on the surface is called vessel pressure. The effects of pressure on the surface must be considered to produce an accurate pressure measurement. Differential pressure measurements accomplish this compensation.

Pressure on the surface is often measured and subtracted from total pressure to determine liquid pressure, particularly in level applications.

1.6.3 Density of a liquid

Density is the mass of a particular substance per unit of volume. A liquid with a greater density has a greater mass per unit of volume. Liquids with greater densities will apply more pressure to a given area than liquids with smaller densities because higher-density liquids are heavier per unit of volume. Variations in temperature cause liquids to expand and contract, which increases or decreases the volume of the liquid. When the volume of a liquid changes, the density will change as well.

Density is often represented in terms of specific gravity. Specific gravity is the ratio of the density of a particular liquid to the density of water at the same temperature. Water has a density of 1,000 kg/m^3 at 60 °F (15.6 °C). Temperature is specified when giving a density value because temperature affects density. The density of gasoline is 660 kg/m^3 at 60 °F (15.6 °C). To calculate the specific gravity of gasoline, divide the density of gasoline by the density of water:

660 kg/m^3 / 1000 kg/m^3 = 0.66

Because specific gravity is a ratio of densities, it does not change as units of measure change. Therefore, the specific gravity of gasoline at 60 °F (15.6 °C) is always 0.66, even if the density of gasoline and the density of water are expressed in a different unit of measure (e.g. lb/ft^3):

41.2038 lb/ft^3 / 62.43 lb/ft^3 = 0.66

The combination of the height of the fluid and the specific gravity results in head pressure.

Head pressure, also known as hydrostatic pressure, is the pressure exerted by a column of fluid. Head pressure is directly proportional to the specific gravity of the fluid and the height of the fluid column.

Depending on where the pressure transmitter is mounted, calculations must be performed to factor out errors and ensure the correct head pressure is seen by the instrument. Pressure-measurement instruments are often mounted above or below the tap, or point, at which the process fluid is being measured.

If the pressure transmitter is mounted below the tap, the column of fluid held in the connection piping between the tap and the instrument will put additional pressure on the sensor of the instrument. If the distance from the tap to the pressure transmitter and the specific gravity of the fluid are known, the added head pressure can be factored out of the measurement. If the pressure-measurement instrument is mounted above the tap, gravity will act on the column of fluid, pulling it away from the instrument's sensor and thus creating a negative head pressure. A negative head pressure can also be calculated and then factored out of a pressure measurement.

1.6.4 Factors affecting density

Fluid density is defined as the mass of a material per unit of volume. Mass is the amount of matter an object contains and is often equivocated to weight and is expressed in terms of weight: pounds, tons, kilograms or grams. If a fluid becomes more concentrated, then more mass is added to that fluid and the density changes. For example, 10% sulfuric acid has a density of 1.07 kg/l, but concentrated sulfuric acid has a density of 1.83 kg/l.

Mass is unaffected by temperature. However, as a fluid is heated or cooled, its volume will expand or contract which will cause the density value (mass per volume) to change. Thus, temperature will have a significant impact on density. For level devices that incorporate density as part of the measurement, the temperature change will impact the level measurement. While compensation for density change can be accomplished by including a temperature measurement, density is a factor that can contribute significant errors to level measurements relying on density.

CHAPTER 2
AVAILABLE TECHNOLOGIES

2

2 Available Technologies

2 Available Technologies

There are many level technologies on the market, all with advantages and limitations. No single technology is good for all applications, but there are applications where many technologies could work. This chapter will give you an overview of most available technologies, how they work, and their advantages and limitations.

2.1 Guided wave radar

Continuous level measurement

2.1.1 Basic principle

Guided wave radar is also called time domain reflectometry (TDR) or micro-impulse radar (MIR). In a guided wave radar installation, the guided wave radar is mounted on the top of the tank or chamber, and the probe usually extends to the full depth of the vessel. A low energy pulse of microwaves, travelling at the speed of light, is sent down the probe. At the point of the liquid level (air / water interface) on the probe, a significant proportion of the microwave energy is reflected back up the probe to the transmitter. The transmitter measures the time delay between the transmitted and received echo signal, and the on-board microprocessor calculates the distance to the liquid surface using the formula:

Distance = (Speed of light x time delay) / 2

Once the transmitter is programmed with the reference gauge height of the application – usually the bottom of the tank or chamber – the liquid level is calculated by the microprocessor.

Because a proportion of the pulse will continue down the probe through low dielectric fluids, a second echo can be detected from an interface between two liquids at a point below the initial liquid level.

This characteristic makes guided wave radar a good technique for measuring liquid/liquid interfaces such as oil and water and measuring through some foams.

Guided wave radar can be used in vessels with tight geometry, in chambers, and in tanks of all sizes. Advanced guided wave radar also works well in low dielectric and turbulent applications. Because it is not dependent on reflecting off a "flat" surface, it works well with many powders and grains as well as liquids with slanted surfaces caused by vortices.
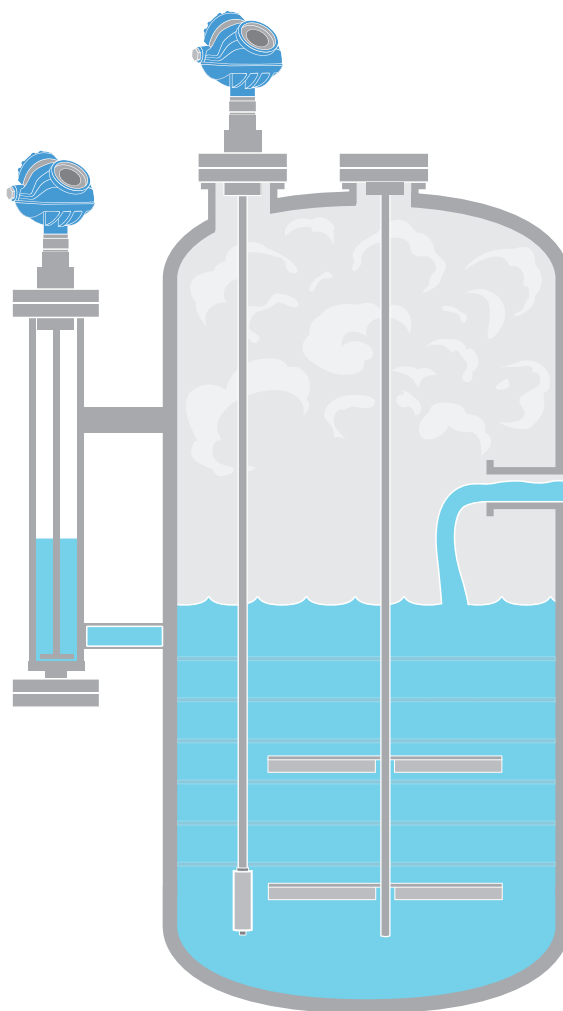
Figure 2.1.1 Guided wave radar can handle disturbing objects and tough process conditions. It can be installed directly in the tank or in a by-pass chamber

2.1.2 Advantages

Guided wave radar provides an accurate and reliable measurement for both level and interface, and can be used in a wide variety of applications. It is a top-down, direct measurement as it measures the distance to the surface. guided wave radar can be used with liquids, sludges, slurries, and some solids. A key advantage of radar is that no compensation is necessary for changes in the density, dielectric, or conductivity of the fluid. Changes in pressure, temperature, and most vapor space conditions have no impact on the accuracy of radar measurements. In addition, radar devices have no moving parts so maintenance is minimal. Guided wave radar is easy to install and can easily replace other technologies, such as displacer and capacitance, even while there is liquid in the tank.

2.1.3 Limitations

While guided wave radar works in many conditions, some precautions need to be taken with respect to probe choice. Several probe styles are available and the application,

length, and mounting restrictions influence the choice. Unless a coax-style probe is used, probes should not be in direct contact with a metallic object, as that will impact the signal. If the application tends to be sticky or coat, then only single lead probes should be used. Some advanced guided wave radars on the market have advanced diagnostics, with the ability to detect build-up on the probe. Chambers with a diameter less than 3 in. (75 mm) may cause problems with build-up and may make it difficult to avoid contact between chamber wall and probe.

2.2 Non-contacting radar

Continuous level measurement

2.2.1 Basic principle

For non-contacting radar level measurement there are two main modulation techniques, pulse radar and FMCW (Frequency Modulated Continuous Wave) radar techniques.

Non-contacting pulse radar sends out a microwave signal that bounces off the product surface and returns to the gauge. The transmitter measures the time delay between the transmitted and received echo signal and the on-board microprocessor calculates the distance to the liquid surface using the formula:

Distance = (Speed of light x time delay) / 2

Once the transmitter is programmed with the reference gauge height of the application – usually the bottom of the tank or chamber – the liquid level is calculated by the microprocessor.

The FMCW radar also transmits microwaves towards the product surface, but the transmitted signal is of continuously varying frequency. When the signal has travelled down to the liquid surface and back to the antenna, it is mixed with the signal that is being transmitted at that time. The difference in frequency between the received and transmitted signal is directly proportional to the distance to the liquid with high precision.

The gauge's susceptibility to corrosion is limited because it is non-contacting and it is an ideal choice for viscous, sticky, and abrasive fluids and for hygienic applications. Non-contacting radar is frequently used in vessels with agitators. Devices with higher frequencies can be completely isolated from the process with PTFE seals and can be used with valves. Most vendors offer non-contacting versions that can be used in applications from 3 to 98 or 131 ft (1 to 30 or 40 m).

The frequency of the non-contacting radar can impact its performance. A lower frequency reduces sensitivity to vapor, foam, and contamination of the antenna, whereas a higher frequency keeps the radar beam narrow in order to minimize influence from nozzles, walls, and disturbing objects. Beam angle is inversely proportional to antenna size. The beam angle of a given frequency will decrease as the antenna size increases.

2.2.2 Advantages

Non-contacting radar provides a top-down, direct measurement as it measures the distance to the surface. It can be used with liquids, sludges, slurries, and solids. A key advantage of radar is that no compensation is necessary for changes in density, dielectric, or conductivity of the fluid. Changes in pressure, temperature, and most vapor space conditions have no impact on the accuracy of radar measurements. In addition, radar devices have no moving parts so maintenance is minimal. Non-contacting radar devices can be isolated from the process by using barriers such as PTFE seals or valves. Since it is not in contact with the measured media, it is also good for corrosive and dirty applications.
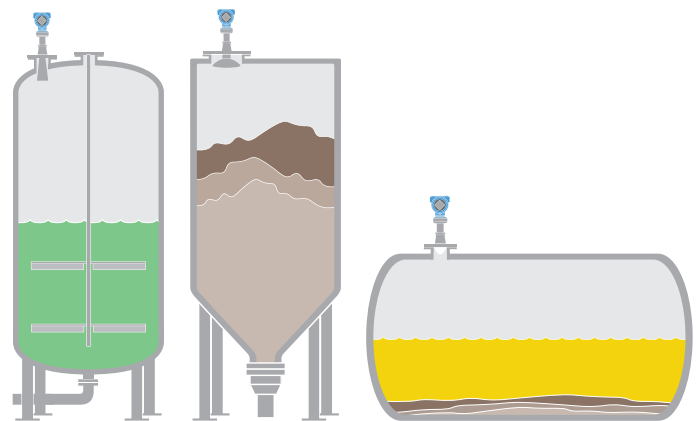
Figure 2.2.1 Non-contacting radars with different antennas to fit different applications.

2.2.3 Limitations

Level measurement indicators enable an on-site level For non-contacting radar, good installation is the key to success. The gauge needs a clear view of the surface with a smooth, unobstructed, unrestricted mounting nozzle.

Obstructions in the tank, such as pipes, strengthening bars, and agitators can cause false echoes, but most transmitters have sophisticated software algorithms to allow masking or ignoring of these echoes.

Non-contacting radar gauges can handle agitation, but their success will depend on a combination of the fluid properties and the amount of turbulence. Dielectric constant (DC) of the medium and the surface conditions will impact the measurement.

The measurement may be influenced by the presence of foam. Energy tends to not be reflected by light and airy foam while a dense and heavy foam typically reflects the energy.

With low dielectric process fluids, much of the radiated energy is lost to the fluid, leaving very little energy to be reflected back to the gauge. Water and most chemical solutions have a high DC; fuel oil, lube oil, and some solids, such as lime, have a low DC.

If the surface is turbulent, whether from agitation, product blending, or splashing, more of the signal is lost. So a combination of a low dielectric fluid and turbulence can limit the return signal to a non-contacting radar gauge. To get around this, bypass pipes or stilling wells can be used to isolate the surface from the turbulence.

2.3 Ultrasonic

Continuous level measurement

2.3.1 Basic principle

An ultrasonic level transmitter is mounted on the top of the tank and transmits an ultrasonic pulse down into the tank. This pulse, travelling at the speed of sound, is reflected back to the transmitter from the liquid surface. The transmitter measures the time delay between the transmitted and received echo signal and the on-board microprocessor calculates the distance to the liquid surface using the formula:-

Distance = (Speed of sound x time delay) / 2
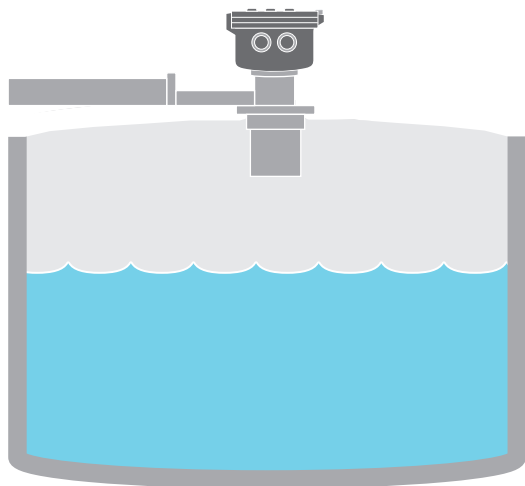
Figure 2.3.1 Illustration showing an ultrasonic transmitter

Once the transmitter is programmed with the bottom reference of the application – usually the bottom of the tank – the liquid level is calculated by the microprocessor.

2.3.2 Advantages

Ultrasonic transmitters are relatively easy to install and is also a very well-established technology within all industries due to it's simplicity and low price point.

Since ultrasonic level transmitters are generally not in contact with the media, corrosion, viscosity, density are factors that you can disregard. The key advantage for ultrasonic level transmitters being the fact that they can be used applications where you would require continuous measurement of the bottom level of an interface by effectively submersing the ultrasonic level transmitter. An example of this application would be sludge blankets, where the sediment level within the water is what is of interest to measure.

2.3.3 Limitations

Ultrasonic level transmitters rely on the pulse being unaffected during its flight time. Anything that could affect this pulse, such as: temperature changes, wind, vapors and steam, gases in air, turbulence, foam, and internal obstruction such as pipes, strengthening bars, and agitators should be avoided. As the pulse needs air to travel through, vacuum applications are not possible either. Materials of construction generally limit the process temperature to around 158 °F (70 °C) and pressure to 43 psig (3 bar).

Ultrasonic level transmitters have to be calibrated to account for the temperature variance over time. This is often done by having a separate temperature transmitter to help calibrate the device. This calibration however, drifts over time and requires the user to periodically re-calibrate their transmitters, which makes the technology more maintenance-heavy than other technologies.

Ultrasonic level transmitters also all have a blanking distance (dead zone), which is the minimum distance from the sensor lens where reliable measurement is not possible. This distance depends on transmitter design, but usually varies between 20cm (8 in) to 60cm (24 in), removing the opportunity to fully utilize a tank.

2.4 Pressure transmitters

Continuous level measurement

2.4.1 Basic principle

Pressure transmitters are a common and well understood technology for liquid level measurement. They are straightforward, easy to use and install, and work in a variety of applications and a wide range of conditions.

If a level measurement is being made on an open/ vented vessel, a gauge (GP) or differential pressure (DP) transmitter is required. If the tank is closed or pressurized, a DP measurement must be made to compensate for the vessel pressure. In addition to basic level measurements, pressure instrumentation can be set up to provide density and interface level measurements.

Open vessel level measurement
In an open-vessel configuration, the head pressure of the liquid is measured to infer a level measurement. Any column of liquid exerts a force at the base of the column because of its own weight. This force, called hydrostatic pressure or head pressure, can be measured in pressure units. Hydrostatic pressure is determined by the following equation:

Hydrostatic Pressure = Height x Specific Gravity

If the liquid level (height) changes, hydrostatic pressure changes proportionally. Therefore, a simple way to measure level is to install a pressure gauge on the holding vessel at the lowest level to be measured. The level of the liquid above the measurement point can then be inferred from hydrostatic pressure by rearranging the formula above to solve for height. If the pressure units are not in units of height, they will need to be converted (e.g. 1 ft H_2O=0.43 psig).

Closed tank level measurement
If a vessel is pressurized, a single GP transmitter is not adequate. When a GP transmitter detects a change in pressure, it cannot distinguish whether it was caused by a change in the liquid level or a change in the vessel pressure. To solve this issue, a DP measurement should be made in closed vessel applications to compensate for the presence of the vessel pressure.

When a DP measurement is made, changes in the overall vessel pressure affect the high and low pressure taps equally, so the effects of the pressure are cancelled out.
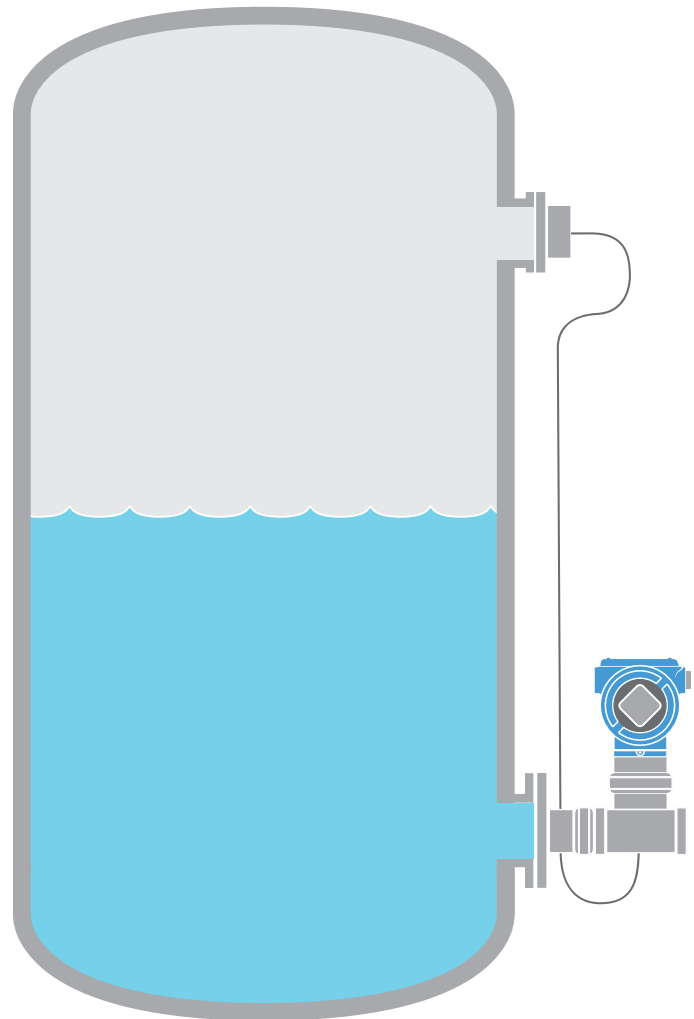
Figure 2.4.1 Illustration showing a pressure transmitter with a high and low pressure taps

The high-pressure tap near the bottom of the vessel measures hydrostatic pressure plus vapor space pressure. The low-pressure tap connected near the top of the vessel reads only the pressure in the vapor space. The difference in pressure between the two taps (differential pressure) is used to determine level. A DP measurement can be made by using a single DP transmitter with impulse piping or capillary and seals, or two gauges or absolute transmitters can be used to calculate DP in an Electronic Remote Sensor (ERST™) configuration.

Level = Differential Pressure / Specific Gravity

2.4.2 Advantages

In general, pressure transmitters are economical, easy to use and well understood. In addition, pressure transmitters can handle almost any tank and liquid, including slurries. They function in a wide pressure and temperature range, as well as in foam and turbulence.

2.4.3 Limitations

Level measurement accuracy with pressure transmitters can be affected by changes in fluid density. Special precautions are therefore required with thick, corrosive, or otherwise hostile fluids. In addition, some fluids (e.g., paper stock) tend to solidify as their concentration increases. Pressure transmitters do not work well with such solidified states. When pressure transmitters are installed with impulse piping (wet or dry legs), then ambient temperature changes can affect the measurement due to density changes in the wet leg fluid or condensation of fluid in dry legs. Closed capillary systems alleviate some of these issues, and can be chosen to minimize the errors.

Electronic Remote Sensor (ERS) technology can further eliminate errors due to temperature changes by replacing impulse piping and capillary with a digital architecture. However, Electronic Remote Sensor technology is designed for tall vessels and applications with low to moderate static pressures.

2.5 Capacitance

Continuous and point level measurement

2.5.1 Basic principle

A capacitor is formed when a level sensing electrode is installed in a vessel. The metal rod of the electrode acts as one plate of the capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. As level rises, the air or gas normally surrounding the electrode is displaced by material having a different dielectric constant. A change in the value of the capacitor takes place because the dielectric between the plates has changed. RF (radio frequency) capacitance instruments detect this change and convert it into a relay actuation or a proportional output signal.

The capacitance relationship is illustrated with the following equation:

$$C = 0.225 \, K \, (A / D)$$

where:

C = Capacitance in picoFarads

K = Dielectric constant of material

A = Area of plates in square in.

D = Distance between the plates in in.

where the interface is used to control the flow of the top and bottom fluids out of the vessel with minimum contamination.
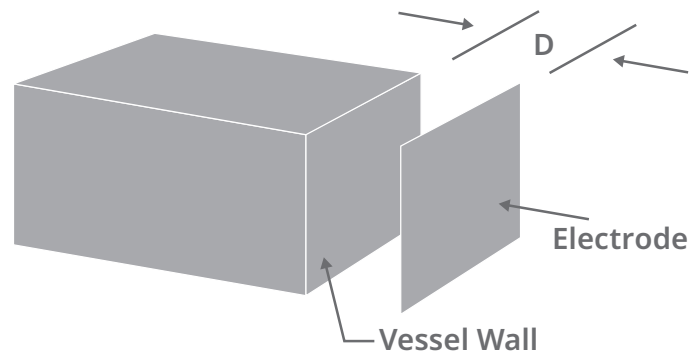
Figure 2.5.1 Capacitance principle

The dielectric constant is a numerical value on a scale of 1 to 100 which relates to the ability of the dielectric (material between the plates) to store an electrostatic charge. The dielectric constant of a material is determined in an actual test cell. In actual practice, capacitance change is produced in different ways depending on the material being measured and the level electrode selection. However, the basic principle always applies. If a higher dielectric material replaces a lower one, the total capacitance output of the system will increase.

If the electrode is made larger (effectively increasing the surface area) the capacitance output increases; if the distance between measuring electrode and reference decreases, then the capacitance output decreases.

2.5.2 Advantages

A capacitor tolerates a variety of process conditions, such as variable density, high temperatures (1000 °F, 540°C), high pressures (5000 psi, 345 bar), viscous products, slurries, foams, and pastes. It can be used to measure point or with multiple points it can measure continuous level in both solids and liquids. It can also measure interface. In addition, a capacitor is inexpensive.

2.5.3 Limitations

For a capacitor, a change in dielectric creates errors in the reading, as does a coating on the probe by product. Options are available to compensate for the build-up of product on capacitance probes. With nonmetallic tanks or tanks without vertical walls, the addition of a reference probe is required. Calibration of a capacitor can be difficult, especially since one cannot "bench calibrate", and changing vapor space can affect the output. Capacitors are also adversely affected by heavy foams.

2.6 Displacer transmitters

Continuous measurement

2.6.1 Basic principle

A displacer transmitter is fitted to the top of a tank or more usually in a chamber which is valved to the tank, and comprises a displacer element which is suspended from a hanger - either a torque tube or a spring - connected to the transmitter/switch head. The displacer element is designed to be heavier than the liquid in which it is being used so that, even when fully immersed in the liquid, it still exerts a downward force on the hanger.

As the liquid in the vessel rises to cover the element, a buoyancy force is created which is equal to the weight of the liquid displaced by the element (Archimedes' principle). This is seen by the transmitter as an effective reduction of the hanging weight of the element, and, as the displacer element hanging weight is proportional to the liquid level around it, the electronics in the transmitter head can give a readout of liquid level.
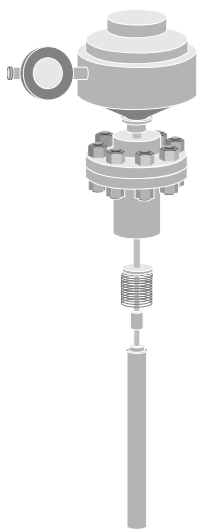
Figure 2.6.1 Illustration showing a spring displacer

2.6.2 Advantages

Displacer transmitters and switches are widely used and, provided they are regularly maintained, and their calibration checked, give years of reliable service. Able to operate at extremes of pressure and temperature, and commonly used to give interface level measurement even where emulsive layers exist between two liquids, these instruments allow level measurements to be made in many difficult applications.

2.6.3 Limitations

The accuracy of the level measurement is dependent upon correct calibration of the instrument at operating conditions. If these conditions change, the level reading will be incorrect.

Torque tube displacer transmitters in particular require regular maintenance and calibration checks, and can suffer from damage during surge conditions. Operating ranges greater than 16 ft (5 m) are impractical, mainly due to handling issues.

2.7 Nuclear

Continuous and point level measurement

2.7.1 Basic principle

Nuclear devices comprise a shielded radioisotope source attached to one side of a vessel or pipe and a detector placed on the opposite side. Gamma rays are emitted from the source and are focused to travel through the tank wall, the medium in the tank, and the far tank wall through to the detector. Nuclear level switches use radioisotope sources sized to provide measurable radiation at the detector when no product material is present between source and detector.
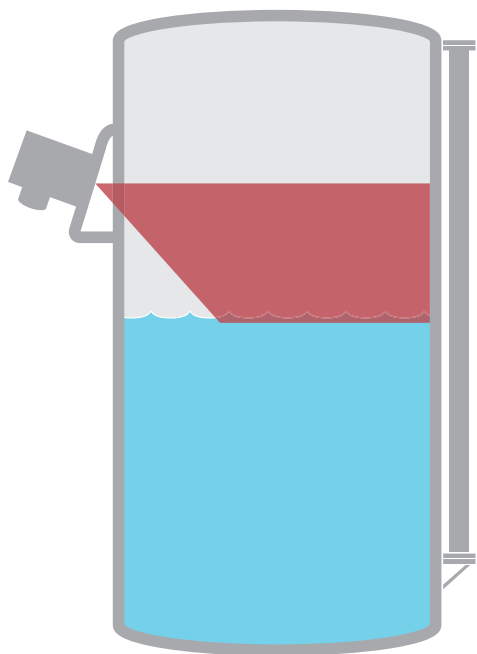
Figure 2.7.1 Illustration showing a nuclear device

Nuclear level transmitters use the same radioisotope sources, but respond to the total absorption of gamma rays as they pass from the source to detector. The amount of radiation reaching the detector is inversely proportional to the amount of material in the vessel.

Although the word "nuclear" sometimes causes concern, the industry has sustained an excellent safety record over the course of the last 30 years or more.

2.7.2 Advantages

The biggest advantage with nuclear technology is that it is non-invasive (i.e. there is no need for any instrument process connections on the tank). In addition, the nuclear level devices are non-contacting and unaffected by high temperatures, high pressures, corrosive materials, abrasive materials, viscous materials, agitation, or clogging/plugging. It can be used for both point and continuous level measurements in both liquids and solids, as well as interface.

2.7.3 Limitations

Large density changes, especially the density of Hydrogen in a material, can create errors. Layers of coating on vessel walls can also affect the measurement results. In order to use the nuclear technology, licensing and leak checks are required, as well as a high degree of health and safety checks and care over source handling and disposal. Nuclear has a relatively high cost.

2.8 Laser

Continuous level measurement
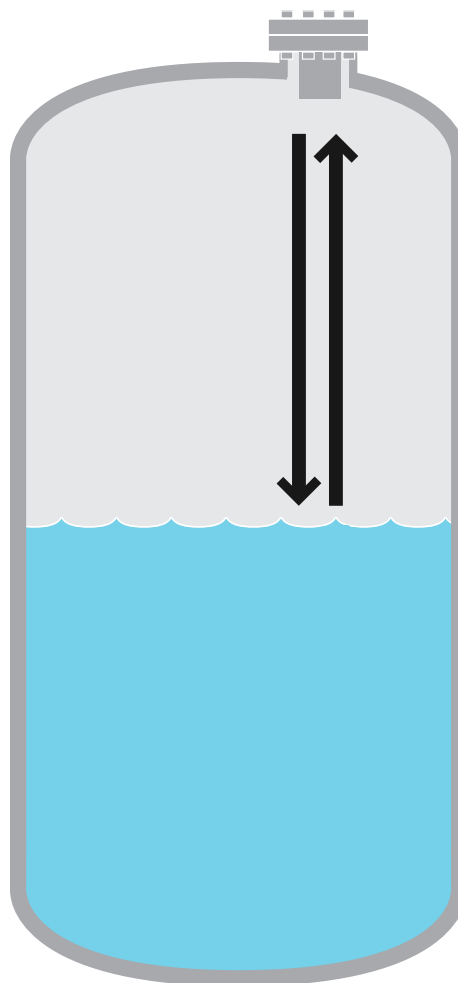
Figure 2.8.1 Illustration showing the laser principle

2.8.1 Basic principle

A laser level sensor uses infrared light to send a focused beam towards the surface. The laser light will reflect off of most solid or liquid surfaces. The time of flight can be measured with precise timing to determine the range or distance of the surface from the sensor.

2.8.2 Advantages

A narrow, focused beam makes this technology good for applications with space restrictions. It is a non-contacting technology, with no moving parts, making it a low maintenance device. Laser level devices work best in cloudy or shiny liquids or solids. The laser technology can handle rapid level changes, has high accuracy, and can measure on long ranges.

2.8.3 Limitations

In order for the laser device to function, the glass window where the laser beam leaves the device must stay clean. Therefore, it cannot tolerate dust, fog, steam, or vapors. In addition, the laser beam may pass through surfaces of clear, still fluids. When it comes to installation of the device, the alignment is critical.

2.9 Magnetostrictive

Continuous level measurement
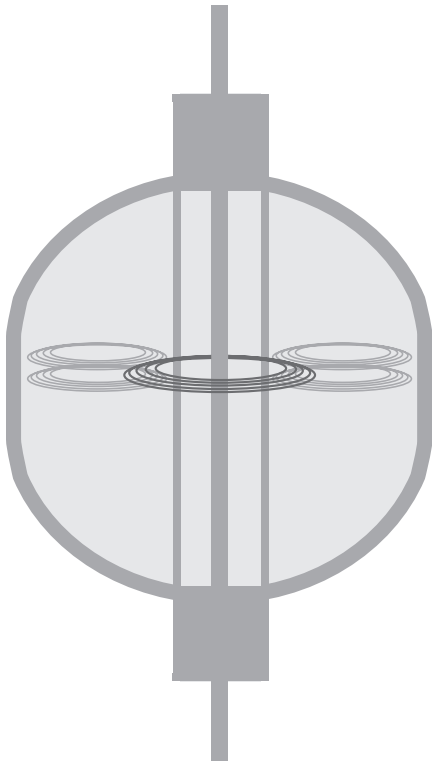
Figure 2.9.1 Illustration showing the magnetostrictive magnetic fields

2.9.1 Basic principle

The magnetostrictive devices measure the intersection of two magnetic fields, one in a float, the other in a guide tube. The float is free to travel up and down the guide tube as the liquid level changes. Electronics send a low current pulse along the guide and when the magnetic field generated by the pulse reaches the field generated by the float, torsional "twist" is initiated. This then creates a sonic wave, which is detected and timed.

2.9.2 Advantages

The magnetostrictive devices are precise 9 ft (3m), can be subject to damage by turbulence or poor installation. Also, it attracts all metal particles in the liquid, thus changing the way it floats.

2.10 Magnetic Level Indicators

Continuous level measurement

2.10.1 Basic principle

A Magnetic Level Indicator (MLI) is a vertical indicator made up of a chamber parallel to the process vessel and a column with visual indicators that show the level.

The Magnetic Level Indicator chamber contains magnetic floats that move up and down with the level and trigger or move the visual indicators in the column. The floats can also trigger any magnetostrictive sensors, which are sensors that respond when they are exposed to a magnetic field.

The chamber is constructed from non-magnetic material which is compatible with the process fluid(s), temperature, and pressure. The chamber is parallel to the process vessel so the level of the fluid(s) in the chamber is at the same level as the fluid in the process but is less turbulent. The chamber is connected via instrument piping to the process vessel and may have several connections. It will contain the same fluids and fluid interfaces that are present in the process vessel, provided that the connections are located such that fluid flow allows good representation of vessel contents.

The magnetic float or floats contained in the chamber are designed to sit at the total level and/or the interface between two adjacent fluids based on their specific gravity. The indicators typically comprise a housing containing a column of flags. The flags are flipped as the lines of flux from the magnetized float or floats pass through the chamber walls and trigger them to move, typically so that they show an alternate color which is on the back side of the flags. This will indicate the position of the float or floats contained in the chamber. As the level of the fluid or fluid interface(s) within the chamber rises and falls, the float or floats rise and fall, and the level is communicated to and displayed by the Magnetic Level Indicators. The magnetic lines of flux also stimulate any other magnetostrictive sensors or switches, such as reed switches, attached to the column.
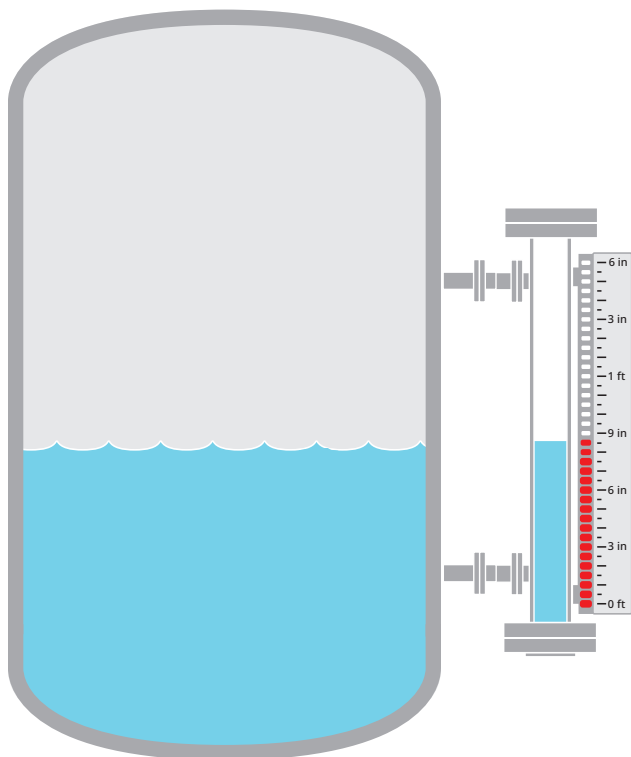
Figure 2.10.1 Illustration showing a Magnetic Level Indicator

2.10.2 Advantages

Magnetic Level Indicators are typically used to provide operating personnel with a visual indication of the level of the process fluid contained within a given vessel. They have an advantage over a sight glass in that the visual indicator itself does not contain any process fluid so the risk of fluid release into the environment due to a broken sight glass or ineffective seals is avoided. Additionally, the level of fluids can be observed from some distance, colorless fluids can be observed, and the level of fluids can be reliably observed even for fluids that would foul or etch a sight glass. Magnetic Level Indicators typically remain in service for decades.

2.10.3 Limitations

Magnetic Level Indicators rely on floats which occasionally foul and stick. If iron filings are present in the media, they can get caught on the magnets and hang the float up. Additionally sticky media including substances like paraffin can occasionally cause a float to stick or hang-up if the chamber is below process temperature. Floats are additionally vulnerable to collapse during hydro testing, steam cleaning, process start-up, and process shut down.

The Magnetic Level Indicators sometimes use a shuttle that is magnetically linked to the float and moves as the float moves. Floats of this type are known to become decoupled

from their "shuttle" type indicators, requiring them to be re-set. The "flag" type indicators are relatively immune to this issue. In certain circumstances, boiler code requires that the plant operator observe the process media directly. In these cases a Magnetic Level Indicators would not be adequate. Float design is dependent on the pressure in the vessel and the specific gravity of the process liquid over the entire temperature range. Applications with high temperature, high pressure, and low specific gravity are the most difficult, but Magnetic Level Indicators may be used at temperatures near 1000 °F (538 °C), at pressures up to more than 4000 psi (275 bar) and with fluids with specific gravities of 0.4 or even lower.

2.11 Float Tank Gauges
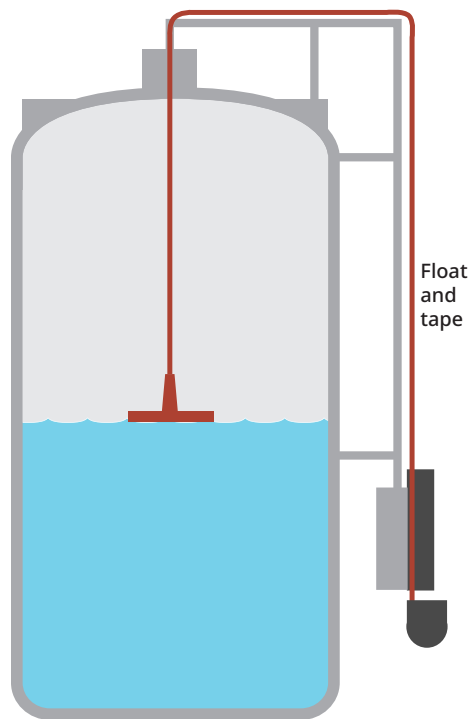
2.11. Float and tape

A float tank gauge consists of a large float inside the tank. The float is mechanically connected to the readout unit outside the tank through a metallic tape. A float gauge requires no electric power to work. The liquid level in the tank movements power the float-tape-readout arrangement. The mechanical readout can be equipped with a transmitter to send the level data to the control room electronically.

A float tank gauge is an intrusive gauge that has moving parts inside the tank. If any of the parts inside the tank breaks the tank may have to be emptied and made gas free to allow repair.

2.12 Servo Tank Gauges

A servo tank gauge is used for continuous level gauging in storage tanks. It is like a float gauge but has a more precise mechanism and gives better accuracy. The servo is an intrusive gauging device and a mechanical apparatus with many moving parts.
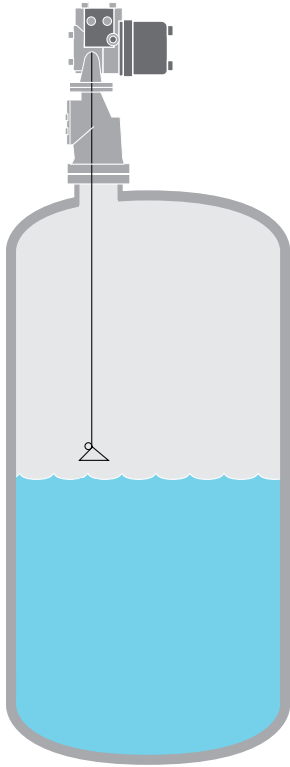
Figure 2.12.1 Illustration showing the servo powered level gauge

2.12.1 Basic principle

The servo powered level gauge uses a bi-directional motor attached to a displacer and wire. A disk shaped displacer is attached to the wire which is rolled up on a measuring drum. The servo motor is controlled by an electronic weighing balance mechanism which continuously senses the buoyancy of the partly immersed displacer. A level rise or fall causes a variation in buoyancy. The wire tension detector controls the bi-directional motor which turns the measuring drum, making the displacer to follow the tank level movements.

The servo gauge must be mounted on a stilling well to prevent horizontal movement of the displacer. Servo level gauges may also be used for density and water interface measurements. For density and water interface measurements a special elongated displacer shall be used. Comprehensive calibration exercises has to be performed to make the density gauging accurate. Servo density gauging can only be performed on clean distilled hydrocarbon liquids.

2.12.2 Limitations

A servo gauge has many moving parts that are susceptible to mechanical wear and sensitive to dirt and product buildup. A density change of the measured product may affect the immersion of the displacer. Hence a recalibration is necessary if the product in the tank is changed. Although it is possible to measure density and/or water interface with a servo gauge, this is achieved by lowering the wire and displacer into the product which could leave product residue on them. This may lead to increased maintenance requirements to maintain accuracy. The real product level measurement is not available during these density and water interface measurements. The servo density gauging method is not described by any industry standards.

2.13 Vibrating fork switches

Point level detection

2.13.1 Basic principle

Vibrating fork switches are a point level technology which operate using the concept of a tuning fork. The switch is mounted on the side or top of a tank or pipe using a flange or threaded process connection such that the forks protrude inside the vessel.

When in air, the forks vibrate at their natural frequency which is monitored by a detector circuit. When media covers the forks, the frequency of oscillation drops and is detected by the switch electronics, which in turn changes the output state of the switch, and providing an effective means of detecting the presence or absence of the media.
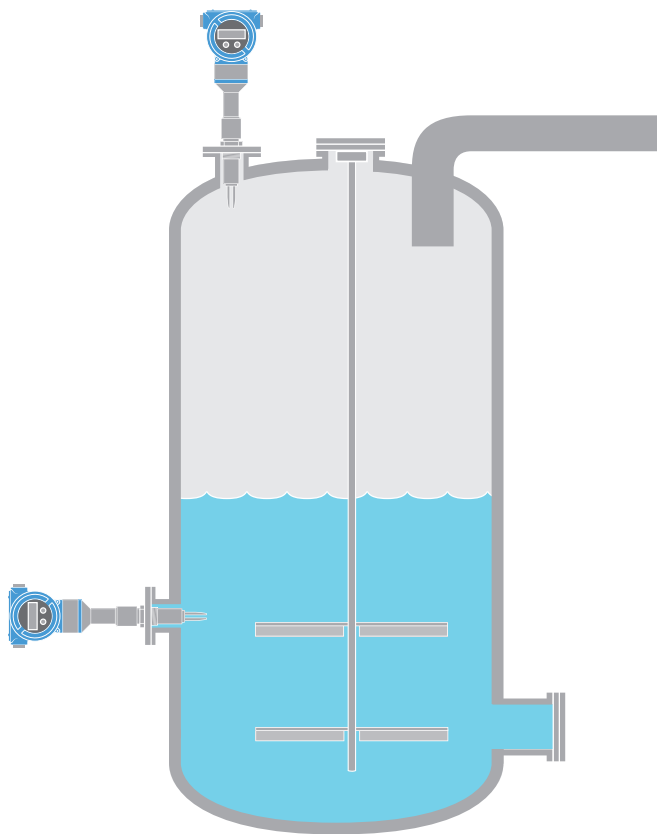
Figure 2.13.1 Illustration showing vibrating fork switches mounted on top and on the side of the tank

2.13.2 Advantages

Vibrating fork switches are virtually unaffected by flow, bubbles, turbulence, foam, vibration, solids content, coating, and changing properties of the liquid making them a highly reliable technology for liquid level detection. There is no need for calibration and they require minimum installation procedures. No moving parts or crevices means virtually no onsite maintenance.

Vibrating fork switches have gained popularity due to their diagnostics capability. Some modern types available have the capability to continuously check and report their mechanical and electronic health. Some also have the ability to monitor small changes and trends in the fork frequency opening up the possibility of inferring characteristics of the liquid at that point level.

2.13.3 Limitations

Vibrating fork switches are not suitable for very viscous media. Gradual build up between the forks, if left unchecked, may cause bridging of the forks, which risks false switching. In extreme high temperature and pressure applications vibrating fork switches may not be suitable and another technology such as float or displacer should be selected.

2.14 Float and displacer switches

Point level detection

2.14.1 Basic principle

A float switch is usually mounted on the side of a tank or in an external chamber, and relies upon the liquid lifting the float through buoyancy principle as it arrives at the switching level. The float carries a permanent magnet as part of the float assembly which interacts with a second permanent magnet in the switch housing. The assembly is glandless as the magnets interact through the wall of the switch body.

These simple electro-mechanical devices are relatively trouble free and give reliable switching in high or low level applications. There are many variations on this theme and models to meet almost any application, process connection, or switching duty are available.

Where switching points are required a long distance below the mounting point of the switch, a displacer type switch can be used. Operating in a similar manner to a displacer transmitter, the displacer element is positioned on a cable and suspended from a spring below the mounting point at the required switching level.
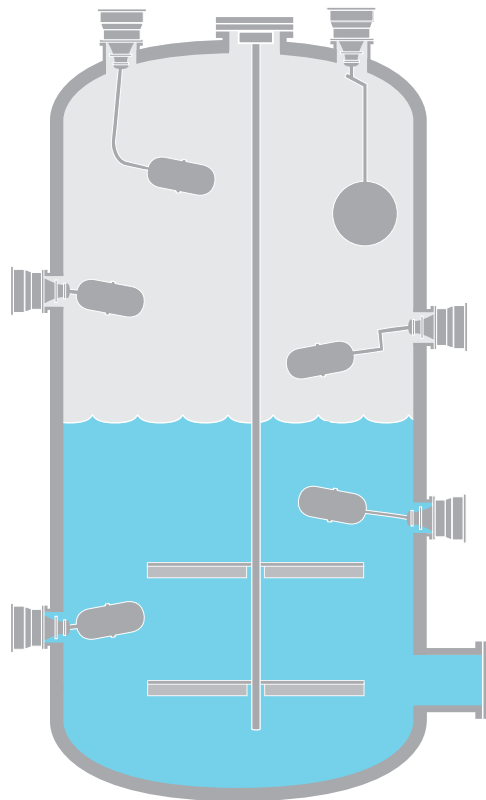
Figure 2.14.1 Illustration showing different mounting positions for float switches

The displacer element has a fixed hanging weight which is supported by the spring. As liquid covers the element, the effective weight seen by the spring is reduced and an operating permanent magnet is lifted which interacts with a second permanent magnet in the switch housing. Displacer designs are also used in very high pressures or where low Specific Gravity liquids are present.

2.14.2 Advantages

Being very simple with only a few components, float and displacer switches are very reliable and easy to maintain. High pressures and temperatures are not a problem, and a variety of wetted materials allow use in almost any liquid.

2.14.3 Limitations

Float and displacer switches are simple passive devices and have no self checking features, so regular checking and maintenance is advisable. The float or displacer is a moving part so it can be subject to sticking in thicker or viscous liquids.

KEY
- 🟢 Good
- 🟡 Application dependent
- 🔴 Not recommended

	Guided Wave Radar	Non-Contacting Radar	Differential Pressure Level	Ultrasonic	Vibrating Fork	Mechanical Float
	Continuous				Point	
Measurement						
Level	🟢	🟢	🟢	🟢	🟢	🟢
Interface	🟢	🔴	🟡	🔴	🔴	🟢
Volume	🟢	🟢	🟢	🟢	🔴	🔴
Density	🔴	🔴	🟢	🔴	🟡	🔴
Mass	🔴	🔴	🟢	🔴	🔴	🔴
Open channel flow	🟡	🟢	🔴	🟢	🔴	🔴
Process Media Characteristics						
Changing density	🟢	🟢	🟡	🟢	🟢	🟡
Changing dielectric	🟢	🟢	🟡	🟢	🟢	🟡
Wide pH variations	🟢	🟢	🟢	🟢	🟢	🟢
Pressure and temperature changes	🟢	🟢	🟡	🟡	🟢	🟡
Bubbling/boiling surfaces	🟢	🟢	🟢	🟡	🟢	🟡
High turbulence	🟢	🟡	🟢	🔴	🟢	🔴
Foam	🟢	🟡	🟢	🔴	🟡	🟢
Corrosive Media	🟡	🟢	🟡	🟢	🟡	🟡
Viscous liquids	🟡	🟢	🟢	🟢	🟡	🟡
Crystallizing liquids	🟡	🟢	🟡	🟢	🟡	🟡
Sludges and slurries	🟡	🟢	🟢	🟢	🟡	🟡
Condensing vapors	🟢	🟢	🟢	🟡	🟢	🟢
Solids, granules, powders	🟢	🟢	🔴	🔴	🟢	🔴
Tank Environment Considerations						
Top-down connection	🟢	🟢	🔴	🟢	🟢	🟢
Side connection	🟡	🔴	🟢	🔴	🟢	🟢
Bottom connection	🔴	🔴	🟢	🔴	🟢	🟢
Stilling wells or chamber applications	🟢	🟢	🟢	🟡	🟢	🟢
Mounting close to tank wall / disturbing object	🟢	🟢	🟢	🟡	🟢	🟢
Long and narrow mounting nozzles	🟡	🟡	🟢	🔴	🟢	🟡
Nozzle in center of tank	🟢	🔴	🟢	🔴	🟢	🟢
Compatible where valves or isolation are required	🟡	🟢	🟢	🔴	🔴	🟡
Angled or slanted surface	🟢	🟢	🟢	🟡	🟢	🔴
Non-metallic vessel	🟡	🟢	🟢	🟢	🟢	🟢
Internal obstructions	🟢	🟡	🟢	🟡	🟢	🟢
Agitation	🟡	🟢	🟢	🟡	🟢	🟡
High empty and fill rates	🟢	🟢	🟢	🟢	🟢	🟢
Small tank < 40 in (1 m)	🟢	🟢	🟡	🟢	🟢	🟢

2

CHAPTER 3
ROSEMOUNT LEVEL MEASUREMENT PRODUCTS

Rosemount Level Measurement Products

3 Rosemount Level Measurement Products

The Rosemount level product offering includes the technologies required for maximum efficiency in a wide range of installation and application conditions, providing robust and reliable measurements. This chapter provides an overview of the offering. For detailed information on a product, please see the Product Data Sheet on Emerson.com

3.1   Guided Wave Radar Transmitters

There are three different Rosemount guided wave radar level transmitters; Rosemount 5300, Rosemount 3300, and Rosemount 3308. For guidance in choosing the correct model for your application, please see table 3.1.1.

Benefits of Rosemount Guided Wave Radar Technology:

- Highly accurate and reliable measurement
- Top mounted, direct level and interface measurement of liquids or solids
- Wide temperature and pressure ranges
- Unaffected by process conditions such as density, viscosity, conductivity, corrosiveness, vapors, turbulence, dust, and changing pressure and temperature
- Good fit for small spaces and easy swap for older technologies
- A wide range of probe styles to cover virtually any application
- Versatile product design resulting in few restrictions in where unit can be installed
- MultiVariable™ output includes the choice of level, interface level, distance, upper product thickness, volume, and signal strength
- A wide variety of wetted materials and process connections
- Robust modular design resulting in low operating cost and increased safety
- Wireless solutions with Rosemount 3308, or with 5300 and 3300 in combination with the Rosemount Wireless THUM Adapter

3.1.1 Rosemount 5300 Guided Wave Radar Level Transmitter

- Direct Switch Technology enables a stronger signal than other 2-wire GWR transmitters, providing better measurement capability and reliability
- Probe End Projection allows for measurement on very low dielectric products over long ranges
- Dynamic Vapor Compensation functionality ensures high accuracy in saturated steam applications
- Advanced Diagnostics (SQM) for a preventative maintenance program or detection of changes in process, such as appearance of foam
- Improved EMC performance with a Smart Galvanic Interface increases safety
- Easy integration into new or existing plants with a choice of 4-20 mA HART™, FOUNDATION ™ fieldbus or Modbus with extensive support for advanced diagnostics
- Powerful and easy-to-use configuration tools
- A wide range of probe styles to cover virtually any application including extreme temperature and pressure probes for demanding environments
- Robust modular design and Multivariable transmitter resulting in low cost and increased safety
- For liquids and solids
- SIL 3 Capable: IEC 61508 certified for use in safety instrumented systems up to SIL 3 (Minimum requirement of single use (1oo1) for SIL 2 and redundant use (1oo2) for SIL 3)
- EN12952-9 and EN12953-11 compliant
- ASME B31.1 available for selected flanges
- Large coax probe enables measurement without upper null zone
- Thin interface detection capabilities down to 1 inch

Rosemount 5300 Guided Wave Radar Level Transmitter

3.1.2 Rosemount 3300 Guided Wave Radar Level Transmitter

• Handles most liquid storage and monitoring applications

• Easy-to-use Radar Configuration Tools makes setup quick and easy and provides diagnostics with waveform plotting and logging tools

• Easily integrated into existing HART and Modbus plant architecture

Rosemount 3300 Guided Wave Radar Level Transmitter

3.1.3 Rosemount 3308 Wireless Guided Wave Radar Level Transmitter

• The world's first true wireless guided wave radar for level and interface measurement

• Handles most liquid storage and monitoring applications

• Fast and simple commissioning with self-organizing network and easy-to-use human centered guided set-up software, with intuitive graphical interface

• Dirty probe detection with Signal Quality Metrics

• Battery powered with nine-year battery life at one minute update rate

• Advanced process and device health diagnostics with proactive alerts

• Direct switch technology provides high signal strength for reliable measurement

• High performance option with ±0.1in (3mm) accuracy

Rosemount 3308 Guided Wave Radar Level Transmitter

Specification and selection guide for guided wave radar[1] KEY ● Available ● Not available	3300	3308	5300
Certification			
Explosion proof or intrinsically safe	●	●	●
Overfill protection (DIBt / WHG)	●	●	●
Certified to IEC 61508 to SIL 2	●	●	●
Marine approvals	●	●	●
EN 12952-9, EN12953-11, CRN and B31.1 compliant	●	●	●
Output			
4-20 mA with HART®	●	●	●
FOUNDATION™ Fieldbus	●	●	●
MODBUS®	●	●	●
*Wireless*HART®	●[2]	●	●[2]
Configuration			
AMS™ Suite / Trex	●	●	●
Customized PC setup and support software	●	●	●
FDI Available	●	●	●
DTM Available[3]	●	●	●
DD Available	●	●	●
Diagnostics			
Standard Diagnostic Capabilities	●	●	●
Signal Quality Metrics	●	●	●
Probe End Projection	●	●	●
Proof Test with Verification Reflector	●	●	●
Probe Materials			
Stainless steel or PTFE covered	●	●	●
Duplex 2205, Alloy C-276, Alloy 400	●	●	●
Max/Min/ Temp/Press			
-40 to 302 °F (-40 to 150 °C) / -14 (-1) to 580 psig (52 bar)	●	●	●
-320 to 752 °F (-196 to 400 °C) / -14 (-1) to 5000 psig (345 bar)	●	●	●
Performance			
Maximum measuring range	75ft/23m	33ft/17m	164ft/50m
Minimum dielectric constant with coaxial / single lead probe [4]	1.4/2.5	2.0[5]	1.2/1.4
Reference accuracy	±0.2in/5mm	±0.1in/3mm	±0.1in/3mm
Challenging applications with single lead probe			
Turbulent hydrocarbons	●	●	●
Level and interface	●[6]	●	●
Coating products	●	●	●
Solids	●	●	●
Saturated steam	●	●	●
Disturbing electromagnetic interference	●[7]	●[7]	●

Table 3.1.1: Specification and selection guide for Rosemount guided wave radar transmitters

[1] For more information please refer to the product data sheet and Guided Wave Radar application and selection guide
[2] With Emerson Wireless 775 THUM™ Adapter
[3] For configuration in Fieldmate, FieldCare, and PactWare
[4] See data sheets for details. Installing a single lead probe in a metallic chamber or enabling Probe End Projection function will improve minimum dielectric constant
[5] At maximum measuring range
[6] Suitable up to 30 ft / 9 m
[7] In metallic tanks. For optimal single lead probe performance in non-metallic tanks, the probe must be mounted with a metal flange, or screwed in to a metal sheet (d > 14 in./350 mm) if a threaded version is used. Consult factory in case of non-metallic tanks or open air applications

3.2 Non-Contacting Radar Transmitters

Benefits of Rosemount Guided Wave Radar Technology:

- Top mounted, non-contacting, direct level measurement

- Smart Echo Supervision™ for difficult measurement applications addressing inconvenient nozzle placements and internal tank obstructions. For more information on Smart Echo Supervision, see chapter 13 of this book.

- Wide temperature and pressure ranges

- Maximum mounting and application flexibility is ensured with a wide range of antennas

- Can be isolated by valves

- Unaffected by process conditions such as density, viscosity, conductivity, coating, corrosiveness, vapors, and changing pressure and temperature

- Good for dirty, coating and corrosive applications

- May be combined with the Rosemount Wireless THUM™ Adapter for wireless solution

- No moving parts and no contact with the liquid

- Can measure through non-metallic tanks or containers

3.2.1 Rosemount 5408 Non-Contacting Radar Level Transmitter

- Unique energy-efficient two-wire FMCW radar for optimal performance

- 26 GHz frequency suitable for a wide range of process applications, both liquids and solids

- Wide temperature and pressure range

- Engineered and user-tested for best-in-class safety, reliability, and ease-of-use

- Low 12V dc lift-off voltage

- Immune to intermittent power loss for up to 2 seconds

- Unique PTFE seal design eliminates need for O-rings

- Rosemount 5408:SIS tailored for SIS requirements, optimal for safety applications and certified to IEC 61508 for SIL2 applications with SIL3 capability.

- Perform safe, easy, and remote proof testing without interrupting the process and with step-by-step guidance with dynamic visualization and printable reports

- Air purging available for dusty applications

- Hygienic process connections and certificates available for sanitary applications

- High flexibility with interchangeable transmitter heads and antennas

- Wide selection of antennas and materials

- Intuitive set up and commissioning in the FDI compliant Radar Master Plus, complete with guided wizards and adaptive graphics

- Advanced diagnostics capabilities including Smart Echo Supervision and measurement reliability with Signal Quality Metrics, via antenna and product surface conditions monitoring, allowing for preventive maintenance and reduced downtime

- Smart Echo Level proof-test can be carried out from the control room without changing the actual level, avoiding process interruption. Proof test wizards with step-by-step interactive guides with remote proof testing capabilities.

- Go back in time for troubleshooting or process insight with on-board data Historian

- Schedule automatic health checks and receive report with Smart Meter Verification

- NAMUR type tested

Rosemount 5408 Non-Contacting Radar Level Transmitter

3.2.2 Rosemount 3408 Non-Contacting Radar Level Transmitter

- Lens antenna available for very small process fittings (3/4") and with optional bracket mounted ATAP (Atmospheric Temperature and Atmospheric Pressure) antenna for outdoor settings

- Available with native *Wireless*HART® option, which eliminates wiring, increases portability and enables the monitoring of assets that previously were too costly or unsafe to access.

- All PTFE wetted parts allow for use in harsh conditions, such as corrosive medias

- Intuitive set up and commissioning in the FDI compliant Radar Master Plus, complete with guided wizards and adaptive graphics

- Convenient configuration and maintenance using optional Bluetooth® technology

- Advanced diagnostics capabilities including Smart Echo Supervision and measurement reliability with Signal Quality Metrics, via antenna and product surface conditions monitoring, allowing for preventive maintenance and reduced downtime

- Proof testing made easy. Smart Echo Level proof-test can be carried out from the control room without changing the actual level, avoiding process interruption

- Schedule automatic health checks and receive report with Smart Meter Verification

- Go back in time for troubleshooting or process insight with on-board data Historian
- 80 GHz and FMCW technology including Smart Echo Supervision makes the sensor less sensitive to inconveniently placed nozzles and internal obstructions within the application
- Fast Sweep Technology provides continuous surface tracking for greater measurement reliability and accuracy, especially in fast filling applications
- Namur type tested and third party certified for use in safety critical applications

Rosemount 3408 Non-Contacting Radar Level Transmitter

3.2.3 Rosemount 1208 Non-Contacting Radar Level and Flow Transmitter

- Compact and robust design to withstand harsh environments, designed for outdoor conditions, submersion and hazardous location installations where flammable gases such as methane are present
- Simple configuration over your tablet/mobile device via Bluetooth® wireless technology
- 4-20 mA HART or 4-20 mA, IO-link, and switching output deliver ease of integration to new or any existing automation systems
- Non-contacting radar technology ensures maintenance free solution unaffected by process conditions such as media density, viscosity, condensation, temperature, and pressure
- Designed for ease of use, no complex configuration needed. Setup within minutes
- M12 electrical connector allows for simple installation, startup, and cable/sensor replacement
- PVDF housing to withstand corrosion in both wastewater- and chemical applications
- Ensure sustainability by measure flow in flumes and open channels with incorporated flow measurement software
- 1.5" G and NPT process connections are compatible with a range of flanges and adapters
- Drinking water and food grade approved material composition allows for use in food- and drinking water applications

- It features 80 GHz FMCW with Smart Echo Supervision to avoid internal obstructions, and also has no dead zone to increase tank utilization.
- Fast Sweep Technology provides continuous surface tracking for greater measurement reliability and accuracy, especially useful in fast filling applications

Rosemount 1208 Non-Contacting Radar Level Transmitter

3.2.4 Rosemount 1408 Non-Contacting Radar Level Transmitter

- World's first non-contacting radar with IO-link connectivity and 4-20 mA output for easy integration to any automation system
- Available with two-wire 4-20mA/HART
- Simple commissioning
- Unique design withstands high cleaning temperatures while still retaining a compact form factor that allows for mounting in tight spaces
- Smart Echo Supervision, ideal for small tanks and internal obstructions
- No dead zone, measures all the way to the antenna without risk of overfilling the tank
- Full breadth of approvals to achieve compliance
- Drip-off sealing disc design to ensure perfect cleanliness during CIP/SIP, insensitive to condensation and build-up
- Unique single chip design combines FMCW and 80 GHz technology together with smart echo algorithms to provide accurate and reliable measurement signals
- Robust design ensures protection against leakage during tank cleaning and external washdowns
- Digital switch output to alert operators of critical level limits
- Available with both hygienic and open-air certifications
- A range of hygienic adapters to fit various process connections

Rosemount 1408 Non-Contacting Radar Level Transmitter

3

Specification and selection guide for non-contacting radar technology[1] KEY 🟢 Available 🔴 Not available	5408	3408	1208	1408
	FMCW	FMCW	FMCW	FMCW
Certification				
Explosion proof, intrinsically safe or fit for hazardous location	🟢	🟢	🟢	🔴
Overfill protection (DIBt / WHG)	🟢	🟢	🔴	🔴
IEC 61508 SIL 2 certified	🟢	🟢	🔴	🔴
Hygienic or food grade approvals	🟢	🔴	🟢	🟢
Marine approvals	🟢	🟢	🔴	🔴
Water approvals	🔴	🟢	🟢	🟢
Output				
Separate wiring for power and communication (e.g. 3-wire)	🔴	🟢	🟢	🟢
4-20 mA with HART	🟢	🟢	🟢	🟢
IO Link	🔴	🔴	🟢	🟢
FOUNDATION™ Fieldbus	🟢	🔴	🔴	🔴
MODBUS®	🔴	🟢	🟢	🟢
NAMUR®	🟢	🟢	🟢	🔴
*Wireless*HART with the Emerson THUM™ Adapter	🟢	🟢	🔴	🔴
Configuration				
AMS™ Suite / Trex	🟢	🟢	🟢	🟢
FDI Available	🟢	🟢	🟢	🟢
DTM Available[2]	🟢	🟢	🟢	🟢
DD Available	🟢	🟢	🟢	🟢
Bluetooth® Wireless Technology	🔴	🟢	🟢	🔴
Diagnostics				
Smart Echo Supervision	🟢	🟢	🟢	🟢
Standard Diagnostic Capabilities	🟢	🟢	🟢	🟢
Signal Quality Metrics	🟢	🟢	🔴	🔴
Smart Meter Verification	🟢	🟢	🔴	🔴
Smart Proof Test Package	🟢	🟢	🔴	🔴
Smart Echo Level Test	🟢	🟢	🔴	🔴
Power advisory	🟢	🔴	🔴	🔴
Antenna Materials				
Stainless steel, Alloy C-276, Alloy 400 or PTFE covered	🟢	🟢	🔴	🟢
Operating Temperature	-76 to 482°F (-60 to 250 °C)	-76 to 392 °F (-60 to 200 °C)	-40 to 176 °F (-40 to 80 °C)	-40 to 302 °F (-40 to 150 °C)
Max/min Pressure	-15 to 1450 psi (-1 to 100 bar)	-15 to 363 psig (-1 to 25 bar)	-15 to 43.5 psig (-1 to 3 bar)	-15 to 116 psig (-1 to 8 bar)
Connections				
Threaded	🟢	🟢	🟢	🟢
Tri Clamp	🟢	🔴	🔴	🟢
Flanged	🟢	🟢	🟢	🟢
Hygienic	🟢	🔴	🟢	🟢

Specification and selection guide for non-contacting radar technology[1] KEY ● Available ● Not available	5408	3408	1208	1408
Performance				
Maximum measuring range	492ft/150m	98ft/30m	49ft/15m	33ft/10m[3]
Minimum dielectric constant	1.5[4]	1.5[4]	2[4]	2[4]
Reference accuracy	0.08in/1mm	0.08in/1mm	0.08in/2mm	0.08in/2mm
Application Considerations				
Heavy vapors or bubbling/boiling surfaces	●	●	●	●
Valves, taller nozzles, small openings, and internal structures	●	●	●	●
High turbulence and rapid level changes	●	●	●	●
Solids, granules, powders	●	●	●	●
Antenna extensions	●	●	●	●

Table 3.2.1: Specification and selection guide for Rosemount non-contacting radar

[1] For more information please refer to the product data sheet (PDS) .
[2] For configuration in Fieldmate, FieldCare, and PactWare.
[3] Measurement is possible up to 49 ft. (15 m) if there is good reflection of the product surface (dielectric constant >10.
[4] If installed in vessel. Min DC is 1.4 if installed in metallic pipe. Measuring range depends on microwave frequency, antenna size, dielectric constant, and process condition. See PDS for details

3.3 Differential Pressure Level Transmitters

Rosemount 3051S direct mount (left) and Rosemount 3051S ERS™ system (right)

3.3.1 Differential Pressure Liquid Level Transmitters

- Level, density, and interface measurements
- Easy to install
- Can be isolated by valves
- Unaffected by vapor space changes, surface conditions, foam, corrosive fluids, internal tank equipment
- Advanced diagnostics with process alerts
- Single model for easy ordering
- Variety of process connections
- Quantified performance for the entire transmitter / seal assembly
- HART, FOUNDATION fieldbus, Profibus, and IEC 62591 (*Wireless*HART) protocols
- Bluetooth® capable

There are a number of Rosemount pressure transmitter models. For guidance in choosing the correct model for your application, please see table 3.5.1.

Rosemount 3051S Electronic Remote Sensor (ERS) System

- A digital pressure solution for tall vessels >10 ft in height
- Eliminates capillary therefore the effects of ambient temperature
- Provides additional process insight with MultiVariable capabilities
- Fast response times (improved by over 90%)
- Easy installation

Rosemount 1199 / 1299 Diaphragm Seal System

- Multiple direct mount and capillary options to match vessel mounting requirements
- Available for all transmitter configurations
- Available in a wide range of materials
- Allows connection to harsh conditions

Rosemount 3051S Thermal Range Expander

- Process temperatures higher than 401 °F (205 °C) up to 770 °F (410 °C) with uncontrolled ambient conditions (typically outdoors)
- Rosemount DP level fill fluid offering covers the widest temperature range with the thermal range expander
- Eliminates the need for heat tracing which can be complicated to install and expensive

Rosemount 319 Flushing Ring

- Allows fast and efficient removal of residue buildup on diaphragm seals
- Reduces labor costs and downtime
- Streamlines parts management

Specification and selection guide for pressure[1] KEY ● Available ● Not available	3051ERS	3051S	3051	2051
Transmitter Protocols				
4-20 mA	●	●	●	●
HART	●	●	●	●
FOUNDATION fieldbus	●	●	●	●
*Wireless*HART	●	●	●	●
*Wireless*HART with the THUM Adapter	●	●	●	●
Profibus	●	●	●	●
Low power (1-5 Vdc)	●	●	●	●
Available Measurements				
DP level, P-Hi pressure, P-Lo pressure P-Hi module temp., P-Lo module temp. 20-Point scaled variable	●	●	●	●
DP level / Pressure, module temp. 2-Point scaled variable	●	●	●	●
DP level / Pressure	●	●	●	●
Hydrostatic level	●	●	●	●
Additional Transmitter Options				
Remote display and interface	●	●	●	●
Remote zero and span	●	●	●	●
Advanced diagnostics	●	●	●	●
Safety certified to IEC 61508	●	●	●	●
Bluetooth® Wireless Technology for configuration and maintenance	●	●	●	●
Process Temperature				
-4 to +194 °F (-20 to +90 °C)	●	●	●	●
-157 to 600 °F (-105 to +316 °C)	●	●	●	●
-157 to +770 °F (-105 to +410 °C)	●	●	●	●
Process Pressure				
Up to PN 100 or ANSI 2500 flange rating	●	●	●	●
Up to 656 ft. (200 m) hydrostatic level	●	●	●	●
Materials of Construction				
15+ available including 316 stainless steel, Tantalum, Alloy C-276, Titanium, gold plated, and PTFE coated	●	●	●	●
316 Stainless steel or aluminum bronze and ceramic capacitive sensor	●	●	●	●

Table 3.3.1: Specifications and selection guide for Rosemount pressure transmitters

[1] *For more information, please refer to the product data sheet (PDS).*

3.4   Level Measurement Switches

3.4.1 Vibrating fork liquid level switches

The Rosemount 2100 vibrating fork series provides reliable, low maintenance point level detection for alarm, monitoring and control of liquids.

- Virtually unaffected by turbulence, foam, vibration, coating, or liquid properties

- Suitable for side or top mounting on vessels or pipes

- Short fork design for minimal intrusion in to vessel

- Easy installation, maintenance and ongoing calibration keep costs down

- Built-in diagnostics continuously monitor electronic and mechanical health

- Fast drip fork design helps minimizes switching time even in viscous or sticky applications

- Rapid wet to dry time for highly responsive switching, adjustable switching delay prevents false switching during turbulence and splashing

There are 5 models in the Rosemount 2100 series:

Rosemount 2110 Level Switch – Vibrating Fork

- Compact lightweight design suitable for installation in small vessel or pipes or for high volume fast-fit / OEM-type applications

- Rugged stainless steel dry and wetside

- Always visible heartbeat led for device status

- Magnetic test point

- Hygienic process connections and certificates available for sanitary applications

Rosemount 2110 Level Switch – Vibrating Fork

Rosemount 2120 Level Switch – Vibrating Fork

- Suitable for almost all liquid applications

- Wide choice of materials, process connection types, and output options

- Heartbeat led for device status

- Suitable for use in hazardous areas

- Magnetic test point

- Extended length forks up to 4m

- Safety certified models available for functional safety applications

- Low power relay model compatible for operation with 12V supply available. Suitable for battery or solar powered installations.

- Hygienic process connections and certificates available for sanitary applications

Rosemount 2120 Level Switch – Vibrating Fork

Rosemount 2130 Level Switch – Vibrating Fork

- Flexibility of Rosemount 2120 options with extended capabilities for challenging process conditions.

- Extended operating temperature range

- Advanced built-in diagnostics continuously check electronic and mechanical health

- Heartbeat led for device status and health

- Magnetic test point

- Safety certified models available for functional safety applications

Rosemount 2130 Level Switch – Vibrating Fork

Rosemount 2140 Level Switch – Vibrating Fork

- The world's first wired HART vibrating fork level detector

- Simple to install into existing HART loops with no additional wiring

- Robust dual compartment housing gives extra protection layer in harsh applications

- Smart and remote diagnostics for continuous access to status and health data from the control room

- Infer changing media characteristics and plan preventative maintenance with advanced functionality

- Unique settled sand and sediment detection function

- Fully integrated local and remote functional test / partial proof test capability

**Rosemount 2140:SIS Level Switch -
Wired HART safety certified model**

- Designed for functional safety, critical control, and overfill prevention applications

- Superior diagnostics coverage and industry-leading low dangerous undetected failure rate of 13 (FIT). Probability of less than 1 dangerous undetected failure in over 8000 years.

- Safe Failure Fraction up to 97%

- Remote configuration, diagnostics and proof-testing capabilities keep workers off the tank

- Fully integrated remote partial proof test simplifies testing and eliminates safety risks from human error

Rosemount 2140:SIS and Rosemount 2140 Level Switches

Rosemount 2160 Wireless Level Switch – Vibrating Fork

- World's first *Wireless*HART liquid level detector for remote and hard to reach locations

- No wiring / additional infrastructure required for installation.

- Install and commission in minutes, remote configuration helps minimize time on tank

- Access advanced diagnostics and powerful HART data whether you are 10m or 10 miles from your tanks helps eliminate routine manual operator rounds

- Reliable continuous operation with up to 10 years battery life

- Scalable technology - easy to expand automation coverage with your plant

Rosemount 2160 Wireless Level Switch – Vibrating Fork

For further guidance in choosing the correct model for your application, please see the table 3.4.1.

3.4.2 Solids switches

Solids switches are used as a low-maintenance technology for indicating the presence of solids media. They are easy to use and install, robust and reliable, and insensitive to dust, electrical charge and adhesion, which makes them suitable for increased safety, reduced maintenance and downtime costs.

There are several types of technologies available to fit the broad variety of solids applications and characteristics in different industries.

Rosemount 2501 Solids Level Switch - Rotating paddle

- Self-diagnosis – device fault alarm
- Adjustable switching delay prevents false switching
- Patented mechanical hysteresis for extended product lifetime
- Unaffected by dust, electrostatic charging and caking
- Withstands heavy loads and high temperatures
- Rotatable housing for easy installation
- Mechanically stable shaft bearing design
- Robust die-cast housing with IP66 protection

Rosemount 2501 Solids Level Switch - Rotating paddle

Rosemount 2511/2521 Solids Level Switch - Vibrating fork

- Able to withstand high mechanical loads due to short extension length
- Adjustable sensitivity
- Adjustable switching delay prevents false switching
- Approvals suitable for use in hazardous/explosive and dusty environments
- Polished forks applicable for use in food and beverage applications
- Reliable, simple, and maintenance free measurement principle
- All wetted parts made from stainless steel
- Robust die-cast housing with IP66 protection

Rosemount 2511 (to the left) and Rosemount 2521 (to the right) Solids Level Switches

Rosemount 2535 Solids Level Switch - Vibrating

- Grain size does not matter
- Not affected by bridging
- Approvals suitable for use in hazardous/explosive and dusty environments
- All wetted parts made from stainless steel
- Good resistance to caking; reliable and maintenance free
- Small process connections
- Robust die-cast housing with IP66 protection

Rosemount 2535 Solids Level Switch - Vibrating Rod

Rosemount 2555 Capacitance probe

- Active Shield Technology protects against media build-up or caking to ensure complete reliability
- Withstand heavy loads and high temperatures
- Approvals suitable for use in hazardous/explosive and dusty environments
- Detects change in product quality and mixture
- Automatic calibration
- Easy to use local operator interface and display
- Continuous self-diagnostic probe
- Electronics housing made of plastic or die-cast aluminum, protection

Rosemount 2555 Solids Level Switch – Capacitance probe

Specification and selection guide for vibrating forks for liquid level measurement[1] KEY ● Available ● Not available		2110	2120	2130	2140	2140: SIS	2160
Certification	Explosion proof certification	○	●	●	●	●	○
	Intrinsically safe	○	●	●	●	●	●
	General area use	●	●	●	●	●	●
	Overfill protection (DIBt/WHG)	●	●	●	●	●	●
	IEC 61508 certified (SIL2)	○	●	●	●	●	○
	Hygienic certification (3A and EHEDG)	●	●	○	○	○	○
Output	Direct load switching (AC or DC)	●	●	●	●	●	●
	8/16 mA output	○	●	●	○	○	○
	DPDT relay output	○	●	●	●	●	○
	DPDT relay output (12V supply)	○	●	●	●	●	○
	PNP for PLCs	●	●	●	○	●	○
	NAMUR Output	○	○	●	○	○	●
	*Wireless*HART	○	○	○	○	○	●
	4-20 mA HART	○	○	○	●	○	●
Configuration	AMS™ Suite / Trex	○	○	○	●	●	●
	FDI Available	○	○	○	●	●	○
	DTM Available[2]	○	○	○	●	●	○
	DD Available	○	○	○	●	●	●
Diagnostics	Basic self-check/ Heartbeat LED	●	●	●	○	○	○
	Advanced and remote health/self-check diagnostics	○	○	○	●	●	●
	Smart diagnostics	○	○	○	●	●	○
Test Function	Functional test	●	●	●	●	●	○
	Remote partial proof-test	○	○	○	●	●	○
Housing	Plastic	○	○	○	○	○	○
	Aluminum	○	●	●	●	●	●
	Stainless steel	●	●	●	●	●	○
Local User Interface	Local display	○	○	○	●	●	●
	Local operator interface	○	○	○	●	●	○
Wetted Material	316L Stainless steel	●	●	●	●	●	●
	ECTFE copolymer, coated 316L SST	○	●	●	●	●	●
	Alloy C (UNS N10002), Alloy C-276 (UNS N10276), Solid	○	●	●	●	●	●

Specification and selection guide for vibrating forks for liquid level measurement[1] KEY 🟢 Available 🔴 Not available		2110	2120	2130	2140	2140: SIS	2160
Process Temperature	-40 to 302 °F (-40 to +150 °C)	🟢	🟢	🟢	🟢	🟢	🟢
	-40 to 356 °F (-40 to +180 °C)	🔴	🔴	🟢	🟢	🟢	🟢
	-94 to 500 °F (-70 to +260 °C)	🔴	🔴	🟢	🟢	🟢	🟢
Process Pressure	1450 psig at 122 °F (100 barg at 50 °C)	🟢	🟢	🟢	🟢	🟢	🟢
IP Rating	IP66/67	🟢	🔴	🔴	🔴	🔴	🔴
	IP66/67 to Type 4X	🔴	🟢	🟢	🟢	🟢	🟢
Electrical Connection	Plug	🟢	🔴	🔴	🔴	🔴	🔴
	Terminal block	🔴	🟢	🟢	🟢	🟢	🟢
	Wireless	🔴	🟢[3]	🟢[3]	🟢[3]	🟢[3]	🟢
Connections	Threaded	🟢	🟢	🟢	🟢	🟢	🟢
	Tri-Clamp	🟢	🟢	🟢	🟢	🟢	🟢
	Flanged	🔴	🟢	🟢	🟢	🟢	🟢
	Extended Lengths Available	🔴	🟢	🟢	🟢	🟢	🟢

Table 3.4.1: Specification and selection guide for vibrating forks

[1] For more information, please refer to the Product Data Sheet.
[2] For configuration in Fieldmate, FieldCare, and PactWare.
[3] When used in conjunction with Rosemount 702 Wireless discrete transmitter.

Specification and selection guide for solid switches[1] KEY ● Available ● Not available	2501	2511	2521	2535	2555
Material Properties					
Granulate/powder	Available	Available	Available	Available	Available
Prone to caking	Available	Not available	Not available	Not available	Available
Abrasive material	Available	Available	Available	Available	Not available
Process Conditions					
Sensitivity (bulk density/ dielectric constant)	≥ 15 g/l	30 g/l or 150 g/l	>5 g/l, 20 g/l, 50 g/l <5 g/l (optional)	≥ 20 g/l	DC value ≥1.5
Process temperature	-40 to 2012 °F -40 to 1100° C	-40 to 302 °F -40 to 150 °C	-40 to 302 °F -40 to 150 °C	-40 to 302 °F -40 to 150 °C	-40 to 932 °F -40 to 500 °C
Process pressure	10 bar	16 bar	16 bar	16 bar	25 bar
High mechanical load	Available	Not available	Not available	Not available	Available
High humidity	Available	Not available	Not available	Not available	Available
High vibration in process	Not available	Not available	Available	Not available	Available
Specification					
Housing (powder coated)	Aluminum IP66	Aluminum IP67	Aluminum IP66	Aluminum IP67	Aluminum IP67
Material of construction	Aluminum or stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel, PPS, or ceramic
Output	Relay	Relay, 3-wire PNP	Relay, 3-wire PNP, Direct load switching, NAMUR	Relay, 3-wire PNP	Relay

Table 3.4.2: Specification and selection guide for solids switches

[1] *For more information, please refer to the Product Data Sheet.*

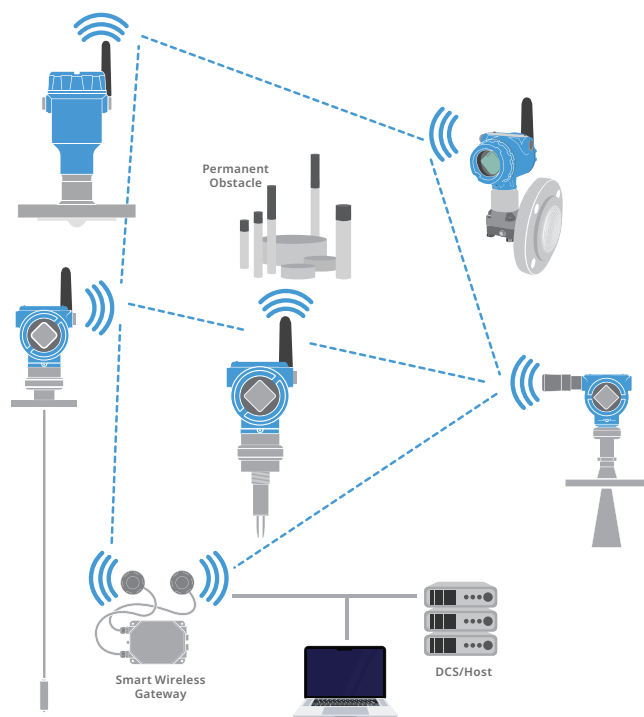## 3.5 Wireless level measurement, detection and control

Figure 3.5.1: Schematic view of a wireless, self-organizing network with process level devices

3.5.1 Introduction

Rosemount offers wireless level solutions for the process industry. Rosemount wireless instrumentation utilizes self-organizing networks to ensure that your measurement information will always be available. Self-organizing networks automatically optimize connectivity to achieve greater than 99% data reliability.

3.5.2 Solar panels and batteries

Level instruments can be powered using a combination of solar panels and batteries as long as this equipment is sized appropriately.

Sizing the batteries is based on the total number of components to be powered, their required voltage and their current consumption.

The solar panel size is based on the battery size requirement and the geographical location of the site. Geographical location is important because the angle of sun on the panel is a factor as well as the average cloud cover in an area. The amount of time a battery needs to provide power without sunlight can be one of the sizing constraints. The solar panel and battery supplier sizes the panels and batteries based on the total power load and on the location of the units.

3.5.3 Rosemount 3408 Wireless Non-Contacting Radar Transmitter

The Rosemount 3408 Wireless Level Transmitter features non-contacting radar level measurement capabilities paired with *Wireless*HART® technology, offering a cost-efficient solution. This wireless transmitter provides reliable and accurate level measurements while eliminating costs associated with cabling. It also offers greater flexibility to add or move measurement points easily, even in remote locations where access is challenging.

- Simple installation and easy integration to any existing host system or architecture with common industry protocols (HART-IP, Modbus, etc.), regardless of the system provider.
- Continuously measures data while adjusting the update rate to match application requirements— ensuring fast monitoring while preserving battery life.
- Minimized maintenance efforts and improved reliability thanks to Signal Quality Metrics, Historian and Smart Echo Supervision capabilities.
- Easy and cost-efficient access to data to make data-driven decisions and efficient inventory management.
- Enhanced safety by increasing process visibility and eliminating manual measurements.
- Reliable data transfer without the risk of losing data.

Rosemount 3408 Wireless Non-Contacting Radar Level Transmitter

3.5.4 Emerson Wireless 775 THUM™ Adapter

The Emerson Wireless 775 THUM adapter is a device that you can retrofit on any existing two or four-wire HART device, and it allows you to wirelessly transmit measurement and diagnostic information that previously was not available. It's an easy way to gain access to the field intelligence already in your plant enabling you to improve quality, safety, availability, operations and maintenance costs.

- Enable alerts and alarms to streamline troubleshooting

- Gain real-time access to advanced diagnostics about the health and performance of the process and equipment

- Move from reactive to proactive maintenance, lowering costs and saving time

- Monitor HART variables to gain insight into process efficiency and condition

- Redundancy through a combination of Wired+Wireless communication

Emerson Wireless 775 THUM Adapter together with Rosemount tank gauging system

The Emerson Wireless 775 THUM Adapter can be used with the following Rosemount level products:

- Rosemount 5300 and 3300 Guided Wave Radar Transmitters

- Rosemount 5408, 3408, 1208, 1408 Non-Contacting Radar Level Transmitters

- Rosemount Tank Gauging System

- Rosemount 3051 series DP Level Transmitters

3.5.5 Rosemount 3051S Wireless Differential Pressure Transmitter

- Industry leading capabilities extended to IEC 62591 (*Wireless*HART).

- Installation-ready integrated wireless level solutions

- Cost effectively implement wireless on the proven SuperModule platform

- Realize a decade of virtually maintenance-free performance

- Optimize safety with the industry's only intrinsically safe power module

- Implement wireless using existing tools and practices

- Ability to monitor more points throughout your facility

at 40-60% cost savings over wired installations.

Rosemount 3051S wireless differential pressure transmitter

3.5.6 Rosemount 2160 Wireless Vibrating Fork Liquid Level Switch

Wireless vibrating fork liquid level switch combines wireless communications with the Rosemount 2100 series vibrating short fork technology. It has all the same features as the wired level switches in the Rosemount 2100 series, but without the complication and cost of wiring.

- Communicates switch output, diagnostics, and alerts – wirelessly

- SmartPower™ - long life power module

- Fork sensor requires low power, battery life approx. 10 years at 60 second update rate

- Long battery life, with fast update rates

- Wireless HART 7

- Configurable to as fast as one second update

Rosemount 2160 wireless vibrating fork switch

3.5.7 Rosemount 702 Wireless Discrete Transmitter

The Rosemount 702 Wireless Discrete Transmitter takes a variety of non-powered switch types such as pressure, flow and level switches as input. It has single or dual channel capacity which cost-effectively enables access to discrete points that are not connected to the control system due to wiring costs and lack of I/O.

- Simple and effective, retrofit to existing switches on plant

3.5.8 Rosemount 3308 Wireless Guided Wave Radar Level Transmitter

The world's first true wireless guided wave radar extends industry leading guided wave radar capabilities to wireless communications. Developed to meet the need for accurate, reliable level and interface monitoring in remote locations, the Rosemount 3308 combines fast and simple commissioning with robust measurement data.

- Coated or corroded probe detection probe detection with Signal Quality Metrics

- Nine year battery life at one minute update rate

- No wires, no moving parts, no re-calibration

- Advanced process and device health diagnostics with proactive alerts

- Direct switch technology provides high signal strength for reliable measurements

Rosemount 3308 wireless guided wave radar transmitter

3.6 Magnetic Level Measurement Technology

Rosemount 9930 Magnetic Level Indicator

The Rosemount 9930 Magnetic Level Indicator is a low-maintenance alternative to sight glasses and other level indicators. It provides non-invasive level indication while reducing leak points and fugitive emissions. The indicator gives you an easy to see level indication that is visible up to 100 ft (30 m) away. It is ideal for your high-temperature, high-pressure and corrosive applications where you want visual indication of both level and interface. When combined with Emerson's externally mounted level transmitters and switches, the Rosemount 9930 provides you with a complete, redundant and cost-effective level solution.

- Minimal leak points as compared to sight glasses

- No process liquid in contact with indicator glass

- Designed for both gas/liquid and liquid/liquid interface measurements

- Measure both interface and top level with one indicator

- Visual level indication to 100 ft. (30 m)

- Designed for both gas/liquid (top level) and/or liquid/liquid (interface) measurements

- Optional construction is available for cryogenic, high-temperature, high-pressure, and corrosive applications

- Dual chamber design optimized for use with the Rosemount 5300, 3308, and 3300 Guided Wave Radars also available

Rosemount 9930 Magnetic Level Indicator

3.7. Level Accessories

Rosemount 9935 Level Bypass Chamber

The Rosemount 9935 Level Bypass Chamber is an expertly engineered chamber optimized for externally mounting Rosemount process level instruments to a vessel, offering an enhanced complete level solution. Rosemount 9935 chambers are the result of more than 35 years of experience in designing and manufacturing chambers, also known as bridles or bypass chambers, in accordance with international codes. The Rosemount 9935 is a self-contained chamber for externally mounting a range of Rosemount process level instruments to a vessel. It is also useful for in-tank restrictions that do not allow mounting of the instrument in a vessel.

- Allows external mounting of process level instrumentation, which enables isolation of the process for live maintenance

- Optimized for use with the Rosemount Guided Wave Radar, Non-Contacting Radar, and Vertical Level Switches

- Rated for pressures up to ASME B16.5 Class 2500

- Designed to ASME B31.3 Process Piping Code. ASME B31.1 Power Piping Code is available upon request

- Used worldwide by major industries: Power, Petro-Chemical, Refining, Oil & gas, Chemical, and Process Steam Raising sectors. Ideal for critical areas and general purpose applications

- Custom design service available

- Two designs available: Standard and T-Piece design

- Industry-preferred weld neck flanges used throughout. All weld are full penetration to increase integrity and reduce crevice corrosion

Rosemount 9935 Level Bypass Chamber

Rosemount 3490 Controller for Level and Flow Measurement

The Rosemount 3490 Series provide comprehensive control functionality for 4–20 mA or HART compatible transmitters, such as the Rosemount 1208 Level and Flow Transmitter.

- Support for up to two 4-20mA or HART compatible transmitters.

- Intuitive wizards enable simple and fast programming

- Uses level and flow measurement to control pumps, totalize flows, monitor tanks and calculate differentials.

- Pre-configured tank volume calculations for different tank shapes, and flow curves for most common weirs and flumes

- Datalogging up to 200k events

- User-centric interface on a brightly lit and colored display

- Ethernet port for host system communication via Modbus TCP/IP

- A webserver for easy downloading of data logs and upgrading of software

- Up to 6 relays for controlling pumps and/or alarms

- Accessories available for different types of field mounting needs

Rosemount 3490 Controller

3.8. Rosemount Tank Gauging Systems

The Rosemount Tank Gauging System delivers the best-in-class bulk liquid measurements with the highest level of precision and accuracy, providing reliable inventory insights for refineries, tank farms, and fuel depots.

The System measures and calculates tank data for:

- Custody transfer

- Inventory management

- Oil movement

- Mass balance and loss estimation/control

- Operational and blending control

- Leak detection and overfill prevention

The Rosemount Tank Gauging System can include a wide range of products as visualized in the system overview below. The key products of the tank gauging system are: the Rosemount 5900S, 2240S, 2410, 2460 and TankMaster.

The tank gauging system may also include the Rosemount 5300 and 5408 described in 3.1 and 3.2. For a full description of the different items, please visit Emerson.com/Rosemount-TankGauging or refer to the book: "The Engineer's Guide to Tank Gauging" for more information on Tank Gauging solutions.

The system can be configured to provide the following tank data and functions:

- Level, level rate, temperature, and water interface level measurement

- Multiple temperature inputs for average calculations

- Relay or analog outputs for SIL 2/SIL 3 high level alarms and customized functions

- Vapor pressure and hydrostatic pressure measurement
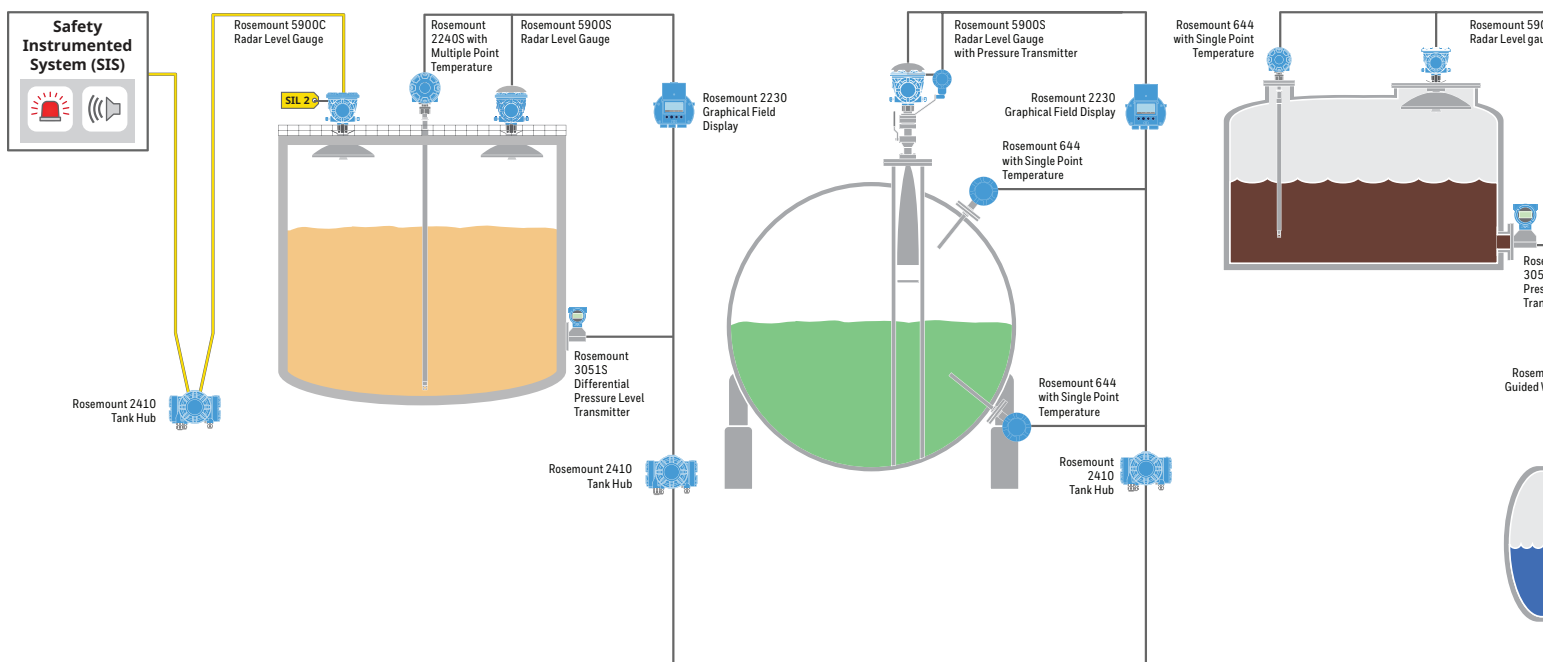
Figure 3.8.1. Rosemount Tank Gauging System Overview

- Total Observed Volume (TOV), and observed density calculations in the Rosemount 2410 Tank Hub

- Net volume calculations according to API (with the TankMaster™ software package or 2460 System Hub)

- Complete inventory, hybrid and custody transfer functions (with the TankMaster software package)

3.8.1 Rosemount 5900S Radar Level Gauge

Rosemount 5900S is a premium non-contact radar level gauge with custody transfer accuracy, suitable for any application in refineries and tank terminals with high requirements on level measurements.

Its FMCW measurement method provides the highest accuracy, remaining unaffected by most of variations in liquid properties, including density.

There are four main types of Rosemount 5900S gauges suitable for various storage tanks:

- Rosemount 5900S with parabolic antenna, for general use in tanks without still-pipe. Can also be used in a demanding tank environment, to measure on asphalt etc.

- Rosemount 5900S with horn antenna, for fixed roof installation without still-pipe

- Rosemount 5900S with still-pipe array antenna, for measurement in existing still-pipes

- Rosemount 5900S with LPG/LNG antenna, for liquefied gas, such as LPG and LNG

Rosemount 5900S Non-Contacting Radar Level Transmitter with parabolic antenna (left) and still-pipe antenna (right).

Key features of the Rosemount 5900S Radar Level Gauge:
- Highest instrument accuracy of 0,5 mm with custody transfer approvals, including the OIML R85:2008 certificate

- SIL 2 and SIL 3 certified by Exida according to IEC 61508-2 and 61508-3

- 2-wire low voltage tankbus for cost efficient and safe installation

- Redundant level device (2-in-1 gauge)

- Can be equipped with antennas for any type of storage tank design
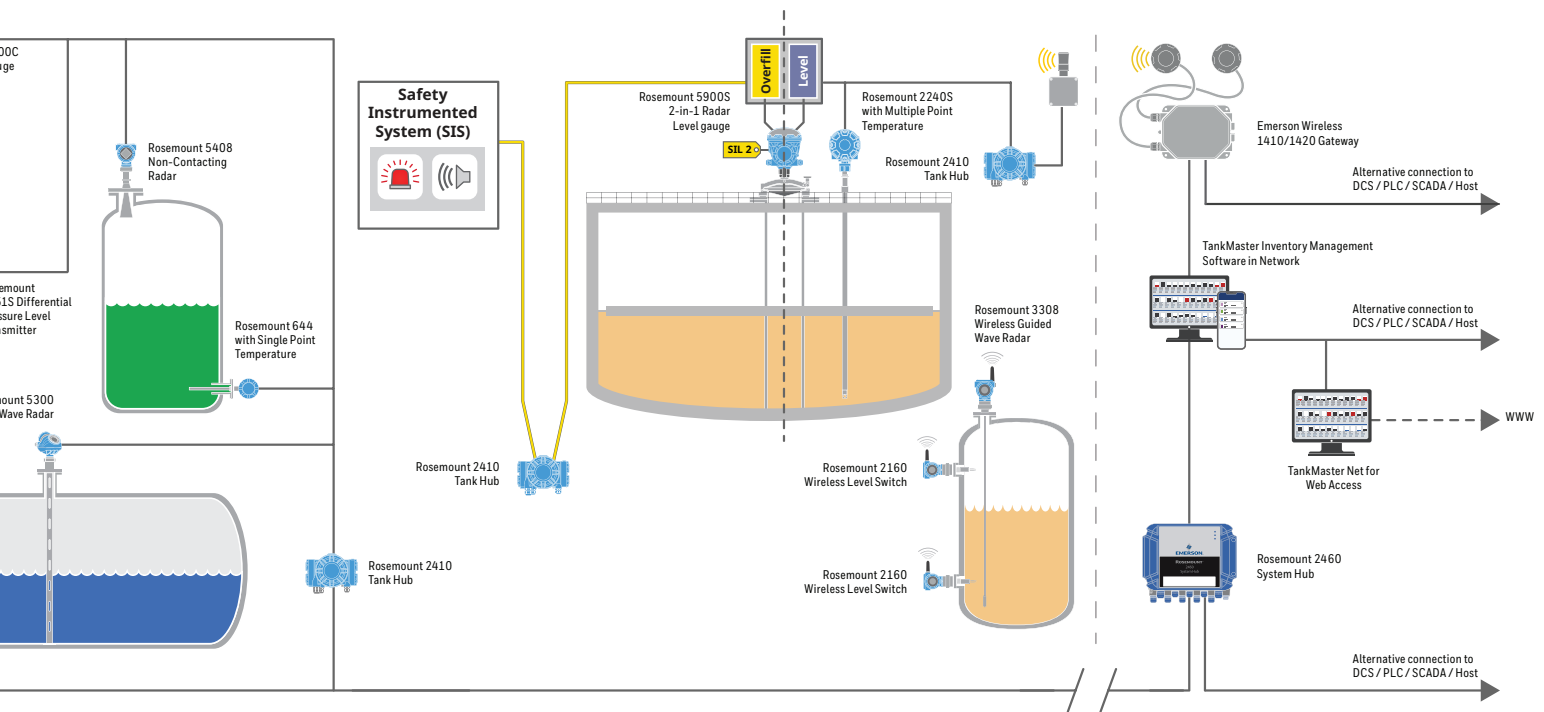
3.8.2 Rosemount 5900C Radar Gauge

The Rosemount 5900C is similar to the 5900S, except it is specifically tailored for applications requiring high accuracy without customer transfer certification. It supports SIL 2 certification for overfill prevention purposes.

3.8.3 Rosemount 2240S Multi-input Temperature Transmitter

The high performance Rosemount 2240S Multi-input Temperature Transmitter is approved for demanding custody transfer applications, which require very accurate level and temperature measurements for net standard volume calculations.

Key features of the Rosemount 2240S temperature transmitter:

- High performance temperature conversion accuracy

- Connection of up to 16 3-wire or 4-wire temperature spot elements

- Two-wire low voltage tankbus for cost efficient and safe installation

- Built-in on-line calibration feature for water level sensor

Rosemount 2240 (to the left), Rosemount 565 (in the middle) and Rosemount 765 (to the right)

Available temperature sensors include:

- Rosemount 565 multiple spot temperature sensor - standard temperature range sensor for atmospheric tanks or for use in thermowell if installed in pressurized tank

- Rosemount 566 temperature sensor - for cryogenic applications

- Rosemount 765 water level sensor integrated with multi spot temperature sensor

3.8.4 Rosemount 2410 Tank Hub

Rosemount 2410 is handling the communication between the field devices and the control room, and it is available in three versions, for single or multiple tanks and a SIS version. It also feeds power to the units on the tankbus.

Rosemount 2410 Tank Hub

Key features of the Rosemount 2410 Tank Hub:

- FISCO compliant intrinsically safe communication bus for the field devices on the tank
- Auto-configuration of tank field devices
- Data collection of measurement values, such as level, temperature, and pressure
- Calculation of average temperature, observed density, and strapping table based volume
- Control room connectivity, through various fieldbus protocols, including WirelessHART output
- SIL2/SIL3 relay and analog output for overfill functionality
- Non-SIL solid state relay output for alarm indication or process control functionality
- Full emulation capability for cost-effective installation in systems supplied by other vendors

3.8.5 Rosemount 2460 System Hub

The Rosemount 2460 System Hub is a data concentrator that continuously polls and stores data from field devices such as radar level gauges, pressure and temperature devices. Measured and calculated data from one or more tanks is communicated via the Rosemount 2410 Tank Hub to the system hub buffer memory. Whenever a request is received, the system hub can immediately send data from a group of tanks to a TankMaster PC or a host. The system hub also supports connection of other tank gauging instruments such as TankRadar™ Pro and TankRadar Rex gauges. In addition, it can be used to connect devices from other vendors, such as Honeywell® Enraf, Whessoe, etc.

Rosemount 2460 System Hub

Key features of the Rosemount 2460 System Hub:
Ensure fast data update rate

- Serves up to 64 tanks
- Benefit from scalable options for all system sizes
- Get real-time inventory calculations with API standard net volumes
- Flexible and configurable multiple port connectivity
- Achieve instrument and system redundancy
- Enable other vendor emulation by bringing in data from Enraf®, GPE, Whessoe, L&J, Varec®, or Modbus compatible gauges

3.8.6 TankMaster

The powerful and easy to use TankMaster software package provides complete tank inventory management solution giving instant insights into tank farm status. It includes functions for custody transfer and inventory control, as well as set-up, configuration and service. All calculations are based on all available API and ISO standards.

The TankMaster software both provide an overview and focus on detail: Total Observed Volume, Gross Observed Volume, Gross Standard Volume, and Net Standard Volume. By adding pressure transmitters, you can also keep track of hydrostatic and vapor pressure, density, and mass. TankMaster presents all these parameters on-line, and with TankMaster Mobile you can offer remote access via the web interface – to others in your own organization or to clients and partners. TankMaster is easily integrated with most host systems on the market, such as DeltaV, Yokogawa, ABB etc.

Key features of the TankMaster inventory management software:

- Real-time calculations based on API and ISO for complete tank farm monitoring
- Interactive configuration and installation of system transmitters
- Reporting via emails, tests or pdf files
- Reliable alarm handling of measured values and alarm reporting via email, or to mobile phones

- Historical data sampling and audit logs for events

- Inventory and Custody transfer functions, such as real-time view of measured data. Metrologically sealed data

- Interoperability with legacy host systems, through OPC and Modbus communication

- Easy-to-use, guided proof test of SIS tank gauges

- Floating roof monitoring module to keep track of floating roof tank status

3.8.7. TankMaster Mobile

Rosemount TankMaster Mobile delivers real-time inventory insights and immediate access to critical tank details like level, volume, temperature, and rate of change. Its design ensures seamless functionality across smartphones, tablets, and computers. With easy data sharing both internally and externally, it empowers teams and partners with the precise information they need, anytime, anywhere

Key features of the TankMaster Mobile inventory management software:

- Works seamlessly on computers, smartphones, and tablets

- User-friendly interface gives immediate overview of inventory data with one click to details for each tank

- Work efficiently by using tank groups - custom, predefined, and automatic

- Compliant with international cybersecurity standard IEC 62443-3-3

- Supports 3-tier network architecture with firewalls to protect from unauthorized access

- Encrypted and safe communication protects data confidentiality

- Access to specific tanks, data points etc. can be controlled for each user

TankMaster Mobile on computers, smartphones and tablets

3.9 Tank monitoring system

The Rosemount Tank Monitoring System offers a cost effective and flexible automation solution for smaller tank farms, providing basic inventory insights through Rosemount TankMaster™ WinView software. By combining the Rosemount 2410 Tank Hub, 5300 Guided Wave Radar, and 5408 Non-Contacting Radar, the system enables reliable overfill prevention and efficient inventory management. Simplified cabling and optional wireless integration with the Emerson Wireless 775 THUM™ Adapter and Rosemount Wireless Gateway further reduce infrastructure complexity, streamlining installation and increasing operational flexibility.
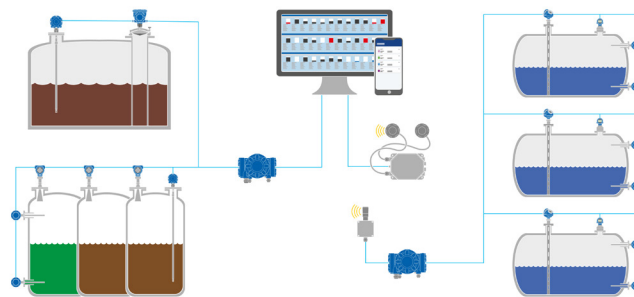
Figure 3.9.1: Tank monitoring system

3.9.1 Rosemount 5300 and Rosemount 5408

By using continuous measurement devices, the process can be controlled from start to finish.

Both products have extensive ranges of functions that enable efficient, reliable and safe operations, even in challenging applications. More information about the products can be found in chapter 3.

3.9.2 Rosemount 2410 Tank Hub

The Rosemount 2410 Tank Hub communicates with and powers the transmitters on the tanks via the Tankbus and complies with FISCO (Field bus Intrinsically Safe Concept) Foundation Fieldbus. The hub manages communication and supervises the status of all connected transmitters. It also offers extensive built-in diagnostics and provides intrinsically safe power to tank devices.

Rosemount 2410 Tank Hub can deliver up to 250mA. It is recommended that a maximum five Rosemount 5300 or maximum ten Rosemount 5408 are connected to ensure safe operations and that startup power is always high. A segment coupler may be used to connect even more transmitters.

More about the Rosemount 2410 Tank Hub can be read in chapter 3.

3.9.3 Rosemount 2460 System Hub

The Rosemount 2460 System Hub is a data concentrator that continuously polls and stores data from field devices such as radar level gauges, pressure and temperature devices. Measured and calculated data from one or more tanks is communicated via the Rosemount 2410 Tank Hub to the system hub buffer memory. Whenever a request is received, the system hub can immediately send data from a group of tanks to a TankMaster PC or a host.

The system hub supports Modbus TCP for connection to host systems. By simply connecting the system hub to the existing LAN network, communication over Ethernet is established: Easy access – special converters are not required, Fast communication, No need for dedicated cabling.

The system hub also supports connection of other tank gauging instruments such as TankRadar™ Pro and TankRadar Rex gauges. In addition, it can be used to connect devices from other vendors, such as Honeywell® Enraf, Whessoe, TIC, Sakura etc.

3.9.4 Rosemount TankMaster WinView

Rosemount TankMaster WinView is a software package with basic inventory capabilities. It is a cost efficient alternative for operational control at smaller tank terminals, marketing terminals, biofuels and chemical plants, etc. Configuration is made with WinSetup, which is included in the delivery.

WinView offers:

*   Alarms
*   Host communication, Modbus and OPC
*   Reports

3.10 Marine Cargo Monitoring System and Marine Fuel Monitoring System

The Rosemount™ Cargo Monitoring System and Fuel Monitoring System are established system solutions for harsh marine applications. The products can be configured in various combinations to suit a wide range of applications, from a small service fuel tank to advanced custody transfer measurement functions on LNG carriers. The core system consists of a processing unit installed in the safe area, along with an Ex is certified tank hub mounted on deck. This hub collects data from various vital instruments on the tank side and transmits the information digitally to the control room.

The system measures and processes tank data for:

*   Custody transfer measurement
*   Cargo monitoring
*   Fuel measurement
*   High level and overfill
*   Miscellaneous marine tanks
*   Draft level measurement
*   Density measurement

The essential products of a marine tank monitoring system for level measurements include the Rosemount Tank Gauging Unit 68, Rosemount Tank Gauging Unit 65, and Rosemount Tank Gauging Unit 53; for temperature measurement, the Rosemount TMU 51 and Rosemount TMU 53; and for pressure measurement, the Rosemount Vapor Pressure Sensor 53 and Rosemount Vapor Pressure Sensor 58. These are complemented by the supply and communication units Rosemount SCU 5110, Rosemount SCU 5113, and Rosemount SCU 6114.

Other Rosemount products and third-party equipment can be utilized through the input and output unit IOU 61. The system can be configured to provide the following tank data and functions:

*   Level gauging
*   Level gauging, Dual measurement (2 in 1)
*   Level gauging and High-level alarm
*   Level gauging and Overfill alarm
*   High level alarm
*   Overfill alarm
*   High level and Overfill alarm
*   Density (LNG)
*   Density and level gauging (LNG)
*   Custom engineered solutions
*   Calibrated in accordance with the definitions stated by Bureau of Weights and Measures (BIPM) and maintained by National Laboratories in member countries
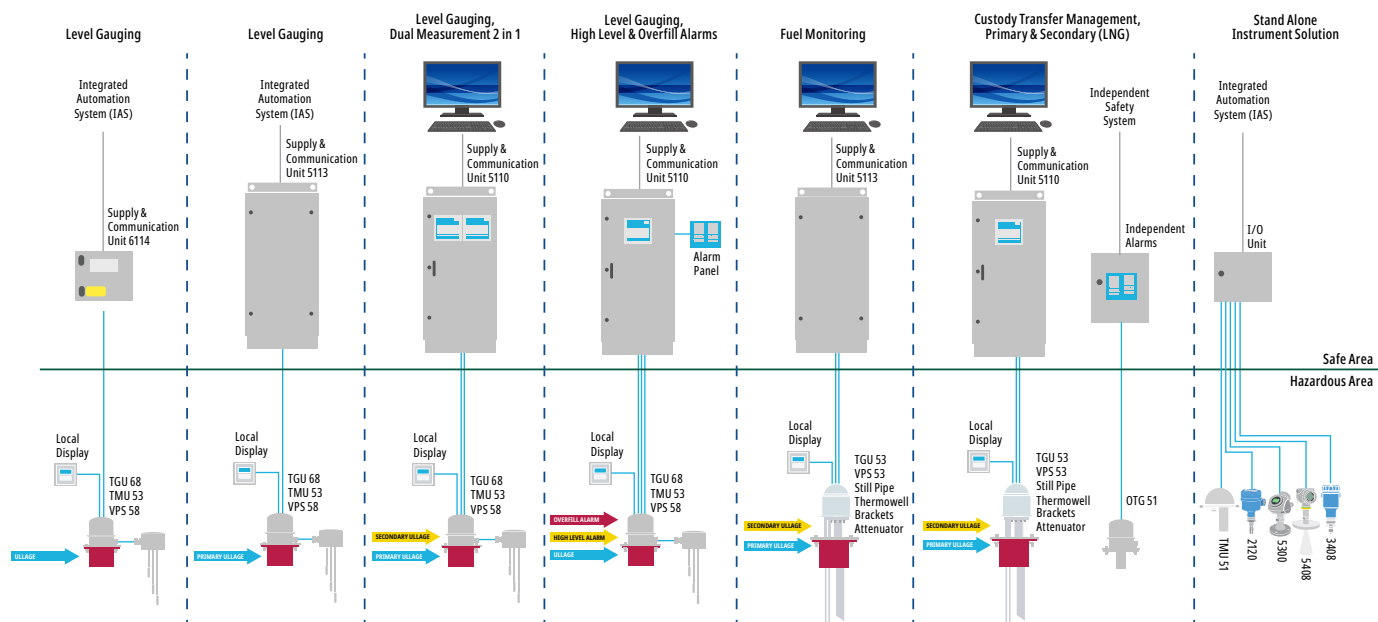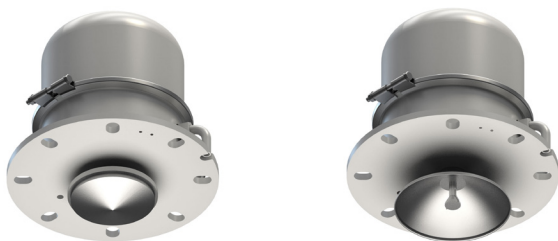
Figure 3.10. Schematic system overview

3.10.1 Rosemount Tank Gauging Unit 65 and Rosemount Tank Gauging Unit 68 Tank Radar Gauges

The Rosemount Tank Gauging Unit 65 and Rosemount Tank Gauging Unit 68 Tank Radar Gauges can be configured with parabolic or still-pipe antennas, allowing them to be tailored for various applications. The integrated hub with level and pressure measurement handles the communication between the deck devices and the cargo and engine control room. The units can be used for cargo monitoring on tankers, offshore structures and large alternative fuel tanks. The FMCW measurement method provides reliability and is unaffected by most liquid property changes, such as density etc.

Rosemount Tank Gauging Unit 65 (to the left) and Rosemount Tank Gauging Unit 68

Key features

- 26 GHz FMCW tank radar gauge, with advanced signal processing, high bandwidth and optimized parabolic antenna
- 10 GHz FMCW tank radar gauge, with still pipe antenna and low-loss mode to withstand build up and deposits inside the pipe

- Accurate and reliable measurement that keeps you operating under adverse conditions in tank
- For marine installations up to 115 feet (35m)
- Robust, withstands harsh conditions on deck
- Easy to install, light weight and narrow beam
- All electronics can be exchanged from the deck without opening the tank to atmosphere
- Optional integrated vapor pressure sensor with optional test valve
- Optional level redundancy measurements
- Optional independent high level and overfill alarm measurements

3.10.2 Rosemount Tank Gauging Unit 53 Tank Radar Gauge

The Rosemount Tank Gauging Unit 53 Tank Radar Gauge is a marine tank hub that incorporates devices for measurement of level, temperature and pressure in the same tailor-made and compact housing which allows for smooth installation with a minimized footprint and only one still pipe antenna. The radar is designed for LNG-, as well as LPG and Ammonia applications with defined tank properties. The unit is equipped with a cone antenna and measures the level of the liquefied gas by use of a still pipe, acting as an extension of the cone antenna. The signals are digitally processed to achieve an accurate reading of the distance to the surface.

By using patented technology, two radar measurements can be done separately and independently from each other in the one and same gauge.

The complete still pipe assembly consists of a gauge socket, joined still pipe segments with equalizing holes and a pin intended for continues verification of the level measurements. Vented thermowells run alongside the radar still pipe in which the temperature sensors are inserted. Brackets for securing the still pipe and the thermowells to the pump tower structure are used in accordance with the appropriate tank engineering practice and are included in the overall scope. The array attenuator is a patented device located below the still pipe for attenuation of the microwave reflection from the tank bottom. This one-of-a-kind solution ensures proper level measurement even with very low liquid levels in the tank.

Rosemount Tank Gauging Unit 53 Tank Radar Gauge

Key features

- Dual channel measurement with one Tank Radar Gauge and one still pipe utilizing two independent radars

- Handles cryogenic applications

- Intrinsically safe

- All electronics can be exchanged from the deck without opening the tank to atmosphere

- FMCW radar technology.

- Integrated part of the Rosemount Custody Transfer System.

- All electronics outside of the tank, integrated under one with no additional cabinets on deck.

- Dual Channel measurement with one Tank Guage Unit and one still pipe, enabling primary and secondary CTMS with less hardware.

- Dual self-adjusting function ensures that the system continuously compensates for altered gas conditions

- Patented array attenuator enables measurement close to tank bottom

- Factory Acceptance Tested using Moveable Echo to simulate any liquid level in tank

3.10.3 Rosemount OTG 51 Overfill Alarm Tank Gauge

The Rosemount OTG 51 Tank Radar Gauge for liquified gas applications is a high level and overfill alarm gauge used in independent safety applications. Alarm limits are configured by software settings which allow for easy adaptation to new requirements. A continuous self-checking function ensures correct operation.

The complete assembly consists of the OTG 51 and a still pipe segment with ventilation hole. The still pipe is supported by brackets to an internal structure, such as pipe tower platforms, or alternatively with finger springs in a protective pipe.

Rosemount OTG 51 Overfill Alarm Tank Gauge

Key features

- Dual channel measurement with one Tank Radar Gauge and one still pipe utilizing two independent radars

- No moving mechanical parts inside of the tank that can break

- Correct indication and communications verified by self-checking system

- Safe operations provided by electrical separation of the high level and overfill alarm and the level/ullage gauging system.

- Automated self-testing function eliminates the need for mechanical test arrangement before use.

3.10.4 Rosemount MIF 61 Multi-Instrument Flange

The Rosemount MIF-61 Multi Instrument Flange is an all-in-one solution enabling straightforward installation of multiple instruments sharing one common tank penetration. With a compact flange and process connection, it's designed to minimize the footprint on the tank while providing the means for complying with the IGF Code.

Rosemount MIF-61 Multi-Instrument Flange

Specification
The MIF-61 is customizable and has the ability to be configured with a range of instruments to meet the need of any application.

- The Rosemount 5408 Non Contacting Radar Level Transmitter, optimized for reliable and accurate performance.

- The Rosemount 5408 has up to 30 times increased radar output strength compared to a traditional two-wire non-contacting radar.

- The Rosemount 5408 is immune to immediate power loss.

- Rosemount 2051T In-Line Pressure Transmitter is selectable as either absolute or as gauge type.

- The Rosemount 2151T provides reliable vapor and space measurement.

- The Rosemount 0306 In-Line Manifold comes with a Block-and-Bleed 2-valve providing instrument isolation, drainage and venting capabilities.

Key Features
- The Rosemount MIF-61 utilizes the same configuration tool for all instruments to streamline the commissioning process.

- Up to two level radar transmitters, two pressure transmitters with integrated manifolds, and up to six temperature transmitters with sensors.

- Supervision function to constantly search for surface level in the overfill prevention zone.

- FMCW based radar instrument.

3.10.5 Rosemount TMU 51 Temperature Measuring Unit

The Rosemount TMU 51 Temperature Measuring Unit enables temperature measurements of the liquid and vapor inside the tanks. The mechanical outline makes it a suitable choice for deck installations

The sensor is based on a Pt100 element with a three-wire connection, or alternatively a four-wire connection.

The unit communicates with the Rosemount TGU Tank Radar Gauge through a sensor bus, which in turn transmits the processed data to the Rosemount SCU Supply and Communication Unit

It is also possible to configure it with 4-20mA analog output.

Rosemount TMU 51 Temperature Measuring Unit

Key Features
- Robust stainless-steel design for installation on deck

- Intrinsically safe temperature transmitter

- Enables temperature measurements of the cargo and vapor inside the tanks

- Suited for up to six spot temperature sensors

- Optional 4-20mA output

3.10.6 Rosemount TMU 53 Temperature Measuring Unit

The TMU 53 Temperature Measuring Unit enables temperature measurements of the liquid and vapor inside the tanks. The mechanical outline makes it a suitable choice for installations on pumps.

Up to three temperature sensors, distributed over the tank height, can be connected to the unit. The sensor is based on a Pt100 element with a three-wire connection

The unit communicates with the Rosemount TGU Tank Radar Gauge through a sensor bus, which in turn transmits the processed data to the Rosemount SCU Supply and Communication Unit

Rosemount TMU 53 Temperature Measuring Unit

Key Features

- Robust stainless-steel design for installation on deck flange

- Intrinsically safe temperature transmitters enable temperature measurements of the cargo and vapor inside the tanks

- Suited for up to three spot temperature sensors

3.10.7 Rosemount 53 and Rosemount 58 Vapor Pressure Sensors

The vapor pressure sensors are installed as an integrated part of Rosemount Tank Gauging Unit 65, 68 and 53, Tank Radar Gauges. The intrinsically safe sensor is installed to measure the vapor pressure. It provides the gauge pressure inside cargo and fuel tanks and absolute pressure inside the liquefied gas tanks.

The signals from the sensor are processed by the tank gauge electronics inside the tank gauge units and transmitted to the Supply and Communication Unit over the same interface as the radar and temperature signals.

Rosemount 53 and Rosemount 58 Vapor Pressure Sensors

Key Features

- Stable and enhanced robust design to fit marine use

- Meets the SOLAS secondary means requirement

3.10.8 Rosemount Supply and Communication Units

The Rosemount Supply and Communication Unit serves as the central hub for connecting Rosemount Tank Gauge Units. This self-contained unit is designed to facilitate intrinsically safe connections for the transmitters included in the radar-based cargo and fuel monitoring systems.

The Rosemount Supply and Communication Unit is available as three standard hubs so the user can customize their system to fit their needs.

Rosemount Supply and Communication Units

3.10.8.1 Rosemount 6114 Supply and Communication Unit

The Rosemount SCU 6114 Supply and Communications Unit serves as the centralized hub for connecting deck devices for the Rosemount CMS and other marine tank monitoring applications. It collects information from the Tank Gauge Units, including data from the level, pressure and temperature transmitters. Each individual cabinet can accommodate up to 17 tank connections. The cabinet is installed indoors in a ventilated and non-hazardous location.

Rosemount 6114 Supply and Communication Unit

Key Features

- Intrinsically safe power to the tank gauge units

- Transmission of data to clients through optional serial or Ethernet link

- Supplies intrinsically safe power to the tank gauge units

- Compact design suited for installations with limited availability of space

- Enabled for connection of up to 17 tank gauge units, including level, pressure and temperature transmitters

- Appropriate choice when prioritizing aspects other than upgradeability

- Utilizes a digital communication architecture to ensure highest possible system accuracy

3.10.8.2 Rosemount 5113 Supply and Communication Unit

The Rosemount SCU 5113 Supply and Communications Unit serves as the centralized hub for connecting deck devices for the Rosemount CMS and other marine tank monitoring applications. It collects information from the tank gauge units, including data from the level, pressure and temperature transmitters. Each individual cabinet can accommodate up to 34 tank connections or 2x17 channels for independent measurement for 2-in-1 enabled tank gauge units. The cabinet is installed indoors in a ventilated and non-hazardous location.

The Rosemount SCU 5113 is designed to allow additive features and functionalities to be included at a later stage, without having to consider replacement of the entire cabinet.

Rosemount 5113 Supply and Communication Unit

Key Features

- Intrinsically safe power to the tank gauge units
- Transmission of data to clients through optional serial or Ethernet link
- Enabled for connection of up to 34 tank gauge units, including level, pressure and temperature transmitters
- A single cabinet accommodating both primary and secondary level functionality
- Utilizes a digital communication architecture to ensure highest possible system accuracy

3.10.8.3 Rosemount 5110 Supply and Communication Unit

The Rosemount SCU 5110 Supply and Communications Unit serves as the centralized hub for connecting deck devices for Rosemount CMS, Rosemount CTMS and other marine tank monitoring applications. It processes all information from the tank gauge units, including data from the level, pressure and temperature transmitters.

The touch screen display, equipped with a built-in monitoring and service agent, enables monitoring of tank data and the execution of service tasks. Each individual cabinet can accommodate up to 34 tank connections, and

multiple cabinets can be interconnected, expanding the system's capabilities. The cabinet is installed indoors in a ventilated and nonhazardous location.

Rosemount 5110 Supply and Communication Unit

Key Features

- Supplies intrinsically safe power to the tank gauge units
- Enabled for connection of up to 34 tank gauge units, including level, pressure and temperature transmitters
- Utilizes a digital communication architecture to ensure highest possible system accuracy
- Designed to facilitate integration of mutually independent high-level and overfill functionality
- Provides redundant measurements to support primary and secondary level gauging in the gas carrier segment
- The integrated 6.5" service agent, along with embedded diagnostics for the connected devices, ensures exceptional system availability
- Replacement of connected transmitters facilitated through an intuitive service tool, minimizing downtime
- Stored configuration data for the tank gauge units
- Configurable relay outputs for system failure and selectable alarm indications
- Independent high level and overfill alarm system capabilities
- A single cabinet accommodating both primary and secondary level functionality
- Dual set of embedded system hubs designed for seamless redundancy to enhance system availability
- Uninterrupted power supply providing backup power in case of a power outage or disruption
- Access all tank data, including innage, ullage, vapor pressure, spot temperatures, and average temperatures (liquid and vapor). This serves as a backup in case workstations are unavailable
- View diagnostics for connected devices

- Perform service actions, such as reboot and plug-and-play replacement of devices, where the device configuration is automatically inherited from stored data

- Conduct radar-based scans of the tanks to optimize radar device configuration, especially in the presence of structures inside the tank

- Initiate data logging to monitor trends, potential misbehaviors and facilitate troubleshooting

- Conduct zero trim adjustment of the vapor pressure sensors

3.10.9 Rosemount 61 Input Output Unit

Rosemount 61 Input and Output Unit is the connection point for miscellaneous instrumentation and the point where the user gets access to analog and digital I/O modules. The modules can accommodate a selectable number of inputs and outputs. This provides a high degree of flexibility, and therefore ensures that the interior of the cabinets can be built fit-for-purpose

It can be configured with a cabinet or on a mounting plate and comes in 2 different sizes. The medium size cabinet holds 1-4 modules, and the large cabinet holds 1-20 modules and up to dual channel isolators. Each analog in- and output and digital output modules holds 4 channels each and the digital input unit holds 8 channels.

The cabinets are designed to manage signals both from safe and hazardous areas. The instrumentation routed from hazardous areas is supplemented with isolating barriers, to allow intrinsically safe loops if required.

Rosemount 61 Input Output Unit

Key Features

- Compact I/O design enables efficient installation with plug and play functionality

- Available as either complete enclosures or as mounting plates

- Provides the user with a selectable number of analog and digital inputs and outputs

- Easily expandable, making it easy to adapt and extend functionality

- Enabled for Ex barriers and other general electronic equipment

- For use indoors, in non-hazardous environment

3.10.10 Rosemount WSU 52 Workstation Unit

The marine system solutions can be configured with operator interface from Emerson or be connected to third party operator systems.

Figure 3.10.1 Rosemount WSU 52 Workstation Unit

3

CHAPTER 4
LIQUID LEVEL APPLICATIONS & TECHNOLOGY SELECTION

Topic   **Page**

4 Liquid Level Applications & Technology Selection

4 Liquid Level Applications & Technology Selection

Understanding the different needs a user has makes the selection between a point/continuous level measurement and a tank gauging system easier.

This chapter lists a number of different applications, gives recommendations on suitable technologies, and will provide key installation information and best practices. Since it is not practical to cover all possible applications, the applications chosen for this chapter are intended to give a broad overview of some very common types of applications that are found in many industries, as well as a few applications that may have specific challenges. It will also provide examples of where the various technologies are used. However, the final decision of the technology choice will include the application conditions, the installation constraints, and the capabilities of the technology.

4.1   Storage Tanks

Storage or intake tanks are used to receive and store materials and feed them into a plant. They are utilized at various stages of the process across different industries; to store raw materials, keep finished products, deliver products to supply tanks, and more. And they can store a wide variety of materials across different industries, such as chemicals, petroleum products, food and beverage materials or gases.

Continuous and point level detection are essential in storage tanks to monitor inventory. With level measurement technology, plants can track accurately the amount of material stored in storage tanks, prevent overfills and underfills, ensure product consistency, optimize tank usage and minimize waste, and increase plant, personnel and environment safety.

4.1.1 Slop oil tanks

Primary function of application
Vessels used for waste recovery of hydrocarbons fluids. These vessels are used to collect oil and water from the process to separate hydrocarbon from water. Water is sent to wastewater plant and oil can often be reused as feedstock or product in plant.
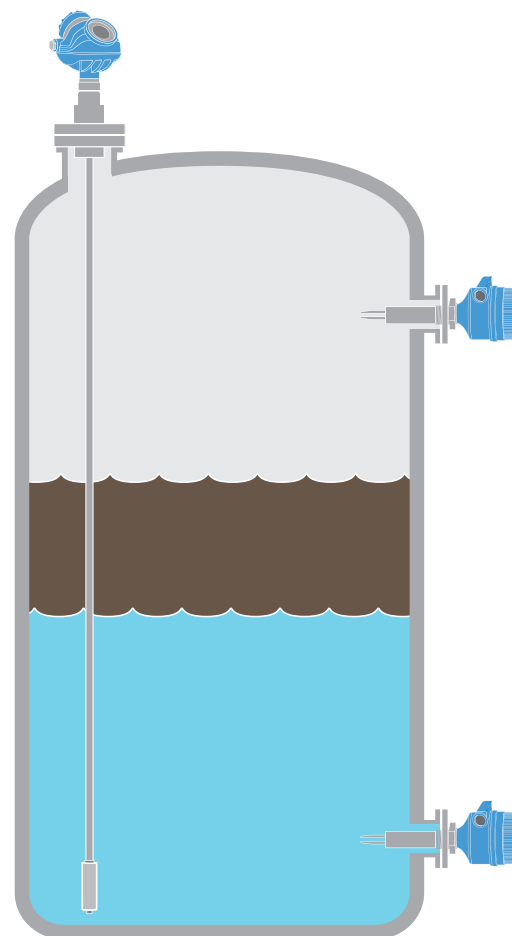
Figure 4.1.1: Slop oil tank with level measurement technology

Application characteristics and challenges
- Slop oil vessels contain a mixture of dirty hydrocarbons and water.
- Deposits and sticky materials are likely to be present.
- Density and other fluid properties can vary.

Suitable Technologies	
Technology	Installation Guidelines
Guided Wave Radar, with single lead probe	Chapter 6
Non-Contacting Radar	Chapter 7
Vibrating Fork Switch	Chapter 10
Differential Pressure Level	Chapter 9

4

4.1.2 Plastic and fiberglass tanks

Primary function of application

Plastic tanks are typically used for storage of corrosive chemicals. They often do not have openings at the top for instrumentation.
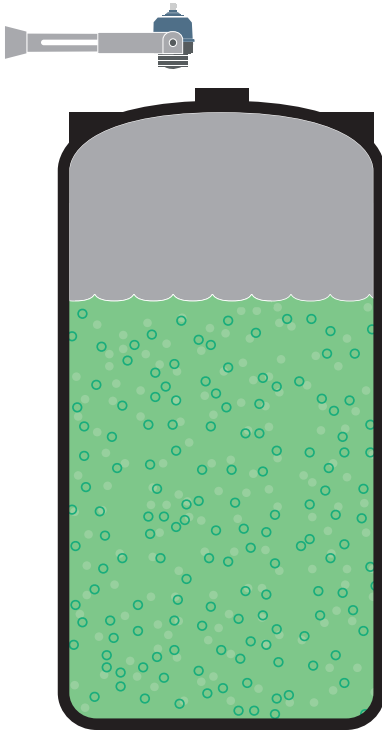
Figure 4.1.2: Level measurement in a plastic tank using non-contacting radar shooting through the roof

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Guided wave radar may be used for solids or oil/water production tanks. Use 5300 with single lead probe	Chapter 6

Best practice

A curved roof surface will allow condensation on the inside of the roof to drain away and prevent interference of the radar signal. It will also allow rain or snow to drain away from the radar path. Flat roof tanks are not recommended for the above reasons.

Mount a non-contacting radar with as large an antenna as possible over the tank roof. The transmitter can be mounted with a bracket attached to a pipe. No flange is required which reduces overall weight. The end of the antenna should be horizontal so that it is parallel to the level surface, not the roof surface.

4.1.3 Sulfur pits

Primary function of application

Elemental molten sulfur is removed as a by-product of desulfurization process in refineries. The collection tanks must be kept hot in order the keep the sulfur fluid.
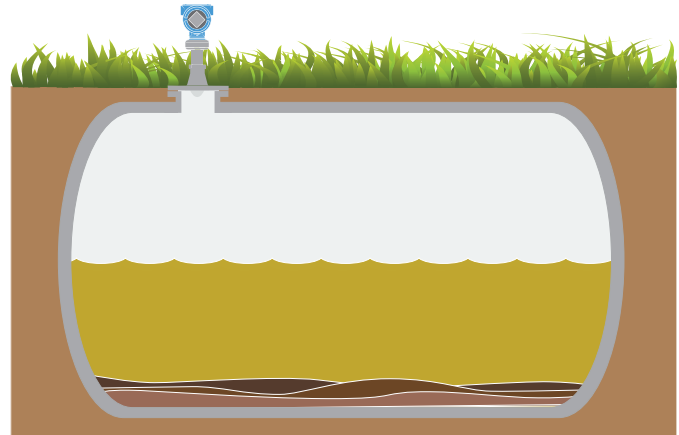
Figure 4.1.3: Rosemount 5408 process seal with nozzle installation

Application characteristics and challenges

Semi-molten solid is kept hot and well insulated. The sulfur vapors can be heavy and will condense in cooler areas. The challenge is to minimize the condensation.

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Guided wave radar, with single flexible probe	Chapter 6
Vibrating Fork Switch	Chapter 10

Best practice

- Use Rosemount 5408 with cone antenna or process seal antenna. If mounted on a nozzle, the nozzle should be well insulated, and heat traced to reduce sulfur condensation. Insulate and heat-trace the nozzle to reduce the amount of build-up.

- If possible, avoid tall nozzles.

- A Rosemount 5408 with parabolic antenna may also be used. The antenna should be inside the vessel. This will minimize potential crystallization or build-up.

- Signal Quality Metrics may be used to monitor signal strength to determine if cleaning of antenna or probe is needed.

4.1.4 Clean-in-Place and Steam-in-Place

Primary function of application
Cleaning-In-Place and Steam-in-Place processes are performed to ensure the cleanliness and sterility of the tanks in which food processes have been running. CIP and SIP tanks make use of spray balls and cleaning agents, such as water, detergent, and chemical, to perform the cleaning. During these processes, level measurement is required to avoid overfills and dry runs.
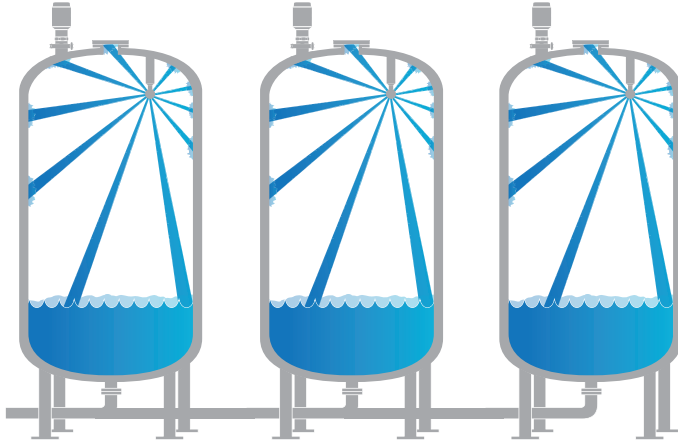
Figure 4.1.4: Storage tanks with CIP Cleaning

Application characteristics and challenges
- High-pressure water and cleaning agents released by spray balls can trigger false alarms or erratic level readings
- Contacting technology can cause bacterial growth and food contamination
- Hygienic approvals are needed
- High pressure and high temperature external washdowns

Suitable Technologies	
Technology	**Installation Guidelines**
Non-Contacting radar	Chapter 7
Vibrating Fork Switch	Chapter 10

4.1.5 Sump applications

4.1.5.1 Sumps (drain pit for waste oil, condensate)

Primary function of application
A sump is a vessel located in a low place or below key equipment that collects waste or overflow liquids Waste oil, waste condensate, chemicals, or water could be collected for reprocessing or disposal.
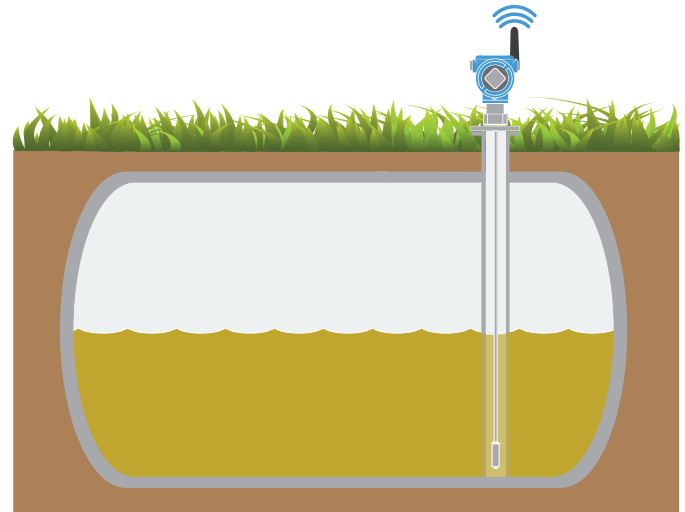
Figure 4.1.5: Condensate sump level with non-contacting radar in a stilling well or guided wave radar

Application characteristics and challenges
- Sumps may contain dirty, oily water
- This is often accessible only with top-down measurements
- It is sometimes desirable to measure interface

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar if no ice is expected	Chapter 6
Differential pressure	Chapter 9
Vibrating Fork Switch	Chapter 10

4.1.5.2 Open atmosphere sumps

Primary function of application

Treated wastewater or rain collection water is stored in open atmosphere sumps. By early detection of oil in the wastewater system, the risk of hydrocarbon to surroundings can be reduced.
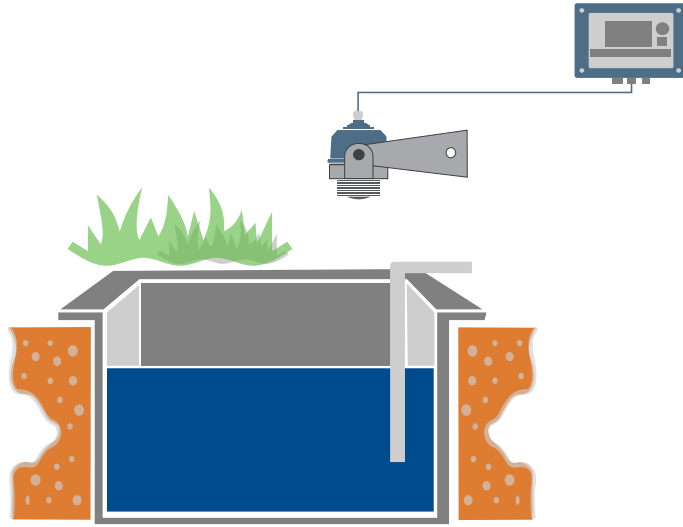
Figure 4.1.5.2: Open sump measurement with non-contacting radar transmitter

Application characteristics and challenges

- Water

- Top- down measurement

Suitable Technologies	
Technology	Installation Guidelines
Guided wave radar with Controller	Chapter 6
Non-Contacting Radar with Controller	Chapter 7

4.1.5.3 Underground sumps

Primary function of application

Underground sumps are used to collect waste product streams. They are often underground for ease of filling and insulation in extreme temperature climates.
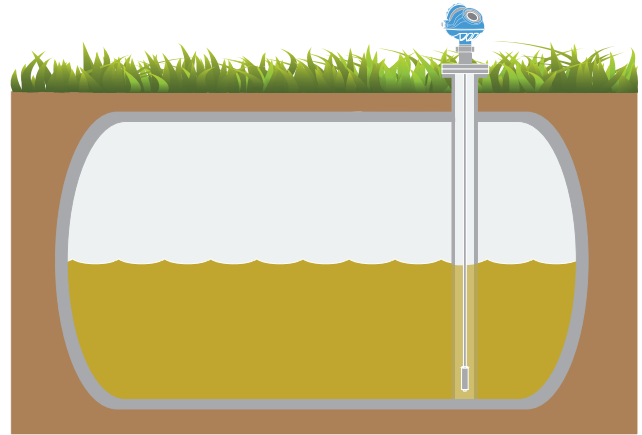
Figure 4.1.5.3: Underground tank with guided wave radar

Application characteristics and challenges

- Sumps may contain dirty, oily water

- This is often accessible only with top-down measurements

- It is sometimes desirable to measure interface

Suitable Technologies	
Technology	Installation Guidelines
Guided wave radar	Chapter 6
Non-Contacting Radar	Chapter 7
Vibrating Fork Switch	Chapter 10

4.2 Ammonia

4.2.1 Ammonia, anhydrous (NH$_3$)

Primary function of application

Ammonia is widely used in many processes in the chemical industry. It is, among other things, the raw material used for the production of fertilizers and is used in many chemical processes. It is also used industrially as a cleaning agent, disinfectant, and as a refrigerant. Ammonia, as used commercially, is often called anhydrous ammonia emphasizing the absence of water in the material and is stored under pressure or at a low temperature. The high risk of handling ammonia, both occupational health and process safety, makes automated measurement critical.
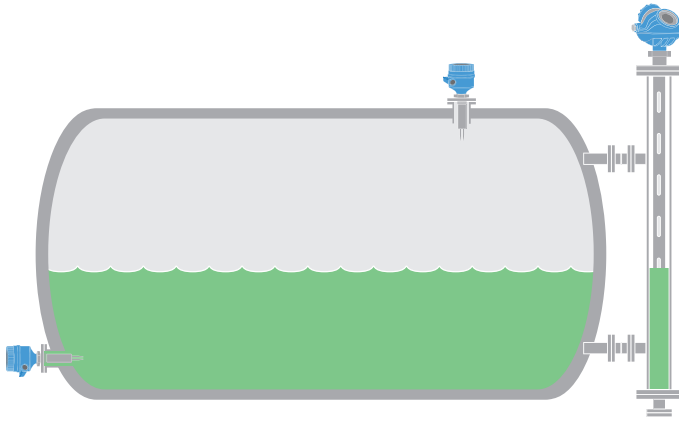
Figure 4.2.1: Level measurement in an ammonia anhydrous tank

Application characteristics and challenges

- Anhydrous ammonia has heavy vapors which can be corrosive to some elastomers

- Density variations are common due to ammonia phase changes with temperature

- Stilling wells and /or valves sometimes present

Suitable Technologies	
Technology	Installation Guidelines
High precision tank gauging system	Chapter 8
Guided wave radar with HP seal	Chapter 6
Non-contacting radar	Chapter 7
Vibrating Fork Switch	Chapter 10
Bypass chamber	Chapter 11
Differential pressure	Chapter 9

Best practice

- If guided wave radar is used, the HP process seal should be chosen. This seal uses no O-rings and has multiple barriers to contain any vapor leaks.

- If non-contacting radar is used choose a low frequency 5900C. A stilling well is recommended.

4.2.2 Ammonia, aqueous (ammonium hydroxide, NH4OH)

Primary function of application

Aqueous ammonia is a solution of ammonia in water and is used in diluted quantities for products like disinfectants or household cleaners and many industrial applications. It is commercially available in concentrations of up to 30% ammonia in water.
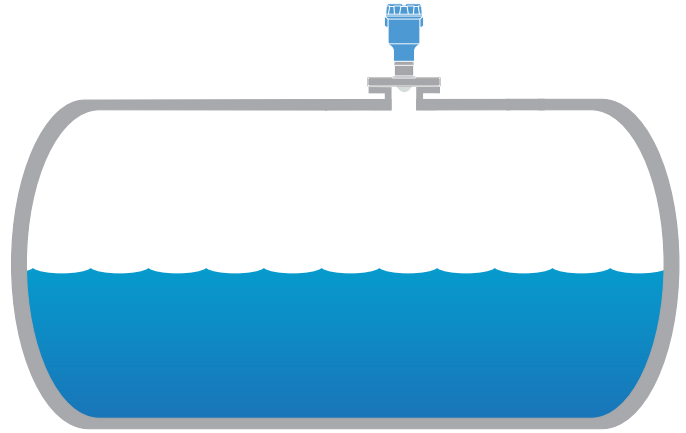
Figure 4.2.2: Level measurement in an ammonia hydroxide tank

Application characteristics and challenges

- Aqueous ammonia is stabilized by the presence of water, so phase changes are not as common as with anhydrous ammonia. Density is more stable.

- Vapors are present

- Valves are sometimes used

Suitable Technologies	
Technology	Installation Guidelines
Guided Wave Radar	Chapter 6
Non-Contacting Radar	Chapter 7
Differential Pressure	Chapter 9
Vibrating Fork Switch	Chapter 10

4.3 Separators

4.3.1 2-phase separator

Primary function of application

A vessel where hydrocarbon fluids are allowed to separate into a gas phase and a liquid phase. Two phase separators may be horizontal or vertical vessels.
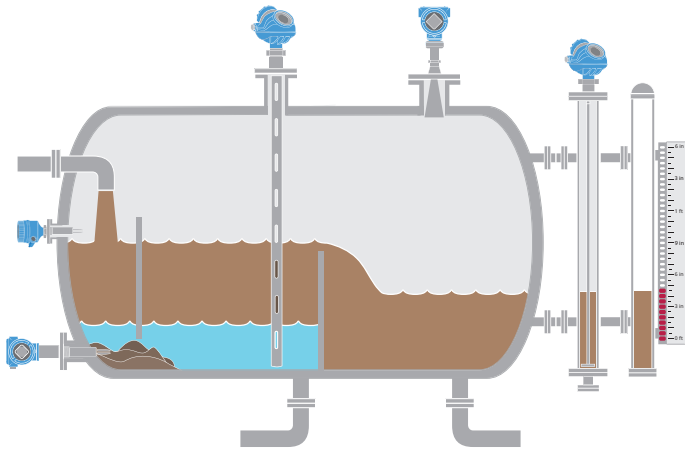
Figure 4.3.1: Two-phase separator

Application characteristics and challenges

Crude hydrocarbons can contain paraffins and other sticky materials. Density of the material can vary with supply. Pressure and temperature will vary widely depending on fluid source and its location in the process.

Depending on well pad geology, some crude hydrocarbons also contain sand and sediment. Over time this can build up in the base of the separator to reduce capacity. Extreme build up may lead to blocked inlets or sediment being drawn down lines and into pumps.

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar, with single lead probe	Chapter 6
Differential pressure	Chapter 9
Vibrating fork switch with sand detection function	Chapter 10
Bypass Chamber and Magnetic Level Indicator	Chapter 11

4.3.2 3-phase separator

Primary function of application

A 3-phase separator is used to separate hydrocarbon fluids into 3 components: gas, oil, and water. This is sometimes also called a Free Water Knock Out (FWKO) where the free water is removed from the oil prior to next processing stage.
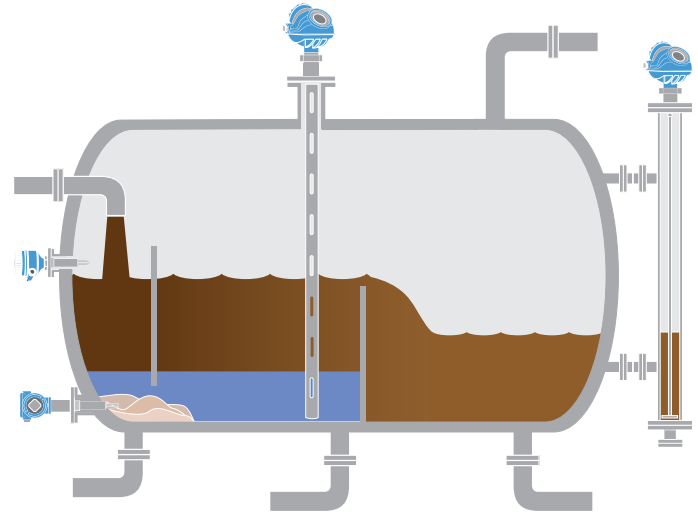
Figure 4.3.2: Three-phase separator

Application characteristics and challenges

Crude hydrocarbons can contain paraffins and other sticky materials. Density of the material can vary with supply. Pressure and temperature will vary widely depending on fluid source and its location in the process.

Some FWKO systems used with heavy crude may be heated.

Depending on well pad geology, some crude hydrocarbons also contain sand and sediment. Over time this can build up in the base of the separator to reduce capacity. Extreme build up may lead to blocked inlets or sediment being drawn down lines and into pumps.

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar, with single lead probe, direct mount or in chamber	Chapter 6
Differential pressure	Chapter 9
Vibrating fork switch with sand detection function	Chapter 10
Bypass Chamber	Chapter 11

4.3.3 Boot separator

Primary function of application

A boot separator includes a smaller section where water is allowed to accumulate for efficient removal.
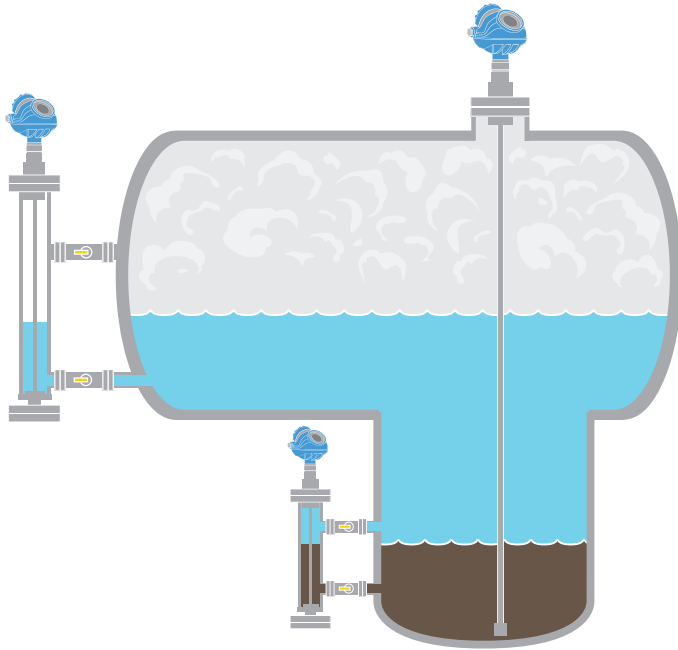
Figure 4.3.3: Two-phase separator with boot

Application characteristics and challenges

- This is an oil and water application. Depending on the fluid separation, an emulsion layer could be present

- Dirty or paraffin laden hydrocarbons could cause some coating, so a single lead probe is recommended

- Usually a small measurement span (<1 m/3 ft) unless mounted from top of vessel and extending into the boot.

Suitable Technologies	
Technology	Installation Guidelines
Guided wave radar with single lead rigid probe	Chapter 6
Vibrating fork switches. Level Switches may also be used to detect when an interface reaches a predetermined point.	Chapter 10
Bypass Chamber	Chapter 11

4.3.4 Flare knockout

Primary function of application

Serves as a recovery vessel in case of process upsets and allows vapors to flare off.
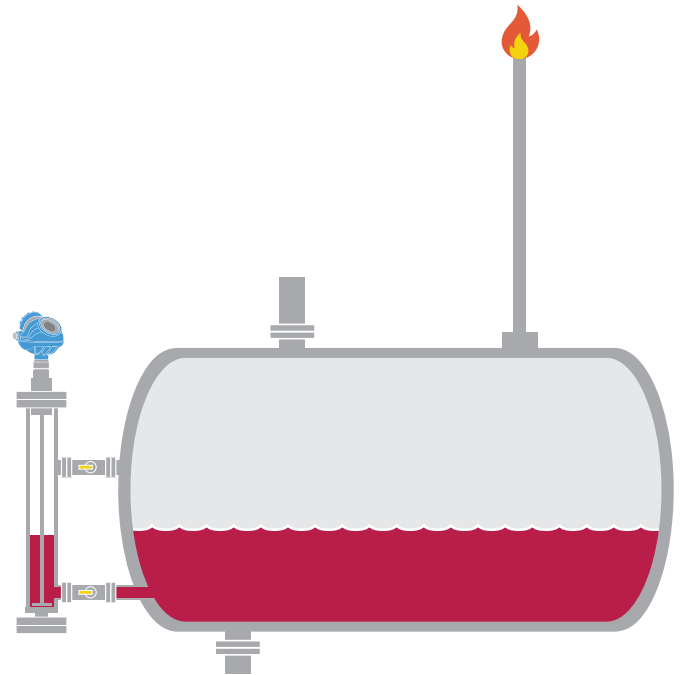
Figure 4.3.4: Flare knockout: a) guided wave radar b) non-contacting radar and switch

Application characteristics and challenges

- Since fluid may be from different sources, the density and other product properties may vary

- Pressure and temperature conditions will vary with location in process.

Suitable Technologies	
Technology	Installation Guidelines
Guided wave radar, with single lead probe, chamber or direct mount	Chapter 6
Differential pressure	Chapter 9
Non-contacting radar for taller vessels	Chapter 9
Vibrating Fork Switch	Chapter 10

Best practice

Guided Wave Radar with single lead probe will minimize issues with product coating. For very tall vessels where fast level changes are expected, such as blowdown drums, consider non-contacting radar.

4.3.5 Settled Sand and Sediment Detection

Primary function of application

Serves to detect when clean out is necessary to ensure vessel operating at maximum capacity and prevent sand being drawn in to lines.
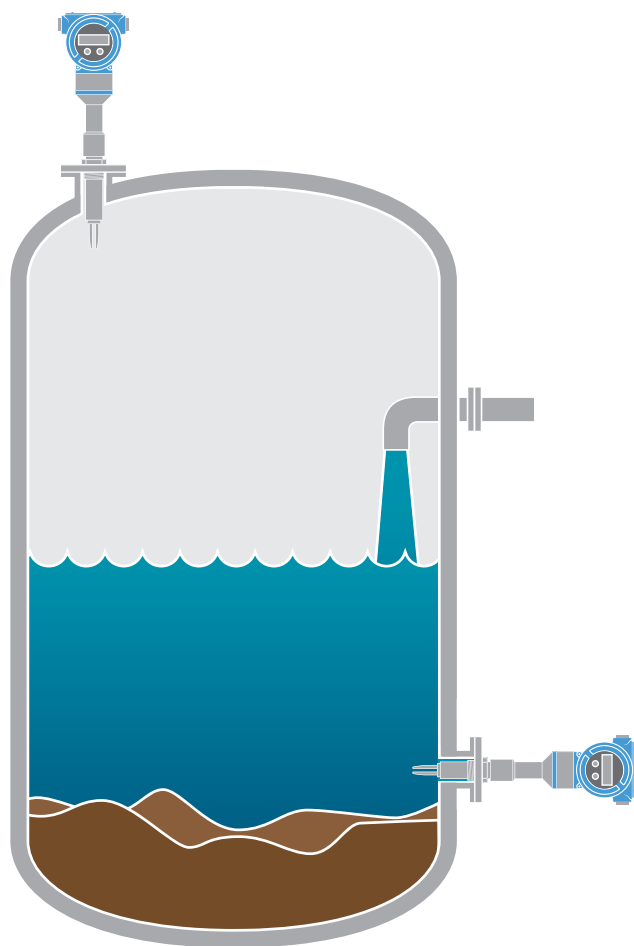
Figure 4.3.5: Vibration forks with sand detection functionality

Application characteristics and challenges

•   Dirty/coating media inside separator that may build up on instrumentation

•   Limited available process inlets into separator vessel

•   Geological differences at different separator locations means characteristics of the sediment may vary

Suitable Technologies	
Technology	**Installation Guidelines**
Vibrating fork switch with sand detection function	Chapter 10

Best practice

•   Consider Rosemount 2140 configured for sand detection function

•   Select appropriate setting according to sediment type - most to least compact

•   Device may be mounted in top or side of separator depending on location of available process inlets

4.4 Distillation towers

Primary function of application

Distillation columns allow separation of fluid mixtures based upon their boiling points. As vapors rise through the column, different components will condense at different temperatures and accumulate for withdrawal.
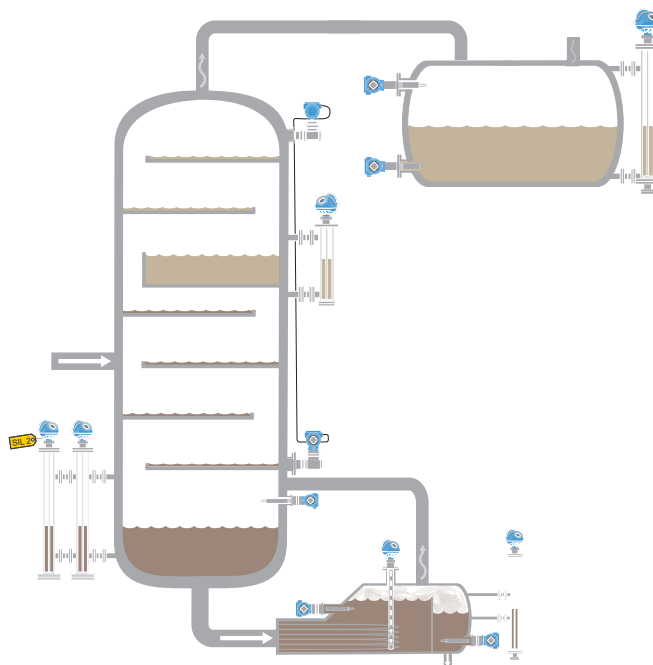
Figure 4.4: Level measurement at distillation tower

Application characteristics and challenges

•   Distillation columns will have a wide temperature range over its height. The lower end can be as high as 750 °F (400 °C).

•   Fluids, especially at the lower end can be dirty and cause coating and plugging of equipment.

•   It is important to insulate chambers and piping to minimize the risk of plugging and to maintain lower viscosity.

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar with single lead probe	Chapter 10
Tray level: DP tuned system	Chapter 9
Column Differential: ERS	Chapter 9
Bypass Chamber	Chapter 11
Vibrating Fork Switch	Chapter 10

Best practice for tray level measurements

- Guided wave radar; use standard pressure seal for upper portion of tower where the temperature is less than 302 °F (150 °C). Use the HTHP pressure seal for lower sections where temperature exceeds 150 °C

- Differential pressure, tuned system. Use high temperature fill fluids with Thermal Range Expander for lower portions of tower

Best practice for column differential

- Differential pressure; 3051S ERS

- Maximum tap-to-tap span = 500 ft. (152.4 m).

- Multiple ERS systems may be required to cover spans beyond 500 ft.

- Thermal range expander will need to be use for the high temperature of 750 °F (400 °C).

- Ratio of static pressure to differential pressure should be less than 100:1 (consult Emerson for applications greater than 100:1).

4.5 Blending tanks and Mixers

Primary function of application

Blending tanks are used for mixing fluids or solids into fluids, usually at ambient conditions. Level measurements are needed to monitor fluid additions, avoid overfills, and ensure consistency in product quality.
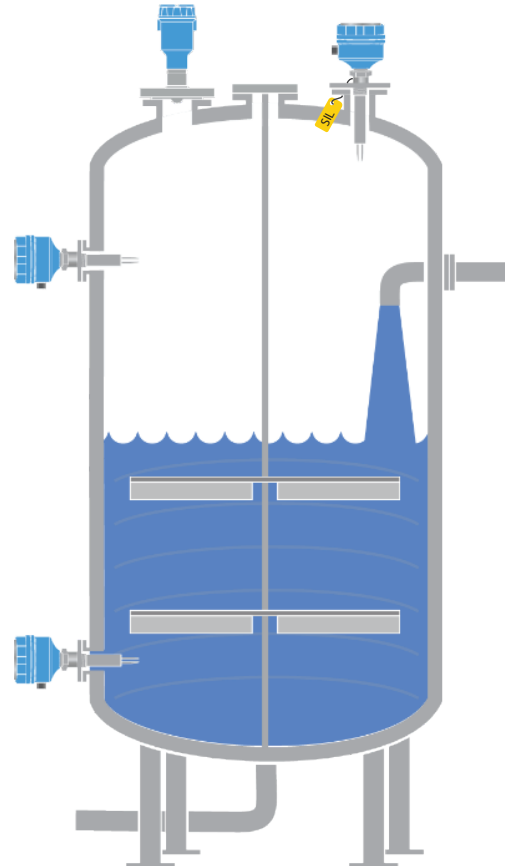
Figure 4.5: Level measurement in a tank with agitation

Application characteristics and challenges

- May be corrosive, vapors, turbulence, foam

- Usually has an agitator for mixing

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Differential pressure	Chapter 9
Vibrating Fork Switch	Chapter 10

4

4.5.1 Slurries

Application characteristics and challenges

Slurries are mixtures of a liquid and suspended particulates. Agitation is usually required to keep the solids in suspension.
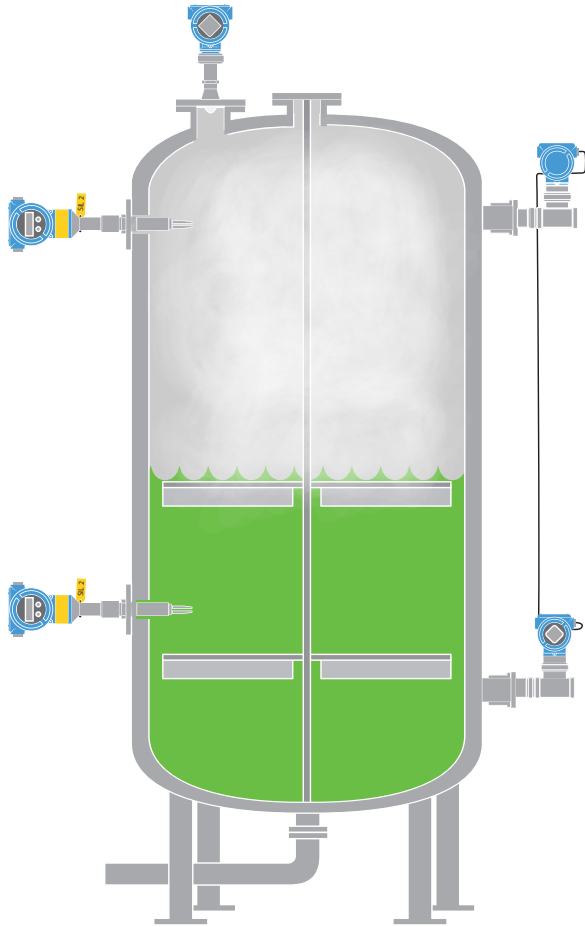
Figure 4.5.1: Slurry level with non-contacting radar and differential pressure

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Differential pressure (ERS or Tuned- System) with extended diaphragm seal	Chapter 9
Vibrating Fork Switch	Chapter 10

4.6 Reactor vessel

Primary function of application

Reactor vessels are similar to blending tanks except that a chemical reaction is required to produce the final product. While the components themselves can create an exothermic or endothermic reaction, sometimes external heat is required.
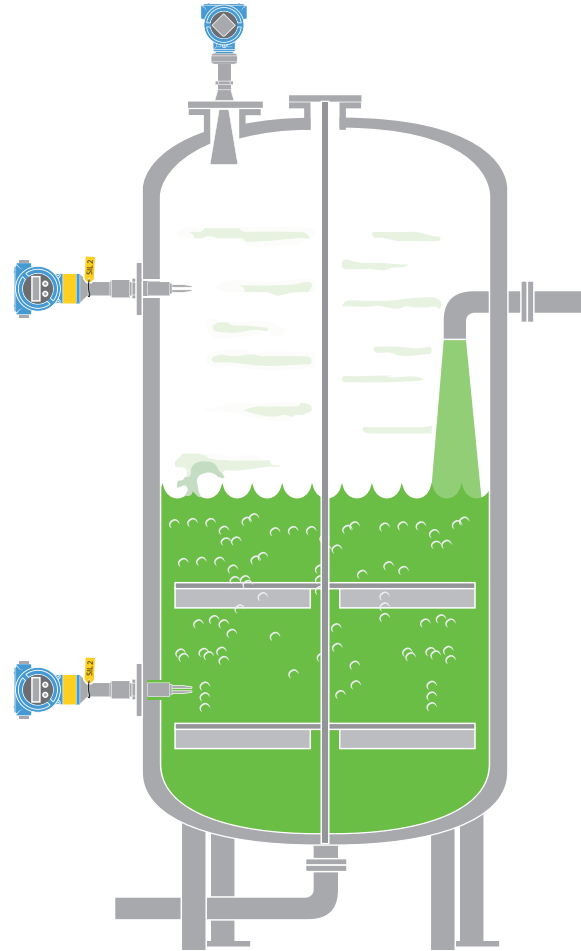
Figure 4.6: Reactor vessel level with non-contacting radar and point level measurement

Application characteristics and challenges

- Vapors, foam, turbulence are often present
- Density can change as part of the reaction
- Pressure can vary from vacuum to positive pressure

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Differential pressure, ERS or tuned system	Chapter 9
Vibrating Fork Switch	Chapter 10

Best practice
- DP, tuned system, for smaller, higher-pressure vessels
- DP, ERS, for taller vessels with lower static pressures (ratio of static pressure to DP span should be less than 100:1)

4.7 Steam generation

4.7.1 Boiler drum level control

Primary function of application
Inaccurate drum level control can cause damage to the steam drum, the boiler, and even the turbine. If the drum level falls below set-point, the boiler may run dry and explode. If the level is higher than the set-point wet steam may be carried over to the turbine which damages the turbine blades. Redundant measurements are required for safety.
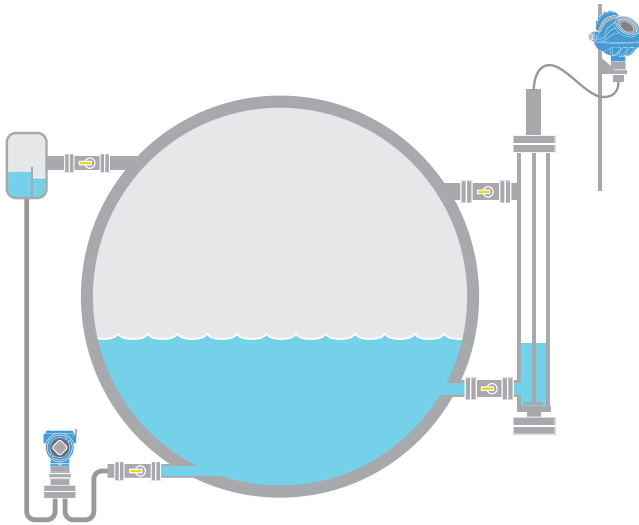
Figure 4.7.1: Boiler drum level control with differential pressure and guided wave radar

Application characteristics and challenges
- High pressure and temperature equipment required
- Density and dielectric of steam increases as pressure and temperature increases
- Density and dielectric of liquid decreases as pressure and temperature increases
- Both steam and liquid density changes require compensation in the DCS for the pressure transmitter level measurement
- Dielectric changes in the steam require compensation for the guided wave radar measurement
- Control range is over small span

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar with Dynamic Vapor Compensation	Chapter 7
Differential pressure, wet leg, balanced	Chapter 9
Bypass Chamber	Chapter 11
Vibrating Fork Switch	Chapter 10

Best practice
- Guided wave radar; with Dynamic Vapor Compensation for systems over 400 psi (27 bar)
- Differential pressure; for boiler drum systems with pressure over 600 psi (42 bar), wet legs are recommended. For systems where the pressure is <600 psi (42 bar), balanced systems are recommended. Thermal Range expander need for high temperature

4.7.2 Boiler feedwater

Primary function of application
Feedwater heaters are staged to gradually increase pressure and temperature of the water prior to the boiler. Control of feedwater heater level can impact overall plant efficiency. Redundant measurements are required for safety.
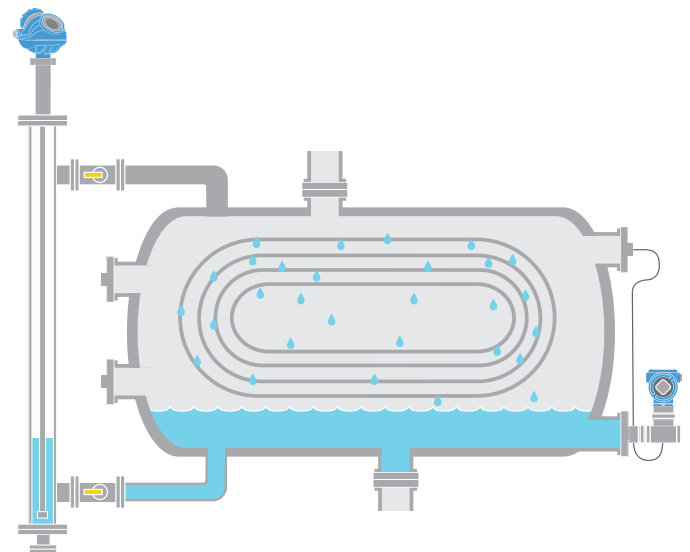
Figure 4.7.2: Feedwater heater level with long and short range installation of external chamber

Application characteristics and challenges
- HP feedwater heaters will have density changes of the liquid and dielectric changes of the vapor as pressure and temperature increase
- Magnetite build-up is common

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar, with Dynamic Vapor Compensation for systems over 400 psi (27 bar) *	Chapter 6
Differential pressure, Thermal Range Expander used for high temperatures	Chapter 9
Bypass Chamber	Chapter 11
Vibrating Fork Switch	Chapter 10

* Use standard GWR probes for lower pressure applications

4.7.3 Deaerator

Primary function of application
Dearators remove non-condensible dissolved gases from makeup water. Steam is used to scrub the feedwater and is recaptured as condensate. Accurate deaerator level control ensures continuous feedwater to boiler feed pump.
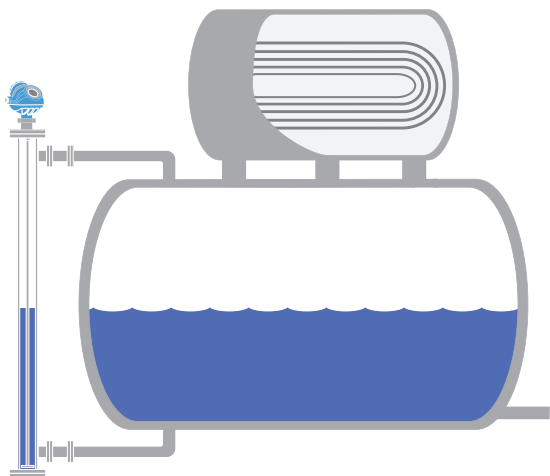
Figure 4.12.4: Deaerator level with guided wave radar

Application characteristics and challenges
- Usually operates at low pressure (< 50 psi) and sometimes at a slight vacuum
- Water is very clean and density is stable

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar	Chapter 6
Differential pressure	Chapter 9
Vibrating Fork Switch	Chapter 10
Bypass Chamber	Chapter 11

Best practice
Use standard pressure seal for guided wave radar

4.8 Cooling tower

Primary function of application
Circulating water from the cooling tower is used to provide cooling to the condensing steam from the turbines. After absorbing heat in the condenser, it is cooled by evaporation as it falls through the cooling tower. A continuous water level is maintained in the cooling tower basin for circulation back to the condensor.

Figure 4.8: Cooling tower basin level with guided wave radar; overview and close-up

Application characteristics and challenges
- While the water being cooled may be clean, windblown debris may collect in the basin
- Foam is sometimes present depending upon water treatment chemical usage
- Depending on the style of the tower and installation locations, the trickling water may be like rain on the level device

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar	Chapter 6
Non-Contacting Radar	Chapter 7

NOTE!
Often, all of these technologies can be mounted with a bracket mount holding the device over the cooling tower basin.

4.9 Open lake or pond level

Primary function of application

Lake or pond levels are monitored to endure adequate supply of make-up water.
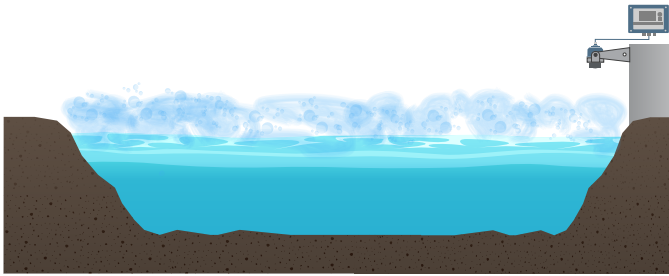
Figure 4.9: Measuring level in a pond

Application characteristics and challenges

- Water
- Top- down measurement

Stilling wells are sometimes used. In cold climates, ice may form on the surface. Non-contacting devices will measure the surface of the ice. Often used in power generation applications, or water and wastewater applications.

Suitable Technologies	
Technology	Installation Guidelines
Guided wave radar if no ice is expected with controller	Chapter 6
Non-Contacting Radar with controller	Chapter 7
Differential pressure	Chapter 9

4.10 Open channel flow

Primary function of application

Open channel flow applications allow the flow of a fluid, usually water, to be measured as it flows through a defined, but open, area. Often there is a restriction of the channel or a weir that will cause a rise in the water level as the flow increases. At this level changes, the flow can be calculated. Established formulas are used for the different types of channels.
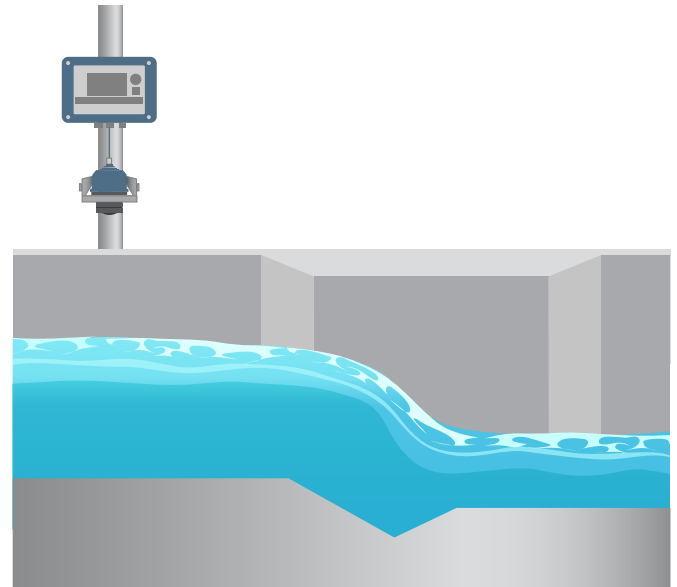
Figure 4.10: Measuring open channel flow

Application characteristics and challenges

Flowing fluid, usually water, rises as it passes through the restriction. The amount of rise can be used to determine flow rate. Measurement is usually made at ambient temperature conditions. In cold weather, warm streams may give off a condensing fog. In some waste streams, foam may be present.

Suitable Technologies	
Technology	Installation Guidelines
Non-Contacting Radar with controller	Chapter 7

4.11 Inlet screen condition monitoring

Primary function of application

Raw water is taken from a reservoir or river. Water intake requires removal of biological impurities and debris and so the water is passed through screens or filter to remove debris. Measurements are taken on both sides of these screens to monitor any clogging.
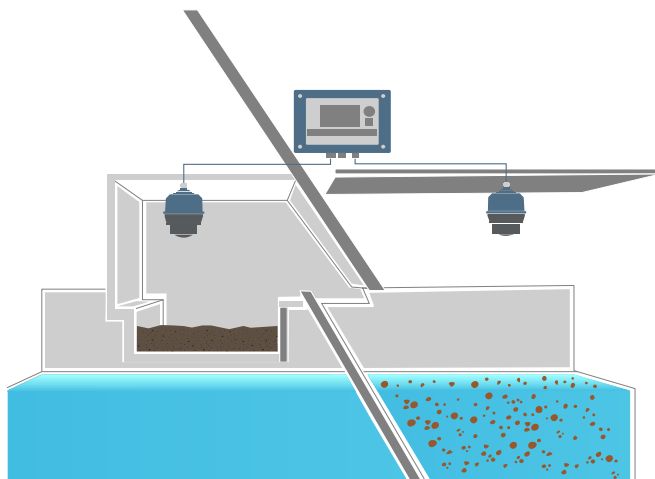
Figure 4.11: Rosemount 1208 Level and Flow Transmitter and Rosemount 3490 on a screening application

Application characteristics and challenges

- Raw water application which may be turbulent
- Upstream side may have floating debris
- Top-down measurement

Suitable Technologies	
Technology	**Installation Guidelines**
Guided wave radar with controller	Chapter 6
Non-Contacting radar with controller	Chapter 7

Best practice

For long range applications, for example where access is limited, radar transmitters are most suitable.

4.12 Large storage tanks

Primary function of application

These are large storage tanks that contain crude oil or products such as refined oil products. These may also contain feedstock for processing. In both cases very accurate measurements are required for accounting and custody transfer purposes.

Tanks can be fitted with either floating roofs or fixed roofs depending on the type of products stored in the tanks. Tanks with floating roofs have a roof that is floating on the top of the liquid and as such minimizes the vapor from the fluids.
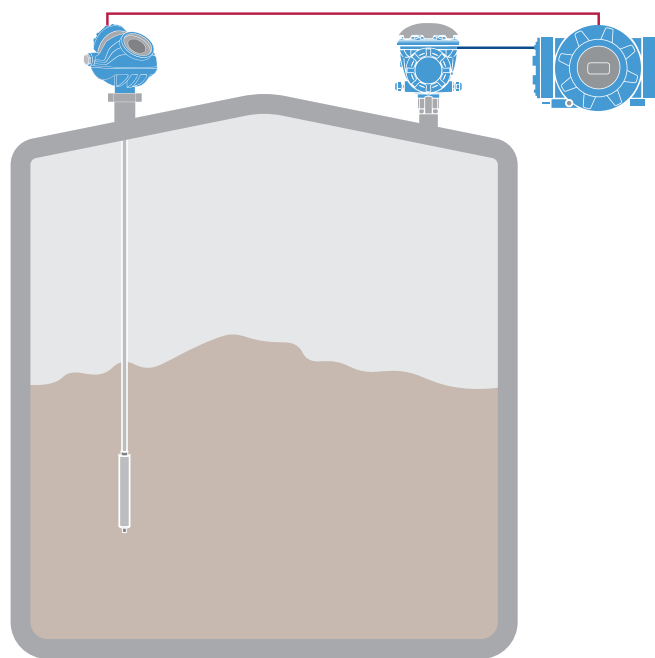
Figure 4.12.1: Storage tank with an inventory tank gauging system
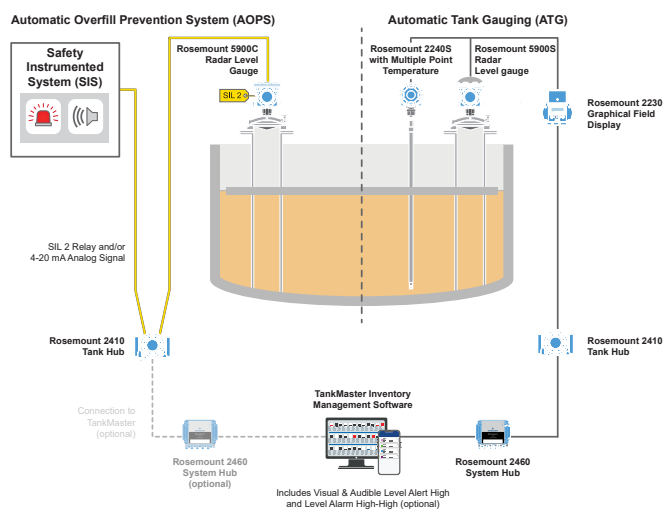
Figure 4.12.2: A floating roof tank with an inventory tank gauging system

Application characteristics and challenges
- Large upright tanks containing crude oil or refined products. Can also be blending tanks, such as at load-out facilities where special additives are mixed in.
- For tanks with floating roofs a stilling well protruding through the roof are often available for the level measurement.

Suitable Technologies	
Technology	Installation Guidelines
High precision tank gauging system	Chapter 8
Non-contacting radar	Chapter 7

4.13 Liquefied Natural Gas (LNG) tanks

Primary function of application
LNG is primarily methane – it also contains some propane and ethane – and cannot be liquefied solely by pressurization. The gas is cooled to -161°C and becomes a liquid in a process known as "liquefication". This reduces its volume by 600 times and makes it economical to transport.
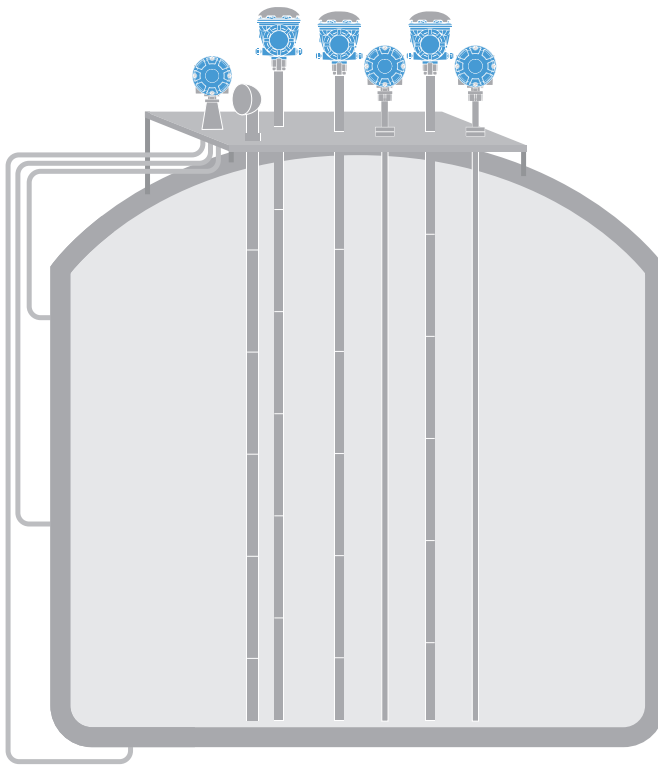
Figure 4.13: LNG tank with inventory tank gauging system

Application characteristics and challenges
Large upright cryogenic tanks with refrigerated liquefied natural gas. Because of the size, cryogenic conditions, safety valves, vapors, and low dielectric values, specialized instruments are required.

Suitable Technologies	
Technology	Installation Guidelines
High precision tank gauging system	Chapter 8

4.14 Liquid Petroleum Gas (LPG) tanks

Primary function of application
LPG is compressed liquid petroleum gas and is composed primarily of propane (up to 95%) and small quantities of butane. It is a by-product of the refining industry and is a fuel source for industrial and domestic use.
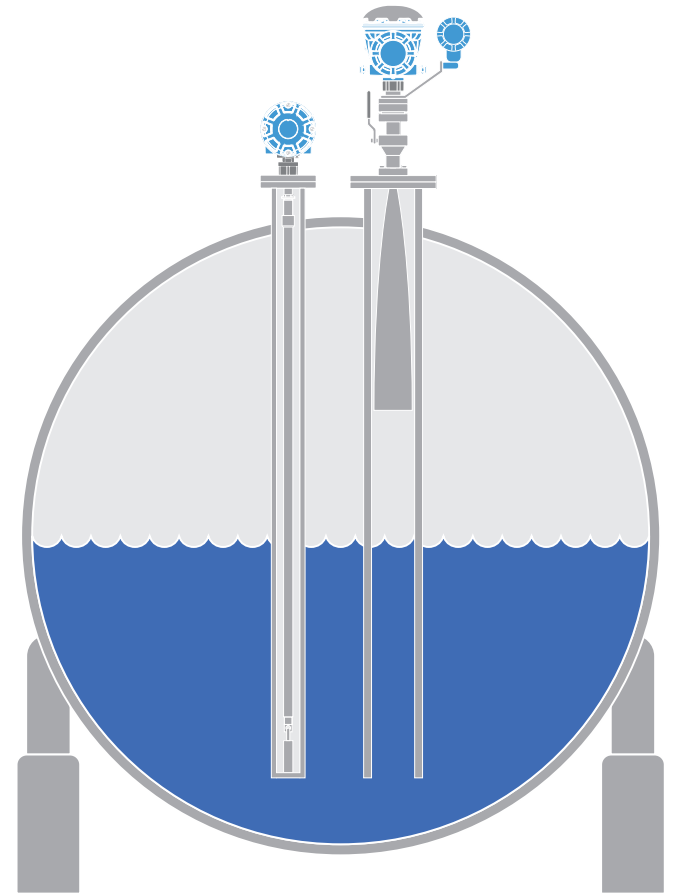
Figure 4.14: An LPG tank with an inventory tank gauging system

Application characteristics and challenges
May be spherical tanks containing products such as propane, butane, isobutane. LPG is stored in a variety of tanks shapes and sizes with horizontal cylinders being very common. Valves are often installed. Stilling wells and chambers are commonly used.

It is a very low dielectric and low density fluid and as such offers challenges to many level measurements. Phase changes and thus density changes are common as the fluid vaporizes and condenses if the storage pressure and temperature change.

Suitable Technologies	
Technology	**Installation Guidelines**
High precision tank gauging system	Chapter 8
Guided wave radar	Chapter 6
Non-contacting radar	Chapter 7
Differential Pressure	Chapter 9

Best practice
- Guided wave radar for smaller, horizontal vessels. If installed directly in the vessel, a coaxial probe should be used. If installed in a chamber, a single lead probe may be used.
- Non-contacting radar with stilling well for larger vessels and those with valves.
- Tank gauging systems for large vessels

4.15 Cryogenic applications

Liquefied gases include materials such as LNG, LPG, ethylene, propylene, R22 and other refrigerants, carbon dioxide, nitrogen, argon, and xenon. These have uses as fuels, refrigerants, raw material components and other.
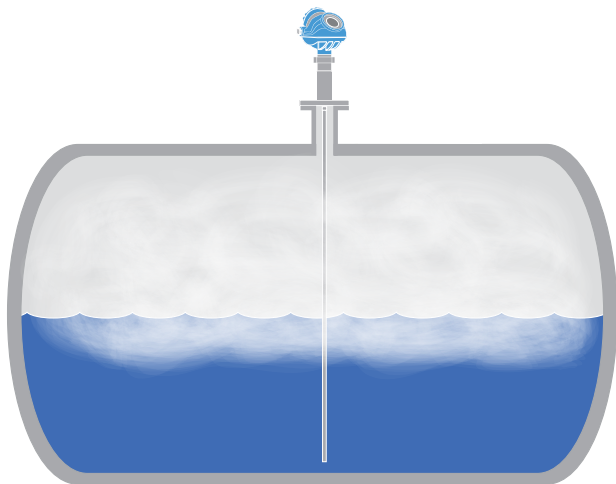
Figure 4.15: Cryogenic tank with Guided Wave Radar Technology

Application characteristics and challenges
These fluids tend to be very clean fluids with low viscosities and low dielectric values. In the processing industries, the vessel size and shapes vary but horizontal bullet cylinders are the most common. The biggest challenge is the temperature and its impact on the fluid properties and thus, the level measurement. As the fluid moves into impulse piping or bypass chambers, the warmer temperature can cause it to expand or vaporize.

In addition, transmitter electronics have ambient temperature limits of -50 or warmer. If too close to the process, the temperature of the electronics may impact the performance of the device.

Dielectric constants of common liquefied gases and refrigerants			
Product	**DC**	**°F**	**°C**
Ammonia (R 717)	25	-103	-75
Argon, Liquefied	1.5	-376.0	-226.7
Boroethane	2.0	-198	-128
Butane	1.4	30.2	-1.0
Carbon dioxide (R 744)	1.6	32.0	0.0
Ethane	1.9	-288.4	-178.0
Ethane (R170)	1.9	-288.4	-178.0
Ethylene	1.5	26.6	-3.0
Fluorine (Liquefied)	1.5	-332.0	-202.2
Freon (various)	1.7 to 1.9	68	20
Hexane	2.0	-130.0	-90.0
Methane (Liquid Natural Gas)	1.7	-295.6	-182.0
Nitrogen (liquefied)	1.3	-310	-190
Propane (R290)	1.6	32.0	0.0
Propylene (R 1270)	11.9	–	–
Trifluromethane (R-23)	6.3	-22	-30
Xenon	1.9	-169.6	-112.0

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar with cryogenic probe	Chapter 6
DP with cold-temperature fill fluid	Chapter 9

Guided wave radar
Use a probe with the cryogenic seal (option C on the 5300 model). Both single and coaxial versions are available and are suitable for temperatures as low as -320 °F (-195 °C). For the very lowest dielectric fluids and for applications where internal obstacles are in the vessel, use the coaxial probe. The single probe can be used in the higher dielectric compounds or in bypass chambers. The probes may be mounted directly in the vessel or in a bypass chamber.

The chamber and connections to it should be well insulated to minimize temperature changes. In the case of the GWR, the insulation should not cover the top of the probe above the flange area. This transition distance is needed to meet the ambient condition limits for the electronics.

Differential Pressure

Use a DP transmitter with a low temperature fill fluid such as Syltherm XLT. This fluid can handle temperatures as low as -105 °C (-157 °F). The high pressure side of the transmitter should be connected with capillary. The low pressure side should use a connection. This will also allow the electronics temperature to meet ambient temperature specifications.

Electronic Remote Sensor (ERS) technology can also be used on taller cryogenic vessels with smaller static pressures.

4.16 Marine Applications

4.16.1. Fuel Service Tanks in Marine

Primary function of application

The primary function of a ship's fuel service tank is to store the fuel used for the ship's propulsion and auxiliary engines. This tank serves as an intermediate storage that ensures a steady and regulated flow of fuel to a ship's engines, maintaining the required pressure and temperature conditions. It also allows for the separation of any contaminants or water from the fuel, ensuring that only clean fuel reaches the engines. For fuels, such as HFOs, diesel oil, LNG, methanol, ammonia or biofuels, the tank is designed to handle specific characteristics, such as cryogenic temperatures or different chemical properties, in a safe and efficient way.
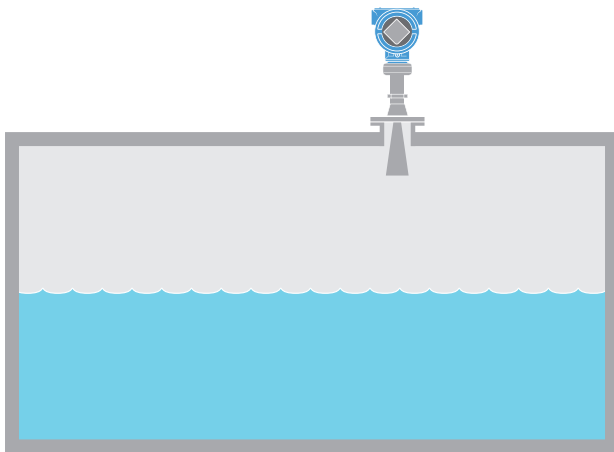
Figure 4.16.1: Marine fuel tank with non-contacting radar

Application characteristics and challenges

Measuring the surface level in a fuel service tank with radar for fuels involves several challenges. These fuels often have low dielectric properties, leading to reduced radar signal reflections. Extreme cold required for cryogenic storage, combined with varying pressures influencing fuel density and surface characteristics will impact radar reflections. Further, the continuous movement of fuel within the tank, caused by ship motion, creates an unstable surface, complicating radar signals ability to reflect back to the radar.

Suitable Technologies	
Technology	**Installation Guidelines**
Non-Contacting Radar	Chapter 7
Guided Wave Radar	Chapter 6

4.16.2. Custody Transfer Measurement in Marine

Primary function of application

The primary function of LNG custody transfer measurement system is to accurately measure the level of LNG in the cargo tanks during custody transfer operations. This ensures precise determination of the volume being managed, which is an essential part when calculating the exact amount of energy exchanged between parties.
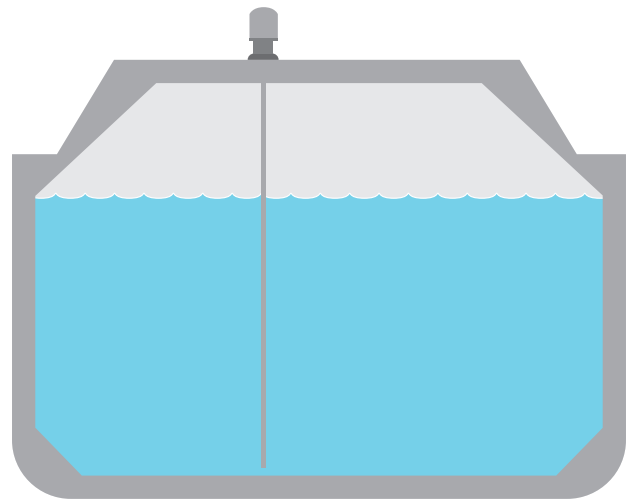
Figure 4.16.2: LNG membrane tank with Custody Transfer Measurement System

Application characteristics and challenges

Measurements for LNG custody transfer primarily aims to provide precise, accurate and certified readings of level and temperature of the LNG, as well as pressure and temperature of the vapor in each cargo tank. This involves challenges such as dealing with the reduced radar signal reflections caused by LNG's low dielectric constant. Achieving high measurement accuracy is crucial for ensuring that the correct volume of LNG is recorded during transfer. The radar system must effectively handle potential measurement errors due to the movement of LNG and variations in temperature and pressure. Accurate volume measurements are crucial for ensuring that the quantity of LNG delivered matches contractual agreements, supporting fair and transparent commercial transactions.

Suitable Technologies	
Technology	**Installation Guidelines**
Tank Radar Gauge TGU 53	Chapter 12

4.16.3. Cargo Tanks on Ships

Primary function of application

Cargo tanks on ships are designed to store liquid cargoes in bulk. They are an essential component of all tanker vessels, which are specialized to carry various types of liquids, such as oil, chemicals, and liquefied gases. The primary function of any cargo tank is to hold the liquid cargo securely during the sea voyage.
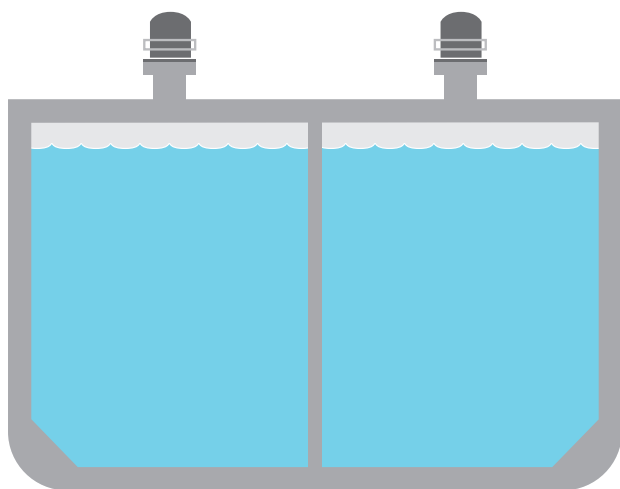
Figure 4.16.3: Cargo tank with Cargo Monitoring System onboard a tanker ship

Application characteristics and challenges

In offshore installations, where off-takes are performed in open sea, the movements create an environment where the level of the media in each cargo tank moves along with external forces. Combined with deep tanks, it represents a challenging application. This can also be translated into vessels, with cargo operations in port, and with perhaps

more shallow tanks, but with many times more challenging cargoes. Where a free propagation antenna is used, it is important that it is of parabolic design, enabling it to pick up weak signals, whenever the in-tank conditions, or low reflective cargo so require. Together with a radar with broad bandwidth it will cover most of the difficult applications on any vessel offshore, or in port.

Suitable Technologies	
Technology	**Installation Guidelines**
Tank Radar Gauge TGU 68	Chapter 12
Tank Radar Gauge TGU 65	Chapter 12

4.17 Point level detection

Primary function of application

The primary purpose of point level detection is to determine whether process media has reached a certain point within a vessel. In the case of a liquid detection application a point level sensor detects if it is dry or wet at a specific point in the vessel.

Point level sensors such as vibrating fork switches or mechanical float switches can be used alone as the primary means of level detection or as a backup to a continuous level measurement device to add redundancy to a system.

Point level sensors have many uses in both process and inventory tank gauging applications. Shown here are some typical uses:

Overfill prevention
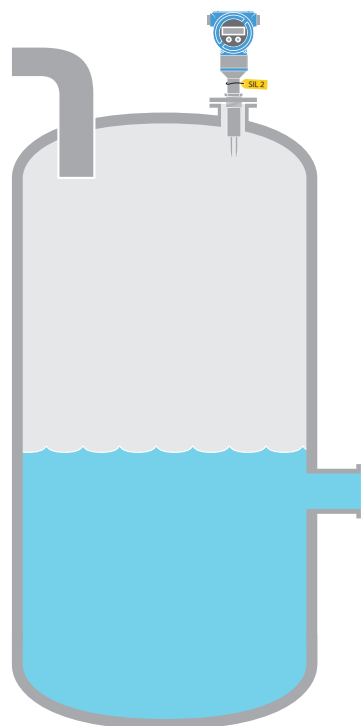
Figure 4.17.1: Overfill prevention

Manual Overfill Prevention Systems (MOPS)
Usually dependent upon human actions ie. alarm notifies an operator to take appropriate action to prevent an overfill.

Application characteristics and challenges :
• May be long periods of time between overfill prevention device being activated

• May be exposed site / harsh ambient conditions

• Some fluids may be viscous / coating

• Corrosive materials may be present

• May be hazardous location

• Liquid level may change rapidly

• Need ability to perform functional test

• Need local and remote warning /alarm message

Automatic overfill prevention system (AOPS)
Safety instrumented function (SIF) automatically shuts down plant assets in the event of an overfill.

Application characteristics and challenges:
• May be exposed site / harsh ambient conditions

• Some hydrocarbons (LNG / LPG) may be lightweight materials (low SG)

• Corrosive materials may be present

• May be hazardous location

• May be long periods of time between overfill prevention device being activated

• Need ability to perform functional test (proof test)

• System and equipment design compliance with IEC61508 / 61511 standards

Vibrating fork switches are a popular modern choice because not only are they a simple and cost effective means of installing reliable overfill prevention, they can be side-mounted on to a vessel if it is not possible to install a top-down solution such as a guided wave or non-contacting radar level transmitter.

Best practice
• Select sensor safety certified to IEC61508 with SFF>90%

• Select sensor with high diagnostics coverage and minimum dangerous undetected failures

• Recommend device with ability to perform proof test remotely ie. from control room

For point level overfill prevention, Rosemount 2140:SIS is recommended

• High and low level alarm
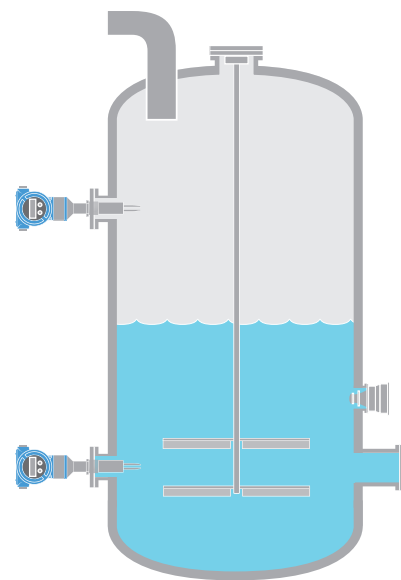
Figure 4.17.2: High and low alarm using vibrating forks

Maximum and minimum level detection in tanks containing many different types of liquids are ideal applications for vibrating forks.

High level alarms send an audio, visual or electronic alert to identify that the process fluid has reached the high limit, typically this is set around the upper 25% of the tank level.

A low level alarm alerts operators to a low condition, which may if left unchecked lead to a run-dry situation or may point to a leak.

It is common practice to fit an independent high level alarm switch as a backup device to the installed level device in case of primary device failure.

Application characteristics and challenges:
• May be exposed site / harsh ambient conditions

• Some fluids may be viscous / coating

• Corrosive materials may be present

• May be hazardous location

• Liquid level may change rapidly

• May need local and remote warning /alarm message

• May be limited access to top of tank / no available inlets

• May be limited power to the installation or installation in remote area

Best practice

- Consider application conditions- where process is corrosive or harsh, vibrating fork switches are recommended for their diagnostics and functional test capabilities

- If access to tank top is limited, vibrating forks may be side-mounted.

- If process has coating characteristics, select vibrating fork technology with no moving parts.

- In remote installations install wireless Rosemount 2160 to extend automation reach without need to install additional infrastructure

- Where power is limited, install Rosemount 2120 with low power relay output option- which is compatible with solar or battery-powered systems or install Rosemount 2160 with integrated power module.

Pump applications

- Pump control
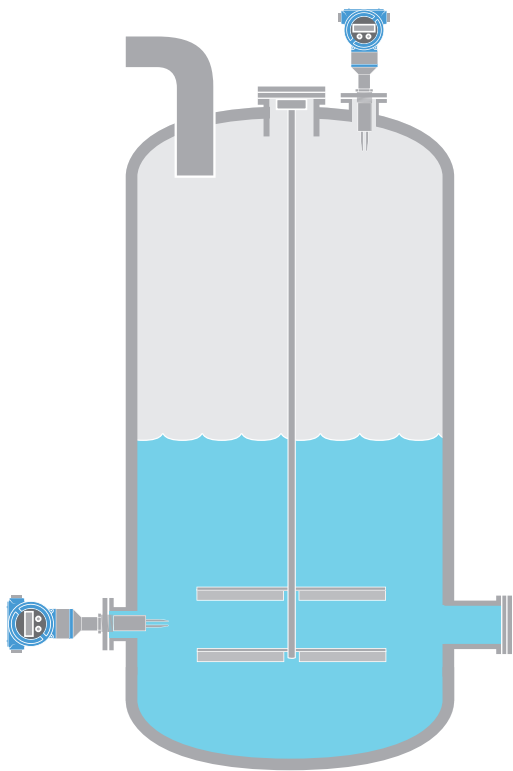
Figure 4.17.3: Pump control

Sometimes a vessel will be fitted with both a high and low level alarm switch to automate filling and emptying cycles to keep liquid contained within the desired limits.

- Pump and dry-run protection
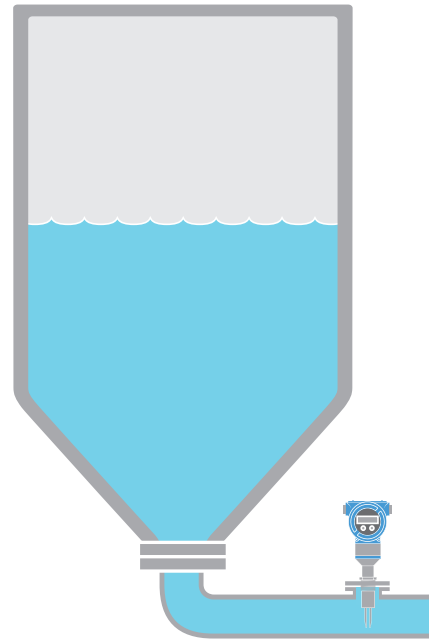
Figure 4.17.4: Pump protection

This application is a subset of low-level alarm whereby a switch at low level either sends an alarm to alert that the process fluid has reached a critical low level. This prevents operation without liquid present which can cause damage to bearings and / or seals or in extreme circumstances a dangerous overheating situation.

Alternatively, the alarm can be used as an alert to start a secondary process such as Clean In Place (CIP).

Point level switches may also be used as a means of monitoring pump lube oil level to ensure that the reservoir does no run dry.

- Empty pipe detection
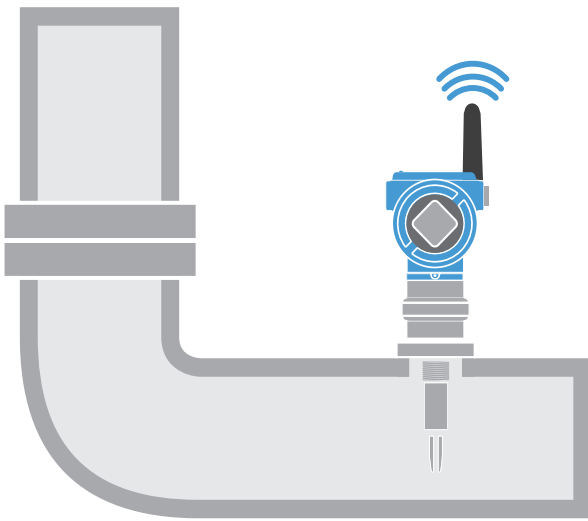
Figure 4.17.5: A wireless with detecting whether there is liquid or not in the pipe

An alarm switch is fitted through the wall of a pipe to detect presence or absence of liquid. This may be as a method to protect a pump or to switch another instrument such as a flow meter on or off.

Suitable Technologies	
Technology	**Installation Guidelines**
Overfill prevention	Chapter 10
High Level Alarm	Chapter 10
Pump Control	Chapter 10
Pump Protection	Chapter 10

Table 4.19.1: Showing the technology suitable for different point level detection applications. See also: Installation guidelines, chapter 10

4.18 Tank monitoring applications

Primary function of application
The tank monitoring system fits small tank farms. Given the wide application coverage for Rosemount 5300 and Rosemount 5408 the system is suitable for many different industries, such as chemical and oil and gas. Typical applications could be batch tanks, clarifiers or smaller remote storage tanks.
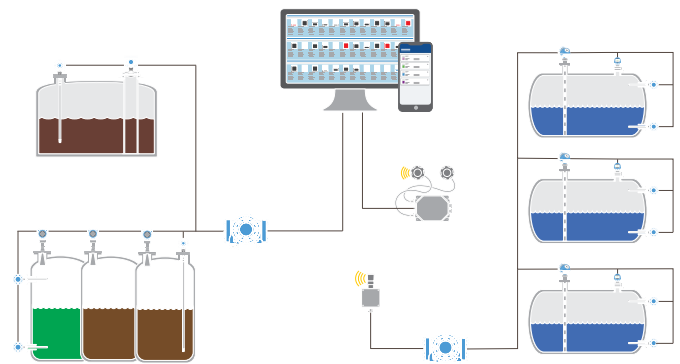
Figure 4.18: Tank monitoring system

Application characteristics and challenges
Depending on the industry and the type of media being measured there are many different challenges. Typically, there will be a group of small tanks with no existing automation or tanks with level control devices, but no overfill prevention system and need the additional safety system. In some cases, there are automated system, but visibility is missing to their tanks to monitor capacity.

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7

Best practice
Use guided wave radar or non-contacting radar depending on application characterizes in the tank farm. To limit wiring needs wireless can be used for remote tank locations.

4

CHAPTER 5
SOLIDS APPLICATIONS & TECHNOLOGY SELECTION

5

5 Solids Applications and Technology Selection

Level measurement on bulks solids can be very challenging. It usually entails dust, uneven surfaces, heavy build-up and rat holes. Solids materials often have a low dielectric constant and bulk density can be very light to dense.

This chapter follows the structure of chapter four and provides recommendations for suitable technologies. However, the final decision of the technology type will include application conditions, installation constraints, and the capabilities of the technology. The solids listed here are selected to represent common applications. The different groups are selected to exhibit common characteristics that often appear with many solids.

5.1 Technologies

5.1.1 Guided wave radar

Guided wave radar can be used in many different applications. It is especially well suited for smaller vessels with diameters <33 ft (10 m) containing powders and small granular materials, and where the installation area is restricted. As vessel height increases, wear on the probe, and increases of the pull force, becomes more of a factor in the suitability of its use. As with any radar device, it reacts quickly to level changes, so it is also appropriate for process applications and small vessels.

5.1.2 Non-Contacting Radar

Non-contacting radar can be used on a large variety of applications. It has no restrictions with respect to the weight of the material so it can be used in applications where guided wave radar may not be appropriate because of pull forces or concerns about probe breakage.

Non-contacting radar can see more of the surface than guided wave radar so will be slightly more accurate. As with any radar device, it reacts quickly to level changes so it is also appropriate for process applications and small vessels.

5.1.3 Point Level Detectors

Limit detection is required in most silos and containers to avoid overfilling and overspills, or run-dry/empty situations. Point level detectors can be used for simple process control, in dense or very light materials, and can handle extreme

conditions such as high temperatures, pressure, mechanical stress, dust and material prone to caking.

Bulk solids level switches utilize several technologies, including rotating paddle, vibrating fork, vibrating rod, and capacitance. The different technologies meet the measurement requirements in bulk solids applications and are suitable for full, demand, or empty detection for different bulk solids in all types of vessels.

5.2 Applications

5.2.1 Seed storage

Primary function of application
Prior to being processed into various kinds of oils, seeds like sunflower, palm kernel, safflower, soybeans, sesame, and canola, or nuts such as peanuts, almonds, and walnuts, are delivered to the plant and stored in big silos to ensure a continuous production process.
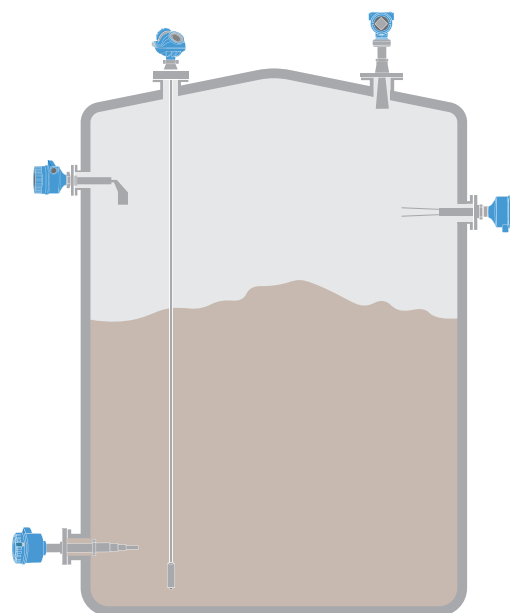
Figure 5.2.1: Guided wave radar, non-contacting radar and level switches on a seed silo

Application characteristics and challenges
- DC is usually <2
- Build-up of material occurs
- Silos may have diameters greater than 15 m (50 ft) and be over 40 m (132 ft) tall
- Dusty environment

Suitable Technologies	
Technology	Installation Guidelines
Non-contacting radar	Chapter 7
Guided Wave Radar	Chapter 6
Level Switches	Chapter 10
Differential Pressure Level	Chapter 9

5.2.2 Flour storage

Primary function of application

There are two main varieties of flour storage:

- A flour mill where the flour is stored prior to being delivered or packed

- In production sites, such as a bakery, where it is stored before being transferred into production.
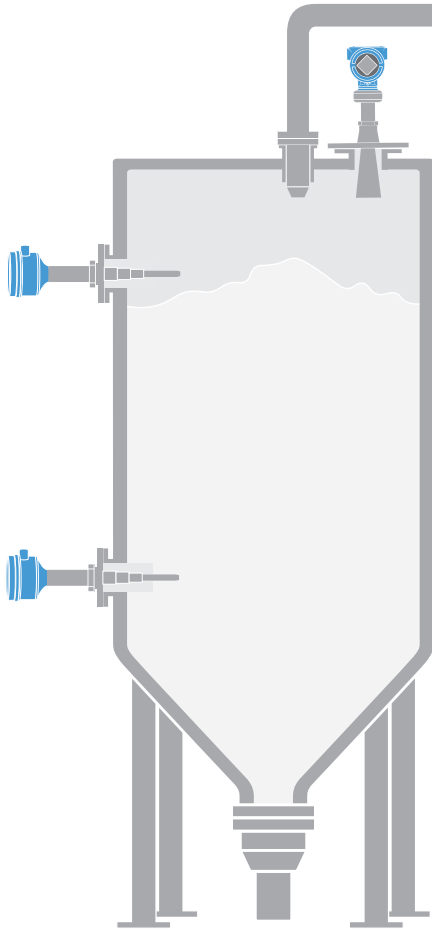
Figure 5.2.2: Flour silo with non-contacting radar

Application characteristics and challenges

- Powder

- DC is <2

- Flour tends to stick to the silo walls, creating build-ups and rat holes

- Can have low bulk density

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

5.2.3 Sugar storage

Primary function of application

There are two main varieties of sugar storage:

- Sugar production plants where sugar, as the final product, is stored prior to being delivered or packaged.

- Food production sites where sugar is stored prior to being transported further into production
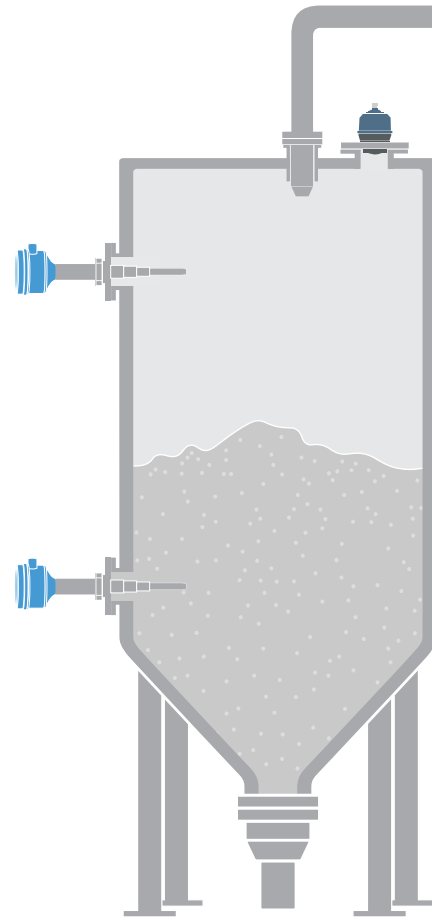
Figure 5.2.3: Sugar storage tank with non-contacting radar and level switches

Application characteristics and challenges

- Sugar and sugar dust tend to accumulate, creating build ups and rat holes

- DC is <2

- The materials' sticky nature makes the sugar stick to the antenna or other system parts

- Dusty environment

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

5.2.4 Grain storage

Primary function of application

Grain is delivered by truck or rail to the plant where it is loaded into storage silos prior to being analyzed, pre-cleaned and transferred into production.
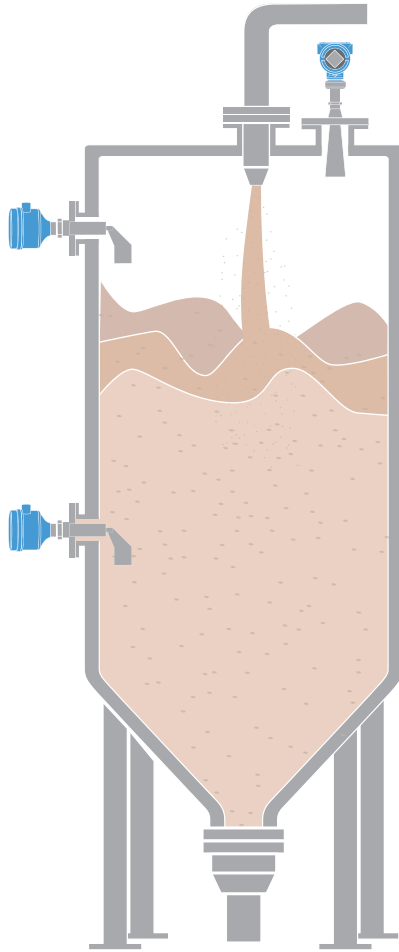
Figure 5.2.4: Non-contacting radar on grain silo

Application characteristics and challenges

- Dust is generated during filling operations
- Different grades of wheat should not be mixed
- The large sizes of the silos, normally with multiple emptying points, promote the creation of irregular formations and build-up inside the silo, making it difficult to measure accurately

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

5.2.5 Coal storage / Bunker / Coal Blending Facility

Primary function of application

The coal goes through a moderate grinding process and then is stored in a coal bunker.

Figure 5.2.5: Non-contacting radar and level switches on a coal storage tank

Application characteristics and challenges

- The storage size and the dusty conditions make it difficult to accurately measure the amount of coal in the bunker or blending facility
- Safety risks to personnel who enter the storage areas to "guesstimate" levels

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7

5.2.6 Coal Hoppers / Coal Day Vessels / Coal Silos / Crushers

Primary function of application

Coal is transported by conveyor and tripper cars to coal hoppers. These hoppers feed ball mills which in turn feed the pulverized coal to the boilers. There will be at least one hopper for each boiler. Typically there are two boilers per unit.
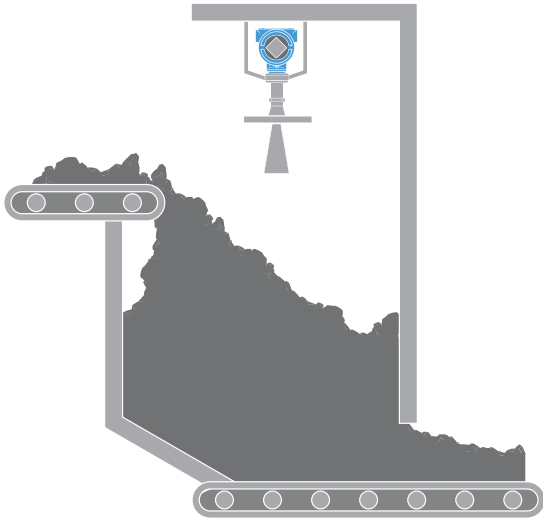
Figure 5.2.6: Non-contacting radar on a secondary crusher stage

Application characteristics and challenges
- Large and very dusty
- Coal is critical for the continuous process and it is necessary to monitor and control the actual volume of coal to prevent process stoppages

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7

5.2.7 Fly ash

Primary function of application

The contents of the fly ash hopper are pneumatically conveyed to a fly ash storage silo. The silo is emptied onto trucks that then haul the material off for use in other applications.
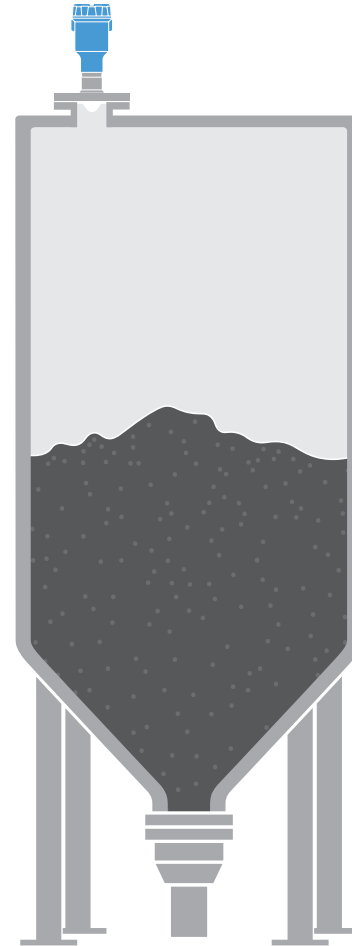
Figure 5.2.7: Fly ash level with non-contacting radar

Application characteristics and challenges
- Fly ash derived from burning coal creates a very dusty environment and tends to stick, creating build-up inside the silo
- Density and dielectric constant of fly ash is low
- Fly ash silos are typically very large to allow continuous flow from the hoppers

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

5.2.8 PP/PE Storage silos

Primary function of application

The final granular product is stored in silos before being shipped to plastic product manufacturing plants or packed in bags.
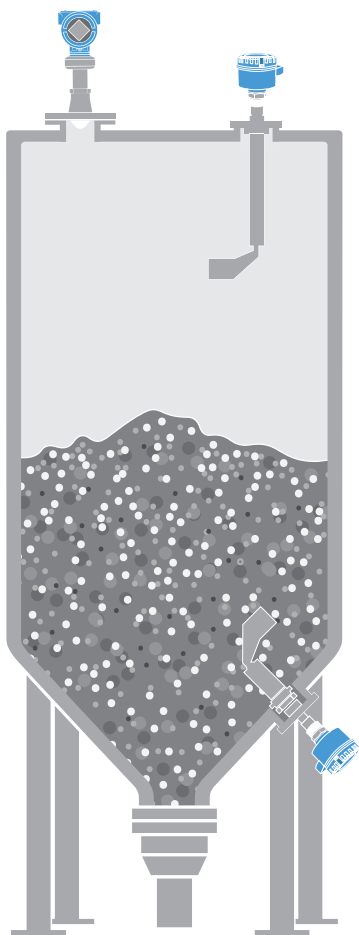
Figure 5.2.8: Polyethylene storage silo with non-contacting radar and level switches

Application characteristics and challenges

- PP and PE pellets can have a low dielectric constant

- Dusty environment

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7
Level Switches	Chapter 10
Differential pressure	Chapter 9

Best practice

Non-contacting radar with higher frequency may be used for small size vessels and for control. Guided wave radar may be used for small size vessels for control purposes with Probe End Projection functionality enabled.

5.2.9 Plastic powder silos

Primary function of application

PVC powder is stored in silos prior to being delivered or packed. The silos can be very large in size containing thousands of tons per silo.
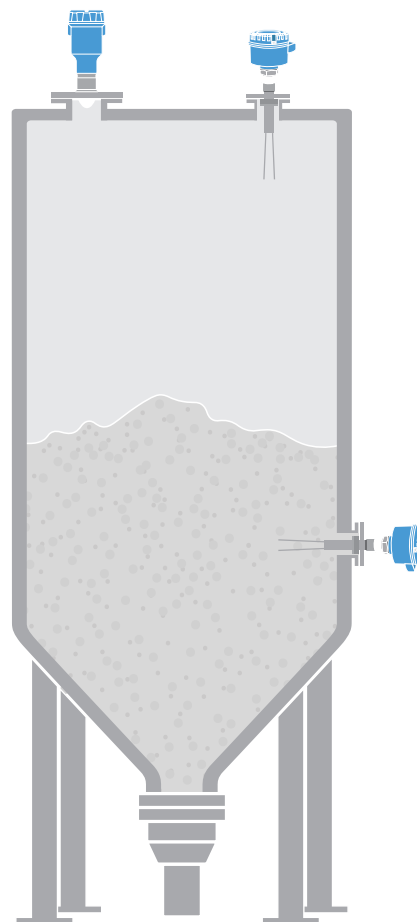
Figure 5.2.9: Plastic powder silo with non-contacting radar and level switches

Application characteristics and challenges

- Great amount of dust generated during filling process

- Relatively low dielectric constant makes measuring the true volume of the stored PVC powder very challenging

Suitable Technologies	
Technology	**Installation Guidelines**
Guided Wave Radar	Chapter 6
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

Best practice

Guided Wave Radar and Non-Contacting Radar for small size vessels and for control.

5.2.10 Fine ore storage

Primary function of application

Fine ore is stored in silos before being processed. The silos hold a supply of fine ore that can be continuously supplied to a furnace in the event of a problem downstream in the ore handling system.
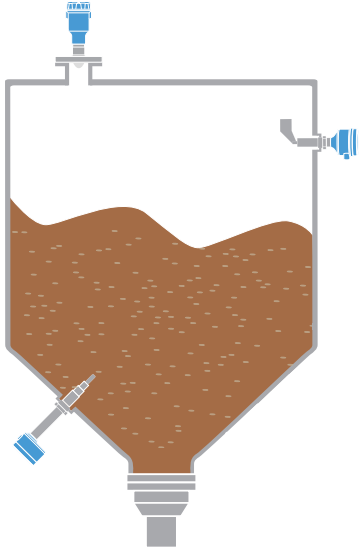
Figure 5.2.10: Fine ore storage silo with non-contacting radar and level switches -

Application characteristics and challenges

• Need for continuous supply of material

• Dusty environment

Suitable Technologies	
Technology	Installation Guidelines
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

5.2.11 Burnt limestone storage

Primary function of application

The burnt limestone is stored in silos before being processed
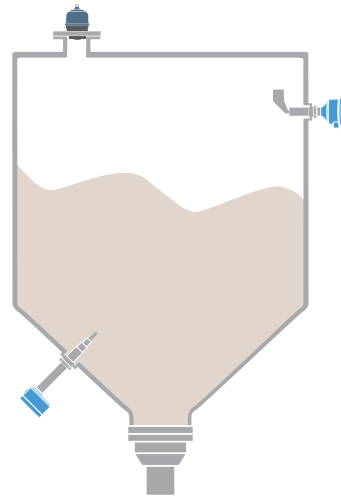
Figure 5.2.11: Burnt limestone storage tank with non-contacting radar and level switches

Application characteristics and challenges

• Burnt limestone generates dust during the filling process and tends to stick to the silo walls, creating rat holes and build-up

• May have low bulk density

Suitable Technologies	
Technology	Installation Guidelines
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

5.2.12 Slacked lime powder silo

Primary function of application

Slacked lime is stored in silos prior to being packed and shipped.
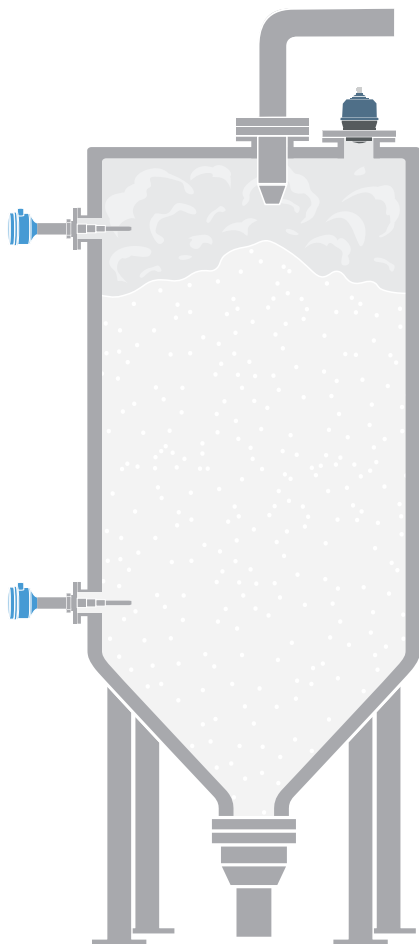
Figure 5.2.12: Slacked lime powder silo with non-contacting radar and vibrating level switches

Application characteristics and challenges

- Slacked lime is a very fine powder that generates a great deal of dust during filling and emptying

- Tends to become sticky, creating rat holes and build-up

- The size of the lime silos vary from site to site and even within the same site

- May have low bulk density

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

Best practice

Non-contacting radar for small/mid size vessels and for control.

5.2.13 Chemical/detergent dry ingredients storage

Primary function of application

Raw materials are stored in silos before being transferred to the production process.
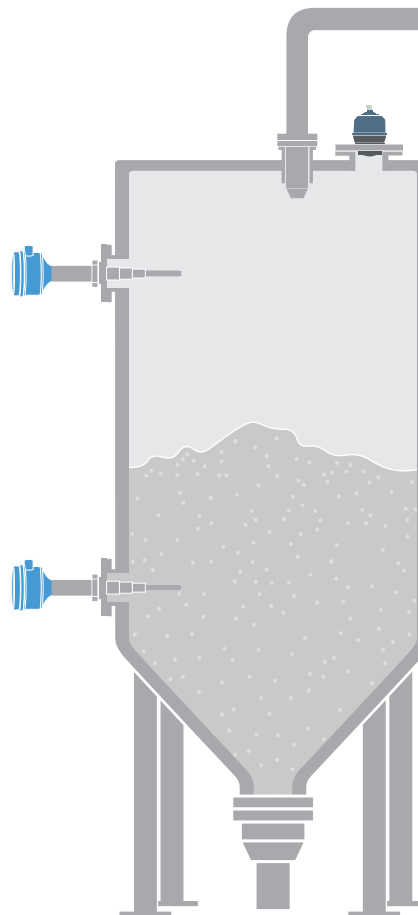
Figure 5.2.13: Detergent dry ingredients storage tank with non-contacting radar and level switches

Application characteristics and challenges

As the raw materials are processed together, it is important to accurately measure the content of the silos to ensure continuous production

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar	Chapter 7
Level Switches	Chapter 10

Best practice

The latest Non-contacting wave radar transmitters are the first choice, due to their high sensitivity and unique software algorithms, they are well suited to control the level in this kind of environment. The air purging option will keep the antenna clean from dust and condensation. In cases where the radar is installed on silos for dryer wood chips, the all-PTFE process seal antenna will be an alternative to the antennas with integrated air purging, maintaining the antenna clean.

5.2.14   Lime, cement, starch storage

Primary function of application

Material is stored in tanks that vary in size for bulk shipping, bagging or to store income material..

Figure 5.2.14: Corn surge bin with guided wave radar and paddle switches

Application characteristics and challenges

- Dusty solids measurement

- Some forms of lime or cement can be very dense, so taller vessels may require non-contacting radar due to excessive pull forces

- DC varies from 2 to 10. Lighter, more powder-like forms tend to have lower dielectric constants (<2). Ex: slaked lime, white cement. Heavier forms such as clinker cement and limestone, tend to have higher DCs

Suitable Technologies	
Technology	**Installation Guidelines**
Non-contacting radar, with PTFE cover to protect from dust	Chapter 7
Guided wave radar, single flexible probe	Chapter 6
Vibrating fork switch	Chapter 10
Vibrating rod switch	Chapter 10
Paddle switch	Chapter 10
Capacitance switch	Chapter 10

5.2.15   Coke

Coal is stored in silos that feed the coke oven which then feeds the coke to the furnace. There will be at least one silo for each furnace. Coke may be mixed with ore in the sintering process. If the coal silos are empty, the furnace would need to be shut down. As the fuel is critical for the process, end-users need to control and monitor the actual level in the silos, to prevent process stoppage.

Figure 5.2.15: Coke storage tank with non-contacting radar, paddle and capacitance switches

Application characteristics and challenges

- Can be dusty

- Often stored in open piles

- DC varies: 2 to 8

- Particle size >10 mm

Suitable Technologies	
Technology	Installation Guidelines
Non-contacting radar	Chapter 7

5.2.16   Coal

Final or intermediate product in coal processing can be stored in warehouses, shelters or bunker storage tanks. These warehouses not only store the material, but they also protect it from rain and wind keeping it dry and contained.
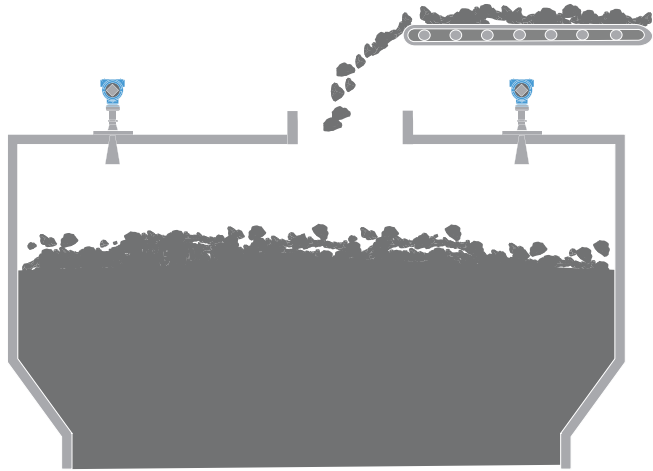
Figure 5.2.16: Coal bunker with non-contacting radars, paddle and capacitance switches

Application characteristics and challenges
- Can be dusty, but often sprayed with water to minimize static charge

Suitable Technologies	
Technology	Installation Guidelines
Non-contacting radar without PTFE cover	Chapter 7

5

CHAPTER 6
GUIDED WAVE RADAR INSTALLATION GUIDELINES

6

6 | Guided Wave Radar Installation Guidelines

6 Guided Wave Radar Installation Guidelines

There are three Rosemount guided wave radar level transmitters; Rosemount 5300 series, Rosemount 3300 series and Rosemount 3308 series. The Rosemount 5300 can be used for the same applications as the Rosemount 3300, plus in applications with longer ranges, lower dielectrics, or where Foundation™ Fieldbus is needed. The Rosemount 3308 can be used in most liquid storage and monitoring applications, where wireless connectivity is needed. Table 3.1.1 on Chapter 3 also provides some guidance regarding which series of guided wave radar to choose for a specific application.

The following chapter will go through some installation guidelines for the Rosemount 5300. For more details on the Rosemount 3300 and Rosemount 3308, please see the Product Data Sheets on Emerson.com.

6.1   Probe selection

There are seven different probe types for Rosemount Guided Wave Radars. The single lead is the preferred choice for most applications. The following guidelines should be used to choose the appropriate probe for the Rosemount guided wave radar transmitters (Consult your local Emerson representative for more information):

KEY
🟢 Good
🟡 Application dependent
🔴 Not recommended

Measurements	Rigid single lead	Segmented rigid single lead	Flexible single lead	Co-axial	Large co-axial
Level	🟢	🟢	🟢	🟢	🟢
Interface (liquid/liquid)	🟢	🟢	🟢	🟢	🟢
Changing density	🟢	🟢	🟢	🟢	🟢
Changing dielectric(1)	🟢	🟢	🟢	🟢	🟢
Wide pH variations	🟢	🟢	🟢	🟢	🟢
Pressure changes	🟢	🟢	🟢	🟢	🟢
Temperature changes	🟢	🟢	🟢	🟢	🟢
Condensing vapors	🟢	🟢	🟢	🟢	🟢
Bubbling/boiling surfaces	🟢	🟢	🟡	🟢	🟢
Foam (mechanical avoidance)	🔴	🔴	🔴	🟡	🟡
Foam (top of foam measurement)	🟡	🟡	🟡	🔴	🔴
Foam (foam and liquid measurement)	🟡	🟡	🟡	🔴	🔴
Clean liquids	🟢	🟢	🟢	🟢	🟢
Liquid with very low dielectric constants	🟢	🟢	🟢[2]	🟢	🟢
Coating/sticky liquids[3]	🟡	🟡	🟡	🔴	🟡
Crystallizing liquids	🟡	🟡	🟡	🔴	🔴
Solids, granules, powders	🟡	🟡	🟢	🔴	🔴
Fibrous liquids	🟢	🟢	🟢	🔴	🔴
Probe is close (<12 in./30 cm) to tank wall / disturbing objects	🟡	🟡	🟡	🟢	🟢
Probe might touch tank wall nozzle or disturbing objects	🔴	🔴	🔴	🟢	🟢
Turbulence	🟢	🟢	🟡	🟢	🟢
Turbulent conditions causing breaking forces	🔴	🔴	🟡	🔴	🔴
Tall narrow nozzles	🟡	🟡	🟡	🟢	🟢
Angled or slanted surface (viscous or solids materials)	🟢	🟢	🟢	🔴	🔴
Liquid or vapor spray might touch probe above surface	🔴	🔴	🔴	🟢	🟢
Disturbing electromagnetic interference in tank	🟡	🟡	🟡	🟢	🟢
Cleanability of probe	🟢	🟢	🟢	🟡	🟡

Table 6.1.1: Probe selection guide

[1] For overall level applications, a changing dielectric has no effect on the measurement. For interface measurements, a changing dielectric for the top fluid will degrade the accuracy of the interface measurement.
[2] Limited measuring range.
[3] For viscous or sticky applications, it is not recommended to use centering discs mounted along the probe.

6.2 Blind zones

The measuring range depends on probe type, dielectric constant of the product and installation environment, and is limited by the blind zones at the very top and bottom of the probe. In the blind zones, the accuracy exceeds ±1.18 in. (30 mm), and measurements may not be possible. Measurements close to blind zones will have reduced accuracy.

	Dielectric constant	Rigid Single Lead	Flexible Single Lead	Segmented	Coaxial	Large coaxial
Upper Blind Zone	80	3.9 in. (10cm)	3.9 in. (10cm)	3.9 in. (10cm)	2 in. (5cm)	0 cm
	2	3.5 in. (9cm)	3.5 in. (9cm)	3.5 in. (9cm)	3.5 in. (9 cm)	0 cm
Reduced Accuracy	80	0.4 in. (1cm)	0.4 in. (1cm)	0.4 in. (1cm)	NA	NA
	2	4.7 in. (12cm)	4.7 in.(12cm)	4.7 in (12cm)	NA	NA
Lower Blind Zone	80	NA	NA	NA	0.8 in. (2 cm)	0.8 in. (2 cm)
	2	NA	NA	NA	5.1 in.(13cm)	4.3 in. (11 cm)

Table 6.2.1: Blind zones for different probe types and dielectric constants, see figure 6.2.1 for illustration of blind zones
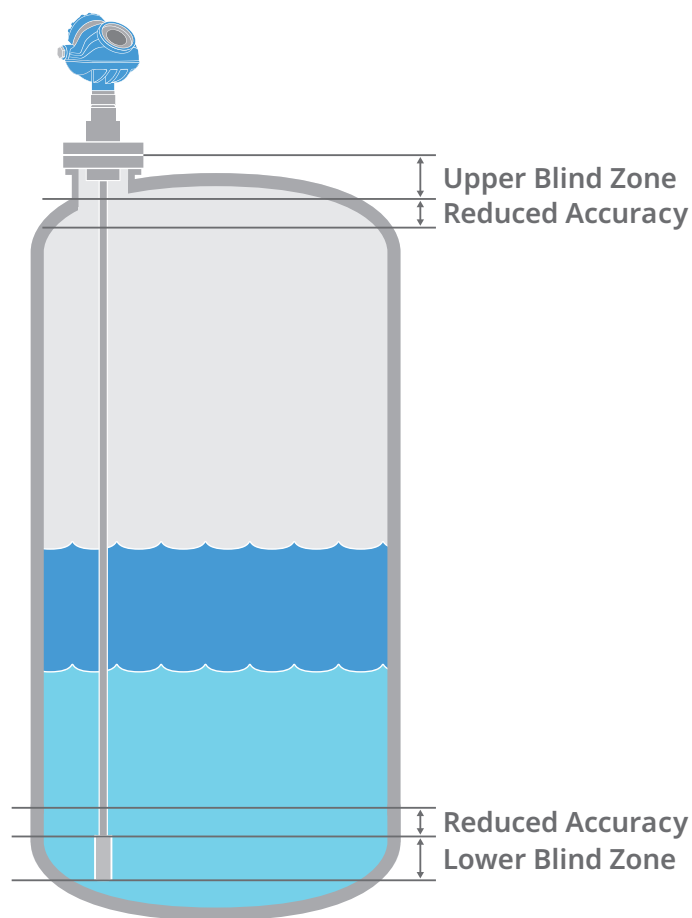
Figure 6.2.1: Illustration showing how the measuring range is related to the blind zones

6.3 Process characteristics

The Rosemount 5300 Series has high sensitivity because of its advanced signal processing and high signal to noise ratio. This makes it able to handle various disturbances. However, the following circumstances should be considered before mounting the transmitter.

Coating
Heavy coating of the probe should be avoided since it may decrease the sensitivity of the transmitter and lead to measurement errors. In viscous or sticky applications, periodic cleaning may be required. For viscous or sticky applications, it is important to choose a suitable probe:

Coaxial	Large coaxial	Twin Lead	Single Lead
Maximum viscosity			
500 cP	1500 cP	1500 cP	8000 cP [1,2]
Coating/build-up			
Coating not recommended	Thin coating allowed but no bridging	Thin coating allowed but no bridging	Coating allowed

Table 6.3.1: Probe type guide for different product viscosities

[1] *Consult your local Emerson representative for agitation/ turbulence and high viscous products.*
[2] *When using probes in viscous or crystallizing media the nozzle area should be kept hot so that deposition near the top of the probe is minimized. Consider using HP or standard probes in such applications. For viscous or sticky applications, it is not recommended to use centering discs mounted along the probe.*

Maximum measurement error due to coating is 1-10% depending on probe type, dielectric constant, coating thickness and coating height above product surface.

The Signal Quality Metrics (SQM) diagnostic option can give an indication of how good the surface signal is compared to the noise, and when to clean the probe.

Bridging
Heavy product coating results in bridging between the pipe and inner rod for coaxial probes, and may cause erroneous level readings, so it must be prevented. A single lead probe is recommended in these situations.

Foam
Rosemount 5300 Series Radar Transmitter measurement in foamy applications depends on the foam properties; light and airy or dense and heavy, high or low dielectrics, etc. If the foam is conductive and dense, the transmitter may measure the surface of the foam. If the foam is less conductive the microwaves may penetrate the foam and measure the liquid surface.

Vapor
In some applications, such as high pressure boiling water, there is a heavy vapor above the product surface that could influence the level measurement. The Rosemount 5300 can be configured to compensate for the influence of vapor.

Boiling hydrocarbons
For products with very low dielectric constants, such as boiling hydrocarbons and solids, the threshold may need to be lowered, and/or the Probe End Projection (PEP) function activated.

6.4 Measuring range (Rosemount 5300 Guided Wave Radar)

The measuring range differs depending on probe type and characteristics of the application. Table 6.4.1 a-d can be used as a guideline for clean liquids.

Rigid single lead / Segmented rigid single lead
Maximum measuring range
9 ft 10 in. (3 m) - for 8 mm probes 19 ft 8 in. (6 m) - for 13 mm probes 32 ft 9 in (10m) - for 13 mm probes (Segmented)
Minimum dielectric constant at max measuring range
1.4 (1.25 if installed in a metallic bypass or stilling well) [1, 2]

Table 6.4.1a: Measuring range guide for rigid single lead probes

Flexible single [1]
Maximum measuring range
164 ft (50 m)
Minimum dielectric constant at maximum measuring range
1.4 up to 49 ft (15 m) [1] 1.8 up to 82 ft (25 m) [1] 2.0 up to 115 ft (35 m) [1] 3 up to 138 ft (42 m) 4 up to 151 ft (46 m) 6 up to 164 ft (50 m)

Table 6.4.1b: Measuring range guide for flexible single lead probes

Coaxial	Large Coaxial
Maximum measuring range	
19 ft 8 in. (6 m)	19 ft. 8 in. (6 m)
Minimum dielectric constant at maximum measuring range	
1.2 (Standard) 1.4 (HP/C) 2.0 (HTHP)	1.2 (Standard) HP/C 1.4 HTHP N/A

Table 6.4.1c: Measuring range guide for coaxial probes

The maximum measuring range differs based on application according to:

- Disturbing objects close to the probe
- Media with higher dielectric constant has better reflection and a longer measuring range
- Surface foam and particles in the tank atmosphere might affect measuring performance
- Heavy coating / contamination on the probe may reduce the measuring range and cause erroneous level readings
- Disturbing EMC environment in tank
- Tank material (e.g. concrete or plastic) for measurements with single lead probes

6.5 Interface

Rosemount 5302 is the ideal choice for measuring the level and interface of materials such as oil and water or other liquids with significant dielectric differences.

Rosemount 5301 can also be used for interface measurement in applications where the probe is fully submerged in the liquid.
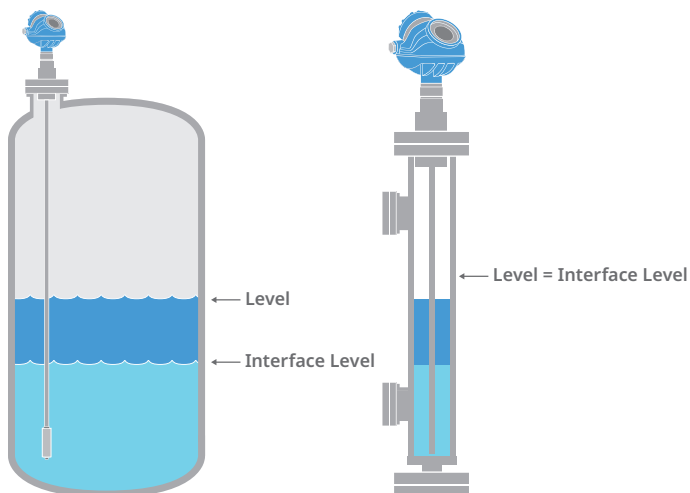
Figure 6.5.1: Interface measurement with a Rosemount 5302 and a Rosemount 5301 (fully submerged probe).

For measuring interface level, the transmitter uses the residual wave of the first reflection. Part of the wave, not reflected at the upper product surface, continues until it is reflected at the lower product surface. The speed of this wave depends fully on the dielectric constant of the upper product. To measure interface, the following criteria have to be fulfilled:

The dielectric constant of the upper product must be known and should be constant. The Rosemount Radar Master software has a built-in dielectric constant calculator to assist in determining the dielectric constant of the upper product

- The upper product must have a lower dielectric constant than the lower product to have a distinct reflection
- The difference between the dielectric constants for the two products must be greater than 6
- The maximum dielectric constant for the upper product: 10 for the coaxial and large coaxial probe, and 7 for the single lead probes
- The maximum interface distance is 164 ft (50m) minus the maximum product thickness. However, characteristics may vary between the different applications

The maximum allowable upper product thickness/measuring range is primarily determined by the dielectric constants of the two liquids.

Target applications include interfaces between oil / oil-like and water / water-like liquids with a low (<3) dielectric constant for the upper product and a high (>20) dielectric constant for the lower product.

For such applications, the maximum measuring range is limited by the length of the coaxial, and rigid single lead probes.

For flexible probes, the maximum measuring range is reduced by the maximum upper product thickness, according to the diagram below. However, characteristics may vary between the different applications.
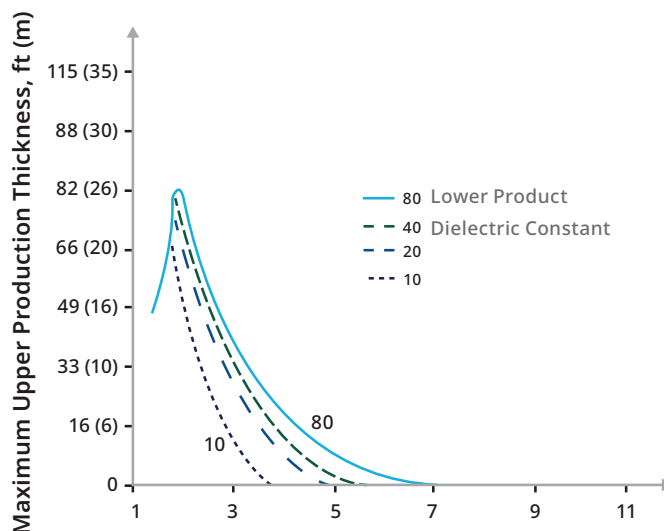
Figure 6.5.2: Maximum upper product thickness for the flexible single lead probe

> **NOTE!**
> Maximum distance to the interface = 164 ft.(50 m) - maximum upper product thickness.

Sometimes an emulsion layer (mix of the products) forms between the two products and can affect interface measurements.

For assistance with emulsion applications, consult your local Emerson representative.

6.6 Vessel characteristics

Heating coils, agitators

Because the radar signal is transmitted along a probe, the Rosemount 5300 Level Transmitter is generally not affected by objects in the tank. Avoid physical contact with metallic objects when single lead probes are used.

Avoid physical contact between probes and agitators, as well as applications with strong fluid movement, unless the probe is anchored. If the probe is able to move 1 ft. (30 cm) from any object, such as an agitator, during operation, the probe tie-down is recommended.

To stabilize the probe for side forces, a weight may be hung at the probe end (flexible probes only) or fix/ guide the probe to the tank bottom.

Tank shape

The guided wave radar transmitter is insensitive to tank shape. Since the radar signal travels along a probe, the shape of the tank bottom has virtually no effect on the measurement performance. The transmitter can handle flat or dish-bottom tanks.

6.7 Process connection

The Rosemount 5300 Series has a threaded connection for easy mounting on a tank roof. It can also be mounted on a nozzle by using different flanges.
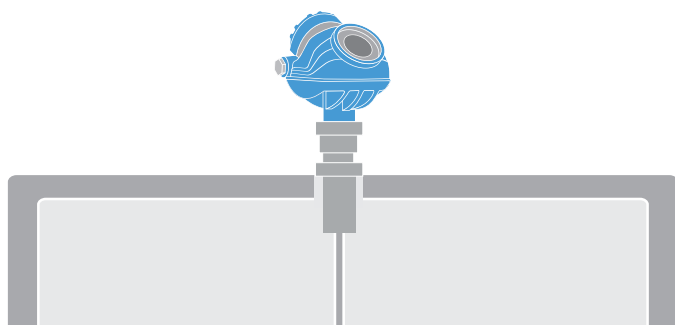
Figure 6.7.1: Mounting on tank roof using threaded connection
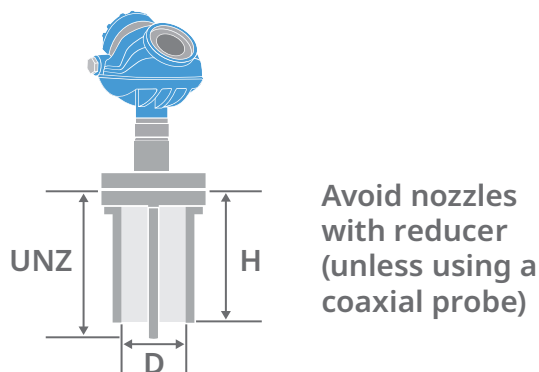
Figure 6.7.2: Mounting in nozzles

The transmitter can be mounted in nozzles by using an appropriate flange. The nozzle sizes given in table 6.7.1 show the recommended dimensions. For small nozzles, it may be necessary to increase the upper null zone (UNZ) to reduce the measuring range in the upper part of the tank. Amplitude threshold adjustments may also be needed in this case. A Trim Near Zone is recommended in most nozzle installations, for example, when there are disturbing obstacles in the near zone.

> **NOTE!**
> The probe should not contact the nozzle, with the exception of the coaxial probe. If the nozzle diameter is less than recommended, the measuring range may be reduced.

Primary function of application

Serves to detect when clean out is necessary to ensure vessel operating at maximum capacity and prevent sand being drawn in to lines.

	Single (rigid/ segmented/ flexible)	Coaxial /Large coaxial
Recommended nozzle diameter (D)	6 in. (150 mm)	> Probe diameter
Minimum nozzle diameter (D)[1]	2 in. (50 mm)	> Probe diameter
Recommended nozzle height (H)[2]	4 in. + nozzle diameter[3]	N/A

[1] The Trim Near Zone function may be necessary or an Upper Null Zone setup may be required to mask the nozzle.
[2] Longer nozzles may be used in certain applications. Consult your local Emerson representative for details.
[3] When using single flexible probes in tall nozzles, it is recommended to use the Long Stud (LS).

A long stud - 10 in. (250 mm) - is recommended for single flexible probes in a tall nozzle.
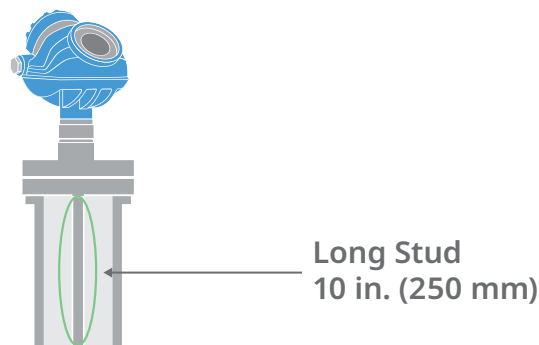
Figure 6.7.3: A single flexible probe with a long stud

NOTE!
For single lead probes, avoid 10-in. (250 mm)/DN250 or larger diameter nozzles, especially in applications with a low dielectric constant. An alternative is to install a smaller nozzle inside the nozzle.

6.8 Free space

For easy access to the transmitter, make sure it is mounted with sufficient service space. For maximum measurement performance, the transmitter should not be mounted close to the tank wall or near other objects in the tank.

If the probe is mounted close to a wall, nozzle or other tank obstruction, noise may appear in the level signal. The minimum clearance shown in table 6.8.1 and table 6.8.2 is recommended
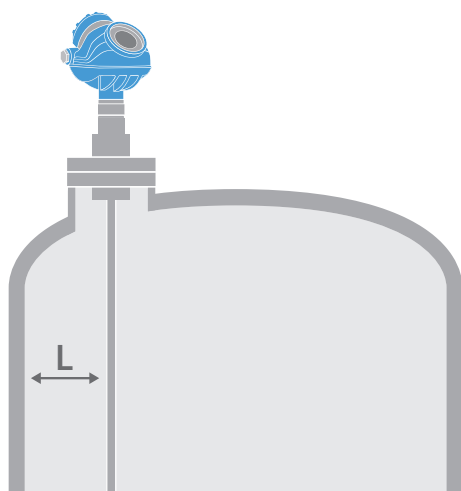
Figure 6.8.1: Free space requirement

Coaxial/large coaxial
0 in. (0 mm)

Table 6.8.1: Recommended minimum free space L to tank wall or other objects in the tank

Rigid / segmented / flexible single	
4 in. (100 mm)	Smooth metal wall
20 in. (500 mm)[1]	Disturbing objects such as pipes and beams concrete or plastic tank walls rugged metal tank walls

Table 6.8.2: Recommended minimum free space L to tank wall or other objects in the tank for single lead probes

[1] *When measuring in low DC (around 1.4). For higher DC, the recommended free space is lower.*

6.9 Insulated tanks

When the Rosemount 5300 is installed in high temperature applications, consider the maximum ambient temperature. Tank insulation should not exceed 4 in. (10 cm).
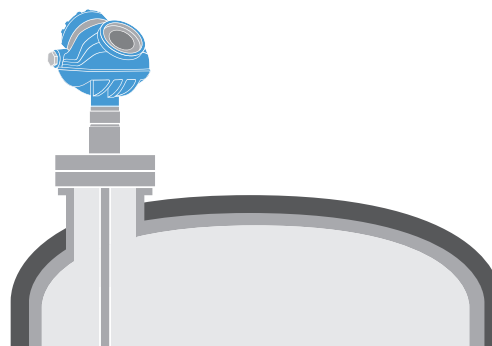
Figure 6.9.1 Tank insulation
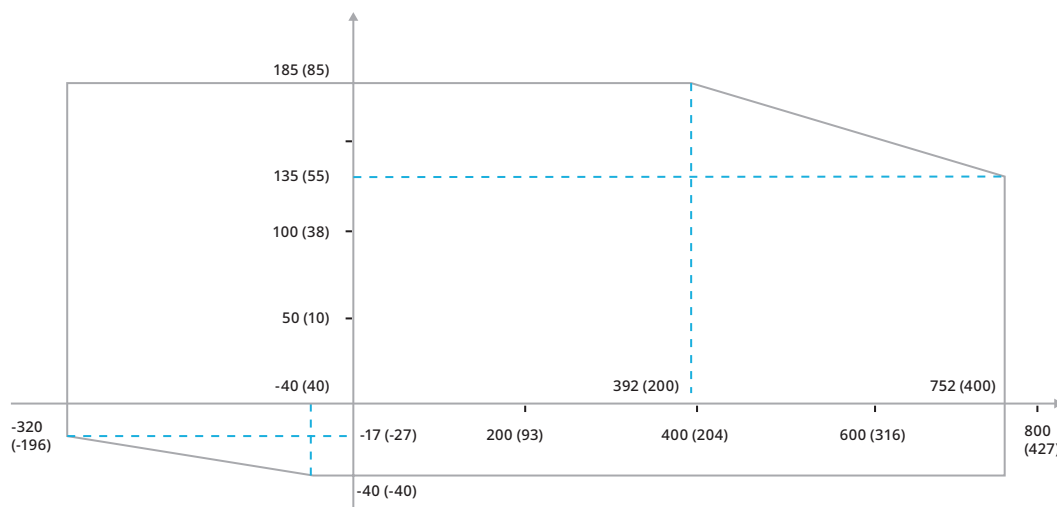
Figure 6.9.2 Ambient temperature vs. process temperature

6.10 Mounting position

For liquids

Tank conditions are recommended to be carefully considered when finding the appropriate mounting position for the transmitter. The transmitter should be mounted so the influence of disturbing objects is reduced to a minimum.

In case of turbulence, the probe may need to be anchored to the bottom.
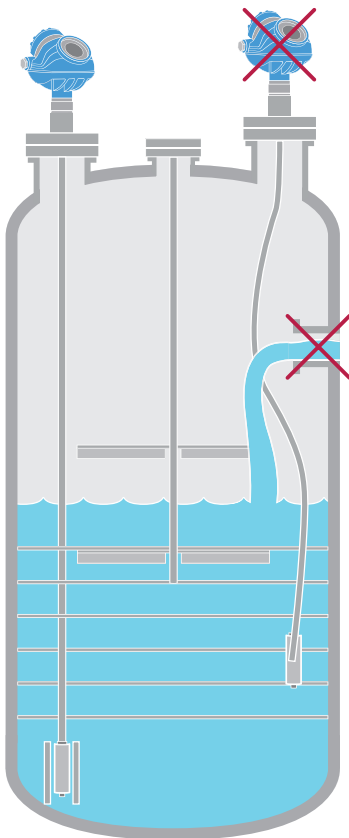
Figure 6.10.1: Mounting position in liquids

When mounting the transmitter the following guidelines should be considered:

- Do not mount close to inlet pipes
- Do not mount close to agitators. If the probe can move to within 12 in. (30 cm) away from an agitator, a probe tie-down is recommended
- If the probe tends to sway from the turbulent conditions in the tank, the probe should be anchored to the tank bottom
- Avoid mounting near heating coils
- The nozzle should not extend into the tank
- The probe should not come into contact with the nozzle or other objects in the tank
- Position the probe so it is subject to a minimum of lateral force

> **NOTE!**
> Violent fluid movements can cause forces that could break rigid probes.

For solids
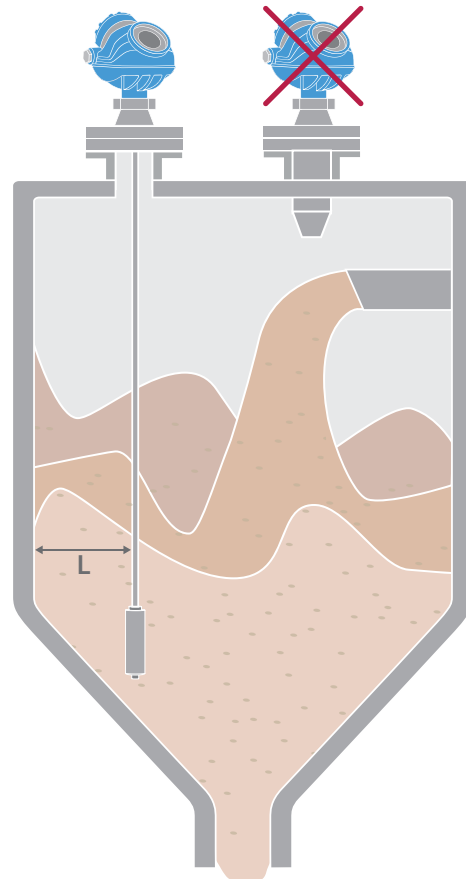
Figure 6.10.2: Mounting position in solids

Consider the following guidelines when mounting the transmitter:

- Do not mount near inlet pipes in order to avoid product filling on the probe
- Regularly check the probe for defects
- It is recommended that the vessel be empty during installation
- For concrete vessels, the distance (L) between the probe and the wall should be at least 20 in. (500 mm)
- Stabilize the probe for side forces, by attaching the probe to the tank bottom For solids, use the 0.24 in. (6 mm) probe, because of the higher tensile strength. The probe should have a sag of >=1 in./100 in. (1 cm/2.54 m) to prevent probe damage
- Avoid anchoring in solids tanks over 98 ft (30 m) in height since tensile loads are much stronger for anchored probes

- Product build-up on the silo walls near the probe may interfere with measurements. Choose a mounting position where the probe is not in contact with, or close to, the product build-up

Material	Tensile load for 0.16 in. (4 mm) flexible single lead probe, lb (kN)				Tensile load for 0.16 in. (4 mm) flexible single lead probe, lb (kN)			
	Probe length 49 ft (15 m)		Probe length 115 ft (35 m)		Probe length 49 ft (15 m)		Probe length 115 ft (35 m)	
	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)
Wheat	670 (3)	1120 (5)	1800 (8)	4500 (20) Exceeds tensile strength limit	900 (4)	1690 (7.5)	2810 (12.5)	6740 (30) Exceeds tensile strength limit
Polypropylene pellets	340 (1.5)	670 (3)	810 (3.6)	2360 (10.5)	450 (2)	920 (4.1)	1190 (5.3)	3510 (15.6)
Cement	340 (1.5)	670 (3)	810 (3.6)	2360 (10.5)	450 (2)	920 (4.1)	1190 (5.3)	3510 (15.6)

Table 6.10.1: Pulling force on probe installed in tanks with different products

6.11 Mounting in non-metallic vessels

For optimal single lead probe performance in non-metallic (plastic) vessels, the probe must be mounted with a metal flange, or screwed in to a metal sheet (d>8 in./200 mm), if the threaded version is used.

Metal flange d> 2 in./DN50

Metal Sheet d> 8 in./200 mm
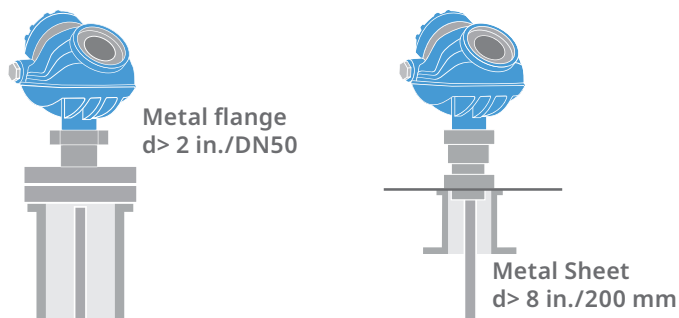
Figure 6.11.1: Mounting in non-metallic vessels

Electromagnetic disturbances should be kept to a minimum since they may affect measurement performance

Metal
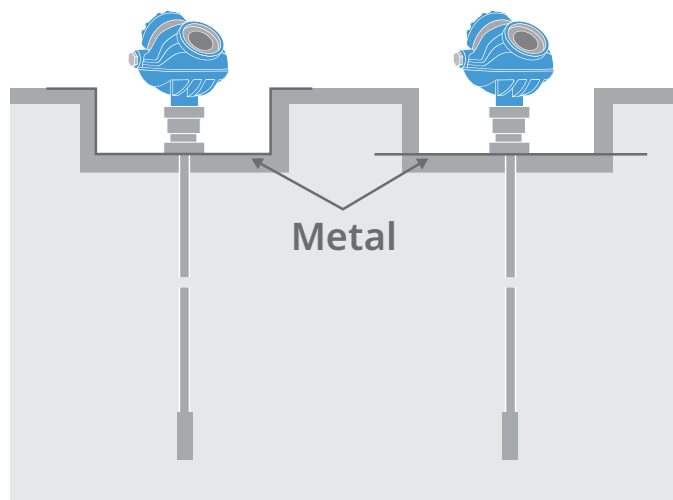
Figure 6.11.2: Installation in concrete silos

6.12 Considerations for solids applications

The flexible single lead probe is recommended for solids and is available in two versions to handle different loads and lengths:

- 0.16 in. (4 mm) diameter tensile strength is minimum 2698 lb (12 kN) Collapse load is maximum 3597 lb (16 kN)

- 0.24 in. (6 mm) diameter Tensile strength is minimum 6519 lb (29 kN Collapse load is maximum 7868 lb (35 kN)

- Keep the following in mind when planning installation of the Rosemount 5300 in solids applications:

- There might be considerable down-pull forces on silo roofs caused by the media, so the silo roof must withstand the maximum probe tensile load

- The tensile load depends on silo size, material density, and the friction coefficient. Forces increase with the buried length, the silo, and probe diameter

- In critical cases, such as for products with a risk for build-up, use a 0.24 in. (6 mm) probe

- Depending on position, forces on probes are two to ten times greater on probes with tie-down, than on probes with ballast weights[1]

[1] The weight should not be fixed for probe 100 ft (30 m) or longer.

Guidelines for the tensile load from free-flowing solids acting on a suspended probe without any tie-down or weight in a smooth metallic wall silo as shown in table 6.10.1. A safety factor of 2 is included for the figures. Consult your local Emerson representative for more information.

> **NOTE!**
> For environments where electrostatic discharges (plastics) are likely to occur, it is recommended that the probe end is grounded.

6.13 Mounting in chamber/ stilling well

Suitable Technologies	
Technology	**Installation Guidelines**
Chambers	See Chapter 11

The chamber is also known as bridle, side pipe, bypass pipe, and cage. Dimensioning the chamber correctly and selecting the appropriate probe is key to the success in these applications.

To prevent the probe from contacting the wall, centering discs are available for the rigid single and flexible single probes.

The disc is attached to the end of the probe, and thus keeps the probe centered in the chamber.

Make sure that the probe does not come into contact with the chamber wall, e.g. by using a centering disc.
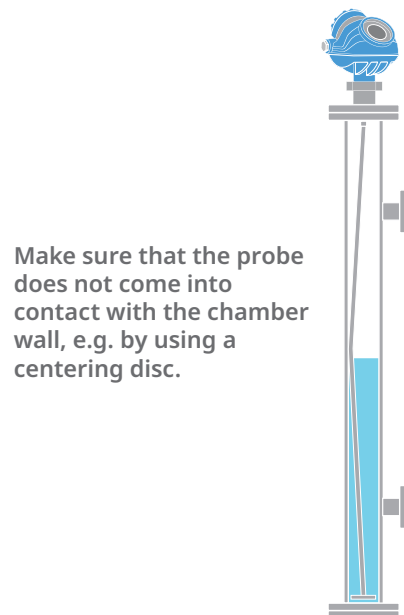
Figure 6.13.1: Prevent probe from coming into contact with the chamber/pipe wall

> **NOTE!**
> To avoid disturbances from an object near the pipe, metal-pipes are preferred, especially in applications with low dielectric constant.
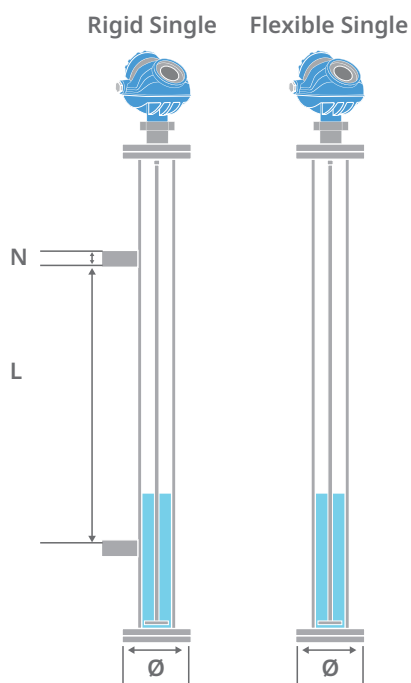
Figure 6.13.2: Mounting single probe in chamber/still pipe

Inlet pipe diameter N<Ø. Effective measuring range L<=12 in. (300 mm).

Probe type	Recommended diameter	Minimum diameter
Rigid single / segmented rigid single	3 or 4 in. (75 or 100 mm)	2 in. (50 mm)
Flexible single	4 in. (100 mm)	Consult your local Emerson representative
Coaxial	3 or 4 in. (75 or 100 mm)	1.5 in. (37.5 mm)
Large coaxial	3 or 4 in. (75 or 100 mm)	2 in. (50 mm)

Table 6.13.1: Recommended and minimum chamber / still pipe diameter for different probes

The recommended chamber diameter is 3 in. (75 mm) or 4 in. (100 mm). Chambers with a diameter less than 3 in. (75 mm) may cause problems with build-up and it may also be difficult to avoid contact between chamber wall and probe. Chambers larger than 6 in. (150 mm) can be used but provide no advantages for radar measurement.

It is recommended that single or large coaxial probes are used with the Rosemount 5300 Series.

The probe must not touch the chamber wall, should extend the full height of the chamber, but not touch the bottom of the chamber. Probe type selection depends on probe length:

- Less than 14.7 ft (4.5 m): rigid single probe is recommended. Use a centering disc for a probe > 3.3 ft. (1 m). If installation requires less head-space, use a flexible single probe with a weight and centering disc.[2]

- More than 14.7 ft (4.5 m): Use flexible single probe with a weight and centering disc

- A short weight for the single flexible 0.16 in. (4 mm) SST probe can be used for measuring close to the probe end. The height is 2 in. (50 mm) and the diameter is 1.5 in. (37.5 mm). Option code W2.

- For hot applications, the chamber should always be insulated to prevent personal injuries and to reduce the amount of energy needed for heating. See figure 6.13.3. It is often an advantage, and sometimes even required, for the radar measurement:

- In hot applications, insulation reduces the amount of condensation, since it prevents the upper part of the chamber from becoming a cold spot

- Insulation prevents product solidification inside the chamber, and clogging of the inlet-pipes

The transition zones and the height of the weight limit *the use of single flexible probes shorter than 3 ft. (1 m). If using the flexible probe, the short weight is recommended.*
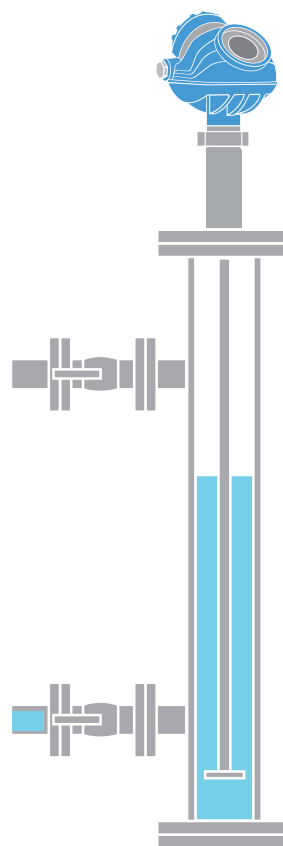
Figure 6.13.3: Insulated chamber

When mounting in a chamber, the probe length to use can be calculated with these formulas:

- Side-and-Side dimension: Probe length = Dimension A + Center-to-Center Dimension + Dimension B - 3.5 in. (85 mm)

- Side-and-Bottom dimension: Probe length = Dimension A + Center-to-Center Dimension - 17 in. (430 mm)
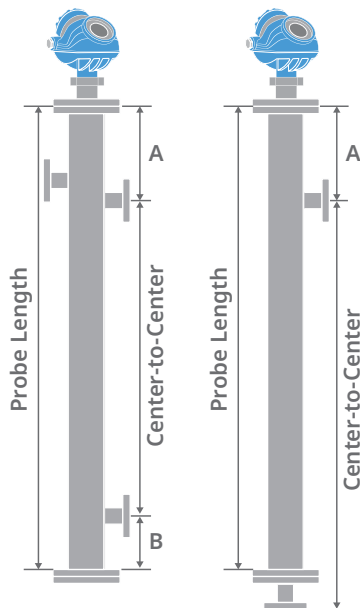
Figure 6.13.4: Chamber dimensions

> **NOTE!**
> The formulas are not valid when using Dynamic Vapor Compensation probes.

For Dynamic Vapor Compensation, probes up to 13.1 ft. (4 m) length are supported.

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 figure 6.13.5) is 22 in. (560 mm) for the short reflector and 28 in. (710 mm) for the long reflector (see illustration on the right), to dynamically compensate up to 100%.

The minimum measuring range for this functionality is 12 in. (300 mm).
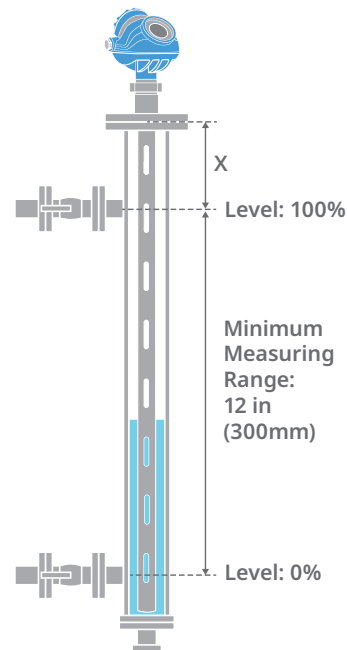
Figure 6.13.5: Minimum distance X for vapor compensation applications

6.13.1 Extra recommendations for installation in stilling well

- 4, 6, or 8 in. diameter pipes are strongly recommended

- The diameter should be consistent for the full length of the pipe

- There should be at least one hole above the liquid surface for pressure equalization.

- There should be multiple holes or slots for stratified fluids or interface measurements to ensure fluid flow-through.

- Holes or slots may be drilled into side of the pipe. The inside of the pipe should be smooth and clear of any rough edges.

- The GWR should not extend out the end of the pipe.

- Include a heavy weight on the end of the cable to pull the wire taut. (option code W3)

- Include a centering disc on the end of the probe - metal or plastic may be used. The centering disc should be slightly smaller than the inside diameter of the pipe and should be completely inside the pipe.

- In smaller diameter pipes, centering discs may be used at intervals along the length of the pipe. These need to be made of a non-metallic, low dielectric reflective material such as PTFE, PEEK or ceramic. This is not recommended if the fluid tends to coat or stick as each disc is a potential site for material build-up.

Figure 6.13.6: GWR mounted in a stilling well
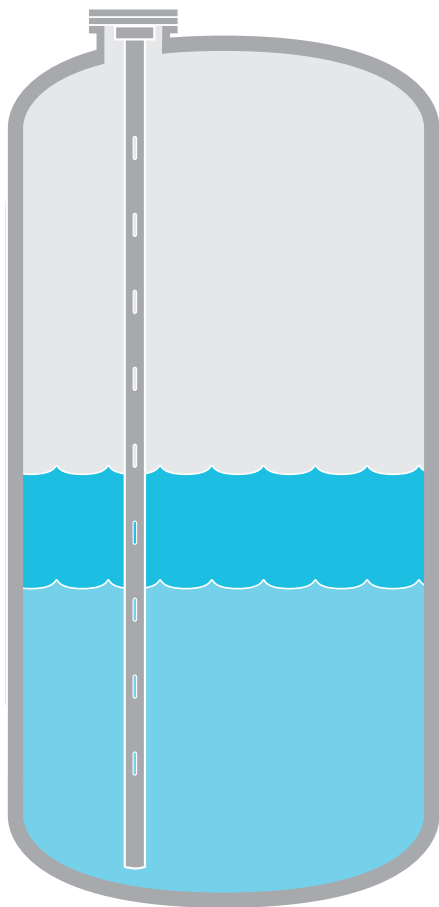
Figure 6.13.7: GWR measuring level and interface in stilling well
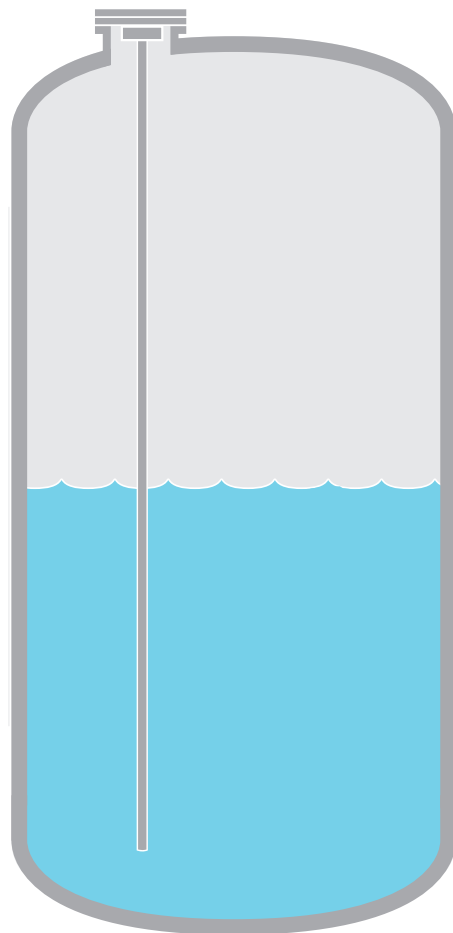
Figure 6.13.8: GWR measuring level in stilling well

6.14 Replacing displacer in existing chamber

A Rosemount 5300 Series transmitter is the perfect replacement for an existing displacer chamber. To simplify installation, proprietary flanges are offered to allow for using the same chambers.

Rosemount 5300 benefits
- No moving parts: Less maintenance - dramatically reduced costs, and as a result, improved measurement availability
- Reliable measurement, that is independent of density, turbulence, and vibrations

Considerations when changing to Rosemount 5300
When changing from a displacer to a Rosemount 5300 Series transmitter, make sure to correctly match the 5300 Series flange choice and probe length to the chamber. Both standard ANSI and EN (DIN), as well as proprietary chamber flanges are available.

Table 6.14.1 shows probe length guidelines.

Chamber manufacturer	Probe Length[1]
Major torque-tube manufacturer (249B, 249C, 2449K, 249N, 259B)	Displacer + 9 in. (229 mm)
Masoneilan (Torque tube operated) proprietary flange	Displacer + 8 in. (203 mm)
Others - torque tube[2]	Displacer V+ 8 in. (203 mm)
Magnetrol (spring operated)[3]	Displacer + between 7.8 in. (195 mm) to 15 in. (383 mm)
Others - spring operated	Displacer + 19.7 in. (500 mm)

Table 6.14.1: Required probe length depending on chamber manufacturers

[1] *If flushing ring is used, add 1 in. (25 mm).*
[2] *For other manufacturers, there are small variations. This is an approximate value, actual length should be verified.*
[3] *Lengths vary depending on model, SG and rating, and should be verified.*

6.15 Anchoring

In turbulent tanks, it may be necessary to fix the probe. Depending on the probe type, different methods can be used to guide the probe to the tank bottom. This may be needed to prevent the probe from hitting the tank wall or other objects in the tank, as well as preventing a probe from breaking.

Flexible single lead probe with weight and ring
A ring (user supplied) can be attached to the weight in a threaded (M8x14) hole at the end of the weight. Attach the ring to a suitable anchoring point.

Weight with internal threads M8x14
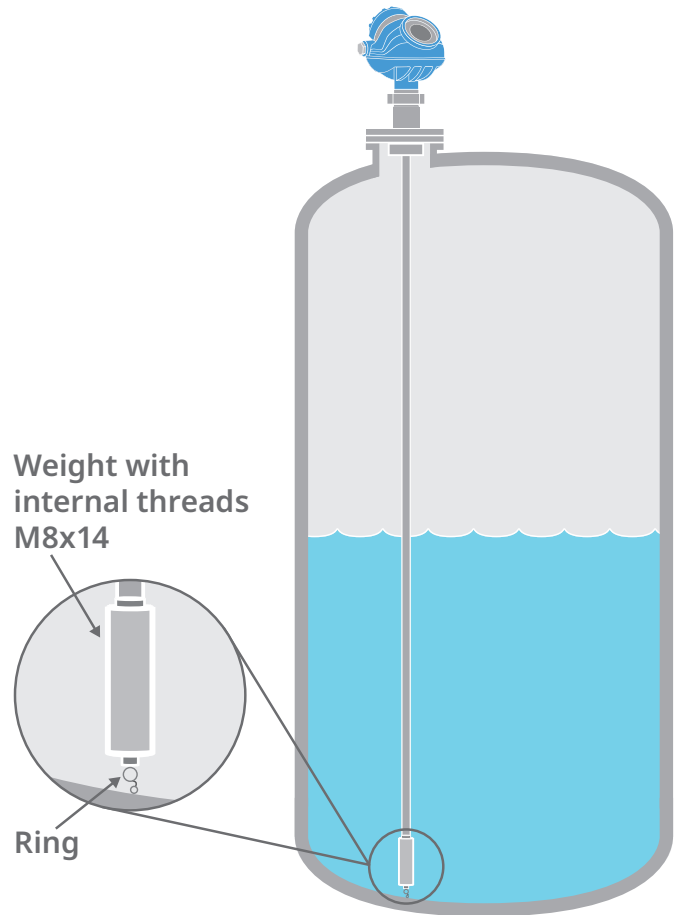
Ring

Figure 6.15.1: Flexible single with weight and ring

Flexible single lead probe with weight and magnet

A magnet (user supplied) can be fastened in a threaded (M8x14) hole at the end of the weight. The probe can then be guided by placing a suitable metal plate beneath the magnet.

Coaxial and large coaxial probe fixed to the tank wall

The coaxial and large coaxial probe can be guided to the tank wall by fixtures fastened to the tank wall. Fixtures are user supplied. Make sure the probe can move freely due to thermal expansion without getting stuck in the fixture.
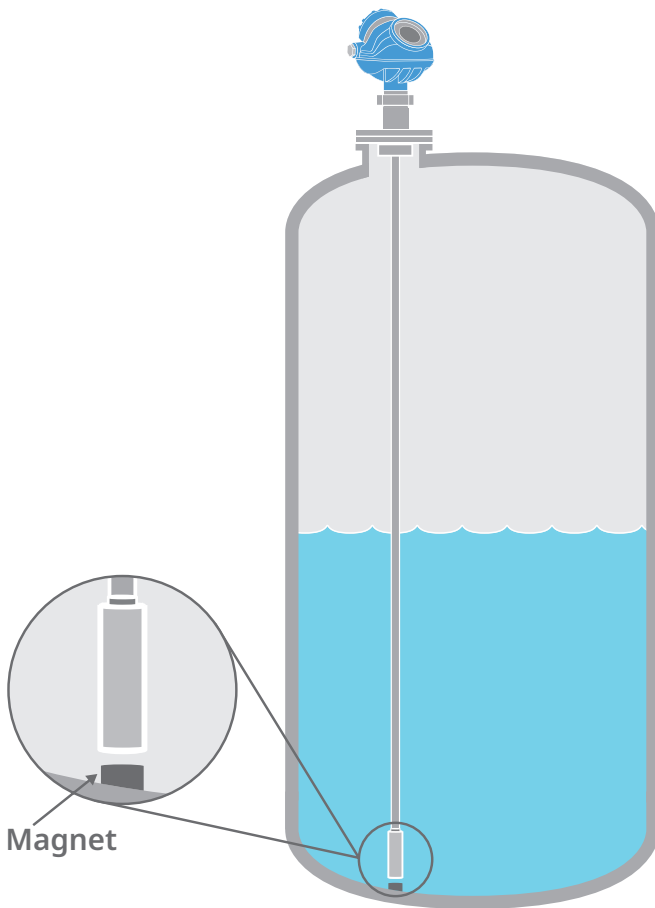
Figure 6.15.2: Flexible single with weight and magnet
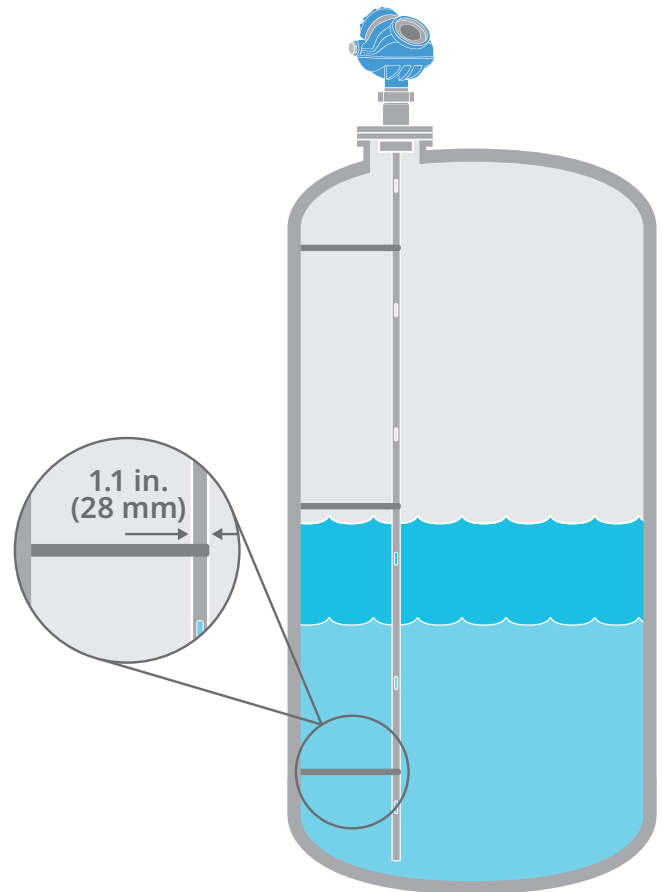
Figure 6.15.3: Coaxial fixed to the tank wall

Coaxial probe and large coaxial probe

The Coaxial probe can be guided by a tube welded on the tank bottom. Tubes are user supplied. Make sure that the probe can move freely in order to handle thermal expansion.

Drain
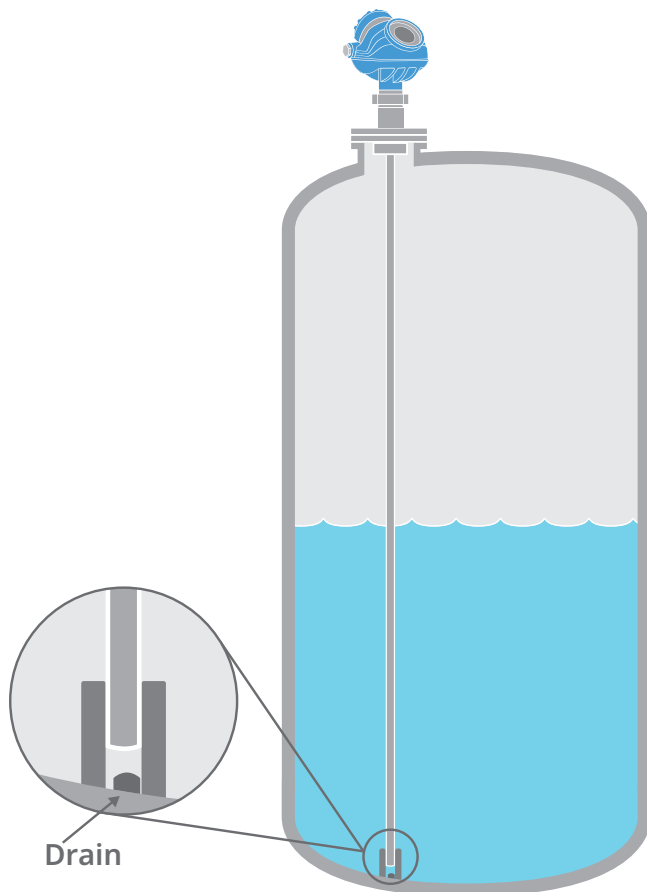
Figure 6.15.4: Coaxial with a welded tube at tank bottom

Flexible single lead probe

The probe rope itself can be used for anchoring. Pull the probe rope through a suitable anchoring point, e.g. a welded eye and fasten it with two clamps. The length of the loop will add to the transition zone. The location of the clamps will determine the beginning of the transition zone. The probe length should be configured as the length from the underside of the flange to the top clamp.
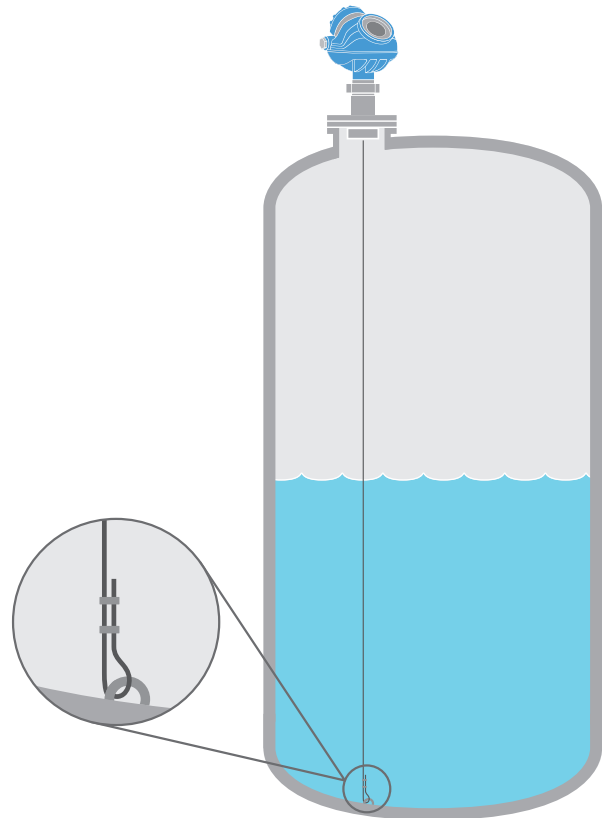
Figure 6.15.5: Flexible single anchored to tank bottom

Solid applications

Pull the probe rope through a suitable anchoring point, e.g. a welded eye and fasten it with two clamps. It is recommended that the probe is slack in order to prevent high tensile loads. The sag should be at least 1.5 in./10 ft (1 cm/m) of the probe length.

> = 1 cm/m
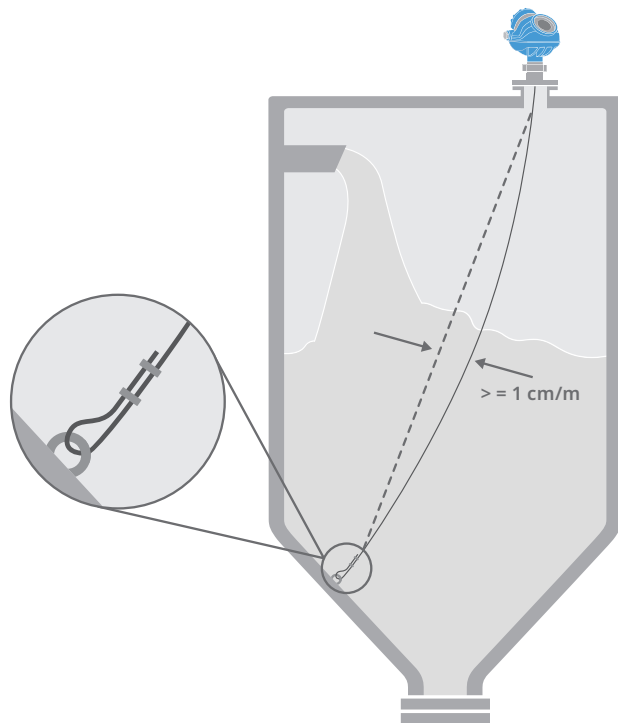
Figure 6.15.6: Anchoring in solid applications

Alternative chuck for flexible single lead probes

Loosen the screws. Pull the probe rope through a suitable anchoring point, e.g. a welded eye. Tighten the screws. The required torque and hex key dimensions:

4 mm wire: 15 Nm, 4 mm

6 mm wire: 25 Nm, 5 mm
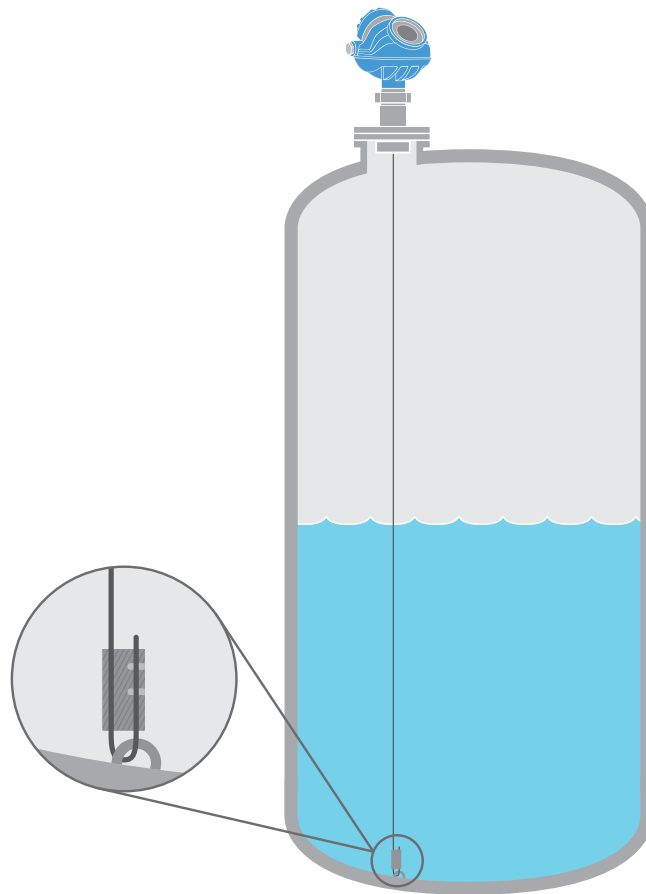
Figure 6.15.7: Flexible single with chuck

6.16 Centering discs

To prevent the probe from contacting the bridle wall when replacing displacers or installing in pipes, centering discs are available for rigid single and flexible single lead probes. The disc is attached to the end of the probe and keeps the probe centered in the bridle/chamber. The discs are made of stainless steel, Alloy C-276, or PTFE.

When mounting a centering disc, it is important that it fits correctly in the pipe.

Pipe Schedule						
Pipe size	5s,5	10s, 10	40s, 40	80s, 80	120	160
2 in.	2 in.	2 in.	2 in.	2 in.	NA[1]	NA[2]
3 in.	3 in.	3 in.	3 in.	3 in.	NA[1]	2 in.
4 in.	4 in.	4 in.	4 in.	4 in.	4 in.	3 in.
5 in.	4 in.	4 in.	4 in.	4 in.	4 in.	4 in.
6 in.	6 in.	6 in.	6 in.	6 in.	4 in.	4 in.
7 in.	NA[1]	NA[1]	5 in.	6 in.	NA[1]	NA[1]
8 in.	8 in.	8 in.	8 in.	8 in.	6 in.	6 in.

Table 6.16.1: Choose the right centering disc diameter for a particular pipe schedule

[1] *Schedule is not available for pipe size.*
[2] *No centering disc is available.*

The below table shows the actual outer diameter for discs.

Outer diameter for discs	
Disc size	Actual disc diameter
2 in.	1.8 in. (45 mm)
3 in.	2.7 in. (68 mm)
4 in.	3.6 in. (92 mm)
6 in.	5.55 in. (141 mm)
8 in.	7.4 in. (188 mm)

Table 6.16.2: Outer diameter for discs according to disc size

> **NOTE!**
> Centering discs may not be used with PTFE covered probes.

To avoid bending the probe (rigid probes), or twisting and coming into contact with the chamber wall (flexible probes), a small clearance distance between centering disc and chamber bottom is recommended. The clearance distance of 1 in. (25 mm) is selected with a dome shaped chamber bottom in mind, which may prevent the centering disc from reaching the bottom.
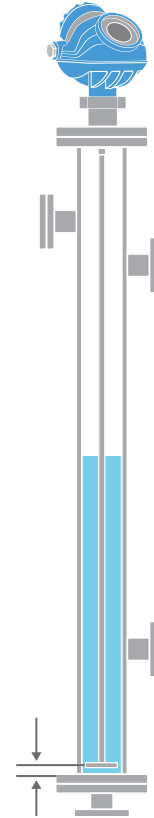
Figure 6.16.1: A clearance distance of 1 in. (25 mm) between the probe end and the chamber bottom is recommended.

6.17 Process seal selection guidelines

The Rosemount 3300 and 5300 guided wave radar level transmitters are designed to be used in a wide variety of level applications. To meet the installation and application demands, five types of process seals are available and are chosen as part of the model number sequence:

S - Standard temperature and pressure process seal

M – Medium temperature and medium pressure

H - High temperature and high pressure

P - High pressure

C - Cryogenic temperatures

The GWR process seals offer a wide range of pressure and temperature capabilities.

In general, the basic recommendation for process seal selection is to choose the lowest rated one that can meet the temperature and pressure needs. This approach achieves two things. It will ensure the greatest signal availability for the measurement since the smallest amount of PTFE or ceramic is used. It will also ensure that sticky heavier products that can occur at lower temperatures will not build up in recessed areas of the seals.

For this reason, we advise the use of the High Pressure instead of the High Temperature/High Pressure seal for applications with a flange temperature less than 392 °F (200 °C), since at those temperatures products may be more viscous and therefore benefit from a completely filled waveguide. Note that it is the flange temperature that is the relevant parameter used as the guideline for selection.*
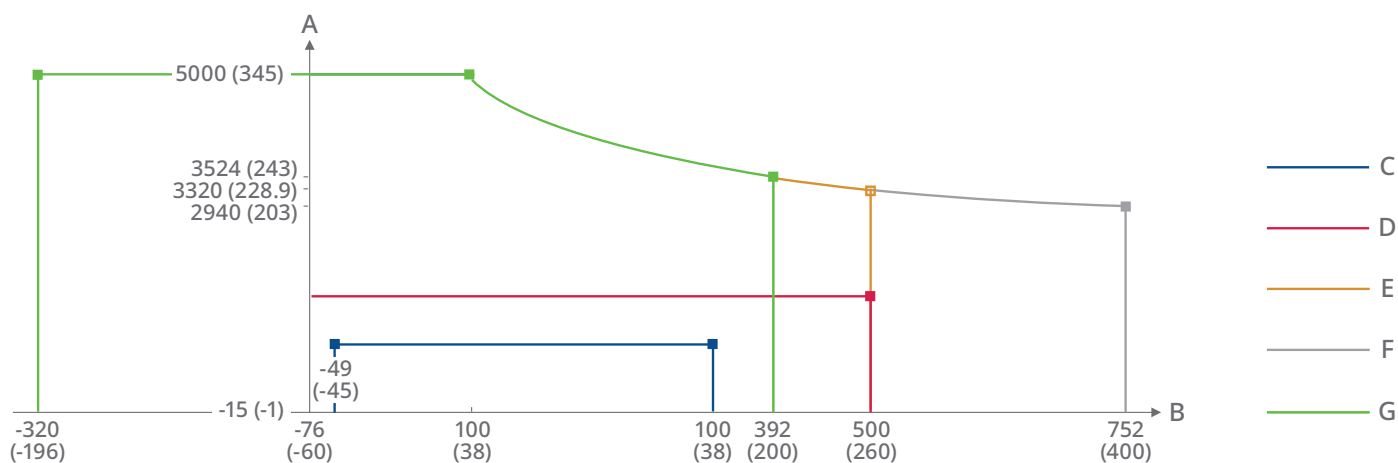
A.   Pressure psig (bar)

B.   Temperature °F (°C)

C.   Standard Temperature (Std) process seal

D.   Medium Temperature / Medium Pressure (MTMP) process seal

E.   High Pressure (HP) process seal

F.   High Temperature / High Pressure (HTHP) process seal

G.   Cryogenic Temperature (C) process seal

Figure 6.17.1: Recommended choice of process seal type

In the case of applications below -76 °F (-60 °C), only the cryogenic probe should be used due to the special welding requirements.

* With the exception of coax probes where internal PTFE spacers in the probe have a temperature limit of 392 °F (200 °C).

6.18 Grounding

Various natural events produce excess transient energy that can enter transmitters via multiple paths. It is critical to practice good grounding techniques in order to optimize the transmitters built-in transient protection. Improper practices can lead to field failures such as erratic mA readings, spiking, difficulty communicating, and possible incorrect levels.

6.19 Guided wave radar installation guidelines for solids applications

Guided wave radar is used in many different applications. It is especially well suited for smaller vessels with <33 ft (10 m) diameter containing powders and small granular materials and where the installation area is restricted. As vessel height increases, wear on the probe becomes more of a factor in the suitability of its use.

Advantages
- Low DC, Probe End Projection
- Small silo intrusion
- Internal obstructions
- 2-wire

Limitations
- Pull force dependent
- Wear on probe
- Inferred volume

Rosemount 5303 Specifications							
Model	Silo height	Silo width	Power	Material restrictions	Protocol	Primary output	Features
Rosemount 5303	3-98 ft (1-30 m)	Unlimited	2-wire	DC > 1.1 up to 39 ft (12 m) with Probe End Projection activated DC > 1.4	4-20 mA, HART®, FOUNDATION™ Fieldbus, Modbus®, WirelessHART®	Level	Probe End Projection, Signal Quality Metrics

Table 6.19.1: Product specification for Rosemount 5303

6.19.1 Mounting considerations

Always install the probe in an empty silo and regularly inspect the probe for damage. For silos taller than 98 ft (30 m), consult your Emerson representative.

Position

Mount the probe as far away as possible from filling and emptying ports. This will minimize load and wear and will help to avoid disturbances from the incoming product. Installing the probe at about 1/3 to 1/2 of the silo radius is recommended to compensate for measurement errors caused by cone shaped surface formation during centered filling. The minimum recommended probe distance to tank wall or disturbing objects is 20 in. (50 cm), unless the wall is comprised of smooth metal, then the distance is 4 in. (10 cm).
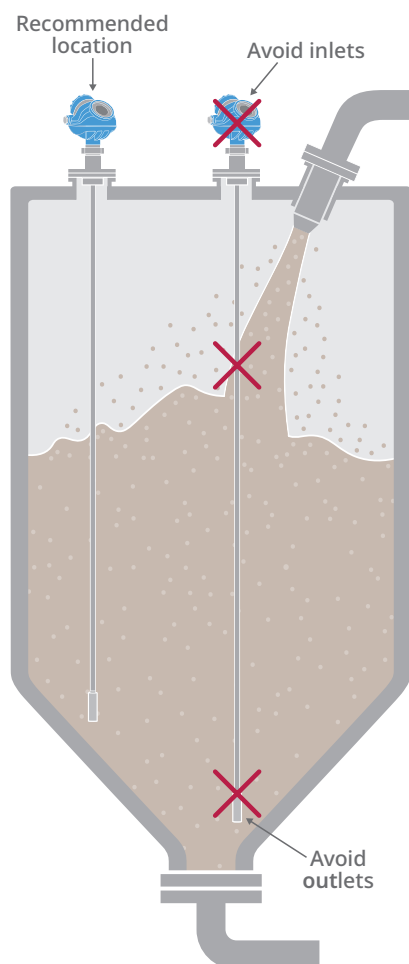
Figure 6.19.1: Mounting positions for guided wave radar

Nozzle

A short nozzle is recommended. The maximum recommended nozzle height is nozzle diameter + 4 in. (100 mm). When nozzles are more than 4 in. (100 mm) in height, a long stud is recommended to prevent the probe from contacting the nozzle. Avoid 10 in. (250 mm)/DN250 or large <D + 4 in (100 mm) or diameter nozzles, especially in applications with low dielectric constants.
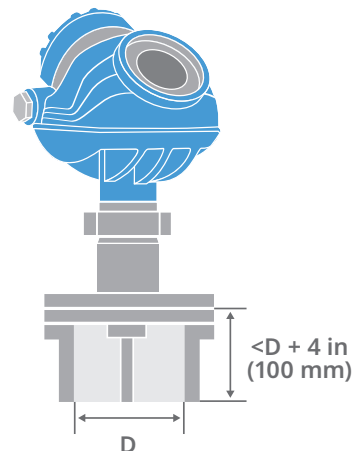
Figure 6.19.2: Nozzle considerations for guided wave radar

Special silos

In case of non-metallic silos, a guided wave radar should be mounted with a metal plate of at least 14 in. (350 mm) in diameter. Use metal shielding for the conduit connections. In the case of bunkers with a concrete roof, a Rosemount 5303 should be installed flush with the inner roof surface or in a nozzle insert.

6.19.2 Probe anchoring

The best practice is to have a free hanging probe but an anchored probe is sometimes needed for application reasons. The probe end should not be fixed for 98 ft (30 m) or longer probes. The probe must be slack when anchoring the probe to reduce the risk of probe breakage. Select a probe longer than the required measuring range so there is a sag in the middle of the probe greater than or equal to 1.5 in. per 10 ft (1 cm per m) of the probe length.

Electrostatic discharges

In some applications, such as plastic pellets, electrostatic charges can build up and eventually discharge. While the Rosemount 5303 electronics can tolerate some static charge, providing a good earth ground for the electronics by anchoring the end of the probe to the vessel will create ground paths for discharge away from the electronics. If the product can build up static electricity, the probe should be properly grounded (R < 1 Ohm).

6.19.3   Pull force

The flexible single lead probe is recommended for solids. It is available in two versions to handle different loads and lengths. Yield strength is the amount of force the probe can withstand before any deformation occurs. It is important to keep the following in mind when planning for installation:

- The silo roof must be able to withstand maximum probe tensile load

- The tensile load depends on the silo size, material density, and the friction coefficient. Forces increase with the buried length, the vessel width and probe diameter

- Forces on probes are generally increased two to ten times when probes are anchored to the vessel

Material	Probe length 49 ft (15 m)		Probe length 115 ft (35 m)	
	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)
Wheat	670 (3)	1120 (5)	1800 (8)	4500 (20)[1]
Plastic pellets	340 (1.5)	670 (3)	810 (3.6)	2360 (10.5)
Fly ash	770 (3.4)	1690 (7.5)	1980 (8.8)	5980 (26.6)[1]
Coal dust	540 (2.4)	1190 (5.3)	1390 (6.2)	4230 (18.8) [1]
Cement	900 (4)	2020 (9)	2470 (11)	7310 (32.5)[1]

Table 6.19.2: Tensile Load for Unanchored 0.16 in. (4 mm) Flexible Single Lead Probe, lb (kN)

[1] *Exceeds the yield strength limit of 2698 lb (12 kN).*

Material	Probe length 49 ft (15 m)		Probe length 115 ft (35 m)	
	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)	Tank Ø = 10 ft (3 m)	Tank Ø = 39 ft (12 m)
Wheat	900 (4)	1690 (7.5)	2810 (12.5)	6740 (30)[1]
Plastic pellets	450 (2)	920 (4.1)	1190 (5.3)	350 (15.6)
Fly ash	1130 (5)	2520 (11.2)	2950 (13.1)	8990 (40)[1]
Coal dust	790 (3.5)	1780 (7.9)	2070 (9.2)	6320 (28.1)
Cement	1350 (6)	2920 (13)	3600 (16)	10790 (48)[1]

Table 6.19.3: Tensile Load for unanchored 0.24 in. (6 mm) Flexible single lead probe, lb (kN)

[1] *Exceeds the yield strength limit of 6519 lb (29 kN).*

CHAPTER 7
NON-CONTACTING RADAR INSTALLATION GUIDELINES

7 | Non-Contacting Radar Installation Guidelines

7 Non-Contacting Radar Installation Guidelines

Non-contacting radar level transmitters can operate in different ways and at different frequencies (See chapter 2), which impacts their measurement performance and mounting flexibility. However, apart from FMCW, all Emerson non-contacting radars are integrated with Smart Echo Supervision, meaning that they will dynamically identify which echoes are false, while keeping track of the surface echo at all times due to it behaving most like one. Rather than solely relying on a narrow beam angle to avoid internal obstructions, Smart Echo Supervision makes Emerson's non-contacting radars smart enough to handle them automatically – greatly increasing mounting flexibility when dealing with inconveniently placed- or tall nozzles, handling isolation- or ball valves, not requiring any baffles and deflectors to be installed for dealing with false echoes, and also removing the need for False Echo Suppression software tools in most applications. This chapter provides installation guidelines to ensure optimal operation.

Rosemount 5408

The Rosemount 5408 is a 2-wire transmitter based on FMCW technology, making it superior in reliability and accuracy. It is capable of handling the most challenging process conditions such as foam, vapor, turbulence, high temperature and pressure. It requires less installation considerations and thanks to Smart Echo Supervision, makes it less affected by internal obstructions. It comes in two versions, one for control (Rosemount 5408) and one for safety instrumented systems (Rosemount 5408:SIS).

Figure 7.1.1: Rosemount 5408 Level Transmitter

Rosemount 3408

The Rosemount 3408 is a versatile radar transmitter based on the latest radar on a chip and fast-sweep FMCW technology and Smart Echo Supervision, thus offering application and installation flexibility as well as overfill prevention in many industries, including chemical. It offers smart features to provide ease-of-use at every touchpoint and simplify operator tasks with intuitive software interface. Additionally, it features optional Bluetooth® to configure it and do maintenance easily and conveniently. Manual or automatic verification at scheduled intervals can be conducted from the control room at any time without process interruptions. Perform proof-testing remotely and in-situ with onboard functionality. NAMUR type tested and third party certified to IEC61508 for use in safety critical applications.

Figure 7.1.2: Rosemount 3408 Level Transmitter

Rosemount 1208

The Rosemount 1208 is a compact level and flow transmitter that provides reliable level measurement and open channel flow calculations. With fast-sweep FMCW technology and Smart Echo Supervision based on the latest radar on a chip technology, it offers reliable and accurate measurements with no dead zone and great mounting flexibility. Very much suitable for non-critical applications within chemical, water and wastewater, as well as utilities cross-industry. It features a compact and encapsulated polymer housing that withstands outdoor conditions and is fully submersible. The device takes minutes to set up, only requiring reference height to be set, providing a plug and play solution. Additionally, it communicates via optional Bluetooth®, 4-20 mA HART® or IO-link and has a broad range of mounting accessories, making it easily integrate into both new as well as existing systems.

Figure 7.1.3: Rosemount 1208 Level and Flow Transmitter

Rosemount 1408

The Rosemount 1408 is a transmitter with hybrid communication options to make it easily integrated into new or existing systems (4-20 mA/HART® or IO-Link and PnP/NpN). It is based on the latest radar on a chip technology and has higher integration in its electronics, helping to improve reliability and efficiency. In addition, fast-sweep FMCW technology and Smart Echo Supervision enable more information to be collected, providing higher accuracy to track product surface reliably all the way to the top of the tank. Together with and a compact design, it is ideal for small tanks with little space for instrumentation.

The unique design ensures that this hygienic and stainless-steel transmitter withstands high cleaning temperatures and external washdowns. The devices smart algorithms can also detect clean in place procedures in order to disregard any measurement values during this process step. The device is quick to setup, only requiring reference height to be set, providing a plug and play solution.

Figure 7.1.4: Rosemount 1408 Level Transmitter

7.1 Measuring range in liquids

The measuring range depends on the microwave frequency, antenna size, the dielectric constant (DC) of the liquid, and process conditions.

A higher dielectric constant value produces a stronger reflection. For the Rosemount 5408, the dielectric constant will not affect the measuring range due to superior signal strength. For more information, contact your local Emerson representative.

7.2 Measuring range in solids

The total measuring range may differ depending on the bulk solid media properties, such as particle size and dielectric constant. Other contributing application conditions include product filling, how the product piles up, silo diameter vs. angle of repose, internal obstacles within the silo, dust, condensation, antenna build up, etc. Non-contacting radar transmitters have no restrictions with respect to the weight of the bulk solid material, so pull forces need not be considered.

Solids have some common characteristics which may cause weak and varying surface reflections. The surface is rarely flat or horizontal, the angle of the sloping surface differs during filling and emptying, and the dielectric constant of many solids is fairly low. Dust is often present in solids applications, and even if the non-contacting radar is not affected by the dust in the vapor space, dust can be sticky and create a layer on the antenna. If this layer becomes too thick, it may affect the measurement. This is best managed by using air purging.

7.3 Mounting location

Before installing a Rosemount non-contacting transmitter, consider specific mounting requirements, vessel, and process characteristics.

For optimal performance, the transmitter should be installed in locations with a clear and unobstructed view of the level surface (A):

*   Filling inlets creating turbulence (B), and stationary metallic objects with horizontal surfaces (C) should be kept outside the signal beam

*   Agitators with large horizontal blades may reduce the performance of the transmitter, so install the transmitter in a location where this effect is minimized. Vertical or slanted blades are often invisible to radar, but create turbulence (D)

*   Do not install the transmitter in the center of the tank (E)

*   Recommended clearance to the wall should always be followed, failure to do so may impact the accuracy (F). Usually, the optimal location is 1/4 of the diameter from the tank wall

*   The antenna is normally aligned vertically
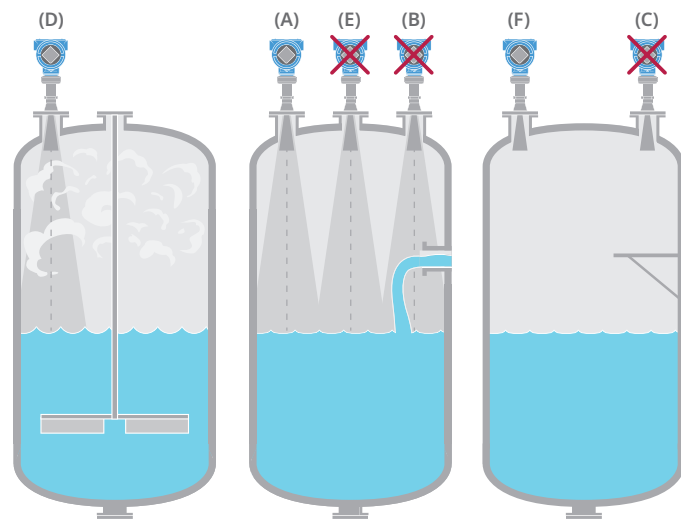
Figure 7.3.1: It is important to consider the proper mounting location

*   A metal still-pipe can be used to avoid disturbing objects, turbulence, and foam (G). Carbon steel or other ferromagnetic low alloy steels are not recommended for still pipes to be used with non-contacting radar. Guided Wave Radar is the recommended technology for such applications.

*   The walls in non-metallic tanks are invisible to the radar signal, so nearby objects outside of the tank may be detected

*   Choose the largest possible antenna diameter for installation. A larger antenna concentrates the radar beam, and will be less susceptible to obstruction interference, and assures maximum antenna gain

*   Multiple transmitters can be used in the same tank without interfering with each other (H)
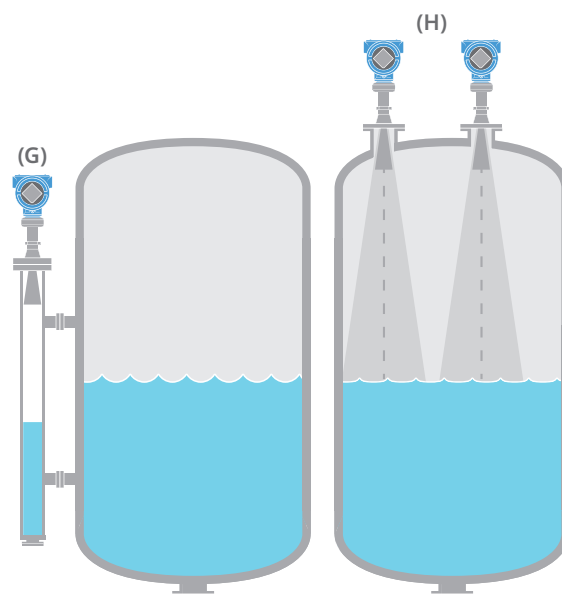
Figure 7.3.2: Mounting in a still pipe and mounting multiple 5408 transmitters in the same tank

7.4 Nozzle considerations

Special considerations may have to be taken because of the nozzle, depending on the selection of transmitter model and antenna.

Rosemount 5408 with cone antenna
The antenna can be recessed in smooth nozzles up to 4 ft (1.2 m). If the inside of the nozzle contains disturbing objects, use the extended cone.
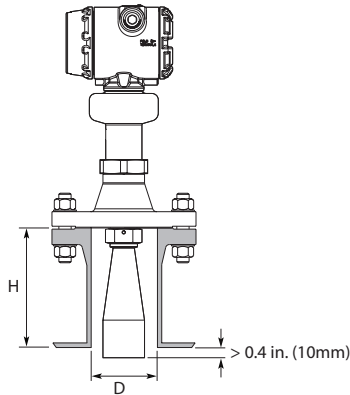
Figure 7.4.1: Nozzle considerations for Rosemount 5408 with cone antenna

Rosemount 5408 with parabolic antenna
The parabolic antenna can be adjusted at an angle in the case of angled tank roofs. The antenna can be recessed in smooth nozzles up to:

- 6 in. (150 mm) for 8-in. pipe sch std.
- 8 in. (200 mm) for 10-in. pipe sch std

Disturbing objects inside the nozzle may impact the measurement and should be avoided.
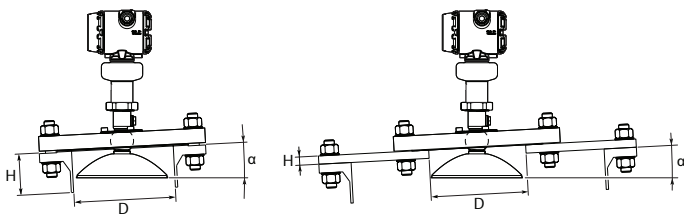
Figure 7.4.2: Nozzle considerations for 5408 with parabolic antenna

Rosemount 5408 with process seal antenna
The antenna can be used on nozzles up to 4 ft (1,2 m). Disturbing objects inside the nozzle may impact the measurement and should therefore be avoided.

The flange on the tank should have a flat or raised face. Other tank flanges may be possible, please consult your local Emerson representative for advice.
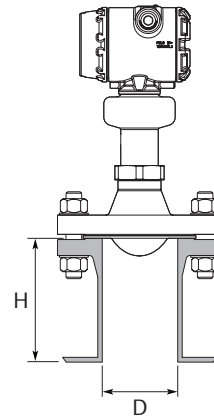
Figure 7.4.3: Nozzle considerations for Rosemount 5408 with process seal antenna

Antenna	Min D	Max H
2" (DN50)	1.77 in. (45 mm)	4 ft. (1.2 m)
3" (DN80)	2.76 in. (70 mm)	4 ft. (1.2 m)
4" (DN100)	2.76 in. (70 mm)	4 ft. (1.2 m)

Extended cone antennas are available up to 20 in. (500mm).

Table 7.4.1: Nozzle considerations for Rosemount 5408 with process seal antenna.

Model	Antenna type/ size/material	L (in. (mm))
5408	Cone 1½-in.	5.59 (142)
	Cone 2 in. (50 mm) SST	5.71 (145)
	Cone 3 in. (75 mm) SST	5.63 (143)
	Cone 4 in. (100 mm) SST	6.54 (166)
	Process seal 2 in.	48 (1200)
	Process seal 3 in.	48 (1200)
	Process seal 4 in.	48 (1200)
	Parabolic Ø 8 in. (200 mm) STD	5.9 (150) or less
	Parabolic Ø 10 in. (250 mm) STD	8.0 (200) or less

Table 7.4.2: Nozzle requirements for Rosemount 5408 non-contacting radar

The flange on the tank should have a flat or raised face. Other tank flanges may be possible, please consult your local Emerson representative for advice.

Rosemount 3408

Please see table 7.4.3 for recommended maximum nozzle height for Rosemount 3408. The inside of the nozzle must be smooth (i.e. avoid bad welding, rust, or deposit).

| Nozzle diameter (D) | Recommended maximum nozzle height(H) | |
	Lens antenna and ATAP lens antenna	Process seal antenna
1 in. (25 mm)	3.9 in. (100 mm)	N/A
1.5 in. (40 mm)	5.9 in. (150 mm)	5.9 in. (150 mm)
2 in. (50 mm)	7.9 in. (200 mm)	19.7 in. (200 mm)
3 in. (80 mm)	11.8 in. (300 mm)	39.4 in. (1000 mm)
4 in. (100 mm)	15.8 in. (400 mm)	39.4 in. (1000 mm)
6 in. (150 mm)	23.6 in. (600 mm)	51.2 in. (1300 mm)

Table 7.4.3: Nozzle considerations for Rosemount 3408
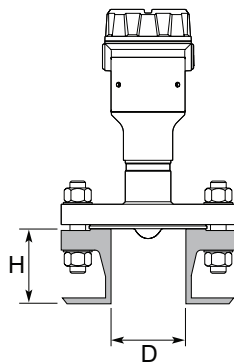
Figure 7.4.4: Nozzle considerations for Rosemount 3408

Rosemount 1408

In order to allow the microwaves to propagate undisturbed, the nozzle dimensions should be kept within the specified limits as shown in Table 7.4.3. The inside of the nozzle must be smooth (i.e. avoid bad welding, rust, or deposit).
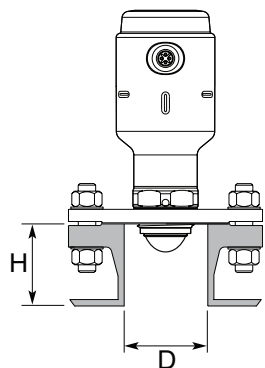
Figure 7.4.5: Nozzle considerations for Rosemount 1408

Nozzle diameter (D)	Maximum nozzle height (H)
1 in. (25 mm)	3.9 in. (100 mm)
1.5 in. (40 mm)	5.9 in. (150 mm)
2 in. (50 mm)	7.9 in. (200 mm)
3 in. (80 mm)	11.8 in. (300 mm)
4 in. (100 mm)	15.8 in. (400 mm)
6 in. (150 mm)	23.6 in. (600 mm)

Table 7.4.4: Nozzle requirements for Rosemount 1408 non-contacting radar

Rosemount 1208

To allow the microwaves to propagate undisturbed, the nozzle dimensions should be kept within the specified limits as given in Table 7.4.4. The inside of the nozzle must be smooth (i.e. avoid bad welding, rust, or deposit).
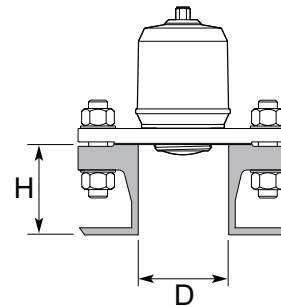
Figure 7.4.6: Nozzle considerations for Rosemount 1208

Nozzle diameter (D)	Maximum nozzle height (H)
1.5 in. (40 mm)	5.9 in. (150 mm)
2 in. (50 mm)	7.9 in. (200 mm)
3 in. (80 mm)	11.8 in. (300 mm)
4 in. (100 mm)	15.8 in. (400 mm)
6 in. (150 mm)	23.6 in. (600 mm)
6 in. (150 mm)	23.6 in. (600 mm)

Table 7.4.5: Nozzle requirements for Rosemount 1208 non-contacting radar

7.5 Service space

If the transmitter is mounted close to a wall or other tank obstructions, such as heating coils and ladders, noise might appear in the measurement signal. Therefore the following minimum clearance, according to table 7.5.1 must be maintained. For easy access to the transmitter, mount it with sufficient service space (see table 7.5.1).
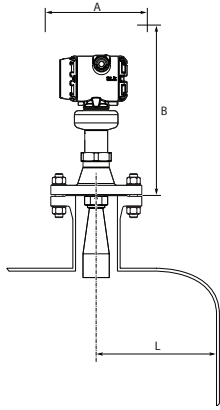
Figure 7.5.1: Service space recommendations for Rosemount 5408

Free space requirements		Distance in. (mm)
Service space with (A)		20 in. (500 mm)
Service space height (B)		24 in. (600 mm)
Distance to tank wall (L)	Minimum	8 in. (200 mm)
	Recommended	1/4 of the tank diameter

Table 7.5.1: Service space recommendations for Rosemount 5408

7.6 Beam Width

Thanks to Smart Echo Supervision™, beam angle considerations are of less importance, even in very challenging applications. For an extra layer or precaution, the following recommendations should be considered when mounting the transmitter:

- The transmitter should be mounted with as few internal structures as possible

- The flat tank wall can be located within the antenna beam angle if there is a minimum distance from the transmitter to the tank wall. See exhibit 17.3 for more details.

7.7 Vessel

Heating coils, agitators and other objects in the tank may lead to disturbing echoes and noise in the measurement signal. Vertical structures cause minimal effect since the radar signal is scattered rather than directed back to the antenna.

The shape of the tank bottom affects the measurement signal when the product surface is close to the tank bottom. Rosemount non-contacting radars have built-in functions which optimize measurement performance for various bottom shapes.

7.8 Disturbing objects

Rosemount non-contacting radar transmitters should be mounted so that objects such as heating coils, ladders, etc. are not in the radar signal path. These objects may cause false echoes resulting in reduced measurement performance. However, the transmitter has built-in functions designed to reduce the influence from disturbing objects where such objects cannot be totally avoided.

Higher frequency radars have a narrower radar beam which is particularly suitable in installations with tall or narrow nozzles, or nozzles close to the tank wall. It may also be used to avoid disturbing objects in the tank.

7.9 Valves

Rosemount 5408 can be isolated from the process by using a valve:

- Use a full-port ball valve

- Ensure there is no edge between the ball valve and the nozzle or still pipe, the inside should be smooth

- The process seal antenna is the preferred choice, since it does not require a spool piece. The cone antenna may also be used

- Valves can be combined with pipes.

7.10 Mounting in chamber/stilling well

Installation in a still pipe/chamber is recommended for tanks where surface conditions may be extremely turbulent. By using a pipe, foam or turbulence is reduced. All cone antenna sizes can be used for still pipe/chamber installations.

Although process radars generally provide robust operation when installed in still pipes, all process radars, regardless of make or type, are designed to perform at their best during free propagation. Installed in still pipes, the process radar's accuracy may be affected due to the microwave propagation through the still pipe. For highest accuracy in still pipes, use the Rosemount 5900 Radar Level Gauge. Its unique array antennas utilize a low-loss microwave mode dedicated for still pipes.

7.10.1 Still pipe

The measurements and numbers are Rosemount 5408 specific.

Pipe

- Pipes should be an all-metal material.
- Pipe should have a constant inside diameter.
- The inner surface must be smooth and clear of any rough edges.(Smooth pipe joints are acceptable, but may reduce accuracy.)
- The end of the pipe must extend beyond the zero level.

Holes

- Maximum hole diameter is 1 in. (25 mm).
- Minimum distance between holes is 6 in. (150 mm).
- Holes should be drilled on one side only and deburred.
- Drill one hole above maximum product surface.

Antenna

- The gap between the cone antenna and the still-pipe should be maximum 0.2 in. (5 mm). If required, order a larger antenna and cut on location.
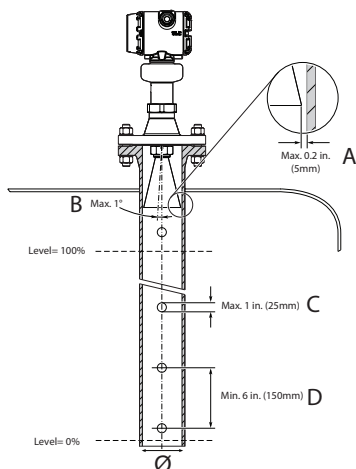
Figure 7.10.1: Still pipe requirements

7.10.2 Chamber

The measurements and numbers are Rosemount 5408 specific.

Consider the following chamber requirements:

- Pipes should be an all-metal material
- Pipe should have a constant inside diameter
- Inlet pipes should not protrude into the inside of the stand pipe
- The inner surface must be smooth and clear of any rough edges (Smooth pipe joints are acceptable, but may reduce accuracy.)
- The gap between the cone antenna and the still-pipe should be maximum 0.2 in. (5 mm). If required, order a larger antenna and cut on location.
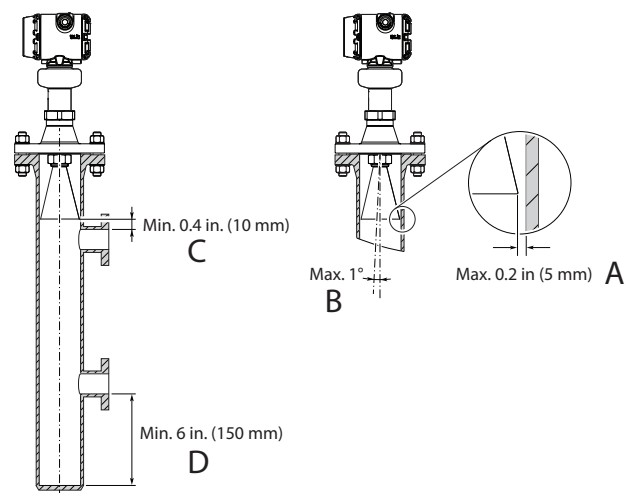
Figure 7.10.2: Chamber requirements

7.11 Grounding

Various natural events produce excess transient energy that can enter transmitters via multiple paths. It is critical to practice good grounding techniques in order to optimize the transmitters built-in transient protection. Improper practices can lead to field failures such as erratic mA readings, spiking, difficulty communicating, and possible incorrect levels.

7.12 Level measurements using non-contacting radar shooting at a metal plate

In some radar level measurement applications it may be beneficial, or even necessary, to use a reflector plate. In these applications the reflector moves along with the surface thereby corresponding to the level. Rosemount non-contacting radars are often ideal for these applications with reflectors, if a few simple guidelines are applied.

Reflector

The reflector, or target, simulates a surface. For Rosemount non-contacting radars, a flat metal plate of arbitrary thickness is recommended. The shape shall be either circular or square.

> **NOTE!**
> The reflector will be smaller than the antenna footprint. Avoid disturbing objects with large horizontal metal surfaces inside the antenna beam.

7.13 Aligning of the transmitter head

The Rosemount 5408 is linearly polarized, which means that its foot print is elliptical and the transmitter must be correctly turned against the tank wall to avoid it.

Open tank
Align the marking on the sensor module toward the tank wall.
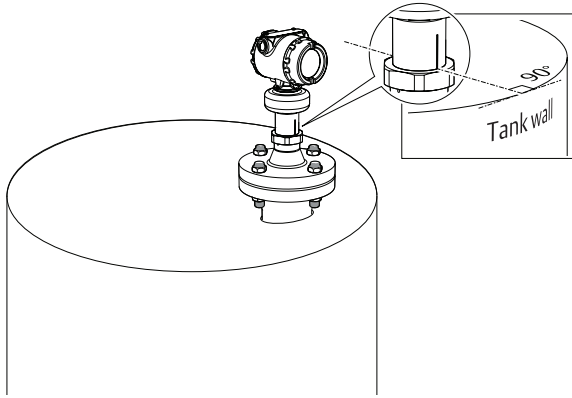
Still Pipe
Align the external ground screw toward the holes of the still pipe.
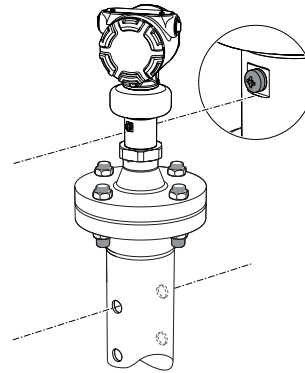
Chamber
Align the external ground screw toward the process connections.
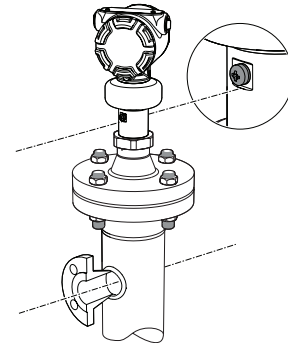
Model	Silo height	Silo width	Power	Antenna vs Material restrictions	Protocol	Features
Rosemount 5408	Parabolic: 3-295 ft (1-90 m) Cone: 3-130 ft (1-40 m)	Unlimited	2-wire	8-in Parabolic: DC > 1.2 up to 115 ft (35 m) DC > 1.5 up to 230ft (70m) DC > 1.7 up to295 ft (90 m) 4-in (DN100) Cone: DC > 1.2 up to 66 ft (20 m) DC > 1.5 up to 130 ft (40 m)	4-20 mA, HART, FOUNDATION Fieldbus, Modbus, WirelessHART	Solids signal processing, air purging
Rosemount 3408	1-in & 1½-in lens: 98 ft. (30m)	Unlimited	2-wire	ATAP: DC > 1.2 up to 66ft (20m) DC >1.35 up to 98ft (30m) 1-in & 1½-in lens: DC > 1.2 up to 49ft (15m) DC > 1.5 up to 98ft (30m) ¾-in Lens antenna: DC > 1.2 up to 33ft (10m) DC > 1.35 up to 49ft (15m)	4-20 mA, HART, Bluetooth®	Solids signal processing, air purging
Rosemount 1208	49.2 ft (15m)	Unlimited	2-wire/ 3-wire	1 ½-in Lens antenna: DC > 2 up to 49ft (15m)	4-20 mA, HART, IO-Link, Bluetooth®	Solids signal processing
Rosemount 1408	49.2 ft (15m)	Unlimited	2-wire / 3-wire	1-in Lens antenna: DC > 2 up to 49ft (15m)	4-20 mA, HART, IO-Link	Solids signal processing

7.14 Non-contacting radar installation guidelines for solids applications

Non-contacting radar is used on a large variety of applications. It has no restrictions with respect to the weight of the material so it can be used in applications where guided wave radar may not be appropriate because of pull forces or concerns about probe breakage.

Non-contacting radars can see more of the surface than guided wave radars, so will be slightly more accurate. As a radar device, they react quickly to level changes so are also appropriate for process applications and small vessels.

Advantages

- Smart Echo Supervision
- Solids signal processing
- Small silo intrusion
- Internal obstructions
- 2-wire

Limitations

- May need purging
- Inferred volume

7.14.1 Mounting considerations

Position

A non-contacting radar should not be mounted in the center of the silo or very close to the tank wall.

General best practice is to mount non-contacting radar at 2/3 tank radius from tank wall. The inlet stream of the product will interfere with readings if it is in the path of the radar beam.
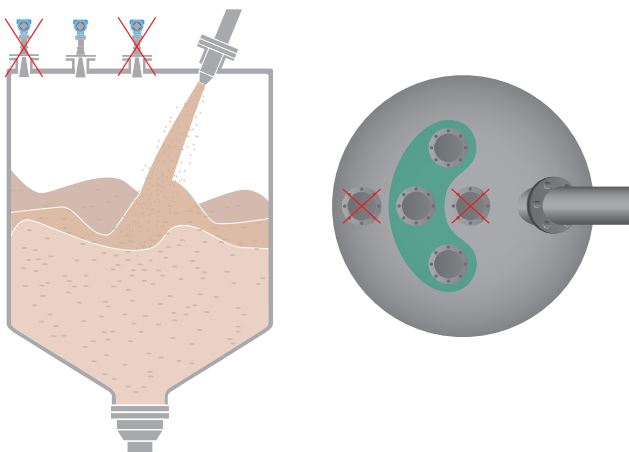
Figure 7.14.1: Mounting position for Non-Contacting Radars

Antenna requirements

The antenna types available for non-contacting radar are: Cone antenna, parabolic antenna, lens antenna, bracket mounted ATAP (Atmospheric Temperature and Atmospheric Pressure) lens antenna, and process seal antenna. They

require different tank connections as displayed in Figure 7.14.2.

Min 0.4 in (10 mm)

Ø correspondent to antenna size

Nozzle height as short as possible

Ø correspondent to antenna size

Nozzle height dependent on antenna inclination and nozzle Ø

Minimum Ø 8 in. (Ø 200 mm)
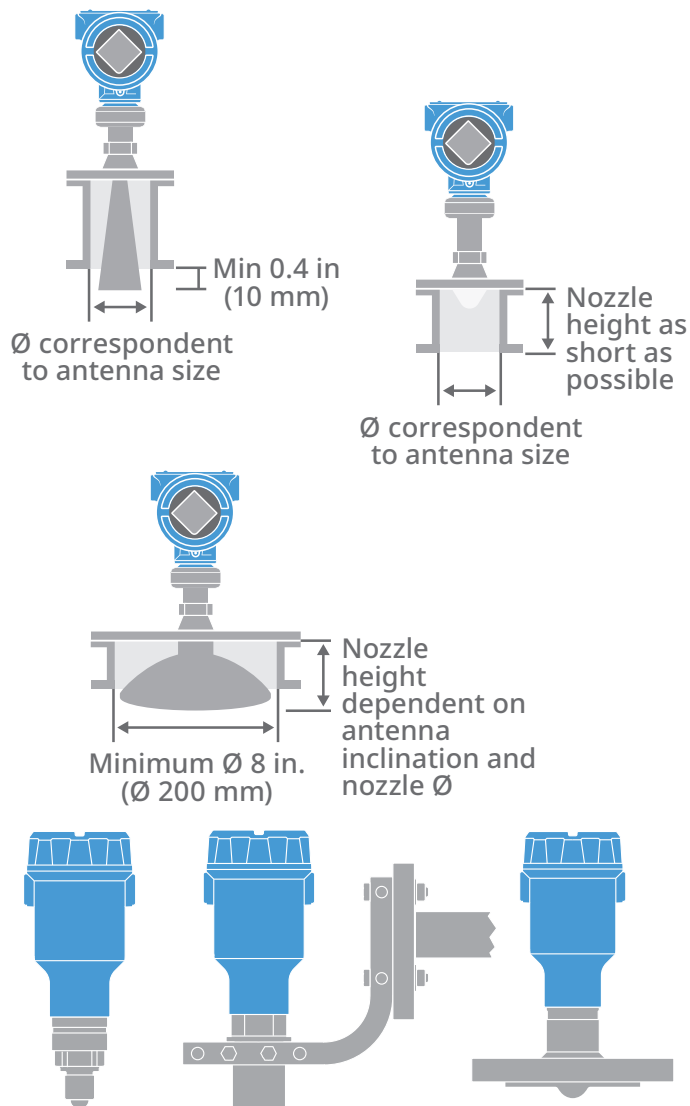
Figure 7.14.2: Tank connections for Rosemount 5408 with cone antenna, parabolic antenna, and process seal antenna, and for Rosemount 3408 with process seal antenna, lens antenna and bracket mounted ATAP lens antenna

For solids applications, it is sufficient to minimize potential disturbances from the nozzle. A shorter nozzle typically results in a stronger surface reflection. This is applicable to all antenna types.

The cone antenna is fixed but should be installed perpendicular to the ground. The parabolic antenna inclination is adjustable. General best practice is to initially align the parabolic antenna perpendicular to the ground as well. Refer to the Rosemount 5408 Level Transmitter Reference Manual for further information.

If the signal is dampened by heavy condensation at the antenna, it often helps to insulate the nozzle. This minimizes the temperature disparity between the internal and ambient temperature. Installing the antenna so it is inside the vessel helps reduce the chance of condensation.

7.14.2 Measuring range

The recommended measuring range for Rosemount 5408 varies depending on antenna type and product dielectric constant.

Rosemount 5408 antenna	Light powder[1]	Light granulates and pellets[2]	Heavy powder[3]	Grain size products[4]	Larger particles[5]
2-in. (DN50) cone/ process seal[6]	16 ft (5 m)	33 ft (10 m)	82 ft (25 m)	82 ft (25 m)	115 ft (40 m)
3-in. (DN80) cone/ process seal[6] 4-in. (DN100) process seal[6]	49 ft (15 m)	66 ft (20 m)	98 ft (30 m)	98 ft (30 m)	130 ft (40 m)
4-in. (DN100) cone[6]	66 ft (20 m)	98 ft (30 m)	131 ft (40 m)	131 ft (40 m)	130 ft (40 m)
8-in. (DN200) parabolic[7]	115 ft (35 m)	131 ft (55 m)	131 ft (70 m)	131 ft (70 m)	130 ft (90 m)

[1] Plastic powder, etc. (Dielectric constant: 1.2)
[2] Plastic pellets, etc. (Dielectric constant: 1.35)
[3] Lime powder, cement, sand, etc. (Dielectric constant: 1.5)
[4] Kernels, brans, etc. (Dielectric constant: 1.5)
[5] Wood chips/pellets, etc. (Dielectric constant: 1.7)
[6] Cone and process seal antennas are the preferred choice for most solid applications.
[7] Recommended for longer measuring ranges, typically > 66 ft (20 m)

Table 7.14.3: Measuring range table for Rosemount 3408

The recommended measuring range for Rosemount 3408 varies depending on antenna type and product dielectric constant.

Rosemount 3408 antenna	Light powder[1]	Light granulates and pellets[2]	Heavy powder[3]	Grain size products[4]	Larger particles[5]
Lens antenna (¾-in. thread)	33 ft (10m)	49 ft (15 m)	49 ft (15 m)	49 ft (15 m)	49 ft (15 m)
Lens antenna (1- and 1½-in. threads)	49 ft (15m)	66 ft (20 m)	98 ft (30m)	98 ft (30 m)	98 ft (30 m)
Process seal and ATAP lens antennas	66 ft (20m)	98 ft (30 m)	98 ft (30 m)	98 ft (30 m)	98 ft (30 m)

[1] Light powder, etc. (Dielectric constant: 1.2)
[2] Plastic pellets, etc. (Dielectric constant: 1.35)
[3] Lime powder, cement, sand, etc. (Dielectric constant: 1.5)
[4] Kernels, brans, etc. (Dielectric constant: 1.5)
[5] Wood chips/pellets, etc. (Dielectric constant: 1.7)

Table 7.14.3: Measuring range table for Rosemount 3408

The figures given in Table 7.14.2 and Table 7.14.3 should be considered as guidelines; the total measuring range may differ depending on other contributing application conditions such as product filling, how the product piles up, silo diameter vs. angle of repose, internal obstacles within the silo, dust, condensation, antenna build-up, etc.

7.14.3 Dust management

Dust is often present in solids applications. Non-contacting radar may not be affected by the dust in the vapor space, but dust can be sticky and create a layer on the antenna. If this layer becomes too thick, it may affect the measurement. This is best managed by using air purging, which is available on the Rosemount 5408 and Rosemount 3408 Non-Contacting Radar Level Transmitters.

The easiest way to determine if air purging is needed is to open the manhole hatch and see if there is a thick layer of dust on it. If so, air purging is most likely needed.

In the absence of air supply, the process seal antenna provides an all PTFE solution — ideal for aggressive media, and is resistant to dust and/or condensation.
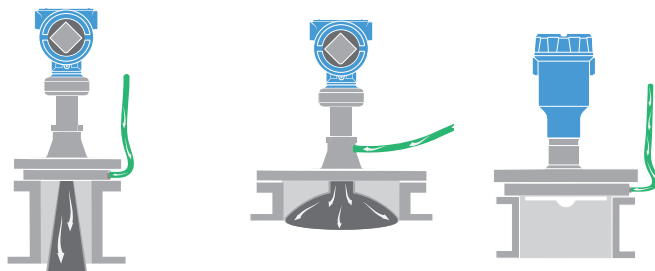
Figure 7.14.3: Dust management for Rosemount 5408 (images to the left) and Rosemount 3408 (last image to the right)

7.15 Measuring on metal plates

In some radar level measurement applications, it may be beneficial, or even the only way, to use a reflector plate. In these applications the reflector (or transmitter head!) is moving along with the surface thereby corresponding to the level.

Multiple mounting arrangements are possible, typically bracket-mounting is preferred but often flanged connection works as well.

We will outline three different metal plate reflector designs that can be used for such applications:

1. **A Flat Metal Plate Reflector**: typical shape is either square or circular. An arbitrary thickness is recommended. The dimensions are presented in below table:

Max. measuring distance	Plate diameter (circular)	Plate dimensions (square)
16 ft (5m)	Ø= 0.98 ft (0.3m)	w= 0.98 ft (0.3m)
32 ft (10m)	Ø= 1.31 ft (0.4m)	w= 1.31 ft (0.4m)
49 ft (15m)	Ø= 1.64 ft (0.5m)	w= 1.64 ft (0.5m)
65 ft (20m)	Ø= 1.96 ft (0.6m)	w= 1.96 ft (0.6m)
98 ft (30m)	Ø= 2.29 ft (0.7m)	w= 2.29 ft (0.7m)
131 ft (40m)	Ø= 2.95 ft (0.9m)	w= 2.95 ft (0.9m)

Table 7.15.1: Flat reflector plate minimum dimensions
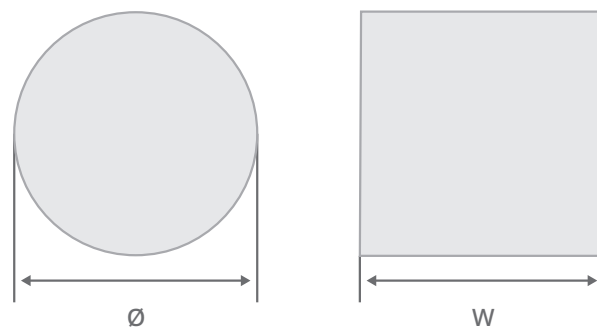
Figure 7.15.1: Circular or square metal reflector plate

This plate type is recommended for short distances, but can work for long distances also if best practice is followed. Not recommended in areas with frequent heavy rain or snow.

2. **A Corrugated Metal Reflector Plate**: typical applications are in tank gauging floating roof monitoring. The gauges measure the distance to a reflector placed on the tank roof. Ensure that the reflector meets recommended design specifications in order to prevent contamination build-up. The gap, (Fig. 3 - B) will ensure that water and snow can drip off the reflector.
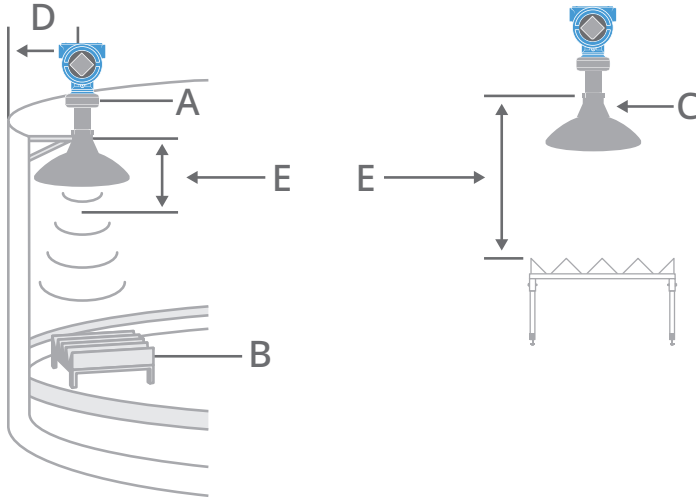
Figure 7.15.2: Corrugated plate installation recommendations

Where:

A. Tilt gauge

B. Reflector

C. Antenna

D. Minimum distance 31.5 in. (800 mm)

E. Recommended free space 31.5 in. (800 mm)
   Minimum distance 19.7 in. (500 mm)

NOTE!
IT is recommended to regularly make visual inspections to verify that each reflector is placed in the right position.
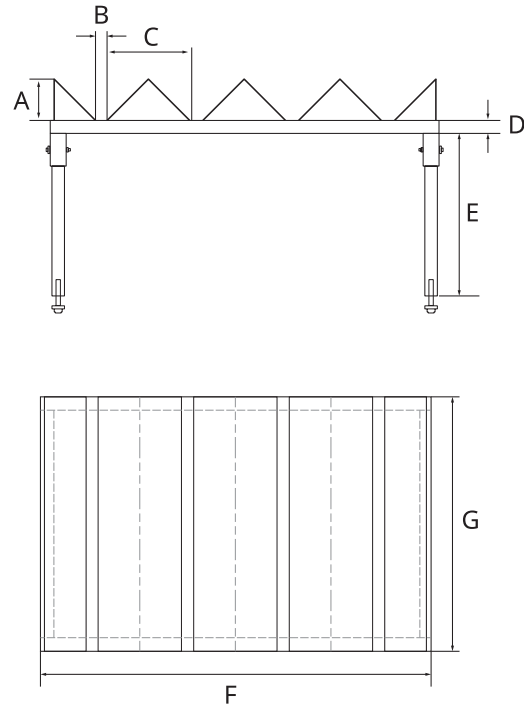
A.	130 mm (5.12 in)	E.	500 mm (19.7 in)
B.	35 mm (1.4 in)	F.	1200 mm (47.2 in)
C.	260 mm (10.2 in)	G.	780 mm (30.7 in)
D.	40 mm (5.12 in)		

Figure 7.15.3: Corrugated reflector plate design

Make sure that the tilt gauge is vertically aligned with the reflector. This will ensure that maximum signal strength is reflected back to the gauge.
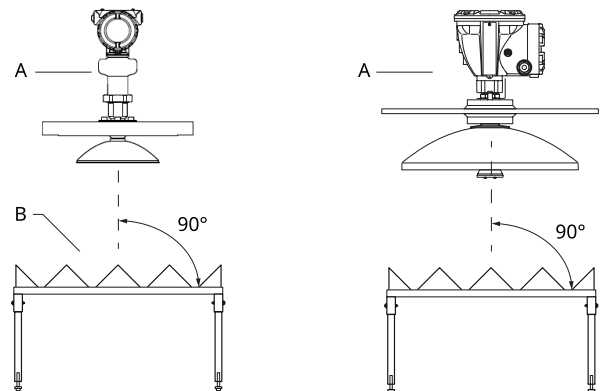
Figure 7.15.4: Antenna inclination

Where:

A. Radar gauge

B. Reflector

This plate is usually for floating roof and roof tilt applications. Can have problems with heavy snow. In such cases, heat tracing can be used.

3. **Triangular Trihedral Reflector Plate**: it is made with three right angle plates, as per below figure 5:
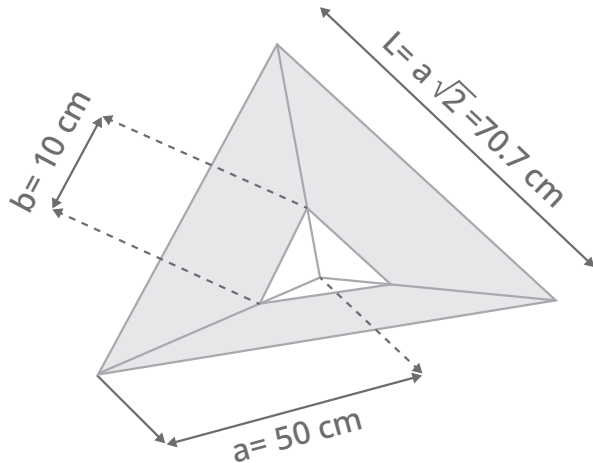
Figure 7.15.5: Trihedral corner reflector (minimum recommended dimensions)

The trihedral reflector is more tolerant to misalignment which provides a quick field setup. This design incorporates a small opening close to the plate center for snow or rain easy drip.

For best performance, the largest possible antenna should be used. For example, at very long distances, the parabolic antenna provides the best signal strength.

This plate can also be prone to heavy snow build-up, but heat tracing can help by-pass such issues.

General recommendation:

Reflector type	Suitable product
Flat plate	Rosemount 3408, Rosemount 5408, Rosemount 5900
Corrugated plate	Rosemount 5408, Rosemount 5900
Trihedral	Rosemount 5408, Rosemount 5900

Please note that none of these reflectors are available from the factory; they have to be supplied by the local sales office or customer. The above guidelines are designed to help with building such an accessory. Consult the factory for more detailed information.

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CHAPTER 8
TANK GAUGING SYSTEM INSTALLATION GUIDELINES

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8 Tank Gauging System Installation Guidelines

Before installing a tank gauging system it is important to survey the site and have a clear plan about the complete installation.

The different instruments needs to be located at suitable positions on the tank and the necessary cabling pulled between the instruments.

It is the responsibility of the user to ensure that the device meets the specific inside tank installation requirements such as:

- Chemical compatibility of wetted materials
- Design/operation pressure and temperature

The radar transmitters needs to be installed so that the influence of disturbing objects is kept to a minimum. It is also important to take into account any inclination of tank roofs and flanges.

If still pipes are used they must be surveyed to make sure that any ventilation holes and inner surfaces are in accordance with requirements.

For a complete specification of each instrument you can identify the model code attached to it and refer to the products data sheet for the details.

See the reference manual for specific requirements and recommendations to consider when installing the devices

- Rosemount 5900S Radar Level Gauge Reference Manual or visit our website www.Emerson.com/Rosemount5900S
- Rosemount 5900C Radar Level Gauge Reference Manual or visit our website www.Emerson.com/Rosemount5900C
- Rosemount 2240S Multi-input Temperature Transmitter Reference Manual or visit our website www.Emerson.com/Rosemount2240S
- Rosemount 2230 Graphical Field Display Reference Manual or visit our website www.Emerson.com/Rosemount2230
- Rosemount 2410 Tank Hub Reference Manual or visit our website www.Emerson.com/Rosemount2410
- Rosemount 2460 System Hub Reference Manual or visit our website www.Emerson.com/Rosemount2460

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CHAPTER 9
PRESSURE INSTALLATION GUIDELINES

Topic   **Page**

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9 Pressure Installation Guidelines

Differential pressure (DP) installations are a straight forward level measurement technique that is easily verified and calibrated. For open or vented tanks, the measurement is done using a gage or differential pressure transmitter installed with an impulse line or a single remote seal. For closed or pressurized tanks, the measurement is done using a differential pressure transmitter with two impulse lines, two seals, or one of each (impulse line and remote seal). The measurement can also be made using two gage pressure transmitters that are linked together digitally and DP is calculated in one of the two devices.

DP level applications may be categorized into five sections:

- Wet systems where impulse piping connects the vessel to the transmitter and is filled with process fluid or condensed vapors
- Direct mount level transmitters where a flange, seal, and fill fluid assembly is mounted to an open or vented tank
- Tuned-System™ Assembly that is comprised of a direct-mount transmitter and seal at the bottom vessel with capillary and a remote seal going to the top of the vessel
- Balanced seal system transmitters where seals are attached to both tank connections and an equal length of capillary is used to connect the seals to the transmitter
- Electronic Remote Sensors (ERS), where two gage (or absolute) pressure sensors are used to calculate DP electronically. One sensor is direct-mounted at the bottom of the vessel. The other is direct-mounted at the top of the vessel, and the two sensors are connected with an electrical wire.

9.1 Pressure and differential pressure using wet leg/dry leg installation

For wet leg applications the objective is to keep the fluid in the leg at a constant height. If the level (or weight) of the fluid changes in the impulse lines, that change will be detected as a change in the level of the tank even if the level of the tank has not changed.

Another common issue with wet legs is that when pressure drops, flashing can occur on the low side and the water in the piping can be lost. (Flashing is the sudden expansion of hot water when the pressure is reduced.) This is especially prevalent in boiler drum applications. In the narrow piping, the water moves back into the drum and a significant reduction in wet leg level height occurs.

To prevent common issues with wet legs, some simple guidelines can be used such as:

- The wet legs should not be insulated. Condensation of fluid in the legs is required for stability
- Wet legs should not be allowed to freeze. Care should be taken to prevent freezing as this can cause a blockage that prevents the pressure signal from reaching the transmitter and it could burst the impulse line. Heat tracing in cold climates is commonly used to prevent freezing
- The legs should be kept parallel or at a slight downward angle, and of equal lengths from the bottom tap to the transmitter
- The length of the wet legs should be kept as short as possible. They need to be below the drum or tank, but no more than 10 ft. (3 meters) below the drum. The longer the impulse line, the longer it takes the pressure signal to reach the transmitter. Long impulse lines increase response time
- A condensate pot should be used to help maintain a filled leg from the steam side of the drum. This will help reduce the effects of flashing
- Use a purge system if there is a chance of sediment building up in the impulse line. Sediment should be prevented from building up in the impulse line. Sediment can block the pressure signal from the transmitter thus preventing a level reading. If purge systems do not work, another method is to manually rod out the impulse line. This is the manual process of sending a rod down the line to clean out the sediment buildup. In some applications the sediment buildup can be so prevalent that a routine maintenance plan is required to purge or rod out the lines
- In boiler drum level applications, the distance from the tank to the condensate pot on the low side of transmitter must be sufficient to dissipate process temperature to below saturated steam temperature. The same is true on the high side of the transmitter. The distance from the tank to the transmitter must be sufficient to dissipate process temperature to below saturated steam temperature. A good guideline is to dissipate the temperature to 50 °F (10 °C) below the saturated steam temperature at the expected pressure

- The impulse line should be done with ½ in. pipe and pipe fittings, not ½ in. tubing and tube fittings. ½ in. schedule 40 pipe has an I.D. of 0.622 in., ½ in. schedule 80 is 0.546 in. ½ in. tubing may have an I.D. of 0.37 in., the I.D. of tube fittings may be even less. This can inhibit free flow of excess condensate

- Use "full port" valves suitable for process pressures and temperature. When used in the open position, they must be fully open
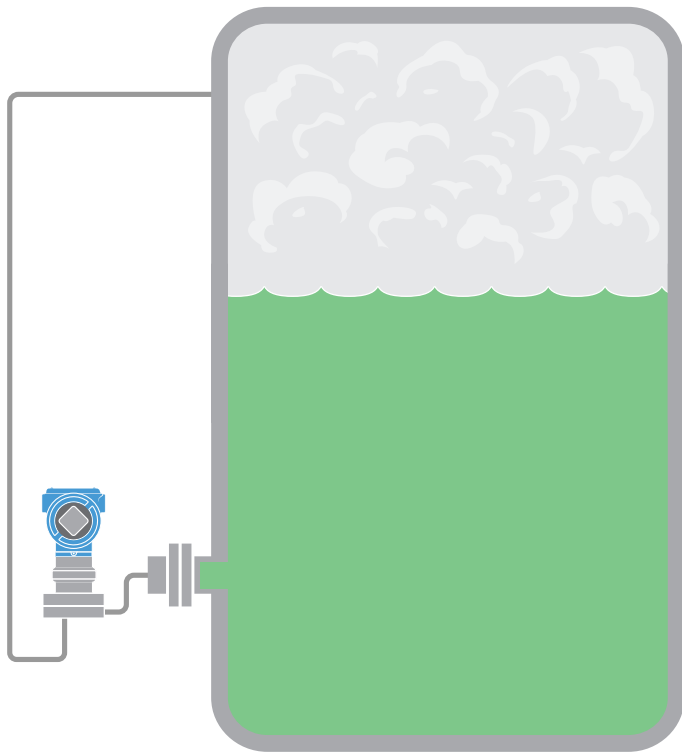
Figure 9.1.1: Illustration of a wet leg installation

9.2 Single pressure installation with seal system – vented/ open tank (LT transmitter)

A seal system consists of a pressure transmitter, one seal, a fill fluid, and a direct mount connection. During operation, the thin, flexible diaphragm and fill fluid separate the pressure sensing element of the transmitter from the process medium. The capillary tubing or direct mount flange connects the diaphragm to the transmitter. Transmitter/ seal systems should be considered when:

- The process temperature is outside of the normal operating ranges of the transmitter and cannot be brought into those limits with impulse piping.

- The process is corrosive and would require frequent transmitter replacement or specific exotic materials of construction.

- The process contains suspended solids or is viscous and may plug the impulse piping.

- There is a need to replace wet/ dry legs to reduce maintenance on applications where the reference leg is not stable or often needs to be refilled / drained.

- The process medium may freeze or solidify in the transmitter or impulse piping.

- There are multiple components to a seal system and choosing the right system will drive the best results and performance. Choose transmitter options based on the following:

- Transmitter specifications Accuracy and total performance
  - Stability
  - Warranty

- Style
  - Coplanar: used for DP measurement
  - In-line: pressure applications

- Sensor range
  - Select the lowest sensor range that will operate at maximum pressure

- Features and capabilities

Choose a process connection based on:
- Size and type of process connection
  - Flanged
  - Threaded
  - Speciality

- Diaphragm choices tied to process fluid and application
  - Small diameter diaphragms on seals are sensitive to temperature changes. Larger diameter diaphragms help to minimize the errors.
  - Choose the right materials of construction: SST, Alloy-C 276, Titanium (etc)
  - Gold-plating (hydrogen permeation)
  - Teflon-coating (non-stick)

- Gasket material should also be considered

- Choose an extended diaphragm for applications where sediment or plugging may be an issue

Choose the linkage between the transmitter and process connection:
- Type of connection
  - Direct mount for easier installation, minimizing temperature effects, and faster response time
  - Capillary connection for higher temperature rating
  - Always use welded connections. Threaded capillary connections leak and entrap air into the system

- Capillary choices
  - Smaller IDs to increase accuracy
  - Larger IDs to improve time response
  - Use shortest lengths possible to improve accuracy and response time
- Each fill fluid has its own unique physical characteristics and plays the largest role in total system performance. The physical characteristics include: viscosity, coefficient of thermal expansion, and specific gravity.
  - Use low viscosity fill fluids to improve response time
  - Use fill fluids with low a coefficient of thermal expansion to reduce temperature effects
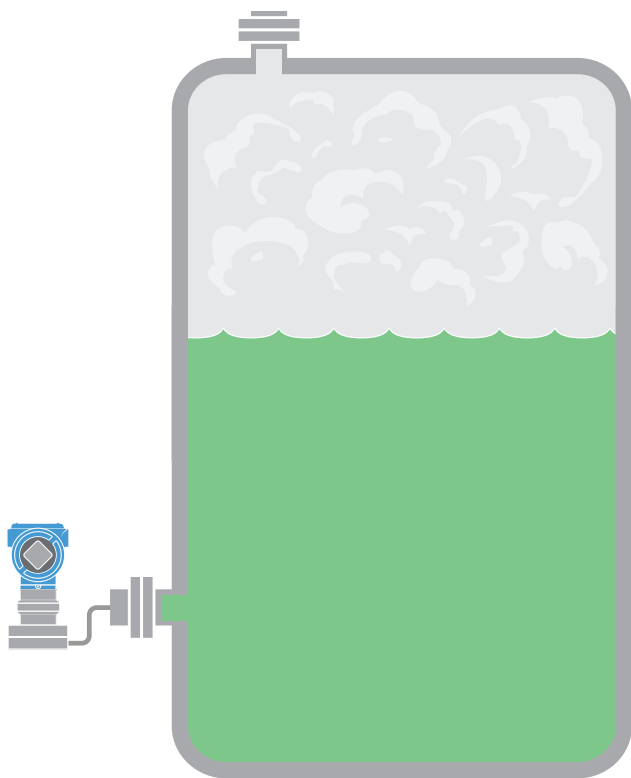
Figure 9.2.1: Illustration of a DP installation in a vented tank

Mounting of the transmitter with a seal assembly is important as well. Although seals provide the user with more mounting flexibility, it is not unlimited. In most cases, direct mounting is the best method. For vacuum applications, the transmitter should always be mounted at or below the level of the bottom tap. For tanks at atmospheric pressure and above, the transmitter can be mounted above the bottom seal, but the distance multiplied by the specific gravity of the fill fluid should always be less than the equivalent of 1 atmosphere of pressure. Both of these measures help prevent damage to the seal and ensure proper function of the entire assembly.

9.3 DP installation using tuned- system assembly

Tuned-system assemblies are a best-practice installation for smaller tanks and applications with higher pressures. Tuned-system assemblies contrast significantly to traditional symmetrical (balanced system) configurations, resulting in reduced temperature induced errors, faster time response, and reduced installed costs. Differential pressure seal systems have traditionally been specified with identical capillary lengths and seal configurations on both the high and low pressure process connection. Specifying symmetrical systems was once believed to achieve best total system performance. Actually, the asymmetry of tuned-system assemblies compensates for temperature-induced errors.

Tuned-system assemblies are an asymmetric configuration of a differential pressure diaphragm seal system. The tuned-system assembly directly mounts the diaphragm seal to the high pressure process connection. Elimination of the excess high pressure capillary immediately improves response time, and performance, while reducing installed cost. Total system error is compensated by leveraging diaphragm induced temperature errors against head effect temperature errors.

Installed cost is reduced by eliminating the excess high pressure capillary. Because the transmitter is directly mounted to the vessel, the mounting stand and mounting bracket are not required to further reduce installed cost.

To see tips on how to choose and install the right tuned-system assembly for your application, please refer to the section titled "Single pressure installation with seal system – vented/open tank."
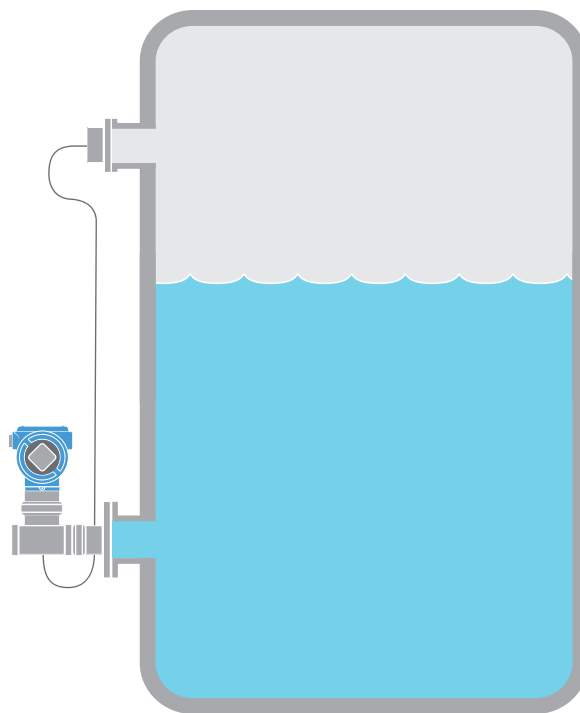
Figure 9.3.1: Illustration of a tuned system

9.4 DP installation with balanced system

Balanced (symmetric) remote seal systems have equal capillary lengths and the same seal types on both the high and low side. As previously mentioned, the balanced system eliminates seal temperature effect but it does not eliminate head temperature effect. Due to this the balanced system is not as accurate and the time response is slower as compared to a tuned-system assembly.

With that said, balanced systems do have their place. To maximize their capability, it is also helpful to use the largest diameter diaphragm that is practical along with the shortest capillary lines that have the smallest internal diameter.

Mounting of the transmitter with a seal assembly is important as well. Although seals provide the user with more mounting flexibility, it is not unlimited. For vacuum applications, the transmitter should always be mounted at or below the level of the bottom tap. For tanks at atmospheric pressure and above, the transmitter can be mounted above the bottom seal, but the distance multiplied by the specific gravity of the fill fluid should always be less than the equivalent of 1 atmosphere of pressure.

Both of these measures help prevent damage to the seal and ensure proper function of the entire assembly.

To see tips on how to choose and install the right balanced system for your application, please refer to the section titled "Single pressure installation with seal system – vented / open tank."

9.5 DP installation using ERS technology

Electronic Remote Sensor (ERS) technology is a best practice installation for differential pressure in distillation towers, tall vessels, and other similar applications that have traditionally required excessive lengths of impulse piping or capillary.

Rather than using a single DP transmitter, the Rosemount 3051S ERS™ System is comprised of two direct-mount gage or absolute sensors that are linked together electronically. The sensor mounted at the bottom of the vessel measures the amount of pressure exerted by both the liquid level and the vapor pressure. The sensor mounted at the top of vessel measures just the vapor pressure. The DP is calculated by taking the bottom pressure (PHI) and subtracting the top pressure (PLO). This calculation is handled by a set of integrated electronics that resides in either one of the sensors.

Because the Rosemount 3051S ERS system uses a digital architecture compared to a traditional mechanical installation, ERS technology can deliver faster time response, a more stable and repeatable measurement, and simplified installations.
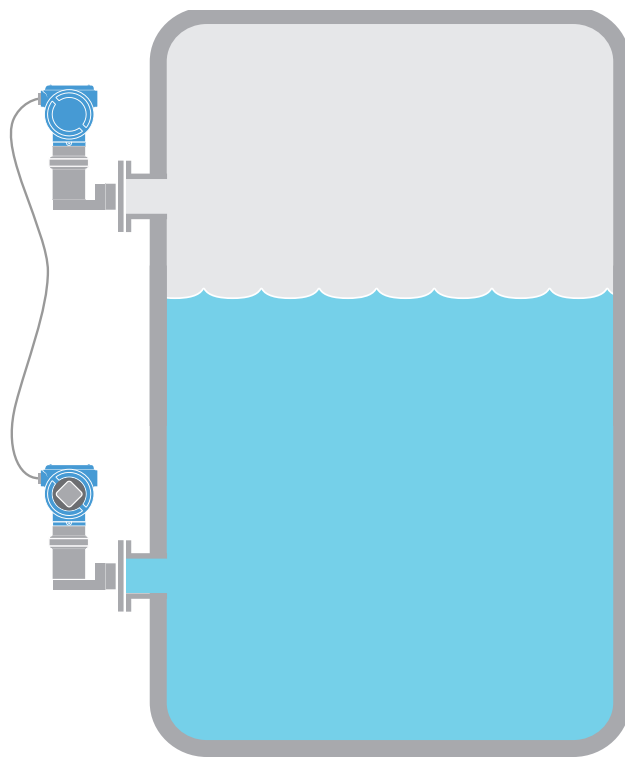
Figure 9.5.1: Illustration of an ERS installation

Figure 9.4.1: Illustration of a balanced system

Sensor selection

When considering the use of a Rosemount 3051S ERS System on a particular application, both the vapor (static) pressure and the DP span need to be taken in account. In a traditional DP transmitter application, the DP sensor is sized just on the DP span from the liquid level. For an ERS application with the use of gage or absolute sensors, the sensor range for each unit needs to be sized on the entire amount of pressure in the vessel (DP + vapor pressure). Because of this, a more traditional DP Level technology, such as a tuned-system assembly, may be a better solution on applications that are operating at higher pressures with small DP spans.

For most ERS applications, the use of two gage sensors should be sufficient. However, two absolute sensors should be used in applications that are subject to vacuum conditions.

Process connections

One of the major benefits of the Rosemount 3051S ERS System is the variety of ways in which the technology can be installed. For example, a Rosemount 3051S ERS System can be installed with standard transmitter flanges, level flanges, instrument manifolds, or direct-mount seals.

Depending on the temperature, physical and chemical characteristics of the process, an appropriate connection type should be used. Below are the temperature limits of various ERS configurations:

Connection type	Temperature limit
Coplanar sensor	
With coplanar flange	250 °F (121 °C)
With traditional flange	300 °F (149 °C)
With level flange	300 °F (149 °C)
With 305 integral manifold	300 °F (149 °C)
In-line sensor:	250 °F (121 °C)
Direct-mount seal (UltraTherm™ 805) Thermal range expander:	770 °F (410 °C)
Remote seal (UltraTherm™ 805) Thermal range expander:	770 °F (410 °C)

For example, applications above 500 °F (260 °C) may require each sensor to be installed either with a short length of impulse piping or a remote seal with a short length of capillary to allow for enough heat dissipation to ensure the instrumentation does not overheat. The Rosemount Thermal Range Expander can also be used which allows direct mounting of ERS system for temperatures up to 770 °F (410 °C). Additionally, the use of seals may still be required for processes that are viscous, corrosive, or other conditions detailed in section 9.2.

Wiring

The wiring between the two sensors is made with a non-proprietary cable. The recommended cable is available from Emerson. Other cables can be used as long as it has independent dual twisted shielded pair wires with an outer shield, and the capacitance must be less than 50 picofarads per foot (163 picofarads per second). Additionally, all wiring should be made in accordance to meet the necessary hazardous location approvals for the installation. For example, the use of rigid conduit may be required for some explosion-proof environments. The cable length between the two ERS sensors is limited to 500 ft. (152.4 meters).

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CHAPTER 10
SWITCH INSTALLATION GUIDELINES

10

10 Switch Installation Guidelines

10 Switch Installation Guidelines

10.1 Vibrating fork switches: Liquids

- Use where the application demands a degree of fail-safety and self-checking

- Use where the liquid is corrosive and demands special wetted materials

- Use where the liquid may contain suspended particles and a device with no moving parts is preferred

- Use when minimal intrusion into the tank or pipe is required

The Rosemount 2100 series consists of five vibrating fork switch types designed for installation in different types of point level applications.

The following guidelines may be used to select the best choice for your installation:

Rosemount 2110 - Compact model. Suitable for installation in small vessels or pipes or for high volume fast-fit, OEM-type applications.

Figure 10.1.1: Rosemount 2110

Rosemount 2120 - Standard model. Wide choice of materials, process connection types and output options (see next section for output selection).

Figure 10.1.2: Rosemount 2120

Rosemount 2130 - Enhanced performance model. Flexibility of Rosemount 2120 options with extended capabilities for challenging process conditions. (See next section for output selection.)

Figure 10.1.3: Rosemount 2130

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Rosemount 2140 - Wired HART model suitable for standard monitoring and control applications. Install in existing HART loops without additional point to point wiring. The Rosemount 2140 model is also available with Safety certification (Rosemount 2140:SIS), and it is suitable for functional safety and critical control applications. It can be installed in existing HART loops without additional point to point wiring.

Figure 10.1.4: Rosemount 2140 and
Figure 10.1.5: Rosemount 2140:SIS

Rosemount 2160 - Wireless HART model. Install automation in remote and hard to reach locations. No wiring / additional infrastructure required for installation.

Figure 10.1.6: Rosemount 2160

10.1.2 Rosemount 2120 and 2130 output selection

Do you require IS certification?

Yes →

Do you require analog interface or DCS?

Yes →

Choose the 8/16 mA cassette (Electronics Code M)
Number of wires: 2 + Ground

Electronics cassette M is suitable for Intrinsically Safe (IS) applications and requires a certified isolating barrier.

This electronics cassette is also suitable for non-hazardous (safe) area applications. It can only be interchanged with the NAMUR cassette

No (from analog interface)

Choose the NAMUR cassette (Electronics Code N)
Number of wires: 2

Electronics cassette N is suitable for Intrinsically Safe (IS) applications and requires a certified isolating barrier.

This electronics cassette is also suitable for non-hazardous (safe) area applications. It can only be interchanged with the 8/16 mA cassette

No (from IS certification)

Do you require voltage free dry contacts (relay)?

Yes →

Choose the Relay cassette (Electronics Code D)
Number of wires: 6 + Ground

No

Do you require 2-wire switching?

Yes →

Choose the Direct Load cassette (Electronics Code L)
Number of wires: 2 + Ground

No

Are you interfacing directly into a PLC or DCS?

Yes →

Choose the PNP/PLC cassette (Electronics Code P)
Number of wires: 3 + Ground

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Table 10.1.2. Vibrating fork switches output selection (b)

8/16 mA

OPERATION MODE
Dry On Mode
Dry On Wet On
Dry
Wet
0.3 / 1 / 3 / 10 / 30
Wet / Dry
Wet On Mode
Seconds Delay
1 2 3
8/16 mA

A certified intrinsically safe barrier must be used to meet IS requirements

The Rosemount 2130

Non-hazardous Area   Hazardous Area

Ion = 15 to 17 mA
Ioff = 7.5 to 8.5 mA

NAMUR

8V dc
OPERATION MODE
Dry On Mode
Dry On Wet On
Dry
Wet
0.3 / 1 / 3 / 10 / 30
Wet / Dry
Wet On Mode
Seconds Delay
1 2
EN 50227 / NAMUR

Isolating Amplifier to NAMUR
(IEC60947-5-6, EN50227)
PSU
NC
C
NO
PSU
Load

The Rosemount 2130

Non-hazardous Area   Hazardous Area

Ion = 2.2 to 2.5 mA
Ioff = 0.8 to 1.0 mA

DPCO Dual Relay

Warning
N L
OPERATION MODE
Seconds Delay
Dry On Wet On
0.3 / 1 / 3 / 10 / 30
Dry On
Dry
Wet
Wet On
Isolate Supply Before Removing
NC C NO NC C NO
1 2 3   4 5 6 7 8 9
RELAY

PSU
PSU
Relay SPDT
C NC
NO
C NC
NO
PSU
Load
NC
NO
NC
NO
C
C
PSU
Load

The Rosemount 2130

Fault Relay

Warning
N L
OPERATION MODE
Seconds Delay
Dry On Wet On
0.3 / 1 / 3 / 10 / 30
Dry On
Dry
Wet
Wet On
Alarm
Isolate Supply Before Removing
Fault
NC C NO NC C NO
1 2 3   4 5 6 7 8 9
FAULT RELAY

PSU
PSU
Relay SPDT
C NC
Alarm Relay
NO
C NC
Fault Relay
NO
PSU
Pump Off
Lamp On
NC
NO
NC
NO
C
C
PSU
Alarm Relay - Energized
Fault Relay - Energized

The Rosemount 2130

Direct Load Switching

LOAD LINE
OPERATION MODE
Dry On Mode
Dry On Wet On
Dry
Wet
0.3 / 1 / 3 / 10 / 30
Wet / Dry
Wet On Mode
Seconds Delay
1 2 3
Direct Load Switching
WARNING
Isolate Supply Before Removing

PSU
Relay SPDT
PSU
C NC
NO
Load

The Rosemount 2130

PNP/PLC

+ OUT −
OPERATION MODE
Dry On Mode
Dry On Wet On
Dry
Wet
0.3 / 1 / 3 / 10 / 30
Wet / Dry
Wet On Mode
Seconds Delay
1 2 3 4
PLC/PNP
Isolate Supply Before Removing

PNP/PLC
+
Input
−

The Rosemount 2130

10.1.3 Installation best practices

- Before installing a Rosemount 2100 level switch, consider specific installation recommendations and mounting requirements.

- Rosemount 2100 series is available in Intrinsically Safe (IS) or explosion-proof/ flameproof versions for hazardous area installations. There are also ordinary location versions for unclassified, safe areas.

- Rosemount 2100 series can be mounted either horizontally or vertically in an open or closed tank, or a pipe. There is a wide range of threaded, flanged, and hygienic process connection options.

- Supported process temperature ranges are dependent on the selected Operating Temperature code in the model number.

- For pipe installation or installation where there is a flow of liquid around the forks, always ensure that the forks are positioned so that the liquid flows through the fork gap (see figure 10.1.4)

- Always install in the normally "on" state for safest operation

  - For high level the recommendation is Dry = on
  - For low level the recommendation is Wet = on

- Always ensure the system is tested by using the local magnetic test point during commissioning (Rosemount 2110, 2120, 2130)

- Ensure sufficient room for mounting and electrical connection

- Provide 0.75 in. (19 mm) of clearance for a standard cover to be removed. If an LCD display is installed (option available for Rosemount 2140 and 2160 models), provide 3 in. (76.2 mm) of clearance for the extended cover to be removed.

- Ensure that the forks do not come into contact with the tank wall or any internal fittings or obstructions

- Avoid installing the 2100 where it will be exposed to liquid entering the tank at the fill point

- Avoid heavy splashing on the forks, however raising the switch time delay reduces accidental switching caused by splashing

- Check for risk of process medium build-up on the level switch forks. Avoid situations where a drying and coating process medium may create an excessive build-up, or implement preventative maintenance programs to ensure the build-up is not enough to impair performance

- Ensure there is no risk of 'bridging' the level switch forks. Examples of products that can create 'bridging' of forks are dense paper slurries and bitumen.

- Ensure there is sufficient distance between build-up on the tank wall and the fork

- Ensure installation does not create tank crevices around the forks where liquid may collect (important for high viscosity and high density liquids)

- Avoid long fork length vibration by supporting the fork (see figure 10.1.8)

- If used in a pump application, mount on sufficient distance from pump to avoid cavitation

- Install Rosemount 2140 at low level in a separator to detect settled sediment build up. Mount the device so the fork tines are situated in the area where sand is most likely to accumulate

10
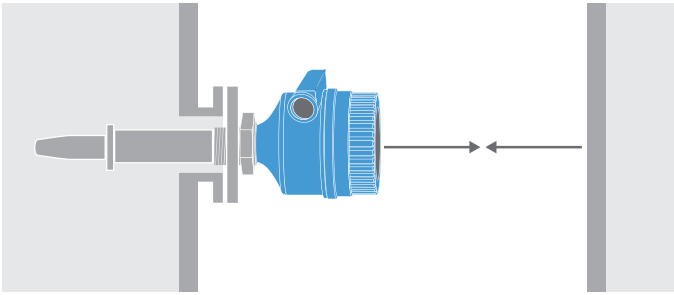
Figure 10.1.7: Ensure adequate space outside tank
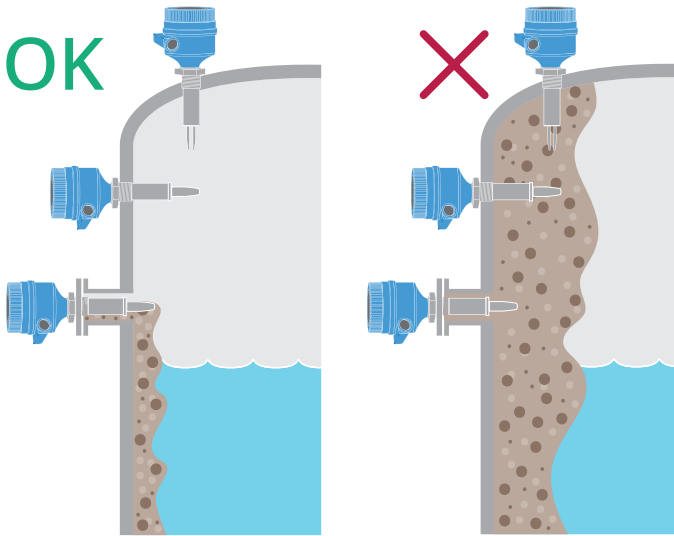
Figure 10.1.8: Example of ok and not ok build-up on tank wall
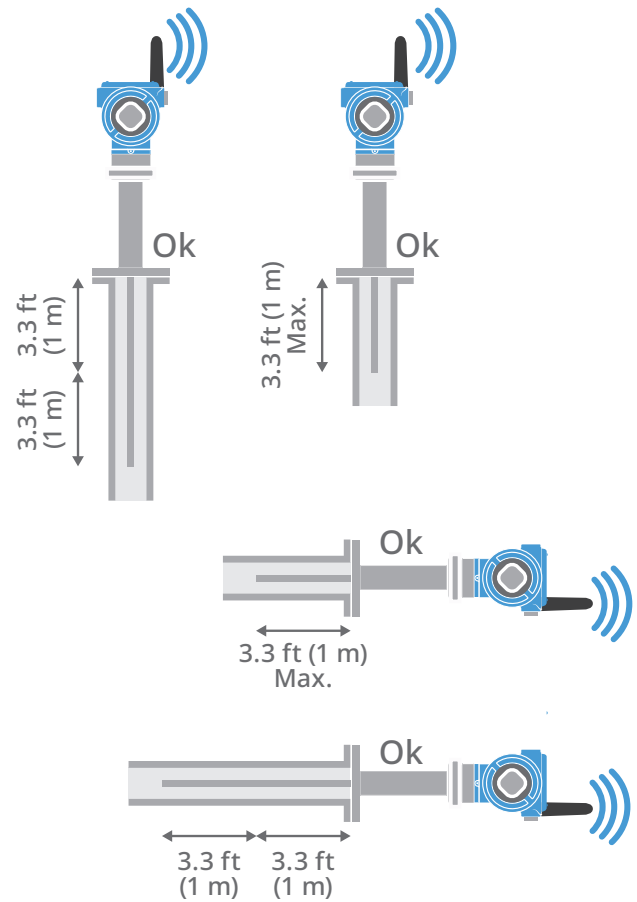
Figure 10.1.9: Support fork every 3 ft (1 m)

OK

×
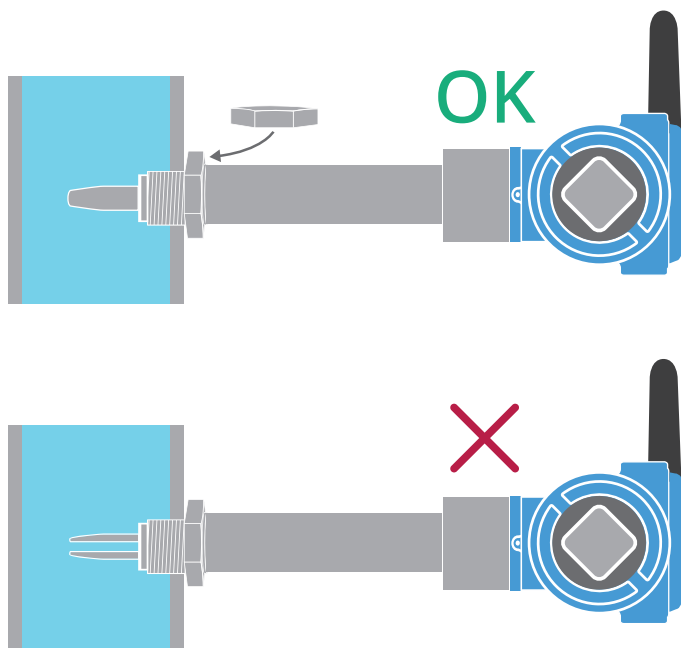
Figure 10.1.10: Illustration showing how to align the fork in a pipe application

A

B

C
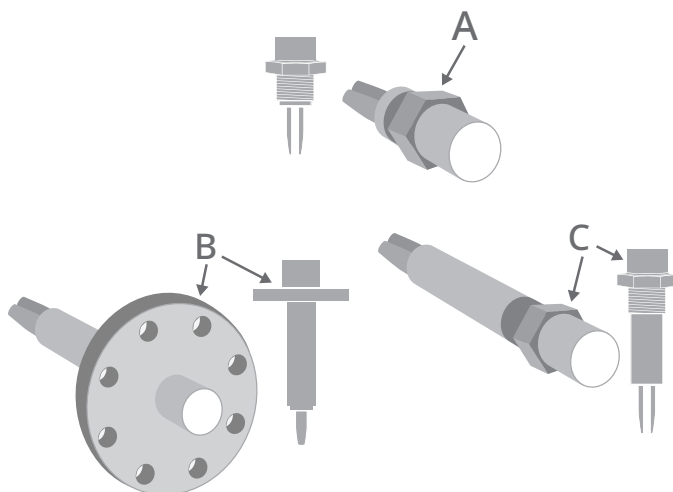
Figure 10.1.11: Illustration showing correct fork alignment

10.2 Solid Switches Installation Guidelines

The Rosemount 2500 series consists of four different technologies for point level detection to suit different types of vessels and process conditions. The level switches have versatile installation options with threaded, flanged, or Tri Clamp process connections and a wide range of extensions available. They can be mounted on top of a silo or on a side wall for full, on demand or low level detection.

Rosemount 2501 - Rosemount 2501 Rotating Paddle is a robust paddle switch that can withstand heavy loads and extreme temperatures. It is available with different paddle shapes and sizes to monitor all bulk media in nearly all types of vessels. Compact boom length is particularly suited for small process vessels.

Figure 10.2.1: Rosemount 2501

Rosemount 2511 - Rosemount 2511 Vibrating Fork is suitable for use in storage and process vessels where high sensitivity is needed. Install the level switch in applications with fine-grained and powdered bulk materials that do not show a strong tendency to form crusts or deposits.

Figure 10.2.2: Rosemount 2511

10

Rosemount 2521 - Rosemount 2521 Vibrating Fork offers an enhanced version suitable for applications with extra high sensitivity requirements. Install the level switch in applications with fine-grained and powdered bulk materials that do not show a strong tendency to form crusts or deposits. The polished forks make it suitable for use in hygienic applications.

Figure 10.2.3: Rosemount 2521

Rosemount 2535 - Rosemount 2535 Vibrating Rod is suitable for use in storage silos and process vessels with fine-grained and powdered materials. The simple design makes it unaffected by grain size, less prone to clogging, and widely used in applications with limited space. Avoid installation in applications with high mechanical forces.

Figure 10.2.4: Rosemount 2535

Rosemount 2555 - Rosemount 2555 Capacitance Probe is a robust point level measurement for use in nearly all types of bulk material in all types of vessels. It can withstand extreme process conditions such as high temperatures, high mechanical stress, and high tensile forces. The level switch offers automatic calibration for easy commissioning, and self-checking diagnostics with easy-to-read display for condition monitoring.

Figure 10.2.5: Rosemount 2555

10.2.1 Installation best practices:

The Rosemount 2500 series switches are simple to install and maintenance-free point level detectors for use in nearly all types of vessels. Before mounting the level switch on a silo (or other vessel), consider installation recommendations and mounting requirements.

The Rosemount 2500 series can be mounted in horizontal, vertical, or angled positions with various extensions and process connection options. Consider mounting in an angled position, approximately 20°, to prevent solids build-up and reduce the mechanical load on the probe.

Avoid mounting the switch near the filling point, internal structures, and walls of a silo/vessel. Refer to the product specifications for minimal distance between the level switch and tank wall/other objects.

A sliding sleeve is recommended to easily change the insertion length of the level switch on site.

If the level switch is mounted in a horizontal position, ensure cable glands are pointed downwards to avoid water from getting inside the housing. Unused conduit entries must be completely sealed with a suitably rated stopping plug.

The fork switches have high sensitivity as default setting, but the sensitivity setting can be adjusted to best match the application in which the level switch is installed. If the bulk material is heavy and has strong tendency to cake or deposit, the sensitivity of the probe can be set at low level.

The FSH/FSL setting can be used as protection against overfilling or running dry. Use the FSH setting when the level switch is to be applied as a full-silo-detector, and the FSL setting when used as an empty-silo-detector. A power failure or line break is regarded as full- or empty-silo signal.

The signal output delay can be adjusted to prevent false switching when there is movement of the bulk material.

For safe operation, make sure that the load at the measuring point does not exceed the maximum loads supported by the level switch.

The Rosemount 2555 offers automatic calibration when the level switch is powered up for the first time. Prior to calibration, make sure that the level switch is correctly mounted and wired, and that the level of solids is below the probe.
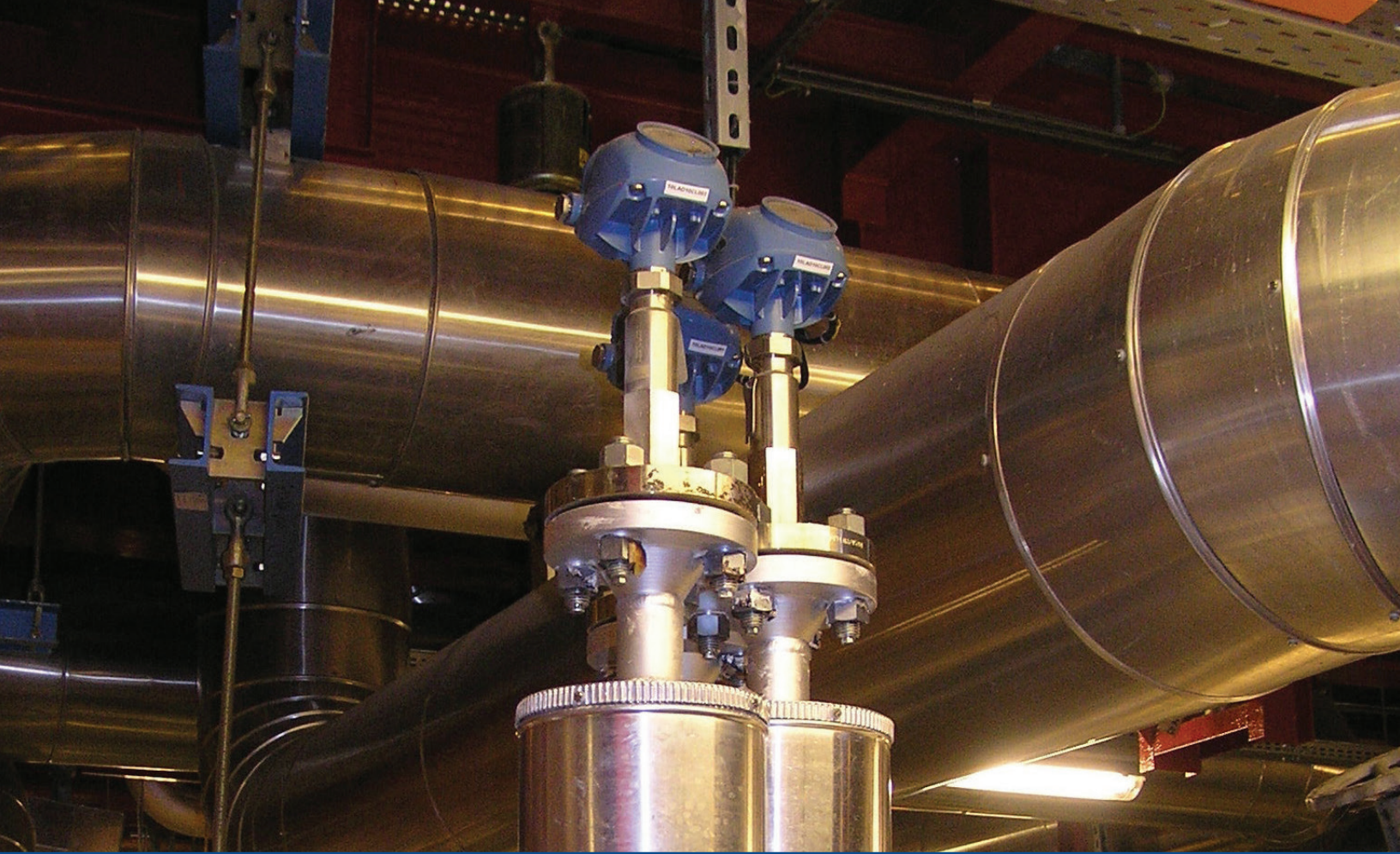
10

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CHAPTER 11
COMPLETE POINT SOLUTION WITH GUIDED WAVE RADAR AND ROSEMOUNT CHAMBERS

11

11 Complete Point Solution

11. Complete point solution with guided wave radar and Rosemount chambers

The Rosemount chamber is designed for complete compatibility with Rosemount level measurement instruments. A combined Rosemount chamber and Rosemount Guided Wave Radar solution (also known as complete point solution) is designed for safety, meeting highest industry standards, and delivers an integrated bolt-on level solution.

11. 1 What are the advantages of a complete point solution?

Complete point solutions offer these advantages:

- Complete measurement solution, ready to install out of the box
- Designed and built to meet the pressure and temperature (P/T) rating for the tank connection
- Built with certified and traceable material
- Manufactured by qualified welders and welding procedures
- Assembled and configured at factory before shipping
- Single site customer inspection option
- Proven performance and technology

11.2 Installation guidelines for guided wave radars in chambers

Chambers are used to obtain a level measurement from the outside of a process vessel. It is important that the level measurement within the chamber replicates the level inside the vessel. To achieve this, there are some key considerations: Chamber and connection sizes, Guided Wave Radar probe selection and installation can all impact the level measurement accuracy.

Guided Wave Radars may be used in 2-in., 3-in., or 4-in. diameter chambers, although the Rosemount chamber is only available in 3-in. and 4-in. options. Emerson encourages the use of larger diameter chambers to avoid potential issues described below.

Several parameters can impact level measurement results in chambers, see table 11.3.1 for size considerations.

The chamber length is specified to accommodate the desired measurement span. While overall weight and cost are key considerations, ultimately the reliability of the measurement may be impacted by the diameter of the chamber, the connections to it and the ambient conditions. Some common issues seen in chamber applications include:

11.2.1 Out-gassing effects

If a fluid is subject to Out-gassing Effects when the system pressure drops, then gas bubbles may cause the level surface to be pushed artificially higher in the chamber. A larger chamber diameter is more tolerant, and any bubbles have less effect on the liquid level.

11.2.2 Chamber diameter

Narrow diameter chambers are more susceptible to the probe touching or getting close to the wall of the chamber, especially as the length increases. Centering discs may be used along the length of the probe to provide additional stability. These can be places for dirt to build up, so they should be used carefully.

Rigid probes are preferred in narrow chambers, but these must be installed carefully in order to avoid bending. If flexible probes are used, then accommodation must be made to pull the probe taut so that it does not touch the wall.

11.2.3 Temperature changes

The fluid in a chamber may change temperature, causing the volume within to expand or contract, thus changing its representation of the level. Use of insulation/ lagging around the chamber can help to prevent this effect.

11.2.4 Condensation of vapors

Condensation from vapors can result in the build-up of additional fluids in the chamber that are not present in the vessel. This is especially common with light end hydrocarbon vapors where the fluid stratifies on top of the measured fluid.

11.2.5 Fluid circulation

With all chamber installations, good fluid circulation will ensure a good representation of the actual level. To accomplish this, minimize any restrictions between the vessel and the chamber and use both larger connections and short process connection piping distances. Insulation and heat tracing will minimize the temperature change and prevent vapor condensation, freezing, or solidification of fluids. If the fluid is viscous, dirty, or tends to build up debris, then a flushing mechanism is essential.

11.3 Probe and chamber selection guidelines

For most applications, single rigid or large coaxial probes are the best choice. When a Guided Wave Radar transmitter is used in a chamber, the microwave signals are guided and contained within the chamber. This results in a stronger signal from the fluid surface which is an advantage for turbulent and/ or low dielectric fluids. Single rigid probes are less susceptible to buildup and are more tolerant in the case of coating than coaxial probes. In very low dielectric but clean fluids, such as liquefied gases like LNG, a large coaxial probe is preferred.

In steam applications, such as high pressure feedwater heaters and boilers, when the pressure is greater than 400 psi (27.6 bar), the dielectric of the steam vapor will impact the level accuracy. To compensate for this, a special probe with a built-in reflector should be used. This probe enables Dynamic Vapor Compensation by using the reflector pulse to complete an on-line dielectric calculation of the steam. When using a Dynamic Vapor Compensation probe, it is important that the reflector is always above the liquid surface and away from any potential disturbances. For this reason, the chambers used for the Dynamic Vapor Compensation probe must have a longer top section.

Several parameters can impact level measurement results in chambers, see table 11.3.1 for size considerations.

Installation parameter	Chamber diameter	
	3 in.	4 in.
Rigid probe	OK	OK
Flexible probe	Fair-use heavy weight	Preferred
Side connections, large (2 in.)	Fair	Preferred
Side connections, small (1 in.)	OK	OK
Overall length (<2 m)	OK	OK
Overall length (> 2 m)	Fair - use centering discs, heavy weight[1]	
	OK	
Low DC fluid (down to 1.4)	OK	OK
High DC fluid	OK	OK
Rapid fill rates	OK	OK
Boiling, turbulence	OK	Preferred
Gas lift	OK	Preferred
Viscous, clogging fluids	Heat trace	Heat trace

[1] Use weight with flexible probe

Table 11.3.1 Installation parameters and chamber size summary

11.4 How to select and size your chamber and guided wave radar

11.4.1 Step 1 Select a chamber

For full specifications, refer to the Rosemount chamber product data sheet. The chamber process connections and instrument connection should be sized to match the vessel and instrument connections respectively.

The location of the bottom connection will determine the chamber style (side-and-side or side-and-bottom process connections). The chamber center to center dimension (B) is critical and must match the process vessel center to center.

Once total chamber length is determined, it is important to verify that there is sufficient clearance above and below the chamber, allowing for Guided Wave Radar, drain etc.

11.4.2 Step 2 Select a Guided Wave Radar transmitter

Single rigid or large coaxial probes are the preferred probe styles for chamber installations. For full Guided Wave Radar specification, please see Product Data Sheets.

11.4.3 Step 3 Verify pressure/temperature (P/T) rating of complete solution

The final P/T rating of the complete solution is based on the material of construction, process seal and flanges selected, see figure 11.4.2. The minimum and maximum temperature depends on type of process seal, flange and the o-ring.

Guided Wave Radar material of construction for flange and process seal (STD seal, HP seal, HTHP seal) (See table 5.12.2 and 5.12.3)

Material of construction for the chamber (stainless steel or carbon steel)

Bolting material (See table 5.12.3)

Gasket (See table 5.12.2)

P/T rating, test pressure (See table 5.12.2)
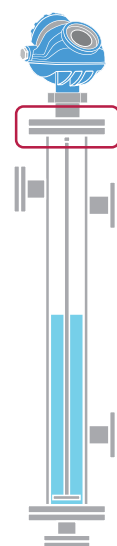
Figure 11. 4.2 Pressure/temperature (P/T) rating considerations

Figure 11. 4.1 Key chamber considerations

ASME B16.5	Gasket	P/T@RT		P/T @ 150 °C/300 °F		P/T @ 250 °C/482 °F		P/T @ 400 °C/750 °F		TP @ RT		TP @ RT	
CLASS				STD seal[1]		HP seal		HTHP seal		STD seal		HTHP/HP seal	
		BAR	PSI	BAR	PSI	BAR	PSI	BAR	PSI	BAR	PSI	BAR	PSI
150#	1a/1b	15.8	230	12.1	175	11.2	160	6.5	95	23.7	345	23.7	345
300#	1a/1b	41.3	600	31.3	455	29.2	420	24.3	355	62.0	900	62.0	900
600#	1a/1b/ RTJ	82.7	1200	[2]	[2]	58.2	840	48.6	705	[2]	[2]	124	1800
900#	1a/1b/ RTJ	124.1	1800	N/A	N/A	87.5	1260	72.9	1060	N/A	N/A	186.2	2700
1500#	1a/1b/ RTJ	206.8	3000	N/A	N/A	145.8	2100	121.5	1765	N/A	N/A	310.2	4500

[1] Final rating depends on flange and o-ring selection (for more information see Reference Manual).
[2] Consider standard seal max rating.
RT: Room temperature TP: Test pressure
HP seal: High pressure seal HTHP seal: High temperature/high pressure seal STD seal: Standard process seal (RTJ) Ring joint
(1a) Soft gasket 1b) Spiral wound gasket

Table 11.4.1 Pressure/Temperature rating for Guided Wave Radar 316L flange welded connections when used with stainless steel or carbon steel Rosemount chamber.

Material of construction in Guided Wave Radar model code	Bolting material[1]	Gasket STD/HTHP	Gasket HP/HTHP	Flange material Guided Wave Radar	Process seal housing material Guided Wave Radar
SST, B16.5, flange connection[2]	Stainless steel SA193 B8M Cl. 2	Soft (1a) with min. thickness 1.6 mm	Spiral wound gasket with nonmetallic filler (1b)	Stainless steel A182 Gr. F316L and EN 10222-5-1.4404	Stainless steel SA479M 316L and EN 10272-1-1.4404
Alloy C-276 plate design	Stainless steel SA193 B8M Cl. 2	Soft (1a) with min. thickness 1.6 mm	Spiral wound gasket with nonmetallic filler (1b)	Stainless steel A182 Gr. F316L and EN 10222-5-1.4404[3]	SB574 Gr. N10276
SST EN1092-1, flange connection[2]	Stainless steel SA193 B8M Cl. 2	Soft (1514-1) with min. thickness 1.6 mm	EN 1514-2	Stainless steel A182 Gr. F316L and EN 10222-5-1,4404	Stainless steel SA479M 316L and EN 10272-1-1.4404

[1] For other types of bolting materials, please contact customer care in your world area.
[2] The Rosemount Guided Wave Radar can be paired with stainless steel or carbon steel chamber.
For other materials, please contact customer care in your world area.
[3] Flange none-wetted, protective plate in UNS N10276

Table 11.4.2 Standard bolting materials supplied with Rosemount Guided Wave Radar and chamber.

For other materials, see product data sheet for availability or contact customer care in your world area.

11.4.4 Step 4 Determine probe length

Standard probes

Rosemount chambers are designed to maximize level measurement reliability over the desired measurement span. The upper and lower portions of the chambers are designed to accommodate the upper and lower transition zones of the Guided Wave Radar for any probe type and application. Therefore, the probe length is determined by the upper (A), center to center (CC), and lower (B) dimension (not available in side-to-bottom chamber), plus a common standard length reduction for each chamber style, see table 11.4.3 and 11.4.4. This ensures that the probe is long enough to extend into the lower portion of the chamber with a small amount of clearance from the base. If the probe is too long, it might get bent when installed into the chamber, causing erratic readings.
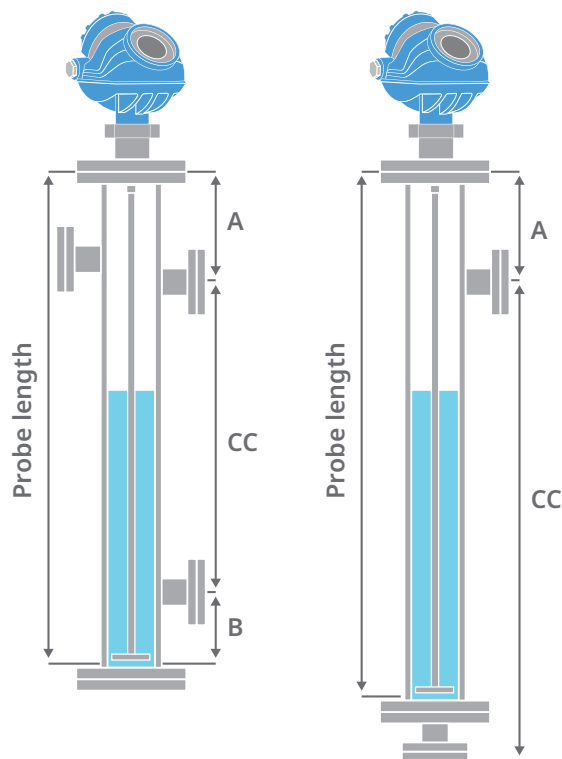
Figure 11.4.3 Side-and-side and side-to-bottom chambers for standard probes

Dynamic Vapor Compensation probes

A Rosemount chamber for use with Dynamic Vapor Compensation probe includes a reflector. This is contained within the upper section of the chamber, which mean that the chamber requires a longer top dimension. The chamber has two options available for dimension (A) when used with a Dynamic Vapor Compensation probe, see table 11.4.3 and 11.4.4. One is optimized for use with the short Dynamic Vapor Compensation reflector while the other option is optimized for use with the long Dynamic Vapor Compensation reflector.
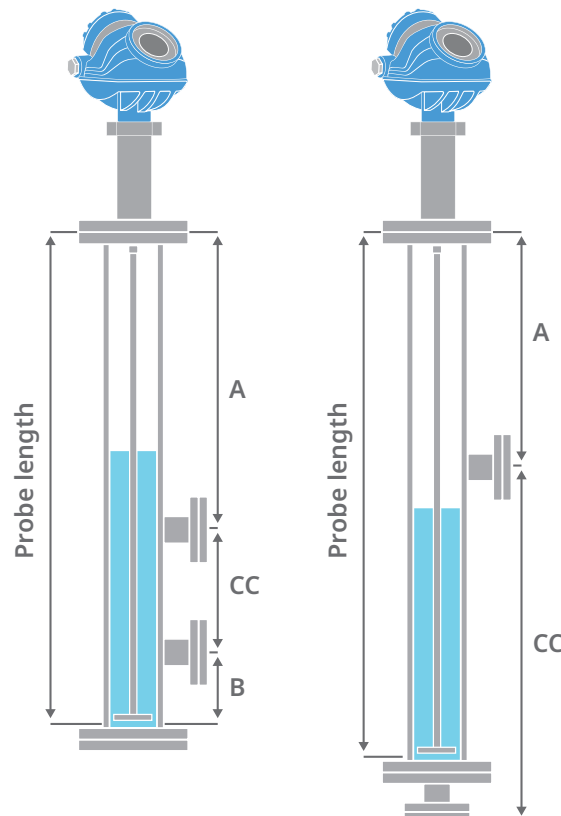
Figure 11.4.4 Side-and-side and side-to-bottom chambers for Dynamic Vapor Compensation probes.

Calculating probe length for compatibility with chamber

It is very important to ensure that the probe length of the Guided Wave Radar is compatible with the chamber length to ensure correct operation. To size the probe length of a Rosemount Guided Wave Radar, first identify the chamber process connection orientation, process connection center to center dimension (B) and the dimension (A), which is determined by the selected chamber. The standard probe length for a given process connection center to center dimension is identified in table 11.4.3 and 11.4.4. Additional to the standard dimensions, custom lengths can be ordered by contacting your Emerson representative.

Chamber	Probe Length
Standard	Dim A + Dim CC + Dim B - 3.5 in. (85 mm)
Short DVC reflector	Dim A + Dim CC + Dim B - 3.5 in. (85 mm)
Long DVC reflector	Dim A + Dim CC + Dim B - 3.5 in. (85 mm)

Table 11. 4.3 Probe length determination for side-and-side chamber

Chamber	Probe Length
Standard	Dim A + Dim CC - 17 in. (430 mm)
Short DVC reflector	Dim A + Dim CC - 17 in. (430 mm)
Long DVC reflector	Dim A + Dim CC - 17 in. (430 mm)

Table 11. 4.4 Probe length determination for side-to-bottom chamber

11.4.5 Step 5 Centering discs

To prevent the probe from contacting the pipe wall in the chamber, a centering disc is recommended. If the probe length is greater than 1.5 m, a centering disc should be used. The centering disc is attached to the end of the probe. For higher-rated chambers, the centering disc should be sized 1 in. smaller than the chamber diameter for higher pipes, see table 11.4.5.
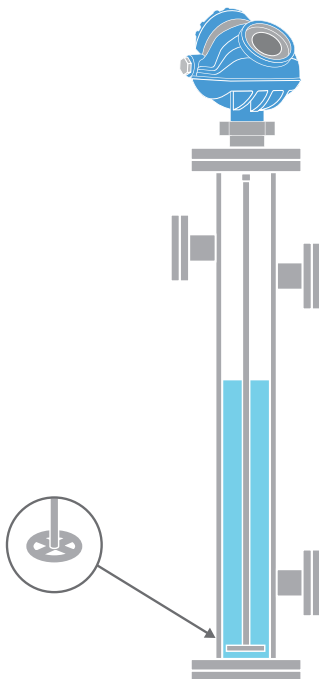
Figure 11.4.5. Centering discs

Chamber Size	Chamber Rating	Centering Disc
3 in. (76 mm)	Up to Class 600/PN 100	3 in. (76 mm)
4 in. (101 mm)	Up to Class 600/PN 100	4 in. (101 mm)
3 in. (76 mm)	Class 900, 1500/	
PN160, 250	2 in. (50 mm)	
4 in. (101 mm)	Class 900, 1500/	
PN160, 250	3 in. (76 mm)	

Table 11.4.5 Centering disc diameters for different chamber sizes and chamber ratings

11.4.6 Step 6 Configuration

Default factory settings are configured into the transmitter according to model codes of the chamber and transmitter characteristics, see figure 11.4.6.

> Pipe diameter = Chamber diameter
> Tank height = Dimension (A) + (B)

Only for HART units

> LRV = 0 (4 mA)
> URV = B (20 mA)
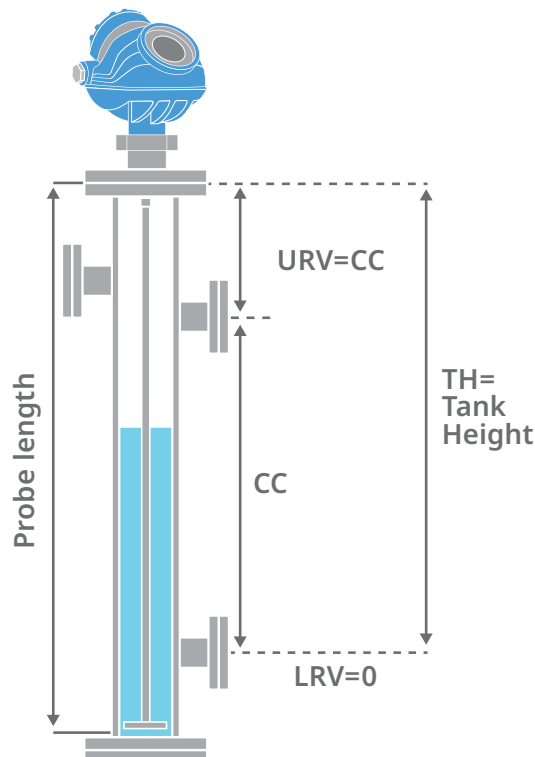
Figure 11.4.6. Transmitter will be configured so that the upper and lower range values align with the dimension (B).

Additional factory configurations can be ordered by including the C1 option code in the transmitter model code.

Consolidated radar and chamber package

To reduce the complexity and ensure a guaranteed fit between radar and chamber, you can choose the option to consolidate. This ensures the Guided Wave Radar and chamber are matched(1).

(1) The units are checked/consolidated together.

IMPORTANT NOTE!
The flange bolts are only hand-tightened. All packing materials must be removed from inside and around the chamber prior to installation. Long rigid probes are shipped separately in order to reduce transportation risk damage.

11

CHAPTER 12
MARINE TANK MONITORING SYSTEM INSTALLATION GUIDELINES

12

12 Marine Tank Monitoring System Installation Guidelines

Before installing a cargo or fuel monitoring system it is important to survey the vessel and have a clear plan about the complete installation.

The different instruments need to be located at suitable positions on the tank and the necessary cabling pulled between the instruments and the cargo control room.

It is the responsibility of the user to ensure that the device meets the specific inside tank installation requirements such as:

- Chemical compatibility of wetted materials
- Design and operational pressure and temperature

The radar transmitters need to be installed so that the influence of disturbing objects is kept to a minimum. It is also important to consider any inclination of the tank bottom.

If still pipes are used, they must be surveyed to make sure that any ventilation holes, inner surfaces and flange joints are in accordance with requirements.

See the reference manual for specific requirements and recommendations to consider when installing the devices

- Rosemount TGU 68 Tank Radar Gauge Reference Manual or visit our website https://www.emerson.com/RosemountTGU68
- Rosemount TGU 65 Tank Radar Gauge Reference Manual or visit our website http://emerson.com/RosemountTGU65
- Rosemount CTMS Custody Transfer Measurement System Reference Manual or visit our website https://emrsn.co/ctms
- Rosemount CMS Cargo Monitoring System Reference Manual or visit our website https://emrsn.co/ctm

12

CHAPTER 13
SOFTWARE

13 Software

<div style="font-size:3em">**13**</div> Software

13 Software

Many instruments are equipped with communication protocols such as HART, Wireless HART, Foundation Fieldbus, and optional Bluetooth® wireless technology. Beyond tracking measured values, suitable software packages can utilize these protocols for advanced user configuration and device diagnostics. These tools can significantly enhance an instrument's value by improving efficiency, reducing maintenance needs, and achieving optimal measurements in complex processes.

Configuration and diagnostics software can be provided in various forms. Typically, a supporting driver is supplied for a device which runs on a suitable host environment such as Emerson's AMS Device Configurator or AMS Device Manager. Host environments can be installed on PCs or mobile devices and will run drivers in different standards.

Additionally, measurement tracking and basic configuration and maintenance for instruments can sometimes be performed via different systems. Other software tools may be provided as independent packages.

The next section will describe some of the software features available for level measurement instruments and their value.

Device Configuration

Configuration settings allow a user to easily commission an instrument for any application. It includes stages such as inputting tank measurements or selecting process variables, system units and operation modes. Emerson Rosemount drivers can also offer a guided setup process, helping the user through the required setups with diagrams and explanations. Available configurations differ per device.

Advanced configurations enable users with distinctive use cases to utilize the instrument to the best capacity. It is recommended to consult the instrument manual or an Emerson representative to understand which settings are available for each instrument.

Configuration is required once during instrument commissioning and again only in the case of substantial changes to the tank use or process.

Process Diagnostics & Troubleshooting

Software features can provide the user with distinctive tools to ensure smooth operation and detect potential issues before problems arise. These tools can be preventative, warning or troubleshooting. Emerson's level instruments offer a variety of tools for this purpose, some of which will be detailed in this section. Available options differ per device.

Alerts – The software tracks both process and device conditions and will alert the user when action is necessary. Some alert levels can be user-adjusted. Alerts could be due to high/low product levels, low measurement confidence, inconsistent power supply and other causes. Alerts actively alert the user to these conditions to enable a timely response, preventing further disruption to the process. For some instruments, the user can see present and past alerts, to detect reoccurring problems and help find underlying causes.

Echo curve – For radar level measurement instruments, the echo curve feature offers a detailed view of detected echoes or reflections. While the device usually correctly identifies and reports the echo corresponding to the substance level, manual intervention may be required to eliminate interference—for example, when an object in the tank causes false readings. The echo curve plot, available in many device drivers, offers a visual representation for intuitive selection and filtering. Users can adjust advanced settings such as manual detection thresholds, marking false echoes, or saving the plot for future reference. This tool enhances the instrument's usability across various scenarios, even when unavoidable interferences are present in the tank.

Historian – Historian keeps a record of detected levels, echoes, and alerts. On supporting devices, this historical data can be used to analyse level trends or troubleshoot errors. In rare cases of false readings, this feature enables thorough investigation and understanding, even after the issue has been resolved, helping to prevent future occurrences.

Advanced Diagnostics and Performance Validation Features

Modern instruments are equipped with advanced diagnostic and validation features to further increase reliability and traceability of instrument performance. Emerson offers a variety of unique tools for this purpose, some of which are detailed in this section. Availability varies by device.
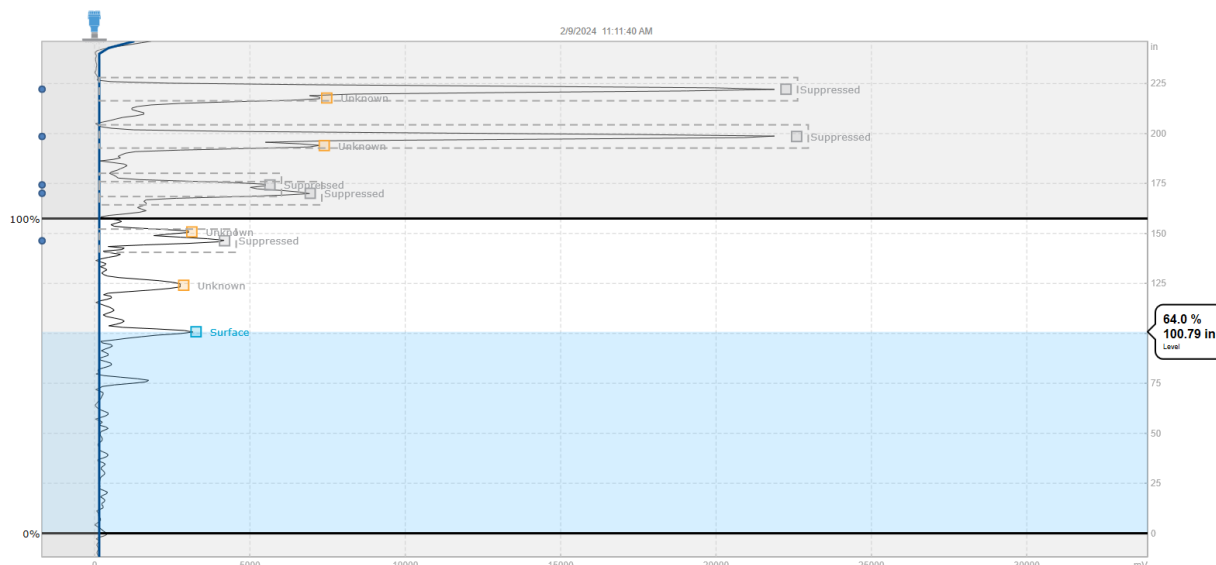
Figure 13.1. Echo Plot with Smart Echo Supervision

Smart Echo Supervision™

Rather than relying solely on a narrow beam angle to avoid internal obstructions and locking onto the wrong level, non-contacting radars in Emerson's portfolio are equipped with a powerful algorithm called Smart Echo Supervision. This feature allows the radars to maintain awareness of the strongest echoes, and by dynamically identifying which echoes are false, maintain tracking on the surface as it behaves most like a liquid- or solids surface. Smart Echo Supervision automatically suppresses echoes that are not moving, reducing installation concerns when dealing with inconveniently placed nozzles, isolation and ball valves, as well as dealing with internal obstructions within the application. Further, Smart Echo Supervision also allows you to not have to deal with the hassle of sending welders into confined spaces to install baffles and deflector plates in order to get rid of false echoes. As illustrated in the echo plot in Figure 13.1, although the surface echo is not the strongest signal, the advanced Smart Echo Supervision technology effectively distinguishes the surface echo. This allows the true level to be reliably and accurately reported.

Smart Proof Tests

The Smart Proof Test Package provides wizards with step-by-step guides for performing proof test procedures as outlined in the Safety Manual. Users follow clear on-screen instructions with dynamic graphics, enhancing process clarity. The wizards support both comprehensive and partial proof tests. The device can save details of the last performed test, including its type, result, and date, increasing traceability. Additionally, a printable report with detailed test results is available, facilitating thorough documentation and compliance.

Smart Echo Level Test & Verification Reflector

Aimed at radar devices, these tests evaluate the accuracy of system responses without changing the tank level. For Non-Contacting Radars the Smart Echo Level Test allows simulation of output values to test the system's reaction without altering the actual process. For Rosemount Guided Wave Radar 5300, a verification reflector kit can be used to manually simulate a level reading. These tests are especially valuable to test system responses to critical alarm situations without the risk involved in recreating them. The tests ensure the correct response to level changes and functions in any installation or with any media.

Smart Meter Verification

Smart Meter Verification is an easy-to-use method of diagnosing the entire transmitter's performance and integrity without interrupting the production process. The verification provides a clear overall pass / fail result, as well as further details on the different tested components. The complete Smart Meter Verification package enables scheduling periodic or single tests and provides access to historical results and generates printable reports with results and configuration change traceability, improving compliance and increasing confidence in the device's performance and status.

Signal Quality Metrics

Signal Quality Metrics enhances measurement reliability by continuously monitoring probe or antenna conditions and product surface conditions. It detects issues such as coating or build-up and evaluates signal strength and noise levels according to user settings. This allows for preventive maintenance by alerting users to potential problems before they affect measurement, helping to avoid unplanned shutdowns. Depending on the product, this feature is valuable for applications prone to antenna contamination and for monitoring critical surface conditions such as turbulence and foam.

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CHAPTER 14
FLANGES & MATERIALS

14

Flanges & Materials

14. Flanges and materials

A flange is a ring-shaped device designed to be used as an alternative to welding or threading various components used throughout the piping system. Flanged connections are used as an alternative to welding because they can be easily disassembled for shipping, routine inspection, maintenance, or replacement. Flanged connections are preferred over threaded connections because threading large bore pipes is not an economical or reliable operation. The flange is an important component of any piping system.

Today there are different standards in different parts of the world. The most commonly used standard is the American Society of Mechanical Engineers (ASME) or American National Standards Institute (ANSI) B16.5 standard. E.g. 4 in. / 300# or equivalent ANSI 4 in. 300lb. The second largest standard is the EN 1092-1 which is a European standard. E.g. DN100 PN40, DN is the abbreviation of Diameter Nominal and is a dimensionless designator. Pressure Nominal (PN) is the rating of Pressure and Temperature.

The Japanese Industrial Standard (JIS) B2210/B2220 (e.g. JIS 40K 100A) is another standard.

When flanges are subject for replacement, it is extremely important to have the correct information available, such as maximum temperature and pressure, facing etc.

Standard flange dimensions can change between revisions, so it is important to check the validity of standard flanges and make sure they are up-to-date.

14.1 Flange types

Flanges have been designed and developed to be used in various environments and applications. Each flange has its own special characteristics and should be carefully selected to meet specific function requirements.

This chapter will focus on the most commonly used ones:

- Blind
- Weld neck
- Slip-on
- Threaded
- Socket weld
- Lap-joint

14.1.1 Blind flange

The blind flange serves as a terminator of a piping system. Usually, it does not have a hub or bored center. Note that it may have a center hole and still be a blind flange. It always has a specified face type and bolting pattern.
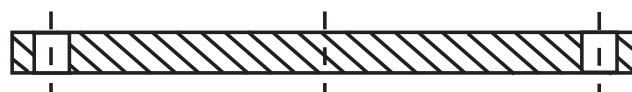
Figure 14.1.1: Blind / blank flange

14.1.2 Welded neck flange

The welded neck flange is designed to reduce high-stress concentrations at the base of the flange and transferring stress to the adjoining pipe. Weld neck flanges are normally used in severe service applications involving high pressures, high temperatures, or sub-zero conditions.

This is the point where it is welded
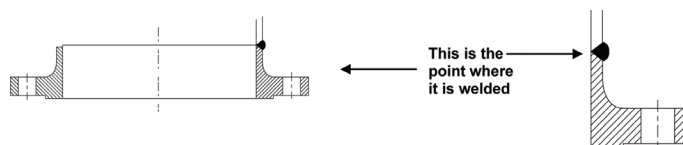
Figure 14.1.2: Welded neck flange

Welded neck flanges should ideally match the inner dimension of the adjoining pipe. Because of these matching inner dimensions, there is no restriction to the flow. Turbulence and erosion are therefore eliminated.

14.1.3 Slip-on flange

The slip-on flange has a low hub that allows the pipe to be inserted into the flange prior to welding. The low hub is shorter in length than the welded neck flange. The main area of usage is where the space limitations necessitate its use. Two fillet welds are required, one internal and one external.
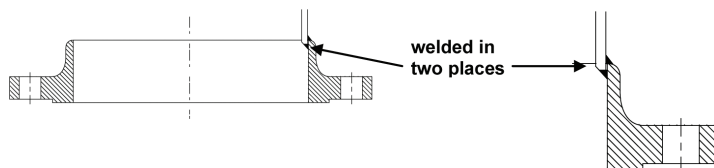
Figure 14.1.3: Slip-on flange, the weld is usually bigger in really than what is shown in the illustration

14.1.4 Threaded flange

The threaded flange is similar to the slip-on flange, but the bore is threaded. The benefit is that it can be assembled without welding. Thus, it is not well suited for conditions involving high temperatures or bending stresses of any significance. In cyclic conditions, the threaded flange can fail after just a few cycles with contraction and expansion.
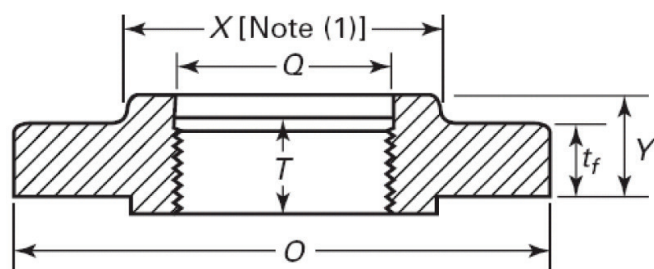
Figure 14.1.4: Threaded flange

14.1.5 Socket weld flange

The socket weld flange is similar to the slip-on flange, primary targeted at smaller diameters (½ in. to 4 in.).
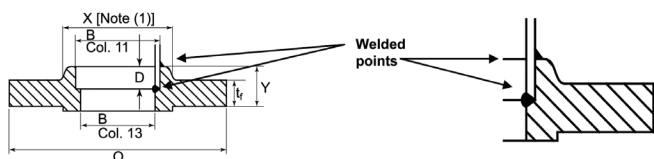
Figure 14.1.5: Socket weld flange

14.1.6 Lap joint flange

The lap-joint flange is primarily used on carbon or low alloy steel piping systems. The lap-joint flange is used mainly in piping systems that require frequent dismantling for inspection or routine maintenance.
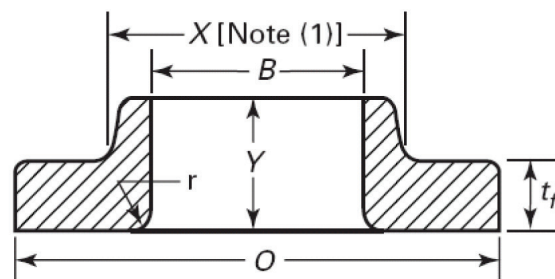
Figure 14.1.6: Lap joint flange
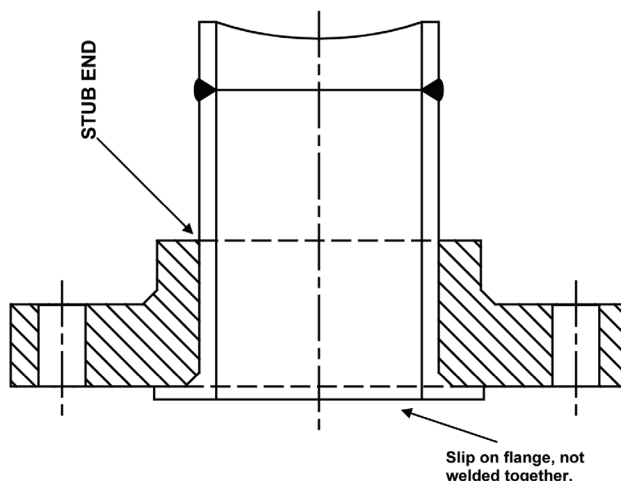
Figure 14.1.6: Slip on flange

14.2 Flange face

The mating surface of a flange, nozzle, or valve is called the face. The face is usually machined to create a serrated surface either by a spiral or concentric rings.

14.2.1 Flat face ASME (B16.5) / Type A (EN-1092-1)

As the name reveals, the flange face is flat. These are most commonly used for lower pressure classes. For EN1092-1, this is standard up to PN63, and for ASME B16.5, this face is available upon request.
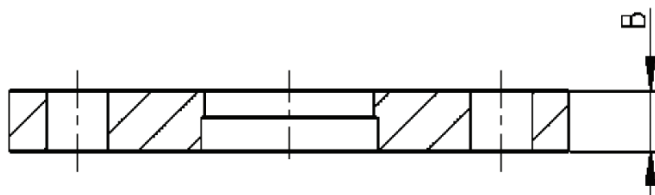
Figure 14.2.1: Flat face

14.2.2 Raised face ASME (B16.5) / Type B1 or B2 (EN-1092-1)

This is the most common face type in use on pipe flanges. As the name reveals, the flange's face has a prominent raised surface. Flanges rated class 150 and 300 have a 1/16 in. raised face, while class 600 and larger have ¼ in. raised face. For EN 1092-1, this is standard from PN100 and upwards.
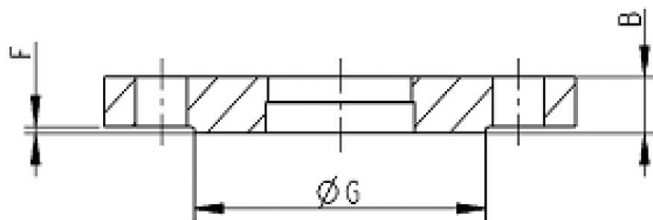
Figure 14.2.2: Raised face

14.2.3 Spigot face Type E (EN-1092-1) / Male (B16.5)

Figure 14.2.3: Spigot face

14.2.4 Recessed face Type F (EN-1092-1) / Female (B16.5)
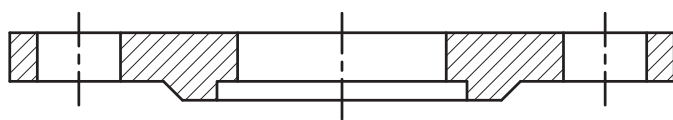
Figure 14.2.4: Recessed face

14.2.5 Groove face type ASME (B16.5) / Type D (EN-1092-1)

The groove face ASME is available in a small and a large option.

Figure 14.2.5: Groove face

14.2.6 Tongue face ASME (B16.5) / Type C (EN-1092-1)

The tongue face ASME is available in a small and a large option.
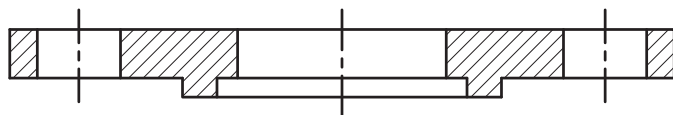
Figure 14.2.6: Tongue face

14.2.7 Ring-type joint face AMSE (B16.5)

The main difference between the ring-type and the above face types is that ring-type joint does not use a gasket to seal. Instead a metallic ring is used placed in the deep groove cut in the flange face. The ring type could either be circular or octagonal shaped. As the bolts are tightened, the metal ring is compressed creating a tight seal. Ring-type joint can be used for all P/T ratings, but is normally used in piping systems rated class 400 or higher.
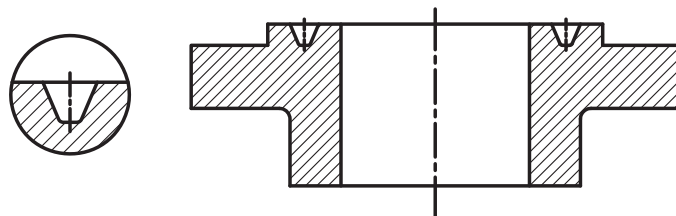
Figure 14.2.7: Ring-type joint face
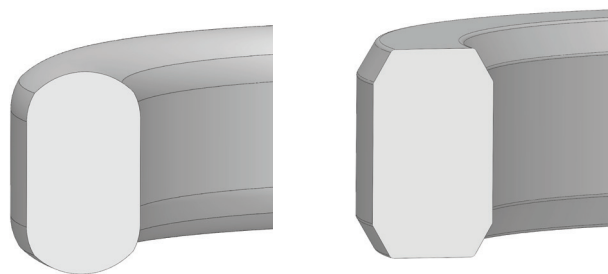
Figure 14.2.8: Circular and octagonal metallic rings for use with ring-type joint face

14.3 Special flanges
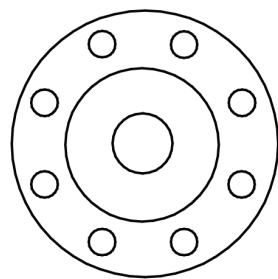
D: Outside Diameter

B: Flange Thickness

F: Raised Face

G: Face Diameter

Bolts: Number of Bolts

K: Bolt Hole Circle Diameter

d_2: Hole Diameter
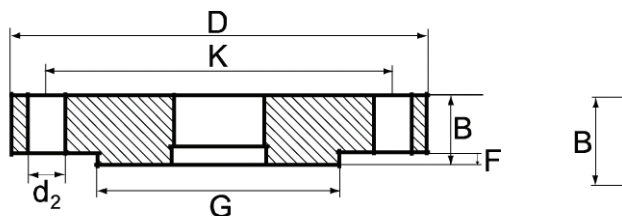
Figure 14.3.1: Dimensions on a raised face
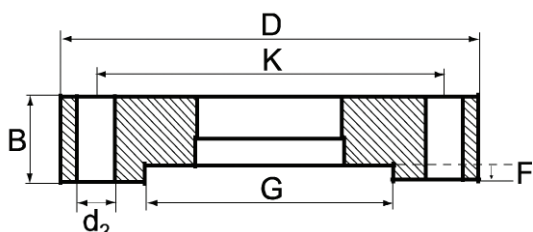
Figure 14.3.2: Dimensions on a recessed face

> **NOTE!**
> Dimensions may be used to aid in the identification of installed flanges. It is not intended for manufacturing use.

Masoneilan and Fisher flanges are also available in vented versions, with the same dimensions as shown in the table below.

Vented flanges must be ordered with a 1½ in. NPT threaded process connection (code RA).

For information about flange temperature and pressure ratings, see Flange rating in section 15.8.

14.4 Gaskets

The tightening of the flange bolts causes the gasket material to flow into the minor machining imperfections, resulting in a fluid-tight seal. The gasket must be compatible with the fluid and the gasket compression needed to maintain sealing. Additionally, the surface finish of the flange has an affect on the seal quality.

Special Flanges	D in. (mm)	B1 in. (mm)	B2 in. (mm)	F in. (mm)	G in. (mm)	# bolts	K in. (mm)
Fisher 249B/ 259B[2]	9.00 (228.6)	1.50 (38.2)	1.25 (31.8)	0.25 (6.4)	5.23 (132.8)	8	7.25 (184.2)
Fisher 249C[3]	5.69 (144.5)	0.94 (23.8)	1.13 (28.6)	-0.19 (-4.8)	3.37 (85.7)	8	4.75 (120.65)
Masoneilan[2]	7.51 (191.0)	1.54 (39.0)	1.30 (33.0)	0.24 (6.0)	4.02 (102.0)	8	5.87 (149.0)

(1) These flanges are also available in a vented version.
(2) Flange with raised face.
(3) Flange with recessed face.

Table 14.4.1: Special flange dimensions

Figure 14.4.1: Spiral wound gasket

14.4.1 Surface finish

The surface finish is an important factor in determining the extent to which a gasket must flow to secure an impervious seal. Bolting that results in adequate gasket flow to form a satisfactory seal with a smooth contact surface may be inadequate to secure a tight joint with a rough surface. A serrated finish is frequently provided for steel flanges, particularly when using a graphite-composition gasket with a wide contact area (e.g raised or lapped). Normally, the surface finish is either in form of concentric rings or machined in spiral patterns. Ring- Type Joint flanges' grooves have high surface finish.

It is evident that the surface finish varies with the type of contact face and gasket used and therefore, should be specified accordingly.
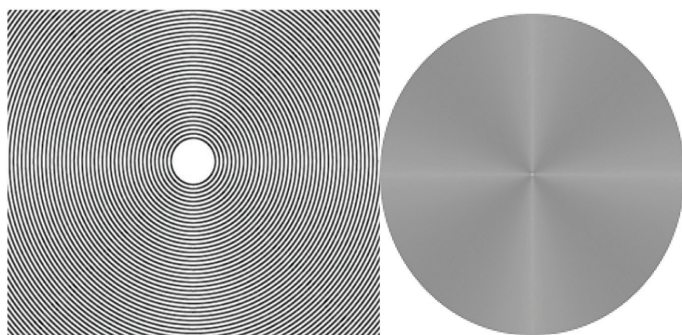
Figure 14.4.2: Radial surface finish

14.4.2 Types and materials

Three types of gaskets are commonly used for pipe flanges with overpressure:

Non-metallic flat gaskets with or without Inserts (EN 1514-1 IBC/ASME B16.21 Gr.1a)
This gasket requires a correct bolt pretension dependent upon the flange size and pressure class to secure a solid seal. Rubbers, cork, PTFE or Graphite are common materials used in pipe systems. Normally, the gasket thickness is 0.05-0.06 in. (1.5 to 1.6 mm).
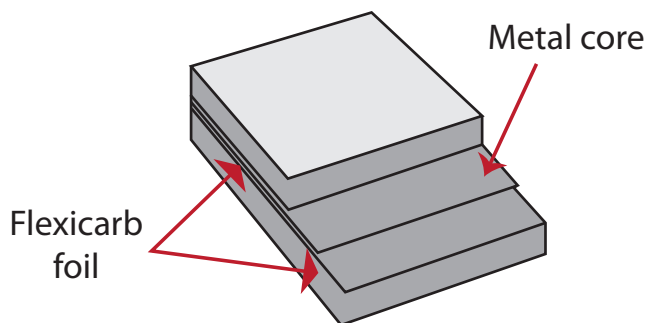
Metal core
Flexicarb foil
Figure 14.4.3: Flat gasket, with metal core and a flexicarb foil

Spiral wound gaskets (EN 1514-2/ASME B16.20 Gr.1b)
A spiral wound gasket comes with or without support ring, and requires a correct bolt pretension dependent upon the flange size and pressure class to secure a solid seal.
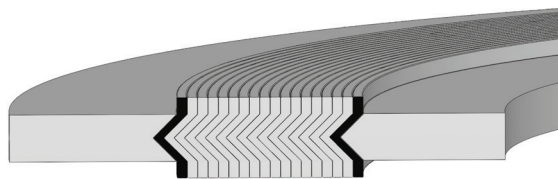
Figure 14.4.4: Spiral wound gasket with inner and outer support ring
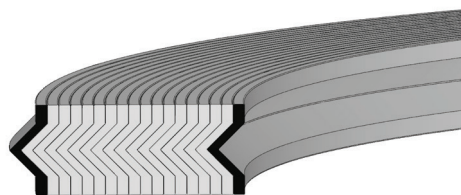
Figure 14.4.5: Spiral wound gasket without support ring

Lens gasket
Machined from steel, have similarities with ring-type Joint.
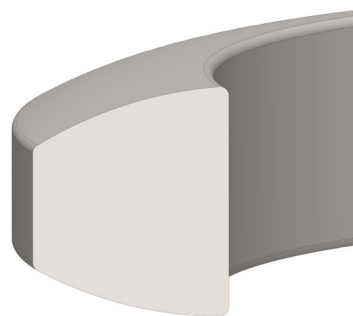
Figure 14.4.6: Lens gasket

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14.5 Bolts

Bolts will complete the flange assembly. The P/T determines the size, spacing, and number of bolts required. It is critical that flange drawings for fabrication convey the exact bolt orientation, otherwise, the mating flange does not align properly.
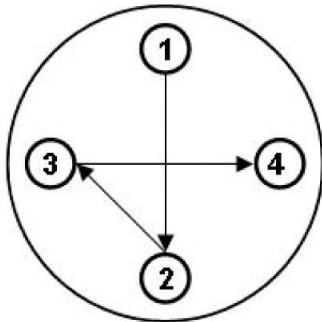
Figure 14.5.1: Bolt tightening scheme

Bolts are available in two types: machine or stud. Machine bolts have a head on one end and threads on the other end. Stud bolts have either threads throughout the whole bolt, or threads on both end but not in the middle.
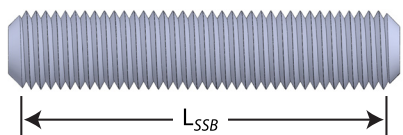
Figure 14.5.2: Stud Bolt (Ref. ASME B16.5)
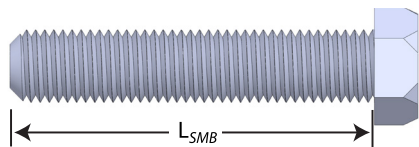
Figure 14.5.3: Stainless Machine Bolt (Ref. ASME B16.5)

14.6 Dimensions and scheduling

The pipe outer diameter is converted into a dimensionless designator (nominal size), e.g. an ASME standard pipe with Nominal Pipe Size (NPS) 2 have 2,375 in. (60,3 mm) outer diameter. This is equivalent to DN 50 in EN 10921-1 standard. See table 12.5.1.

The wall thickness of the pipe is specified by the scheduling number, in ASME B16.5 these numbers span from 5 to 160. The pipe schedule number will increase as the pipe thickness increases. The higher the scheduling number is, the thicker the pipe is.

ASME versus European pipes							
NPS	DN	NPS	DN	NPS	DN	NPS	DN
1/8	6	3 ½	90	22	550	44	1100
1/4	8	4	100	24	600	48	1200
3/8	10	5	125	26	650	52	1300
1/2	15	6	150	28	700	56	1400
3/4	20	8	200	30	750	60	1500
1	25	10	250	32	800	64	1600
1 ¼	32	12	300	34	850	68	1700
1 ½	40	14	350	36	900	72	1800
2	50	16	400	38	950	76	1900
2 ½	65	18	450	40	1000	80	2000
3	80	20	500	42	1050		

Table 14.6.1: ASME vs. European pipes

14.7 Materials

There are a number of different materials available. The below section gives some background on the most common materials for flanges and wetted material in level devices.

14.7.1 Alloy 825

Alloy 825 is an austenitic nickel-iron-chromium-molybdenum-copper alloy containing high levels of chromium, nickel, copper and molybdenum. This makes it tolerant to high temperatures, and substantially more resistant to corrosive environments (oxidizing and reducing) compared to conventional austenitic stainless steels.

14.7.2 316/316L

Type 316 is an austenitic chromium nickel stainless steel containing molybdenum. This addition increases general corrosion resistance, improves resistance to pitting from chloride ion solutions, and provides increased strength at elevated temperatures.

Type 316L is an extra-low carbon version of Type 316 that minimizes harmful carbide precipitation due to welding. Typical uses include exhaust manifolds, furnace parts, heat exchangers, jet engine parts, pharmaceutical and photographic equipment, valve and pump trim, chemical equipment, digesters, tanks, evaporators, pulp, paper and textile processing equipment, parts exposed to marine atmospheres and tubing.

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Type 316L is used extensively for weldments where its immunity to carbide precipitation due to welding assures optimum corrosion resistance.

A material can be dual certified and comply to both 316 and 316L at the time. It can be triple certified and comply to EN standards as well e.g. 1.4404.

14.7.3 Alloy C-276

- One of the few alloys resistant to wet chloride gas, hypochlorite and chlorine dioxide solutions.

- Exceptional resistance to strong solutions of oxidizing salts, such as ferric and cupric chlorides.

- Not prone to grain boundary precipitation in the welded condition and therefore suitable for many chemical process applications

Some typical applications include equipment chloride processes and processes utilizing halide or acid catalysts. Other industry applications are pulp and paper (digesters and bleach areas), scrubbers and ducting for flue gas desulfurization, pharmaceutical and food processing equipment.

14.7.4 Alloy A-400

Alloy 400 is a nickel-copper alloy with excellent corrosion resistance in a wide variety of media. The alloy is characterized by good general corrosion resistance, good weldability and moderate to high strength. The alloy has been used in a variety of applications. It has excellent resistance to rapidly flowing brackish water or seawater. It is particularly resistant to hydrochloric and hydrofluoric acids when they are de-aerated. The alloy is slightly magnetic at room temperature. The alloy is widely used in the chemical, oil and marine industries.

14.7.5 Duplex

Duplex stainless steel is a mixture of austenitic and ferrite materials and has high thermal conductivity, high mechanical strength and excellent resistance to stress corrosion cracking.

It is a cost effective alternative to alloys such as C-276 in applications where stress cracking is of concern. Its high mechanical strength allows it to meet higher flange ratings than 316 stainless steel's.

There are a number of grades of Duplex, where Duplex 2205 is known as the "workhorse" grade because of its broad suitability. This material is often used in environments where chlorides and sour gas (H2S) are common. There are temperature limitations for using Duplex, it can not be used when the temperature is very high or too low, e.g. cryogenic applications.

14.8 Flange ratings and standards

The P/T rating (pressure and temperature) can be defined as the maximum pressure allowed for a specific temperature at which the flange will be operating.

For the ASME B.16.5 standard, these P/T ratings are divided into seven different classes 150, 300, 400, 600, 900, 1500, and 2500. The same concept applies to other standards as well. See table 12.8.1.

When combining the temperature with the internal pressure, a selection of appropriate size, rating, and type of flange can be accomplished. The main benefit of using a pressure/temperature rating system is that a class can be used in a number of applications.

When the temperature decreases, the pressure can be increased, and vice versa. E.g. a Class 150 316L steel flange is rated to perform at 302 °F (150 °C) at 174 psig (12 bar). If the temperature decreases to 122 °F (50 °C), the flange pressure rating increases to 222 psig (15.3 bar).

While the pressure/temperature rating is important, the class rating number is not "directly linked" to the actual temperature or pressure. Typically, a higher class means an increase in flange diameter and thickness. The actual P/T rating is given by the combination of class and material.

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Pressure - Temperature Ratings for Group 2.2 Materials i.e. ASME SA182 316 Classes working pressure (bar)						
Temp (°C)	150	300	400	600	900	1500	2500[1]
-29 to 38	19.0	49.6	66.2	99.3	148.9	248.2	344.7
50	18.4	48.1	64.2	96.2	144.3	240.6	333.5
100	16.2	42.2	56.3	84.4	126.6	211.0	289.9
150	14.8	38.5	51.3	77.0	115.5	192.5	261.6
200	13.7	35.7	47.6	71.3	107.0	178.3	243.0
250	12.1	33.4	44.5	66.8	100.1	166.9	228.9
300	10.2	31.6	42.2	63.2	94.9	158.1	217.2
325	9.3	30.9	41.2	61.8	92.7	154.4	212.3
350	8.4	30.3	40.4	60.7	91.0	151.6	208.9
375	7.4	29.9	39.8	59.8	89.6	149.4	206.3
400	6.5	29.4	39.3	58.9	88.3	147.2	202.5

Classes working pressure (psig)						
Temp (°F)	150	300	400	600	900	1500	2500 [1]
-20 to 100	230	600	800	1200	1800	3000	5000
200	195	510	680	1020	1535	2555	4260
300	175	455	610	910	1370	2280	3800
400	160	420	560	840	1260	2100	3500
500	150	395	525	785	1180	1970	3280
600	140	370	495	745	1115	1860	3100
650	125	365	485	730	1095	1825	3040
700	110	360	480	720	1080	1800	3000
750	95	355	470	705	1060	1765	2940

[1] Only avaliable for 316L standard

Table 14.8.1: P/T rating from ASME B16.5 Table 2-2.2 (bar) and annex F (psig)

Pressure - Temperature Ratings for Group 13E0 Material No. 1.4404 Classes working pressure (bar)						
Temp (°C)	PN 16	PN 40	PN 63	PN 100	PN 160	PN 250	PN 320
RT	16.0	40.0	63.0	100.0	160.0	250.0	320.0
100	15.1	37.9	59.7	94.7	151.6	236.9	303.2
150	13.7	34.4	54.3	86.1	137.9	215.4	275.8
200	12.7	31.8	50.1	79.5	127.2	198.8	254.4
250	11.9	29.9	47.1	74.7	119.6	186.9	239.2
300	11.0	27.6	43.5	69.0	110.4	172.6	220.9
350	10.5	26.4	41.7	66.1	105.9	165.4	211.8
400	10.2	25.7	40.5	64.2	102.8	160.7	205.7
350	8.4	30.3	40.4	60.7	91.0	151.6	208.9
375	7.4	29.9	39.8	59.8	89.6	149.4	206.3
400	6.5	29.4	39.3	58.9	88.3	147.2	202.5

Classes working pressure (psig)						
Temp (°F)	PN 16	PN 40	PN 63	PN 100	PN 160	PN 250	PN 320
RT	232	580	914	1450	2321	3626	4641
212	219	550	866	1373	2199	3436	4398
302	199	499	788	1249	2000	3124	4000
392	184	461	727	1153	1845	2883	3690
482	173	434	683	1083	1735	2711	3469
572	160	400	631	1001	1601	2503	3204
662	152	383	605	959	1536	2399	3072
752	148	373	587	931	1491	2331	2983

Table 14.8.2: P/T rating from EN 1092-1:2007 (bar) and annex F (psig)

14

14.8.1 What happens in practice?

When the bolt pretension increases, it causes the gasket material to flow into the minor machining imperfections, resulting in a fluid-tight seal.
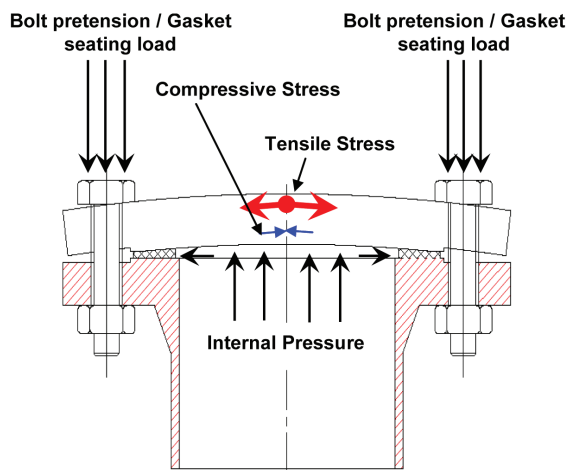
Figure 14.8.1: Internal pressure on the flange causes both tensile stress and compressive stress as represented by the red and blue arrows respectively.

14.9 ID and markings

All standard flanges should be permanently marked on the external diameter with:

- Material
- Flange standard
- Pressure/temperature rating (Class/PN)
- Pipe size (NPS/DN)
- Manufacturer

In this section, we focus on how to identify three commonly used standards: ASME, EN, and JIS. All of these standards give directions how marking should be performed, and therefore facilitate identification.

14.9.1 ASME B16.5

According to the B16.5 standard, a flange should be marked to aid identification. Several different parameters should be visible and are important for identification:

- The manufacturer's name or trademark
- Nominal Pipe Size (NPS)
- Flange rating designation (e.g. Class 150 or 300)
- Material designation – the raw material of the flange according to American Standards for Testing Materials (ASTM)
- Ring gasket number – used when the flange face is a ring type joint
- Suitable identification for traceability

14.9.2 EN 1092-1

According to the EN 1092-1 standard, all flanges except integral flanges should be marked with:

- Manufacturer's name or trade mark
- Number of standard, i.e. EN 1092-1
- Flange/collar type number
- Diameter Nominal, e.g. DN 150
- PN designation, e.g. PN 40
- Either the name or the number or the grade of the material, e.g. 1.4404
- Suitable identification for traceability. E.g. CH E52357, when test certification is required

Example: Manufacturers name /EN 1092-1/11/DN 150/PN 40/1.4404/CH E52357

14.9.3 JIS B2220

According to the JIS B2220 standard, all flange types except integral type flange (IT) shall be marked with the following: Nominal Pressure (K)Nominal Size (A), may be omitted

- Symbol of material
- Melting or casting number
- Manufacturers name or trademark

14.10 Ordering a flange

When ordering a flange, provide the information given below to avoid misunderstanding and misinterpretation.

Flanges in accordance with a standard
- Size
- Class
- Face
- Gasket (type/dimension)
- Design P/T rating (maximum and working temperature and pressure)

Non-standard flanges
(also applies to flanges of unknown standard)
- Outer diameter of the flange
- Pipe diameter
- Hole pattern and hole size
- Face

> **NOTE!**
> Flange facing of the flange needed must be given in every case, not the pipe facing.

14.11 Centering discs

Figure 14.11.1: Centering disc mounted on a single rigid probe

Pipe Diameter	Schedule	Centering Disc
2 in.	40	S2/P2
2 in.	80	S2/P2
3 in.	40	S3/P3
3 in.	80	S3/P3
3 in.	160	S2/P2
4 in.	40	S4/P4
4 in.	80	S4/P4
4 in.	120	S3/P3
4 in.	160	S3/P3
6 in.	40	S6/P6
6 in.	80	S6/P6
6 in.	120	S4/P4
6 in.	160	S4/P4
8 in.	40	S8/P8
8 in.	80	S8/P8
8 in.	100	S6/P6
8 in.	120	S6/P6
8 in.	140	S6/P6
8 in.	160	S6/P6

Table 14.11.1: Pipe size and schedule number, matched to centering disc

Centering disc outer diameter					
Schedule	1.8 in. (45 mm)	2.7in (68 mm)	3.6 in. (92 mm)	5.55 in. (141 mm)	7.4 in. (188 mm)
≤80	2.in	3 in.	4 in.	6 in.	8 in.
100	-	-	-	8 in.	-
120	-	4 in.	6 in.	8 in.	-
140	-	-	-	8 in.	-
160	3 in.	4 in.	6 in.	8 in.	-

Table 14.11.2: Centering disc outer diameter

CHAPTER 15
PRODUCT APPROVALS AND CERTIFICATIONS

15 Product Approvals and Certifications

15. Product approvals and certifications

Product certification process
The manufacturer's approval group is typically responsible for obtaining and maintaining product approvals required by legislation, applications, customers etc. The products are designed, constructed, approved, manufactured and maintained in accordance with applicable industry standards. The product certification process begins with the early phase of evaluating the product design concept and continues throughout the product's lifetime. The work is carried out either as a part of a new development project (when designing a new product) or as a maintenance task (when changes are introduced to an existing product). Typically, approvals engineers work closely with design engineers, product managers, marketing, operations and technical writers, as well as external parties to ensure that all applicable requirements are met. Equipment designed using specific Ex protection methods in hazardous areas must be tested and certified by recognized bodies/agencies to ensure compliance with safety standards. This certification confirms that the equipment will not generate sufficient energy to ignite an explosive atmosphere.

15.1 Hazardous Area Approvals

A hazardous area is an area in which explosive atmospheres (flammable gases, vapors, or dust) are present, or may be expected to be present, in quantities such as to require special precaution for the construction and use of electrical equipment. The hazardous conditions may be either man-made (as in petrochemical plants) or naturally occurring (as with coal mining). It is important to ensure that all electrical equipment installed in a hazardous area cannot form a spark or hot surface that would ignite flammable atmospheres. To ensure safety in hazardous areas, all equipment is examined and tested by a recognized testing authority before it is used in a hazardous area.

The fire triangle
Three components must be present for fire or explosion to occur (i.e., for an area to be classified as hazardous)

- Explosive material in sufficient quantities (e.g., petrol, hydrogen, vapors from a flammable liquid, combustible dusts)

- Ignition source of sufficient energy to ignite the explosive material (e.g., flames, welding, hot surfaces etc.)

- Oxygen

These three components comprise the fire triangle. An explosion will not occur if any one of the three components is missing.
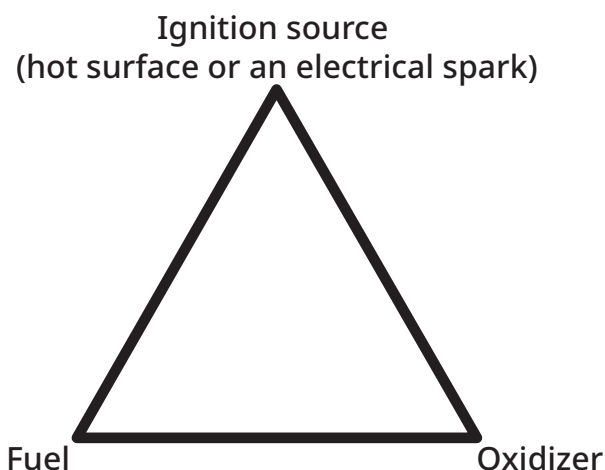
Figure 15.1.1: The fire triangle

Industry regulations/standards and Approval agencies
The most common industry regulations and standards used in the process control industry are:

- ATmospheres Explosives (ATEX) and related European Standards (EN) - EN 60079 Series

- International Electrotechnical Commission (IEC) - IEC 60079 Series

- Occupational Safety and Health Administration (OSHA)
  - Canadian Standards Association (CSA) in Canada (CSA C22.
  - Factory Mutual (FM) in the United States (FM 3810, 3600, 3610 etc.)
  - UL (Underwriters Laboratories)

Approval agencies around the world certify instruments to meet these standards. Some of Approval agencies are:

- FM Approvals (USA)
- CSA Group (Canada)
- DEKRA Certification BV (Netherlands)
- BASEEFA (United Kingdom)
- NEMKO (Norway)
- UL (Underwriters Laboratories) (USA)
- SGS Group (UK)
- TIIS and CML (Japan)
- NEPSI (China)

Ex Certification Mark
Some approval agency uses specific logos to indicate that an Ex certificate has been granted by this agency to a particular product. Few examples as follows:

ATEX and IEC Marking
Products that are certified to comply with ATEX and/or IEC Ex standard, are marked as follows:
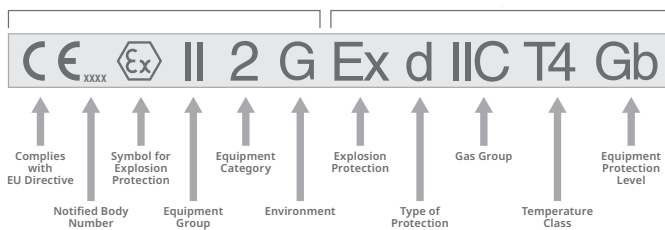
Figure 15.1.2: Example of ATEX and IEC Ex approval markings

North American Marking
Products that are certified to comply with North American Ex standard, are marked as follows:
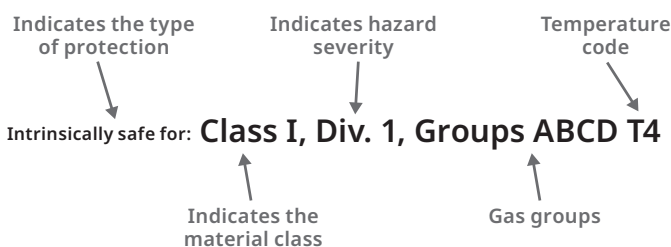
Figure 15.1.3: Example of North American Ex markings for Divisions

15.1.2 Methods of protection

Many methods of protection in hazardous areas work by eliminating one of the three components of the fire triangle. Methods of protection include: Exclusion, Containment, Energy limitation, Avoidance.

The most common methods of protection used in the process control industry are containment, energy limitation, and avoidance, which are described below.

Containment
Users can use the containment method so that if an explosion occurs, it is contained within the equipment enclosure. Thus, sparks or flames will not leak into the hazardous atmosphere and cause another fire or explosion. Containment is often used with spark-producing parts, such as switch gears, control boards, or transformers.

Explosion-proof enclosures (Ex db)
Explosion-proof (or flameproof) enclosures are used to surround equipment parts that could ignite an explosive atmosphere (e.g., by sparking). Explosion-proof enclosures must meet the following conditions:

- All enclosure joints leading to the outside environment must be flameproof
- The enclosure must have sufficient strength to withstand an internal explosion without rupture or permanent deformation
- The enclosure's surface temperature must never exceed the ignition temperature of the ambient gas-air mixture. When selecting an explosion-proof material, users should consider the material's thickness, corrosion resistance, impact strength, and porosity

The design must also prevent explosions by removing sufficient energy from escaping gases so that energy levels are below the minimum ignition energy levels of any flammable gases and combustible dusts in the ambient atmosphere. If energy levels are maintained below these levels, an explosion will not occur.

Energy limitation
Energy limitation is aimed at preventing ignition of explosive atmospheres by limiting the energy available in a system. The goal of energy limitation is to ensure that any energy released is below the threshold required to ignite the explosive mixture. This method typically considers electrical energy (e.g., currents, voltages) and thermal energy (e.g., heat produced by equipment). The aim is to minimize both electrical and thermal energy that could ignite flammable materials.

Intrinsic safety (Ex i)

One of the most common applications of energy limitation is in the intrinsic safety protection method. Intrinsically safe (I.S.) equipment and wiring prevents explosion by limiting the electrical energy to ignite flammable gases, vapors, or dusts in the atmosphere under normal or defined fault conditions. Typically, the energy allowed into the hazardous location is limited by an external mounted I.S. barrier (provided by the installer). Advantages of I.S. approaches include:

• Less operator action required to maintain a safe system

• Easier to maintain and repair the equipment

I.S. devices are assigned maximum voltage, current, capacitance, inductance and power supply limits. The magnitude of these parameters determines the level of energy storage allowed in the I.S. circuit.

Avoidance

Avoidance as an Ex protection method focuses on preventing the presence of explosive atmospheres in the first place, rather than relying solely on equipment design to mitigate risks. This proactive approach aims to eliminate or minimize the conditions that could lead to an explosion. By addressing potential hazards through design, materials selection, process control, and training, organizations can significantly enhance safety in environments where flammable substances are present.

Increased safety (Ex e)

Increased Safety (often denoted as Ex e) is a method of explosion protection designed to enhance the safety of electrical equipment operating in potentially explosive atmospheres. This method aims to minimize the risk of ignition by ensuring that equipment does not produce sparks or excessive heat that could ignite flammable gases, vapors, or dust. By focusing on robust design, limiting operating conditions, and ensuring reliability, this method helps mitigate the risk of ignition and enhances overall safety in hazardous environments.

Common increased safety applications include terminal and connection boxes, control boxes, and light fittings.

Non-sparking equipment (Ex n)

Non-sparking equipment is equipment with which special precautions are taken with connections and wiring to increase reliability. The equipment does not produce arcs, sparks, or hot surfaces in normal operation. Non-sparking equipment is commonly used with three-phase induction motors in hazardous areas.

Ex marking for various types of protection

Type of protection	Marking
Explosion-proof enclosures in Zone 1	Ex db
Intrinsic safety in Zone 0	Ex ia
Intrinsic safety in Zone 1	Ex ib
Increased safety in Zone 1	Ex eb
Non-sparking equipment in Zone 2	Ex n

Table 15.1: Examples of suitable protection types for different zones

15.1.3 Hazardous Area Classification

The classification of hazardous area is crucial for ensuring safety in environments where flammable gases, vapors, or dusts may be present. Designated hazardous area zone and division classifications are explained and defined in the regulations that describe the degrees of risk in different types of hazardous areas. Classification of the hazardous areas differ in their approach and terminology between different national regulations (e.g. North America and Europe).

North American Classification (NEC/CEC)

In North America, the Class/Division/Group system is based on Article 500 of the National Electrical Code (NEC)

• **Classes -** defines the general nature of the hazardous material in the surrounding atmosphere

• **Divisions -** defines the probability of hazardous material being present the surrounding atmosphere

• **Groups -** defines the type of the hazardous material in the surrounding atmosphere

Class	Nature of Hazardous Material
Class I	Hazardous because flammable gases or vapors are present (or may be present) in quantities sufficient to produce explosive or ignitable mixtures.
Class II	Hazardous because combustible or conductive dusts are present (or may be present) in quantities sufficient to produce explosive or ignitable mixtures.
Class III	Hazardous because ignitable fibers or flyings are present (or may be present) in quantities sufficient to produce explosive or ignitable mixtures.

15

Division	Probability of Hazardous Material
Division 1	The substance referred to by class has a high probability of producing an explosive or ignitable mixture due to it being present continuously, intermittently, or periodically or from the equipment itself under normal operating conditions.
Division 2	The substance referred to by class has a low probability of producing an explosive or ignitable mixture and is present only during abnormal conditions for a short period of time - such as a container failure or system breakdown

Group	Type of Hazardous Material
Group A	Atmosphere containing acetylene
Group B	Atmosphere containing a flammable gas, a flammable liquid produced vapor, or a combustible liquid such as hydrogen or fuel and combustible process gases containing more than 30% hydrogen by volume - or gases of equivalent hazard such as butadiene, ethyleneoxide, propylenexide and acrolein.

Group	Type of Hazardous Material
Group C	Atmosphere containing a flammable gas, a flammable liquid produced vapor or a combustible liquid-produced vapor such as carbon monoxide,ether, hydrogen sulfide, morphline, cyclopropane, ethyl, isoprene, acetaldhyde and ethylene or gases of equivalent hazard.
Group D	Atmosphere containing flammable gas, flammable liquid produced vapor, or combustible liquid produced vapor such as gasoline, acetone, ammonia, benzene, butane, ethanol, hexane, methanol, methane, vinyl chloride, natural gas, naphtha, propane or gases of equivalent hazard.
Group E	Atmosphere containing combustible metal dusts, including aluminum, magnesium, bronze, chromium, titanium, zinc and their commercial alloys or other combustible dusts whose particle size, abrasiveness and conductivity present similar hazards in connection with electrical equipment.
Group F	Atmosphere containing carbonaceous dusts, carbon black, coal black, charcoal, coal or coke dusts or dusts that have been sesitized by other materials so they present an explosion hazard.
Group G	Atmosphere containing combustible dust not included in Group E & F - such as flour, grain, starch, sugar, wood, plastics and chemicals.

EU Classification (ATEX/IECEx)

In the European Union, the classification of explosive atmospheres is governed by the ATEX (ATmosphères EXplosibles) directives, specifically ATEX 99/92/EC (for workplace safety) and ATEX 2014/34/EU (for equipment).

Zones - defines the general nature (or properties) of the hazardous material - if its gas or dust, and the probability of the hazardous material in the surrounding atmosphere

Groups - defines the type of the hazardous material and (partly) the location of the surrounding atmosphere

15

Zone	Nature and Probability of Hazardous Material
Zone 0	Ignitable concentrations of flammable gases or vapors which are present continuously or for long periods of time.
Zone 1	Ignitable concentrations of flammable gases or vapors which are likely to occur under normal operating conditions.
Zone 2	Ignitable concentrations of flammable gases or vapors which are not likely to occur under normal operating conditions and do so only for a short period of time

Zone	Nature and Probability of Hazardous Material
Zone 20	Ignitable concentrations of flammable gases or vapors which are present continuously or for long periods of time.
Zone 21	An area where combustible dusts or ignitable fibers and flyings are likely to occur under normal operating conditions.
Zone 22	An area where combustible dusts or ignitable fibers and flyings are not likely to occur under normal operating conditions and do so only for a short period of time.

Group	Type of Hazardous Material and Location of Atmosphere
Group I	Mines susceptible to firedamp (flammable mixture of gases naturally occurring in a mine).
Group II	Explosive gas atmosphere other than mines susceptible to firedamp. Group II equipment is subdivided into three subgroups.

Group	Type of Hazardous Material and Location of Atmosphere
A	Atmospheres containing propane, acetone, benzene, butane, methane, petrol, hexane, paint solvents or gases and vapors of equivalent hazard.
B	Atmospheres containing ethylene, propylene oxide, ethylene oxide, butadiene, cyclopropane, ethyl ether, or gases and vapors of equivalent hazard.
C	Atmospheres containing acetylene, hydrogen, carbon disulphide or gases and vapors of equivalent hazard.
Group III	Explosive dust atmosphere. Group III equipment is subdivided into three sub-groups.
A	Atmospheres containing combustible flyings.
B	Atmospheres containing non-conductive dust.
C	Atmospheres containing conductive dust.

Explosive Substances Codes

Explosion substances codes differ between IEC/ATEX and North American markings.

Representative substance	North American explosive substances group	IEC explosive substances group
Acetylene	Class I, Group A	IIC
Hydrogen	Class I, Group B	IIC
Ethylene	Class I, Group C	IIB
Propane	Class I, Group D	IIA
Methane	Class I, Group D	I
Conductive metals	Class II, Group E	N/A
Carbonaceous	Class II, Group F	N/A
Grain	Class II, Group G	N/A
Fibers	Class III	N/A

Table 15.3: Explosive substances Groups

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Temperature class

Temperature class defines the maximum surface temperature exposed to the Hazardous location. It shall be selected to be lower than the applicable auto ignition temperature of the hazardous substance. Similar temperature classification is used in both IEC/ ATEX and North American markings.

Temp. group	Max. surface temp. °C (°F)	Examples of gases and vapors against which protection is afforded
T1	450 (842)	Hydrogen, ammonia
T2	300 (572)	Acetone, ethanol, propane
T3	200 (392)	Petrol, crude oil
T4	135 (275)	n-heptane, ethyl ether
T5	100 (212)	None specified yet
T6*	85 (185)	Carbon disulfide

Table 15.4: Temperature group codes

* For process industry T4 is the most applicable temperature group. T6 is used only for carbon disulfide applications.*

15.1.4 Markings

The hazardous area classifications also specify which types of equipment protection are allowed in each zone or division. For example, sand filling is allowed in Division 2 and in Zones 1 and 2. Explosion-proof equipment is allowed in Zones 1 and 2. North America certificates indicate the hazardous area division in their certification markings. IEC/ ATEX certificates indicate the hazardous area zone in their certification markings.

The following examples show how hazardous area classifications are designated in product specifications:

Model code I1: Ex ia IIC T4 Ga (Tamb = –50 °C to 70 °C)
I1 is a ATEX marking that indicates that the instrument may be used with gases in Group IIC at temperatures within the range associated with group T4 and in ambient temperatures between –50 °C and 70 °C. This protection type is intrinsically safe level ia, and equipment protection level Ga (suitable for installation in Zone 0, 1 and 2).

Model code I7: Ex ia IIC T4 Ga (-50 °C _< Tamb _< 70 °C)
I7 is a IECEx marking that indicates that the intrinsic safety instrument may be used with gases in Group IIC at temperatures within the range associated with group T4 and in ambient temperatures between -50 °C and 70 °C. This protection type is intrinsically safe level ia, and equipment protection level Ga (suitable for installation in Zone 0, 1 and 2).

Model code E5: Explosion Proof for Class I, Division 1, Groups B, C, and D
E5 is a North America (US) marking that indicates the instrument may be safely used in hazardous areas with ignitable concentrations of gases (in gas groups B, C, and D) or vapors (Class I) present most of the time or for short periods of time under normal conditions.

Model code I5: Non-incendive for Class II, Division 2, Groups A, B, C, and D.
I5 is a North America (US) marking that indicates the instrument may be safely used in hazardous areas with ignitable concentrations of dust (Class II) present only under fault conditions.

Model code I6: Intrinsically Safe for Class I, Division 1, Groups A, B, C, and D; Temperature Code T4
I6 is a North America (Canada) marking that indicates that the instrument may be safely used with gases in gas groups A, B, C, and D at temperatures within the range associated with group T4.

15.1.5 Hazardous Area Installation Practices

Hazardous area installation practices are essential for ensuring safety in environments where flammable gases, vapors, or dust are present. Here are some key practices:

1. Zoning and Classification

- Zone/Division Classification: Areas are classified into zones/divisions

- Area Assessment: Conducting a thorough risk assessment to determine the appropriate classification for the installation.

2. Selection of Equipment

- Using equipment designed and certified to operate safely in hazardous environments

3. Installation Techniques

- Sealing and Gasketing: Ensuring proper sealing of junction boxes and connections to prevent gas ingress.

- Proper Cable Management: Using appropriate cable types and ensuring they are installed in a way that minimizes risk (e.g., using armored cables in high-risk areas).

4. Earthing and Bonding

- Grounding: Ensuring all equipment is properly grounded to prevent static discharge.

- Bonding: Connecting different metal parts to eliminate potential differences in voltage, reducing the risk of sparks.

5. Maintenance and Inspection

- Conducting routine checks to ensure equipment remains compliant and functional.

- Implementing a preventive maintenance schedule to address wear and tear that could lead to hazardous situations.

6. Training and Procedures

- Ensuring all personnel are trained in hazardous area practices and understand the risks.

- Establishing and practicing emergency response procedures for incidents involving hazardous materials.

7. Documentation

- Maintaining detailed records of installations, inspections, and maintenance to ensure compliance with regulations.

- Clearly labeling hazardous areas and equipment to inform personnel of potential risks.

8. Use of Barriers and Ventilation

- Installing barriers to contain potential leaks or spills.

- Ensuring adequate ventilation to disperse potentially hazardous gases or vapors.

Users must follow local installation standards, depending on their geographic location such as: North America—National Electrical Code (NEC) NFPA 70, Europe (ATEX) - EN60079-14 etc. By following these practices, organizations can minimize risks and enhance safety in hazardous areas, ensuring compliance with relevant regulations and standards.

Explosion-proof installation
Figure below shows the typical NEC requirements for an explosion-proof installation. Note that rigid metal conduits (or another approved conduit) must be used to enclose electrical wiring in hazardous areas. In addition, conduit seals should be placed along the electrical conduit line. In Europe, most explosion-proof installations use cable glands. Both methods are acceptable.
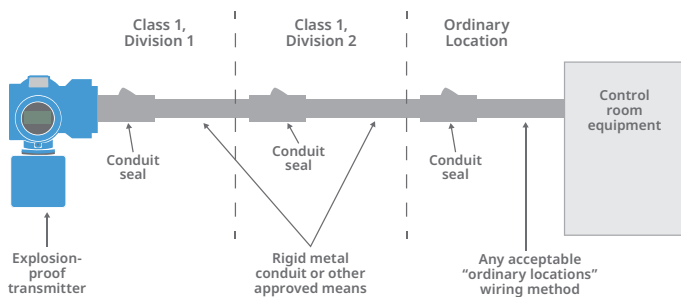
Figure 15.1.5.1: NEC explosion-proof installation

Intrinsic safety installation
Figure below shows the typical NEC requirements for an I.S. installation. Users should consider functional issues such as communications and temperature effect when performing an I.S. installation. The I.S. barrier must be located outside the hazardous area.
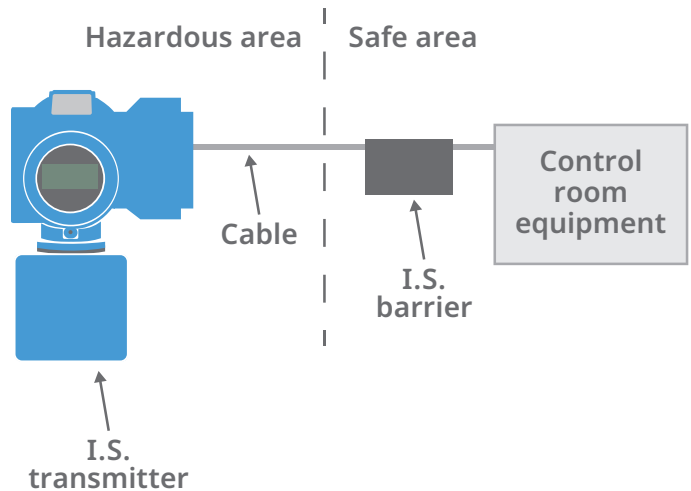
Figure 15.1.5.2: Intrinsic safety installation

Specific conditions for safe use
In many cases, an Ex certificate has associated unique installation or maintenance requirements, often called Specific Conditions for Safe use. For ATEX, IECEx (and some other) certificates, this is indicated by the letter "X" at the end of the certificate number.

These requirements are listed in the certificate, and also in the Product Certifications document and/or Control drawing or Installation manual.

Sealing installation
The NEC requires that electrical enclosures be sealed if:

- The equipment marking requires sealing

- The equipment contains a source of electrical or thermal ignition

- The equipment has a provision for process connection but does not incorporate dual independent sealing of process fluids

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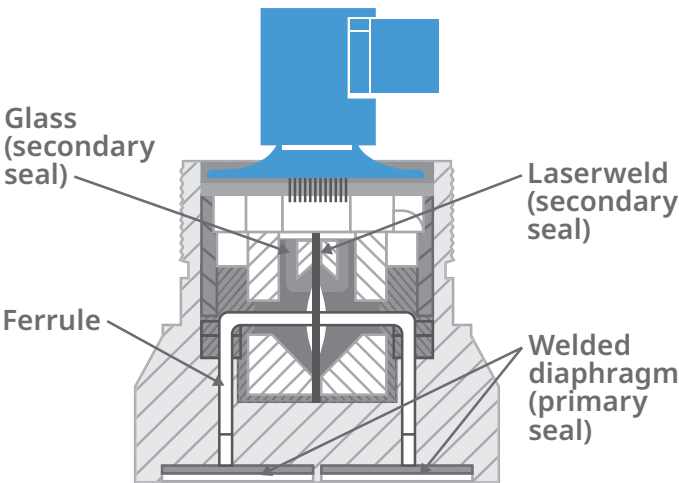
Figure 15.1.5.3: Example of a sealed enclosure

Glass (secondary seal)

Ferrule

Laserweld (secondary seal)

Welded diaphragm (primary seal)

15.2 Enclosure ratings

When it comes to enclosures, there are differences between the North American market and the rest of the world. In North America, an enclosure has a "Type rating" (UL 50/50E and the CSA C22.2 No. 94.1/94.2) or a "NEMA Type rating" (NEMA 250). That standard, IEC 60529, is a system of classification for the degree of protection, known as "IP Code". Ingress protection (IP) describes the degree of protection an enclosure provides from ingress of water or foreign bodies

15.2.1 IEC ingress protection codes

IEC 60529 uses the codes in table below to designate an enclosure's ability to protect against different types of solids and liquids. The first number indicates the degree of protection against solid foreign particles. The second number indicates the degree of protection against harmful entry of water. If either the first or second number is indicated with an X or a zero, then no protection is provided in that category.

IP68 and IP67 are two commonly seen IP ratings. A device with an IP68 rating is completely protected against dust (as indicated by the 6) and can withstand continuous immersion in water (as denoted by the 8).

A device with an IP67 rating is fully protected against dust and can survive temporary immersion in water, rather than the prolonged ingress protection that IP68 provides.

Solids (First Number)		Liquids (Second Number)	
1	Protected against a solid object greater than 50mm, like a hand	1	Protected against vertically falling water drops with limited ingress
2	Protected against a solid object greater than 12.5mm such as a finger	2	Protected against vertically falling water drops with enclosure tilted up to 15 degrees
3	Protected against a solid object greater than 2.5mm such as a screwdriver	3	Protected against water sprays of up to 60 degrees from the vertical with limited ingress for 3 minutes
4	Protected against a solid object greater than 1mm such as a wire	4	Protected against water splashed from all directions with limited ingress
5	Limited dust ingress, will not alter operation of equipment for 2-8 hours	5	Protected against water jets with limited ingress
6	Dust tight, no dust ingress for 2-8 hours	6	Protected against water from heavy seas or powerful jets of water
		7	Protected against the effects of immersion in water between 15cm and 1m for 30 minutes
		8	Protected against the effects of immersion in water under pressure for long periods

Table 15.5: IEC enclosure protection codes

15.2.2 NEMA ingress protection ratings

NEMA indicates an enclosure's degree of protection against various materials using the numbers 1–13. The numbers cover liquid, solid, and hazardous area requirements. NEMA uses a standard rating system that defines the types of environments in which an electrical enclosure can be used, and frequently signifies a fixed enclosure's ability to withstand certain environmental conditions. Types 1, 2, 5, 12, 12K, and 13 are meant for enclosures for indoor locations; Types 3, 3X, 3R, 3RX, 3S, 3SX, 4, 4X, 6, and 6P are for enclosures for indoor or outdoor locations; and Types 7 and 9 are intended for enclosures for hazardous (classified) locations.

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NEMA rating	Description
1	General purpose enclosure
2	Drip-tight enclosure
3	Weather proof
4	Water-tight
4X	Water-tight and corrosion resistant
5	Dust-tight
6	Submersible
7	Hazardous locations (Class I, Groups C and D)
8	Hazardous locations (Class I, oil-immersed)
9	Hazardous locations (Class II, Groups E, F, and G)
10	Explosion-proof (Bureau of Mines 0)

Table 15.6: NEMA enclosure protection codes

Comparing NEMA enclosure types with IEC classifications

The IEC 60529 is not a product standard, i.e. it does not cover key points of an enclosure such as the construction, the doors, windows (if applicable), cover securement requirements, the corrosion resistance requirements, the potential effects of icing, and the requirements for gaskets such as the aging test and the oil resistance test. These additional areas are crucial to the overall safety of an enclosure, especially when the said enclosures will go into a particular environment (which are covered under the type ratings).

Because of this reason and because tests and evaluations for other characteristics are not identical, IEC enclosure classification designations cannot be exactly equated with NEMA enclosure type numbers. Table below shows general comparisons between NEMA enclosure types and IEC enclosure classifications that are similar but not exact.

NEMA rating	IEC code
3	IP54
4	IP56
4x	IP56
5	IP52
6	IP67
12	IP52

Table 15.7: Comparing NEMA with IEC designations

For further information please contact Emerson.

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CHAPTER 16
SAFETY INSTRUMENTED SYSTEMS

16 Safety Instrumented Systems

16. Safety Instrumented Systems

Primary function of application

IEC61511 is the globally accepted standard which sets out practices in process and bulk liquid industries that ensure the safety of industrial processes through the use of completely or partially electrical / electronic / programmable instrumentation. Such systems are known as Safety Instrumented Systems (SIS).

To meet safety requirements and environmental regulations, most storage tanks need to be equipped with an overfill alarm to avoid overfilling and consequent safety and environmental hazards.

The overfill alarm is normally connected to a safety system which operates separately from the system used for the operation of the tank.

Depending on the degree of hazard the overspill could result in, the safety system may also need redundancy.
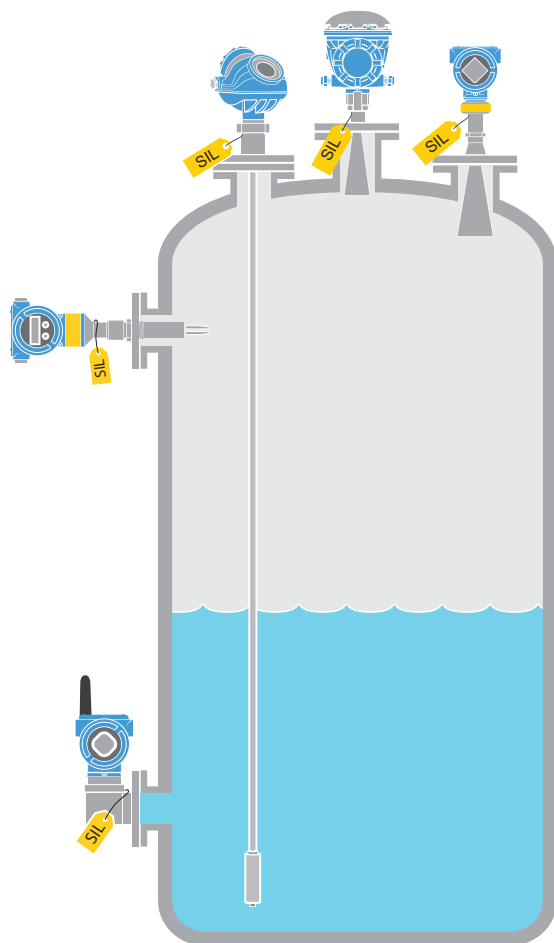
Figure 16.1: Storage tank with SIL suitable instrumentation

Application characteristics and challenges

- Storage tanks can have stilling wells and / or floating roofs. Sometimes the position of the floating roof is measured.

- Stored fluids may be light (eg. LPG) and subject to phase changes- for example boiling or vaporizing under storage temperature and pressure changes

- Fluids can be viscous or dirty and may cause coating and plugging of equipment

- Fluids may be hazardous; corrosive and / or flammable

- Measurement points often situated in hazardous locations

- Proof testing procedures can be complex and pose risks

Suitable technologies

Within a Safety Instrumented System, there is no 'one size fits all' technology and system. Different applications have their own specific challenges and it is important to select the appropriate technologies that meet these.

IEC61511 prescribes two different options for the selection of SIS equipment:

- IEC61508 compliant equipment

- Self-qualification of the equipment based on the prior-use clause in IEC61511

Float switches, vibrating fork switches, non-contacting radars, guided wave radars, and DP level technology can all be suitable technologies depending on the application type and level of risk reduction required.

Electronic level measurement technology has gained in popularity in recent years due to diagnostics capability. Many types available today have the ability to continuously monitor their mechanical and electronic "health" and signal if there is a problem. Some are also equipped with a means of performing a functional or proof-test, either locally via a test button or magnetic test point, or remotely by sending a command from the host system. This allows operators to periodically check the integrity of their overfill prevention device "in process" without having to remove it from the vessel.

Sensors may be classed as Type A or Type B. Type A device is an analog device in which all failure modes can be predicted and tested for. Type B devices have microprocessors in them which means it has software/firmware which can't be tested for all failure modes.

Selecting IEC61508 compliant equipment generally r esults in less work when implementing a Safety instrumented System.

Best practice

- As a result of recent changes in regulatory requirements, and the increase in use of SIS safety systems, measurement and control instrumentation has to meet specific levels of functional safety. Instruments with built-in diagnostics and self-checking capability to meet the needs of SIL1, 2 or 3 safety systems are required

- Select technology which has been safety-assessed and certified to IEC61508 by an independent third party

- Select technology with high diagnostics coverage

- Consider undetected dangerous failure modes

- Consider technology with minimum number for greatest reliability

- To reduce risk during routine proof testing, select a technology which facilitates a method of "in process" proof-testing whereby the liquid level does not need to be changed and the device can be tested without removal from the vessel

- Consider technology with enhanced remote functionality—such as remote configuration, diagnostics, and proof testing—to reduce operator time spent in hazardous locations

16.1 Safety Integrity Level (SIL)

The process industry sector's international standard for safety instrumented systems IEC 61511 defines SIL as the degree of necessary risk reduction for a certain safety function. A function is furthermore defined as a set of instruments intended to detect an imminent accident, decide to take an action and carry out actions as appropriate. At a minimum, the instruments included are a sensor, a logic solver and a final element. This could typically be one or more level transmitter communicating with a PLC that is set to control a shutdown valve. There are many procedures available for the actual determination of a function's SIL, but their common goal is to determine the probability of occurrence of harm and the severity of that harm. Each safety function is determined to be SIL 1, SIL 2, SIL 3 or SIL 4. The higher the SIL, the higher are the requirements to achieve a tolerable risk. Most functions are determined to be SIL 1, some are SIL 2 and few are SIL 3.

For any given SIL, the actual targets vary depending on devices complexity, likelihood of demand, and the architecture's redundancy or voting schemes used. Most modern devices are deemed complex (Type B) because of the use of microprocessors. The likelihood of demand depends on the way the function operates. If the safe action is demanded more often than the test interval or more than once a year, it is considered as a continuous or high

demand of operation. Finally, redundancy in the instrument architecture is referred to as a system's Hardware Fault Tolerance, i.e. the ability to be able to undertake the required safety instrumented function in the presence of dangerous faults in hardware. For example, it is common to use 3 sensors in parallel and a 2oo3 (2-out-of-3) voting for SIL 2 functions. This provides a hardware fault tolerance of 1 since the failure of one of the devices does not prevent the safety action from occurring.

It has become convenient to classify devices as SIL 1, SIL 2, or SIL 3 devices, but there is actually no such thing. The important target for a device is that a device's Safe Failure Fraction (SFF) is not lower than the specified SFF and that the Probability of Failure on Demand (PFD) is as low as possible. These failure probabilities are calculated by performing a Failure Modes, Effects, and Diagnostic Analysis (FMEDA).

The SIL also sets requirements for systematic safety integrity, which defines a set of techniques and measures required to prevent systematic failures from being designed into a device or a system. These requirements can either be met by establishing a rigorous development process, or by establishing that the device has sufficient operating history to argue that it has been proven in use. Electric and electronic devices can be certified for use in functional safety applications according to IEC 61508, providing application developers the evidence required to demonstrate that the application including the device is also compliant.

IEC 61508 addresses the requirements for manufacturers of safety components used on SIS and IEC 61511 outline the requirements for end-users and integrators only.

16.2 Selecting a safe sensor

Within IEC 61511, there are two options for selecting sensors. The first option is a safety certified device that is designed per IEC 61508. This means that the manufacturer proves that the device or transmitter is safe and the user proves the actual interface to the process is safe.

The second option is to select a sensor based on "Prior-use". That means the end user proves that the entire system is safe.

16.3 FMEDA

One step in selecting a sensor technology is to look at the safety and reliability of the sensor. This is typically in the form of a Failure Modes, Effects, and Diagnostic Analysis or FMEDA. This evaluation can be carried out for non-certified and certified products. This is an exercise where typically an independent 3rd party (e.g. Exida, TÜV, FM or SP), will look at the schematics and hardware of the product and identify all the failure modes. It will give the safe detected, safe undetected, dangerous detected, and dangerous undetected failures.

Two key metrics are the Safe Failure Fraction (SFF) and Probability of Failure on Demand (PFD). The Safe Failure Fraction (SFF) tells if the product is suitable for a function with a given SIL and Hardware Fault Tolerance. The PFD tells the risk of a sensor to not perform safe when needed. When any instrument is first commissioned, its PFD is 0. The PFD will increase over time though, until a proof test is carried out to restore the PFD. A function's SIL defines the maximum allowed PFD. The speed at which the PFD increases is unique for each instrument and specifications typically show instruments' PFD after 1 year for comparisons.

It is important is that the proof test interval of a sensor is greater than or equal to your plant turnaround interval. This way, there is no process interruption and there is a reduced risk to your personnel.

16.4 Certified sensors

For a certified sensor, there are really two systems. The 1st system is the actual device or transmitter. For this system or top half, the burden is on the manufacturer to prove that it is safe. The second system, or bottom half, is the actual interface to the process. The 2nd half or bottom portion is the user's responsibility. The user must prove it's safe.

Both of these systems will have a probability of failure on demand or PFD – there will be a PFD for the transmitter and a PFD for the interface and these will be added together. Probability of Failure on Demand is the probability that the loop/device will be in a failure mode when there is a demand on the system.

16.5 Prior-use

For a prior-use transmitter, the user proves that the entire system is safe. The user must have data to support that both the transmitter and interface are safe to use in that application. In addition, there are two ways to claim SIL suitable prior-use; either with a SFF from the hardware assessment (according to IEC 61508), or with a SFF from the hardware assessment (according to IEC 61508) combined with plant specific proven-in-use data (per IEC 61511). This means, as an example; a sensor with a SFF >90% will be SIL 2 suitable (if the system has a Hardware Fault Tolerance (HFT) of 0) and a sensor with a SFF in the range of 60 to <90% will be SIL 1 suitable in that same system.

However, users can reduce the HFT by one according to IEC 61511 in their validation together with proven-in-use data. See table below.

Note: Scope in IEC 61511-1 part 1 states: "...does not apply to manufacturers wishing to claim that devices are suitable for use in safety instrumented systems ..."

Proven-in-use data should be plant specific data and manufacturers, or assessors for manufacturers, cannot qualify and claim proven-in-use as per IEC 61511.

SFF	HFT=0	HFT=1 (0*)	HFT=2 (1*)
<60%	N/A	SIL1	SIL2
60%...<90%	SIL1	SIL2	SIL3
90%...<99%	SIL2	SIL3	(SIL4)
≥99%	SIL3	(SIL4)	(SIL4)

*Table 16.5.1 Prior-use Safety Integrity Levels based on SFF for type B safety related subsystems. *Users can reduce the Hardware Fault Tolerance (HTF) by one with proven-in-use according to IEC 61511 in their validation. Only users, not manufacturers can do this.*

SIS Application

Certified — Mfg proves it's safe / User proves it's safe

Prior-use — User proves it's safe

Figure 16.4.1: Responsibility of proof for SIS sensors

16.6 Rosemount 2120 level switch - certified to IEC61508 (SIL2) vibrating fork

The Rosemount 2130 series has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of a FMEDA (Failure mode, effects and diagnostic analysis) report. Rosemount 2100 series is considered to be a type B device. With a Safe Failure Fraction (SFF) > 90% for 4 of the electronic output options, it is certified SIL 2 suitable.

The Rosemount 2120 vibrating fork level switch with output types K-NAMUR, G-PNP/PLC, and H-8/16mA is a Type B device according to IEC 61508, with a SFF >90% and is certified SIL2 suitable, having a hardware fault tolerance of 0.

Figure 16.6.1: Rosemount 2120 with SIL2

Output type	Level of integrity	SFF
Namur (K)	SIL 2 @ HFT=0, Route 1H SIL 3 @ HFT=1, Route 1H	>91.1%
8/16mA (H)	SIL 2 @ HFT=0, Route 1H SIL 3 @ HFT=1, Route 1H	>90.9%
PNP/PLC (G)	SIL 2 @ HFT=0, Route 1H SIL 3 @ HFT=1, Route 1H	>90%
Relay (V)	SIL 1 @ HFT=0, Route 1H SIL 2 @ HFT=1, Route 1H	>72%

Table 15.6.1: Rosemount 2120 certificates and approvals

16.7 Rosemount 2130 level switch - certified to IEC61508 (SIL2) vibrating fork

The Rosemount 2130 has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of a FMEDA (Failure mode, effects and diagnostic analysis) report. Rosemount 2130 is equipped with a magnetic test point as standard, allowing operators to perform a quick, simple and safe local partial-proof test "in process".

The Rosemount 2130 vibrating fork level switch with output types N-NAMUR, P-PNP/PLC, L-Direct Load and M-8/16mA is a Type B device according to IEC 61508, with a SFF >90% and is certified SIL2 suitable, having a hardware fault tolerance of 0.

The Rosemount 2130 vibrating fork level switch with output type D – DPDT/DPCO relay is considered to be a Type B subsystem with hardware fault tolerance of 0. With a Safe Failure Fraction (SFF) <90%, it has shown prior use SIL1 suitable with HFT=0 and SIL 2 suitable with HFT=1.

Figure 16.7.1: Rosemount 2130 with SIL2

Output type	Level of integrity	SFF
Namur (N) PNP/PLC (P) Load Switching (L) 8/16mA (M)	SIL 2 @ HFT=0	>90%
Relay (D)	SIL1 @ HFT=0 SIL 2 @ HFT=1	>76.8%

Table 16.7.1: Rosemount 2130 certificates and approvals

16.8 Rosemount 2140:SIS level detector-certified to IEC61508 (SIL2) vibrating fork

The Rosemount 2140:SIS Vibrating Fork Liquid Level Detector has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of FMEDA (Failure Mode, Effects and Diagnostics Analysis) report. It is classified as a Type B device that meets the requirements of providing a level of integrity to SIL 2 @ HFT=0, Route 1H with a SFF up to 97.7% depending on configuration.

Rosemount 2140:SIS is equipped with a fully integrated remote partial proof test function, activated via a HART command from the host. A push button to perform same test "locally" is also included.

- SFF up to 97.7%

- PFDAVG: 6.82E-03 based on proof test interval of 1 year

- Proof test interval: supports >5 years (based on sensor average probability of failure on demand should be better or equal to 3.5E-03 for SIL2)

- Valid for 4–20 mA with HART communication

Figure 15.8.1: Rosemount 2140:SIS

Level of integrity	SFF
SIL 2 @ HFT=0, Route 1H	>97.7%

Table 16.8.1: Rosemount 2140 certificates and approvals

16.9 Rosemount 5300 level transmitter - certified to IEC61508 (SIL2) guided wave radar

The Rosemount 5300 has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of a FMEDA (Failure Mode, Effects and Diagnostic Analysis) report.

Rosemount 5300 is considered to be a type B device. With Safe Failure Fraction (SFF) > 90% it has shown prior-use SIL 2 suitable. This option provides the safety instrumentation engineer with the required failure data as per IEC 61508 / IEC 61511 and with proof test recommendations.

- SFF: >90%

- PFDAVG: 6.13E-04 based on proof test interval of 1 year

- Proof test interval: supports 5 years (based on sensor average probability of failure on demand should be better or equal to 3.5E-03 for SIL2)

- Valid for 4-20 mA output (HART)

Figure 16.9.1: Rosemount 5300 with SIL2

Level of integrity	SFF
SIL3 @ HFT=1, Route 1H	>91.5%
SIL2 @ HFT=0, Route 1H	>91.5%
SIL3 @ HFT=1, Route 2H	-
SIL2 @ HFT=0, Route 2H	-

Table 16.9.1: Rosemount 5300 certificates and approvals

16.10 Rosemount 5408:SIS level transmitter - certified to IEC61508 (SIL2) non-contacting radar

The Rosemount 5408:SIS has been certified to SIL 2 by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of FMEDA (Failure Mode, Effects and Diagnostics Analysis) report. It is classified as a Type B device that meets the requirements of providing a level of integrity to SIL2 @ HFT=0 & SIL3 @ HFT=1, Route 1H with a SFF>92.7%. Valid for 4-20mA output (HART).

Figure 16.10.1: Rosemount 5408:SIS with SIL2

Level of integrity	SFF
SIL3 @ HFT=1, Route 1H	>92.7%
SIL2 @ HFT=0, Route 1H	>92.7%

Table 16.10.1: Rosemount 5408:SIS certificates and approvals

16.11 Rosemount Pressure Transmitters and Remote Seals

Rosemount Pressure Transmitter and Remote Seals are designed to perform with the highest levels of reliability and safety. These devices have been evaluated by a third party to be available either with safety certification to IEC 61508, with documentation available to support Probability of Failure on Demand (PFD) calculations or with Failure Modes, Effects, and Diagnostics Analysis (FMEDA) to support justification for use in IEC 61511 Prior Use justification.

Devices included are:

- Rosemount 3051S Transmitters
- Rosemount 3051S ERS Systems
- Rosemount 3051 Transmitters
- Rosemount 2051 Transmitters
- Rosemount 1199 / 1299 Diaphragm Seal System

Figure 16.11.1: Rosemount 3051SAL liquid level transmitter with SIL3

NOTE!
For more information regarding safety, including certificates, FMEDA reports, and safety manuals, go to: Emerson.com/Rosemount

16.12 Rosemount 5900S radar level gauge

- certified to IEC61508 (SIL2) non-contacting radar

The Rosemount 5900S Radar Level Gauge has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of FMEDA (Failure Mode, Effects and Diagnostics Analysis) report. It is classified as a Type B device that meets the requirements of providing a level of integrity to SIL2 @ HFT=0, Route 1H with a SFF>90.9% and SIL2 @ HFT=0, Route 2H. Valid for 4-20mA output (HART) and discrete output.

Figure 16.12.1: Rosemount 5900S radar level gauge with SIL2

Level of integrity	SFF
SIL2 @ HFT=0, Route 1H	>90.9%
SIL2 @ HFT=0, Route 2H	

Table 16.12.1: Rosemount 5900S certificates and approvals

16.13 Rosemount 5900S 2-in-1 radar level gauge

- certified to IEC61508 (SIL3) non-contacting radar

The 5900S is the world's first SIL3-certified radar level gauge for overfill prevention. With patented 2-in-1 functionality, a single enclosure contains two independent sets of radar level gauge electronics. The highest level of safety with SIL3 can now be achieved with a single gauge (HFT=0), requiring only a single tank-opening and a single installation, without compromising on the custody transfer grade accuracy. The certification has been carried out by Exida.

• SFF > 99 %

• Output: Discrete output (routed through the Rosemount 2410 Tank Hub)

Figure 16.13.1: Rosemount 5900S 2-in-1 radar level gauge with SIL3

Level of integrity	SFF
SIL3 @ HFT=0, Route 1H	>99%

Table 16.13.2: Rosemount 5900S 2-in-1 certificates and approvals

NOTE! For more information regarding safety, including certificates, FMEDA reports, and safety manuals, go to: Emerson.com/Rosemount

16.14 Rosemount 5900C radar level gauge - certified to IEC61508 (SIL2) non-contacting radar

The Rosemount 5900C Radar Level Gauge has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of FMEDA (Failure Mode, Effects and Diagnostics Analysis) report. It is classified as a Type B device that meets the requirements of providing a level of integrity to SIL2 @ HFT=0, Route 1H with a SFF>90.9% and SIL2 @ HFT=0, Route 2H. Valid for 4-20mA output (HART) and discrete output.

Figure 16.14.1: Rosemount 5900C radar level gauge with SIL2

Level of integrity	SFF
SIL2 @ HFT=0, Route 1H	>90.9%
SIL2 @ HFT=0, Route 2H	

Table 16.14.1: Rosemount 5900C certificates and approvals

CHAPTER 17
REFERENCE MATERIAL

17 Reference material

17 Reference Material

17.1 Dielectric Constants

Compound	DC	°F	°C	State
Activated coke pellets	14	RT	RT	S
Alum (aluminium potassium sulphate)	4.2	140	60	
Alum (aluminium sulphate)	2.6	68	20	
Amino-2-methylpropane	4.4	70	21	
Aminoalkyd resin	3.9-4.2			L
Aminododecane (dodecylamine)	3.1	86	30	S
Aminoethylamino ethanol	21.8	68	20	L
Aminofulsenforte	22.0	77	25	L
Aminohexacane	2.7	131	55	L
Amino-octadecane, stearylamine	2.6	136	58	L
Aminoocetane	3.9	54	12	L
Aminoocetane	4.1	36	2	L
Aminopentane	4.5	72	22	L
Amino-tetradecane	2.9	104	40	L
Aminotoluene	4.6	68	20	L
Aminox	2.4	275.0	135.0	S
Amlmercaptan	4.7	68	20	L
Ammonia	1.0072	32.0	0.0	GA
Ammonia	14.9	77	25	L
Ammonia	15.5	68	20	L
Ammonia	18.9	40.0	4.4	L
Ammonia	22.0	-30.0	-34.4	L
Ammonia	22.7	-58	-50	L
Ammonia	25.0	-104.0	-75.6	L
Ammonia	25.0	-74.0	-58.9	L
Ammonia, aqueous (25%)	31.6	68	20	L
Amp (2-amino-2-methyl-1-propanol)	18-20	122-86	50-30	L

Compound	DC	°F	°C	State
Asbestos, blue	3.4	68	20	S
Asbestos, dry	10.2	68	20	S
Ash, cement kiln	12.5	75.0	23.9	S
Ash, fly (boiler)	1.7	125.0	51.7	S
Ash, fly (boiler)	1.9	80.0	26.7	S
Ash, soda	3.6	75.0	23.9	S
Asphalt	2.7	75.2	24.0	L
Asphalt	3.7	400.0	204.4	L
Aviation gasoline	1.9	77.0	25.0	L
Bayol	2.1	75.2	24.0	L
Bayol-16	2.2	75.2	24.0	L
Bayol-d	2.1	75.2	24.0	L
Bayol-f	2.1	75.2	24.0	L
Benzaldehyde	10.9	59	15	L
Benzaldehyde	17.0	68	20	L
Benzaldehyde	19.0	32.0	0.0	L
Benzene	1.0028	700.0	371.1	GA
Benzene	2.1	275.0	135.0	L
Benzene	2.3	68	20	L
Benzene, (bromomethyl)	6.7	68	20	L
Benzene, (dichloromethyl)	6.9	68	20	L
Benzene, (trifluoromethyl)	9.2	77.0	25.0	L
Benzene, heavy	3.2	68	20	L
Benzene, pure	1.9	68	20	L
Benzenediol	13.6	248.0	120.0	L
Benzenephosphonic acid dichloride	26.0	68	20	L
Benzenephosphonic acid difluoride	27.9	68	20	L
Benzenesulfonyl chloride	28.9	122.0	50.0	L

Compound	DC	°F	°C	State
Benzenesulfonyl chloride, (trifluoromethylsulfonyl)-	4.7	77.0	25.0	L
Benzenethiol	4.3	86.0	30.0	L
Benzenethiol, (trifluoromethylsulfonyl)-	28.5	77.0	25.0	L
Benzil	5.9	158	70	L
Benzil	13.0	203.0	95.0	L
Benzine (ligroin)	7.6	75.0	23.9	L
Benzole	2.3	50	10	L
Benzole, heavy	3.2	68	20	L
Benzole+ malonate, without emulsion	3.5	68	20	L
Benzonitrile	22.0	160.0	71.1	L
Benzonitrile	25.9-26	68	20	L
Benzophenone	12.6	80.6	27.0	L
Benzotrichloride	7.4	68	20	L
Benzotrichloride	19.0	68	20	L
Benzoyl (p-chlorophenyl) thiodiimine	7.9	19.4	-7.0	L
Benzoyl (p-fluorophenyl) thiodiimine	7.3	152.6	67.0	L
Benzoyl (p-methylphenyl) thiodiimine	13.1	154.4	68.0	L
Benzoyl (p-trifluoro-methylsulfonyl) phenythiodiimine	15.9	158.0	70.0	L
Benzoyl acetate	11.5	70	21.0	L
Benzoyl acetone	3.8	68	20	L
Benzoyl acetone	29.0	68	20	L
Benzoyl bromide	21.3	68	20	L
Benzoyl chloride	19.0	75.0	23.9	L
Benzoyl chloride	20.0	68	20	L
Benzoyl chloride	23.0	68	20	L
Benzoyl chloride	22.7	68	20	L
Benzoylimidosulfurous dichloride	31.6	104.0	40.0	L
Benzyl acetate	5.0	70.0	21.1	L
Benzyl acetate	5.3	86.0	30.0	L
Benzyl alcohol	6.6	270	132	L
Benzyl alcohol	9.5	158	70	L
Benzyl alcohol	11.9	86.0	30.0	L

Compound	DC	°F	°C	State
Benzyl alcohol	13.0	68	20	L
Benzyl benzoate	4.8	68	20	L
Benzyl benzoate	5.3	86.0	30.0	L
Benzyl butanoate	4.6	82.4	28.0	L
Benzyl chloride	7.0	55	13	L
Benzyl chloride	6.4-6.9	68	20	L
Benzyl cyanide	6.0	155.0	68.3	L
Benzyl cyanide	18.3	68	20	L
Benzyl ethyl ether	3.9	77.0	25.0	L
Benzyl ethylamine	4.3	68	20	L
Benzyl formate	6.3	86.0	30.0	L
Benzyl iodide	4.6	68	20	L
Benzyl phenyl ether	3.7	104.0	40.0	L
Benzyl phenylacetate	4.5	86.0	30.0	L
Benzyl propanoate	5.1	86.0	30.0	L
Benzyl salicylate	4.1	68	20.0	L
Benzyl salicylate	4.1	82.4	28.0	L
Benzylamine (amino toluene)	4.3	120.0	48.9	L
Benzylamine (amino toluene)	4.6	68	20	L
Benzylamine (amino toluene)	5.5	32.0	0.0	L
Benzylethylamine	4.3	68	20.0	L
Benzylmethylamine	4.4	66.2	19.0	L
Benzylthiol	4.7	77.0	25.0	L
Biopropanol	25.0	68	20.0	L
Bis(1-methylpropoxy) dimethylsilane	3.0	77.0	25.0	L
Bis(3-methylbutyl)amine	2.5	64.4	18.0	L
Bis(trimethylsilaneoxyethyl) amine	3.6	104.0	40.0	L
Bitumen	2.3	140	60.0	L
Bitumen	2.8	68	20.0	L
Bitumen froth	4.1	75	23.9	L
Bone meal	1.7	68	20.0	S
Butadiene	2.1	17.6	-8.0	L
Butanal	13.0	77.0	25.0	L
Butane	1.4	30.2	-1.0	L

Compound	DC	°F	°C	State
Butane	1.8	71.6	22.0	L
Butane	2.9	68	20	L
Butanediol	22.4	77.0	25.0	L
Butanediol	30.0	80.0	26.7	L
Butanediol dinitrate	18.0-18.9	68	20	L
Butanediol-(1,3)-dinitrate	18.9	68	20	L
Butanediol-(1,4)	30.2	86	30	L
Butanediol-(2,3)-dinitrate	28.8	68	20	L
Butanediodiacetate	5.1	77	25	L
Butanol (butyl alcohol)	15.4	104	40	L
Butanol (butyl alcohol)	23.8	-13	-25	L
Butanone (-2)	17.6	104	40	L
Butanone (-2)-oxime	3.4	68	20	L
Butanone oxime	3.4	68	20	L
Butanoneoxim	3.4	68	20	L
Butene	2.0	73.4	23.0	L
Butoxyacetylene	6.6	77.0	25.0	L
Butoxyacetylene	6.6	68	20	L
Butoxyethanol	9.4	77.0	25.0	L
Butoxyethyl isocyanate	9.4	68	20	L
Butoxytrimethylsilane	2.7	77.0	25.0	L
Buthyl acetate	2.4	-108	-78	L
Butyl acetate	3.4	140.0	60.0	L
Butyl acetate	5.1	68	20	L
Butyl acrylate	4.2	68	20	L
Butyl acrylate	5.3	82.4	28.0	L
Butyl acohol (butanol)	7.0	140	60	L
Butyl acohol (butanol)	11.2	86	30	L
Butyl acohol (butanol)	19.5	50	10	L
Butyl acohol (butanol)	20.0	75.0	23.0	L
Butyl acohol (butanol)	23.8	-13	-25	L
Butyl acohol (n-)	7.8	66.0	18.9	L
Butyl benzene	2.3	86	30	L
Butyl benzoate	5.5	86.0	30.0	L
Butylsilane	2.5	68	20	L
Butyoxytrimethylsilane	2.8	77.0	25.0	L
Calcium sulphate	2.3	75.0	23.9	S
Calcium sulphate	5.6	75.0	23.9	S

Compound	DC	°F	°C	State
Carbon bisulfide, pure	2.6	68	20	L
Carbon dioxide	1.000921	68	20	GA
Carbon dioxide	1.5	71.6	22.0	L
Carbon dioxide	1.6	32.0	0.0	L
Carbon disulphide	2.2	180.0	82.2	L
Carbon disulphide	2.2	350.0	176.7	L
Chlorine	1.5	287.0	141.7	L
Chlorine	1.7	170.6	77.0	L
Chlorine	1.9	58.0	14.4	L
Chlorine	2.0	32.0	0.0	L
Chlorine	2.1	-85.0	-65.0	L
Chlorine pentafluoride	4.3	-112.0	-80.0	L
Chloro-2-methyl butane	12.3	-59	-50	L
Chloro-2-methyl propane	6.5	59	15	L
Chloro-2-methyl propane	9.2	86	30	L
Chloro-2-methyl propane	11.7	14	-10	L
Chloro-2-nitro-benzene	37.7	122	50	S
Chloro-3-bromobenzene	4.6	68	20	S
Chloro-3-methyl butane	6.1	66	19	L
Chloro-3-nitro-benzene	13.3	149	65	L
Chloro-3-nitro-benzotrifluoride	12.8	86	30	L
Chloro-4-ethyl-benzene	6.0	77	25	L
Chloro-4-nitro-benzene	8.1	248	120	L
Chloro-5-nitro-benzotrifluoride	9.8	86	30	L
Chloro-a, dihydroxiprone	31.0	68	20	GA
Chlorobenzene	5.9	68	20	L
Chlorobenzene	6.1	32	0	L
Chlorobenzene	7.2	-50	-45.6	L
Chlorobenzene sulfonylchloride	11.8	140.0	60.0	L
Chlorobutane	6.8	108	42	L
Chlorobutane	7.3	68	20	L
Chlorobutane	9.1	-20.0	-28.9	L
Chlorobutane	12.2	-130	-90	L
Chlorobutyl formate	9.1	68	2	
Chloroethane	9.5	68	20	L
Chloroethanol	25.8	68	20	L

Compound	DC	°F	°C	State
Chlorohexanol	21.6	-23.8	-31.0	L
Chloromethane	12.6	-35.0	-37.2	L
Chloromethane-4	12.6			
Chloromethylbutane	12.3	-58.0	-50.0	L
Chloromethyldioxolanone	97.5	104.0	40.0	L
Chloromethylpropane	7.0	68	20	L
Chloromethylthiophenol	5.5	86.0	30.0	L
Chloronitrobenzene	8.1	248.0	120.0	L
Chloronitropropane	31.9	-9.4	-23.0	L
Chloronitrotoluene	28.1	82.4	28.0	L
Chloropyridine	27.3	77.0	25.0	L
Chlorothioanisole	6.0	77.0	25.0	L
Cleaner's naphtha	2.0	68	20	L
Coal 15% moisture	4.0	68	20	S
Coal 65% moisture	25.3	68	20	S
Coal bituminous 0% H$_2$O	3.2	700.0	371.1	S
Coal bituminous 0% H$_2$O	4.1	400.0	204.4	S
Coal bituminous 0% H$_2$O	7.5	77.0	25.0	S
Coal dust	2.5	68	20	S
Coal powder	4.6	68	20	S
Coal tar	2.0-3.0			S?
Coal, powder, fine	2-4			S
Coke	3.0	68	20	S
Coke	8.0	68	20	S
Coke	1.1-2.2			S
Coke (from coal)	1.6	75.0	23.9	S
Common salt 0.9	22.0	230	110	S
Common salt 0.9	23.0	68	20	S
Corn cobs	1.8	75.0	23.9	S
Corn cobs 2% H$_2$O (crushed)	2.0	75.0	23.9	S
Crude tar	4.0	68	20	L
Cumene	2.4	68	20	L
Cyclohexadione	4.4	170.0	76.7	L
Cyclohexane	2.0	68	20	L
Cyclohexane	2.0	68	20	L
Cyclohexanecarboxylic acid (hexahydrobenzoic acid)	2.6	88.0	31.0	L

Compound	DC	°F	°C	State
Cyclohexanedione	4.4	172.4	78.0	L
Cyclohexanemethanol	8.1	176.0	80.0	L
Cyclohexanemethanol	9.7	140.0	60.0	L
Cyclohexanethiol	5.4	77.0	25.0	L
Cyclohexanol	12.5	113	45	L
Cyclohexanol	14.1	95	35	L
Cyclohexanol	14.8	77	25	L
Cyclohexanol	15.0	68	20	L
Cyclohexanone	19.0	-40.0	-40.0	L
Cyclohexanone (ketohexamethylene)	18.2	68	20	L
Decane	1.8	340.0	171.1	L
Decane	2.0	68	20	L
Dibromobenzene	2.6	203	95	L
Dibromobenzene	2.6	23.0	-5.0	S
Dibromobenzene	4.5	190.0	87.8	L
Dibromobenzene	4.7	73	23	L
Dibromobenzene	7.5	68	20	L
Dibromobenzene	8.8	68	20	L
Dibromobenzene (p-)	4.5	190.0	87.8	S
Dibromobutane	4.7	68	20	L
Dibromobutane	5.8	77	25	L
Dibromodecane	6.6	86.0	30.0	L
Dibromodichloromethane	2.5	77.0	25.0	L
Dibromodifluoromethane	2.9	32.0	0.0	L
Dibromoethane	4.1	212	100	L
Dibromoethane	4.1	265.0	129.4	L
Dibromoethane	4.6	131	55	L
Dibromoethane	4.7	104	40	L
Dibromoethane	4.8	77	25	L
Dibromoethane	7.1	77	25	L
Dibromoethane	7.7	32	0	L
Dibromoethylene	2.9	68	20	L
Dibromoethylene	3.0	32	0	L
Dibromoethylene (cis)	7.1	77.0	25.0	L
Dibromoethylene (cis-1, 2)	7.7	32.0	0.0	L
Dibromoethylene (trans)	2.9	77.0	25.0	L
Dibromoheptane	3.8	77	25	L
Dibromoheptane	3.8	150.0	65.6	L

Compound	DC	°F	°C	State
Dibromoheptane	5.08	24.0	-4.4	L
Dibromoheptane	5.1	76.0	24.4	L
Dibromohexane	4.7-5.0	77.0	25.0	L
Dibromomethane	6.7	104	40	L
Dibromomethane	7.0	68	20	L
Dibromomethane	7.8	50.0	10.0	L
Dibromomethylpropane	4.1	68	20	L
Dibromononane	7.2	68	20	L
Dibromooctane	7.4	77.0	25.0	L
Dibromopentane	4.3	68	20	L
Dibromopropane	4.3	68	20	L
Dibutoxydimethylsilane	2.8	77.0	25.0	L
Dichloro-1-chloromethylbenzene	6.3	77.0	25.0	L
Dichloro-1-methyl benzene	9.0	77	25	L
Dichloro-1-nitroethane	16.3	86.0	30.0	L
Dichloro-2-chloroethylbenzene	5.2	75.2	24.0	L
Dichloro-2-methyl propane	7.2	73	23	L
Dichloro-2-vinyl benzene	2.6	77	25	L
Dichloro-3,5bis(trifluoromethyl) benzene	3.1	86.0	30.0	L
Diesel fuel	2.1	68	20	L
Diethanolamine, (dea)	22-25	122-86	50-30	L
Diethoxyethane	3.9	68	20	L
Diethoxymethane	2.5	68	20	L
Diethyanolamine	25.8	68	20	L
Diethylamine	3.7	68	20	L
Diethylsilane	2.5	68	20	L
Diethyoxydimethylsilane	3.2	77	25	L
Diisopropanolamine, (dipa)	13.2-13.9	122-86	50-30	L
Dimethoxydimethylsilane	3.7	77.0	25.0	L
Dimethyl sulfate				
	55.0	77.0	25.0	L
Dimethyl sulfide	6.3	68	20	L
Dimethyl sulfone	47.4	230.0	110.0	L
Dimethyl sulfoxide	47.2	68	20	L

Compound	DC	°F	°C	State
Dimethylbis (1-methylethoxy)silane	3.0	77.0	25.0	L
Dimethyldiphenoxysilane	3.5	77.0	25.0	L
Dimethyldipropoxysilane	3.0	77.0	25.0	L
Dimethyldipropysilane	2.1	68	20	L
Ethane	1.9	-288.4	-178.0	L
Ethoxytrimethylsilane	3.0	77.0	25.0	L
Ethylbenzamide	42.6	176.0	80.0	L
Ethylbenzene	2.4	68	20	L
Ethylbenzene	3.0	76.0	24.4	L
Ethylbenzylamine	4.3	68	20	L
Ethylene	1.5	26.6	-3.0	L
Ethylene glycol	37.0	68	20	L
Ethylene glycol	38.7	68	20	L
Ethylene glycol	46.7	59	15	L
Ethylene oxide	12.4	68	20	L
Ethylene oxide	13.9	30	-1	L
Ethylene sulfite	39.6	77.0	25.0	L
Fly ash	3.3	68	20	S
Fly ash	1.9-2.6			S
Gasoline	2.0	70.0	21.1	L
Gasoline, fuel	2.1	75.0	23.9	L
Glycol	37.0	68	20	L
Glycol	41.0	68	20	L
Gypsum	2.8	75.0	23.9	S
Heavy oil	3.0			L
Heavy oil, c	2.6			L
Helium	1.1	-358.0	-216.7	GA
Helium	1.1	-455.8	-271.0	GA
Helium -3	1.055	58.0	14.4	GA
Helium, liquid	1.9-2.0			L
Heptane	1.9	68	20	L
Heptane	2.1	-130.0	-90.0	L
Hexane	1.8	167	75	L
Hexane	1.9	68	20	L
Hexane	1.9	86	30	L
Hexane	2.0	-130.0	-90.0	L
Hexane	3.2	-200.0	-128.9	L

Compound	DC	°F	°C	State
Hexane (cis-3-)	2.1	76.0	24.4	L
Hexane (n-)	1.9	68	20	L
Hexanone	14.6	68	20	L
Hexanone-(2)	14.6	58	15	L
Hexene	2.0	69.8	21.0	L
Hexene (cis-3-)	2.1	76.0	24.4	L
Hexene (trans-3-)	2.0	76.0	24.4	L
Hexylamine	4.1	68	20	L
Hydrazine	51.7	32	0	L
Hydrazine	51.7	77.0	25.0	L
Hydrazine	52.9	68	20	L
Hydrochloric acid	2.6	68	20	L
Hydrochloric acid	4.6	68	20	L
Hydrochloric acid	4.6	82	28	L
Hydrochloric acid	6.3	5	-15	L
Hydrochloric acid	10.1	-121	-85	L
Hydrochloric acid	10.2	-162	-108	L
Hydrochloric acid	11.8	-172	-113	L
Hydrocyanic acid	2.3	68	20	L
Hydrocyanic acid	158.0-158.1	32.0	0.0	L
Hydrofluoric acid	83.6	32.0	0.0	L
Hydrogen sulfide	5.9	50.0	10.0	L
Hydrogen sulfide	9.3	-120.0	-84.4	L
Hydrogen sulphide	5.9	50	10	L
Hydrogen sulphide	8.0	-78	-61	L
Hydrogen sulphide	9.0	-109	-79	L
Hydrogen superoxide, 30%	11.0	68	20	L
Isobutane (methyl propane)	1.8			L
Isobutylsilane	2.5	68	20	L
Isooctane	2.1-2.3			L
Isopentane	1.8	68	20	L
Isopentane	1.9	32	0	L
Jet fuel (jp1)	2.1	77.0	25.0	L
Jet fuel (jp3)	2.0	77.0	25.0	L
Jet fuel (military-jp4)	1.7	69.8	21.0	L
Kerosene (commercial)	1.8	70.0	21.1	L
Lime	2.6	75.0	23.9	S

Compound	DC	°F	°C	State
Lime	10.9	75.0	23.9	S
Lime (reburned)	2.2	75.0	23.9	S
Lime 1% H_2O	4.2	75.0	23.9	S
Lime 2% H_2O	7.7	75.0	23.9	S
Lime granulate	4.0	68	20	S
Lime powder	3.3	68	20	S
Lime, carbon-dioxide process	3.1	68	20	S
Lime, munster	1.8	RT	RT	S
Lime, phosphoric acid	5.0	68	20	S
Lime, slaked, 4 weeks old	2.2	68	20	S
Lime, slaked, dolomite	1.8	RT	RT	S
Lime, slaked, refined	4.0	68	20	S
Limestone	9.0	75.0	23.9	S
Limestone .6% H_2O	2.8	75.0	23.9	S
Limestone 2% H_2O	2.3	75.0	23.9	S
Liquid parafin	2.0	68	20	L
Liquified air	1.5			L
Liquified hydrogen	1.2			L
Lpg	1.6-1.9			L
Methane	1.005-1.05	10	50	GA
Methane (liq. Natural gas)	1.7	-295.6	-182.0	L
Methanol (wood alcohol, methyl alcohol)	33.0	68	20	L
Methanol (wood alcohol, methyl alcohol)	37.5	32.0	0.0	L
Methanol (wood alcohol, methyl alcohol)	56.6	-112.0	-80.0	L
Methanol, impure	20.4	68	20	L
Methoxytrimethylsilane	3.2	77.0	25.0	L
Methyl mercaptan	7.6	35.0	1.7	L
Methyl naphthalin	2.7	77	25	
Methyl nitrate	23.5	64	18	L
Methyl nitrate	23.9	68	20	L
Methylamine	9.4	77	25	L
Methylamine	10.5	21.0	-6.1	L
Methylamine	11.3	32	0	L
Methylamine	11.4	14	-10	L
Methylamine	16.7	-72.4	-58.0	L

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Compound	DC	°F	°C	State
Methylnaphthalene	2.7	68	20	L
Methylnaphthalene	2.7	104.0	40.0	L
Methylpentadiene-(1,3)	2.4	77	25	L
Methylpentadiene-(1,3)	2.5	122	50	L
Methylpentadiene-(1,3)	3.2	-103	-75	L
Methylpentane	1.9	68	20	L
Methyltriphenoxysilane	3.6	77.0	25.0	L
Mineral oil	2.1	80.0	26.7	L
Naphtha (refinery cut)	2.0	75.0	23.9	L
Naphthalene	2.3	185.0	85.0	L
Naphthalene	2.5	75.0	23.9	S
Naphthalene	2.5	194	90	L
Naphthalene	2.5	68	20	S
Naphthenic acid	2.6	68	20	L
Naphthol	5.0	212.0	100.0	L
Naphtholine	2.5	75.0	23.9	L
Naphthonitrile	6.4	70.0	21.1	L
Naphthonitrile	16.0	158.0	70.0	L
Naphthyl nitrile	19.2	72	22	L
Naphthyl salicylate	6.3	68	20	L
Naphthylamine	5.2	140.0	60.0	L
Naphthyleneylacetamide	24.3	320.0	160.0	L
Napthonitrile	6.4	69.8	21.0	L
Napthyl ethyl ether	3.2	68	20	L
Nitric acid	50.0	14.0	-10.0	L
Nitric acid 97% hno3	33.6	68	20	L
Nitric acid 98% hno3	19.0	68	20	L
Nitrogen	1.00058	68	20	GA
Nitrogen	1.5	-346.0	-210.0	L
Nitrogen	1.4	-352	-213	L
Nitrogen	1.5	-318	-195	L
Nitrogen (liquified)	1.3	-310	-190	L
Nitrogen (liquified)	1.5	336.0	168.9	L
N- methyldiethanolamine, (mdea)	19-22	122-86	50-30	L
Nonane	1.8	230.0	110.0	L
Nonane	2.0	68	20	L
Nonane	2.1	-60.0	-51.1	L

Compound	DC	°F	°C	State
Octane	1.061			GA
Octane	1.8	230.0	110.0	L
Octane	1.9	160.0	71.1	L
Octane	1.9	77	25	L
Octane	1.95	68	20	L
Octanone	7.4	212.0	100.0	L
Octanone	9.5	68	20	L
Octanone	12.5	-4.0	-20.0	L
Octylene	4.1	66.2	19.0	L
Oil	2.04 - 3	68	20	L
Oil / dea 124	2.4	68	20	L
Oil / water mixture	24.2	68	20	L
Oil b1	6.0	68	20	L
Oil b3	4.2	68	20	L
Oil d8	6.8	122	50	L
Oil, conserve+c2733	2.4	68	20	L
Oil, fuel (#2)	2.7	75.0	23.9	L
Oil, hb-40	2.3	77.0	25.0	L
Oil, heating	2.1	68	20	L
Oil, heavy	2.2	68	20	L
Oil, kel-f grade #1	2.1	77.0	25.0	L
Oil, kel-f grade #10	2.1	77.0	25.0	L
Oil, kel-f grade #3	2.1	77.0	25.0	L
Oil, lube	2.1-2.4	68	20	L
Oil, mobil	2.3	68	20	L
Oil, motor	2.6	68	20	L
Oil, motor 10w40 and sae30	2.2	75.0	23.9	L
Oil, non-conductive	3.0	68	20	L
Oil, paraffin	2.2-4.7	68	20	L
Oil, petroleum	2.1	68	20	L
Oil, pyranol	5.3	68	20	L
Oil, sae 90	2.2	50	10	L
Oil, sae 90	2.2	140	60	L
Oil, transformer (lube oil)	2.1	68	20	L
Oil, transil	2.2	78.8	26.0	L
Oil, transil 10c	2.1	78.8	26.0	L
Oil, transmission	2.2	80.6	27.0	L

Compound	DC	°F	°C	State
Oil, turpentine	2.2	68	20	L
Pallman chips (wood, moist)	2.3	68	20	S
Paper, wood, dry	2.0	75.0	23.9	S
Pe chips	1.3	RT	RT	S
Pe granulat, white (polyethylene)	1.3	RT	RT	S
Pe powder, non-stabilised	1.4	RT	RT	S
Pe, powder	1.6	RT	RT	S
Pellets	2.1	68	20	S
Pentandione	23.0	68	20	L
Pentane	1.8	68	20	L
Pentane	2.0	-130.0	-90.0	L
Pentanediol	17.3	73.4	23.0	L
Pentanedione	26.5	86.0	30.0	L
Pentanol	13.4	77.0	25.0	L
Phenylethylene (styrene)	2.3	167.0	75.0	L
Phenylethylene (styrene)	2.4	77.0	25.0	L
Polyester (plastic chips)	1.9	75.0	23.9	S
Polyester (plastic flakes)	2.0	75.0	23.9	S
Polyester (plastic powder)	1.4	75.0	23.9	S
Polyester resin	1.9	68	20	S
Polyester resin	5.1	68	20	S
Polyester resin	2.8	75.0	23.9	S
Polyester resin	5.5	75.0	23.9	L
Polyester resin (flexible)	4.1	75.0	23.9	S
Polypropylene	1.6	68	20	S
Polypropylene	1.5	75.0	23.9	S
Polypropylene, powder	1.25			S
Polypropylene, liquid	2.2-2.4	68	20	L
Polypropylene, pellet	1.5-1.8			S
Polypropylene, plastic	1.60	75.0	23.9	S
Polystyrene	2.5			S
Polystyrene plastic (pellets)	1.90	75.0	23.9	S
Polystyrene resin	2.4	75.0	23.9	S
Propane	1.6	32.0	0.0	L
Propane	1.7	68	20	L
Propanediol	27.5	86.0	30.0	L

Compound	DC	°F	°C	State
Propanediol dinitrate	19.0	68	20	L
Propanedithiol	7.2	68	20	L
Propanenitrile	29.7	68	20	L
Propanethiol	5.9	59.0	15.0	L
Propanetriol 1,2-diacetate	18.2	-20.2	-29.0	L
Propanetriol 1,3-diacetate	9.8	59.0	15.0	L
Propene	1.3	197.0	91.7	L
Propene	1.7	150.0	65.6	L
Propene	1.8	112.0	44.4	L
Propene	1.9	68	20	L
Propene	2.1	-63.4	-53.0	L
Propylamine	2.9	72	22	L
Propylamine	5.1	73.4	23.0	L
Propylamine	5.3	68	20	L
Propylbenzene	2.4	68	20	L
Propylene (liquid)	11.9			L
Propylene glycol	29.5	68	20	L
Propylene glycol (pg)	25-28	122-86	50-30	L
Pyrazine	2.8	120.0	48.9	L
Pyridine	2.8	122.0	50.0	L
Pyridine	12.3	77	25	L
Pyridine	12.5	68	20	L
Reburned lime	2.2			S
Resin	1.5	68	20	
Resin, natural	2.2	RT	RT	S
Resin, polyester "atlas", +c2480 pechiney	2.3	68	20	
Resin, technical purity	24.5	68	20	
Rock salt 0-25mm	4.3	68	20	S
Salt	3.0-15.0			S
Salt water	32.0	68	20	L
Sawdust	1.3	RT	RT	S
Sawdust, (dry)	1.6	75.0	23.9	S
Shavings-dust, dry	1.3	68	20	S
Shavings-dust, moist	2.0	68	20	S
Slaked lime, powder	2.0-3.5			S
Slate	7.0	75.0	23.9	S
Soda (sodium carbonate)	4.6	RT	RT	S

Compound	DC	°F	°C	State
Soda (sodium carbonate)	5.1	RT	RT	S
Soda (sodium carbonate)	5.6	RT	RT	S
Sodium carbonate (10h20)	5.3	75.0	23.9	S
Sodium carbonate (anhyd)	8.4	75.0	23.9	S
Sodium carbonate (soda, soda ash)	5.3-8.4			S
Sodium hydroxide	25.8	68	20	
Sodium hypochlorite	6.7			S
Sodium phosphate	1.6-1.9			S
Sodium sulfite	5			
Sodium tripolyphosphate	2.3	75.0	23.9	S
Sodium tripolyphosphate	4.7	77	25	S
Steam at 0.3 psi (0.02 bar)	1.0002	68	20	GA
Steam at 14.7 psi (1 bar)	1.006	211	100	GA
Steam at 225 psi (15.5 bar)	1.064	392	200	GA
Steam at 577 psi (39.7 bar)	1.152	482	250	GA
Steam at 1246psi (85.9 bar	1.351	572	300	GA
Steam at 2398 psi (165 .4 bar)	1.863	662	350	GA
Stearate (2458 a)	1.1	68	20	
Stearate (2458 b)	1.4	68	20	
Sulfate, fine	3.6	68	20	S
Sulfinyl aniline, (trifluoromethylsaulfonyl) -n-	15.1	168.8	76.0	L
Sulfinylaniline	7.0	77.0	25.0	L
Sulfite, spent liquor	32.0	68	20	L
Sulfur	2.2	75.0	23.9	S
Sulfur	3.4	752.0	400.0	L
Sulfur	3.5	447.0	230.6	L
Sulfur	3.5	68	20	S
Sulfur	3.55	244.0	117.8	L
Sulfur	1.6-3.4	75.0	23.9	S
Sulfur chloride	3.0	77.0	25.0	L
Sulfur chloride	4.8	59	15	L
Sulfur dioxide	14.0	68	20	L
Sulfur dioxide	15.0	32	0	L
Sulfur dioxide	17.6	-4.0	-20.0	L
Sulfur dioxide	17.7	-6	-21	L

Compound	DC	°F	°C	State
Sulfur, powder	1.6-3.6			S
Sulfuric acid	21.9	68	20	L
Sulfuric acid, 15%	31.0	68	20	L
Sulfuric acid, 95%	8.3	68	20	L
Sulfuric acid, 96%	7.8	68	20	L
Sulfuric acid, 97%	8.6	68	20	L
Sulfuric acid, 98%	7.2	68	20	L
Sulfuric acid, conc.	3.5	70	21	L
Tar paste bt 80/125 with bitumen	4.0	68	20	S
Tar paste t 40/60, very thin	4.7	68	20	S
Tar paste tv 49/51, very thick	4.3	158	70	S
Tar, crude	4.0	68	20	L
Tar, crude with 4.1% moisture	5.5	68	20	L
Tar, oil	3.8	86	30	L
Tetra (methylpropoxy) silane	2.6	77.0	25.0	L
Tetraethoxysilane	2.5	68	20	L
Tetraethylsilane	2.1	68	20	L
Tetramethylsilane	1.9	68	20	L
Tetrapentoxysilane	2.8	77.0	25.0	L
Tetraphenoxysilane	3.5	140.0	60.0	L
Tetrapropoxysilane	3.2	77.0	25.0	L
Toluene	2.0	360.0	182.2	L
Toluene	2.2	260.0	126.7	L
Toluene	2.4	32.0	0.0	L
Toluene	2.3	68	20	L
Toluene diisocyanate	5.1	68	20	L
Toluene, (trifluoromethylsulfonyl)	23.4	104.0	40.0	L
Transformer oil	2.1	68	20	L
Triethanolamine, (tea)	24-28	122-86	50-30	L
Triethoxymethylsilane	3.8	77.0	25.0	L
Triethylsilane	2.3	68	20	L
Trihexoxymethylsilane	2.9	77.0	25.0	L
Trimethoxymethylsilane	4.9	77.0	25.0	L
Trimethylchlorosilane	10.2	32.0	0.0	L

Compound	DC	°F	°C	State
Trimethylhexoxy silane	2.7	77.0	25.0	L
Trimethylisopropoxysilane	2.9	77.0	25.0	L
Trimethylphenoxylsilane	3.4	77.0	25.0	L
Trimethylphenylsilane	2.4	77.0	25.0	L
Trimethylpropoxysilane	2.9	77.0	25.0	L
Tripropoxymethylsilane	3.4	77.0	25.0	L
Tris(1-methylethoxy) methylsilane	3.3	77.0	25.0	L
Tris(butoxymethyl)silane	3.1	77.0	25.0	L
Tris(sec-butoxymethyl) silane	3.0	77.0	25.0	L
Urea	2.9	RT	RT	S
Urea	3.5	71.6	22.0	L
Urea	3.5	75.0	23.9	S
Urea resin	6.2-9.5			S
Vaselin oil	1.6	68	20	L
Vaseline	2.2-2.9	77.0	25.0	S
Water	10.1	687	364	L
Water	20.4	248	120	L
Water	34.5	390	199	L
Water	80.4	68	20	L
Water	88.0	32	0	L
Water	48.0-55.0	212	100	L
Water at 0.3 psi (0.02 bar)	80.0	68	20	L
Water at 1305 psi (90 bar)	19.69	578	303	L
Water at 14.5 psi (1 bar)	55.0	211	100	L
Water at 2175 psi (150 bar)	14.30	649	343	L
Water at 2320 psi (160 bar)	13.57	658	348	L
Water at 580 psi (40 bar)	26.94	482	250	L
Water, deionized	30.0	68	20	L
Water, demineralised	30.0	68	20	L
Water, distilled	34.0	77.0	25.0	L
Water, frozen (ice)	3.2	10.0	-12.0	S
Water, heavy	78.3	77	25	L
Water, heavy (deuterium oxide)	80.0	68	20	L
Wax	1.8	68	20	S
Wax	2.4-6.5			S

Compound	DC	°F	°C	State
Wax: paraffin	1.9	250.0	121.1	L
Wax: paraffin	2.2	75.0	23.9	S
Wax: parawax	2.3	75.0	23.9	S
Wax: petroleum	2.1	300.0	148.9	L
Wax: petroleum	3.0	200.0	93.3	L
Wood chippings, wood moist	2.3	68	20	S
Wood chips	1.1	68	20	S
Wood pulp dust	1.5	68	20	S
Wood shavings, coarse and compact	1.4	68	20	S
Wood shavings, coarse and loose	1.1	68	20	S
Wood shavings, dry	1.2	68	20	S
Wood shavings, fine and compact	1.3	68	20	S
Wood shavings, fine and loose	1.1	68	20	S
Wood shavings, moist	1.7	68	20	S
Wood, dry	2-6			S
Xylene	2.4	77	25	L
Xylene (c8h10) (p-)	2.2	56	13	L
Xylene (m-)	2.3	86	30	L
Xylene (m-)	2.4	68	20	L
Xylene (o-)	2.5	77	25	L
Xylene (o-)	2.6	68	20	L
Xylene (p-)	2.3	68	20	L

17.2 Conversion Matrixes

17 | Reference Material

17.2.1 Temperature Conversion

-459.4° to 0°			1° to 60°			61° to 290°			300° to 890°			900° to 3000°		
C	F C	F	C	F C	F	C	F C	F	C	F C	F	C	F C	F
-273	-459.4		-17.2	1	33.8	16.1	61	141.8	149	300	572	482	900	1652
-268	-450		-16.7	2	35.6	16.7	62	143.6	154	310	590	488	910	1670
-262	-440		-16.1	3	37.4	17.2	63	145.4	160	320	608	493	920	1688
-257	-430		-15.6	4	39.2	17.8	64	147.2	166	330	626	499	930	1706
-251	-420		-15.0	5	41.0	18.3	65	149.0	171	340	644	504	940	1724
-246	-410		-14.4	6	42.8	18.9	66	150.8	177	350	662	510	950	1742
-240	-400		-13.9	7	44.6	19.4	67	152.6	182	360	680	516	960	1760
-234	-390		-13.3	8	46.4	20.0	68	154.4	188	370	698	521	970	1778
-229	-380		-12.8	9	48.2	20.6	69	156.2	193	380	716	527	980	1796
-223	-370		-12.2	10	50.0	21.1	70	158.0	199	390	734	532	990	1814
-218	-360		-11.7	11	51.8	21.7	71	159.8	204	400	752	538	1000	1832
-212	-350		-11.1	12	53.6	22.2	72	161.6	210	410	770	549	1020	1868
-207	-340		-10.6	13	55.4	22.8	73	163.4	216	420	788	560	1040	1904
-201	-330		-10.0	14	57.2	23.3	74	165.2	221	430	806	571	1060	1940
-196	-320		-9.4	15	59.0	23.9	75	167.0	227	440	824	582	1080	1976
-190	-310		-8.9	16	60.8	24.4	76	168.8	232	450	842	593	1100	2012
-184	-300		-8.3	17	62.6	25.0	77	170.6	238	460	860	604	1120	2048
-179	-290		-7.8	18	64.4	25.6	78	172.4	243	470	878	616	1140	2084
-173	-280		-7.2	19	66.2	26.1	79	174.2	249	480	896	627	1160	2120
-169	-273	-459.4	-6.7	20	68.0	26.7	80	176.0	254	490	914	638	1180	2156
-168	-270	-454	-6.1	21	69.8	27.2	81	177.8	260	500	932	649	1200	2192
-162	-260	-436	-5.6	22	71.6	27.8	82	179.6	266	510	950	660	1220	2228
-157	-250	-418	-5.0	23	73.4	28.3	83	181.4	271	520	968	671	1240	2264
-151	-240	-400	-4.4	24	75.2	28.9	84	183.2	277	530	986	682	1260	2300
-146	-230	-382	-3.9	25	77.0	29.4	85	185.0	282	540	1004	693	1280	2336
-140	-220	-364	-3.3	26	78.8	30.0	86	186.8	288	550	1022	704	1300	2372
-134	-210	-346	-2.8	27	80.6	30.6	87	188.6	293	560	1040	732	1350	2462
-129	-200	-328	-2.2	28	82.4	31.1	88	190.4	299	570	1058	760	1400	2552
-123	-190	-310	-1.7	29	84.2	31.7	89	192.2	304	580	1076	788	1450	2642
-118	-180	-292	-1.1	30	86.0	32.2	90	194.0	310	590	1094	816	1500	2732
-112	-170	-274	-0.6	31	87.8	32.8	91	195.8	316	600	1112	843	1550	2822
-107	-160	-256	0.0	32	89.6	33.3	92	197.6	321	610	1130	871	1600	2912
-101	-150	-238	0.6	33	91.4	33.9	93	199.4	327	620	1148	899	1650	3002
-96	-140	-220	1.1	34	93.2	34.4	94	201.2	332	630	1166	927	1700	3092
-90	-130	-202	1.7	35	95.0	35.0	95	203.0	338	640	1184	954	1750	3182

-459.4° to 0°			1° to 60°			61° to 290°			300° to 890°			900° to 3000°		
C	F C	F	C	F C	F	C	F C	F	C	F C	F	C	F C	F
-84	-120	-184	2.2	36	96.8	35.6	96	204.8	343	650	1202	982	1800	3272
-79	-110	-166	2.8	37	98.6	36.1	97	206.6	349	660	1220	1010	1850	3362
-73	-100	-148	3.3	38	100.4	36.7	98	208.4	354	670	1238	1038	1900	3452
-68	-90	-130	3.9	39	102.2	37.2	99	210.2	360	680	1256	1066	1950	3542
-62	-80	-112	4.4	40	104.0	37.8	100	212.0	366	690	1274	1093	2000	3632
-57	-70	-94	5.0	41	105.8	43	110	230	371	700	1292	1121	2050	3722
-51	-60	-76	5.6	42	107.6	49	120	248	377	710	1310	1149	2100	3812
-46	-50	-58	6.1	43	109.4	54	130	266	382	720	1328	1177	2150	3902
-40	-40	-40	6.7	44	111.2	60	140	284	388	730	1346	1204	2200	3992
-34	-30	-22	7.2	45	113.0	66	150	302	393	740	1364	1232	2250	4082
-29	-20	-4	7.8	46	114.8	71	160	320	399	750	1382	1260	2300	4172
-23	-10	14	8.3	47	116.6	77	170	338	404	760	1400	1288	2350	4262
-17.8	0	32	8.9	48	118.4	82	180	356	410	770	1418	1316	2400	4352
			9.4	49	120.2	88	190	374	416	780	1436	1343	2450	4442
			10.0	50	122.0	93	200	392	421	790	1454	1371	2500	4532
			10.6	51	123.8	99	210	410	427	800	1472	1399	2550	4622
			11.1	52	125.6	100	212	413.6	432	810	1490	1427	2600	4712
			11.7	53	127.4	104	220	428	438	820	1508	1454	2650	4802
			12.2	54	129.2	110	230	446	443	830	1526	1482	2700	4892
			12.8	55	131.0	116	240	464	449	840	1544	1510	2750	4982
			13.3	56	132.8	121	250	482	454	850	1562	1538	2800	5072
			13.9	57	134.6	127	260	500	460	860	1580	1566	2850	5162
			14.4	58	136.4	132	270	518	466	870	1598	1593	2900	5252
			15.0	59	138.2	138	280	536	471	880	1616	1621	2950	5342
			15.6	60	140.0	143	290	554	477	890	1634	1649	3000	5432

[1] *Locate temperature in middle column. If in degrees Celsius, read Fahrenheit equivalent in right hand column; if in degrees Fahrenheit, read Celsius equivalent in left hand column.*

17.2.2 Pressure Conversion

	Inches²			Inches³						
	Psi	**KPA**	**H₂O**	**mm H₂O**	**Hg**	**mm Hg**	**Bars**	**m Bars**	**Kg/cm²**	**gm/cm²**
PSI	1	6.8948	27.7620	705.1500	2.0360	51.7149	0.0689	68.9470	0.0703	70.3070
KPA	0.1450	1	4.0266	102.2742	0.2953	7.5006	0.0100	10.0000	0.0102	10 197
in H₂O*	0.0361	0.2483	1	25.4210	0.0734	1.8650	0.0025	2.4864	0.0025	2.5355
mm H₂O	0.0014	0.0098	0.0394	1	0.0028	0.0734	0.0001	0.0979	0.00001	0.0982
in Hg**	0.4912	3.3867	13.6195	345 936	1	25.4000	0.0339	33.8639	0.0345	34 532
mm Hg	0.0193	0.1331	0.5362	13.6195	0.0394	1	0.0013	1.3332	0.0014	1.3595
Bars	14.5040	100 000	402 180	10215.0	29.5300	750 060	1	1000	1.0197	1019.72
m Bars	0.0145	0.1000	0.4022	10.2150	0.0295	0.7501	0.001	1	0.0010	1.0197
Kg/cm²	14.2233	97.9047	394 408	10018.0	28.9590	735 559	0.9000	980 700	1	1000
gm/cm²	0.0142	0.0979	0.3944	10.0180	0.0290	0.7356	0.0009	0.9807	0.001	1

[1] *EXAMPLE*
1 mm Hg = 0.5362 inH₂O = 1.3332 mBars
97 mm Hg = 97(0.5362) = 52.0114 inv
97 mm Hg = 97(1.332) = 129.3204 mBars
[2] *at 60 °F*
[3] *at 32 °F*

17.2.3 Volume Conversion

From/to	cm³	liter	m³	in³	ft³	yd³	fl oz	fl pt	fl qt	gal	gal (Imp.)	bbl (oil)	bbl (liq)
cm³	1	0.001	1X10-6	0.06102	3.53X10-5	1.31X10-4	0.03381	0.00211	0.00106	2.64X10-4	2.20X10-4	6.29X10-6	8.39X10-6
liter	1000	1	0.001	61.02	0.03532	0.00131	33.81	2.113	1.057	0.2642	0.2200	0.00629	0.00839
m³	1X106	1000	1	6.10X104	35.31	1.308	3.38X104	2113	1057	264.2	220.0	6.290	8.386
in³	16.39	0.01639	1.64X10-5	1	5.79X10-4	2.14X10-5	0.5541	0.03463	0.01732	0.00433	0.00360	1.03X10-4	1.37X10-4
ft³	2.83X104	28.32	0.02832	1728	1	0.03704	957.5	59.84	29.92	7.481	6.229	0.1781	0.2375
yd³	7.65X105	764.5	0.7646	4.67X104	27	1	2.59X104	1616	807.9	202.0	168.2	4.809	6.412
fl oz	29.57	0.02957	2.96X10-6	1.805	0.00104	3.87X10-5	1	0.06250	0.03125	0.00781	0.00651	1.86X10-4	2.48X10-4
fl pt	473.2	0.4732	4.73X10-4	28.88	0.01671	6.19X10-4	16	1	0.5000	0.1250	0.1041	0.00298	0.00397
fl qt	946.4	0.0463	9.46X10-4	57.75	0.03342	0.00124	32	2	1	0.2500	0.2082	0.00595	0.00794
gal	3785	3.785	0.00379	231.0	0.1337	0.00495	128	8	4	1	0.8327	0.02381	0.03175
gal (Imp)	4546	4.546	0.00455	277.4	0.1605	0.00595	153.7	9.608	4.804	1.201	1	0.02859	0.03813
bbl (oil)	1.59X105	159.0	0.1590	9702	5.615	0.2079	5376	336	168	42	34.97	1	1.333

¹ 1 cord = 128 ft3 = 3.625 m³

17.2.4 Flow rate conversion

From/to	lit/sec	gal/min	ft3/sec	ft3/min	bbl/hr	bbl/day
lit/sec	1	15.85	0.03532	2.119	22.66	543.8
gal/min	0.06309	1	0.00223	0.1337	1.429	34.30
ft3/sec	28.32	48.8	1	60	641.1	1.54×10^4
ft3/min	0.4719	7.481	0.01667	1	10.69	256.5
bbl/hr	0.04415	0.6997	0.00156	0.09359	1	24
bbl/day	0.00184	0.02917	6.50×10^{-5}	0.00390	0.04167	1

[1] bbl refers to bbl oil = 42 gallons

17.2.5 Equivalents

Linear Measure		Measure of Volume	
1 micron	0.000001 m	1 cu cm	0.061 cu in
1 mm	0.03937 in	1 cu in	16.39 cu cm
1 mm	0.00328 ft	1 cu dm	0.0353 cu ft
1 cm	0.3937 in	1 cu ft	28.317 cu dm
1 in	2.54 cm	1 cu yd	0.7646 cu m
1 in	25.4 mm	1 stere	0.2759 cord
1 dm	3.937 in	1 cord	3.264 steres
1 dm	0.328 foot	1 l	0.908 qt dry
1 ft	3.048 dm	1 l	1.0567 qts liq
1 ft	30.48 cm	1 qt dry	1.101 l
1 ft	304.8 mm	1 qt liq	0.9463 l
1 m	39.37 in	1 dal	2.6417 gals
1 m	1.0936 yds	1 dal	1.135 pk
1 yd	0.9144 m	1 gal	0.3785 dal
1 dam	1.9884 rods	1 pk	0.881 dal
1 rod	0.5029 dal	1 hi	2.8375 bsh
1 km	0.62137 mi	1 bsh	0.3524 hi
1 mi	1.6093 km		

Square Measure		Weights	
1 sq cm	0.1550 sq in	1 g	0.03527 oz
1 sq cm	0.00108 sq ft	1 ounce	28.35 grams
1 sq in	6.4516 sq cm	1 kg	2.2046 lbs
1 sq dm	0.1076 sq ft	1 lb	0.4536 kg
1 sq ft	929.03 sq cm	1 metric ton	0.98421 English ton
1 sq ft	9.2903 sq dec	1 English ton	1.016 metric ton
1 sq m	1.196 sq yds	1 kg	2.205 pounds
1 sq yd	0.8361 sq m	1 cu in water (60 °F)	0.073551 cu in mercury (32 °F)
1 acre	160 sq rods	1 cu in of mercury (32 °F)	13.596 cu in of water (60 °F)
1 sq rod	0.00625 acre	1 cu in mercury (32 °F)	0.4905 lbs
1 hectare	2.47 acres		
1 acre	0.4047 ha		
1 sq km	0.386 sq mi		
1 sq mi	2.59 sq km		
Circumference of a circle	2 Tir		
Circumference of a circle	Tid		
Area of a circle	Tir2		
Area of a circle	Tid2/4		

Velocity			
		1 ft/sec	0.3048 m/sec
		1 m/sec	3.2808 ft/sec

Density			
		1 lb/cu in	27.68 gram/cu cm
		1 gr/cu cm	0.03613 lb/cu in
		1 lb/cu ft	16.0184 kg/cu m
		1 kg/cu m	0.06243 lb/cu ft

17.2.6 English to metric system conversion

1 To convert from:	2 To:	3 Multiply by:	Convert Col 2 to Col 1 Multiply by:
acre-feet	cubic meters	1233	8.11×10^{-4}
cubic feet (cu ft) (US)	cubic centimeters	28,317	3.53×10^{-5}
cubic feet (cu ft) (US)	cubic meters	0.0283	35.33
cubic feet (cu ft) (US)	liters	28.32	0.035
cu ft/min	cu cm/sec	472	0.0021
cu ft/min	liters/sec	0.472	2 119
cu ft/sec	liters/min	1699	5.886×10^{-4}
cubic inches (US)	cubic meters	1.64×10^{-5}	61,024
cubic inches (US)	liters	0.0164	61,024
cubic inches (US)	milliliters (ml)	16 387	0.0610
feet (US)	meters	0.3048	3 281
feet (US)	millimeters (mm)	304.8	3.28×10^{-3}
feet/min	cm/sec	0.508	1.97
feet/min	kilometers/hr	1.829×10^{-2}	54.68
feet/min	meters/min	0.305	3.28
ft/sec2	km/hr/sec	1.0973	0.911
gallons (US)	cu cm (ml)	3785	2.64×10^{-4}
gallons (US)	liters	3 785	0.264
gallons/min	liters/sec	0.063	15.87
US gal/min	cu meters/hr	0.227	4.4
US gal/sq ft/min	cu meters/hr/sq meters	2.45	0.408
grains (troy)	grams	0.0648	15 432
grains (troy)	milligrams (mg)	64.8	0.01543
grains/gal (US)	grams/liter	0.0171	58 417
grains/gal (US)	ppm	17.1	0.0584
inches (US)	centimeters (cm)	2.54	0.3937
inches (US)	millimeters (mm)	25.4	0.0394
miles (US)	kilometers (km)	1 609	0.6215
miles (US)	meters	1609	6.214×10^{-4}
miles/hr	cm/sec	44.7	0.0224

1 To convert from:	2 To:	3 Multiply by:	Convert Col 2 to Col 1 Multiply by:
miles/hr	meters/min	26.82	0.0373
miles/min	kilometers/hr	96.6	1.03×10^{-2}
ounces (avoirdupois)	grams	28.35	0.0353
ounces (US fluid)	ml	29.6	0.0338
ounces (US fluid)	liters	0.0296	33.81
pounds (av)	grams	453.6	0.0022
pounds (av)/ sq in	kgr/cm2	0.071	14 223
pounds (av)	kilograms	0.4536	2 205
pounds (av)	grains	7000	14.2×10^{-5}
pounds/cu ft	grams/l	16.02	0.0624
pounds/ft	grams/cm	14.88	0.067
pounds/gal US)	grams/ml	0.12	8 345
pounds/gal (US)	grams/liter	119.8	8.34×10^{-3}
quart (US liq)	ml	946.4	0.001057
quart (US liq)	liters	0.946	1 057
square feet (US)	sq cm	929	1.08×10^{-3}
square feet (US)	sq meters	0.0929	10.76
square inches (US)	sq cm	6 452	0.155

17.2.7 Decimal equivalents

8ths	16ths	32nds	64ths	
1/8 = 0.125	1/16 = 0.0625	1/32 = 0.03125	1/64 = 0.015625	33/64 = 0.515625
1/4 = 0.250	3/16 = 0.1875	3/32 = 0.09375	3/64 = 0.046875	35/64 = 0.546875
3/8 = 0.375	5/16 = 0.3125	5/32 = 0.15625	5/64 = 0.078125	37/64 = 0.578125
1/2 = 0.500	7/16 = 0.4375	7/32 = 0.21875	7/64 = 0.109375	39/64 = 0.609375
5/8 = 0.625	9/16 = 0.5625	9/32 = 0.28125	9/64 = 0.140625	41/64 = 0.640625
3/4 = 0.750	11/16 = 0.6875	11/32 = 0.34375	11/64 = 0.171875	43/64 = 0.671875
7/8 = 0.875	13/16 = 0.8125	13/32 = 0.40625	13/64 = 0.203125	45/64 = 0.703125
	15/16 = 0.9375	15/32 = 0.46875	15/64 = 0.234375	47/64 = 0.734375
		17/32 = 0.53125	17/64 = 0.265625	49/64 = 0.765625
		19/32 = 0.59375	19/64 = 0.296875	51/64 = 0.796875
		21/32 = 0.65625	21/64 = 0.328125	53/64 = 0.828125
		23/32 = 0.71875	23/64 = 0.359375	55/64 = 0.859375
		25/32 = 0.78125	25/64 = 0.390625	57/64 = 0.890625
		27/32 = 0.84375	27/32 = 0.421875	59/64 = 0.921875
		29/32 = 0.90625	29/32 = 0.453125	61/64 = 0.953125
		31/32 = 0.96875	31/64 = 0.484375	63/64 = 0.984375

17.2.8 Multiplication factors

Prefix	Symbol	Name	Multiplication Factor	
atto	a	one-quintillionth	0.000 000 000 000 000 001	10^{-18}
femto	f	one-quadrillionth	0.000 000 000 000 001	10^{-15}
pico	p	one-trillionth	0.000 000 000 001	10^{-12}
nano	n	one-billionth	0.000 000 001	10^{-9}
micro	m	one-millionth	0.000 001	10^{-6}
milli	m	one-thousandth	0.001	10^{-3}
centi	c	one-hundreth	0.01	10^{-2}
deci	d	one-tenth	0.1	10^{-1}
uni		one	1.0	10^{0}
deka	da	ten	10.0	10^{1}
hecto	h	one hundred	100.0	10^{2}
kilo	k	one thousand	1 000.0	10^{3}
mega	M	one million	1 000 000.0	10^{6}
giga	G	one billion	1 000 000 000.0	10^{9}
tera	T	one trillion	1 000 000 000 000.0	10^{12}

17.2.9 Maximum permissible ID and minimum wall in accordance with ASTM A106 pipe

Nominal Pipe Size	Outside Diam. Max.	Wall I.D.	Schedule 10	Schedule 20	Schedule 30	Standard Weight	Schedule 40	Schedule 60	Extra Strong	Schedule 80	Schedule 100	Schedule 120	Schedule 140	Schedule 160	Dbl. Ext. Strong
1/8	0.421	Wall I.D.				0.060 0.302	0.060 0.302		0.083 0.254	0.083 0.254					
1/4	0.556	Wall I.D.				0.077 0.402	0.077 0.402		0.110 0.335	0.110 0.335					
3/8	0.691	Wall I.D.				0.080 0.531	0.080 0.531		0.110 0.470	0.110 0.470					
1/2	0.856	Wall I.D.				0.095 0.665	0.095 0.665		0.129 0.598	0.129 0.598				0.164 0.528	0.257 0.341
3/4	1.066	Wall I.D.				0.099 0.868	0.099 0.868		0.135 0.796	0.135 0.796				0.191 0.684	0.270 0.527
1	1.331	Wall I.D.				0.116 1.098	0.116 1.098		0.157 1.017	0.157 1.017				0.219 0.893	0.313 0.704
1¼	1.676	Wall I.D.				0.123 1.431	0.123 1.431		0.167 1.341	0.167 1.341				0.219 1.238	0.334 1.007
1½	1.916	Wall I.D.				0.127 1.662	0.127 1.662		0.175 1.566	0.175 1.566				0.246 1.424	0.350 1.216
2	2.406	Wall I.D.				0.135 2.137	0.135 2.137		0.191 2.025	0.191 2.025				0.300 1.806	0.382 1.643
2½	2.906	Wall I.D.				0.178 2.551	0.178 2.551		0.242 2.423	0.242 2.423				0.328 2.250	0.483 1.940
3	3.531	Wall I.D.				0.189 3.153	0.189 3.153		0.263 3.006	0.263 3.006				0.383 2.765	0.525 2.481
3½	4.031	Wall I.D.				0.198 3.636	0.198 3.636		0.278 3.475	0.278 3.475					0.557 2.918
4	4.531	Wall I.D.				0.207 4.117	0.207 4.117		0.295 3.942	0.295 3.942		0.295 3.942		0.465 3.602	0.590 3.352
5	5.626	Wall I.D.				0.226 5.174	0.226 5.174		0.328 4.969	0.328 4.969		0.438 4.751		0.547 4.532	0.656 4.313
6	6.688	Wall I.D.				0.245 6.198	0.245 6.198		0.378 5.932	0.378 5.932		0.492 5.704		0.628 5.431	0.756 5.176
8		Wall I.D.		0.219 8.250	0.242 8.203	0.282 8.124	0.282 8.124	0.355 7.977	0.438 7.813	0.438 7.813	0.519 7.650	0.628 7.431	0.711 7.267	0.793 7.102	0.766 7.156
10	10.844	Wall I.D.		0.219 10.406	0.269 10.307	0.319 10.205	0.319 10.205	0.438 9.969	0.438 9.969	0.519 9.806	0.628 9.587	0.738 9.369	0.875 9.094	0.984 8.875	
12	12.844	Wall I.D.		0.219 12.406	0.289 12.266	0.328 12.188	0.355 12.133	0.492 11.860	0.438 11.969	0.601 11.642	0.738 11.369	0.875 11.094	0.984 10.875	1.148 10.548	
14	14.094	Wall I.D.	0.219 13.656	0.273 13.548	0.328 13.438	0.328 13.438	0.328 13.327	0.519 13.056	0.438 13.219	0.656 12.781	0.820 12.454	0.956 12.181	1.094 11.906	1.230 11.633	
16	16.094	Wall I.D.	0.219 15.656	0.273 15.548	0.328 15.438	0.328 15.438	0.438 15.219	0.574 14.946	0.438 15.219	0.738 14.619	0.902 14.290	1.066 13.962	1.258 13.577	1.394 13.306	

Nominal Pipe Size	Outside Diam. Max.	Wall I.D.	Extra													
			Schedule 10	Schedule 20	Schedule 30	Standard Weight	Schedule 40	Schedule 60	Extra Strong	Schedule 80	Schedule 100	Schedule 120	Schedule 140	Schedule 160	Dbl. Ext. Strong
18	18.094	Wall	0.219	0.273	0.383	0.328	0.492	0.656	0.438	0.820	1.012	1.203	1.367	1.558	
		I.D.	17.656	17.548	17.327	17.438	17.110	16.781	17.219	16.454	16.071	15.688	15.360	14.977	
20	20.125	Wall	0.219	0.328	0.438	0.328	0.519	0.711	0.438	0.902	1.121	1.313	1.531	1.722	
		I.D.	19.688	19.469	19.250	19.469	19.087	18.704	19.250	18.321	17.883	17.500	17.063	16.681	
24	24.125	Wall	0.219	0.328	0.492	0.328	0.601	0.847	0.438	1.066	1.340	1.586	1.804	2.050	
		I.D.	23.688	23.469	23.142	23.469	22.923	22.431	23.250	21.994	21.446	20.954	20.517	20.025	
30	30.125	Wall	0.273	0.438	0.547	0.328			0.438						
		I.D.	29.579	29.250	29.031	29.469			29.250						

17.2.10 Dimensions of welded and seamless pipe carbon and alloy steel

Nominal Wall Thickness and Inside Diameters

Nominal Pipe Size	Outside Diameter	Wall Thickness / Inside Diameter	Schedule 5S*	Schedule 10S*	Schedule 40S	Schedule 80S
1/8	0.405	Wall / I.D.	–	0.049 / 0.307	0.068 / 0.269	0.095 / 0.215
1/4	0.540	Wall / I.D.	–	0.065 / 0.410	0.088 / 0.364	0.119 / 0.302
3/8	0.675	Wall / I.D.	–	0.065 / 0.545	0.091 / 0.493	0.126 / 0.423
1/2	0.480	Wall / I.D.	0.065 / 0.710	0.083 / 0.674	0.109 / 0.622	0.147 / 0.546
3/4	1.050	Wall / I.D.	0.065 / 0.920	0.083 / 0.884	0.113 / 0.824	0.154 / 0.742
1	1.315	Wall / I.D.	0.065 / 1.185	0.109 / 1.097	0.133 / 1.049	0.179 / 0.957
1¼	1.660	Wall / I.D.	0.065 / 1.530	0.109 / 1.442	0.140 / 1.380	0.191 / 1.278
1½	1.900	Wall / I.D.	0.065 / 1.770	0.109 / 1.682	0.145 / 1.610	0.200 / 1.500
2	2.375	Wall / I.D.	0.065 / 2.245	0.109 / 2.157	0.154 / 2.067	0.218 / 1.939
2½	2.875	Wall / I.D.	0.083 / 2.709	0.120 / 2.635	0.203 / 2.469	0.276 / 2.323
3	3.500	Wall / I.D.	0.083 / 3.334	0.120 / 3.260	0.216 / 3.068	0.300 / 2.900
3½	4.00	Wall / I.D.	0.083 / 3.834	0.120 / 3.760	0.226 / 3.548	0.318 / 3.364
4	4500	Wall / I.D.	0.083 / 4.334	0.120 / 4.260	0.237 / 4.026	0.337 / 3.826
5	5.563	Wall / I.D.	0.109 / 5.345	0.134 / 5.295	0.258 / 5.047	0.375 / 4.813
6	6.625	Wall / I.D.	0.109 / 6.407	0.134 / 6.357	0.280 / 6.065	0.432 / 5.761

Nominal Wall Thickness and Inside Diameters

Nominal Pipe Size	Outside Diameter	Wall Thickness / Inside Diameter	Schedule 5S*	Schedule 10S*	Schedule 40S	Schedule 80S
8	8.625	Wall / I.D.	0.109 / 8.407	0.148 / 8.329	0.322 / 7.981	0.500 / 7.625
10	10.750	Wall / I.D.	0.134 / 10.482	0.165 / 10.420	0.365 / 10.020	0.500** / 9.750**
12	12.750	Wall / I.D.	0.156 / 12.438	0.180 / 12.390	0.375** / 12.000**	0.500** / 11.750**
14	14.00	Wall / I.D.	0.156 / 13.688	0.188 / 13.624	–	–
16	16.000	Wall / I.D.	0.165 / 15.670	0.188 / 15.624	–	–
18	18.000	Wall / I.D.	0.165 / 17.670	0.188 / 17.624	–	–
20	20.000	Wall / I.D.	0.188 / 19.624	0.218 / 19.564	–	–
24	24.000	Wall / I.D.	0.218 / 23.564	0.250 / 23.500	–	–
30	30.000	Wall / I.D.	0.250 / 29.500	0.312 / 29.376	–	–

All dimensions given for inches. The wall thicknesses shown represent nominal or average wall dimensions which are subject to 12.5% mill tolerance.

Sizes 14" through 30" show dimensions commonly used in the industry.

* Schedule 5S and 10S wall thicknesses do not permit threading in accordance with ASA B2.1.

**Schedule 40S and schedule 80S in these sizes do not agree with schedule 40 and schedule 80 of ASA

B36.10 and that they are identical to standard weight and extra strong respectively of ASA B36.10.

17.3 Saturated steam table

17.3.1 Saturated steam table (Metric units) (page 1 of 2)

Gage Pressure (bar)	Absolute Pressure (bar)	Temperature (°C)	Specific Volume (m3/)	Specific Enthalpy (kj/kg)		
				Sat. Liquid	Evap.	Sat. Vapor
-1,0	0,008	3,8	160	15,8	2493	2509
-1,0	0,02	17,5	67	73,5	2460	2534
-1,0	0,05	32,9	28,2	137,8	2424	2562
-0,9	0,1	45,8	14,7	191,8	2393	2585
-0,8	0,2	60,1	7,65	251,5	2358	2610
-0,7	0,28	67,5	5,58	282,7	2340	2623
-0,7	0,35	72,7	4,53	304,3	2327	2632
-0,6	0,45	78,7	3,58	329,6	2312	2642
-0,5	0,55	83,7	2,96	350,6	2299	2650
-0,4	0,65	88	2,53	368,6	2288	2657
-0,3	0,75	91,8	2,22	384,5	2279	2663
-0,2	0,85	95,2	1,97	398,6	2270	2668
-0,1	0,95	98,2	1,78	411,5	2262	2673
0,0	1	99,6	1,69	417,5	2258	2675
0,0	1,01325	100	1,673	419,11	2257	2676
0,1	1,1	102,32	1,5492	428,9	2251	2679
0,3	1,3	107,13	1,3252	449,2	2238	2687
0,6	1,6	113,32	1,0913	475,4	2221	2696
1,0	2	120,23	0,88554	504,8	2202	2707
1,3	2,3	124,71	0,77694	523,8	2189	2713
1,6	2,6	128,73	0,6927	540,9	2178	2719
2,0	3	133,54	0,60567	561,5	2164	2725
2,5	3,5	138,88	0,5241	584,3	2148	2733
3,0	4	143,63	0,46232	604,7	2134	2739
3,5	4,5	147,92	0,41384	623,2	2121	2744
4,0	5	151,85	0,37478	640,2	2109	2749
5,0	6	158,84	0,31556	670,5	2086	2757
6,0	7	164,96	0,27275	697,1	2066	2764
7,0	8	170,41	0,24032	721,0	2048	2769
8,0	9	175,36	0,21486	742,7	2031	2774
9,0	10	179,88	0,19435	762,6	2015	2778
11,5	12,5	189,81	0,15698	806,7	1979	2786
14,0	15	198,28	0,13171	844,7	1947	2792
16,5	17,5	205,72	0,11342	878,3	v	2796
19,0	20	212,37	0,09958	908,6	1890	2799
21,5	22,5	218,4	0,0887	936,3	1865	2801
24,0	25	223,94	0,07994	962,0	1840	2802
26,5	27,5	229,06	0,07271	985,9	1817	2803
29,0	30	233,84	0,06666	1008,4	1795	2803
34,0	35	242,54	0,05705	1049,8	1753	2803
39,0	40	250,33	0,04977	1087,5	1713	2801
44,0	45	257,41	0,04405	1122,2	1676	2798
49,0	50	263,92	0,03944	1154,5	1640	2794
54,0	55	269,94	0,03564	1185,0	1605	2790
59,0	60	275,56	0,03244	1213,8	1571	2784
64,0	65	280,83	0,02972	1241,1	1538	2779

17.3.1 Saturated steam table (Metric units) (page 2 of 2)

Gage Pressure (bar)	Absolute Pressure (bar)	Temperature (°C)	Specific Volume (m3/)	Specific Enthalpy (kj/kg)		
				Sat. Liquid	Evap.	Sat. Vapor
69,0	70	285,8	0,02737	1267,4	1505	2772
74,0	75	290,51	0,02533	1292,7	1473	2766
79,0	80	294,98	0,02352	1317,1	1441	2758
84,0	85	299,24	0,02191	1340,7	1410	2751
89,0	90	303,31	0,02048	1363,6	1379	2743
94,0	95	307,22	0,01919	1386,0	1348	2734
99,0	100	310,96	0,01802	1407,8	1317	2725
109,0	110	318,04	0,01598	1450,2	1255	2706
119,0	120	324,64	0,01426	1491,3	1194	2685
129,0	130	330,81	0,01278	1531,4	1131	2662
139,0	140	336,63	0,01149	1571,0	1067	2638
149,0	150	342,12	0,01035	1610,3	1001	2611
159,0	160	347,32	0,009319	1649,8	932	2582
169,0	170	352,26	0,00838	1690,0	858	2548

17.3.2 Saturated steam table (English units) (page 1 of 2)

Gage Pressure (Lbs./Sq in)	Absolute Pressure (Lbs./Sq in)	Temperature (°F)	Specific Volume (Cu ft/Lb)	Specific Enthalpy (B.T.U./Lb)		
				Sat. Liquid	Evap.	Sat. Vapor
-14.59	0.11	38	2634.2	6.02	1072.1	1078.1
-14.58	0.12	40	2445.8	8.03	1071.0	1079.0
-14.55	0.15	46	1963.7	14.05	1067.6	1081.6
-14.51	0.19	52	1589.2	20.06	1064.2	1084.2
-14.46	0.24	58	1292.2	26.06	1060.8	1086.9
-14.43	0.27	62	1129.2	30.06	1058.5	1088.6
-14.36	0.34	68	926.5	36.05	1055.2	1091.2
-14.34	0.36	70	868.4	38.05	1054	1092.1
-14.28	0.42	74	764.1	42.05	1051.8	1093.8
-14.23	0.47	78	673.9	46.04	1049.5	1095.6
-14.2	0.5	80	642	47.60	1047.5	1095.1
-13.7	1	101	334	69.69	1035.3	1105.0
-12.7	2	126	174	93.97	1021.6	1115.6
-11.7	3	142	119	109.33	1012.7	1120.0
-9.7	5	162	74.0	130.10	1000.4	1130.6
-7.2	7.5	180	50.3	147.81	989.9	1137.7
-4.7	10	193	38.4	161.13	981.8	1143.0
-0.7	14	209	28.0	177.55	971.8	1149.3
0.0	14 696	212	26.8	180.00	970.2	1150.2
1.3	16	216	24.8	184.35	967.4	1151.8
2.3	17	219	23.4	187.48	965.4	1152.9
3.3	18	222	22.2	190.48	963.5	1154.0
4.3	19	225	21.1	193.34	961.7	1155.0
5.3	20	228	20.1	196.09	959.9	1156.0
7.3	22	233	18.4	201.25	956.6	1157.8
10.3	25	240	16.3	208.33	951.9	1160.2
15.3	30	250	13.7	218.73	945.0	1163.7
20.3	35	259	11.9	227.82	938.9	1166.7
25.3	40	267	10.5	235.93	933.3	1169.2
30.3	45	274	9.40	243.28	928.2	1171.5
35.3	50	281	8.51	249.98	923.5	1173.5
40.3	55	287	7.78	256.19	919.1	1175.3
45.3	60	293	7.17	261.98	915.0	1177.0
50.3	65	298	6.65	267.39	911.1	1178.5
55.3	70	303	6.20	272.49	907.4	1179.9
60.3	75	307	5.81	277.32	903.9	1181.2
65.3	80	312	5.47	281.90	900.5	1182.4
70.3	85	316	5.16	286.90	897.3	1183.6
75.3	90	320	4.89	290.45	894.2	1184.6
80.3	95	324	4.65	294.47	891.2	1185.6

17.3.2 Saturated steam table (English units) (page 2 of 2)

Gage Pressure (Lbs./Sq in)	Absolute Pressure (Lbs./Sq in)	Temperature (°F)	Specific Volume (Cu ft/Lb)	Specific Enthalpy (B.T.U./Lb)		
				Sat. Liquid	Evap.	Sat. Vapor
85.3	100	328	4.42	298.33	888.2	1186.6
90.3	105	331	4.22	302.03	885.4	1187.5
95.3	110	335	4.04	305.61	882.7	1188.3
100.3	115	338	3.88	309.04	880.0	1189.1
105.3	120	341	3.72	312.37	877.4	1189.8
110.3	125	344	3.60	315.60	874.9	1190.5
115.3	130	347	3.45	318.73	872.4	1191.2
120.3	135	350	3.33	321.77	870.0	1191.8
125.3	140	353	3.22	324.74	867.7	1192.4
130.3	145	356	3.20	327.63	865.3	1193.0
135.3	150	358	3.01	330.44	863.1	1193.5
140.3	155	361	2.92	333.18	860.8	1194.0
145.3	160	363	2.83	335.86	858.7	1194.5
150.3	165	366	2.75	338.47	856.5	1195.0
155.3	170	368	2.67	341.03	854.5	1195.4
160.3	175	370	2.60	343.54	852.3	1195.9
165.3	180	373	2.53	345.99	850.3	1196.3
170.3	185	375	2.46	348.42	848.2	1196.7
175.3	190	377	2.40	350.77	846.3	1197.0
180.3	195	380	2.34	353.07	844.3	1197.4
185.3	200	382	2.28	355.33	842.4	1197.8
210.3	225	392	2 039	366.10	833.2	1199.3
235.3	250	401	1 841	376.02	824.5	1200.5
260.3	275	409	1 678	385.24	816.3	1201.6
285.3	300	417	1 541	393.90	808.5	1202.4
335.3	350	432	1 324	409.81	793.7	1203.6
385.3	400	444	1 160	424.2	779.8	1204.1
435.3	450	456	1 030	437.4	766.7	1204.1
485.3	500	467	0.926	449.7	754.0	1203.7
585.3	600	486	0.767	472.3	729.8	1202.1
685.3	700	503	0.653	492.9	706.8	1199.7

Gage Pressure (Lbs./Sq in)	Absolute Pressure (Lbs./Sq in)	Temperature (°F)	Specific Volume (Cu ft/Lb)	Specific Enthalpy (B.T.U./Lb)		
				Sat. Liquid	Evap.	Sat. Vapor
785.3	800	518	0.565	511.8	684.9	1196.7
885.3	900	532	0.496	529.5	663.8	1193.3
985.3	1000	544	0.442	546.0	643.5	1189.6
1235.3	1250	572	0.341	583.6	595.6	1179.2
1485.3	1500	596	0.274	617.5	550.2	1167.6
1985.3	2000	635	0.187	679.0	460.0	1139.0
2485.3	2500	668	0.130	742.8	352.8	1095.6
2985.3	3000	695	0.084	823.1	202.5	1025.6
3211.3	3226	706	0.0522	925.0	0	925.0

17.4 Non-Contacting Radar Transmitter Beam Angle Considerations
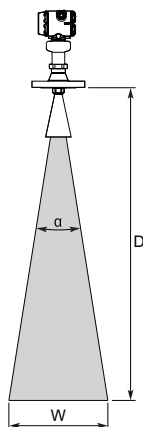
Figure 17.4.1: Beam width for the Rosemount 5408

	Beam width (W)		
Distance (D) – ft (m)	Process seal or ATAP lens antenna	Lens antenna (1-and ½-in)	Lens antenna (¾-in)
16 (5)	2.2 (0.7)	2.5 (0.8)	3.4 (1.1)
33 (10)	4.6 (1.4)	5.2 (1.6)	6.9 (2.1)
49 (15)	6.9 (2.1)	7.7 (2.4)	10.3 (3.2)
66 (20)	9.2 (2.8)	10.4 (3.2)	13.9 (4.3)
82 (25m)	11.5 (3.5)	12.9 (3.9)	17.2 (5.3)
98 (30m)	13.7 (4.2)	15.4 (4.7)	20.6 (6.3)

Table 17.4.4: Beam width for the Rosemount 3408

	Beam width (W)				
Distance (D) – ft (m)	1½-in cone	2-in Cone or process seal	3-in Cone or process seal	4-in Cone or process seal	Parabolic
16 (5)	6.2 (1.9)	5.2 (1.6)	4.0 (1.2)	2.9 (0.9)	1.3 (0.4)
33 (10)	12.8 (3.9)	10.4 (3.2)	8.1 (2.5)	5.7 (1.8)	2.6 (0.8)
49 (15)	19.0 (5.8)	15.6 (4.8)	12.1 (3.7)	8.6 (2.6)	3.9 (1.2)
66 (20)	25.6 (7.8)	20.8 (6.3)	16.1 (4.9)	11.5 (3.5)	5.2 (1.6)
82 (25)	31.8 (9.7)	26.0 (7.9)	20.1 (6.1)	14.3 (4.4)	6.4 (2.0)
98 (30)	38.4 (11.7)	31.2 (9.5)	24.2 (7.4)	17.2 (5.3)	7.7 (2.4)
131 (40)	51.2 (15.6)	41.6 (12.7)	32.2 (9.8)	23.0 (7.0)	10.3 (3.1)
197 (60)	N/A	N/A	N/A	34.5 (10.5)	15.4 (4.7)
262 (80)	N/A	N/A	N/A	45.9 (14.0)	20.7 (6.3)
328 (100)	N/A	N/A	N/A	57.4 (17.5)	25.9 (7.9)
492 (150)	N/A	N/A	N/A	86.0 (26.2)	38.7 (11.8)

Table 17.4.2: Beam width for the Rosemount 5408

Antenna size	Beam angle (α)
1½-in (DN 40) cone	22°
2-in (DN50) cone/process seal	18°
3-in (DN80) cone/process seal	14°
4-in (DN100) cone/process seal	10°
8-in (DN200) parabolic	4.5°

Table 17.4.3: Beam width angle for the Rosemount 5408 for different antenna types

Antenna size	Beam angle (α)
Process seal antenna	8°
Lens antenna (¾-in thread)	12°
Lens antenna (1- and 1½-in threads)	9°
ATAP lens antenna	8°

Table 17.4.5: Beam width angle for the Rosemount 3408 for different antenna types

	Beam width (W)	
Distance (D) – ft (m)	ATAP lens antenna	Lens antenna
6.6 (2)	0.9 (0.3)	1.2 (0.4)
13.1 (4)	1.8 (0.6)	2.3 (0.7)
19.7 (6)	2.8 (0.8)	3.4 (1.0)
26.2 (8)	3.7 (1.1)	4.6 (1.4)
32.8 (10)	4.6 (1.4)	5.7 (1.7)

Table 17.4.6: Beam width and angle for Rosemount 1408

Distance (D)	Beam width (W)
	Lens antenna
6.6 ft. (2 m)	0.9 ft. (0.3 m)
13.1 ft. (4 m)	1.8 ft. (0.6 m)
19.7 ft. (6 m)	2.8 ft. (0.8 m)
26.2 ft. (8 m)	3.7 ft. (1.1 m)
32.8 ft. (10 m)	4.6 ft. (1.4 m)
49.2 ft. (15 m)	6.9 ft. (2.1 m)

Table 17.4.7: Beam width and angle for Rosemount 1208

17.5 Glossary

A

Active leg

A regulator and a nitrogen blanket used to prevent vapor condensation in the vapor space. A top transmitter is required because the regulator is not a perfect controller.

Address (HART®)

Units using HART protocol may be multi-dropped to communicate digitally with a control system. The HART address range is 0 to 15.

Address (MODBUS®)

Units using MODBUS to communicate with host system may have addresses ranging from 1 to 247.

Antenna

The transmitting and receiving part of a radar level gauge that directs the radar signal toward the material being measured. Different types of antennas are available to fit different applications. Examples are: cone, parabolic and still-pipe antennas

API

The abbreviation for American Petroleum Institute. API is a trade association representing American Oil and Gas industry. API has led the development of petroleum and petrochemical equipment and operating standards for more than 75 years. For Level measurement the Manual of Petroleum Measurement Standard is applicable. www.api. org

ASU

The abbreviation for Average Sensing Unit—an accessory to a custody transfer level measurement system. The ASU receives multiple temperature sensor input readings, averages the appropriate temperature readings (from submerged sensors), and sends the average temperature input to the level device.

Attenuation

The reduction in the level of a quantity, such as the intensity of a wave, over an interval of a variable, such as the distance from a source.

Average area

The average area of a tank is used for calculating density and is expressed as volume per level (example: bbls/ft, liters/meter, gallons/ft, etc.)

B

Balanced remote seal system

A situation where the remote seal system (diaphragm seal, capillary and fill fluid) is the same on both the high and the low pressure side of a transmitter.

Baumé

An indication of specific gravity in degrees. Baumé is calibrated in accordance with, or according to, either of two arbitrary hydrometer scales for liquids lighter than water, or for liquids heavier than water.

Blanking distance

See dead zone

Brix

The determination of sugar concentration by density measurement.

Build-up

The coating of process material, from liquids or solids, on the sensor. The build-up may be wet, dry, conductive or non-conductive.

C

Capacitance

An electrical term referring to the property of an electric nonconductor that permits the storage of energy as result of electric displacement when opposite surfaces of the nonconductor are maintained at a difference of potential. The unit of capacitance is the Farad.

Capacitance probe

An electrically isolated rod inserted into a vessel to measure level or interface level. It consists of a probe and transmitter pre-calibrated by the manufacturer. As the level or interface changes, a corresponding change in capacitance changes between the rod and the vessel, or between the rod and the ground. Measured capacitance is proportional to liquid level

The information needed for proper calibration includes: the dielectric constant of the product, the angle of probe insertion, the length of inactive section, and the length of the probe.

Capacitance transmitter

A device consisting of a set electronics for the capacitance probe that outputs a calibrated signal proportional to level or interface level.

Capacitive span

The amount of capacitance increase sensed by a capacitance probe, with a specific probe and a specific level change.

CDS

The abbreviation for Configuration Data Sheet. A detailed survey form that identifies all the data needed to fully configure a device.

Closed tank

A tank that is not open to atmospheric pressure. It may be either pressurized or evacuated of pressure.

Concentric shield

A circular plate surrounding a probe. It is a sometimes used with capacitance probes to provide a second capacitance plate. This is done when: the measurement is made in nonmetallic tanks, in metal tanks without straight walls, or when the distance between the capacitance plates needs to be minimized.

Condensate pot

In DP applications, the condensate pot is located at the bottom of a dry leg. It is used for collecting any moisture that may appear in the dry leg due to variances of temperature in the dry leg. Typically, a drain valve or spout is located on the condensate pot to remove any accumulated moisture from the dry leg.

Conversely, in wet leg applications, the condensate pot is located at the top of wet leg where it is used to hold a constant fluid height. This is especially useful in steam applications where the system sees large pressure variations that could cause the wet leg to lose fluid.

Conductive

The ability of a material to transmit the flow of electricity. Usually measured in micromhos. It is the reciprocal of resistance.

Configuration

The process of downloading information into a device that determines how it operates. Configuration includes a completed customer configuration data sheet (CDS) and the CDS data that has been downloaded into the device.

Continuous level

An on-line measurement of a material throughout its entire span. The level of the process material is indicated at any point.

Critical zone

The distance above the pins, in a floating roof tank, within which the mass of the roof is only partially supported by the product (i.e., once the level is equal to the pin height plus the critical zone the roof becomes free floating and is totally supported by the product). This zone is usually marked on the strapping table for the tank.

Custody Transfer

Custody transfer in the oil and gas industry refers to the transactions of raw and refined petroleum between tanks and tankers; tankers and ships and other transactions. During custody transfer, accuracy is of great importance to both the company delivering the material and the recipient. This type of transfer must meet requirements set by industry bodies such as API or ISO and metrology standards such as OIML, PTB, GOST among others.

D

Dead zone

A zone where measurements are not performed.

Density

An expression of mass per volume that is usually expressed in grams per cubic centimeter or pounds per cubic foot. Density varies with temperature. Fluid densities are stated for a specific reference temperature. The density of water is 1 gram per cubic centimeter at 4° C.

Density (measured)

The density measured at the product temperature

Density (standard)

The density of a product at a reference temperature. The density measured is corrected back to a reference temperature, typically 60° F (15° C) per API standard.

Density correction

A method for correcting density to standard or reference conditions. API 2540 is the standard for petroleum products. If the product is non-petroleum, a polynomial is derived from a product density versus a temperature table of approximately 20 points.

Dielectric

A nonconductor of direct electric current; an insulator.

Dielectric constant

The ratio of the conductivity of a material to that of a vacuum. It is a unitless value representing a material's influence on an electric field. A lower value indicates higher electrical insulation properties. In radar level applications, a material with a higher dielectric constant is more reflective of a radar signal.

Dielectric material

The insulating material between the plates of a capacitor.

Differential pressure

The pressure applied to both the low and high side of the transmitter. Used in pressurized applications where the head pressure is applied to both the high and low sides of the transmitter so as to cancel each other out.

Displacer

A level measurement technology using a precisely sized float that when immersed in a fluid will be buoyed up by a force equal to the weight of the fluid displaced. A change can be detected by this proportional change in apparent weight.

Dry leg

The use of tubing (possibly heat traced and insulated to keep the product in a vapor state) running from the vapor space to the low pressure side of the installed pressure transmitter(s). The transmitter(s) are used in the differential pressure mode. This method allows the transmitters to be calibrated with a lower pressure span. No top transmitter is needed, although one could be used to monitor the vapor pressure.

Dynamic Vapor Compensation

A continuous correction for the change in vapor dielectric properties where an on-line vapor dielectric measurement is accomplished through the use of a reflector at a known distance.

E

Electromagnetic spectrum

The classification of electromagnetic waves by frequency and wave length.

Electromagnetic wave

An electromagnetic wave in which both the electric and the magnetic fields vary periodically usually at the same frequency.

Electronic remote sensors

A method where two independent pressure sensors are used to measure level or differential pressure.

Elevation

A term used to indicate that the lower calibrated value of the span of the pressure transmitter is not based at zero differential pressure, but below zero. Thus, zero is elevated. For example, a span of -10 to +50 in H_2O is elevated.

F

Farad

The basic metric unit of electrical capacitance measurement.

Float gauge

The traditional technique for measuring level. A buoyant float resting on a liquid surface is mechanically connected to a gauge head by a perforated tape. A spring motor in the gauge head keeps the tape taut. The tape perforations are counted and related to a liquid level.

Floating roof

A roof on an upright cylinder tank that rests on the product stored inside the tank. The roof height follows any changes in product level. This prevents the product inside the tank from easily evaporating. The floating roof has legs (or pins) that prevent the floating roof from resting on the floor of the tank when the tank is empty.

Flow rate

The flow rate is positive when pumping into the tank and negative when pumping out. The flow rate is calculated as: (volume of tank 1 – volume of tank 2) / the calculation period. Flow rate can also be calculated using level or mass.

Flow rate calculation period

The time between flow rate calculation updates.

FMCW

The abbreviation for Frequency Modulated Continuous Wave. In radar level terminology, it refers to a continuous radio sine wave that is generated with a changing (modulated) frequency providing a highly accurate and stable level measurement.

Formula based

A calculation based on the dimensions of the tank to determine the volume of a tank at a certain level.

Foundation Fieldbus

An all-digital, serial, two-way communications system that serves as the base-level network in a plant or factory automation environment. It is an open architecture, developed and administered by the Fieldbus Foundation.

It's targeted for applications using basic and advanced regulatory control, and for much of the discrete control associated with those functions.

Frequency

The number of vibrations or cycles per unit of time, measured in Hertz, or cycles per second.

Full trim

In a pressure transmitter, the sensor trim function in which two accurate, end-point pressures are applied, and all output is linearized between them.

G

Gamma

The high energy electromagnetic waves similar to x-rays. The most common type of radiation used in nuclear level devices.

Gauge board

Traditional technique for measuring tank level. A buoyant float resting on a liquid surface is mechanically connected to an indicator mounted on the side of the tank.

Gauge well

See stilling well.

Generator

The unit within a radar gauge that produces an electromagnetic wave by using an oscillator.

Guide poll

See stilling well.

Guided wave radar (GWR)

A method using a low frequency microwave pulse where the signal travels from the transmitter along the length of the probe. When the signal reaches a media with a different dielectric constant, the signal will be reflected back to the transmitter. The distance to the surface is subtracted from the gauge height to determine level. GWR may also be used to measure interface level if the first fluid has a low dielectric and the second fluid has a higher dielectric. In this case, a portion of signal is reflected back from the low dielectric fluid and the rest of the signal travels to the second media.

H

HART®

An acronym for Highway Addressable Remote Transducer. A communications standard that provides simultaneous analog and digital signal transmission between control rooms and field devices. HART superimposes digital communications on a 4-20 mA line. The analog signal is locked at 4 mA when in multi-drop mode.

Head effect

In a remote seal system of a differential pressure transmitter, the head effect is a change in pressure exerted by the fill fluid column due to a change in a fluid's density. This happens when the ambient temperature of the capillary changes.

Head pressure

The pressure in a tank due to the weight of the product liquid in the tank. It does not include the vapor pressure in a pressurized tank.

Heat trace

A method used to keep the tank and transmitter flanges at a constant temperature. Mainly used with viscous products or products that may condense or solidify at cooler temperatures.

Hertz

A unit of frequency used to measure electromagnetic waves in cycles per second.

Homogeneous

The consistent distribution of the characteristics of a material throughout its entire quantity.

Hot tap

A method for installing a flange connection on a tank without taking the tank out of service.

Hydrostatic

The measurement of the pressure or force/area exerted by a column of liquid.

I

Inactive shield

See concentric shield.

Interface

The point at which two fluids meet. Although it can also refer to the interface of a liquid and a vapor, it normally refers to the interface of two immiscible (non-mixable) liquids.

Inventory level

The term associated with the accurate level measurements needed for inventory management and/or custody transfer applications. Usually, the accuracy of these measurements needs to better than ±1/8 in or ±3 mm. See also process level.

K

K constants

Correction coefficient used for calculating product expansion due to changes in temperature.

L

Level

The height of a column of liquid or solid material.

Level switch

A level switch is used to indicate when the level has reached a predefined point. A level switch may be used to protect the tank from overfilling. It is typically located near the top of a tank so that when the product submerges its contacts, the level switch will activate a controller to shut off the flow of product into the tank. A level switch may also be used for low level indication or for pump protection.

Lower range value (LRV)

The range value corresponding to the analog output value 4 mA.

M

Mark-space

A communications method used by traditional tank measurement devices. The baud rate is approximately 200 bits per second. The maximum wiring distance is 10,000 ft. (3,048 meters).

Mass

The weight of a material.

Mass (effective)

Mass calculated with buoyancy effects.

Mass (true)

Mass calculated without buoyancy effects.

Micro impulse radar

See Guided wave radar

Microwave

A comparatively short electromagnetic wave, between 1 mm and 1 meter in length. Microwaves are used by radar devices to detect the surface of a material.

MODBUS®

A communications protocol developed by Gould- Modicon to distribute digital communications between a host system and a field device.

Multidrop

A communications method where several transmitters are connected to a single communications transmission line. With the HART smart protocol, up to 15 transmitters can be connected on a single twisted pair of wires. Each transmitter is identified by a unique address (1-15).

Multi-spot temperature sensor

A sensor that measures temperature with several spot temperature sensors placed at different heights in one probe to provide a product temperature profile and an average temperature.

N

Near zone

Referred to as the region directly below the upper reference point of a guided wave radar transmitter and includes a distance up to 3.3 ft (1 m).

Non-conductive

The ability of a material to resist the flow of electrons. See conductive.

Non-contact

An instrument that does not touch the process, but may require an opening in the tank wall to function. Ultrasonic and radar are non-contact devices.

Non-intrusive

An instrument or sensor that may require an opening in the tank wall and may come in contact with the process, but does not disrupt the flow or movement of the process. Pressure transmitters are examples of non-intrusive devices because they do not protrude into the process. Non contacting radar is non-intrusive.

Non-invasive

An instrument or sensor that does not have any contact with the product, nor does it require an opening in the tank wall. Nuclear is a noninvasive device. Radar can be used non-invasively on plastic or fiberglass tanks.

Nuclear

A method of measuring level or density with the use of radioactive source emitting (or nucleonic) gamma rays. Low level gamma energy is beamed through the walls of a tank. The process level blocks the energy transmission and a detector measures the energy received on the opposite side of the tank. The amount of energy received is proportional to the level.

O

Open tank

A tank that is not pressurized. Atmospheric pressure is seen by the product surface.

OIML

The International Organization of Legal Metrology is an intergovernmental treaty organization consisting of 57 member countries and several observing members.

OIML develops global procedures and guidelines concerning the manufacture and use of measuring instruments for legal metrology applications. www.oiml.org

P

Pin height

The height at which the floating roof is totally supported by the pins, rather than the product.

Picofarad

One-trillionth farad (10-12 farad). Common unit used in calculation and discussion of capacitance values occurring in level applications.

Point indication

Yes/No indication of attained level.

Point level

The term associated with detection of the presence or absence of material at a specific level height.

Pressure transmitter

A device commonly used for measuring level in process applications. It uses the principle that the measured hydrostatic pressure is equal to the height of the fluid multiplied by its specific gravity.

Probe end projection (PEP)

A method of inferring level with guided wave radar where the end of the probe is used in combination with the media's dielectric constant to calculate the location of the surface. It is used in low dielectric media where the end of the probe is detectable below the surface and the actual surface is too weak to reflect the signal reliably.

Process level

The term associated with continuous level measurements in the process industries. Generally, the accuracy requirements of this measurement are not as stringent as with inventory level. See also inventory level

Product temperature

The temperature of the material being measured. It may be a manually entered constant if no temperature sensor is installed on the tank. If a sensor is used, it is automatically used for compensation purposes. Temperature compensation is needed for standard volume and density calculations. It is also needed for compensation of signal travel time for ultrasonic transmitters when the vapor space temperature is different from ambient conditions.

PROFIBUS (Process Field Bus)

A standard for field bus communication in automation technology.

PROFIBUS DP (Decentralized Peripherals)

Is used to operate sensors and actuators via a centralized controller in production (factory) automation applications. The many standard diagnostic options, in particular, are focused on here.

PROFIBUS PA (Process Automation)

Is used to monitor measuring equipment via a process control system in process automation applications. This variant is designed for use in explosion/hazardous areas.

Propagation

To cause to spread out and affect a greater number or greater area.

Pulse radar

A method of using radar to measure level. The radio signal is generated in pulses and the time-of- flight for the return signal is measured to determine material level.

R

Radar

An acronym for radio detecting and ranging. A device or system for locating an object by means of super high frequency radio waves. Radio waves are reflected from an object or surface and received, observed and analyzed by the receiving part of the device, in such a way that characteristics (such as distance and direction) of the object may be determined.

Radio frequency (RF)

A band or range of high frequency microwaves.

Rag layer

A layer that sometimes forms in-between two fluids. Since it is a combination of the two fluids and possibly some vapors, it can create some error in the measurement of the exact location of the interface.

Rathole

A hole formed in the center of a bin of dry solid material. Often occurs with fine powders where air becomes entrapped and the wall friction causes the material to be trapped as dead space. Ratholing can cause periods of no flow conditions or controlled flooding.

Receiver

The part of a radar transmitter that receives return signals reflected from the surface of a material or obstructions within a tank.

Reference

Usually the point on a tank where the level is equal to zero. All sensor mounting heights are measured from the reference point.

Reference temperature

The temperature at which actual density and actual volume are referenced to calculate standard density and standard volume. This reference temperature is required for all applications where standard density and volume calculations are required.

Reflectivity

The degree to which an object can reflect light, images, sound waves, or microwaves back to an instrument.

Remote seal

Remote seal systems act as a pressure transport medium between the process and the sensor of the pressure transmitter. Remote seals are used: when it is necessary to isolate the transmitter from the process due to high process temperature, for corrosive or viscous products, for applications that require the use of sanitary connections, to avoid contamination between batches, or when there is a need to make density or interface measurements.

Remote seal system

A combination of the remote diaphragm seal, capillary, and fill fluid attached to a transmitter. A seal system may be one high pressure, low pressure, or both sides of a pressure transmitter.

RTD

The abbreviation for Resistance Temperature Detector. A device that predictably changes its resistance when a change in temperature is detected.

S

Sensor trim

The digital trim function that allows adjustment of the digital process variable reading to a precise pressure input. Zero trim and full trim are the two sensor trim functions.

Servo gauge

A traditional technique for measuring level. A displacer rests on a liquid surface and is connected via a wire to a detector plate. The detector plate drives a servo motor to raise or lower the displacer to keep a constant tension on the wire. The servo motor is attached to a drum that stores any excess measuring wire. Each revolution of the drum is associated with the level of the product.

SIL

Safety Integrated Level.

SIS

Safety Instrumented System.

Specific gravity

The ratio of the density of a compound to the density of water. It is a dimensionless number. If a compound has a density of 13.6 g/cc and water has a density of 1g/cc, the compound's specific gravity is 13.6. If a compound has a density of 75 pounds per cubic foot and water has a density of 62.4 pounds per cubic foot, the specific gravity of the compound is 1.2.

Still pipe

See stilling well.

Stilling well

A large diameter pipe, mounted vertically inside the tank, travelling the entire height of the tank to function as a baffle. It is also known as a gauge well, still pipe, or guide pole. It is used with level gauges that float on the product surface and some top down non- contact level measurement technologies. The stilling well minimizes the effect of any tank turbulence on the product surface. In tank gauging the stilling well is also used for sampling and hand-gauge measurements.

Strapping method

Identifies the tank strapping method used for the tank. It uses two methods: strapping table (actual) or formula based (calculated).

Strapping table

A table (usually created by the manufacturer of the tank) that shows a volume versus level relationship.

Stratification (density)

The division or settlement of some products into layers, based on their density. The density at the top of the tank can be different from the density at the bottom of the tank. Density stratification can affect the level and volume calculations but has virtually no effect on mass.

Stratification (temperature)

The difference in the temperature of products inside the tank that have a higher temperature near the tank shell (due to the sun), than in the middle of the tank. This temperature difference causes the product to expand differently throughout the tank, affecting gross volume and level.

Strike plate

A plate mounted horizontally on the inside wall near the bottom of the tank. The strike plate is used as a reference point when measuring level by hand dipping. The floor of a tank is not always used as a reference point when hand dipping due to the possible deformation of the tank floor when the product is in the tank.

Supernatant

The clear fluid above a sediment or precipitate.

Suppression

A term used to indicate that the lower calibrated value of the span of the pressure transmitter is not based at zero differential pressure but above zero. Thus, zero is suppressed. Example: A span of +20 to +100 in H_2O is suppressed.

T

Tank diameter

The inner diameter of the tank. This dimension is always measured horizontally, despite the tank shape. It is the length dimension of a horizontal bullet type tank.

Tank elevation

The elevation of the site where the tank is located.

Tank height

The total inside height of the tank. Height is always measured vertically, despite the tank shape. It is the diameter of a horizontal bullet type tank.

Tank I.D.

The name of the tank in text or numerals.

Tank tag

The instrument number.

Tank type

The tank shape that best describes the tank. This is needed for correctly calculating a formula based strapping table. Some examples of different tank types are: upright cylinder, horizontal cylinder, sphere, upright bullet and horizontal bullet.

Tapering

The decrease in the strength of a signal between two points or between two frequencies.

Temperature range

The minimum and maximum range of temperatures encountered by the product during operation.

Temperature sensor

A device that measures the temperature of the product inside the tank. Typically this is an RTD, although the bottom pressure transmitter with local temperature sensor could also be used. See also multi-spot temperature sensor.

Thermal expansion

The amount of expansion of material due to changes in temperature. Usually measured in mm/m/° C.

Thermo well

The housing for a temperature sensing device protruding into a tank. It allows an RTD to be replaced even when the tank is in use (full).

Threshold

Used with top-down technologies as a filtering method. Different amplitude thresholds are used in order to filter out unwanted signals in order to pick up the correct pulses.

Time domain reflectometry (TDR)

See Guided Wave Radar.

Time-of-flight

The elapsed time from the instant a particle leaves a source to the instant it reaches a detector.

Traditional volume

The volume calculated from a strapping table and level measurement.

Transducer

A device that receives information in the form of one quantity and converts it to information in the form of the same or another quantity.

Transfer type

The method by which the product will be transferred to and from the tank—either gross volume, standard volume, level, or mass.

Transition zone

A short distance from either the reference peak or the end of the probe where the signal peak and reference or end of probe peak may be merged. Measurements in this area may not meet accuracy or linearity specifications. The length of the transition zones is dependent on probe type and dielectric constant of the measured media.

Transmitter

A transducer that responds to a measured variable by means of a sensing element and converts it to a standardized transmission signal.

Trim near zone

Software functionality that minimizes the Upper Transition Zone and ensures that measurement performance in the near zone is maintained.

U

Ullage

The amount that a container (as a tank) lacks of being full. Also could be thought of as the vapor space above the product in the vessel. Sometimes referred to as "outage."

Ullage pressure

See vapor pressure.

Ultrasonic

A method of measuring level where a sound pulse is transmitted from the instrument to the surface of the material. The sound pulse is reflected off the surface and the echo is detected by the instrument. The amount of time to return to the instrument is inversely proportional to the level.

Upper null zone

The distance designated from the upper reference point where no measurements will be recognized by the device. Used with top down level devices to ignore undesired peaks close to the device.

Unbalanced remote seal

A situation where the remote seal system (diaphragm seal, capillary, and fill fluid) is different on the high and low sides of a pressure transmitter.

Upper range value (URV)

The range value corresponding to the analog output value, 20 mA.

V

Vapor compensation

A calculation used to correct for properties of the vapor.

Vapor pressure

Pressure of the vapor in the vapor space of a pressurized tank.

Vent hole

The hole near the top of the stilling well that allows air release as fluid rises in the tube. Ensures that the level within the tube is equal to the vessel level at all times.

Vented tank

A tank that is covered but not pressurized. A vent located on top of the tank releases any pressure buildup.

Viscosity

The resistance that a gaseous or liquid system offers to flow when it is subjected to a shear stress. Also known as flow resistance.

Volume

The amount of space occupied as measured in cubic units (as in, ft., and meters).

Volume (measured)

The volume measured at product temperature.

Volume (roof)

The volume of product displaced by the weight of the floating roof.

Volume (standard)

The volume of a product at a reference temperature. The volume measured is corrected back to a reference temperature, typically 60° F (15° C) per API standard.

W

Water bottom level

The level of water at the bottom of a tank.

Water bottom volume

The volume of water at the bottom of a tank.

Wave guide

The entire path, in a radar gauge, through which the radar signal travels. It includes the coaxial-to-wave guide adapter, the housing- to-flange adapter, and the mounting flange.

Wave length

A measure, expressed in meters, of the length of each complete electromagnetic wave.

Wet leg

A filled reference connection between the vapor space area of a tank and the low pressure side of the transmitter. Wet legs are used when condensation is common and dry legs are impractical. The pressure exerted by the weight of the fluid in the wet leg must be compensated for in the calibration of the pressure transmitter.

Wetted parts

The portion of an instrument exposed to a process.

Z

Zero level

Physical material level at which a level instrument is calibrated to indicate either "0%" or "low level."

Zero trim

A zero-based, one-point adjustment used in differential pressure applications to compensate for mounting position effects or zero shifts caused by static pressure.

17.6 Frequently Asked Questions

17.6.1: General questions

Can I datalog with a Rosemount 3490?

The Rosemount 3490 Controller has data logging capabilities, allowing storage of up to 200,000 data points. These logs can be easily accessed and downloaded through an integrated web server, conveniently available via the Ethernet port.

17.6.2 General radar

Can I use solar or battery power?

Rosemount 3308 is the only radar that operates solely on a battery, which makes it suitable for installations where there is no infrastucture. Most devices will run on 12–24V dc (direct current), although there are some devices that run on 110 or 220V. A few devices may operate on low power or wireless with battery power. Level instruments can be powered using a combination of solar panels and batteries as long as this equipment is sized appropriately. Sizing the batteries is based on the total number of components to be powered, their required voltage and their current consumption.

When using wireless THUMs on radar how much power do I need?

When wiring Rosemount radars with an Emerson Wireless THUM™ Adapter, add 2.5V dc to the power requirements. THUM adapters must be mounted in IS installations but can be remotely mounted if combined with non-IS transmitters.

Rosemount Radar					
		5408	5300	3300	3408*
Power requirement: HART	Explosion/Flameproof	12 - 42.4V dc	20 - 42.4V dc	16 - 42V dc	12 - 35V dc
	With remote mounted THUM	14.5 - 42.4V dc	22.5 - 42.5V dc	17.5 - 42V dc	14.5 - 35V dc
	I.S/ Standard	12 - 30V dc	16 - 30V dc	11- 30V dc	12 - 30V dc
	With THUM	14.5 - 30V dc	18.5 - 30V dc	13.5 - 30V dc	14.5 - 30 Vdc
Power requirement: Foundation Fieldbus	Explosion/Flameproof	N/A	16 - 32V dc	N/A	
	IS/ Standard		9 - 30V dc	N/A	
	FISCO		9 - 17.5V dc	N/A	
Power requirement: Modbus	Standard	N/A	8 - 30V dc	8.30V dc	

NOTE: The minimum voltage requirement for 3408 depends on outputted current. Please refer to the Product Data Sheet(a link to 3408 PDS can be added) for more info.

Table 17.6.1: Power supply requirements for Rosemount radars

Why should I use radar techology?

The radar signal is virtually unaffected by the tank content and tank atmosphere, temperature or pressure. The measurement is not influenced by changing material characteristics such as density, dielectric properties and viscosity. Since there are no moving parts, the transmitters are virtually maintenance free.

What is the principle of operation?

Radar level measurement technology can be broken down into two different categories; pulsed and Frequency Modulated Continuous Wave (FMCW). Before the release of the new generation of FMCW radars, an advantage with pulsed technology was that it required less processing power. Therefore most two-wire gauges are based on pulsed technology.

With FMCW, higher accuracy can be achieved but more processing power is required and therefore FMCW-radars are typically four-wire. However, recent advances have resulted in some 2-wire FMCW devices. With pulsed transmitters the level measurement is a function of the time taken from the radar signal to travel to the surface and back. With FMCW gauges the transmitter constantly emits a swept frequency and the distance is calculated by the difference in frequency of emitted and received signals.

Are radar gauges safe?

Yes. The emitted signal is less than three percent of maximum leakage allowed from a microwave oven. Radar waves are of no greater intensity than the constant radio, cellular and other communication waves that surround us every day. Furthermore the transmitter is normally placed in a metallic tank that acts as a Faraday's cage and therefore the radar waves are isolated within the tank.

What is the difference in frequency between pulsed technology guided wave radar and non-contacting radar?

With guided wave radar the pulsed microwave is guided down the tank by the probe, making it less sensitive to disturbances than free propagating microwaves. Non-contacting radar uses a carrier frequency, typically 6 Hz or 26 Hz, to carry the microwaves, which are radiated into the tank with an antenna.

What generates and transmits the microwave pulse in non-contacting and guided wave radars?

The microwave pulse is generated in the microwave module. A crystal clock with a pulse repetition frequency (PRF) of 1.8 MHz triggers a pulse generator. A short pulse (1 ns), is then generated by fast transistors on the pulse generator circuit. The generated pulses are then transferred via the coupling net and out/in to the probe/antenna and into the tank. The reflected microwave is transferred back to the transmitter via the coupling net into the receiver, and then processed by the transmitter logic.

The Rosemount Non-Contacting Radars use a microwave module especially designed for optimal performance in demanding applications. The measurement principle is fast-sweep Frequency Modulated Continuous Wave (FMCW). Radar signals are continuously transmitted towards the product surface with a microwave frequency modulated over a span. The level is proportional to the frequency difference between currently received and transmitted signals. FMCW technology maximizes radar signal strength and produces a robust and reliable measurement (with 30 times more power on the surface than traditional two-wire non-contacting radars). The unique design also allows the transmitters to operate with only 12 V dc lift-off voltage and they are also self-powered for up to 2 seconds to maintain operation despite cable glitches or lightning.

How does the frequency of the radar affect the measurement?

A higher frequency provides a more concentrated narrow beam which can be useful in applications where there are obstacles present in the tank such as man-ways, agitators or heating coils. The downside of high frequency is that the measurement is more affected by vapors, dust and product build up on the antenna, low frequency radar which has a longer wavelength and wider beam angle, tends to cope better with steam, dust, condensation, contamination and turbulent surfaces.

In what way does the dielectric constant (DC) of the media affect the measurement?

Electromagnetic energy is emitted from all radar devices. When the emitted signal reaches a point where there is a change in DC, usually the media surface, some of the signal is reflected back to the transmitter. The amount of energy that is reflected back to the transmitter is proportional to the DC of the media. A rule-of-thumb is that the value of the dielectric constant represents the percentage of energy that is reflected. Thus a DC of eight means that eight percent of the emitted energy is reflected back to the transmitter. Fundamentally, media with a higher DC provide stronger return signals and are therefore easier to measure.

Does radar work on foam?

The effects of foam on a radar measurement can be difficult to predict. In some applications the foam may dampen out the signal completely while other types of foam may

be transparent to the transmitter. The thickness, density and the dielectric constant are factors that need to be considered when evaluating an application with foam.

On dry foam the microwave typically passes through and detects the liquid surface below. On medium foam the signal can be absorbed or scattered and the results are therefore hard to predict. If the foam is wet the microwaves are often reflected from the foam surface and thereby the foam surface level is measured.

The frequency at which the radar operates also affects how foam is measured. Lower frequency radars (6 to 26 GHz) in general penetrate foam to a larger extent than higher frequency radars.

Will two or more radar units in one vessel conflict with each other?

You can use more than one non-contacting radar unit in one tank since the signatures from the transmitters are unique, so they will not interfere with each other.

Guided wave radars may however interfere with each others if the probes are installed too close to each other. For that reason the probes need to be installed a certain distance away from each other, unless coaxial probes are used.

Will radio noise or other interference cause problems?

The transmitters use a specific narrow frequency and are therefore not prone to disturbances from other sources. It is very uncommon with disturbances and it is rare that the disturbance source operates at precisely the same frequency as the transmitter. Furthermore, the transmitters are often installed in metallic tanks that provide a Faraday's cage which prevents electromagnetic disturbances from the outside to enter the tank.

With guided wave radar, if disturbances are present in the tank and a Rosemount 3300 is used, the coaxial probe is recommended, since the radar signal travels inside of the pipe, undisturbed by the interference sources on the outside. When using a Rosemount 5300, a coaxial probe is only required if the disturbances are very close. Otherwise because of the advanced signal processing capabilities, minor disturbances can be ignored with threshold settings.

Are there any restrictions on the nozzle height?

Since the nozzle, and especially the lower end of the nozzle, can create interfering echoes, it is recommended that the height of the nozzle is kept within certain values depending on the type of probe / antenna and type of transmitter used. For more information regarding these

values please refer to Section 6.7 Process Connection - Guided Wave Radar Installation Guidelines or Section 7.4 Nozzle Considerations - Non-Contacting Radar Installation Guidelines.

Are there any restrictions on the nozzle diameter?

In conjunction with the above statement, the nozzle diameter also affects the measurement, since a diameter nozzle that is too small will create disturbance echoes. For more information regarding these values please refer to Section 6.7 Process connection - Guided Wave Radar Installation Guidelines or Section 7.4 Nozzle Considerations - Non-Contacting Radar Installation Guidelines.

Are there any restrictions when measuring in stilling wells?

Stilling wells should be an all-metal material. Non-metallic stilling wells or sections are not recommended for non-contacting radar. Plastic, plexiglas, or other non-metal materials do not shield the radar from outside disturbances and offer minimal, if any, application benefit. See Section 6.13 Mounting in Chamber/Stilling well – Guided wave radar Installation Guidelines and Section 7.10 Mounting in Chamber/Stilling well– Non-Contacting Radar Installation Guidelines for further information.

All pipes 5" and bigger should use the 5900C or 5900S with the array antenna. Refer to best practices for using radar in still pipes and chambers on Emerson.com

What are DDs and DTMs, and how do they affect configuration tools and host systems for the radar products?

Device Descriptors (DDs aka EDDs) offer access to configuration and diagnostics for Rosemount radars in DD compatible host systems such as AMS Device Manager, DeltaV and 475 Field Communicator. It is also possible to view the echo curve that can be used for advanced configuration and troubleshooting. Device Type Managers (DTMs) offer similar functionality as DDs, but are used in FDT/DTM compatible host systems. The echo curve is available also in DTMs.

DDs and DTMs used in host systems provide easy access to transmitters from the control room. Available features (e.g. echo curve support) depend on the capability of the host system and the DD/DTM.

DDs and DTMs for specific hosts are available to download on Emerson.com/Rosemount. (Rosemount Radar Master is a point-to-point configuration tool streamlined for Rosemount radar configuration and troubleshooting. This tool is not based on DD or FDT/DTM technology.)

How do I know if the Fieldbus measurement device is fully interoperable with my control system?

Emerson has a long standing program of carrying out work with other vendors to test Emerson devices on competitive hosts. For more than a decade this program has established that the Rosemount Foundation Fieldbus strategy works well on competitive hosts. All level Fieldbus Foundation devices have DD or DTMs that allow them to operate with specific host systems. These DDs and DTMs are tested for compatibility with individual host systems through the Fieldbus Foundation Host Interoperability Support Test (HIST). To find out if these tests are complete for a specific device and host system, go to the Fieldbus Foundation website (www.fieldbus.org) and look for the registered product list.

Some system vendors also provide a list of devices that have been tested on their systems. In addition, some competitive host vendors provide Emerson with comprehensive test reports. Some provide test summaries and certificates. Some don't provide external documentation, but still test for interoperability and work with Emerson to address any issues that may be revealed. In any case, testing can be validated between Rosemount field devices and host systems.

17.5.3 Guided wave radar

What is the principle of operation for guided wave radar?

The Rosemount 3300, 3308 and 5300 series use TDR (Time Domain Reflectometry) technology which means the transmitter sends out radar pulses. The actual level measurement is a function of the time taken from when the electromagnetic signal is emitted to the time at which the echo from the media is received.

What is the frequency of guided wave radar?

Radar frequency usually refers to carrier-frequency. Guided wave radar does not use a carrier frequency like non-contacting radar and therefore it is not relevant to talk about the frequency.

How do you interpret the electrical distance in the tank plot in Radar Configuration Tools (RCT) and Rosemount Radar Master (RRM)?

The electrical distance that is shown on the x-axis of the tank plot is used when comparing the distance measured by the transmitter and the real distance.

Due to the influence from the dielectric properties on the wave propagation speed, the electrical distance values have to be adjusted when the wave is not traveling through air. The electrical length shows the distance with the assumption that the wave travels in air. Practically this means that the distance to the first level peak will have the same electrical distance and real distance. When the waves continue down through the media, the real length from the surface to the end of the probe or to the interface level can be calculated through the formula below:

$$Real\ Distance = \frac{Electrical\ Distance}{\sqrt{DC\ of\ Media}}$$

The distance to the upper product can be read straight from the plot while the interface distance has to be calculated using the formula above.

How viscous can the measured media be?

The different probes have different maximum limits regarding the viscosity of the measured media. Single probes are more suitable for high viscosity media while the coaxial probe can be used on low viscosity media. The guidelines for the different probes and examples of viscosity are shown below:

Probe type	Max viscosity
Coaxial	500 cP
Single leads	8000 cP

Table 17.6.2: Probe type and viscosity

Media	Viscosity
Water	1 cP
Light machine oil	102 cP
Heavy machine oil	233 cP
Honey	10000 cP

Table 17.6.3: Media and viscosity

How will coating affect the measurement?

If coating forms on the probe, the measured signal will be weaker. If the media itself has a high dielectric constant some coating is not of much concern, but if it is a low DC media, coating can be a problem. If a coaxial probe is used the coating can cause bridging between the two leads and this will create false echoes that can lead the transmitter to interpret a bridge as the actual level. A single lead probe is recommended in coating applications.

Coating can cause an accuracy influence. Maximum error due to coating is 1-10% depending on probe type, dielectric constant, coating thickness and coating height above product surface.

What are the special considerations for interface measurement?

The Rosemount 3302, 3308 and 5302 can measure both level plus interface, and the Rosemount 5302 is the ideal choice for measuring the level of oil, and the interface of oil and water, or other liquids with significant dielectric differences. The Rosemount 3301 and 5301 can measure interface with a fully immersed probe. For more information see Section 6.5 Interface - Guided Wave Radar Installation Guidelines.

Can the Rosemount 3302 and 5302 read multiple interfaces?

No. The Rosemount 3302 and 5302 can measure the surface layer and only one liquid/liquid interface. There are criteria which must be met in order to measure the interface of two liquids. Please see Section 6.5 Interface - Guided Wave Radar Installation Guidelines.

Can guided wave radar measure emulsion layers?

In general, emulsion layers are hard to predict and when present, the interface will sometimes measure at the top of the emulsion layer, sometimes at the bottom and at other times somewhere within the emulsion layer. The results will vary with the fluid mix and will be dependent on the differences in the DCs of the two layers. In many cases, the interface will be measured at the top of the emulsion layer. Small emulsion layers (< 2 in (50 mm)) may not be detected at all.

Are there special flanges available for replacing displacers?

Yes. Masoneilan and Fisher 249B and 249C displacer flanges are available. The code for Masoneilan is TM, the code for Fisher 249B and 259B is TF, and the code for Fisher 249C is TT.

Will the guided wave radar see sand in the bottom of a vessel?

No. Since the sand will be embedded in water which is a high dielectric media (DC~80) the transmitter will only see the water. The same is true for all media that are embedded in water.

Is there an inactive part of the probe?

No, however probes do have transition zones which are areas where measurements are non-linear or have reduced accuracy. These occur at the very top and bottom of the probe. The measuring range is reduced by the upper and lower transition zones, creating an effective measuring range between them. The desired measurement points should be in the effective measuring range, but interference can still be created in the transition zones. How large the upper and lower transition zones are depends on probe type and the dielectric constant of the measured media. For details please refer to Section 6.2 Transition Zones – Guided Wave Radar Installation Guidelines.

What outputs are available?

Measurement data is transmitted as an analog mA signal with a superimposed digital HART signal (Rosemount 3300/5300) or Foundation™ Fieldbus signal (Rosemount 5300). The HART signal can be used in multidrop mode. By sending the digital HART signal to the optional HART Tri-loop, it is possible to have up to three additional 4-20 mA analog signals. The HART signal can also be used with an Emerson THUM for wireless transmission of the HART data. Modbus communication is also available for the Rosemount 3300 and 5300.

How close to the tank wall can the probe be mounted?

Like the nozzle, the tank wall can also affect the measurement through disturbance echoes. The minimum distance to the tank wall is the same as the distance to any disturbing object that may be present in the tank. If there are obstacles present in the tank the coaxial probe is the best probe to use. If the tank wall is metallic and smooth the probe can be mounted closer to the wall. For details please refer to Section 6.8 Free space – guided wave radar installation guidelines.

What are the special considerations when measuring ammonia?

Tanks with anhydrous ammonia have a heavy vapor above the surface that attenuates the signal from the radar transmitter. A higher pressure in the tank will cause a more attenuated signal. A special formula is therefore used to evaluate what the maximum measuring range is in anhydrous ammonia as a function of the pressure in the tank. The results are shown below. See also the section on ammonia, anhydrous (NH_3) in chapter 4. Note that, when measuring hydrous (aqueous) ammonia, this formula does not apply. Hydrous or aqueous ammonia has a high dielectric constant and therefore provides good reflection.
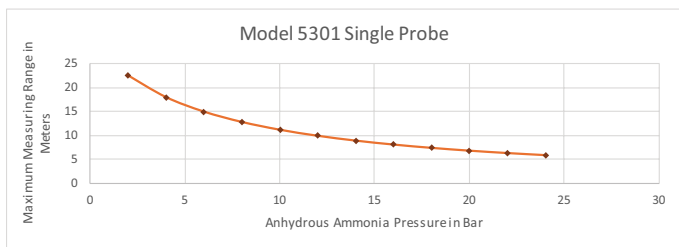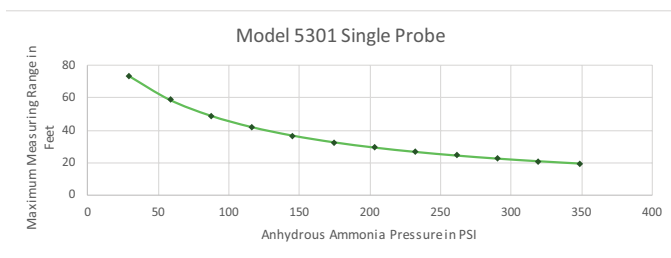
Figure 17.6.1: Measuring range in psi vs ft

Figure 17.6.2: Measuring range in bar vs meters

What pull force will break a flexible single lead probe?

In solids applications, media might cause down-pull forces on silo roofs. The silo roof must be able to withstand the probe collapse load or at least the maximum probe tensile load. The tensile load depends on the silo size, material density, and the friction coefficient. Forces increase with the buried length and the silo and probe diameter. In critical cases, such as for products with a risk for build-up, it is better to use a 0.24 in (6 mm) probe. Depending on their position, forces on probes are generally two to ten times greater on probes with tie-down than on probes with ballast weights. For more detailed information regarding measurement of solids please refer to Section 6.12 Considerations for solid applications – guided wave radar installation guidelines.

For the 0.16 in (4 mm) in diameter cable the tensile strength is 2698 lb (12 kN) and the collapse load is 3597 lb (16 kN). For the 0.24 in (6 mm) in diameter cable the tensile strength is 6744 lb (29 kN) and the collapse load is 7868 lb (35 (kN). Note: Abrasive media can wear out the probe. Consider using non-contacting radar or a PA coated probe. PTFE coated probes are not recommended for solids applications.

What is the damping unit and what is the default value?

The damping value is the parameter that defines how fast the device reacts to a change of the level, and the units are in seconds. The default value is set at 10 seconds for Rosemount 3300 Series and 2 seconds for the Rosemount 5300 Series. The default value provides a good output current accuracy and stability as well good response time. The damping can be set to a lower or higher value if the application needs it, for example rapid level changes. A high value makes the level steady but the device reacts slowly to level changes in the tank. A low value makes the device react quickly to level changes but the presented level value can be somewhat jumpy.

Is there a way to use the Rosemount 3300 Series in Foundation Fieldbus systems?

It is possible to use the Rosemount 848T as a converter from HART to FF. You will not be able to do any advanced configuration but you will be able to read the primary variable, look at the status, set hi and low alarms and some other standard FF functions through the AI block.

What measurement error will an incorrect dielectric constant cause on an interface level?

Errors due to changes in the medium's dielectric values can be significant. It is calculated by:

$$Error = \frac{Physical\ Thickness}{\sqrt{Dielectric\ A}} \qquad \frac{Physical\ Thickness}{\sqrt{Dielectric\ B}}$$

For example, if the physical thickness is 20 in (51 cm) and dielectric varies from 2 to 4:

$$Error = \frac{20}{\sqrt{2}} - \frac{20}{\sqrt{4}} = 4.14\ in\ (11\ cm)$$

17.6.4 Non-contacting radar

Can I power up an explosion proof Rosemount 5408 with Rosemount 3490?

The Rosemount 3490 controller provides a nominal 24V DC intrinsically safe supply. Most HART transmitters will require a minimum input voltage to work correctly and for HART communication to function. Increasing the load current in the loop will result in a decrease in the terminal output voltage of the Rosemount 3490 controller.

The absolute minimum output voltage for the Rosemount 3490 Controller is 14.4 vdc at 22.5 mA. At 20 mA it is 15.3 vdc. An explosion proof Rosemount 5408 or 3408 versus a non-explosion proof version does not affect power limitations, using HART protocol does. If using HART, for 23 mA, the 5408 has the minimum output voltage requirement of 17.8 V. This exceeds the maximum output voltage at that current for 3490. 3408 has the same power limits as 5408 if using HART. However, instead of suffering from power starvation, the update rate is lowered, and it will still be powered by the 3490 Controller.

To avoid voltage insufficiency, consider setting the instrument in Multidrop mode. It will then be forced to a permanent 4 mA current.

What is the principle of operation for Rosemount non-contacting radars?

The Rosemount Non-Contacting Radars use FMCW technology. The transmitters constantly emits a swept frequency signal and the distance is calculated by the difference in frequency between the emitted and received signal at any point in time. One advantage with FMCW is that higher accuracy can be achieved. For more general information regarding the principle operation please refer to "What is the principle of operation" under general questions.

How close to the tank wall can a non-contacting transmitter be mounted?

The minimum distance to the tank wall depends on which antenna is used. With a more concentrated beam (larger antenna), the closer to the tank wall the device can be mounted. For detailed information please refer to Section 7.3 Mounting location, Non-Contacting Radar Installation Guidelines.

Are there any special considerations when installing non-contacting radars in a stilling well?

Even though process radars generally provide robust operation installed in still pipes, all process radars regardless of make or type are designed to perform at their very best during free propagation. Installed in still pipes, the process radar's accuracy may be affected due to the microwave propagation through the still pipe. For highest accuracy in still pipes, we have developed the Rosemount 5900 Radar Level Gauges with unique array antennas utilizing a low-loss microwave mode dedicated for still pipes. Installation in a stilling well can be required either when the existing tank connection includes a stilling well or when the measurement is improved by measuring in a stilling well (e.g. with turbulence).

The cone antenna is used for stilling well applications and the size of the antenna should match the size of the stilling well. For optimal accuracy the inside of the stilling well must be clean and free from deposit, rust, gaps ,slots etc. The largest stilling well / antenna that can be used is 8 in. For more detailed information on measurement in stilling wells please see Section 7.10 - Mounting in Chamber/Stilling Well – Non-Contacting Radar Installation Guidelines.

Why do you use process seal antennas?

To isolate electronics from process in tank such as vapor and corrosion. The process seal antenna is also resistant against condensation and build-up. It is an all PTFE antenna (all materials exposed to tank atmosphere are made of food-grade modified PTFE). It is also 3-A certified and thus suitable for hygienic applications. The process seal antennas are available with flanged as well as Tri-Clamp tank connections.

What is the difference between a cone and a horn antenna?

They are just different names for the same type of antenna.

17.6.5 Switches

Which cassette do I use?

The relay switch cassette is the most common when IS certification is not required. For more information on cassette selection, refer to section output selection in Switch Installation Guidelines (chapter 11)

Can I replace just the electronics in the field?

For the Rosemount 2110, 2140 and 2160, electronics are not replaceable. For the Rosemount 2120 and 2130 with non-IS electronics, the electronic cassette can be replaced in the field by following a simple replacement procedure as advised in a manual supplement. For IS electronics, the electronic cassette cannot be replaced in the field as this operation must be performed at an approved manufacturing location.

Can the electronics types be interchanged in the field?

For the Rosemount 2110, 2140 and 2160, electronics are not interchangeable. For the Rosemount 2120 and 2130 for non-IS electronics, the electronic cassettes can be interchanged in the field by following a simple replacement procedure as advised in a manual supplement. In the event that a switch is fitted with an alternative electronics type, the instruments label will also need to be updated accordingly.

For IS electronics, the electronic cassette cannot be interchanged in the field because they have a different fork type from non-IS versions which are not compatible with non-IS electronics.

Can I use solar or battery power?

A lower power consumption variant of the Rosemount 2120 is available, which runs from a 12V supply. This makes it suitable for use where power is limited, including solar and battery-powered applications.

The wireless Rosemount 2160 is powered by a replaceable power module.

Can I replace the fork sensor in the field?

No, it is not possible to replace the fork sensor in the field. The fork is specifically tuned to the housing.

Can the Rosemount 2100 series be used for solids applications?

No, the 2100 series is not recommended for solids applications. The 2100 series is a liquid level switch only.

Rosemount 2140 has a special setting enabling it to be used to detect settled "wet" sediment in the base of a vessel eg. sand in a separator or salt in a brine tank (Sand Switch functionality). Refer to the Sediment detection section in chapter 4 Liquid level Applications and technology

Do vibrating fork switches detect foam?

The effects of foam can be difficult to predict, however Rosemount 2100 is designed to switch in liquids rather than foams. The technology has good resistance to foam. However in some cases where a dense foam is present it may be possible to detect a small fork frequency shift-even though the device does not actually "switch" from dry to wet. Rosemount 2140 and 2160 with HARTcommunication protocol enable the fork frequency to be monitored.

How to vibrating fork switches react to media build up on the fork tines?

In general the Rosemount 2100 series has good resistance to light to moderate build up on the fork tines without any effect on reliability.

However, it is important that the tines are not "bridged" by heavy build up, since this can result in an incorrect "wet" measurement. Advanced diagnostics included in some variants can detect build up so that cleaning can be carried out before functionality is affected.

My application is "corrosive". Which process wetted materials are suitable?

A number of wetted material types and polymer coatings, are available to suit applications involving corrosive media (e.g. acids, alkalis, salts etc.) including hastelloy, ECTFE (Halar) and PFA. It is the customer's responsibility to ensure chemical compatibility with the materials of construction selected.

17.6.6 Chamber questions

Why are chambers used?

Externally mounting a level measurement instrument (e.g. a guided wave radar) in a chamber gives a number of benefits:

a. The chamber may be valved off to allow live instrument maintenance without disturbing the process.

b. Isolating the chamber for live maintenance of measurement instruments increases safety where high process temperatures, pressures or hazardous liquids are present

c. Level measurements can be made without interference from internal structures inside the tank (e.g. agitators, heat exchangers)

d. A chamber can minimize level changes in vessels with turbulent liquid by calming the surface

How do I ensure the guided wave radar is sized correctly with the chamber?

Refer to chapter 11- Complete point solution with guided wave radar and Rosemount chambers, for assistance on best practices in sizing and installing.

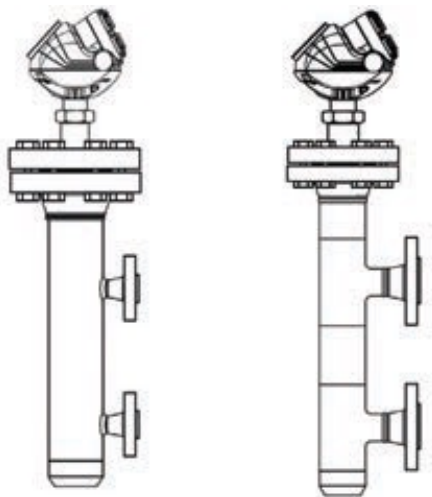## The Rosemount chamber has two designs - why?

Figure 17.6.3: Chamber designs

With the standard design, the process connections are welded directly onto the chamber body keeping the number of welds to a minimum. This increases safety, due to fewer welded joints.

In instances when a larger process connection (e.g. 1½-in (40mm) or 2-in (50mm)) is required on a 3-in (80mm) chamber, the T-piece design is used so that the larger process connections can fit onto the smaller chamber body.

NOTE! As more components are required with this design, there are more weld joints. The standard design should therefore be regarded as the first choice unless it is critical to have 1½-in (40mm). or 2-in (50mm) process connections on a 3-in (80mm) chamber.

Why does the Rosemount chamber use weld-neck flanges?

Weld neck flanges with full penetration welds are used throughout on the Rosemount chamber. This is the industry's preferred standard. Stress levels are reduced compared to alternatives such as slip-on flanges.

17.6.7 Differential Pressure level

Does a balanced / symmetrical capillary assembly eliminate all temperature effects?

This type of system is traditionally specified because it supposedly compensates for all temperature effects. For example, as the outdoor temperature changes (whether from night to day or season to season), the oil volume in the capillary will expand and contract, causing changes in the internal pressure of the capillary system. These changes in pressure will result in measurement error, called "seal temperature effect". A balanced symmetrical system was initially thought to cancel out this error, because the same expansion / contraction of oil volume will occur on both the high and low sides of the transmitter. While this may be true, there is another source of temperature error that is not addressed.

When a capillary seal system is installed and there is a vertical separation between the two seals (such as on vessels and distillation towers), there is "head pressure" that is exerted on the low side of the transmitter from the weight of the oil in the capillary. As the temperature conditions change, the density of the oil in the capillary will fluctuate and cause a change in the head pressure that is measured by the transmitter. This source of error is called "head temperature effect." While balanced systems can cancel out seal temperature effect, they do not compensate for head temperature effect.

The asymmetrical design of a Tuned-System Assembly purposely induces seal temperature effects to counteract the head temperature effects that will always be present on any vertical installation. This results in less net temperature effects for better performance and faster time response.

What special considerations should be accounted for in vacuum applications?

When selecting a fill fluid for use in a capillary system that will be installed on a vacuum application, it is important to verify that the fill fluid will not vaporize when subject to vacuum conditions. The point at which a fluid will turn to a vapor state is dependent on the operating temperatures and pressures of the process. The Instrument Toolkit sizing software can verify a specified fill fluid will not vaporize for a given application.

Another consideration for vacuum applications is the mounting location of the transmitter. Differential pressure transmitters have a 0.5 psia (25 mmHgA) static pressure limit. In vacuum applications, the transmitter needs to be mounted at or below the bottom seal depending on the static limit. A rule of thumb is to mount the transmitter one

meter (3.28 ft.) below the bottom seal, so there will always be at least 0.5 psia (25 mmHgA) on the transmitter.

Finally, the entire transmitter / seal assembly should be specified with "all-welded" construction for any vacuum application that will be at or below 6 psia (300 mmHgA). This type of construction eliminates all gasket and threaded connections for a 100% hermetically sealed system that is designed to maximize performance and robustness in deep vacuum conditions.

Can I use Electronic Remote Sensor technology on every DP level application in my plant?

Electronic Remote Sensor technology is designed for taller vessels and distillation towers, and applications with lower static pressures. Because the sensors in a Rosemount 3051S ERS System are specified and sized based on the combined static pressure and the DP column from the liquid level, the technology is not designed for use in applications with high static pressures and small DP spans. Because a Tuned-System Assembly is sized just on the DP column, this type of technology will continue to be the optimal solution for smaller, higher pressure vessels. ERS technology should be the first consideration for applications with tap to tap distances >10ft (3m) and static pressures <800 psi (55 bar). Published performance specifications are available for ERS systems with Enhanced Performance option. The Instrument Toolkit sizing software can further assist with selecting the optimal technology for each application.

Are additional seal types, materials and options available beyond what is published in the product data sheet?

Yes, additional seal types, materials, and options are available. Contact your local Emerson representative for information on special seal types and requests.

17.6.8 Emerson Wireless 775 THUM Adapter

How does the THUM Adapter work?

The THUM adapter easily attaches to any 2 or 4-wire HART device and uses WirelessHART technology to transmit the measurement and/or diagnostic information. The THUM adapter, which consists of a radio transmitter, receiver, microprocessor, and antenna, plugs into a standard electrical conduit connection. It is electrically connected to the loop wiring and accesses HART data without affecting the analog control signal.

HART data passes through the network to the Wireless Gateway. The gateway brings data from all the devices together into a central location.

How many HART devices can be used on a single Wireless Gateway?

Up to 100.

What is the minimum number of devices for a robust WirelessHART network?

Best practices show that the benefits of redundant pathways can be seen in as little as 2 devices. Customer installations show that networks are very robust with as little as 5 devices. The simplest case of a self-organizing network is a point to point architecture with each device connected to the gateway. As more devices are added, the robustness of the network increases significantly.

How many hosts can communicate with a single Wireless Gateway?

Many at the same time. For example: legacy host systems (PLCs, DCS) and AMS Device Manager.

Is a site survey required?

No. Emerson Wireless solutions for field networks use self-organizing WirelessHART technology, making wireless signals immune to possible obstacles or barriers. However, for tank gauging, due to the long distances between the tanks, a plot plan using the wireless snap-on tool is required, to ensure a strong and reliable network.

Can WirelessHART devices, such as the Rosemount 2160 vibrating fork, and wired HART devices with the THUM Adapter all be on the same network?

Yes.

With what devices will the THUM adapter work?

The THUM adapter is designed to work with any two or four wire HART Revision 5 or higher devices, which applies to all Rosemount process level devices.

Is battery power required?

No. The THUM Adapter has been designed so that it draws power from a 4-20 mA signal without compromising the loop, or overall quality and safety.

Are there any special requirements for the power supply when connecting the THUM Adapter?

During normal operation, or in fault condition, the THUM Adapter will cause a maximum drop of 2.5 volts in the connected loop. It is important to ensure that the power supply can provide at least 2.5 volts more than the minimum input voltage of the transmitter to make sure it works properly with the THUM Adapter installed.

Does the THUM Adapter affect device approvals?

The THUM Adapter is classified as intrinsically safe and can be placed on an IS loop without affecting device approvals.

Can I install the THUM Adapter on my application with some vibration?

Some applications may have heavy vibrations close to the maximum specification according to the product documentation for the transmitter. This may include vessels with heavy agitation, rapid fluid movement, or in cases where external equipment may induce vibrations. In these cases, the effects of vibration may become excessive for additional items attached to top-mounted devices. If this is likely, remote mounting of the THUM Adapter is recommended.

What is the maximum cable length between the remote mounting kit and the transmitter?

The cable length is restricted by the maximum length that can be used for HART communication and also by the IS entity parameters for the THUM Adapter and the transmitter, depending on the cable being used. Read more about the HART communication restrictions here: https://fieldcommgroup.org/

What additional tools do I need to get the benefits of the THUM Adapter?

You will need a Wireless Gateway to access the measurement and diagnostic information unlocked by the THUM Adapter. From the Wireless Gateway the information can be integrated into your system through one of many ways such as Serial, TCP, and OPC. AMS Suite can be used as convenient way to access the information made available by the THUM Adapter.

What type of data can the THUM Adapter provide?

The wireless transmission supports multivariable data handled by the transmitter, such as level, interface, distance, volume and temperature, as well as alerts and device warnings.

Can advanced diagnostics and the THUM adapter tell me when the signal strength drops, e.g. when the sensor is coated?

Yes, the THUM Adapter can provide annunciation of signal strength and other diagnostic applications configured by the user.

What other diagnostics can the THUM Adapter transmit?

The THUM Adapter enables access to all the information often left stranded in the transmitter. To name a few: distance to target, echo size/signal strength, transmitter temperature, loop testing, as well as Signal Quality Metrics in the Rosemount 5300 guided wave radar. To put it simply, the THUM Adapter unleashes the features of the level devices.

Can I view echo curves for my radar transmitters when using the THUM Adapter in a 4-20 mA system?

Yes, you can view the echo curves in AMS, or any host system that supports the use of enhanced DDs, such as the Rosemount 5300 Series, but it will take longer than with a direct connection.

17.6.9 Tank Gauging and Level Systems

What are the main benefits of selecting a tank gauging system that is based on high precision radar technology?

There are several reasons and features that make a radar technology system an excellent choice for tank gauging. The Rosemount Tank Gauging System provides the highest accuracy with custody transfer approvals, including the OIML R85:2008 and other national legal meterological approvals. It also complies with the international standard API MPMS chapter 3.1B and chapter 7 and more.

In addition, radar level gauge technology provides an outstanding reliability with no moving parts and only the antenna inside the tank. With its FMCW radar technique it enables the highest accuracy, reliable and stable level measurement with no need for periodical re-calibrations. The instrument accuracy is +/- 0.02 in (0.5mm). Top-down installation provides easy and fast installation and commissioning. Overall, using such a system results in a low total cost of ownership.

We need to comply with OIML R85, what do we need to think about?

The OIML standard R85 is available in two versions, one from 1998 and the most recent from 2008. The Rosemount Tank Gauging System complies with the latest version, OIML R85:2008.

What type of communication bus is the Rosemount Tank Gauging System using?

The Rosemount Tank Gauging System communication is based on an open industry standard, Foundation Fieldbus, which allows integration of any device supporting this communication protocol. The system can also easily connect to virtually all major host systems via Modbus, Modbus TCP, OPC or IEC 62591 (WirelessHART)

Is there a wireless tank gauging solution?

Yes, the Rosemount Tank Gauging System supports Emerson's wireless solution, which is based on IEC 62591 (WirelessHART), the industry standard for wireless field networks. There are already thousands of tank gauges delivered all over the world using wireless communication.

We are looking to use the Rosemount Tank Gauging System in a Safety Instrumented system (SIS). Is that possible and what SIL levels can be achieved?

The Rosemount 5900S Radar Level Gauge is the world's first SIL 3 certified radar level gauge for overfill prevention. The highest level of safety can now be achieved with a single gauge, and only one tank opening, without compromising the custody transfer accuracy grade. Certification has been carried out by Exida. Rosemount 5900S is also available with SIL 2 certification, and this is also the case for Rosemount 5900C. Other system components are also SIL certified, such as the Rosemount 5300 and Rosemount 5408 level transmitters. They can be used for separate continuous overfill measurements in a tank gauging system.

There are several different antennas available, but they are quite different in both shape and size. Why do we need to have different antennas?

There are different storage tank types, and the various antennas are made to fit these different tanks. Each antenna is optimized according to the specific tank, in order to achieve the best measurement performance. It is important to follow the guidelines for where to use each antenna. For example, the array antenna is designed for use in various still-pipes, with the antenna sized to fit the pipe. The Parabolic antenna is designed for mounting on a fixed roof tank and also to withstand heavily condensing and sticky products, while the Horn antenna is designed to fit smaller tank nozzles. Specific LPG/LNG antennas are also available to meet the demands in such applications. The antennas are developed based on over 35 years of experience in the radar level measurement market.

The parabolic antenna in your antenna offering is fairly large. Normally we do not have such large nozzles on the tank. How and where do you mount such an antenna?

The Parabolic antenna is 440 mm (17 in) in diameter and is designed to fit virtually all manway covers on fixed roof tanks.

Can you use radar to measure the water interface in the bottom of the storage tank?

Measuring the water level in the bottom of a tank is important to determine the real product volume. Another important measurement to obtain the real volume is product temperature. The radar gauge itself does not measure the water level, but there is an integrated water level sensor located at the end of the multiple spot temperature sensor. In this way the user will get product level, product temperature and level of water in the bottom of the tank.

When installing a multiple spot temperature sensor, how should the individual spot sensors be positioned?

There are recommendations and guidelines in both ISO and API standards to have a temperature spot in at least every 3 m (9.84 ft.). For an accurate and precise average temperature measurement Emerson recommends a temperature spot per every 2 m (6.56 ft.). It is also important to put the lowest spot at a minimum of 500 mm (1.64 ft.) above the tank bottom and the top spot at a minimum of 500 mm (1.64 ft.) below the tanks high-high level alarm point. This is to ensure temperature readings represent product temperature with minimum influence from the outside.

For more information,visit
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